Aerobic Capacity in Individuals with Osteoarthritis of the Knee

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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 publication for the qualification of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

Signed..

Date...

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Abstract

Objective

The objective of this study was to assess if individuals with osteoarthritis (OA) of the knee have reduced aerobic capacity compared with age and gender matched healthy controls. This study also assessed the accuracy of submaximal exercise testing for predicting aerobic capacity in individuals with OA.

Study design

A cross sectional comparison study was undertaken with 24 participants with radiographic evidence of knee OA and 20 age and gender matched healthy participants within the control group.

Background

OA of the knee is a musculoskeletal condition that affects a large number of individuals. With an aging population the incidence of OA is set to increase. OA is associated with pain, joint stiffness and reduced muscle strength. It has been demonstrated some years earlier that OA is associated with a reduction in aerobic capacity. This is thought to be as a result of reduced physical activity, and exercise avoidance. In recent years there has been increased emphasis on physical exercise as a treatment approach to OA, and a series of guidelines have been introduced to promote physical activity in elderly and diseased individuals. Theoretically the increased awareness of the benefits of exercise should result in improvements in aerobic capacity in individuals with OA. However, no studies have examined this.

As maximal effort exercise testing is expensive to undertake and requires significant training it is not practical in the clinical setting therefore submaximal effort exercise testing is a preferred

alternative. However to date there have been no studies that provide evidence of the accuracy of submaximal exercise tests for predicting aerobic capacity in individuals with OA.

Method

Forty four participants aged 47-81 years were recruited. Four participants were excluded from the study for failing to achieve two of the three determinants of aerobic capacity. Therefore total numbers for the study were 22 participants in the OA group (12 males, 10 females) and 18 participants in the control group (9 males, 9 females). Both groups had a mean age of 67 years with a SD of 10 years

A submaximal cycler ergometer test was utilised to predict aerobic capacity. Aerobic capacity was predicted from an equation that utilised exercise work rate (WR) and heart rate (HR) at the completion of the test.

A ramped cycle ergometer exercise protocol was used for the measure of maximal aerobic capacity. The incremental resistance for the test was calculated so participants reached maximal exertion between 8-12 minutes. A breath by breath analysis of expired gas, participant HR and perceived exertion was used to determine if maximal effort was reached.

Results

There was a significant ($P<0.05$) reduction in aerobic capacity observed between individuals with OA of the knee (mean: 22 ml/kg/min) compared with age and gender matched healthy controls (mean: 27 ml/kg/min).

The mean predicted values from the submaximal test were 19ml/kg/min and 22ml/kg/min for the OA and control groups respectively. The submaximal exercise test under-predicted aerobic capacity in both groups. The Intraclass correlation coefficients (ICCs) were .75 and .72 for the OA and control groups respectively.

Conclusion

The findings of this study are consistent with other literature indicating that individuals with OA of the knee have reduced aerobic capacity when compared with age and gender matched healthy controls.

This study also indicates that submaximal exercise testing is a safe and accurate predictor of aerobic capacity in individuals with OA.

Chapter 1

Introduction

1.1 Statement of the problem

Osteoarthritis (OA) is the most prevalent form of arthritis, and a major cause of disability. It is thought that almost 15% of people aged over 55-years will experience severe knee pain as a result of OA (Peat, McCarney, & Croft, 2001). OA is one of the leading causes of pain and disability in New Zealand. The financial cost of arthritis in New Zealand is estimated at $3.2 billion, with $695 million of this in the health sector alone (Access Economics, 2010). Women are more likely to be affected by arthritis (57.8%) and individuals aged 45-64 equate to 42% of all arthritis sufferers (Access Economics, 2010). As this age bracket encompasses the most productive working years of one's life, where the highest wages are obtained, it is of concern. In 2005 4.9% of New Zealanders were unable to work due to OA (Access Economics, 2010).

OA is associated with pain, joint stiffness, and muscle weakness. These parameters can result in a reduction in activity levels and even difficulty performing activities of daily living (Escalante, García-Hermoso, & Saavedra, 2011). These changes have been thought to result in a reduction in aerobic capacity. Aerobic capacity is a measure of an individual's cardiovascular system in response to exercise (Huggett, Connelly, & Overend, 2005). Although aerobic capacity is reduced with age (Inbar et al., 1994), with OA this reduction is accelerated and is associated with obesity, hypertension, elevated levels of blood glucose and reduced high density lipid (HDL) cholesterol levels (Philbin et al., 1996). These factors are also strongly associated with increased risk of coronary heart disease (CHD) (Philbin et al., 1996). Inactivity is thought to be the leading cause of cardiovascular de-conditioning in individuals with severe joint arthritis (Ries, Philbin, & Groff, 1995). Research indicates that maintaining activity throughout life can reduce the age related declines in aerobic capacity by half (Kasch et al., 1999).

Maximal effort exercise testing is the gold standard in measuring aerobic capacity (Noonan & Dean, 2000). Patients with chronic OA have often been excluded from exercise stress testing due to the assumption that their musculoskeletal disability may limit the diagnostic value of the test (Philbin, Ries, & French, 1995). A small number of studies (Philbin, Groff, Ries, & Miller, 1995; Philbin, Ries, et al., 1995) have utilised cycle ergometry to examine aerobic capacity in individuals with OA of the knee. The outcomes of these studies suggested that those individuals with OA of the knee have a reduction in aerobic capacity. However it is 18-years since these studies have been undertaken. During this time there has been increased awareness of the need to be active and exercise regularly to limit the occurrence of cardiovascular disease. Furthermore, the American College of Sports Medicine (ACSM) (Nelson et al., 2007) has established guidelines that set out the volume and intensity of aerobic exercise required each week to maintain good health when individuals have chronic diseases. Given this increased awareness of the benefits of exercise it is of interest to examine aerobic capacity at this time to determine whether reduced aerobic capacity is still observed in a cohort of individuals with OA.

If cardiovascular fitness is to be improved in these individuals, appropriate assessment tests are required, from which training programs can be implemented and evaluated more effectively. Unfortunately maximal effort exercise tests are costly, time consuming, require a well equipped laboratory, trained staff, medical supervision, and significant motivation from participants (Beekley et al., 2004). Therefore submaximal exercise tests have been developed for use in a clinical setting to predict aerobic capacity (Beekley et al., 2004). At this time no studies have examined the accuracy of a submaximal exercise test on the prediction of aerobic capacity in individuals with OA of the knee.

1.2 Purpose of the study

The purpose of the study was twofold:

1. To measure and compare maximal aerobic capacity in individuals with OA of the knee and healthy age and gender matched controls.
2. To assess the accuracy of a submaximal cycle ergometer exercise test for predicting aerobic capacity in individuals with OA of the knee.

1.3 Significance of the problem

This study will have significance for health professionals in the prescription of aerobic exercise in individuals with OA of the knee. Examining the difference in aerobic capacity between individuals with and without OA of the knee will provide information concerning the risk of development of co-morbidities associated with reduced aerobic capacity.

In addition this study will provide an indication of the accuracy of a submaximal exercise tests for providing baseline measures of aerobic capacity. If accurate, this can be utilised in assessment and as an outcome measure to assist in the implementation of training and rehabilitation programmes.

Chapter 2

Review of Literature

This chapter begins with a description of the process of OA, the risk factors associated with the development of OA and the co-morbidities associated with OA. A review of aerobic capacity follows, beginning with aerobic capacity in healthy elderly, followed by a review of aerobic capacity in individuals with OA of the knee. This is followed by a review pertaining to maximal effort exercise tests for the measurement of aerobic capacity in the elderly. Finally, the chapter concludes with a review of submaximal exercise tests used to predict aerobic capacity.

2.1 Search Strategy

An initial search of the literature was undertaken, from which an extensive keyword list was obtained and included terms specific to OA of the knee and aerobic fitness. These words were knee, OA, arthritis, exercise, aerobic, fitness, capacity, cardiovascular, co-morbidities, exercise, test(ing), endurance, hip, lower limb, cycle, ergometry, treadmill, resistance, cardiorespiratory, cardiopulmonary, anaerobic, function. A more extensive literature search was then made using nine electronic databases (AMED, Blackwell Synergy, CINAHL, EBM Reviews (including Cochrane Reviews), EBSCO Health Databases (including MEDLINE), PEDro, ProQuest 5000, Science Direct and Sports Discus). The literature review was also supplemented by a review of bibliographies of past review papers on aerobic testing and a citation search on key authors. The keyword list and combination of search terms was recorded to ensure a standardised approach to the search for literature.

As no intervention or follow-up was required for the current study, it being a cross sectional comparison design, no formal examination of internal validity of the literature was undertaken. However, within the review, the validity and reliability of techniques for measuring aerobic capacity are discussed in detail.

2.2 Risk factors for the development of OA

OA is not a singular disease but is an end point of a complex range of disorders that result in structural and functional failure of synovial joints. OA occurs when there is disequilibrium between breakdown and repair of joint tissue (Garstang & Stitik, 2006). OA is likely the result of a number of different factors and can have both primary and secondary forms with differing disease processes. It is associated with cartilage destruction and bone changes. There are two major groups of risk factors for the development of OA, systemic factors and local factors (Garstang & Stitik, 2006).

2.2.1 Systemic Factors

Patterns of incidence of OA in New Zealand support the theory that ethnicity influences the development of OA. In New Zealand the incidence of OA in Asian and Pacific Island populations is significantly lower than that of European populations. There is also a significantly lower incidence of OA in Maori populations compared with non-Maori, however this is thought to be linked more so with life expectancy of Maori being a lot lower than that of non-Maori (Access Economics, 2010). Strong prevalence patterns emerge from epidemiologic studies of OA. There is a strong correlation between both age and gender and the incidence of OA. In the United Kingdom (UK) approximately 25% of people over the age of 55 years have a persistent episode of knee pain in the space of a year (Peat et al., 2001). The prevalence of painful disabling OA in individuals aged over 55 years is 10% (Peat et al., 2001). Before the age of 50 men have a slightly higher incidence of OA than women, however after the age of 50 women have higher incidences of hand, foot and knee OA than men (Felson et al., 2000). The high incidence in the development of OA in women post menopause is suggestive of estrogen deficiency playing a role in the disease process (Felson et al., 2000). Nutritional factors have also been thought to play a role in the development and progression of OA. An observational study highlighting the effect of antioxidant micronutrient intake on OA found that individuals with low vitamin C levels had a four-fold increase in the development of OA (McAlindon et al., 1996). Furthermore a high vitamin C intake was associated with a significantly lower risk of developing knee pain in individuals with evidence of radiographic knee OA (McAlindon et al., 1996).

2.2.2 Local Factors

Other risk factors that play a role in the development of OA include local biomechanical factors including previous joint injury, obesity, physical activity, malalignment of the joints and muscle weakness (Garstang & Stitik, 2006). Radiographs taken 24.5 years following anterior cruciate ligament (ACL) reconstruction showed that 39% of individuals with healthy medial meniscus at the time of surgery had abnormal or severely abnormal radiographs (Pernin, Verdonk, Selmi, Massin, & Neyret, 2010). However 70% of patients who had a partial or full medial menisectomy at the time of surgery had abnormal or severely abnormal radiographs at the 24.5 year follow-up. Furthermore 80% of patients with medial cartilage damage at the time of surgery demonstrated abnormal or severely abnormal radiographs at the 24.5 year follow-up (Pernin et al., 2010).

Muscle activation following serious knee injury is often compromised. Glatthorn, Berendts, Bizzini, Munzinger, and Maffiuletti (2010) found that following arthroscopic partial menisectomy peak quadriceps muscle torque and electromyography (EMG) activity was reduced in the operated limb. An asymmetry was also observed between limbs in the vastus medialis muscle during both concentric and eccentric exercise. The authors (Glatthorn et al., 2010) suggest this might be a reflection of neural impairment resulting in muscle activation failure. Interestingly, muscle weakness with and without atrophy is found in the quadriceps in individuals with OA of the knee suggesting that the weakness may be as a result of muscle dysfunction not muscle size (Slemenda et al., 1997).

Altered joint alignment is also thought to contribute to the incidence of OA. Individuals who have undergone ACL reconstruction have a 21% increase in knee abduction moment compared with healthy uninjured knees (Butler, Minick, Ferber, & Underwood, 2009). An increased varus knee alignment has also been associated with increased radiographic severity of OA and is thought to increase the pain associated with OA in particular during weight bearing activity (Lo, Harvey, & McAlindon, 2012).

Obesity is potentially the most modifiable risk factor in the development of OA. In a survey carried out in the United States of America from 1999-2000 the prevalence of obesity for those aged 20 years and older was just over 30%. Twenty eight percent of men were obese compared to 34% of women (Ogden, Carroll, & Flegal, 2003). A high body mass index (BMI) is strongly associated with increased risk of OA, and body mass increases correlate directly with increased risk of OA development. A 10lb gain in body mass has been shown to increase OA risk by 40% (Felson et al., 1997). Interestingly the odds of developing OA were reduced by 50% for every two units of BMI lost over a 10 year study interval. This equates to approximately five kilograms (Felson, Zhang, Anthony, Naimark, & Anderson, 1992).

2.3 Disease process of OA

The key pathologic changes seen in OA are loss of articular cartilage, accompanied by thickening and remodelling of subchondral bone (Huber, Trattnig, & Lintner, 2000). It is unknown if bony or cartilage changes occur concurrently, or if one tissue is involved earlier than the other. OA typically progresses to involve much of the tissue that forms synovial joints. This includes synovial tissue, ligaments, capsule and muscles that cross the joint (Garstang & Stitik, 2006).

In the initial stages of OA, irregularities in the superficial layer of articular cartilage will expand into the transitional zone (Guilak et al., 2004). Thereafter, focal regions of articular cartilage loss develop along with changes to the deepest calcified cartilage layer (Garstang & Stitik, 2006). In the late stages of OA, the loss of articular cartilage may be full thickness resulting in exposure of the bone. Alterations in subchondral bone activity also occur early on in the disease process (Kwan Tat, Lajeunesse, Pelletier, & Martel-Pelletier, 2010). These include sclerosis of subchondral bone trabeculae, formation of bone cavities and osteophyte formation (Lajeunesse & Reboul, 2003). Subchondral bone alterations are thought to be associated with abnormal osteoblast function (Lajeunesse & Reboul, 2003).

2.4 Grading severity of OA

The presence and severity of OA is typically classified using a radiographic grading scale. The most frequently used scale is that of Kellgren and Lawrence (1957). The Kellgren and Lawrence scale uses a five point scale (Table 2.1), measuring severity of OA from grade zero (least severe) to grade four (most severe). The reliability of this system has been shown to be moderate for predicting osteophytes and joint space narrowing (Kessler, Guenther, & Puhl, 1998).

Table 2.1 The Kellgren and Lawrence radiographic grading system

Grade	**Radiograph Appearance**
Grade 0	Normal
Grade 1	Doubtful joint space narrowing
Grade 2	Minimal joint space narrowing, and osteophytes
Grade 3	Moderate joint space narrowing and osteophytes
Grade 4	Severe joint space narrowing and osteophyte formation

Radiographs are insensitive to the earliest features of OA and therefore the absence of positive radiographic findings should not be interpreted as absence of symptomatic disease (Hunter, 2009). Conversely, there is strong evidence to suggest that the presence of radiographic knee OA is highly sensitive and that the presence of osteophytes is the most reliable radiographic feature for the detection of OA (Kijowski, Blankenbaker, Stanton, Fine, & De Smet, 2006).

It is also important to consider clinical presentation in the diagnosis of OA. In clinical practice, history and physical examination are seen as valuable compliments to radiography (Larsson, Petersson, & Ekdahl, 1998). The primary symptoms of OA include pain, stiffness and movement restriction (Larsson et al., 1998). The American College of Rheumatology has developed a set of guidelines to assist in the identification of OA (Altman, 1987). The complete guidelines are presented in Table 2.2.

Table 2.2 Classification criteria for OA of the knee

Clinical	**Clinical and Laboratory**	**Clinical and Radiographic**
Knee pain	Knee pain	Knee pain
+	+	+
At least 3 of 6	At least 5 of 9	At least 1 of 3
Age> 50 years	Age> 50 years	Age> 50 years
Stiffness< 30mins	Stiffness< 30mins	Stiffness< 30mins
Crepitus	Crepitus	Crepitus
Bony tenderness	Bony tenderness	+
Bony enlargement	Bony enlargement	Osteophytes
No palpable warmth	No palpable warmth	
	ESR< 40mm/h	
	RF< 1:40	
	SF OA	

Notes: ESR= Erythrocyte sedimentation rate; RF= Rheumatoid factor; SFOA= Synovial fluid of osteoarthritis

These criteria provide a useful screening tool upon which the initial decision regarding the presence of OA can be made.

2.5 Associated co-morbidities

The pain associated with OA of the knee results in avoidance of activity. This in turn leads to disuse of muscles, which exacerbates muscle weakness creating a vicious cycle of disuse, muscle weakness, pain and disability (Ettinger, Davis, Neuhaus, & Mallon, 1994). Inactivity also leads to reduced aerobic capacity which contributes to further disability in older adults. Reduced aerobic capacity and deconditioning are also associated with cardiopulmonary diseases (Ettinger et al., 1994).

Philbin et al (1996) examined the whether the presence of OA was associated with increased risk factors for coronary heart disease (CHD) compared to age and gender matched controls. Forty-six participants with OA of the hip and or knee were evaluated and their results were compared with 23 non-arthritic participants who served as a control. Fasting blood samples were taken for measures of glucose and cholesterol and the Framingham Heart Study database was used to predict each participant's likelihood for experiencing a CHD event. Participants with OA were less likely to participate in regular or vigorous physical activity compared with the control group. Participants with OA were found to have significantly higher Body mass index (BMI), waist to hip ratio, systolic blood pressure (BP), blood glucose and lower high density lipid (HDL) cholesterol levels. Predicted CHD events were also much higher in OA participants compared with the control group. The authors surmised that the results highlighted a higher prevalence of modifiable CHD risk factors in individuals with OA compared with the control group.

More recently Chan, Ngai, Ip, Lam, and Lai (2009) investigated the co-morbidities associated with OA in 455 Chinese. Cardiovascular co-morbidities were reported in 33% of participants, while gastro-intestinal problems were reported in 29% of participants and respiratory co-morbidities were reported in 27% of participants. Participants who were considered overweight or obese, of which there were 68% had significantly higher cardiovascular and endocrine co-morbidities than those participants who were not overweight. The authors believed that the results provided further support for the relationship between OA and obesity, and provided evidence to support the hypothesis that OA is associated with an increased risk of cardiovascular co-morbidities.

When looking at the co-morbidities associated with OA in a sample of patients in England and Wales Kadam, Jordan and Croft (2004) have shown that individuals with OA present to their general practitioner (GP) more frequently than those without OA. Thirty one percent of individuals with OA had six or more co-morbidities compared with only 21% of the control group. The most frequently observed co-morbidity was musculoskeletal joint or soft tissue injury. This was followed closely by gastro-intestinal complaints this could be as a result of increased anti inflammatory use in individuals with OA. The authors (Kadam et al., 2004) have questioned whether these co-morbidities may increase the disability associated with OA.

2.6 Loss of Function

The pain and stiffness associated with OA result in reduced joint movements, muscle wasting, weakness and decreased activity levels. These factors cause a loss of functional independence and reduced self-efficacy in individuals with OA. As many as 80% of individuals with OA report some degree of movement limitation, and 25% cannot perform simple activities of daily life (Escalante et al., 2011). A large cohort study (n=4059) (Ettinger et al., 1994) looking at the long term physical function in individuals with OA found that 44-71% of individuals with symptomatic OA of the knee reported difficulty with ambulation and mobility tasks. This compared with 19-28% of individuals without symptomatic OA of the knee.

Within the literature, physical function and symptoms are often measured with self-report questionnaires. One of the more frequently utilised self report questionnaires in the literature is the Western Ontario and McMasters Universities OA Index (WOMAC). The WOMAC questionnaire is a 24-item self-administered questionnaire divided into sub-scales for pain, joint stiffness and physical function (Bellamy, Buchanan, Goldsmith, Campbell, & Stitt, 1988). It has demonstrated reliability, validity and responsiveness for people with hip and or knee OA (Davis et al., 2009).

Another self-report questionnaire used to assess lower limb function is the lower limb task questionnaire (LLTQ). The LLTQ is a 20-item questionnaire with two sub-scales; the activities of daily living (ADL) sub-scale and the sport/recreation sub-scale with 10 items each. For some populations the sport/recreation sub-scale may not be appropriate therefore the ADL sub-scale is sufficient (McKay, Prapavessis, & McNair, 2013). The LLTQ has strong internal consistency, concurrent validity and is a highly reliable measure (McNair et al., 2007).

2.7 Physical activity

A reduction in physical activity is not only associated with OA but is also strongly associated with the aging process. In a recent New Zealand survey two thirds of older adults aged 75-years and over did not participate in any physical activity (Ministry of Health, 2012). Physical activity is a modifiable factor associated with improved health status in the elderly (Giles & Marshall, 2009). The assessment of physical activity is important as it provides researchers and health professionals with a better understanding of the association of physical activity to various health or disease end points (Colbert, Matthews, Havighurst, Kim, & Schoeller, 2011). It is not only important to quantify the amount of physical activity performed, it is also important to know the intensity and frequency of the activity (Colbert et al., 2011).

In recent years, the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) have updated their recommendations for the type and amount of activity necessary to maintain physical activity in older age (≥65 years)(Nelson et al., 2007). The updated recommendations are similar to the updated recommendations for younger adults and include at least 30 minutes of moderate intensity aerobic exercise at least five days of the week, or 20 minutes of vigorous activity on at least three days of the week (Nelson et al., 2007). Moderate intensity exercise describes a moderate level of effort relative to an individual's fitness levels. On a 10 point scale, where zero is no effort and 10 is all out effort, moderate exercise would be described as five to six, and vigorous effort would be described as seven to eight (Nelson et al., 2007). This recommended activity is in addition to routine activities of daily living. To accurately assess how many older adults are meeting these recommendations, valid and reliable measures of physical activity are required.

Stewart et al. (2001) developed a self-report questionnaire to provide physical activity outcome measures for an intervention aimed at increasing physical activity in older adults; the Community Healthy Activities Model Program for Seniors (CHAMPS). It was felt at the time of the study that the outcome measures available were not sensitive to changes in physical activity levels for primarily sedentary older adults (Stewart et al., 2001). The CHAMPS questionnaire is a 41-point self-report questionnaire where participants are asked to report participation in an activity over an average week in the last four weeks. They then report the frequency and duration of their participation in each activity. Each activity is given a metabolic equivalent of task (MET) value modified for age. Equations were provided to estimate caloric expenditure per week for each task. There was moderate reliability found for the measure of caloric expenditure (intraclass correlation coefficient (ICC) 0.67 and 0.66). There was a slightly lower correlation for frequency of activity (ICC 0.58 and 0.62) indicating that frequency may be more difficult to recall.

There have been two studies by Cyarto, Marshall, Dickinson, and Brown (2006) and Giles and Marshall (2009) that recently evaluated the reliability and validity of the CHAMPS questionnaire in a sample of 167 and 100 elderly Australians respectively. The reliability coefficients for test- retest reliability for moderate intensity exercise were 0.81-0.88 (Cyarto et al., 2006). This was much higher than the test- retest reliability for vigorous intensity exercise which was 0.34-0.45 (Cyarto et al., 2006). The CHAMPS questionnaire has been shown to provide valid and reliable measures of physical activity in older Australian adults (Giles & Marshall, 2009). However lower validity coefficients were observed between pedometer measured steps and CHAMPS walking and total activity levels (r_s=.57 and r_s=.52) (Giles & Marshall, 2009).

Harada, Chiu, King and Stewart (2001) have also compared the CHAMPS questionnaire against other self-report activity measures. There was acceptable validity demonstrated in the CHAMPS questionnaire when compared with other self-report physical activity measures. The reliability of the CHAMPS questionnaire for all activity measures was 0.62 and the reliability for moderate intensity physical activity was 0.76 (Pearson's and Intraclass coefficients) (Harada et al., 2001).

2.8 Aerobic capacity

Aerobic capacity provides another measure of physical function. Maximal aerobic capacity also known as maximal oxygen uptake is defined as the highest rate oxygen can be taken up and utilised by the body during severe exercise (Bassett & Howley, 2000). Maximal oxygen uptake was first defined in 1923 (Hill & Lupton, 1923) and was described as the oxygen intake during an exercise intensity at which point oxygen intake reaches a maximum beyond where no increase in effort can raise it. During exercise, oxygen uptake increases in a linear fashion with work load. The point where work load continues to increase and oxygen uptake plateaus is thought to be maximal aerobic capacity. Maximal aerobic capacity is largely dependent on the ability of the oxygen transport system to deliver blood and the ability of the cells to utilise oxygen in energy production (Hartung, Krock, Crandall, Bisson, & Myhre, 1993). The burden of extra energy output outside of that provided by oxygen utilisation falls on the anaerobic processes, and when this occurs there is a considerable increase in various metabolites

(Astrand, 1967). There are a number of components that influence aerobic capacity; these include the pulmonary diffusing capacity, maximal cardiac output, oxygen carrying capacity of blood and skeletal muscles (Bassett & Howley, 2000). For a detailed perspective of the key physiological interactions that affect aerobic capacity in healthy and diseased subjects, the reader is referred to Jones (1997).

Physical exercise requires the interaction of physiological control mechanisms to enable the cardiovascular and ventilator systems to support the increased demands of contracting muscles (Wasserman et al., 2012). Studying the respiration in response to exercise provides information on the functional competence of the organ systems coupling (Wasserman et al., 2012). Cardiopulmonary exercise testing (CPET) provides indirect observation of the cellular, cardiovascular and ventilatory systems responses simultaneously under precise conditions of metabolic stress. CPET provides information to determine a normal or abnormal response characteristic, grade the adequacy of the cardiovascular and ventilator system coupling and assess the responses of diseased systems to treatment (Wasserman et al., 2012).

In the following section more detailed analysis of the effects of aging and the effects of arthritis on aerobic capacity is presented. For clarity, the focus in this section is on purpose, findings and implications. For more detailed information concerning the specific methods undertaken in studies presented, the reader is referred to Appendix 1.

2.9 Changes in aerobic capacity with age

Older adults have displayed a 55% lower aerobic capacity than younger adults during cycle ergometer tests (Andersson, Lundahl, Wecke, Lindblom, & Nilsson, 2011). In untrained individuals aerobic capacity is reduced by 10% per decade (Inbar et al., 1994) whereas in individuals who maintain physical activity throughout their lifetime the decline can be as low as 5-6% per decade (Kasch et al., 1999). There are a number of physiological changes associated with aging that lead to this reduction. Aging results in reduced heart rate (HR), reduced stroke volume and a reduction in cardiac output (Fleg, 1986). Respiratory performance also reduces with age, these changes are thought to be as a result of reduced chest wall compliance, reduced static recoil of the lungs and decreased strength of respiratory muscles (Lalley, 2013). Older adults have significantly reduced muscle bulk, with associated loss of muscle oxidative capacity (Conley et al., 2000). This reduction in aerobic performance contributes to a reduction in functional capacity which can lead to disability, loss of independence and increased cardiovascular mortality in older adults (Kalapotharakos, 2007).

Diseases of the cardiovascular, pulmonary and musculoskeletal systems result in a further reduction in maximal oxygen consumption, reduced peak work output and reduced anaerobic threshold (Posner, Gorman, Klein, & Woldow, 1986). In an investigation of the prognostic value of aerobic testing in older adults with cardiovascular disease, or who are at risk of developing cardiovascular disease, Goraya et al. (2000) indicated that 35% of older adults with cardiovascular disease have a low aerobic capacity, with 22% having severely abnormal aerobic capacity. Those patients with severely abnormal aerobic capacity had the worst overall survival at follow-up six years later (Goraya et al., 2000). Simon et al. (2001) noted that during aerobic exercise testing in individuals with chronic obstructive pulmonary disease (COPD) individuals will often stop the test before reaching their physiological limits due to limitations in oxygen extraction during exercise. Other studies have also found that COPD is also associated with a reduction in peak aerobic capacity and peak quadriceps strength (Spruit, Franssen, Rutten, Wagers, & Wouters, 2012).

It has been suggested that some of the age related change in aerobic capacity can be attributed to the selective loss of muscle mass associated with advancing age. Fleg and Lakatta (1988) examined what effect the normalising of VO_2 to muscle mass would have on the relationship between VO_2max and age. Both male and female groups demonstrated a strong negative correlation between VO_2max and age. Once VO_2max was normalised for muscle mass the age related decline of VO_2max was reduced from 60% to 14% in males and from 50% to 8% in females. The magnitude of age related decline in VO_2max between ages 30 and 70 years was reduced from 39% to 18% in males, and from 30% to 14% in females, after normalisation for muscle mass. These findings suggested that at least half the age associated reduction in aerobic capacity could be attributed to the selective loss of muscle mass that accompanies advancing age (Fleg & Lakatta, 1988). However not all findings support this view. Lovell, Cuneo, Delphinus, and Gass (2011) examined the relationship between lower limb strength and aerobic capacity. Participants completed a 16 week strength training programme. Improvements were seen in aerobic capacity between baseline and completion of a 16 week strengthening programme. However, following four weeks of detraining aerobic capacity had returned to baseline despite maintaining the strength gains made with the 16 week training programme. The authors believe these results indicate that the aerobic capacity achieved during cycle ergometry in older men may not be affected by lower limb strength. It should also be noted that despite increases in leg strength there did not appear to be any influence on the ability of older men to reach plateau during maximal aerobic exercise testing (Lovell et al., 2011).

An individual's aerobic capacity has been used as a measure for determining living status and functional independence. Many sedentary older adults perform daily tasks at a level close to their aerobic capacity threshold (Huggett et al., 2005). A study by Cress et al. (1996) showed that independent community dwelling older adults had a significantly higher aerobic capacity compared with independent or dependent older adults who were living in a residential care facility. These differences in aerobic capacity remained significant even after correcting for age. The independent community dwelling older adults had a 41% greater aerobic capacity compared with those who were dependent and in long term care (Cress et al., 1996).

More recent work by Cress and Meyer (2003) indicated that the aerobic capacity required for an individual to maintain independence in older age is 20 ml/kg/min. In this study individuals who self-reported functional limitations, and who live in congregate care facilities, had a VO_2 peak below the threshold of 20 ml/kg/min. These individuals were more likely to require the physical support that a care facility provides. Such measures, if accurate, provide a mechanism for easily determining an individual’s physical reserve, predicting dependency of living status and thus are an indicator that is relatively unbiased for assisting with late-life physical independence decisions (Cress & Meyer, 2003). For each millilitre of oxygen uptake below the 20 ml/kg/min threshold an associated eight fold reduction in physical function has been observed (Arnett, Laity, Agawal, & Cress, 2008).

2.10 Changes in aerobic capacity with OA

OA has long been associated with joint pain and reduced activity, however there is little research exploring the relationship between OA and aerobic capacity. Patients with chronic OA are often excluded from exercise testing because the assumption is that their musculoskeletal disabilities will limit the diagnostic value of the test (Philbin, Ries, et al., 1995). A very early study by Minor, Hewett, Webel, Dreisinger, and Kay (1988) assessed exercise tolerance and disease related measures in individuals with OA and rheumatoid arthritis (RA). Aerobic capacity was measured using a maximal effort treadmill test based on the Naughton protocol (Naughton, 1978). One hundred and twenty participants aged 21-83 years were tested at baseline (40 RA and 80 OA). Mean aerobic capacity scores across the RA and OA groups ranged from 17-19 ml/kg/min and 17-22 ml/kg/min respectively. However this study lacked a control group for comparison. A follow-up study by Minor, Hewett, Webel, Anderson, and Kay (1989) looked at the efficacy of a physical exercise programme in this same group. Following 12-weeks of aerobic exercise there was a mean increase in aerobic capacity scores in both the OA and RA groups (2.58 ml/kg/min and 4 ml/kg/min respectively). This study indicates that individuals with RA and OA are able to tolerate a maximal effort treadmill test and that improvements in aerobic capacity can be seen in these individuals.

More recently Philbin, Ries, et al. (1995) assessed the feasibility of exercise testing in individuals with OA. These authors gathered data from a series of 61 individuals awaiting total joint arthroplasty and 23 non arthritic individuals who acted as a control. Participants were asked to perform a maximal symptom limited cardiopulmonary exercise test using arm or leg ergometry. Electrocardiograph (ECG) and BP readings were taken pre and post exercise and a non-invasive cardiopulmonary assessment was performed during exercise. Participants were asked to state the single physical symptom that they perceived as the greatest physical impediment to continued exercise. Ninety seven percent of the participants were capable of symptom limited exercise using leg ergometry. In both the exercise and the control group, there was a high rate of achievement of physiological variables indicative of a maximal exercise response. No test had to be terminated early. There were no adverse cardiovascular or rheumatologic complications and no exacerbations of musculoskeletal symptoms. Despite 24% of participants being diagnosed with CHD prior to testing, there were no differences in the rates of achievement between those with CHD and those without. The results suggested that individuals with end stage OA were not only willing but could also safely perform maximal cardiopulmonary testing. Philbin, Ries, et al. (1995) also demonstrated that leg and arm ergometry could be used successfully in exercise testing in individuals with OA. However there was a trend for lower HRs and lower respiratory exchange ratios (RER) in the arm ergometry group. Arm ergometry also achieved lower mean aerobic capacity scores (10.8 ml/kg/min) than leg ergometry (15.1 ml/kg/min). The results of this study suggested that although individuals with OA were capable of performing symptom limited exercise, they produce significantly lower cardiovascular fitness scores when compared with healthy individuals. The authors believed that this reduced exercise tolerance was reflective of true cardiovascular deconditioning (Philbin, Ries, et al., 1995).

Philbin, Groff, et al. (1995) also assessed the same group of 37 individuals who completed the leg ergometry testing in the previously mentioned study and compared their aerobic capacity scores with the same group of 23 age and gender matched non arthritic individuals this time data was separated to observe the differences in aerobic capacity in individuals with hip and knee OA. CHD was more frequently recorded in individuals with OA than the healthy age matched group. No statistically significant differences were noted in the rate of achievement of indicators of maximal cardiovascular exercise between OA and controls. This study provided further convincing support for the feasibility of maximal cardiopulmonary testing in individuals with OA and indicates a similar degree of exercise effort compared to the control group. True aerobic capacity was observed infrequently across all groups, however all individuals were capable of symptom limited exercise and no adverse responses were recorded. The findings of this study were consistent with their previous study (Philbin, Groff, et al., 1995). There was a significant reduction in mean aerobic capacity in the OA group (12.2 ml/kg/min) compared with control group (16.8 ml/kg/min). Therefore the reduced aerobic capacity scores most likely reflect their chronic musculoskeletal disability.

In another study, Ries et al, (1995) assessed the relationship between severity of OA and cardiovascular fitness. Forty seven individuals were divided into three groups- severe OA, moderate OA and a control group. Individuals with severe OA (scheduled for joint replacement) had significantly higher body mass, increased incidence of CHD and poor outcomes on functional capabilities such as walking, bending and household tasks. In maximal aerobic exercise testing, individuals with severe OA demonstrated significantly lower aerobic capacity scores (13.9 ml/kg/min) during maximal leg or arm ergometry compared the moderate arthritic group (16.2 ml/kg/min) and the control group (21.5 ml/kg/min). The results indicated that the more severe the OA, the lower measured aerobic capacity levels achieved. Healthy individuals also demonstrated significantly higher exercise duration, and exercise workload when compared with individuals with moderate and severe OA.

In the Ries et al. (1995) study all individuals who took part in the maximal aerobic test were able to reach anaerobic threshold during exercise including those individuals with severe OA. Mean RER's were significantly greater than 1.0 at peak exercise in all groups. These finding again indicated good compliance to exercise testing and were indicative of a maximal cardiovascular response to exercise. This study also noted a strong correlation between poor aerobic capacity scores and functional outcome measures. The authors believed this indicated that poor cardiovascular fitness in OA was as a result of progressive inactivity in this group of individuals. Ries et al. (1995) concluded that those individuals that were scheduled for total joint arthroplasty represented the most poorly deconditioned group of individuals with OA thus predisposing this group to significant post-operative complications.

In a follow-up to earlier work, Ries et al. (1996) assessed the effect of total knee joint arthroplasty on cardiovascular fitness scores. The authors collected data from subjects following total knee arthroplasty and from individuals with medically managed OA over a two year period. Participants were asked to perform a maximum symptom limited cardiovascular fitness test at the time of enrolment in the study, then at one and two year follow-ups. None of the participants were put through a specific exercise programme between each follow-up. There were 10 participants from the surgical group and nine from the control group who attended all testing sessions. Individuals who had total knee arthroplasty demonstrated improvements in cardiovascular health at both the one and two year follow-up. Pre-operatively, their aerobic capacity values were well below normal (14 ml/kg/min) and improvements were mild at both one and two years post arthroplasty (15.7 ml/kg/min and 16.4 ml/kg/min respectively). The control group demonstrated no significant changes in aerobic capacity (17 ml/kg/min) at any point in the study. Scores from Arthritis Impact Scale were also unchanged for the control group throughout the two year period however, in the arthroplasty group significant improvements were seen in scores for walking, mobility, bending, household tasks, pain and overall impact of OA. The results of this study suggested that gradual reconditioning takes place following total joint arthroplasty and this was likely due to the increased activity due to reduced joint pain.

Berry et al. (1996) performed a large cohort study to develop an equation to estimate aerobic capacity in older adults with OA of the knee or cardiovascular disease. Four hundred and fourteen participants with OA of the knee and 362 participants with cardiovascular disease took part in the study. All participants completed a maximal effort aerobic exercise test based on the Naughton protocol (Naughton, 1978) using a treadmill. Interestingly, older individuals with knee OA demonstrated lower aerobic capacity scores than those individuals with cardiovascular disease (17.1 ml/kg/min and 23.7 ml/kg/min respectively). The individuals with OA also had increased body mass compared with the cardiovascular disease group. The aerobic capacity levels from this study were similar to those in other studies (Ries et al., 1995; Ries et al., 1996) examining individuals with moderate to severe OA.

Aerobic capacity has been used as an outcome measure for both aerobic and resistance based exercise programmes in individuals with OA. Two separate studies by Ettinger et al. (1997) and Mangione et al. (1999) have used a treadmill exercise test to measure aerobic capacity scores in individuals with OA of the knee prior to undergoing aerobic or strength based rehabilitation programmes. Following 10 weeks of a stationary exercise bike programme Mangione et al. (1999) observed a small improvement in aerobic capacity in individuals with OA of the knee (pre intervention 20 ml/kg/min; post intervention 21 ml/kg/min). Ettinger et al. (1997) noted the mean aerobic capacity levels in individuals at baseline and following a strength or health education programme ranged from 17-18.4 ml/kg/min. The baseline levels (17-20 ml/kg/min) from these studies (Ettinger et al., 1997; Mangione et al., 1999) were higher than those from earlier studies (Philbin, Groff, et al., 1995; Philbin, Ries, et al., 1995). These differences could be attributed to the testing modalities implemented in the studies. Treadmill testing will frequently produce higher aerobic capacity levels compared to cycle ergometry (Maeder et al., 2005).

A number of studies have performed maximal effort exercise tests in individuals with RA. It should be noted that in many instances the subjects with RA were notably younger than those in studies examining OA. Baslund et al. (1993) measured the aerobic capacity of a group of 18 patients with RA (mean age 49 years) at baseline and following eight weeks of bicycle training. Participants were separated into a treatment group and a control group and at baseline aerobic capacity levels for the exercise group were significantly higher than the control group (27.2 ml/kg/min and 20.9 ml/kg/min respectively).

More recently Cimen, Deviren, and Yorgancloğlu (2001) measured pulmonary function, aerobic capacity and respiratory muscle strength in individuals with RA compared with a control group. Twenty five participants with RA and 21 healthy controls took part in the study. The mean age of participants in the RA group was 48 years and 45 years for the control. The mean aerobic capacity levels for the RA group were significantly lower than the control group (65.6 ml/kg/min and 77.4 ml/kg/min respectively). These levels of capacity however were considerably higher than other studies that have looked at aerobic capacity in individuals with RA (Baslund et al., 1993; Hakkinen, Hannonen, Nyman, & Hakkinen, 2002; Häkkinen, Hannonen, Nyman, Lyyski, & Häkkinen, 2003). In fact the aerobic capacity scores from this study are similar to those seen in elite athletes (Caputo & Denadai, 2006). Such findings indicated that there was potentially a fault with the measurement equipment or calibration process.

Hakkinen, et al. (2002) measured neuromuscular performance capacity in 23 individuals with RA compared with 12 healthy controls. Participants were separated into three groups. There were 12 with early stage RA (mean age 42 years), 11 with long standing RA (mean age 49 years) and 12 in the control group (mean age 42 years). Participants underwent a maximal effort cycle ergometer test to measure aerobic capacity. Individuals with longstanding RA demonstrated the lowest mean aerobic capacity levels (23.1 ml/kg/min). Interestingly, this was followed by the healthy control group (24.8 ml/kg/min) and the highest aerobic capacity levels were seen in individuals with early stage RA (26.7 ml/kg/min). This same group of participants were retested following 21-weeks of strength and endurance training Hakkinen et al. (2003). These results demonstrated that small improvements in aerobic capacity were observed across all groups. The greatest improvements were seen in individuals with long standing RA (4.8 ml/kg/min) compared with 2.7 ml/kg/min for the early RA group and 1.8 ml/kg/min for the control group.

Maximal effort treadmill exercise tests have also been used to establish oxygen uptake in patients with RA (Chang et al., 2009; de Carvalho, Tebexreni, Salles, Barros Neto, & Natour, 2004; Komatireddy, Leitch, Cella, Browning, & Minor, 1997). Komatireddy et al. (1997) studied the efficacy of low load resistive muscle training in patients with moderate and severe symptoms of RA. Forty nine participants aged 35-76 years took part in the study. The authors report a number of patients being unable to exercise to maximal effort due to physical disability. A mean aerobic capacity of 18-20 ml/kg/min was reported for moderate and severe RA groups. The authors believe that the exercise protocol was not appropriate for their population and recommend the use of the Naughton protocol (Naughton, 1978).

A more recent study by de Carvalho et al. (2004) measured oxygen uptake during walking in individuals with RA. Participants (mean age 47 years) performed a ramped treadmill protocol until HR maximum was achieved or participants were unable to continue due to pain. Individuals with low grade rheumatoid symptoms produced similar aerobic capacity scores to the control group 24.89 and 24.28 ml/kg/min respectively. However individuals with moderate severity RA symptoms demonstrated a reduction in aerobic capacity (mean 21.76 ml/kg/min) compared with the control group.

A study by Chang et al. (2009), found that of the 96 RA participants 30 were unable to tolerate a treadmill exercise test due to painful knees, unstable angina and haemodynamic compromise. The mean age of the participants was 54 years for males and 50 years for females. The mean aerobic capacity levels for males and females were 23.54 ml/kg/min and 21.80 ml/kg/min respectively. Similar findings were seen in a recent study by Stavropoulos-Kalinoglu et al. (2012). Using an individual ramped exercise protocol, Stavropoulos-Kalinoglu et al. (2012) noted mean aerobic capacity levels of 23.7 ml/kg/min in a group of 36 participants with a mean age of 53.9 years.

To minimise stress on individuals with RA, some researchers have utilised submaximal tests to predict maximal aerobic capacity. Using the Astrand submaximal cycle ergometer test to predict aerobic capacity in individuals with RA, Ekdahl and Broman (1992) found that individuals with moderate severity RA aged 54 years and under had a significantly ($p<0.001$) lower predicted aerobic capacity compared with age and gender matched healthy controls (mean 22.3 and 31.7 ml/kg/min respectively). Mean aerobic capacity in individuals aged over 54 years (18.7 ml/kg/min) was also significantly lower than the control group (21.9 ml/kg/min). These values were lower than the predicted aerobic capacity levels at baseline in a study looking at high and low intensity exercise in individuals with RA (van den Ende et al., 1996). Predicted aerobic capacity in individuals with a mean age of 52 years ranged from 25.8-32.8 ml/kg/min.

Similarly, Neuberger et al. (2007) used a modified Astrand (Siconolfi, Cullinane, Carleton, & Thompson, 1982) submaximal cycle test to determine aerobic capacity in adults with RA. Levels of 21-23 ml/kg/min were observed.

Eurenius, Brodin, Opava and The Para Study Group (2007), undertook a large cohort study assessing the applicability of two separate submaximal exercise test for measuring aerobic fitness in individuals with RA. Two hundred and fifteen participants underwent a cycle ergometer test and 208 individuals performed a treadmill test. Interestingly, the treadmill test elicited lower mean aerobic capacity scores than the cycle ergometer test (25 ml/kg/min and 29 ml/kg/min respectively). This is an unusual finding as generally treadmill testing will produce higher aerobic capacity levels than a cycle ergometer (Huggett et al., 2005). However, a limitation of this study was that the same people were not tested on the cycle and treadmill.

To examine the effect of aerobic capacity and physical activity on fatigue in individuals with RA, Munsterman, Takken and Wittink (2013) used a single stage submaximal walking test to predict aerobic capacity. Sixty participants completed the study and the mean aerobic capacity for this group was 27.8 ml/kg/min. There was no control group in this study with which to compare data.

In summary it is apparent that inflammatory joint pathologies (OA and RA) are associated with a reduction in aerobic capacity when compared to age and gender matched healthy controls. It is apparent that those individuals with OA are more likely to achieve maximal levels of aerobic capacity compared to those with RA. The combination of multiple joint pathologies and systematic dysfunction is the most likely reason. Where maximal levels are reached, those with RA tended to have greater levels of aerobic capacity which is most likely due to their younger age at testing.

2.11 Methods for assessing maximal aerobic capacity in elderly

Maximal exercise testing is the gold standard for assessing maximal aerobic capacity (Noonan & Dean, 2000). Different exercise equipment has been used to measure aerobic capacity, including treadmill testing, cycle ergometry and arm ergometry, though the latter is infrequently used. In respect to treadmill testing the Bruce test and modified Bruce treadmill test are frequently utilised. The protocol begins with three minute stages of walking at 1.7 mph at 0%, 5% or 10% grade (depending on individual fitness levels). There after the grade is increased 2% every three minutes and the speed is incremented 0.8 mph every three minutes until the grade reaches 18% and the speed reaches five mph. After this increment, the speed is increased by 0.5 mph every three minutes. In a typical cycle protocol the test starts with two to three minutes of unloaded pedalling and progresses with a ramped increase of 5-20 watts per minute. These increments differ across studies and the most popular are discussed in more detail later in this section.

The criteria determining when maximal aerobic capacity has been reached is an on-going debate in the literature. The term VO_2peak and VO_2max are often used as though they are synonymous, however it is important to distinguish the difference between them (Whipp, 2010). VO_2peak is simply the highest value of VO_2 attained during an exercise test designed to bring the subject to the limit of tolerance. Unfortunately however it is the highest value achieved regardless of the subject's effort in the test. So while it defines the highest VO_2 value attained during a single test it does not define the highest value attainable by the subject (Whipp, 2010). The highest VO_2 value attainable by the subject is the VO_2max. Its rigorous determination depends on one particular criteria being met; this being that VO_2 does not continue to increase despite a further increase in work rate (WR), thus a plateau is seen when VO_2 is plotted as a function of WR (Whipp, 2010). The incidence of end exercise plateaus may be as low as 50% during incremental treadmill tests (Day, Rossiter, Coats, Skasick, & Whipp, 2003). Unless there is demonstrable evidence of a plateau being reached during exercise testing the maximally achieved VO_2 value must be termed the participants VO_2peak (Whipp, 2010). When this occurs there is uncertainty as to whether this value is the maximal effort given by the subject (Whipp, 2010).

Day et al. (2003) looked at the incidence of VO_2 plateau during an incremental maximal effort cycle ergometer test and assessed the relationship between VO_2peak values seen in incremental exercise tests to those obtained during a maximal constant load exercise test.

Participants performed an incremental ramped maximal effort cycle ergometer test with 15, 20 or 25 Watts/min ramps. Resistance was chosen to bring subjects to their limit of tolerance between 10-15 minutes. Thirty eight participants then completed a constant load exercise test at 90% of the maximum work rate (WR) obtained during the incremental test. The constant load test lasted between 4-10 minutes. Six subjects completed a further five constant load exercise tests to their limit of tolerance. All of the exercise tests included a three to four minute warm-up and a six minute cool-down at 20 watts. A plateau in VO_2 was consistently observed in the plot of VO_2 as a function of WR for the series of maximal effort constant load exercise tests. During the incremental maximal effort exercise test a plateau in VO_2 was only seen in 17% of tests. There was no difference in the incidence of VO_2 plateau in those with higher VO_2 scores than those with lower VO_2 scores. Interestingly the VO_2peak values obtained during incremental exercise testing did not differ significantly from the VO_2 plateau obtained in the plot of VO_2 and WR in the constant load tests. The data from this study suggests that the VO_2peak attained during maximal effort incremental cycle ergometry testing is likely to be a valid index of VO_2max despite there being no evidence of an actual plateau. However without performing both the constant load and incremental exercise uncertainty remains (Day et al., 2003).

It is therefore important to have additional variables to determine if maximal effort was reached. A number of additional measures are recorded during maximal effort exercise testing. These include; HR, blood lactate, rating of perceived exertion (RPE) which has been shown to have a strong linear relationship with VO_2 when used for predicting maximal aerobic capacity (Eston, Lambrick, Sheppard, & Parfitt, 2008) and RER. The values used to determine VO_2max vary between studies. Table 2.3 outlines the criteria for establishing maximal exercise effort between studies.

Table 2.3 Variables for determining maximal exercise effort

Author	RER	RPE (Borg Scale)	VO_2	HR (BPM)
Philbin et al., (1995)	≥1.0	n/a	n/a	>80% age predicted HR max
Philbin et al., (1995)	≥1.0	n/a	n/a	>80% age predicted HR max
Takeshima, et al., (1996)	>1.0	n/a	Plateau	>90% age predicted HR max
Neder, et al., (1999)	>1.2	n/a	Plateauing of VO_2	>90% age predicted HR max
Dvorak, et al., (2000)	>1.0	n/a	n/a	At or above age predicted HR max
Neder, et al., (2001)	n/a	n/a	Average of VO_2 of last 15-seconds	n/a
Cress & Meyer (2003)	>1.0	>18	n/a	Within 10bpm of age predicted HR max
Simar, et al., (2005)	>1.0	n/a	15 second plateau in VO_2	Within 5bpm of age predicted HR max
Arnett (2008)	>1.0	>18	n/a	Within 10bpm of age predicted HR max
Andersson., et al, (2011)	>1.1	>17	Levelling off of VO_2	n/a
Cadore, et al., (2011)	>1.1	n/a	n/a	Age predicted HR max was achieved
Lovell, et al., (2011)	>1.15	n/a	Plateau in VO_2	Within 10bpm of age predicted HR max

Within the literature it is generally accepted that participants have exercised to their maximal capacity if they have achieved at least two out of three measured variables or obtained a plateau in their VO_2 despite an increase in work load during the test.

Exercise stress testing is most frequently carried out using a treadmill or bicycle ergometer. The treadmill provides the more familiar a functional exercise modality of walking, however exercise on a treadmill is not always appropriate for individuals with musculoskeletal conditions such as OA in which weight bearing exercise may cause pain and for individuals who have balance and coordination issues (Huggett et al., 2005). A study looking at the aerobic capacity in active octogenarians used both incremental exercise tests performed a treadmill and cycle ergometer (Simar et al., 2005). Seventeen master's athletes were recruited for the study, each participant underwent two maximal effort exercise test performed on a cycle ergometer and treadmill. The cycle ergometer began with three minutes of rest followed by three minutes of unloaded pedalling and then a ramped incremental protocol 0f 5-15 watts/min for females and 10-20 watt/min increase for men. The treadmill test consisted of a three minute warm-up at a 0% grade and the grade was then increased by 1-1.5% per-minute until exhaustion. Both protocols were designed for the test to stop between 8-12 minutes. Breath by breath analysis was recorded every 20-seconds, ECG and HR were also monitored throughout the test. The mean exercise duration for the maximal effort tests was 10-minutes for each test. The maximal HR value was only 4% higher during treadmill testing compared with cycle ergometer testing however the treadmill test produced 22% higher VO_2 scores than the cycle ergometer test. The results of this study show similar differences between protocols as seen in studies of diseased populations. In patients with ischemic heart disease treadmill testing produced VO_2 scores 28% higher than cycle and arm ergometer tests (Wani, Bainbridge, & Martin, 1997). Hsia, Casaburi, Pradhan, Torres and Porszasz, (2009) compared treadmill and cycle ergometer testing in individuals with COPD. A similar ramped cycle protocol consisting of three minutes rest, three minutes warm-up and five W/min increases in resistance was compared with a linear treadmill test and the Bruce treadmill test. Both treadmill tests produced similar VO_2 scores which were 17% higher than the VO_2 scores attained during the cycle ergometer test.

When participants have been asked to rank stress testing modalities from most preferred to least preferred, the treadmill test was perceived as the most work and the least preferred modality, cycle ergometry was medium difficulty and the second most preferred. Arm ergometry was the least difficult modality and the most preferred by participants (Wani et al., 1997). There was also more extensive stress-induced myocardial ischemia during treadmill testing and arm ergometry than leg ergometry. Both arm and leg ergometry provide useful information, are comfortable for participants and should be considered when performing stress testing on elderly and individuals who cannot perform on a treadmill (Wani et al., 1997).

In individuals with RA and OA of the knee maximal effort treadmill exercise tests have been utilised. Most often the procedure is based on the Naughton or modified Naughton protocol (Berry et al., 1996; Chang et al., 2009; Ettinger et al., 1997; Mangione et al., 1999; Minor et al., 1989). The Naughton protocol consists of nine steps. Each step lasts two minutes, the resistance starts at one mph and is increased to two mph following the first step. The gradient is increased from 0-21% by the completion of the test. This procedure was not well tolerated by all participants. In one study by Chang et al. (2009) a third of participants were unable to complete the exercise test due to pain and discomfort. The Bruce treadmill test has also been used on a sample of individuals with RA, unfortunately the authors (Komatireddy et al., 1997) reported that this protocol was not the most appropriate protocol for their study population.

In recent years cycle ergometry has established itself as a predominant method for conducting stress tests, the potential advantage is reduced upper body motion during pedalling, even at high work rates compared with treadmill walking resulting in better ECG tracing and ease of collecting blood pressure measures (Hambrecht et al., 1992). The cycle ergometer is more practical for exercise testing; it takes up less space, is more affordable and is easier to move. The cycle ergometer is also safer for older adults with balance problems as some frail older adults find it difficult to ambulate even at the lowest speeds on a treadmill (Huggett et al., 2005).

The few studies (Philbin, Ries, et al., 1995; Philbin et al., 1996) that have examined aerobic capacity in OA have used a maximal effort incremental cycle ergometer protocol. The resistance increase varies from the beginning of the test to the end. Initially resistance is increased by five Watts per 60 seconds then 10-Watts, 15-watts, 20-watts and over the last minute of the test resistance is increased by 25-watts. No exercise test progressed past 200 Watts. All participants were able to reach a maximum aerobic capacity or a VO_2 peak using this protocol (Philbin, Ries, et al., 1995; Philbin et al., 1996). HR was monitored with ECG and BP was recorded at the beginning, during the test and at the completion of the test. All participants achieved a RER greater than 1.0 and the mean percentage of HR maximum was 91-98%. Each test had a mean duration of 7-10minutes. Ries et al. (1995, 1996, 1997) used the same incremental cycle ergometer protocol when looking at aerobic capacity in individuals with severe OA and also following total hip and knee joint replacement.

When looking at HR recovery following maximal effort exercise testing Maeder, Ammann, Rickli, and Brunner-La Rocca (2009) found that HR recovers much quicker in the first minute following cycle ergometry than treadmill exercise testing and that this response gradually reduces within the second and third minutes of recovery. This is despite the fact that both exercise modalities elicit similar HR responses at maximal exercise.

When assessing the optimal protocol length for cardiopulmonary exercise testing using a cycle ergometer test, Buchfuhrer, Hansen, Robinson, Sue, and Wasserman (1983) have demonstrated that 8-17 minutes produces the highest aerobic capacity. Tests lasting less than eight minutes produce a reduction in aerobic capacity of approximately 10% and those lasting greater than 17-minutes result in a 5% reduction in aerobic capacity. The authors (Buchfuhrer et al., 1983) suggest an optimal testing protocol of 10±2 minutes.

Wassermann et al, (2012) derived a protocol that involves the patient exercising on a stationary exercise bike while measures of gas exchange are made breath by breath at rest, during three minutes of unloaded cycling and while the work rate is increased continuously each minute. When selecting the work rate increase; VO_2 during unloaded exercise is estimated from patients weight and estimates of peak VO_2 are made from patients age and height, from this the work rate required to reach peak VO_2 in 10-minutes is calculated. This equation has been used to predict work rate when assessing cardiorespiratory fitness in elderly men with chronic cardiovascular and metabolic diseases; 96 participants aged 60-91 years of age completed a maximal effort exercise test using an individualised ramped protocol on a cycle ergometer. All participants achieved VO_2peak which was determined as the point of volitional exhaustion (Maranhão Neto, de Leon, Lira, & Farinatti, 2012). This same method has been used as a screening tool to identify high risk participants prior to undergoing thoracic surgery (Older, Hall, & Hader, 1999). The cardiopulmonary exercise test (CPET) test closely mimics a post-operative situation as it requires increased cardiac output to satisfy increased oxygen demand. Patients who have poor oxygen delivery on the cycle ergometer would be expected to have poor cardiac output following surgery.

2.11.1 Summary

Based on the review of literature, an incremental cycle ergometer test using the Wasserman equation for predicting work rate has been selected to measure maximal aerobic capacity in the current study. Incremental cycle ergometer testing to symptom limited maximum addresses most clinical and fitness issues (Wasserman et al., 2012). The CPET test is easy to administer, it takes less than one hour to perform, it requires little preparation, and can be performed in an outpatient setting, the test is extremely safe with less than three episodes of myocardial ischemia in over 2000 tests (Older et al., 1999). Cycle ergometer testing provides reduced joint stress, greater ease of obtaining ECG and blood pressure measures, is relatively inexpensive, practical, easy to manoeuvre, occupies less space and provides increased safety with respect to frail older adults (Huggett et al., 2005). Cycle ergometer testing has also been shown to be feasible for use in individuals with OA of the knee (Philbin, Ries, et al., 1995). Maximal aerobic capacity will be determined by participants achieving two of the following three variables: RER > 1.0, maximum HR within 90% of age predicted HR maximum and an RPE ≥ 17 (Table 2.3).

2.12 Sub-maximal exercise testing

The direct measurement of maximal aerobic capacity requires an extensive laboratory, highly trained staff, specialised equipment and significant motivation from subjects to perform the protocol successfully. In addition maximal exercise testing can be hazardous if participants have not been adequately screened for medical contraindications to testing or are tested without appropriate safeguards or supervision. As a result of these requirements alternative tests have been derived to predict maximal aerobic capacity from submaximal performance. The accuracy of predicting maximal aerobic capacity from submaximal HR is based on the assumption that the relationship between HR and oxygen consumption is linear at the submaximal workloads undertaken (Beekley et al., 2004). Those most frequently used tests include the ACSM submaximal ergometer test, the YMCA submaximal cycle ergometer test and the Astrand and Rhyming cycle protocol.

The validity and reliability of the ACSM submaximal cycle ergometer test compared with a ramped maximal cycle test was assessed by Griewe, Kaminsky, Whaley and Dwyer (1995). Thirty individuals of moderate activity level aged 21-54 years of age were tested. Subjects completed a ramped maximal effort cycle test with the ramped protocol. Then on a separate testing occasion participants returned for submaximal testing using either protocol A, B or C from the ACSM submaximal cycle protocol. The test is terminated either at the end of the fourth stage or when 65-70% of age predicted HR max is attained. The study showed a significant difference between actual HR max from the maximal test and age predicted HR max. It also showed that the ACSM submaximal cycle protocol significantly overestimated VO_2max in over 85% of the tests performed. The authors believe the reason for limitations in reliability and validity of the ACSM submaximal protocol is the intra individual variation in HR at submaximal power output. As the ACSM protocol terminates when HR reaches 65-70% of age predicted HR max, subjects are unable to reach exercise intensities adequate enough to reduce the intra individual HR variation and thus lead to large errors in estimation of VO_2max.

The ACSM equation has been compared to a new equation for the prediction of aerobic fitness during treadmill exercise in older individuals with OA of the knee and cardiovascular disease (Berry et al., 1996). The study involved 414 participants with radiographic knee OA and 362 participants with documented cardiovascular disease. The OA participants had been collected from a fitness and arthritis in senior's trial (FAST). Participants completed a graded treadmill exercise test with increases in both speed and incline during each stage of the test. An equation (FAST equation) was developed from regression analysis of the interaction of speed, grade of incline and the effect on VO_2 values obtained from each stage of the test in participants with OA to predict aerobic capacity in diseased populations. Both the FAST equation and the ACSM equation were used to estimate VO_2peak in the group with cardiovascular disease to assess the accuracy of both equations on this population. Following testing the VO_2 scores during each stage of the test were plotted against the VO_2 scores estimated from the ACSM equation. The difference between the two values became progressively larger during the later stages of the test. The results from this study show that when the ACSM equation is applied to incremental treadmill exercise it will significantly overestimate VO_2 in older patients with OA of the knee and cardiovascular disease. However, the newly developed FAST equation accurately predicts aerobic capacity at each stage in both participants with knee OA and cardiovascular disease during incremental treadmill exercise (Berry et al., 1996).

Another easy to administer test used frequently in the literature is the YMCA submaximal cycle ergometer test. Beekley et al. (2004) performed a study to cross-validate the YMCA submaximal cycle ergometer test. They tested 102 men and women aged 20-54 years of age. Participants performed two separate maximal effort exercise tests on separate days one test using a treadmill and the second test using a cycle ergometer and the YMCA cycle ergometer test was performed on a third day. The YMCA test is designed to have three stages, each stage lasting at least three minutes. Participant's HR has to reach a plateau over each stage or an additional minute is added to each stage. If the participants HR does not reach 110 beats per minute (BPM) at the completion of the three stages a fourth stage is added. The test is completed when a participants HR exceeds 110 BPM and plateaus or varies by <five BPM over a two minute period. Beekley et al. (2004) showed that all participants recorded higher VO_2 scores during maximal effort testing using the treadmill compared with the cycle ergometer. The YMCA cycle ergometer test produced similar VO_2 values to that seen on the maximal effort treadmill test, however the submaximal cycle ergometer test significantly over predicted VO_2 values when compared with the maximal effort cycle ergometer test.

The Astrand and Ryhming nomogram (Astrand & Rhyming, 1954) is probably the most frequently used equation for predicting VO_2 max from a submaximal effort exercise test. The protocol has an initial exercise rate of 49.0 watts for women and 98.0 watts for men. If the HR after six minutes at this exercise rate is not between 125 and 170 BPM then the subjects would pedal for a further six minutes with the exercise rate 49.0 watts higher. The nomogram allows for the calculation of VO_2 max from steady state HR between 125 and 170 BPM and work load (watts) reached during a test with a submaximal rate of work. The original nomogram was calculated based on values obtained from healthy well-trained men and women aged 20-30 years. Later an age correlation factor was introduced to account for the decrease in HR max with age (Astrand, 1960). This correlation factor was only incorporated for ages up to 65 years.

A number of studies have attempted to modify the Astrand and Ryhming protocol to improve the accuracy with elderly and unfit populations. Siconolfi et al (1982) modified the Astrand-Ryhming protocol for use in elderly and epidemiological populations. The population group assessed consisted of individuals aged 20-70 years of age, with at least 10 men and 10 women per age decade. The Astrand and Ryhming protocol was modified and the initial submaximal exercise rate was based on activity levels and the age of the individual. The initial exercise rate of 24.5 Watts was set for males over the age of 35 and for all females, for men under 35 years of age the initial exercise rate was set at 49.0 Watts. For men 35 years and older and for all women the exercise rate was increased by 24.5 Watts every two minutes and for men under 35 years of age the increase was 49.0 Watts every two minutes until target HR was achieved. Target HR is 70% of age predicted HR maximum (calculated by 220 minus age). Once target HR was met participants continued to exercise for an additional two minute period until steady state HR was achieved. Steady state is measured by consecutive HR readings one minute apart differing by less than five BPM. VO_2max is estimated from the Astrand and Ryhming nomogram (Astrand & Rhyming, 1954) using the mean steady state HR and the final work rate. The age correction factor developed by Astrand (Astrand, 1960) is not used. A separate regression equation for both male and female participants was derived from the measured VO_2max of the test group. All the participants who took part in the validation group were able to reach 70% of HR max and reach steady state during the submaximal test protocol. During the submaximal exercise test steady state HR occurred at 80% of actual peak HR and at 76% of predicted maximum HR. The data from the validity group indicated no significant difference between directly measured VO_2max and that predicted from the regression equations (less than 0.12 l-min^{-1}). The Siconolfi et al. (1982) protocol had lower variability with predicted VO_2max, and has higher correlations with actual and predicted VO_2max (0.87-0.94) than the Astrand age correlation (0.73-0.86). This protocol has also been used to measure aerobic fitness in individuals with RA (Neuberger et al., 2007).

Legge and Banister (1986) developed a new nomogram which incorporates the linear relationship between VO_2 and ΔHR (subtraction of the HR during unloaded pedalling from the maximum HR obtained during the test) to improve the accuracy of the Astrand and Ryhming nomogram for predicting Aerobic capacity. Forty males aged 20-29 years with mixed athletic ability took part in the study. Raw HR data on all subjects was transformed in an attempt to distinguish the degree of fitness between individuals. The new HR variable delta HR (ΔHR) was determined by the subtraction of the HR at the completion of four minutes of unloaded pedalling from the maximum HR obtained during the test. This is thought to define the range of HR variation peculiar to each individual during exercise to a maximum. Throughout the study variables collected justified the relationship between ΔHR and VO_2 as a linear function. Regression lines of %VO_2 max against ΔHR for each sub group were plotted from mean data of these groups. Thus for submaximal constant load work for which the steady state VO_2 has been measured or calculated, a corresponding ΔHR measurement could be obtained. The percent of maximum VO_2 that this ΔHR represents may then be read from the appropriate regression line describing the %VO_2 /ΔHR relationship of the group with which the individual is best identified (trained or untrained). Maximal oxygen uptake was predicted on two occasions for five untrained, five trained and four moderately trained individuals. These predictions were compared with directly measured VO_2max values. The correlation coefficient between observed and predicted VO_2 max was significantly better than that of the Astrand and Rhyming nomogram (Astrand & Rhyming, 1954). However this nomogram has still only been administered on men aged 20-29, however the authors believe that it may be equally applicable for elderly and female populations.

Alternative measures for predicting aerobic capacity have been explored recently (Eston et al., 2008; Nunes et al., 2009). The uses of patient perception and ventilatory measures have replaced the traditional submaximal HR measures to predict aerobic capacity.

Using participant perception to estimate VO_2max has been explored by Eston, et al. (2008). They looked at the relationship between RPE and VO_2 to assess if perceptually regulated graded exercise was a valid and reliable predictor of aerobic capacity. There was no significant difference between actual and predicted VO_2max values across the trials. The RPE values from 9-17 equated to 35-78% of VO_2max indicating a strong linear relationship between VO_2 and RPE. The current study indicates that perceptually regulated exercise can accurately predict maximal aerobic capacity however the authors agree that the current protocol needs some adjustment to make it accessible for use in a clinical setting (Eston et al., 2008).

More recently Nunes et al (2009) performed a study to develop an accurate equation to estimate VO_2max in healthy non athletic women aged 20-75 years using submaximal ventilatory indicators. Ventilatory thresholds have been used to determine aerobic fitness and sports performance (Nunes et al., 2009). There are two thresholds identified the first and second ventilator threshold (VT1 and VT2) these are in line with breaks on the VE curve. The continued increase in exercise intensity following VT2 at the plateau of the curve is deemed VO_2max. VT2 was measured by the V-slope method (Beaver, Wasserman, & Whipp, 1986). ECG tracing was used to record HR at VT2 and HR max at the end of the test. The equation to predict VO_2 max uses the Astrand Ryhming nomogram (Astrand & Rhyming, 1954) and the HR which is determined at VT2. The authors describe stopping the test at second ventilator threshold before the participant reached maximum effort. The findings showed that the VO_2max results observed and estimated showed comparable distribution and similar median values. By using the submaximal prediction equation, a progressive exercise stress test can be terminated before the extreme stress of the final stages of a maximal stress test. However this protocol required breath by breath analysis of gases, thus making it not accessible in most clinical settings.

2.12.1 Summary

Based on the review of literature a modified Astrand and Ryhming (Siconolfi et al., 1982) protocol was chosen for predicting maximal aerobic capacity in the current study. A number of authors (Ekdahl & Broman, 1992; Eurenius et al., 2007; Eurenius & Stenström, 2005; van den Ende et al., 1996) have used the Astrand and Ryhming protocol corrected for age (Astrand, 1960). However the age correction factor does not measure past 65 years. As OA is a disease affecting the elderly, and a HR of 130 BPM is the minimum required for the Astrand and Ryhming protocol, the appropriateness of selecting this protocol for predicting aerobic capacity in elderly diseased individuals is questioned. Therefore an alternative equation which has been used to predict aerobic capacity in healthy older adults (Siconolfi et al., 1982) and older adults with RA (Neuberger et al., 2007) was selected.

Chapter 3

Methodology

3.1 Introduction

The primary aim was to investigate whether individuals with OA of the knee have reduced aerobic capacity compared with age and gender matched individuals without OA of the knee. The second part of this study investigated the accuracy of a submaximal cycle ergometer test for the prediction of aerobic capacity in older adults and individuals with OA of the knee.

The population of interest were adults aged 45-80 years of age. Two separate groups were targeted for the study. The first group were individuals with moderate to severe OA. The second group were healthy age and gender matched individuals to act as a control. Participant's pain, function, and physical activity were measured using a series of self report questionnaires including the WOMAC, LLTQ and the CHAMPS questionnaire. These variables were recorded to compare the activity levels of the participants in the study with the recommended exercise guidelines from the ACSM.

The same participants performed both a submaximal and maximal effort cycle ergometer test during one two hour testing session. The results of these tests allowed an indication of the accuracy of the submaximal test to measure maximum aerobic capacity.

3.2 Study design

A cross sectional comparison study was utilised to assess the above mentioned aims. The procedures utilised in the study were approved by the Northern Y Regional Ethics Committee (approval number NTY/11/05/052 Appendix 2). All subjects received an information sheet

(Appendix 3) regarding this study and were required to sign a consent form (Appendix 4) prior to taking part.

3.3 Selection of participants

3.3.1 Participants

Twenty-five participants with OA of the knee joint were recruited for the study and twenty five age and gender matched healthy individuals were recruited for the control group. The participants were recruited from referrals within North Shore Hospital and through responses to an advertisement in the North Shore Times. The advertisement asked for participants aged between 45 and 80 years of age with OA of the knee or for participants who had no history of knee injury. Interested individuals were contacted via phone and screened at the physical examination using The American College of Rheumatology guidelines (Altman, 1987) for the following inclusion and exclusion criteria.

3.3.2 OA group

Inclusion criteria:

- History of knee pain
- At least three of the following:
    - 50 years of age or older
    - Stiffness lasting less than 30 minutes
    - Crepitus
    - Bony tenderness
    - Bony enlargement
    - No warmth to the touch
- X-ray diagnosis of grade two OA or more on the Kellgren and Lawrence scale (Kellgren & Lawrence, 1957)

Exclusion criteria:

- Any history of significant other lower limb pathology
- Any medical condition that would place the participant at risk of completing exercise at maximal or submaximal level (e.g.: unstable angina, recent myocardial infarction)
- Neurological conditions (e.g. cerebrovascular accident)
- Cognitive impairment
- Inability to provide informed consent
- Use of HR controlling medication (Beta-blocker)

3.3.3 Control group

Inclusion criteria:

- Aged 45-80 years of age
- Two healthy lower limbs

Exclusion criteria:

- Any significant knee injury, diagnosis of OA, or any other lower limb pathology
- Any medical condition that would place the participant at risk of completing exercise at maximal or submaximal level (e.g.: unstable angina, recent myocardial infarction)
- Neurological conditions (e.g. cerebrovascular accident)
- Cognitive impairment
- Inability to provide informed consent
- Use of HR controlling medication (Beta-blocker)

A Physical Activity Readiness Questionnaire (PAR-Q) (Appendix 5) was included in the information packs sent to the participants prior to taking part in the study. Subjects were instructed to view the PAR-Q and if they answered yes to any of the questions excluding the bone and joint question they were to seek advice from their physician prior to taking part in the study.

3.4 Function and activity questionnaires

Between exercise tests participants completed the following questionnaires to determine baseline pain, function, health status and activity levels: The Community Healthy Activities Model Program for Seniors Physical Activity Questionnaire (CHAMPS), the Lower Limb Task Questionnaire (LLTQ), and the Western Ontario and McMaster Universities OA Index (WOMAC).

The LLTQ (McNair et al., 2007) is divided into two distinct sections relating to activities of daily living (ADL's) and recreational activities. In each section participants are asked to rate the degree of pain and difficulty completing 10 different tasks in the last 24-hours (0= unable, 4= no difficulty) and how important they rate each task (1= not important, 4= very important). Where a task had not been completed in the last 24-hours participants were asked to record their best estimate. The task difficulty was scored for both ADL's and recreational activities. Each section has a possible score range from 0 (maximum incapacity) to 40 (normal functional capacity) (see Appendix 6).

The WOMAC questionnaire is one of the most commonly used outcome measures, it has been demonstrated to be a valid, reliable and responsive measure for people with knee OA (Bellamy et al., 1988; Davis et al., 2009). The WOMAC questionnaire measures three separate dimensions; pain (five questions), stiffness (two questions) and function (17 questions). The original WOMAC consists of five Likert-boxes for participants to rate their symptoms from none, mild, moderate, severe and extreme (Roos, Klässbo, & Lohmander, 1999). These are given a numerical value from 0-4 respectively. WOMAC scores range from 0 (no dysfunction) to 96 (maximum dysfunction) (see Appendix 8).

The CHAMPS questionnaire measures physical activity in older adults (Stewart et al., 2001). It is a valid and reliable tool for measuring physical activity in older adults and more importantly the data from CHAMPS might help to identify older adults who are insufficiently active and require a physical activity intervention (Cyarto et al., 2006). It contains 41 questions about various tasks in which participants record participation, frequency and duration for a typical week in the previous four weeks (see Appendix 7). As well as providing information concerning level and frequency of physical tasks, the CHAMPS questionnaire also provides an estimate of caloric expenditure (Stewart et al., 2001).

3.5 Procedures

Testing was conducted in a treatment room in the physiotherapy outpatient clinic at North Shore Hospital. All subjects were tested by the principal investigator and all tests were supervised by an Anaesthetic consultant. Participants were asked to refrain from eating a large meal within two hours of exercise testing.

Height (using wall mounted measuring tape), weight (Salter 9108 Scales) and patient medication were recorded. During a single testing session, participants underwent both a submaximal cycle ergometer test followed by a maximal effort cycle ergometer test. A pilot study was performed prior to commencing this study to determine if randomisation of testing order was required. The results of the pilot study indicated that there was no difference in aerobic capacity if individuals performed the maximal effort test or submaximal effort test first. Throughout this study participants performed the submaximal effort exercise test first. Subjects were given time to familiarise themselves with the testing equipment and were screened with a resting ECG for any irregularities prior to performing the maximal effort exercise test.

3.5.1 Calibration

The CORTEX Metalyzer 3B (CORTEX Biophysik GmbH Leipzig Germany) was switched on at least 30 minutes prior to testing. After 30 minutes the device was calibrated following the on screen calibration procedure according to the manufacturer's guidelines. Barometric pressure was measured using a hand held barometer (GPB 3300 Greisinger electronics), ambient air was calibrated against a cortex calibration gas (5% CO_2, 15%O_2 Bal. N_2) via a sample line connected to the cortex device and the flow sensor was calibrated using a (MediKro 9424) 3000mL calibration syringe which was opened and closed to ensure correct volume calibration.

3.5.2 Electrocardiogram (ECG)

Participants were fitted with a 12 lead ECG (Custo Med) (Custo med GmbH Ottobrunn Germany) with wireless feedback. A resting ECG was performed with the participant positioned in supine lying with two pillows. The ECG was then recorded constantly through the testing with signals transmitted to the Cortex software via a Bluetooth device.

3.5.3 Participant positioning

Participants were positioned on a stationary exercise bike (Custo Med EC3000) (Custo med GmbH Ottobrunn Germany). The seat was electronically adjusted until there was 5-10 degrees of flexion at the knee or the participant could complete a full pedal revolution without knee restriction. An automatic blood pressure cuff was attached to the participant's right arm (Custo Med MA3000) and a pulse oximeter (CORTEX) was placed on the participant's fourth digit of their left hand to measure arterial blood oxygen levels. A mask with oxygen flow sensors (CORTEX Metalyzer 3B) was placed over the participant's mouth and nose and attached to a head net. This allowed expired air to be collected continuously throughout the test. The handle bars were adjusted for participant comfort. A sensor adjustment was performed prior to the sample line being inserted on to the face mask.

Figure 3.1 Participant set up on the cycle ergometer

3.6 Submaximal exercise test

A modified Astrand and Ryhming protocol for older and inactive adults was utilised (Siconolfi et al., 1982). The submaximal test began with a two minute 45 second rest period prior to starting the exercise. This allowed resting data to be collected. Automatic blood pressure measures were collected every two minutes. In order to record perceived exertion, participants were shown a Borg scale (Borg, 1998). The Borg rating of perceived exertion (RPE) values were recorded at the initial pedaling and at the completion of the test. Following the period of rest participants were instructed to pedal at 60 revolutions per minute (RPM). Initial resistance was set at 25 watts resistance for two-minutes and increased by 25 watts every two minutes until 70% of participants age predicted HR max was attained. The resistance remained at this level until the steady state HR was achieved. The test was terminated once HR plateau (HR varied by less than five BPM one minute apart) was achieved. Participants were then asked to complete a cool down for three minutes at five watts resistance where vital signs were monitored and BP measures were taken.

3.6.1 Prediction of aerobic capacity

VO_2 max was calculated using a modified Astrand Ryhming protocol for estimating VO_2 in older and inactive men and women (Siconolfi et al., 1982). The equation is

$$\text{For Males: } Y = 0.348(X_1) - 0.035(X_2) + 3.011$$

$$\text{For Females: } Y = 0.302(X_1) - 0.019(X_2) + 1.593$$

where: Y is VO_2 ($l.min^{-1}$), X_1 is the VO_2 ($l.min^{-1}$) from the Astrand and Ryhming nomogram not corrected for age and X_2 is the age (years).

VO_2 can be expressed as an absolute value however in the current study VO_2 will be calculated in ml/kg/min to allow a comparison with other studies.

3.7 Maximal exercise test protocol

The maximal effort test was performed at least 20 minutes following the sub-maximal test, when HR, RER and blood pressure measures had returned to the pre exercise level. Pilot testing had indicated that this interval was sufficient for the criteria to be met.

A ramped exercise protocol was used for the maximal effort test. The incremental resistance for the test was calculated based on the Wasserman method (Wasserman et al., 2012). The maximal effort test began with a three minute rest period where resting data was collected. The participants were then instructed to pedal at 60 RPM for three minutes of unloaded pedaling before the ramped protocol began. The ramped protocol involved a consistent increase in resistance every minute. A typical test involved 10 increments of 10-20 watts. Every two minutes an automated blood pressure measurement was recorded and participants were asked their perceived exertion (Borg, 1998). The test was stopped when the participants could longer maintain 60 RPM under verbal encouragement, or if they experienced any adverse reaction or the therapist believed it was a health risk for the test to continue. Participants were asked to perform a cool-down for three minutes at five watts resistance with an RPM of 40 following the test. Cardiovascular and respiratory measures were monitored and recorded throughout the warm-down. A test was considered maximal effort if participants achieved at least two of the following criteria: a HR within 90% of age predicted HR maximum, a RER > 1.0 and a RPE > 17 (Andersson et al., 2011; Takeshima et al., 1996). As the participant stops pedaling they are asked if they stopped due to knee pain, and if not what the main reasoning for stopping was.

At the completion of the test three resting ECG's were performed three minutes apart to ensure that there was no adverse cardiovascular reaction to the exercise test and that cardiac parameters had returned to normal prior to the participant being cleared to leave the testing facility.

3.8 Data analysis

Data analysis were undertaken using the Statistics Package for Social Sciences (SPSS) software programme version 20 (Chicago, Illinois, USA) and Graphpad Prism software programme (San Diego, California, USA). Data was checked for normality using D'Agostino-Pearson test and the Generalised Extreme Studentised Deviate (ESD) procedure (Rosner, 1983). An independent t-test allowed the comparison of maximal VO_2 in subjects with OA and in healthy age and gender matched individuals. A t-test was also used to compare activity levels across the groups.

Intraclass correlation coefficients were used to identify the level of agreement between the maximal test and the submaximal test for OA and control groups. For this analysis, a two way mixed model was utilised with the mode of assessment as the fixed variable, and the subjects as the random variable (Müller & Büttner, 1994).

Bland and Altman plots allow an assessment of error. A comparison of actual and predicted aerobic capacity scores were plotted using a Bland and Altman plot (Bland & Altman, 1986), enabling an appreciation of the distribution of error between these two tests. Bland and Altman's bias and 95% limits of agreement were calculated. The former refers to the mean of the difference scores, and the latter as the bias plus or minus 1.96 times its SD. Typical Errors (Hopkins, 2000) were calculated by dividing the standard deviation of all subject's difference scores by the square root of two. The submaximal test result was subtracted from the maximal effort test result for each subject. Hence a positive difference score reflects underestimation by the submaximal test.

For the CHAMPS data, an independent t-test was utilised to analyse the activity related energy expenditure per week across the OA and control groups. A sub-analysis that enabled a comparison with the activity guidelines of the ACSM examined the hours per week of moderate/vigorous activity undertaken in the two groups, these activity levels being most relevant to aerobic capacity. For this analysis, a Mann-Whitney test was undertaken. A Pearson's correlation co-efficient that explored the association between VO_2peak and moderate/vigorous activity was calculated for the whole group and the OA group.

The alpha level was set at 0.05 for all tests.

Chapter 4

Results

4.1 Introduction

The following chapter is divided in to three sections; the first section provides a description of the participants who took part in the study. The second section provides the findings from the exercise tests in the OA and non OA groups, and the accuracy of the of the submaximal exercise test for predicting maximal aerobic capacity. The third section provides the findings for activity participation and physical function across the two groups.

4.2 Subjects

Forty four participants aged 47-81 years were recruited from an advertisement in the local newspaper. There were 24 participants with radiographic evidence of knee OA (Kellgren and Lawrence grade >2) and 20 age and gender matched healthy participants within the control group. The additional four OA subjects had control subjects that matched their age and gender. The OA group consisted of 13 males and 11 females and the control group had 10 males and 10 females. Four participants were excluded from the study for failing to achieve two of the three determinants of aerobic capacity. Therefore total numbers for the study were 22 participants in the OA group (12 males, 10 females) and 18 participants in the control group (9 males, 9 females). Both groups had a mean age of 67 years with a SD of 10 years. Participant demographic data for each group is displayed in Table 4.1.

Table 4.1 Demographic data for study participants

	OA	**Control**
Number of Participants	22	18
Male	12	9
Female	10	9
Maori/Pacific Population	2	2
Independent Living	22	18
Medication for cardiovascular disease	12	8
Diabetes	1	0
Age		
Range	47-81	49-81
Mean (SD)	67(10)	67(10)
Height (cm)- *Mean(SD)*	1.71(0.1)	1.69(0.1)
Mass (kg) - *Mean (SD)*	83(13)	74(14)
BMI - *Mean(SD)*	29(4)	26(4)
Kellgren and Lawrence x-ray - *Mean(SD)*	3(1)	n/a

4.3 Aerobic capacity

An independent t-test showed the significant difference ($P<0.05$) in the aerobic capacity across the OA and control groups. There was an 18% reduction in aerobic capacity in the OA group compared with the control group. The OA group had a mean aerobic capacity of 22 ml/kg/min (SD= 7 ml/kg/min) with a spread of 12-42 ml/kg/min. The mean aerobic capacity of the control group was 27 ml/kg/min (SD= 8 ml/kg/min) with a data spread of 18-52 ml/kg/min. Figure 4.1 shows the comparison in aerobic capacity between the two groups.

At the completion of the test participants were asked their reason for stopping the exercise test. No participants stopped due to pain at the knee joint. The most common reason for stopping was breathlessness and leg muscle fatigue.

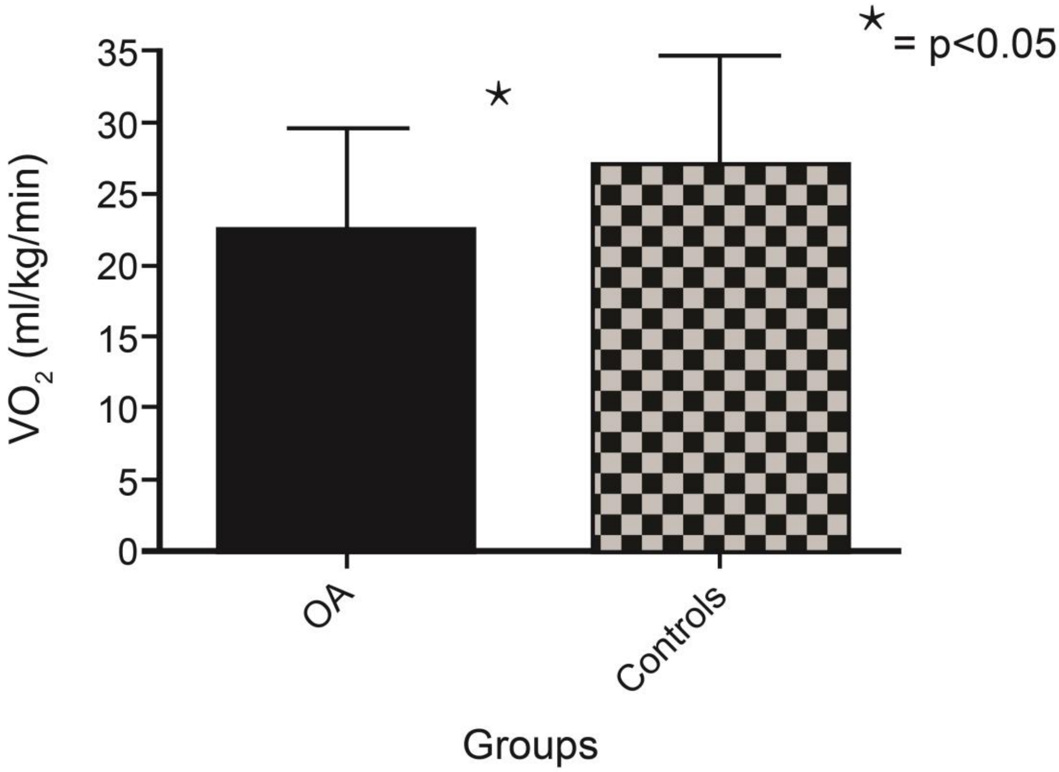

Figure 4.1 Aerobic capacity between OA and control groups from maximal effort exercise test

4.4 Accuracy of submaximal exercise test for predicting aerobic capacity

The mean predicted values from the submaximal test were 19 ml/kg/min and 22 ml/kg/min for the OA and control groups respectively.

The Bland and Altman graphs show that there was a positive bias of 3.4 and 4.8 for the OA and control groups respectively (Figure 4.2 and 4.3). The limits of agreement were from -2.5 to 12.3 and -4.8 to 11.6 ml/kg/min for the OA and control groups respectively. The typical error was 3.5 and 2.7 ml/kg/min for the OA and control groups respectively.

Intraclass correlation coefficients (ICC) between maximal test and the submaximal test were calculated for OA and control groups. The ICCs were .75 and .72 for the OA and control groups respectively.

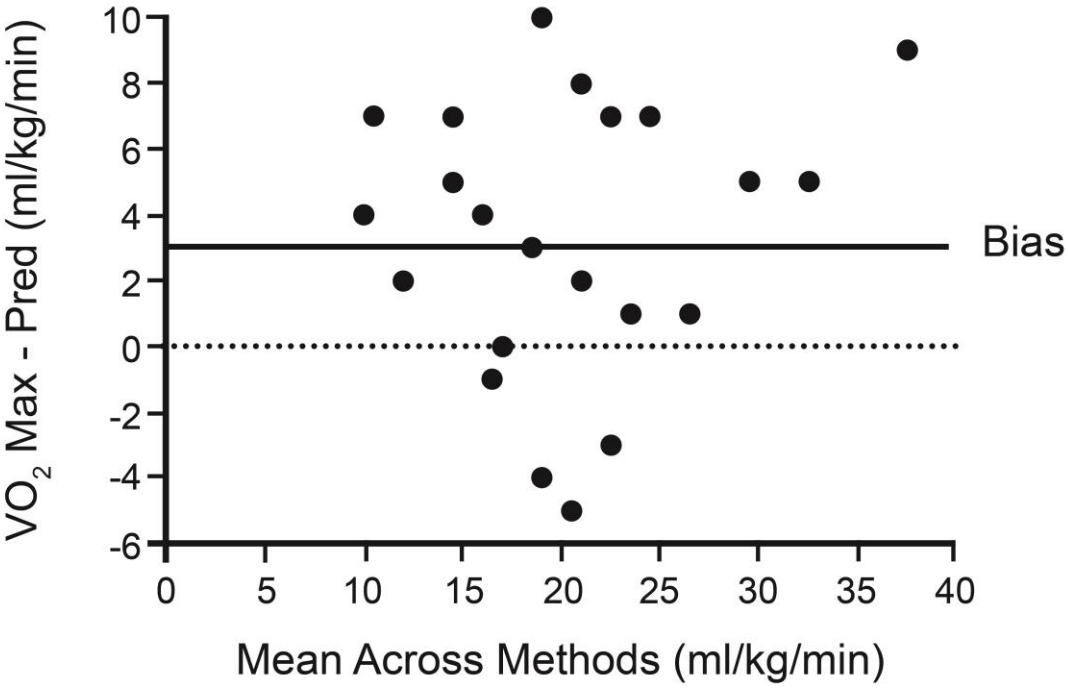

Figure 4.2 Bland and Altman plot for the OA group

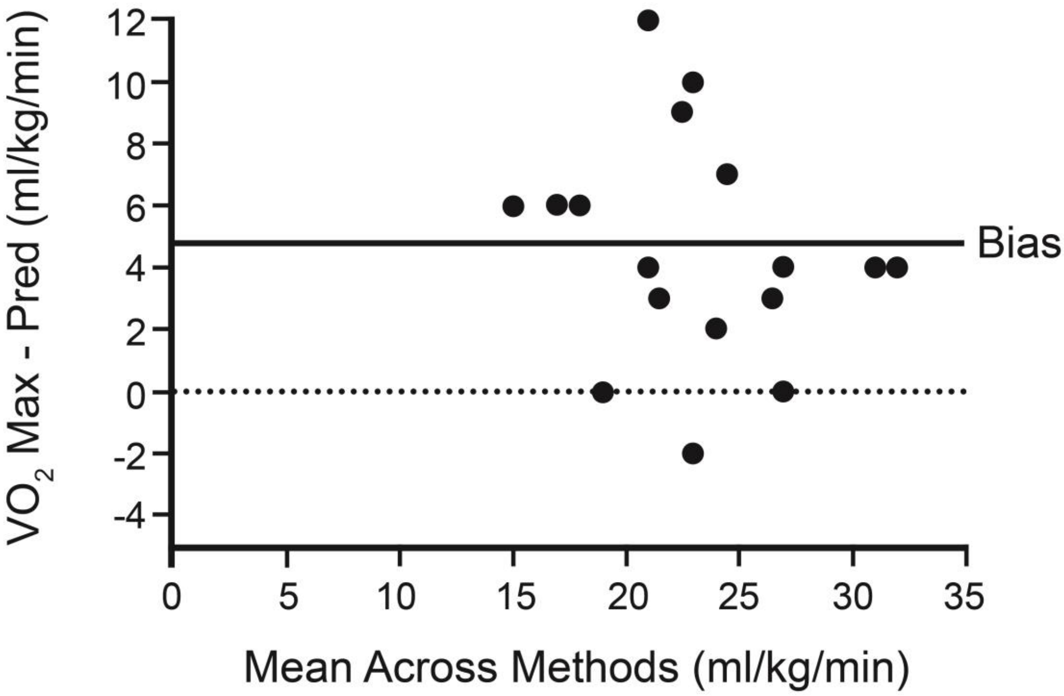

Figure 4.3 Bland and Altman plot for the control group

4.5 Physical function and activity participation

The OA group had significantly lower scores (P<0.05) for both ADL's and recreational activities on the LLTQ (Figure 4.4). There was also a significant difference in weekly calorific expenditure between the OA and control groups. Table 4.2 outlines the mean scores and SD for each group. Figure 4 shows the spread of data between the two groups.

Table 4.2 Results from WOMAC and Lower limb task questionnaire (LLTQ)

	OA		Control	
	Mean	**SD**	**Mean**	**SD**
WOMAC Pain (out of 20)	5	3	0.4	1
WOMAC Stiffness (out of 8)	3	2	0.3	1
WOMAC Function (out of 68)	15	11	1	2
WOMAC Total (out of 96)	23	15	2	3
LLTQ (ADL's) (out of 40)	32	6	39	2
LLTQ (Recreational Activities) (out of 40)	16	10	32	8

*LLTQ= Lower Limb Task Questionnaire ** ADL's= Activities of Daily Living

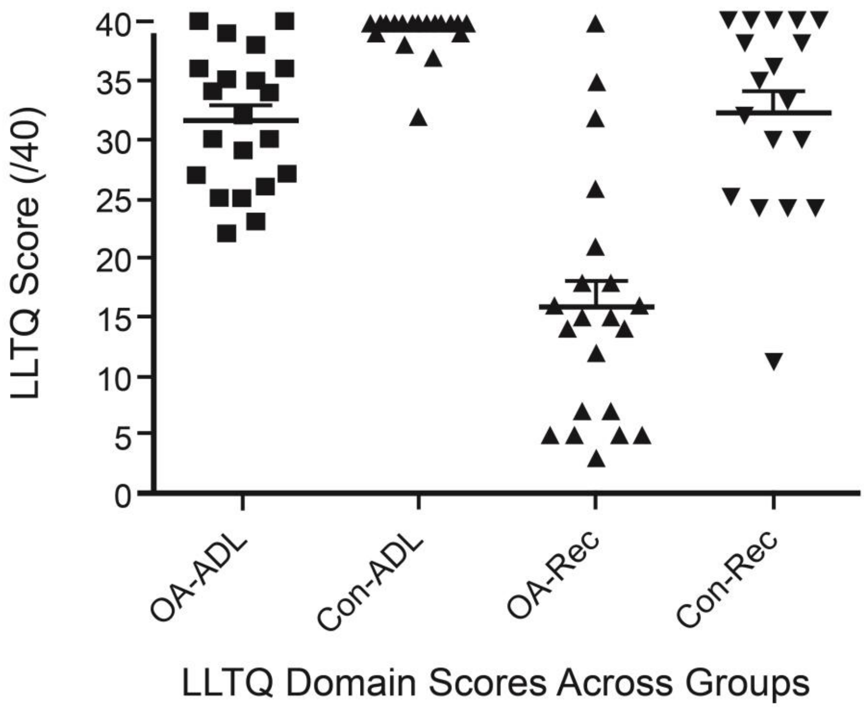

Figure 4.4 LLTQ scores across the groups

For the CHAMPS data, there was a significant difference ($p<0.05$) in activity related energy expenditure per week across the OA and control groups. The means (SD) were 4328 (2356) and 6052 (2449) kcal/week respectively. The hours per week of physical activity at moderate and vigorous levels was also significantly different ($p<0.05$) across the groups (see Figure 4.5). The correlation coefficient between the VO_2 peak and moderate/vigorous activity undertaken was mild ($r = 0.3$, $p<0.05$) across the whole group and slightly higher ($r = 0.4$, $p<0.05$) when focused upon the OA group only.

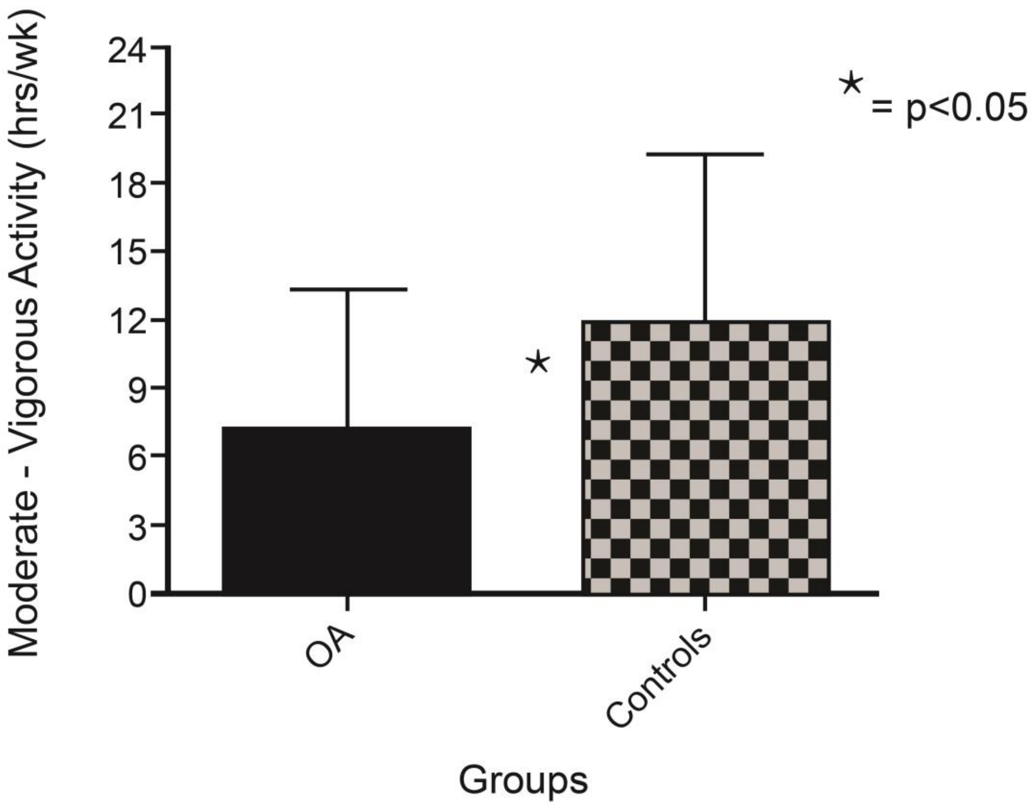

Figure 4.5 Hours of moderate and vigorous activity undertaken per week across the OA and control groups. Data are medians and interquartile ranges.

Chapter 5

Discussion

5.1 Introduction

OA is a progressive disease process associated with pain, muscle wasting and joint stiffness (Peat et al., 2001). The pain associated with OA of the knee results in avoidance of activity. This in turn leads to disuse of muscles, which exacerbates muscle weakness creating a vicious cycle of disuse, muscle weakness, pain and disability (Ettinger et al., 1994).

Reduced activity levels result in a reduction in aerobic capacity which contributes to further disability in older adults. There is little current literature examining the influence that OA of the knee has on aerobic capacity. Therefore the current study examined the difference in maximal aerobic capacity in individuals with OA of the knee compared with age and gender matched healthy controls. In early studies (Philbin, Groff, et al., 1995; Philbin, Ries, et al., 1995; Ries et al., 1995; Ries et al., 1996) a reduction in aerobic capacity in individuals with OA was observed. However it was of interest to assess if these differences in aerobic capacity have changed over time, as there is increased interest in exercise and the introduction of exercise guidelines from The ACSM (Nelson et al., 2007) for individuals with chronic physical conditions.

Poor aerobic capacity and associated deconditioning in OA increase the incidence of cardiovascular disease (Ettinger et al., 1994). Therefore it is important to have effective testing procedures in place for assessing cardiovascular fitness in these individuals. Such exercise tests are a useful screening tool for cardiovascular disease and are also useful when implementing physical activity programmes. Maximal effort exercise testing in elderly and diseased populations carries significant risks. It involves costly laboratory equipment and requires supervision from experienced medical practitioners (Beekley et al., 2004). Submaximal exercise testing overcomes a number of the limitations of maximal effort testing and provides an alternative method for the measurement of aerobic capacity (Noonan & Dean, 2000). The second part of this study assessed the accuracy of a submaximal effort exercise test to predict maximal aerobic capacity in individuals with OA of the knee.

5.2 Analysis of study participants

The mean age of participants was 67 years. This was the same as that reported in previous studies (Philbin, Ries, et al., 1995; Ries et al., 1995) examining aerobic capacity in individuals with knee OA. There was an even spread of male and female participants across the OA and control groups. The OA group had higher body mass (83kg versus 74kg) and greater BMI scores (29 versus 26) than the control group. These findings were similar to another study (Ries et al., 1996) examining individuals with OA of the knee joint. These levels are of concern; the World Health Organisation (World Health Organisation, 2013) has indicated that a BMI of 25-29 is associated with an increased risk of diabetes, ischemic stroke and CHD. With a BMI greater than 30, this risk increases significantly. Over 55% of participants with knee OA in the current study were taking medication for cardiovascular disease including cholesterol and blood pressure medications. This was higher than Chan et al. (2009) who looked at co-morbidities associated with OA in individuals living in Hong Kong where approximately 33% of participants were found to have cardiovascular co-morbidities. In respect to the control group in the current study, there were 44% of participants taking medication for cardiovascular disease. These findings may indicate some differences in lifestyle between individuals in New Zealand and in Hong Kong.

Participant's pain, stiffness and function were measured with the WOMAC. The pain and function scores are significantly lower than a large cohort study (Papakostidou et al., 2012) examining pain, stiffness and physical function in individuals prior to total knee joint replacements, however the mean for stiffness values were similar. The pain and physical function scores align much closer to large cohort studies looking at individuals with early radiographic OA changes (Bieleman et al., 2009) and individuals with non-symptomatic knee OA (Kim et al., 2011). Yet the participants in the current study all had moderate changes as indicated by a Kellgren and Lawrence score greater than two which was a requirement for inclusion. Other authors (Hunter, 2009) have noted discrepancies between structural changes and pain and function as measured by the WOMAC.

Similar results were observed for the LLTQ which was also used to record physical function across both activities of daily living and recreational activities. The OA group had a mean difficulty score with activities of daily living of 32. This was notably greater than McKay et al. (2013) who reported a mean score of 21 for activities of daily living in individuals just prior to undergoing total knee replacement. Interestingly the control group in the current study had a mean difficulty score of activities of daily living of 39 with very little spread across participants (Figure 4.4). The mean LLTQ score for recreational activities in individuals with OA of the knee was 16. This was 50% less than the recreational activity score from the control group (LLTQ score of 32). The much greater changes across recreational activities are of interest. These changes could be due to the participant's perception of an activity. In a recent study (Larmer, McNair, Smythe, & Williams, 2011), it has been demonstrated that when an individual performs a particular task the level of difficulty they experience with this is less than what they perceived it to be.

Difficulty in function is further highlighted by the CHAMPS. The OA groups mean weekly caloric expenditure of 4328 kcal/week was significantly less than the control group 6052 kcal/week. The results from the OA group are not dissimilar to a study (Harada et al., 2001) looking at self-report physical activity in a group of older adults recruited from a community centre (3484 kcal/week). However the caloric expenditure in both the OA and the control groups were significantly higher than a large cohort study (Stewart et al., 2001) looking at caloric expenditure in in-active community dwelling elderly (2420 kcal/week).

Subjects with OA reported completing eight hours of moderate intensity exercise and one hour of vigorous exercise per week compared with 11-hours of moderate intensity and three hours of vigorous intensity exercise from the control group. This is a notably higher amount of moderate intensity exercise compared with a sample of older Australian adults (Cyarto et al., 2006). However the OA group reported similar levels of vigorous exercise when compared with the Australian elderly.

The reason for the higher levels of caloric expenditure and increased hours of moderate and vigorous exercise irrespective of having OA or not may be a reflection of age. The mean age of participants in the current study (67 years) is 7-10 years younger than a number of other studies looking at activity levels in elderly with the mean age of 74-79 years (Cyarto et al., 2006; Stewart et al., 2001). A number of age related changes can take place between these years. A number of older adults will exit the work force at 65 years of age. In early years of retirement individuals are more likely to maintain physical activity, however as aging progresses a reduction in physical activity is observed. In a recent New Zealand survey only a third of individuals aged 75 years and older participated in physical activity (Ministry of Health, 2012).

The ACSM has produced a number of guidelines on exercise prescription and exercise participation. The recommended activity required to maintain good health in all adults is a minimum of 30 minutes per day of moderate intensity aerobic exercise performed on five days of the week or 20-minutes of vigorous intensity exercise completed on three days of the week (Nelson et al., 2007). In the current study, 87% of participants with OA of the knee and 100% of participants in the control group met the recommended activity levels required to maintain good health. Interestingly in studies of American adults only 32-42% of adults over the age of 65 were meeting these recommendations (Macera et al., 2005). On any given day it has been reported (Ham, Kruger, & Tudor-Locke, 2009) that 22-29% of individuals will engage in 30 minutes or more of physical activity. Therefore the findings of the current study are positive and suggest that initiatives to promote increased physical activity in older adults are being taken up here in New Zealand.

5.3 Analysis of maximal aerobic capacity

Given the decreased levels of moderate and vigorous activity observed in the OA group, one would predict that aerobic capacity would be reduced compared to controls, and indeed an 18% reduction was observed. The mean aerobic capacity value in the control group was 27 ml/kg/min. This is significantly higher than aerobic capacity scores in large cohort studies (Cress et al., 1996; Cress & Meyer, 2003) examining aerobic capacity in a population of inactive elderly. However the aerobic capacity levels from the control group in the current study compare well with studies looking at aerobic capacity in previously active elderly (Andersson et al., 2011; Simar et al., 2005) and untrained but healthy older men (Takeshima et al., 1996).

The mean aerobic capacity values for individuals with OA were 22 ml/kg/min. This is higher than the VO_2 peak measures observed in a previous studies (Philbin, Groff, et al., 1995; Philbin, Ries, et al., 1995; Ries et al., 1995) which ranged from 13-15 ml/kg/min during cycle ergometer testing and 17-18 ml/kg/min during treadmill testing (Ettinger et al., 1997). Interestingly, at 24 months following total joint replacement, Ries et al. (1996) reported mean VO_2peak scores had reached 16 ml/kg/min indicative of a mild increase in aerobic capacity. The aerobic capacity levels in the current study align much closer to the results of studies (Baslund et al., 1993; Hakkinen et al., 2002; Häkkinen et al., 2003) that examined aerobic capacity in individuals with moderate to severe RA who attained values of 20-27 ml/kg/min.

The magnitude of difference in aerobic capacity observed between the OA and control groups in the current study was 18%. This is significantly lower than the magnitude of difference measured in a previous study (Ries et al., 1995) examining the effect OA severity has on aerobic capacity. A 35% difference was observed between controls and individuals with severe OA and a 25% difference was observed between individuals with moderate OA and healthy controls. Overall these findings provide some indirect evidence to speculate that there are greater aerobic fitness levels in older adults with and without OA now than at the time the Philbin and Ries studies were published some 17-18 years earlier.

An aerobic capacity level of 20 ml/kg/min has been suggested by Cress and Meyer (2003) to be required to maintain independence with activities of daily living. This figure was derived from comparing aerobic capacity levels in independent community dwelling older adults with that of older adults living in a supervised care facility. A closer examination of the data from the current study showed that 10% of the control group and 45% of the OA group had less than this criterion. Surprisingly, all subjects in the current study were living independently. This could suggest that some individuals are working close to the aerobic capacity required for performing activities of daily living or perhaps individuals have adapted their lifestyles to manage more independently. Alternatively, cross-cultural differences in lifestyle between Americans living in Georgia and those here in Auckland may be responsible. It may also be that a greater promotion of physical activity in the decade since this study was published may have led to increased levels of physical activity.

It was expected that there might be a correlation between hours of moderate/vigorous physical activity and the maximum aerobic capacity test. While significant this was only mild, thus indicative of additional factors influencing the relationship. These factors include the classification of moderate activity in the CHAMPS questionnaire, for instance, the inclusion of heavy gardening, golf, and heavy housework under moderate physical activity. While these are important activities, their influence on aerobic capacity is questionable.

5.4 Analysis of submaximal exercise testing

In the current study the submaximal exercise test under predicted aerobic capacity by a mean of 18% in the control group and 13% in individuals with OA. The standard error of estimate in the Siconolfi protocol was 9.5-13%, and the original Astrand and Ryhming protocol had a consistent error of 15% (Siconolfi et al., 1982). In the current study the correlations between actual and predicted aerobic capacity were .75 and .72 for the OA and control groups respectively. This is lower than the original study by Siconolfi et al. (1982) where the correlation between actual and predicted aerobic capacity was .87-.94. The use of a Pearson product-moment correlation to measure the relationship between actual and predicted aerobic capacity was a limitation of the Siconolfi study as this method cannot take into account systematic differences across the variables. The original Astrand and Ryhming (1954) protocol reported a correlation of .71 between the measured and predicted aerobic capacity.

The mean aerobic capacity predicted for the OA and control groups were 19 ml/kg/min and 22 ml/kg/min respectively. These results are similar to the original study on this protocol which also produced predicted aerobic capacity scores of 19-22 ml/kg/min (Siconolfi et al., 1982). The protocol has also been used to predict aerobic capacity in individuals with RA. The predicted aerobic capacity in this group produced similar results to the current study with baseline measures of 21-23 ml/kg/min (Neuberger et al., 2007) however no comparison was made to actual measured aerobic capacity.

If the predictive test had over predicted aerobic capacity this could lead to therapists prescribing exercise at a significantly higher percentage of an individual's aerobic capacity than intended, placing unneeded stress upon both the cardiovascular and musculoskeletal systems. Some submaximal exercise tests have been shown to over predict aerobic capacity in individuals with OA and cardiovascular disease (Berry et al., 1996) and healthy middle aged and older adults (Greiwe et al., 1995). It has been suggested (Berry et al., 1996; Greiwe et al.,

1995) that protocols that significantly overestimate aerobic capacity should be avoided when an accurate measure of aerobic capacity is required. Thus under estimation is more advantageous, particularly in older population groups as it is more likely to be safe.

5.5 Limitations of the study

The subjects in the current study were volunteers responding to an advertisement in the local newspaper. As the advertisement was asking for participants to take part in an exercise test, this might have appealed to more active members of the population thus creating a more active population sample. Further work might sample individuals more randomly from a database of people known to have OA.

The inclusion criteria for the current study used radiographic findings. Although all participants went to the same clinic for their x-rays, the results were interpreted by two or three different radiologists therefore this may reduce the accuracy of the x-ray grading. However this was standardised through provision of the scoring criteria. The reliability of the Kellgren and Lawrence scale has also been shown (Kellgren & Lawrence, 1957) to be moderately high for inter observer agreement.

The method for determining if maximal aerobic capacity has been achieved was chosen from a number of studies (Philbin, Groff, et al., 1995; Philbin, Ries, et al., 1995; Takeshima et al., 1996). Maximal effort was achieved if participants met two of the following three criteria: RPE>17, within 90% of HR maximum and RER>1.0. Using the criteria, 92% of OA participants and 90% of the control group reached a maximal aerobic capacity. However, the criteria to determine whether a true maximum has been achieved, remains a topic of debate in the exercise physiology literature. Some authors (Midgley, McNaughton, Polman, & Marchant, 2007)have suggested that a verification phase or exhaustive phase should be undertaken.

However such testing in the elderly, particularly those with cardiovascular issues would be unsafe.

Cycle ergometry has been used in a number of other studies (Cress & Meyer, 2003; Day et al., 2003; Simar et al., 2005; Takeshima et al., 1996) for measuring maximum aerobic capacity and has been shown to be a practical measure of aerobic capacity in individuals with severe OA (Philbin, Ries, et al., 1995). However it is not a familiar piece of equipment for all individuals and thus we may see different results between individuals who are familiar with cycle ergometry and those who are not. Cycle ergometry is associated with more leg fatigue (Wani et al., 1997) than in treadmill testing and indeed when asked at the completion of the test, the majority of participants indicated that this was the source of most discomfort. However the use of a treadmill in the elderly requires more time in training to be able to perform safely due to balance and coordination problems (Huggett et al., 2005). Furthermore the load placed upon the knee joint may lead to an increased number of patients stopping their test due to knee pain before the criteria for establishing maximal aerobic capacity has been reached.

5.6 Summary and conclusions

The purpose of this study was two-fold. Firstly this study investigated whether individuals with OA of the knee had reduced aerobic capacity compared with age and gender matched healthy controls. There was an 18% reduction in aerobic capacity in individuals with OA of the knee compared with healthy age and gender matched controls. While the difference between the two groups was indeed statistically significant and such a deficit is worthy of attention, self-reports of physical activity indicate that the majority of subjects were meeting the ACSM recommendations for physical activity in older adults.

With respect to the accuracy of submaximal exercise testing for predicting aerobic capacity; the submaximal test utilised in the current study under predicted aerobic capacity. While greater accuracy in prediction would be ideal, underestimation is more preferable than over prediction from the perspective of delivering an easier programme that is less likely to stress the injured joint and cardiovascular system to unsafe levels.

5.7 Clinical implications

Arthritis affects approximately 15% of New Zealanders, OA of the hip and knee account for 70% of arthritis related hospital visits each year (Access Economics, 2010). As the population ages, the incidence of OA is set to rise. OA has been linked to reduced activity levels, reduced independence with activities of daily living, reduced productivity and an increased risk of cardiovascular disease. In recent years there has been a shift in the management of individuals with OA. With a greater emphasis placed upon exercise. Given the increased interest in activity levels and exercise in individuals with OA, the information gained in the current study is of importance for both increasing knowledge of baseline fitness levels in individuals with OA and establishing if aerobic capacity is indeed reduced in these individuals.

If aerobic capacity is to be improved in individuals with OA of the knee it is important to establish an accurate testing protocol with which to assess these changes. The results of the submaximal exercise tests demonstrated that an easy to administer submaximal effort cycle ergometer test provides a reasonable estimation of aerobic capacity in individuals with OA of the knee. As maximal effort exercise testing is expensive and impractical in most clinical environments, the results of the current study provide therapists with a relatively safe and effective submaximal exercise test.

5.8 Future research

An area of interest is to assess if the differences in aerobic capacity that are observed between individuals with knee OA and healthy controls is also seen in individuals with OA of the hip. As this condition affects 5% of people aged 65 years and older with this figure set to rise to 20%

by 2030 (Wright, Cook, & Abbott, 2009) it is worthy of attention. The differences in the patterns of disuse of the muscles about the hip might influence the capacity to perform aerobic work. However as yet there has been little research in this area.

Another area of interest would be to develop a regression equation to predict aerobic capacity in individuals with knee OA. However increased numbers would be required to accommodate co-variants for such an analysis to be done appropriately.

Further research may utilise the submaximal exercise protocol from the current study to assess the outcomes of programmes that endeavour to increase aerobic capacity in individuals with OA of the knee. This protocol has been shown to be a reliable measure for predicting aerobic capacity in this population. And it would be of interest to assess the sensitivity of this protocol for assessing change in these individuals.

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Appendices

Appendix 1

Methodology of maximal aerobic testing studies:

Author	Participants	Testing protocol	Resistance	Results
Fleg et al. (1988)	184 participants aged 22-87 years	Modified Balke protocol on motor driven treadmill	Constant speed 3.5mph for men and 3.0mph for women. Incline was increased by 3% every 2-minutes until exhaustion.	VO_2 in men ranged from 15.6-54.1 ml/kg/min VO_2 in women ranged from 15.2-42.7 ml/kg/min.
Minor et al. (1988)	120 patients aged 21-78 years of age with OA and RA	Naughton treadmill protocol	10 stages each stage lasting 2-mins except stage 2 lasting 4-mins. Speed increases from 1.5mph-4.0mph. gradient increases from 1.0-15.0%	VO_2 in OA was 17.9 for females and 21.6 for males. VO_2 in RA was 17.8 for females and 19.4 for males.
Baslund et al. (1993)	18 participants with RA aged <65 years	Maximal effort cycle ergometer test	Not defined	Mean VO_2 of 20.9-27.2 ml/kg/min
Philbin et al. (1995)	37 end stage OA 23 Controls	Ramped Cycle ergometer protocol	60RPM incremental protocol with increases every minute. Initial resistance 5W then 10, 15, 25, 35, 45, 60, 75, 90, 110, 130, 150, 175W	VO_2 in hip group 14.9ml/kg/min VO_2 in knee group 12.8ml/kg/min VO_2 in the control group varied from 17-19ml/kg/min
Philbin et al. (1995)	61 with severe OA and RA 23 Controls	Ramped cycle ergometer protocol	60RPM incremental protocol with increases every minute. Initial resistance 5W then 10, 15, 25, 35, 45, 60, 75, 90, 110, 130, 150, 175, 200W	VO_2 15ml/kg/min
Ries et al. (1995)	16 severe OA 17 moderate OA 14 healthy control	Ramped cycle ergometer protocol	Not stated	VO_2 severe OA 13.9ml/kg/min VO_2 moderate OA 16.2ml/kg/min VO_2 Control 21.5ml/kg/min
Ries, et al. (1996)	19 Participants 16 Controls	Ramped cycle ergometer protocol	Not stated	VO_2 started at 14.4ml/kg/min at 2-years follow-up increased to 16.4ml/kg/min
Berry et al. (1996)	414 participants with OA and 362 with CVD	Modified Naughton treadmill protocol	10 stages each stage lasting 2-mins except stage 2 lasting 4-mins. Speed increases from 1.5mph-4.0mph. gradient increases from 1.0-15.0%	VO_2 scores in OA group were 17ml/kg/min VO_2 scores in CVD group were 23.7ml/kg/min
Cress et al. (1996)	148 participants aged 70 years and older; 78 community dwellers, 31 long term independent residents and 39 dependent residents	Ramped cycle ergometer protocol	Resistance was increased at a fixed rate of 8-16 W per minute.	VO_2peak ion community dwellers was 22 ml/kg/min, in independent residents VO_2peak was 19 ml/kg/min, in dependent residents VO_2 peak was 13 ml/kg/min.
Takeshima et al. (1996)	243 men aged 60-85 years divided into two groups trained and	Incremental cycle ergometer test	2-minute warm-up at 0 W resistance was increased 15 W per minute until	VO_2peak in the untrained group was only 70% of that found in the trained group. VO_2peak in trained group was

	untrained. 72 in trained group 172 in untrained group		exhaustion.	38.6 ml/kg/min compared with 26 ml/kg /min in the untrained group. 74 of the 172 in the untrained group did not reach the criteria used to determine VO_2peak.
Ettinger et al. (1997)	365 participants with knee OA	Modified Naughton protocol	10 stages each stage lasting 2-mins except stage 2 lasting 4-mins. Speed increases from 1.5mph-4.0mph. gradient increases from 1.0-15.0%	VO_2 scores varied from 17-18.3ml/kg/min
Komatireddy et al. (1997)	49 participants with RA aged 35-76 years	Modified Bruce treadmill protocol	Modified Bruce: warm-up stage 2.72kph /0% gradient, then 4 stages 2.72kph/5% gradient, 2.72/10% gradient, 4kph/12% and 5.44kph/14%.	VO_2 peak had a mean range of 18.1-20.2 ml/kg/min
Wani et al. (1997)	16 patients 65 years and older	Modified Bruce treadmill test, arm ergometer test with ramped protocol, leg ergometry with ramped protocol	Modified Bruce: warm-up stage 2.72kph /0% gradient, then 4 stages 2.72kph/5% gradient, 2.72/10% gradient, 4kph/12% and 5.44kph/14%. Arm ergometer: initial warm-up 10W with 10W increase every 2 minutes. Leg ergometry: initial warm-up 20W and increased 20W every 2 minutes.	VO_2peak on treadmill test 16-19 ml/kg/min VO_2peak on arm ergometer test 11-14 ml/kg/min VO_2peak on leg ergometer test 12-15 ml/kg/min.
Mangione et al. (1999)	39 participants aged 52-82 years with OA	Naughton treadmill protocol	10 stages each stage lasting 2-mins except stage 2 lasting 4-mins. Speed increases from 1.5mph-4.0mph. gradient increases from 1.0-15.0%	Mean VO_2 peak scores pre intervention were 20.32 ml/kg/min and 21.20 ml/kg/min post intervention
Cimen et al. (2001)	25 patients with RA aged 25-71 years	Cycle ergometer test	3 minute warm-up followed by 25 W resistance increases every 3 minutes followed by a 3 minute recovery	VO_2 was 65.56 ml/kg/min for RA group and 77.43 ml/kg/min for control group
Hakkinen et al. (2002)	23 females with RA and 12 healthy controls mean ages 41-49.	Maximal effort cycle ergometer test	50 W initial WR with increases of 25 W every 2 mins.	VO_2 max for long standing RA was 23.1 ml/kg/min, 26.7 ml/kg/min for early RA and 24.8 ml/kg/min for healthy controls
Cress & Meyer (2003)	192 subjects aged 65-97 years. Participants were divided into three groups; community dwellers, independent in a residential facility and dependent in a residential care facility	Ramped cycle ergometer protocol	Resistance was increased at a fixed rate of 8-16 W per minute.	VO_2peak in the community dwelling group was 21 ml/kg/min VO_2peak in the independent care facility group was 16.8 ml/kg/min VO_2peak in the dependent group was 12.8 ml/kg/min.
Day et al. (2003)	71 participants aged 19-61	Ramped Cycle ergometer test, constant load cycle ergometer test	Ramped test included 15, 20 or 25 W/min increases. Constant load test was performed at 90% of maximum work rate attained during the ramped test.	During the ramped test VO_2peak averaged 3.51 l/min. During the constant load tests the VO_2peak averaged 3.64 l/min.
De Carvalho	35 individuals with RA	Treadmill	2.5, 3.0, 3.5, 4.0, 4.5, and	Mean VO_2 ranged from 21.76-26.42

et al. (2004)	and 35 healthy controls with a mean age of 47 years	exercise test	5.0 km/h with 3 minutes at each speed and then 6.0 km/h for 1 minute following this ramped levels were increased from 5, 10 and 15%	ml/kg/min
Simar et al. (2005)	17 subjects aged 80 years and over.	Ramped cycle ergometer protocol, treadmill protocol and 6-minute walk test	Cycle ergometer: 3-minutes rest, 3-minutes warm-up, then increases of 5-15 W/min for females and 10-20 W/min in males. Treadmill: 3-minute rest, 3-minute warm-up at 0% grade, then increased gradient by 1-1.5% every minute until exhaustion. 6-minute walk test: along 30M corridor.	VO_2peak in cycle ergometer was 23 ml/kg/min, on treadmill the VO_2peak was 28ml/kg/min and in the 6-minute walking test VO_2peak was measured at 21 ml/kg/min.
Arnett et al. (2008)	29 men and 23 women aged 70-92 years.	Modified Balke incremental treadmill protocol	Participants walked at fastest comfortable pace for 2-minute warm-up. Speed remained constant but incline increased 2-3% every 2-minutes.	Average VO_2peak was measured at 20 ml/kg/min
Chang et al. (2009)	96 patients with RA	Naughton Protocol	10 stages each stage lasting 2-mins except stage 2 lasting 4-mins. Speed increases from 1.5mph-4.0mph. gradient increases from 1.0-15.0%	Mean VO_2 peak in males was 27.39 ml/kg/min and 22.60 ml/kg/min for females.
Andersson et al. (2011)	44 participants 23 old (64-79 years), 21 young (20-32 years).	Cycle ergometer test with step wise increases to exhaustion, 6-minute walk test, 5-minute pyramid test	Cycle ergometer test: starting load for old female, old male, young female, young male was 75, 75, 125, 175 W respectively with increases of 15, 15, 20, 25 W each minute. 6-minute walk test along a 50M hallway. A shuttle obstacle test.	VO_2 for older females, older males, young females and young males was 22.9 ml/kg/min, 26.8 ml/kg/min, 43.4 ml/kg/min and 52 ml/kg/min respectively.
Lovell et al. (2011)	24 men aged 70-80 years	Incremental cycle ergometer test with Ramped Protocol	Test begins with 3-minutes warm-up at 15 W and resistance is increased by 5 W every 20 seconds.	VO_2 normal values for the groups Control group: 1.85 L/min Study group: 1.94 L/min Following 16-weeks training Study group had a 10% increase in VO_2.

Appendix 2

Health
and
Disability
Ethics
Committees

Northern Y Regional Ethics Committee
Ministry of Health
3rd Floor, BNZ Building
354 Victoria Street
PO Box 1031
Hamilton 3204
Phone (07) 858 7021
Fax (07) 858 7070
Email: northerny_ethicscommittee@moh.govt.nz

15 September 2011

Brydie Steele
2/22 Emerson Street
St Heliers
Auckland

Dear Brydie-

Ethics ref: **NTY/11/05/052** **(please quote in all correspondence)**
Study title: **Treadmill versus cycle ergometry for testing the cardiovascular capacity of individuals with and without osteoarthritis of the knee.**
Investigators: **Professor Peter McNair, Dr Duncan Reid, Miss Brydie Steele, Dr Peter Kalinowski**

This study was given ethical approval by the Northern Y Regional Ethics Committee .

Approved Documents

— Information sheet version 2 dated 17/07/11
— Consent form version 1 dated 27/03/11
— Advert : volunteers required for arthritis research
— Letters to participant's doctor

This approval is valid until 31 December 2012, provided that Annual Progress Reports are submitted (see below).

Access to ACC

For the purposes of section 32 of the Accident Compensation Act 2001, the Committee is satisfied that this study is not being conducted principally for the benefit of the manufacturer or distributor of the medicine or item in respect of which the trial is being carried out. Participants injured as a result of treatment received in this trial will therefore be eligible to be considered for compensation in respect of those injuries under the ACC scheme.

Amendments and Protocol Deviations

All significant amendments to this proposal must receive prior approval from the Committee. Significant amendments include (but are not limited to) changes to:

— the researcher responsible for the conduct of the study at a study site
— the addition of an extra study site
— the design or duration of the study
— the method of recruitment
— information sheets and informed consent procedures.

Significant deviations from the approved protocol must be reported to the Committee as soon as possible.

Annual Progress Reports and Final Reports
The first Annual Progress Report for this study is due to the Committee by 15 September 2012. The Annual Report Form that should be used is available at www.ethicscommittees.health.govt.nz. Please note that if you do not provide a progress report by this date, ethical approval may be withdrawn.

A Final Report is also required at the conclusion of the study. The Final Report Form is also available at www.ethicscommittees.health.govt.nz.

Requirements for the Reporting of Serious Adverse Events (SAEs)
SAEs occurring in this study must be individually reported to the Committee within 7-15 days only where they:

- are *unexpected* because they are not outlined in the investigator's brochure, and
- are not defined study end-points (e.g. death or hospitalisation), and
- occur in patients located in New Zealand, and
- if the study involves blinding, result in a decision to break the study code.

There is no requirement for the individual reporting to ethics committees of SAEs that do not meet all of these criteria. However, if your study is overseen by a data monitoring committee, copies of its letters of recommendation to the Principal Investigator should be forwarded to the Committee as soon as possible.

Please see www.ethicscommittees.health.govt.nz for more information on the reporting of SAEs, and to download the SAE Report Form.

Statement of compliance
The committee is constituted in accordance with its Terms of Reference. It complies with the *Operational Standard for Ethics Committees* and the principles of international good clinical practice.

The committee is approved by the Health Research Council's Ethics Committee for the purposes of section 25(1)(c) of the Health Research Council Act 1990.

We wish you all the best with your study.

Yours sincerely

Amrita Kuruvilla
Administrator
Northern Y Regional Ethics Committee
Email: amrita_kuruvilla@moh.govt.nz

Appendix 3

INFORMATION SHEET

Stationary exercise bike for testing aerobic fitness in individuals with osteoarthritis of the knee

Principal investigator:
Peter J. McNair *PhD MNZSP*
Professor
Health and Rehabilitation Research Institute
AUT University
(09) 921 9999 ext 7143

Co-investigator:
Dr Duncan Reid
Health and Rehabilitation Institute
AUT University
(09) 921 9999 ext 7806

Co-investigator:
Dr Peter Kalinowski
Anaesthetist
North Shore Hospital
Waitemata DHB
021 504 902

Co-investigator:
Brydie Steele *BHSc Physio, PGD Musculo*
Senior Physiotherapist
Shore Physiotherapy
Auckland
027 278 7408

You are invited to take part in the following study which forms part of a Masters qualification and is being undertaken by researchers from AUT University and North Shore Hospital. This information sheet explains the study to you, and you can then decide whether you would like to be involved. If you do not understand any aspect of the study described below, please ask for clarification. You may have a friend, family or Whānau member support you to help you understand the risks and/or benefits of this study and any other explanation you may require. An interpreter can be provided should you need one.

Participating in this study is entirely your choice, and if you do agree to take part, you are free to withdraw from the study at any time without having to give a reason and without any adverse consequences. You do not have to decide immediately about participating in the study. We will call you approximately 3 days after you receive this form and ask you if you wish to participate in the study. You can take longer to decide if you wish, but please note that if the full number of participants is reached before your decision is made, you will not be included in the study.

Purpose of the study

Osteoarthritis (OA) of the knee is a disease process associated with cartilage destruction, bone thickening and new bone growth. It is common in the aging population and is often associated with reduced activity levels and reduced cardiovascular fitness. This is thought to contribute to a number of associated medical co-morbidities. If cardiovascular fitness is to be improved in individuals with OA appropriate assessment tests are required. The purpose of this study is to compare three standard tests used for measuring cardiovascular fitness and establish the test that would be most appropriate for people with OA of the knee. This study will also compare the results from people with OA of the knee to a group of age matched healthy participants. As well as measuring VO2 (cardiovascular fitness) levels we will also record subjective data such as pain and activity levels. Findings from this research may lead to more effective exercise assessment in people with OA of the knee and a clearer picture of the fitness deficits in people with OA of the knee

Selection of participants

This study will involve:
- 25-participants aged 45-75 years with a history of knee pain or a diagnosis of OA of the knee
- 25- Participants aged 45-75 years with no history of knee or lower limb injury

What does the study involve?

This study will be undertaken at the Physiotherapy department at North Shore Hospital. Participants will be asked to attend two testing sessions over a three week period that will take approximately 1-hour per session in total. If you have OA of the knee you will also be asked to provide a recent x-ray, within 12-months to confirm a diagnosis of OA. If you have not had an x-ray taken recently we will arrange for this to be done and we will pay the cost for any x-rays to be completed. If you have had no history of knee pain and you are part of our control group you will not need to complete an x-ray. A choice of petrol or Westfield vouchers will be provided after each session to compensate you for your time and travel costs.

Testing session one:

In your first session you will be familiarised with the lab and the equipment, you will be asked to fill out a series of questionnaires so we can understand your current level of activity and your pain experiences. You will then perform a 6-minute light to moderate intensity sub-maximal exercise test on an exercycle. We may stop the test at any time because of signs of fatigue or changes in your heart rate or symptoms you may experience. It is important for you to realise that you may stop when you wish because of feelings of fatigue or any other discomfort.

During the sub-maximal test:

- You will be familiarised with the exercycle.
- We will record your resting heart rate and blood pressure.
- You will perform a short warm-up on the exercycle.
- The testing session will commence and will consist of approximately 6-minutes of light to medium intensity exercise.
- You will be asked to pedal at a steady state for the duration of the test, resistance will be maintained and your heart rate will be measured
- Heart rate will be monitored throughout each stage. We will also ask you your perceived exertion rating during the test.
- Your appearance and symptoms will be monitored and checked regularly.
- The test will be terminated at 6-minutes or when your heart rate plateaus at 70% of your age adjusted heart rate maximum, if you request to stop, if you experience an emergency situation, experience an adverse sign or symptom or if you fail to perform the exercise test protocol accurately.
- An appropriate cool down will be implemented at the completion of the test.
- Your heart rate, blood pressure, and physical signs and symptoms will be monitored until these measures return to their pre-test levels.

You will rest for 15-minutes until your heart rate has returned to the pre test levels. You will then be asked to perform a maximal effort exercise test on an exercycle. The exercise intensity will begin at a low level and will be advanced in stages depending on your fitness level. This is a strenuous test performed using a standardised testing method. You might experience breathlessness and muscle fatigue during the test. We may stop the test at any time because of signs of fatigue or changes in your heart rate, ECG, or symptoms you may experience. It is important for you to realise that you may stop when you wish because of feelings of fatigue or any other discomfort.

During the maximal effort test:

- Your resting heart rate and blood pressure will be recorded.
- You will be fitted with a face mask to measure your breathing, and surface electrodes and leads will be attached to your chest to monitor your heart rate and heart signals throughout the test.
- The testing session will commence, it will begin at an easy level and increase incrementally until you attain your maximal age adjusted heart rate and other physiological parameters.
- Your appearance and symptoms will be monitored and checked throughout the test.
- You will be given encouragement by the therapist throughout the testing.
- Testing will be terminated once maximal age adjusted heart rate and other physiological parameters are reached or if you request to stop, if you experience an emergency situation, if you experience any adverse signs or symptoms or if you fail to perform the exercise test protocol accurately.

- An appropriate cool down will be implemented at the completion of the test.
- Your heart rate, blood pressure, and physical signs and symptoms will be monitored until these measures return to their pre-test levels.

If you have any questions before or following your participation in the study, you are most welcome to contact Brydie Steele (contact details at the top of page 1 on this form).

Benefits, risks and safety

Benefits

At the completion of the study the participants will have a good understanding of their current aerobic capacity, cholesterol levels and associated co-morbidities. The potential benefit of this study is substantial for the management of OA in New Zealand

It will provide us with measures of fitness and general health that allow an appreciation of further treatment needed to help people with OA.

Risks and Safety

1. Subjects will feel breathless at the end of the test.
2. They may experience transient exercise induced muscle discomfort. This might last for 2-3 days should they not be accustomed to exercise.
3. There is the possibility of abnormal blood pressure, fainting and rapid or slow heart rate responses and breathlessness but these are temporary in most instances.
4. You will be exposed to a small dose of radiation when you have x-ray imaging taken.

To minimise the risks

Every effort will be made to minimise the risks by performing preliminary screening tests, careful evaluation of preliminary findings relating to health and fitness levels will be carried out. All participants will be carefully observed throughout the testing process and heart rate, blood pressure and perceived exertion will be measured throughout the test. There will be a medical doctor present or close by during all the maximal exercise testing. Emergency equipment and trained personnel are available to deal with any unusual events that may arise.

The radiation exposure from a single weight bearing view of the lower limb is approximately 0.0001mSv this equates to approximately 3hours worth of natural background radiation exposure and is of negligible risk of radiation related illnesses.

Compensation

In the unlikely event of a physical injury as a result of your participation in this study, you may be covered by ACC under the Injury Prevention, Rehabilitation, and Compensation Act 2001. ACC cover is not automatic, and your case will need to be assessed by ACC according to the provisions of the Injury Prevention, Rehabilitation, and Compensation Act 2001. If your claim is accepted by ACC, you still might not get any compensation. This depends on a number of factors, such as whether you are an earner or non-earner. ACC usually provides only partial reimbursement of costs and expenses, and there may be no lump sum compensation payable. There is no cover for mental injury unless it is a result of physical injury. If you have ACC cover, generally this will affect your right to sue the investigators.

If you have any questions about ACC, contact your nearest ACC office (4377800) or the principal investigator.
If you have private medical insurance, please check with your insurance company before agreeing to take part in this study. You should do this to ensure that your participation will not affect your medical insurance.

Confidentiality

No material that could personally identify you will be used in any reports on this study unless your personal approval is given for the distribution of results to specific persons (e.g. your doctor). All participants will be assigned a number and only the researchers involved in this study will have access to your name. All participant records will be locked away under lock and key by the principal researcher.

If you wish to have a copy of the results of this research, you are entitled to this on request from Peter McNair. These will be available after the study is completed and published. You are advised however that a significant delay may occur between testing and the publication of the results.

Finally

If you agree to participate in the study, please complete the attached consent form.

If you have any queries or concerns regarding your rights as a participant in this research study, you can contact an independent Health and Disability Advocate. This is a free service provided under the Health & Disability Commissioner Act:

Free phone (NZ wide):	0800 555 050
Free Fax (NZ wide):	0800 2787 7678 (0800 2 SUPPORT)
Email:	**advocacy@hdc.org.nz**

To ensure ongoing cultural safety Nga Kai Tataki - Maori Research Review Committee Waitemata DHB encourage those who identify themselves as Maori and who are participating in health research or clinical trials to seek cultural support and advice from either Mo Wai Te Ora – Maori Health Services or their own Kaumatua or Whaea.
For assistance please contact the Services Clinical Leader for Mo Wai Te Ora – Maori Health on 09 486 1491 ext: 2324 or the Maori Research Advisor on 09 486 1491 ext: 2553.

Appendix 4

CONSENT FORM

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Stationary exercise bike for testing aerobic fitness In individuals with osteoarthritis of the knee

Principal investigator:
Professor Peter McNair
Health and Rehabilitation Research Centre
AUT University
(09) 921 9999 ext 7143

English	I wish to have an interpreter.	Yes	No
Maori	E hiahia ana ahau ki tetahi kaiwhakamaori/kaiwhaka pakeha korero.	Ae	Kao
Cook Island	Ka inangaro au i tetai tangata uri reo.	Ae	Kare
Fijian	Au gadreva me dua e vakadewa vosa vei au	Io	Sega
Niuean	Fia manako au ke fakaaoga e taha tagata fakahokohoko kupu.	E	Nakai
Samoan	Ou te mana'o ia i ai se fa'amatala upu.	Ioe	Leai
Tokelaun	Ko au e fofou ki he tino ke fakaliliu te gagana Peletania ki na gagana o na motu o te Pahefika	Ioe	Leai
Tongan	Oku ou fiema'u ha fakatonulea.	Io	Ikai

- I have read and I understand the information sheet dated **27th March 2011** asking for volunteers to take part in the study designed to investigate treadmill versus stationary exercise bike for testing aerobic fitness in individuals with osteoarthritis of the knee.
- I have had an opportunity to ask questions and am satisfied with the answers given.
- I have had time to discuss this with Whanau/family and or a friend if I chose to.
- I understand that taking part in this study is voluntary (my choice), and that I may withdraw from the study at any time.
- I understand the compensation provisions for this study.
- I know who to contact if I have any queries relating to this study.
- I have had time to consider whether to take part in the study.
- 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 wish to receive a copy of the research results once they have been published: Yes/No (Please note that there may be a significant delay between data collection and the publishing of results).

I ________________________________ (full name) hereby consent to take part in this study.

Signature: ____ Date: _____________

Contact Address (to send results of the study, if applicable):

____

Appendix 5

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

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

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ______________________

SIGNATURE ______________________ DATE ______________________

SIGNATURE OF PARENT ______________________ WITNESS ______________________
or GUARDIAN (for participants under the age of majority)

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

 Supported by: Health Canada Santé Canada

continued on other side...

Appendix 6

APPENDIX 1: LOWER-LIMB TASKS QUESTIONNAIRE

Activities of daily living section

Patient: ______________ **Date:**____________

INSTRUCTIONS

Please rate your ability to do the following activities in the **past 24 hours** by circling the number below the appropriate response.

If you did not have the opportunity to perform an activity in the **past 24 hours**, please make your *best estimate* on which response would be the most accurate.

Please also rate how important each task is to you in your daily life according to the following scale:

1. = Not important
2. = Mildly important
3. = Moderately important
4. = Very important

Please answer all questions.

		NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE	IMPORTANCE OF TASK			
1.	Walk for 10 minutes	4	3	2	1	0	1	2	3	4
2.	Walk up or down 10 steps (1 flight)	4	3	2	1	0	1	2	3	4
3.	Stand for 10 minutes	4	3	2	1	0	1	2	3	4
4.	Stand for a typical work day	4	3	2	1	0	1	2	3	4
5.	Get on and off a bus	4	3	2	1	0	1	2	3	4
6.	Get up from a lounge chair	4	3	2	1	0	1	2	3	4
7.	Push or pull a heavy trolley	4	3	2	1	0	1	2	3	4
8.	Get in and out of a car	4	3	2	1	0	1	2	3	4
9.	Get out of bed in the morning	4	3	2	1	0	1	2	3	4
10.	Walk across a slope	4	3	2	1	0	1	2	3	4
			TOTAL (/40) :____							

Recreational Activities section

Patient: ______________ **Date:**____________

INSTRUCTIONS

Please rate your ability to do the following activities in the **past 24 hours** by circling the number below the appropriate response.

If you did not have the opportunity to perform an activity in the **past 24 hours**, please make your *best estimate* on which response would be the most accurate.

Please also rate how important each task is to you in your daily life according to the following scale:

1. = Not important
2. = Mildly important
3. = Moderately important
4. = Very important

Please answer all questions.

		NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE	IMPORTANCE OF TASK			
1.	Jog for 10 minutes	4	3	2	1	0	1	2	3	4
2.	Pivot or twist quickly while walking	4	3	2	1	0	1	2	3	4
3.	Jump for distance	4	3	2	1	0	1	2	3	4
4.	Run fast/sprint	4	3	2	1	0	1	2	3	4
5.	Stop and start moving quickly	4	3	2	1	0	1	2	3	4
6.	Jump upwards and land	4	3	2	1	0	1	2	3	4
7.	Kick a ball hard	4	3	2	1	0	1	2	3	4
8.	Pivot or twist quickly while running	4	3	2	1	0	1	2	3	4
9.	Kneel on both knees for 5 minutes	4	3	2	1	0	1	2	3	4
10.	Squat to the ground/floor	4	3	2	1	0	1	2	3	4
			TOTAL (/40):___							

Appendix 7

CHAMPS: Activities Questionnaire for Older Adults

CHAMPS Activities Questionnaire for Older Adults

Date:___________________________________

CHAMPS: Community Healthy Activities Model Program for Seniors

Institute for Health & Aging, University of California San Francisco

Stanford Centre for Research in Disease Prevention, Stanford University

Contact: Anita L. Stewart, Ph.D., UCSF, anitast@itsa.ucsf.edu

This questionnaire is about activities that you may have done in the past 4 weeks. The questions on the following pages are similar to the example shown below.

INSTRUCTIONS

If you DID the activity in the past 4 weeks:

Step #1 Check the YES box.

Step #2 Think about how many TIMES a week you usually did it, and write your response in the space provided.

Step #3 Circle how many TOTAL HOURS in a typical week you did the activity.

Here is an example of how Mrs. Jones would answer question #1: Mrs. Jones usually visits her friends Maria and Olga twice a week. She usually spends one hour on Monday with Maria and two hours on Wednesday with Olga. Therefore, the total hours a week that she visits with friends is 3 hours a week.

In a typical week during the past 4 weeks, did you…	

1. Visit with friends or family (other than those you live with)? 2 ☐ **YES** How many TIMES a week?______ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

If you DID NOT do the activity:

- **Check the NO box and move to the next question**

In a typical week during the past 4 weeks, did you …							
1. Visit with friends or family (other than those you live with)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
2. Go to the senior centre? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
3. Do volunteer work? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
4. Attend church or take part in church activities? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
5. Attend other club or group meetings? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
6. Use a computer? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
7. Dance (such as square, folk, line, ballroom) (do not count aerobic dance here)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
8. Do woodworking, needlework, drawing, or other arts or crafts? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
9. Play golf, carrying or pulling your equipment (count walking time only)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
10. Play golf, riding a cart (count walking time only)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
11. Attend a concert, movie, lecture, or sport event? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
12. Play cards, bingo, or board games with other people? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
13. Shoot pool or billiards? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
14. Play singles tennis (do <u>not</u> count doubles)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
15. Play doubles tennis (do <u>not</u> count singles)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
16. Skate (ice, roller, in-line)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
17. Play a musical instrument? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
18. Read? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
19. Do heavy work around the house (such as washing windows, cleaning gutters)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
20. Do light work around the house (such as sweeping or vacuuming)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
21. Do heavy gardening (such as spading, raking)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
22. Do light gardening (such as watering plants)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
23. Work on your car, truck, lawn mower, or other machinery? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

****Please note: For the following questions about running and walking, include use of a treadmill.**

24. Jog or run? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
25. Walk uphill or hike uphill (count only uphill part)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
26. Walk <u>fast or briskly</u> for exercise (do <u>not</u> count walking leisurely or uphill)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
27. Walk to do errands (such as to/from a store or to take children to school (count walk time only)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
28. Walk leisurely for exercise or pleasure? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL hours a week did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
29. Ride a bicycle or stationary cycle? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
30. Do other aerobic machines such as rowing, or step machines (do <u>not</u> count treadmill or stationary cycle)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
31. Do water exercises (do <u>not</u> count other swimming)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
32. Swim moderately or fast? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
33. Swim gently? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
34. Do stretching or flexibility exercises (do <u>not</u> count yoga or Tai-chi)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
35. Do yoga or Tai-chi? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
36. Do aerobics or aerobic dancing? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
37. Do moderate to heavy strength training (such as hand-held weights of <u>more than 5 lbs</u>., weight machines, or push-ups)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
38. Do light strength training (such as hand-held weights of <u>5 lbs. or less</u> or elastic bands)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
39. Do general conditioning exercises, such as light calisthenics or chair exercises (do <u>not</u> count strength training)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours
40. Play basketball, soccer, or racquetball (do <u>not</u> count time on sidelines)? ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

In a typical week during the past 4 weeks, did you …							
41. Do other types of physical activity not previously mentioned (please specify)? ____________________ ☐ **YES** How many TIMES a week?_____ ➔ ☐ **NO**	How many TOTAL <u>hours a week</u> did you usually do it? ➔	Less than 1 hour	1-2½ hours	3-4½ hours	5-6½ hours	7-8½ hours	9 or more hours

Thank You

Appendix 8

Your Full Name: ___________________________________ Today's Date:
_________/_________/_________

Month Day Year

<u>WOMAC OSTEOARTHRITIS INDEX</u>

1. The following questions concern the amount of pain you are currently experiencing in your knees. For each situation, please enter the amount of pain you have experienced in the <u>past 48 hours.</u>

		None	mild	moderate	severe	extreme
A. Walking on a flat surface	A.	☐	☐	☐	☐	☐
B. Going up or down stairs	B.	☐	☐	☐	☐	☐
C. At night while in bed	C.	☐	☐	☐	☐	☐
D. Sitting or lying	D.	☐	☐	☐	☐	☐
E. Standing upright	E.	☐	☐	☐	☐	☐

2. Please describe the level of pain you have experienced in the past 48 hours for each one of your knees.

		None	mild	moderate	severe	extreme
A. Right knee	A.	☐	☐	☐	☐	☐
B. Left knee	B.	☐	☐	☐	☐	☐

3. How <u>severe</u> is your stiffness <u>after first awakening</u> in the morning?

None	mild	moderate	severe	extreme
☐	☐	☐	☐	☐

4. How severe is your <u>stiffness</u> after sitting, lying, or resting <u>later in the day</u>?

None	mild	moderate	severe	extreme
☐	☐	☐	☐	☐

5. The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities, please indicate the degree of difficulty you have experienced in the last 48 hours, in your knees.

What degree of difficulty do you have with:

		None	mild	moderate	severe	extreme
A. Descending (going down) stairs	A.	☐	☐	☐	☐	☐
B. Ascending (going up) stairs	B.	☐	☐	☐	☐	☐
C. Rising from sitting	C.	☐	☐	☐	☐	☐
D. Standing	D.	☐	☐	☐	☐	☐
E. Bending to floor	E.	☐	☐	☐	☐	☐
F. Walking on a flat surface	F.	☐	☐	☐	☐	☐
G. Getting in/out of car	G.	☐	☐	☐	☐	☐
H. Going shopping	H.	☐	☐	☐	☐	☐
I. Putting on socks/stockings	I.	☐	☐	☐	☐	☐
J. Rising from bed	J.	☐	☐	☐	☐	☐
K. Taking off socks/stockings	K.	☐	☐	☐	☐	☐
L. Lying in bed	L.	☐	☐	☐	☐	☐
M. Getting in/out of bath	M.	☐	☐	☐	☐	☐
N. Sitting	N.	☐	☐	☐	☐	☐
O. Getting on/off toile	O.	☐	☐	☐	☐	☐
P. Heavy domestic duties (mowing the lawn, lifting heavy grocery bags)	P.	☐	☐	☐	☐	☐
Q. Light domestic duties (such as tidying a room, dusting, cooking)	Q.	☐	☐	☐	☐	☐

Appendix 9

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

MEMORANDUM

Auckland University of Technology Ethics Committee (AUTEC)

To:	Peter McNair
From:	**Dr Rosemary Godbold** Executive Secretary, AUTEC
Date:	13 January 2012
Subject:	Ethics Application Number 12/09 **Treadmill versus cycle ergometry for testing the cardiovascular capacity of individuals with and without osteoarthritis of the knee.**

Dear Peter

I am pleased to advise that the Chair of the Auckland University of Technology Ethics Committee (AUTEC) and I have approved your ethics application. This delegated approval is made in accordance with section 5.3.3.2 of AUTEC's *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement at AUTEC's meeting on .

Your ethics application is approved for a period of three years until 13 January 2015.

I advise that as part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/research/research-ethics/ethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 13 January 2015;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/research/research-ethics/ethics. This report is to be submitted either when the approval expires on 13 January 2015 or on completion of the project, whichever comes sooner;

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

Please note that AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this.

When communicating with us about this application, we ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact me by email at ethics@aut.ac.nz or by telephone on 921 9999 at extension 6902.

On behalf of AUTEC and myself, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely

Dr Rosemary Godbold
Executive Secretary
Auckland University of Technology Ethics Committee

Cc: **Brydie Steele steveandbrydie@xtra.co.nz, Duncan Reid**

From the desk of ...
Dr Rosemary Godbold
Executive Secretary
AUTEC

Private Bag 92006, Auckland 1142
New Zealand
E-mail: ethics@aut.ac.nz

Tel: 64 9 921 9999
ext 8860
Fax: 64 9 921 9902

Appendix 10

Waitemata District Health Board *Te Wai Awhina*

NORTH SHORE HOSPITAL
Shakespeare Road
Private Bag 93-503, Takapuna
Auckland 9
Telephone: (09) 486 1491
Facsimile: (09) 486 8908

Monday 14 November 2011

Ms Brydie Steele
2/22 Emerson Street
St Heliers 1071
Auckland

Tena koe Brydie,

RE: Treadmill verses stationary exercise bike for testing aerobic fitness in individuals with osteoarthritis of the knee.

Please be advised that the above research study and associated documents were reviewed by Nga Kai Tataki – Waitemata Maori Research Review Committee (MRRC). As a result Nga Kai Tataki MRRC is pleased to advise that your application has been approved and will continue to be supported, however, please note the following recommendations that arouse from the members' discussions regarding the research protocol:

1. Please revisit page 4 Q13 of the NAF application and correct the answer, the 'yes' box needs to be ticked?
2. The participant information sheets for Waitemata DHB need to contain the official Maori Health support clause available to download from the Knowledge Centre website or by contacting the Maori Research Advisor for *Awhina* Health Campus.

The subsequent endorsement of your research is subject to the condition that before proceeding researchers must advise any Maori participants that they should seek advice and tautoko from their own whanau, Kaumatua or Kuia or their local Maori Health Services. Please send Nga Kai Tataki MRRC a 1-2 page summary of your findings once your research is complete.

Hei kona mai i roto i nga mihi.

Tanekaha Rosieur *for*
Chairperson
Nga Kai Tataki MRRC

Giovanni Maihi Armaneo
Maori Research Advisor
***Awhina* Health Campus**