Functional and physiological measures in individuals with hip osteoarthritis

by

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Abstract

**Background:** Osteoarthritis of the hip joint causes difficulties to the elderly because it impacts their ability to conduct their normal activities of daily living, such as walking, cooking, bathing, dressing, using the toilet, and performing household chores. Moreover, the joints can become painful, stiff, and swollen. The resulting pain causes limited motion, restriction of social activities, and compromised work capacity. The interaction of these factors can affect both functional and physiological status. The normal course of action for these subjects is to be referred to an orthopedic surgeon; however, the functional and physiological impact of waiting times for hip replacement consultation or surgery on subject’s function has not been properly assessed with objective outcome measures. **Objectives:** The purpose of this study was to investigate the differences in objective outcome measures of functional and physiological status between subjects with hip OA who were preoperative candidates for hip surgery and those who were diagnosed with hip OA at the time of referral and time of consultation. **Methods:** Subjects with hip osteoarthritis were selected based on their position in the continuum of care once they had been referred to a surgeon. These groups were: referral (REF) (n=7), consultation (CON) (n=7) and pre-operatively (PREOP) (n=7). Individuals with hip OA were evaluated using functional (6MWT and TUG) and physiological (hip muscle isokinetic strength - Biodex and VO₂peak) outcome measures. **Results:** The 6 minutes walk test (6MWT), timed up and go (TUG) and VO₂peak were significantly different
between the three groups (p < 0.001, p = 0.005 and p = 0.001). However, no significant difference was observed in hip flexion and extension muscle strength between groups. Post Hoc analysis revealed that the REF group walked significantly greater distances (p < 0.001) when compared to the PREOP group during the 6MWT. Both REF and CON groups showed significantly shorter times in the TUG test (p < 0.009 and p < 0.02 respectively) when compared to the PREOP group and finally the VO₂peak in the REF group was significantly higher than the predicted VO₂peak of the CON (p = 0.002) and the PREOP (p = 0.002) groups, respectively. **Conclusion:** Subjects with hip osteoarthritis who are within four weeks of surgery generally walked shorter distances, demonstrate worse mobility and balance control and a lower aerobic capacity than individuals with hip OA at the time of referral to a surgeon and at the time of consultation with the surgeon. Contrary to expectation, this study did not find differences in hip muscle strength, between those with hip osteoarthritis at the time of referral; at the time of consultation and within four weeks prior to surgery.
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Chapter 1

Introduction

Osteoarthritis (OA) is one of the most prevalent musculoskeletal conditions affecting the elderly adult population worldwide (Hinman, Heywood and Day, 2007) and its prevalence and incidence are predicted to increase significantly in the future as the population ages (Felson and Zhang, 1998). OA is the wearing down of cartilage in the joints of the body, causing varying degrees of pain, stiffness and swelling (Felson, 2006).

The increase in incidence and severity of OA in the population greater than 55 years old makes it a growing public health problem (Badley and Crotty, 1995). In Canada, OA is the leading cause of long-term disability, accounting for more than 25% of all long-term disability cases (The Arthritis Society, 1999).

In 1998, the Public Health Agency of Canada (PHAC) estimated the economic burden of arthritis at approximately $4.4 billion annually, representing just over one-quarter of the total cost of musculoskeletal diseases. Arthritis accounts for nearly one-third of hospital care expenditures for musculoskeletal disease, over 40% of drug expenditures, and more than one-quarter of both musculoskeletal mortality costs and morbidity due to long-term disability. Of the total arthritis expenditures in 1998, $908.9 million (20%) were direct costs and $3.5 billion were indirect costs (80%). This level of disability has a strong impact on society, which is becoming more debilitated and less productive, leading to a direct increase in health care costs (Fisher, Gresham and Pendergast, 1993).
Despite the volume of research on OA, little information exists about the natural history and pathogenesis of OA (Felson and Zhang, 1998). A disease with multiple etiologies, OA results in deterioration of the articular cartilage of joints, hardening of the sub-chondral bone, and overgrowth of new bone at the joint margins (La Mantia and Marks, 2006). Risk factors considered important in the development of OA include obesity, female gender, physical and mechanical stress and work activity (Panush and Holtz, 1994).

Individuals with OA also tend to report their health as fair or poor rather than very good or excellent, and these individuals have twice as many visits to health care providers compared to individuals without OA (Resnick, 2001). Consequently, the population with OA is more likely to be restricted in their physical and social life than healthy adults in the general population (Croft et al., 2002).

The hip joint is one of the most frequently affected joints in OA (Felson, 2006). Ten percent of subjects 75 years of age and older are affected by hip OA (Hinman, Heywood and Day, 2007). For those over the age of 65, OA of the hip accounts for greater physical disability in lower extremity tasks, such as walking, stair climbing, and rising from a chair, than any other condition (Guccione et al., 1994). The result of hip OA is that many individuals end up requiring hip replacement surgery.

According to the Canadian Institute for Health Information (CIHI, 2006), total hip replacement surgery has progressively increased in Canada. CIHI has
reported that the number of hip replacement surgeries is increasing at a faster rate than the population is aging. In 2006, the Canadian Joint Replacement Registry (CJRR) published its Annual Report on Hip and Knee Replacements in Canada and found that even after accounting for population changes and aging, there was a 21% increase in the rate of hip replacements over 10 years (between 1994–1995 and 2004–2005). This increased demand for total joint replacement continues to exceed the available resources, which increases the waiting times for both consultation and joint replacement surgery (CIHI, 2006).

The Canadian health care system is publicly funded and based on universal and equitable access for all procedures (CIHI, 2006). In terms of waiting lists, this system translates into universal, equitable access for all procedures based on patient need (Short, 1999). If all else is equal, and the health intervention offers some tangible benefit, those with the greatest need should be served first (Lewis et al., 2000). In a well-organized health care system, waiting lists should not include patients whose health will deteriorate rapidly while they wait for surgery, nor should those unlikely to benefit from early treatment get precedence over those for whom early treatment will provide great benefit (Gudex et al., 1990).

In November 2004, Ontario officially launched the Wait Time Strategy, designed to improve access to healthcare services in the public system by reducing the time adult Ontarians wait for total hip replacement. However, the Ministry of Health and Long-Term Care (MHLTC) has made it a priority program
and has increased funding to meet growing demand, because waiting lists keep getting longer (Trypuc, MacLeod and Hudson, 2006).

Thousands of Canadians are on waiting lists for major joint arthroplasty in hopes of reducing their disability and improving their quality of life (Kelly et al., 2001). The negative impact of waiting times for surgery on a patient’s quality of life and self-reported physical function has been shown in several studies using subjective questionnaires such as the Western Ontario McMaster Universities Osteoarthritis Index (WOMAC) (Garbuz, Xu and Duncan, 2006) and SF-36 (Brazier, Roberts and Deverill, 2002). However, studies that have used objective measures to assess functional and physiological status of patients with hip OA who are on waiting lists are limited (Brazier et al., 1999).

Therefore the aim of this study was to investigate the functional and physiological differences in distinct groups of subjects diagnosed with hip OA at three points in the continuum of care: at the time of referral to an orthopedic surgeon, at the time of consultation with an orthopedic surgeon and within four weeks pre-operatively. It was hypothesized that subjects with hip OA who are within four weeks pre-operatively would demonstrate lower functional and physiological status compared to those at the time of referral to an orthopedic surgeon and those at the time of consultation with the orthopedic surgeon. These three time points in the continuum of care were chosen because they are defined as critical by the Ministry of Health and Long Term Care (MHLTC) of Ontario.
Chapter 2  
Literature Review  

2.1. The role of the Wait Time Strategy and the diagnostic criteria for total hip replacement

The main purpose of the Wait Time Strategy in Ontario is to improve access to healthcare services in the public system and subsequently reduce the time adult Ontarians wait for total joint replacement (Trypuc, MacLeod and Hudson, 2006). However, despite the increase in the number of surgeries performed, waiting lists keep getting longer (Muckhin and Marin, 2008). These procedures are considered the end-stage treatments for reducing pain and disability, and with an aging population the number of people requiring surgery is expected to rise even higher (Muckhin and Marin, 2008).

A patient’s wait in the continuum of care may begin long before the orthopedic surgeon and patient agree that surgery is necessary. For instance, a person may live with pain without going to see their family physician. A person may then wait to see a family physician or other primary care provider to obtain a referral to an orthopedic surgeon. If a person does not have a family physician, there may be further delays. Although the wait time for the patient begins when the family physician makes the referral to an orthopedic surgeon, for the purposes of the Wait Time Strategy, the wait for surgery is defined as being from the time the patient sees the orthopedic surgeon and both the surgeon and
patient agree to the surgery, to the date the patient receives the operation (MHLTC, 2005). Consequently, three groups of patients are identified during the total wait time frame: those patients who are referred from the family physician, but are not part of the waiting list for surgery, are at the beginning of the wait time 1. The second group, are those patients who were already assessed by the orthopedic surgeon for consult and are waiting to be informed about the next available date on the waiting list for surgery. They are between wait time 1 and wait time 2. Finally those who are waiting for surgery and are considered preoperative candidates on the waiting list for a total hip replacement are at the end of wait time 2 (MHLTC, 2005). These points in the continuum of care are illustrated in Figure 1.

**Figure 1**: adaptation of patient’s Journey scheme – Ministry of Health and Long-Term Care

[Diagram showing the process of patient's journey through the hospital system, including wait times and key events such as family physician referral, orthopedic surgeon assessment, patient-agreed surgery, and operation receipt.]
There appears to be general consensus that total joint replacements are appropriate if a patient has persistent pain or disability that interferes with daily activities, that is not relieved by medical treatment, and for which there is radiological evidence of joint damage (MHLTC, 2005). According to some Ontario clinicians, the most important factors affecting the appropriateness of total joint replacements are the presence and severity of pain, the severity of functional impairment, problems with performing a care giving role, and the perceived likelihood of improvement in function with surgery (Naylor and Williams, 1996). Surgeons use their professional judgments to prioritize patients by the urgency of their condition. According to Naylor and Williams (1996), there is general consensus among physician experts in Ontario that patients with sufficient pain and/or functional impairment to warrant a planned, primary total joint replacement should wait no more than 26 weeks. However, this protocol has not been established formally.

In 2005, the Ontario Joint Replacement Registry (OJRR) developed wait time threshold guidelines for total hip and knee replacement surgery based on patient severity and outcomes. The OJRR determined waiting thresholds based on pre-operative Western Ontario and McMaster University Osteoarthritis Index (WOMAC) scores, literature review, and one year post-operative outcomes (MHLTC, 2005). The WOMAC is a disease-specific multi-dimensional, self-administered, health status instrument developed specifically for patients with lower extremity arthritis (Bellamy, 1989). It is widely used for evaluating
effectiveness of therapeutic interventions for the treatment of OA (Bellamy, 1989). The WOMAC consists of 24 questions aggregated into 3 sub-scales measuring: pain (5 items), stiffness (2 items), and physical function (17 items). The likert-scaled version (LK3.1) uses mild, moderate, severe, and extreme response levels for each item. Items are rated using one of five responses (0 = none, 1 = mild, 2 = moderate, 3 = severe, 4 = extreme). Three subscale scores are calculated, pain (0 to 20), stiffness (0 to 8), and physical function (0 to 68). A low score indicates less difficulty, and a high score indicates more difficulty (Roos et al., 1999). Consequently, the higher the final total scores the worse the patient’s perceived level of severity of their OA.

Three patient priorities and wait time targets were recommended by the OJRR based on disease severity at the time of decision for surgery. Priorities ranged from Priority I (highest) with a maximum wait of one month to Priority III with a maximum wait of six months. The priorities are to be followed in conjunction with the surgeon’s clinical assessment, taking into consideration patient preference; for instance, a patient may prefer to delay surgery beyond the recommended threshold. Table 1 presents the Ontario’s Wait Time Strategy Panel’s recommended priority rating scale and the target time frame for total hip and knee joint replacement in Ontario.
Table 1: Adaptation of the recommended priority rating scale and target time frame for total hip and knee replacement.

<table>
<thead>
<tr>
<th>Priority Rating</th>
<th>Target Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4 weeks maximum (1 months)</td>
</tr>
<tr>
<td></td>
<td>• Peri-Prosthetic fracture, septic replaced total joint.</td>
</tr>
<tr>
<td></td>
<td>• Recurrent dislocation of a total hip joint replacement.</td>
</tr>
<tr>
<td></td>
<td>• Any situation that has the potential to deteriorate quickly and result in an emergency admission.</td>
</tr>
<tr>
<td>II</td>
<td>12 weeks maximum (3 months)</td>
</tr>
<tr>
<td></td>
<td>• Baseline WOMAC &gt; 70/100 (note 1)</td>
</tr>
<tr>
<td></td>
<td>• Affected joint is a threat to role and independence</td>
</tr>
<tr>
<td>III</td>
<td>26 weeks maximum (6.5 months)</td>
</tr>
<tr>
<td></td>
<td>• Baseline WOMAC &lt; 70/100</td>
</tr>
<tr>
<td></td>
<td>• Affected joint is not a threat to role and independence.</td>
</tr>
</tbody>
</table>

*http://www.health.gov.on.ca/transformation/wait_times/providers/reports/hip_knee_ep_report_0905.pdf*

*Note 1: Use WOMAC scale with 0 = no disability and 100 = most severe disability.*

Another important guideline for total hip and knee replacement surgery is the Western Canada Waiting List Project (WCWL). The WCWL is a federally and provincially funded partnership of organizations created to develop tools for managing waitlists (MHLTC, 2005). The WCWL panel on hip and knee replacement surgery developed maximum acceptable wait times for hip and knee replacement surgery by identifying seven key criteria affecting urgency: pain on motion, at rest and with walking; other functional limitations; abnormal findings on examination; potential for progression of disease based on X-ray findings; and threat to role and/or independence (Canadian Medical Association, 2005).
Ratings were weighted and summed to produce three priority levels ranging from I (least urgent) with a maximum wait of five months, to III (most urgent) with a maximum wait of one month (MHLTC, 2005).

It has been observed that using a guideline to prioritize individuals in the continuum of care for total hip replacement is an important mechanism to ensure that the Canadian health care system is more organized and consistently meets patient’s needs (MHLTC, 2005). As a result, patients whose health tends to deteriorate rapidly while they wait for surgery would be more likely to receive treatment earlier compared to those who are unlikely to benefit from early treatment.

2.2. Advanced practice physiotherapy and the diagnostic criteria for total hip replacement

The demand for hip joint replacements is increasing largely due to an aging population that has age-related musculoskeletal diseases (Muckhin and Marin, 2008). In addition, new technologies are making joint surgery a more viable option for both young and older people (MHLTC, 2005). The Canadian Joint Replacement Registry (CJRR) reported in 2005 that degenerative OA was one of the most common diagnoses resulting in the need for 81% of the primary total hip replacements. The increased demand for total hip replacement continues to exceed the available resources, which can increase wait times for both orthopedic consultation and joint replacement surgery (Hudson, 2006).
According to a report by the Canadian Medical Association (CMA) in 2005, patients who require a total hip replacement and wait for longer periods of time (more than 6 months from the day the surgeon and patient agreed to have surgery to the actual surgical day) tend to show a negative impact on their quality of life scores and self-reported physical function (CMA, 2005). In addition, there are economic advantages to performing surgery earlier. It was observed that there is a potential for substantial savings in resources as a result of timely surgery (MHLTC, 2005).

One potential solution to address this problem is to have non-physician healthcare professionals assessing and diagnosing patients referred to orthopedic surgeons, thereby allowing surgeons time to perform more surgery (Cooper, 2001). Over the past 30 years, many health care professions in Ontario have increased their educational qualifications, and have become more specialized and skilled (Trypuc, MacLeod and Hudson, 2006). Using another health professional to assess and diagnose patients with hip OA can decrease the wait for orthopedic care by reducing the number of patients the orthopedic surgeon must assess (Aiken et al., 2007), so that only those who are potential candidates for a total hip replacement are seen by the orthopedic surgeon at the time of consultation.

In the publicly funded healthcare system, an obvious choice to provide effective management for total hip and total knee replacement patients is the physiotherapist, because physiotherapists are considered experts in the
conservative management of musculoskeletal impairments (College of Physiotherapists of Ontario, 2006).

Aiken et al. (2008) observed a significant correlation between the preoperative assessments done by a physiotherapist and an orthopedic surgeon to prioritize patients for surgery. Both the physiotherapist and the orthopedic surgeons used the WOMAC and the Western Canada Wait List Hip and Knee Prioritization Tool (WCWL- HKPT) which is part of the regular assessment of individuals with hip and knee OA. The authors found that 13 (34%) out of the 38 patients were not considered candidates for surgery by both the physiotherapist and the orthopedic surgeon. There was a 100% agreement on the surgical versus non- surgical determination between the two healthcare professionals. The WCWL - HKPT score for the remaining 25 patients who did require surgery was 30.4/100 (±19.3) for the orthopedic surgeon and 41.6/100 (±17.9) for the physiotherapist. They agreed on the WCWL - HKPT prioritization for 16 (64%) of the subjects. In the other nine cases (36%) the physiotherapist rated the subjects as having a higher surgical priority than the surgeon did. However, it is expected that the surgeon is the one who decides on surgical prioritization, and consequently the difference in scores for surgical prioritization between physiotherapist and surgeon did not result in any change in surgical criteria for the patient. Besides, it is preferable that the physiotherapist be more cautious than less. Finally the authors concluded that the physiotherapists with advanced training in reading radiographs are able to identify and diagnose patients with hip
and knee OA. In addition, physiotherapists use the same major radiological findings (cartilage degradation, presence of osteophytes and narrowing of joint space) as the orthopedic surgeon to properly diagnose a patient with OA. Consequently they are the appropriate non-physician healthcare professional to assess patients referred to orthopedic surgeons for total hip and knee replacement.

### 2.3. Indications of deterioration while waiting for total hip replacement

One of the most significant threats to an older person, who has the ability to live and function independently, is loss of mobility. Consequently, physical disability due to OA is an important public health concern for older adults (Croft et al., 2002). OA and other joint disorders are correlated with advancing age and so an aging population contributes to an increase in hip OA replacement procedures (Croft et al., 2002). Currently, joint replacement of the hip is employed as a solution to improve quality of life (QOL) in this population (Norman-Taylor, Palmer and Villar, 1995).

In general, the longer the wait for elective surgery, the poorer the health related quality of life experienced by the patients who live with the burden of unrelieved symptoms (Brazier et al., 1999). Although there are indications of deterioration in health status while waiting for a total hip replacement, a study by Kelly et al., (2001) did not find significant differences over time in pain, quality of life and self-reported physical function in subjects with hip OA who were waiting
for a total joint replacement. The WOMAC and the SF-36 health status instruments were administered at the time the patient was placed on the waiting list and again just before surgery. Minimal change in pain, QOL and physical function occurred in these hip arthroplasty candidates. Overall, waiting time did not appear to have a negative impact on the amount of pain, QOL and level of physical function experienced (Kelly et al. 2001).

On the other hand, Garbuz, Xu and Duncan (2006) found a significant improvement in QOL and self-reported physical function, as measured by the WOMAC, in subjects who were diagnosed with severe hip OA and waited less than six months to undergo a hip replacement compared to those in a similar condition who waited longer than six months. They initially hypothesized that longer waiting times are detrimental to the achievement of the full benefit of surgery. They concluded that waiting longer than six months resulted in a 50% decrease in the chances of achieving a better post-operative outcome compared to waiting less than six months. They also found that each additional month spent waiting was associated with an 8% decrease in the chance of a better functional outcome after surgery (Garbuz, Xu and Duncan 2006). Physiologically, prolonging the arthritic process in these joints may result in muscle atrophy, tissue contracture, and deterioration of general medical status, which may not be completely recoverable after surgery (Williams et al., 1997).

Despite the recognized value and reliability of self-report measures such as the WOMAC and their usefulness in evaluating multiple aspects of function in
a single test (Kennedy et al., 2002); self-report measures may be limited by impaired cognition or memory and/or inability to answer accurately or completely (Maly, Costigan and Olney, 2006). In contrast, objective performance measures tend to assess only a single attribute from the domain of interest. They provide an objective measurement of a person’s physiological or functional status at that point in time, are sensitive to change over time, and are useful in assessing subjects with cognitive limitations (Kennedy et al., 2002).

The International Classification of Functioning (ICF) of the World Health Organization (WHO) (2001), states that disability is not only a consequence of body malfunction (physiological impairment), but it also depends upon the individual's levels of activity and participation (functional status). Therefore, it is important to assess the difference among individuals physiological and functional status while they are in the continuum of care for hip replacement.

2.4. Function measured by the 6MWT and the TUG

Walking is an important functional activity and the use of a walking test as a clinical tool to assess function has been reported as effective (Singh et al., 1992). Most activities of daily living represent exertion at sub-maximal exercise levels, so a measure of the ability to sustain a given sub-maximal exercise is an important component of the assessment of function (Solway et al., 2001). The self-paced 6-Minute Walk Test (6MWT) assesses a submaximal level of functional capacity (Bautmans, Lambert and Mets, 2004). Walking tests such as
the 6MWT and the Timed Up & Go test (TUG) are predictors of function (Gibbons et al., 2001). Maly et al., (2006) reported that both the 6MWT and TUG test are reliable and useful tools to determine the mobility of subjects with various levels of OA severity.

Maly et al., (2006) suggested that activities of daily living such as walking and standing from a chair are better measured in an objective way. Moreover, walking is performed as a primary activity by many older healthy subjects, but is decreased in those with impairments such as OA. Thus, an objective test like 6MWT may better measure the variation in functional capacity of subjects with OA than subjective tools (Kervio, Carre and Ville, 2003).

The ability to walk for a distance is a quick and inexpensive measure of function, and this ability is an important component of quality of life, since it reflects the capacity to undertake day-to-day activities (Enright et al., 1998). The 6MWT measures the distance that a person can walk on a flat, hard surface in 6 minutes, consequently the 6MWT can be performed by many elderly, frail and severely limited patients (Crapo et al., 2002). Bautmans et al. (2004) found that 6MWT has a negative relationship with age (r= -0.42, p< 0.001). They observed that older individuals demonstrated reduction in mobility as measured by the distance walked. A positive relationship has also been observed (r= 0.40, p< 0.001) between health status and 6MWT distance. Individuals presenting with poor health status (joint, cardiac and/or respiratory problem) show decreased distances as compared to those with no health problems (Bautmans et al., 2004).
The test-retest reliability of the 6MWT is excellent (ICC= 0.95) when measured in older adults (n= 86) >65 years of age on two different days (Harada et al., 1995). Kennedy et al. (2005) examined the test-retest reliability of the 6MWT in patients with end-stage OA (n= 21). The test interval between the first and second test was 92 days and between the first and third test was 178 days. Interclass correlation showed very good test-retest reliability between the three testing times (ICC= 0.90) (Kennedy et al., 2005). The 6MWT also shows good construct validity with the WOMAC (r= 0.64) and SF-36 (r= 0.69), which are considered two important subjective tools for measuring pain and function (Finch et al., 2002).

The TUG test is frequently used to assess balance and mobility in elderly individuals. This test measures the time in seconds an individual takes to stand up from an armchair, walk a distance of 3m, turn, walk back to the chair and sit down again (Podsiadlo and Richardson, 1991), (Steffen, Hacker and Mollinger, 2002). Because it is fast and does not require special equipment, the TUG can be applied during a regular consult (Podsiadlo and Richardson, 1991).

The TUG is commonly used by orthopedic surgeons, physiotherapists and other healthcare professionals to assess levels of balance and mobility of their patients. More than 30% of subjects over the age of 65 years fall annually, with that number rising to 40% in subjects over the age of 80 years. Moreover, poor balance in elderly individuals has been recognized as one of the main causes of falls resulting in hip trauma (Hatch et al. 2003). The score of the TUG test is the
time required to complete the task. According to Shumway-Cook (2000), the cut-off score in community-dwelling elderly subjects with high risk of falls is 14 seconds; therefore, elderly adults who took longer than 14 seconds to complete the TUG test demonstrate a higher risk for falls due to reduced balance and mobility.

The TUG test correlates well with scores on the Berg Balance Scale (r = -0.81), gait speed (r = -0.61) and Barthel Index of activity of daily living (r = -0.78) in elderly individuals, and it also appears to predict the patient's ability to go outside alone safely (Podsiadlo and Richardson, 1991). These data suggest that the TUG test is a reliable and valid test for quantifying balance and functional mobility that may also be useful for following clinical change over time. The test is quick, requires no special equipment or training, and is easily included as part of the routine medical examination (Podsiadlo, 2002).

The 6MWT and TUG also are important predictors of morbidity and mortality in patients with cardiac and respiratory diseases, and in those with OA (Enright, 2003). Consequently, these tests are frequently used to assess the limitation of function in older individuals and also in those with OA of the hip (Kennedy et al. 2002).

2.5. Hip muscle strength in individuals with OA

To date there is only one specific study on weakness of muscles associated with OA of the hip. To study the hip muscle strength and cross
sectional area (CSA) in men with hip osteoarthritis Arokoski et al. (2002) selected 27 men (aged 47-64 yrs) with unilateral or bilateral hip OA and 30 (age-matched, randomly selected) healthy male controls. The maximal isometric hip abductor, adductor, flexor, and extensor strength (Nm) at 0 degrees of hip flexion in the supine position was determined with a dynamometer. The isokinetic hip flexion and extension strength (peak torque, Nm) was determined using an angular velocity of 60°/s. The subjective severity of hip pain was rated by visual analog scale prior to the muscle strength test. The CSA of the pelvic and thigh muscles was measured from magnetic resonance images. The interclass correlation coefficients (ICCs) for repeated measures of muscle strength varied from 0.70 to 0.94 in controls and from 0.84 to 0.98 in subjects with OA. Hip isometric adductor and abductor strength was 25% and 31% lower (p < 0.001) in subjects with OA than in controls, respectively. The hip isometric and isokinetic flexion strength values were 18 and 22% lower (p < 0.01) in subjects with OA than in controls, but extension strength did not differ between groups. In subjects with OA, the hip flexion and extension isometric and isokinetic strength values were 13 and 22% lower (p < 0.05) on the more deteriorated side compared to the better side. CSA of the pelvic and thigh muscles did not differ between the groups. However, in subjects with OA, the CSA of the pelvic and thigh muscles was 6 and 13% less (p < 0.05 to < 0.001) on the more severely affected hip compared to the better hip. The authors concluded that men with hip OA have significantly lower abduction, adduction, and flexion muscle strength than controls. The decrease in muscle
size combined with hip pain may contribute to the reduction of muscle strength in hip OA (Arokoski et al., 2002).

Other studies also reporting weakness of lower extremity muscles pertained to OA of the knee. Information obtained from these studies was extrapolated to outline and explain that there is a relationship between muscle weakness and lower extremity OA. Physiological impairments in individuals with knee OA have been primarily assessed through quadriceps strength (Mattsson, Brostrom and Linarsson, 1990). Weakness of lower extremity muscles, especially the quadriceps muscles, is commonly identified among individuals with knee OA. It is therefore concluded that muscle dysfunction is an associated factor in the progressive and pathological process of OA over time (Slemenda, 1997, Hurley and Scott, 1998).

It is not known whether quadriceps muscle weakness precedes or follows joint pain, or whether it is mediated by disuse atrophy or by physiological mechanisms that inhibit muscle contraction (Hurley and Scott, 1998). It has been suggested by Slemenda (1997) that quadriceps weakness is commonly associated with OA of the knee, and weakness is widely believed to result from disuse atrophy secondary to pain in the involved joint.

In order to test muscle strength in individuals with knee OA, the Biodex Isokinetic dynamometer is one of the most accurate methods of assessment (Aquino and Leme, 2006). Isokinetic activity is a dynamic activity in that it involves motion. It differs from isotonic activity, in that the velocity is controlled
and maintained at a specific speed of movement (Astrand et al, 2003). Isokinetic means “having the same motion”. This type of activity can load a muscle contraction to its maximum capacity throughout the entire joint range in a continuous reciprocal motion (Drouin et al, 2004). An isokinetic contraction can recruit a larger number of muscle fibers than any other method of exercise (Drouin et al, 2004). This type of muscle contraction has become a popular method by which to assess dynamic muscle function in both clinical and research settings (Bertocci et al, 2004).

The impact of hip muscle weakness on the course of osteoarthritic disease itself is not well understood (Arokoski et al. 2002). Because muscle weakness is a common complaint among individuals with knee OA (Yamada et al. 2001 and Aquino and Leme, 2006) most studies on muscle performance have concerned muscles affecting the knee joint, whereas little information is available about functional properties of muscles moving the hip joint in OA. Therefore, understanding the relationship between hip muscle weakness and OA of the hip and its progression is particularly important.

2.6. Aerobic capacity in individuals with hip OA

$\text{VO}_{2}\text{max}$ or maximum oxygen uptake, is considered the gold standard of aerobic fitness. It is the maximum amount of oxygen the body can consume while exercising to maximum capacity. $\text{VO}_{2}\text{max}$ is usually standardized to body weight and expressed in milliliters of oxygen per kilogram of body weight per minute.
However, tests measuring VO$_2$max are strenuous and have the potential to be dangerous since any problems with the respiratory and cardiovascular systems may be greatly exacerbated. On the other hand, peak oxygen uptake or VO$_2$peak is defined as the peak volume of maximal oxygen consumed per minute during an aerobic activity (Helgerud, Oiestad and Hoff, 2005). The VO$_2$peak is commonly used instead of maximal aerobic capacity of individuals, such as untrained older subjects, who are not able to participate in strenuous activities (Helgerud, Oiestad and Hoff, 2005). In order to obtain the VO$_2$peak the individual needs to get to his or her maximal heart rate, however the maximal heart rate does not need to be sustained during the exercise test. However, to obtain VO$_2$max an individual must sustain his or her maximal heart rate until a plateau is observed during the last minute of exercise which is very strenuous (Achetnen and Jeukendrup, 2003; Astrand et al, 2003). Moreover, the VO$_2$peak is safer and more comfortable to obtain than the VO$_2$max and it is an important component of overall health status.

Oxygen consumption measured during exercise testing is directly related to cardiac output and it is affected positively by increased activity level or exercise intensity (training effect) and negatively by a sedentary life style (Astrand et al, 2003). Peak oxygen consumption is a powerful predictor of mortality and an indicator of fitness level; therefore, the VO$_2$peak is an important marker for physiological status. Protocols have been developed that use the work
/ heart rate (HR) relationship at submaximal levels to estimate \( \text{VO}_2\text{peak} \) (Astrand et al, 2003).

Submaximal tests are usually used in laboratory testing to avoid the risks of an exhausting maximal work rate (Helgerud, Oiestad and Hoff, 2005). Submaximal tests are usually safer to use in sedentary individuals and consequently in an older population with hip OA. A submaximal test will predict the level of aerobic capacity of individuals who can not be submitted to a maximal test. During a maximal test for aerobic capacity, the individuals must reach their maximal heart rate. Consequently, it can be virtually impossible for older subjects who are usually sedentary or have health problems to complete such a test (Helgerud, Oiestad and Hoff, 2005). Based on the assumption that there is a linear relationship between cardiac output and oxygen uptake, the submaximal exercise test estimates an individual’s aerobic capacity. Such tests can safely measure changes in oxygen utilization over time, for example to measure a decline in the aerobic capacity as a result of a chronic disease process or to evaluate if a specific training program has been effective in improving an individual’s aerobic response (Astrand et al, 2003).

The Astrand-Ryhming submaximal test using a treadmill is widely used to predict \( \text{VO}_2\text{peak} \) in well trained individuals with a workload that may vary from 100 to 150 W. For subjects who are expected to be physically unfit, such as untrained elderly subject, a lower work rate of 50 W is suitable (Astrand et al, 2003). However, even submaximal exercise with lower work rates to predict
VO$_2$peak can be difficult for some frail elderly subjects with hip OA (Ries et al., 1997). Moreover, using a treadmill or a bicycle ergometer can often be limited by pain in lower extremity joints and can lead to local muscle fatigue and limit performance before the capacity of the cardiovascular system is reached. The purpose of a functional capacity test is to assess the capacity of the cardiovascular system rather than the endurance capacity of particular muscle groups (Noonan and Dean, 2000).

Therefore, instead of using a treadmill or a bicycle ergometer to predict VO$_2$peak, Helgerud et al., (2005) applied a submaximal arm ergometer test as a useful alternative to estimate VO$_2$peak in older individuals with lower extremity impairments caused by vascular, neurological conditions or orthopedic problems, such as in subjects with hip OA. Ries et al., (1997) have previously suggested that to relieve the weight-bearing stresses that occur with treadmill exercise it is recommended that an arm ergometer should be utilized to predict VO$_2$peak with a submaximal exercise test in subjects with hip OA. Frequencies between 70 and 80 revolutions per minutes (rpm) are normally used in submaximal arm ergometer tests, since a higher rpm could fatigue the arms and make the test uncomfortable (Smith et al., 2001).

Subjects obtain approximately 70% of their maximal oxygen uptake compared to leg exercise when exercising with arms. However, heart rate and arterial blood pressure are significantly higher at a given oxygen uptake and cardiac output in arm exercise as compared with leg exercise (Astrand et al.,
This means that 70% is the highest oxygen uptake that someone who is not considered a specially trained subject could obtain during an activity with an arm ergometer.

The correlation coefficient (R) for percentage VO$_2$peak and HR in submaximal loads was 0.80 for men and 0.60 for women. Unlike Astrand-Ryhming’s submaximal test, the standard error values in Helgerud’s study were only 11.8 and 10.7% for untrained men and women respectively. However, no correlation between VO$_2$peak and age was observed in this study, therefore, no correction factor for age is used to predict VO$_2$peak.

When predicting the VO$_2$peak prior to total joint replacement, Philbin et al. (1995) observed that bicycle ergometry exercise testing seemed to be an appropriate choice for predicting decrease in aerobic capacity in patients with OA of the hip. Ries et al., (1997) observed the effect of total hip arthroplasty on cardiovascular fitness during a submaximal test with a bicycle ergometer. A group of 30 individuals with hip OA, who underwent total joint replacement, showed a significant increase ($p = 0.036$) in VO$_2$peak (ml/kg/min) by six months postoperatively and did not change during the remainder of the study period. The authors concluded that individuals who underwent a total hip arthroplasty are more likely to increase their aerobic capacity during the first six months after surgery and subsequently sustain this achieved level of aerobic capacity with maintenance of their activities of daily living.
It is assumed that limitations in aerobic capacity and muscular dysfunction may preclude individuals with hip OA from continuing their activities of daily living and may manifest as a subjective sensation of fatigue (Astrand et al., 2003). However, the difference in levels of VO$_2$peak of individuals who were diagnosed with different stages of hip OA has not been assessed.

2.7. Purpose:

In order to improve our understanding of functional and physiological differences of patients diagnosed with OA of the hip, this study investigated group differences in objective measures of mobility, strength, and peak oxygen uptake in subjects with hip OA at three points in the continuum of care. These points are defined as the time of referral to an orthopedic surgeon, the time of consultation with an orthopedic surgeon, and within four weeks pre-operatively. The subjects were diagnosed with hip OA by a physiotherapist or an orthopedic surgeon. To make the diagnosis of OA, radiological findings were used however a specific classification system for radiographs was not used.

2.8. Objective and Hypothesis

2.8.1. General Objective:

The aim of this study was to investigate functional and physiological differences in distinct groups of subjects diagnosed with hip OA at three points in the continuum of care: at the time of referral to an orthopedic surgeon, at the time
of consultation with an orthopedic surgeon, and within four weeks pre-operatively.

2.8.2. Specific Objectives:

The specific objectives were to:

- Investigate group differences in function as measured by the 6MWT and the TUG, in subjects diagnosed with hip OA at the time of referral, at time of consultation, and within four weeks pre-operatively.
- Investigate group differences in physiological function as measured by VO$_2$peak and strength, in subjects diagnosed with hip OA at the time of referral, at time of consultation, and within four weeks pre-operatively.

2.8.3. Hypothesis:

It was hypothesized that subjects with hip OA who were within four weeks prior to surgery would demonstrate lower functional and physiological status compared to those at the time of referral to an orthopedic surgeon and those at the time of consultation with the orthopedic surgeon.
Chapter 3
Methods

3.1. Research Design

This study involved patients referred to three orthopedic surgeons who operate at the Kingston General Hospital (KGH). This study was a cross-sectional design using a sample of patients with hip OA who were in the continuum of care. The participants in this study were selected based on three time points in the continuum of care: at the time that patients were referred to an orthopedic surgeon for a hip OA consult (REF), at the time of consultation with the orthopedic surgeon (CON), and within four weeks prior to surgery (PREOP). The assessment of these three groups at three time points in the continuum of care was done in order to determine differences in functional and physiological status of those individuals. It must be taken into consideration that only the individuals at the time of consultation and those within four weeks prior to surgery were truly on a “waiting list for surgery” as defined by MHLTC. However, all subjects of these three groups were diagnosed with OA of the hip.

The subjects at the time of referral were assessed and diagnosed with hip OA by a registered physiotherapist who increased his educational qualification, and had become more specialized and skilled in the advanced practice of physiotherapy including reading radiographs. The subjects at the time of
consultation were assessed and diagnosed with hip OA by one of the three participating surgeons using radiological findings.

Radiological findings were used by the physiotherapist and the orthopedic surgeon to make the diagnosis of OA; however, a specific classification system for radiographs was not used. The WOMAC index questionnaire was used to obtain the subjects' perceived level of severity and the WCWL – HKPT was used by the physiotherapist and orthopedic surgeon to determine the subjects' prioritization for surgery.

3.2. Sample Selection

3.2.1 Sample Size

As we were interested in the differences between the objective measures of functional and physiological status between groups, differences between groups on the 6 MWT was the primary outcome measurement in this study. Due to the novelty of the present study, a precise sample size calculation was not possible. However, from similar studies done by Kennedy et al. (2005) and Mahon et al. (2002), the sample size calculation was based on a minimal clinically significant difference of 61.34 m (Kennedy et al., 2005) and a population mean baseline of 351 m (SD 110m) (Mahon et al., 2002). Using these numbers, we needed 25 subjects per time point (a total of n=75) in order to detect change at a 0.05 significance level with 80% power.
3.2.2. Recruitment

Subjects were recruited from the caseload of the three orthopedic surgeons. The subjects were identified using the current waiting list of these surgeons. The subjects were contacted directly by a research assistant. Once the potential subjects agreed to participate they came to the laboratory where they received a letter of information (Appendix I) explaining the purpose of the study and the activities that they were required to perform and a consent form to sign if they agreed to participate (Appendix II).

3.2.2. Inclusion Criteria

Subjects were included in the study if they:

- had been diagnosed with OA of the hip by a physiotherapist, according to their radiological findings, and were waiting to consult with one of the three participating orthopedic surgeons.

- had been diagnosed with OA of the hip by one of the three participating surgeons, according to their radiological findings, and were waiting to be informed about the next available date on the waiting list for surgery.

- had been diagnosed with OA of the hip and were waiting for a total hip replacement.

- were able to tolerate moderate activity for one to two hours.

- had the ability to provide informed consent.
3.2.3. Exclusion Criteria

Subjects were excluded from participating in any group if they had:

- any systemic illnesses such as rheumatoid arthritis, asthma/emphysema, cancer, or neurological diseases such as Parkinson's disease or Alzheimer's disease, which limited their function enough for them to be unable to participate. If these conditions were mild or did not limit their function, they were allowed to participate.

- unstable angina or had had a heart attack during the previous month or if they had uncontrolled hypertension.

- a history of any type of chronic shoulder and/or elbow impairment.

3.3. Data Collection

Data were collected in one testing session. During this session, objective measures of the 6MWT, TUG, strength and prediction of peak oxygen uptake, were obtained and recorded on a data collection sheet (Appendix III). In order to avoid older subjects overworking and becoming exhausted or aggravating pain symptoms during the testing session, they were allowed to rest for at least one minute between each test and the Borg rating of perceived exertion scale (RPE) (Appendix IV) was used (Borg, 1998). The participants were asked to grade their level of fatigue and dyspnea indicating the respective number (from 6 = no exertion to 20 = maximum exertion) on the Borg scale. In addition, a Visual Analog Scale (VAS) which is a pain scale ranging from 0 to 10 was used (Finch
et al., 2002). However, the VAS and Borg RPE were obtained for safety purposes only, and data were not analyzed.

The 6MWT and TUG were the objective measures of function, and strength as measured on a Biodex and aerobic capacity (VO2peak) using an arm ergometer were the objective measures of physiological function.

Figure 2 illustrates the order in which the testing was performed. The purpose and the objectives of the study were explained to the subjects during the lab visit and demographic information and medical information such as medications, health status, current activity level and family history was obtained by interview. In order to prevent any potential factors that could affect the performance on the VO2peak test, subjects were requested not to eat, smoke, or exercise for two hours prior to testing. As illustrated, the VO2peak was the first objective test measured and then the other tests were administered in a randomized order.
All the information collected in this study was kept confidential and subjects’ data were preserved on a computer, which was accessible only by the investigators. Subject’s files were stored in a locked cabinet.
3.3.1. Outcome Measures

3.3.1.1. The 6 Minute Walk test

The 6MWT is a self-paced walk test, in which the maximum distance that a person can walk in 6 minutes is determined and reported in meters. This test was conducted in an enclosed, quiet corridor on a 25-meter track delineated by two cones. In this experiment, subjects were instructed to walk from one cone to the other, covering as much ground as possible in six minutes. Individuals were told that they could rest if they became too short of breath or tired, but to continue walking when they were able to do so. At the end of the six minutes, the subjects were asked to stop. To calculate the walking distance a metre wheel was used to measure the additional steps of any incomplete laps (in meters).

Before starting the test, the subjects sat in a chair, located at the starting position, for a five-minute rest period. During this time the test was explained to the subjects and their pulse rate was checked to ensure it was between 50 beats/min and 100 beats/min, indicating a normal resting heart rate (HR) (Johnson, 2007). The test did not start until the pulse rate indicated a normal resting HR. If any abnormality (higher 100 beats/min or lower than 50 beats/min) had been observed in the pulse rate, the test would not have been initiated. However, all the subjects demonstrated a normal resting HR before testing consequently, they were all tested. The testing time was measured by the researcher who was using a stopwatch.
While the patient was walking, standardized phrases such as “keep up your work”, “you are doing very well”, and “you are doing an excellent job” were used because the encouragement and enthusiasm of the investigator can make a difference of up to 30% in the distance walked by subjects performing the 6MWT (Enright, 2003).

When the test was finished the Borg RPE and the pain level (using the VAS) were noted to ensure the subjects was not fatigued or sore.

3.3.1.2. Timed Up and Go (TUG)

The Timed Up and Go (TUG) test is widely employed in the examination of older individuals and it was developed to measure balance and mobility in this population (Finch, Walsh, Thomas and Woodhouse, 1998). The procedure for the TUG requires documenting the time, in seconds, that an individual takes to rise from a standard armchair, walk 3 meters, turn, walk back to the chair and sit down quickly and safely (Podsiadlo and Richardson, 1991).

In this experiment, the test was initiated with the subjects sitting in the chair with their back leaning on the back of the chair, both arms on the arms of the chair, legs lined up and feet flat on the floor. The chair was stable and positioned such that it did not move when the subjects moved from sitting to standing. Individuals were asked to wear comfortable/regular footwear when performing the test.
In this testing session, the subjects were allowed to use any assistive devise that they would normally use for walking, such as a cane or walker, to make them feel safe and comfortable during the test. Prior to testing, the subjects were warned that there would be two trials and then they were instructed about the basic sequence of the test, as described: “When I say, “go”, you will stand up from the chair, walk to the mark (line) on the floor, turn around, walk back to the chair and sit down. “I will be timing you using the stopwatch.” The subjects were allowed to rest, as much as they needed, between each trial. They were frequently asked how they were feeling and their pulse rate was constantly monitored during the resting period. In the case of severe pain or any cardio-respiratory discomfort, the test would have been terminated. However, all the subjects demonstrated a normal resting HR and they did not complain about pain or respiratory discomfort between tests consequently, they were all tested. The researcher measured the time with a stopwatch. The test started on the word “GO” and stopped when the subjects were seated again properly in the chair with their back resting on the back of the chair.

When the test was finished the subjects were asked to grade their level of fatigue and dyspnea using the Borg RPE scale to ensure the subjects was not fatigued. Then they were asked to grade their level pain (using the VAS) to ensure the subjects was sore.
3.3.1.3. Isokinetic Strength (Biodex)

The isokinetic dynamometer Biodex System 3 Pro consists of a secure seat, a dynamometer with a T-base and an operation panel connected to a microcomputer. The Biodex isokinetic dynamometer is an electromechanical device, which provides measures of peak torque of different joints through different angular velocities, in healthy and disabled individuals (Bertocci et al., 2004). The Biodex can provide a constant velocity while accommodating resistance throughout a joint's range of motion (ROM). This resistance is supplied using an electric servo-controlled mechanism at a user-defined constant velocity (Drouin et al., 2004). Moreover, the Biodex software compensates for the effects of gravity as part of the setup with the subjects positioned appropriately. The software calculates the gravitational correction values before each test by measuring the torque exerted on the dynamometer arm by the weight of the limb.

The Biodex processing filter was another important feature applied to eliminate spike artifacts. It reduces the amplitude of any artifacts so higher frequencies are attenuated more and lower frequencies less (Kongsgaard et al. 2007). Consequently, because the amplitude of the artifact is minimized to the same level or even lower than the maximum peak torque; the results obtained after each test are the maximum peak torque during the velocity set for the test, which was 60°/second. Calibration of the Biodex dynamometer was performed according to the specifications outlined in the manufacturer’s service manual.
The Biodex isokinetic dynamometer was used in this study to test functional muscle performance in subjects with hip OA. The concentric maximum peak torque of hip flexion and extension during a single testing session was measured. The testing protocol involved the subjects standing on the isokinetic dynamometer platform with straps placed over their shoulders and across their waist to ensure that the torso was stable. In addition, a cushion was placed between the subject's back and the back of the seat to provide more comfort and stability to the subjects during the test (Figures 3 and 4). An adjustable lever arm was attached to the subject's thigh by a padded cuff, approximately midway between hip and knee.
The axis of rotation of the dynamometer arm was positioned just lateral to the greater trochanter while the subject was standing. The subject's hips were set in a 0° angle (0° = anatomical position) as a starting position, and then the concentric isokinetic test was performed. During the test, the subject started from 0° and then pushed the lever arm of the isokinetic device up and down, through a range of motion, between 90° of hip flexion to 10° of hip extension.

A set of two trials was conducted each consisting of continuous ROM for hip flexion-extension, repeated five times at an angular velocity of 60° / sec. The
greatest peak torque between the two trials was recorded (Aquino and Leme, 2006).

Figure 4: Hip torque extension

The subject was instructed to push their thigh up and down in a constant motion and to apply as much force as they could in a consistent way during each repetition. Standardized verbal encouragement such as “push up hard” and “pull down hard” was given during the testing. Each subject was given a minimum of one-minute recovery between trials and then the test was repeated.
3.3.1.4. Submaximal Arm Ergometer Test

The arm ergometry test was used to predict the VO$_2$ peak in subjects with hip OA at three time points in the continuum of care and consequently to investigate group differences in physiological aerobic function. The subjects were asked to pedal at a frequency of 70 revolutions per minute (rpm) against a constant workload of 21 Watts (125kg/m) for females and 42 Watts (250kg/m) for males. The workload was adjusted and maintained using the weights from the arm ergometer as recommended by the manufacture A digital meter, located on the arm ergometer, was used to keep the subjects at frequency of 70 rpm and additional verbal feedback was also used to help the subjects maintain the correct frequency.

According to Helgerud et al. 2005, to predict VO$_2$ peak using an arm cycling submaximal test, the subjects should achieve a continuous steady state heart rate, which is observed during the last minute of submaximal test. The test’s length of time was four minutes and pulse rate was taken every 10 seconds during the last 30 seconds, between the third and fourth minutes. If the difference between the lowest and the highest pulse rate, taken in the last 30 seconds of exercising, did not exceed 5 bpm, a steady state heart rate was considered to be present. The average HR, from the steady state, was used to find a corresponding VO$_2$ peak (L.min) estimated from the nomogram table (Appendix V) (Helgerud, Oyestad and Hoff, 2005).
All the subjects reached at least 110 bpm or more consequently, a new test was not needed. However, if their heart rates had not reached at least 110 bpm during the last 30 seconds of testing, the workload would have been increased by 21 W (125 kg/min) and a new test would have been initiated. Figure 5 shows a schematic representation of the protocol.

Figure 5: Schematic Illustration of the Cardio-respiratory Test

To perform the test a mechanically braked arm ergometer cycle (Monark, Ergomedic 891E, Monark Exercise AS, Sweden), was utilized and manually calibrated as recommended by the manufacturer.
The arm ergometer consisted of a stable base of support with enough space to place a chair. An ordinary chair was used throughout the test and foam rubber pillows regulated the height of the subjects, so that the arms and the shoulders were aligned to the pedal’s arm brace and the elbows were flexed to approximately 5° when the arms were extended horizontally. The legs were not braced and the feet were placed flat on the floor (Figure 6).

![Figure 6: Illustration of the Cardio-respiratory Test](image-url)
The heart rate was monitored constantly using a chest strap heart rate monitor and digital watch set (Polar Electro, Inc Woodbury, NY) (Astrand et al, 2003). To monitor the subject’s physical condition during this submaximal cycle ergometer test the Borg RPE scale was administered every minute during the test. In the event of pressure or pain in the chest, marked shortness of breath or distress followed by other symptoms such as dizziness, nausea, blurry vision, or excessive exhaustion (Borg RPE > 17 - very hard), the test would have been discontinued immediately. However, none of the subjects complained about the above symptoms before and during testing session consequently, they were all tested.

3.3.2. Self-Reported Measures

3.3.2.1. Demographic Information and descriptive measures

The demographic data that were collected in this study included age, sex, height, weight, past medical history, duration of symptoms and study assessment time. The duration of symptoms data was obtained by asking the subjects how long they have lived with the burden of OA symptoms, consequently they answered based on their memory. The study assessment time data was obtained using the dates they were referred from a family doctor to an orthopedic surgeon, to the date they were assessed in the study. However, subjects in the REF group were assessed after being diagnosed with hip OA by a physiotherapist. The CON group was assessed after consulting with the orthopedic surgeon and being
diagnosed with hip OA and the PREOP group was assessed 4 weeks prior to hip replacement surgery.

3.4 Statistical Analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS 16) and Microsoft Office Excel 2003. Initially, all variables were analyzed using univariate descriptive statistics. Variables such as age, gender, body mass index (BMI) and time (according to location on waiting list) were recorded from each group (REF), (CON) and (PREOP) and the mean, standard deviation and median were calculated to summarize the group data. Tests for the underlying assumptions (e.g. normality, homogeneity of variance) of statistical tests used in the present study were performed on all data. For all statistical analyses, the level of statistical significance was set at α=0.05. When multiple comparisons were used, a polynomial planned contrast to predict linear differences across the groups was applied, and Bonferroni corrections were used to adjust the level of significance and reduce the chances of a type I error (Howell, 1999).

3.4.1. Age, BMI, Study Assessment Time and WOMAC Scores

The first set of analyses focused on the age, BMI, study assessment time, duration of symptoms and WOMAC scores differences between groups (REF / CON / PREOP). A one-way ANOVA for independent samples compared whether age, BMI, study assessment time, duration of symptom and WOMAC scores
were significantly different between groups. Then a non-parametric correlation (Spearman’s correlation) between WOMAC scores and the three groups and WOMAC scores and the study assessment time, was used, to observe whether there was an association between these three measures.

3.4.2. Functional and Physiological measures

The second set of analyses focused on Multivariate analyses to identify whether functional and physiological status, in subjects with hip OA, was different between groups. Differences in physiologic measures (VO₂ Peak and strength) and functional measures (distance on the 6MWT and time on the TUG) in these three groups were investigated using a Multivariate Analyses of Variance (MANOVA). Based on the statistical significance of the analyses described above, post-hoc tests were performed using the Bonferroni method. A polynomial planned contrast test was used to observe whether there was a linear difference between groups.
CHAPTER 4

Results

Each group, REF, CON and PREOP, was composed of 7 subjects for a total of 21 individuals. The principal method of recruitment of subjects with hip OA was by inviting those who were on the waiting list of the three participating orthopedic surgeons in Kingston, ON to participate in the study. The subjects were contacted directly by a research assistant. A total of 21 individuals agreed to participate and they were subdivided into three groups based on each one’s position in the continuum of care (time of referral to a surgeon, time of consultation with a surgeon and within four weeks prior to surgery).

4.1 Descriptive results

The composition of the three groups was similar and information is summarized in Table 2. There were 4 women and 3 men in the REF and CON groups and 4 men and 3 women in the PREOP group. On average, subjects from the REF group were 68.8 (±3.3) years old, subjects in the CON group were 68.5 (± 4.6) years old and subjects in the PREOP group were 72.1 (± 5.0) years old. The BMI of the REF group was 24 kg/m² (± 1.5), the CON group was 28.1 kg/m² (± 5.5) and the PREOP group was 26.6 kg/m² (± 3.0). No significant differences were observed in age or BMI (p > 0.05) and therefore, there was not enough evidence to support a significant difference between age or BMI between groups.
Consequently, none of the functional and physiological differences observed between groups could be attributed to a difference in age or BMI between groups.

The average duration of symptoms for subjects in the REF group was 28 months ($\pm 16.4$), for subjects in the CON group was 47.1 months ($\pm 18.5$) and for subjects in the PREOP group was 57.6 months ($\pm 27.0$). The duration of symptoms was nearly significantly different between groups. Consequently, the p-value ($\rho = 0.051$) was considered as a trend towards significance, which may indicate that individuals who are further along in the continuum of care for hip OA also have lived longer with symptoms of hip OA.

The difference in months from the date that subjects of each group were referred to an orthopedic surgeon to the date they were assessed for this study, which is called study assessment time, was significantly different ($\rho = 0.001$) between groups. This indicates that each group was, in fact, located at distinct time point at the time in continuum of care. Subjects in the REF group were assessed when they had been in the continuum of care for 4.3 months ($\pm 3.4$), subjects in the CON group had waited 7.9 months ($\pm 1.3$) and subjects in the PREOP group waited 12.3 months ($\pm 4.7$). Pos hoc analysis, using Bonferroni method, indicated that there was a significant difference ($p = 0.001$) between the study assessment time for REF group and PREOP group. This result indicated that there was a difference in time spent in the continuum of care for hip OA between individuals in the REF group and individuals in the PREOP group.
However, no difference was observed between REF and CON groups and between CON and PREOP groups. **Figure 7** shows a representation of each group from the time they were referred to the time they were assessed in this study.
Figure 7: Three time points in the continuum of care and Study Assessment time
The WOMAC scores between groups were significantly different (p < 0.001). Post hoc analysis, using Bonferroni method, indicated that there were significant differences in severity between REF and CON (p= 0.001), between REF and PREOP (p= 0.001), and between CON and PREOP (p= 0.038). These results indicated that each group had a different level of OA severity and the PREOP group had the highest WOMAC scores, which means that the PREOP group had the highest perceived level of severity (73.0 ± 2.6) compared to the other two groups (Table 2). However, the WOMAC index was used to support the differences in functional and physiological outcome measures between groups, not to classify each group according to its level of severity. In addition, there was a significant positive correlation (r=.90, p < 0.001) between the three groups and WOMAC scores as well as between the study assessment time and WOMAC (r = .71, p = 0.001). These results indicated that functional and physiological differences between the three groups could be attributed not only to perceived levels of severity but also to the three different points in the continuum of care. The characteristics of the subjects from REF, CON and PREOP groups, are summarized in Table 2.
All subjects were asked to report medical conditions such as hypertension, osteoporosis, visual impairments, vascular problems, or heart disease for which they were taking medications. Among these medications, only the beta-adrenergic antagonist reported by one of the subjects would potentially affect the submaximal oxygen test. This medication may have reduced the predicted VO$_2$peak score because decreased heart rate is an expected side effect of this medication (Ries et al., 1997). However, the VO2peak score (27.45ml/kg/min) of this subject was not bellow to the VO2peak score of his PREOP group average (26.52ml/kg/min).

**Table 2: Subjects characteristics and statistical comparison**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>REF (n=7)</th>
<th>CON (n=7)</th>
<th>PREOP (n=7)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>3 / 4</td>
<td>3 / 4</td>
<td>4 / 3</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>24.0 (± 1.5)</td>
<td>28.1 (± 5.5)</td>
<td>26.6 (± 3.0)</td>
<td>0.14</td>
</tr>
<tr>
<td>(minimum – maximum)</td>
<td>(21.7 – 25.6)</td>
<td>(20.9 – 38.8)</td>
<td>(22.5 – 30.1)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>68.8 (± 3.3)</td>
<td>68.5 (± 4.6)</td>
<td>72.1 (± 5.0)</td>
<td>0.26</td>
</tr>
<tr>
<td>(minimum – maximum)</td>
<td>(65 – 74)</td>
<td>(62 – 75)</td>
<td>(65 – 77)</td>
<td></td>
</tr>
<tr>
<td>Study Assessment Time (months)</td>
<td>4.3 (± 3.4)</td>
<td>7.9 (± 1.3)</td>
<td>12.3 (± 4.7)</td>
<td>0.001</td>
</tr>
<tr>
<td>(minimum – maximum)</td>
<td>(1 – 11)</td>
<td>(6 – 10)</td>
<td>(8 – 22)</td>
<td></td>
</tr>
<tr>
<td>Duration of symptoms (months)</td>
<td>28 (± 16.4)</td>
<td>47.1 (± 18.5)</td>
<td>57.6 (± 27.0)</td>
<td>0.051</td>
</tr>
<tr>
<td>(minimum – maximum)</td>
<td>(12 – 60)</td>
<td>(24 – 75)</td>
<td>(28 – 96)</td>
<td></td>
</tr>
<tr>
<td>WOMAC (/100)</td>
<td>49.7 (± 4.9)</td>
<td>66.6 (± 5.0)</td>
<td>73.0 (± 2.6)</td>
<td>0.001</td>
</tr>
<tr>
<td>(minimum – maximum)</td>
<td>(41 - 56)</td>
<td>(56 – 71)</td>
<td>(70 – 77)</td>
<td></td>
</tr>
</tbody>
</table>

BMI = body mass index SD = standard deviation
The medication usage of the subjects is summarized in Table 3. The use of pain medication (Acetaminophen), supplements (Glucosamine or Shark Cartilage) and non-steroidal anti-inflammatory drugs (Celebrex, Vioxx and Naproxyn) was also reported. Note that low back pain was a common characteristic among individuals with hip OA. There were in the REF, CON and PREOP groups together a total of 14 subjects (66.7%) who complained of low back pain after having been diagnosed with hip OA and only 7 subjects (33.3%) had no such complaints. Only one subject out of 21 has had history of joint replacement surgery in a different joint.

Table 3: Characteristics of subjects with hip OA

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>REF (n=7)</th>
<th>CON (n=7)</th>
<th>PREOP (n=7)</th>
<th>n=21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using pain medication (acetaminophen)</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Using NSAIDS (naproxyn/ celebrex/ vioxx)</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>LBP yes / no</td>
<td>5 / 2</td>
<td>5 / 2</td>
<td>4 / 3</td>
<td>14/7</td>
</tr>
<tr>
<td>SxHx yes / no</td>
<td>1 / 6</td>
<td>0 / 7</td>
<td>0 / 7</td>
<td>1/20</td>
</tr>
<tr>
<td>Supplements: (glucosamine/shark cartilage)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

LBP = low back pain; NSAIDS = non-steroidal anti-inflammatory drugs; SxHx = past joint surgical history.
4.2. Comparison of 6MWT, TUG, Strength and VO$_2$peak

A MANOVA was used to analyze whether functional or physiological status were different between individuals with hip OA at the time of referral, at the time of consultation and four weeks prior to surgery. Using an alpha level of 0.05, the polynomial planned contrast test revealed a significant linear difference in distance for the 6MWT ($p < 0.001$), time for the TUG ($p < 0.003$), and oxygen capacity as measured by the VO$_2$peak ($p < 0.001$) across groups. The hip flexion and extension peak torques were not significantly different between groups.

4.2.1. Comparison of the 6MWT between groups

The 6MWT is a test in which the maximum distance that a person can walk in 6 minutes is determined and reported in meters. There was a significant difference between the three groups ($F_{(2, 18)} = 12.31, p < 0.001$). Post hoc analysis, performed using the Bonferroni method, revealed that the REF group walked a significantly greater distance ($p < 0.001$) when compared to the PREOP group. However, no difference was observed between REF and CON groups and between CON and PREOP groups (Table 4, Figure 8).

Although no significant differences in distance walked between REF group and CON group was observed; the REF group walked further distances than CON group. Similarly, the CON group walked further distances than the PREOP
group, even though no significant difference was observed between these two groups.

Table 4: 6MWT (mean ± 1 standard deviation – unit: meter)

<table>
<thead>
<tr>
<th>Group</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>REF</td>
<td>423.7 ± 39.37</td>
</tr>
<tr>
<td>CON</td>
<td>342.1 ± 75.5</td>
</tr>
<tr>
<td>PREOP</td>
<td>265.0 ± 59.0</td>
</tr>
</tbody>
</table>

Figure 8: Six minute walk test (6MWT), Note: Error bar (one standard deviation)

4.2.2. Comparison of the TUG between groups

The TUG test was developed to measure balance and mobility. It determines how fast subjects are able to rise from a standard armchair, walk 3 meters, turn, walk back to the chair and sit down quickly and safely. The time is expressed in seconds. Therefore, the faster subjects are, the more balance
control and mobility they demonstrate. There was a significant difference between the three groups ($F_{(2, 18)} = 7.15, p = 0.005$). Post hoc analysis, performed using the Bonferroni method, revealed that both REF and CON groups were significantly faster ($p < 0.009$ and $p < 0.02$ respectively) than the PREOP group during the TUG test. However, no difference was observed between REF and CON groups (Table 5, Figure 9). Results emphasized that individuals in the PREOP group demonstrated significantly poorer balance control and mobility than individuals in the REF and CON groups.

**Table 5**: TUG (mean ± 1 standard deviation – unit: seconds)

<table>
<thead>
<tr>
<th></th>
<th>REF</th>
<th>CON</th>
<th>PREOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (sec)</td>
<td>8.82 ± 2.36</td>
<td>10.11 ± 3.76</td>
<td>14.97 ± 2.81</td>
</tr>
</tbody>
</table>

**Figure 9**: Timed Up and Go (TUG), **Note**: Error bar (one standard deviation)
4.2.3. Flexion and extension peak torque

To test functional muscle performance of the subjects with hip OA, the Biodex System 3 Pro was used to measure the concentric peak torque of hip flexion and extension during a single testing session. There was no significant difference between groups (p > 0.05) for either flexion peak torque or extension peak torque (Table 6, Figure 10, and Figure 11).

Table 6: Hip torque (mean ± 1 standard deviation – unit: Newton meter)

<table>
<thead>
<tr>
<th></th>
<th>REF</th>
<th>CON</th>
<th>PREOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>82.45 ± 10.70</td>
<td>77.01 ± 12.18</td>
<td>77.92 ± 10.44</td>
</tr>
<tr>
<td>Extension</td>
<td>66.04 ± 15.44</td>
<td>49.97 ± 24.29</td>
<td>64.92 ± 23.60</td>
</tr>
</tbody>
</table>

Figure 10: Hip flexion torque, Note: Error bar (one standard deviation)
Additionally, all data for hip flexion and extension were corrected using a Biodex processing filter to eliminate spike artifacts. A sharp artifact could have directly affected the results of one or more groups, however the data were visually inspected after correction was done by the filter, and no artifacts were identified. Therefore the non-significant results could not be attributed to artifact data.

4.2.4. Comparison of the VO$_2$peak between groups

To predict the VO$_2$peak in subjects with hip OA a submaximal arm ergometer test was used. The submaximal exercise test estimates an individual's aerobic capacity. There was a significant difference between the three groups
\( F(2, 18) = 11.60, \ p = 0.001 \). Post hoc analysis performed using the Bonferroni method, revealed that the level of \( \text{VO}_2\text{peak} \) from the REF group was significantly higher than the \( \text{VO}_2\text{peak} \) level of the CON (\( p = 0.002 \)) and the PREOP (\( p = 0.002 \)) groups, respectively. However, no difference was observed between CON and PREOP groups (Table 8, Figure 13).

Table 7: \( \text{VO}_2\text{peak} \) (mean ± 1 standard deviation – unit: ml/kg/minute)

<table>
<thead>
<tr>
<th>Group</th>
<th>REF</th>
<th>CON</th>
<th>PREOP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>34.81 ± 2.72</td>
<td>25.49 ± 5.40</td>
<td>25.63 ± 3.86</td>
</tr>
</tbody>
</table>

Figure 13: Submaximal oxygen consumption, Note: Error bar (one standard deviation)
CHAPTER 5
Discussion

5.1 Summary of findings

The purpose of this study was to investigate the functional and physiological differences in three distinct groups of subjects diagnosed with hip OA at distinct points in the continuum of care: at the time of referral to an orthopedic surgeon, at the time of consultation with an orthopedic surgeon and within four weeks pre-operatively. It was hypothesized that subjects with hip OA who are within four weeks prior to surgery would demonstrate lower functional and physiological status than those at the time of referral to an orthopedic surgeon and those at the time of consultation with the orthopedic surgeon.

Individuals who are considered preoperative candidates for hip replacement usually tend to be older and more overweight than those individuals at the time of referral and at time of consultation (Nilsdotter, A.-K. and Lohmander, L. S. 2002; Rampersaud et al. 2008). However, in this study the subjects at the time of referral, at time of consultation and within four weeks prior to surgery were similar in age and BMI. Consequently, none of the functional and physiological differences observed between groups could be attributed to age and/or weight.

This study revealed group differences, implying that individuals at the time of referral, at the time of consultation and, within four weeks prior to surgery were
dealing with distinct functional and physiological limitations. As expected, subjects within four weeks prior to surgery were generally able to walk shorter distances in 6 minutes, they demonstrated poorer mobility and balance control and they had lower aerobic capacity than those who had just been referred to a the surgeon (Tables 4, 5 and 7). Other studies (Williams et al., 1997; Garbuz, Xu and Duncan, 2006) with longitudinal design support that the longer the time spent waiting to have hip replacement surgery, the worse the perceived level of disability of individuals with hip OA. However, using objective measures our findings suggested that the functional (6MWT and TUG) and physiological (VO_{2peak}) status of subjects with hip OA who were within four weeks prior to surgery was poorer than individuals at the time of referral. Mahon et al., (2002) observed that a shorter wait for surgery was associated with larger gains in health related quality of life and mobility post operatively compared to a longer wait to have surgery. This implies that the functional outcome after surgery will tend to be worse for those who wait for longer periods to have surgery.

Contrary to our hypothesis, our finding for hip muscle strength showed no significant differences between groups.

5.1.1. The 6MWT

The 6MWT test was significantly different (p < 0.001) between groups. Our analysis showed that subjects who were pre-operative candidates walked significantly shorter distances when compared to subjects at the time of referral
This finding reinforced Bautmans et al.'s (2004) finding that distance achieved on the 6MWT decreased as the health status in community-dwelling elderly persons decreased. When compared to the distances reported for healthy elderly individuals, our findings suggested that despite the location in the continuum of care individuals diagnosed with hip OA tend to demonstrate a limitation in walking capacity compared to healthy elderly individuals of a similar age. Camarri et al. (2005) observed that a group of 33 healthy elderly individuals aged 64.5 ± 5.2 years obtained an average score of 659 ± 62 meters during the 6MWT. Likewise, Troosters et al., (1999) reported a score of 631 ± 91 meters in a group of 51 healthy older subjects (65 ± 10 years) during the 6MWT. However, as summarized in Table 4, individuals at time of referral walked only 423.7 ± 39.37 meters, those at the time of consultation walked 342.1 ± 75.5m and those pre-operatively walked 265.0 ± 59.0m. These results indicate that all subjects with hip OA in our study were able to walk shorter distances in 6 minutes than their healthy counterparts.

On the other hand, when compared to other studies, including subjects with hip OA, our study obtained similar results. Stratford et al. (2006) reported 6MWT preoperative scores of 428.7 ± 115.9m in 85 individuals with a median age of 65 years. Kennedy et al., (2005) also reported similar preoperative scores (412 ± 123m) in 150 subjects with hip OA aged 63.7 ± 10.7 years. Both authors suggested that 6MWT scores were sensitive to change in subjects who were waiting to undergo a total hip replacement and that individuals with OA tend to
walk less distance than healthy individuals of a similar age. The 6MWT scores in our study for individuals at the time of referral (423.7 ± 39.37m) were similar to those reported in previous studies in individuals with hip OA.

An increased level of pain in the PREOP group could be a possible reason to explain the shorter distance walked by this group. However, the level of pain between groups was not obtained as an outcome measure. The visual analog scale (VAS) was used as a precaution to avoid older subjects overworking and aggravating their pain symptoms during the testing session and/or between tests. According to Stratford et al., (2006) the increased level of pain in individuals with hip OA can directly affect their functional capacities and consequently reduce their level of activity. Another explanation could be based on the aerobic capacity of the PREOP group which was significantly reduced (p=0.002) when compared to the REF group. Subjects in the REF group who walked significantly further distances than PREOP group in 6 minutes obtained a VO$_2$ peak of 34.81ml/kg/min, while subjects in the PREOP group obtained a VO$_2$ peak of 25.63ml/kg/min. This suggests that one reason individuals in the PREOP group were not able to walk as far as individuals in the REF group was because those from the PREOP group tended to fatigue more quickly than those in the REF group.

Interestingly, studies comparing the difference in 6MWT between individuals with hip OA at the time of referral, at the time of consultation and within four weeks prior to surgery have not been completed. Therefore, this study
demonstrates the importance of understanding the functional differences in those individuals with hip OA. Our results indicated that individuals with hip OA at the time of referral are able to walk longer distances than individuals who are within four weeks prior to surgery. These results suggest that those individuals, who have been in the continuum of care for longer period of time, have decreased functional capacity as demonstrated by their walking ability. Since individual decline was not measured, this assumption is based on group differences only and it suggests that this may be worth exploring further.

5.1.2. The TUG

The Timed Up and Go (TUG) test was developed to measure balance and mobility. There was a significant difference between the three groups in this study ($p = 0.005$). The longer subjects take to finish the TUG test the worse their balance control and mobility (Arnold and Faulkner, 2007). This study revealed that the time to finish the TUG test for subjects at the time of referral was significantly shorter ($p < 0.009$) than the time for subjects who were within four weeks prior to surgery. In a similar way, subjects at the time of consultation demonstrated significantly better TUG score ($p < 0.02$) than the subjects who were within four weeks prior to surgery. Our findings corroborate those of other studies in which time to complete the TUG increased in a population diagnosed with hip OA (Arnold and Faulkner, 2007; Kennedy et al., 2001). Arnold and Faulkner (2007) stated that 45% of the 106 individuals with hip OA in their study
fell at least once annually. They obtained a TUG average score of 12.8 ± 5.3 (seconds) from individuals with a mean age of 74.4 ± 6.2 years who had a history of falls. In another study with healthy older individuals, Shumway-Cook et al. (2000) observed that individuals with a mean age of 78.4 ± 5.8 years achieved a score of 8.4 ± 1.7 seconds during the TUG test. Even though subjects at the time of referral demonstrated similar score (8.82 ± 2.36), they were approximately 10 years younger than the healthy individuals in the Shumway-Cook study. This indicates that hip OA can affect subjects’ balance and mobility at a younger age than their healthy counterparts.

An increased time to finish the TUG test observed in the PREOP group could be attributed to an accentuated level of pain in this group. The perceived level of severity obtained with the WOMAC scores indicated that individuals in the PREOP group who took more time to complete the TUG test had significantly higher levels of perceived severity than individuals in the REF (p = 0.001) and CON (p = 0.038) groups. Garbuz, Xu and Duncan (2006) observed that the higher the level of perceived severity in individuals with hip OA the worse their functional capacities. The results of this study indicated that the levels of perceived severity related to issues such as pain and stiffness were related to reduced levels of functional activities in subjects with OA.

Petterson et al. (2007) observed gender differences among individuals with hip OA. They reported higher scores in the TUG for both men and women (8.16 ± 2.34 and 10.62 ± 2.68 seconds) with hip OA compared with matched
healthy control subjects (6.30 ± 1.27 and 6.90 ± 1.16 seconds). Although those subjects with OA were younger (men: 61.3 ± 7.7 yrs and women: 62.3 ± 6.8 yrs) than the subjects in the current study (Table 2), the scores were similar to the ones obtained in our study. Our results indicated that individuals with hip OA who were within four weeks prior to surgery took significantly more time to complete the TUG test as compared to individuals at the time of referral or at the time of consultation. This suggests that individuals, who have been in the continuum of care for longer period of time, may demonstrate worse mobility and balance control. Similarly, individuals at the time of consultation, who are placed on waiting list to have surgery, may also show less mobility and balance control before they undergo surgery. However, these results are based on group differences only and further investigation is warranted.

5.1.3. Hip flexion and extension muscle isokinetic strength

It was hypothesized that subjects with hip OA within four weeks prior to surgery would demonstrate lower hip flexion and extension muscle strength than those individuals who were at the time of referral and at the time of consultation. The results of this study did not support this hypothesis since no significant difference was found between the three groups (p > 0.05) for either hip flexion muscle strength (Figure 10) or hip extension muscle strength (Figure 11). However, redoing a power calculation, it was observed that to find significant results for hip muscle flexors with 80% power, alpha level of p<0.05 and effect
size of 0.164 it would be necessary to have a sample size of 363 individuals (121 per group). Similarly, to find significant results for hip muscles extensor with 80% power, alpha level of p<0.05 and effect size of 0.34 it would be necessary to have a sample size of 87 individuals (29 per group). Therefore, the sample size in this study was insufficient to detect such a difference.

Published studies available on weakness of muscles associated with OA of the hip are limited therefore, the information about weakness of lower extremity muscles related to OA of the knee obtained from other studies was extrapolated to outline and explain whether there is a relationship between muscle weakness and OA. It was found by Slemenda et al., (1997) that quadriceps weakness may be present in patients who have knee OA but do not have pain at the joint, or muscle atrophy. However, Yamada et al. (2001) did not find any difference between knee flexor and extensor muscle strength in 32 women with osteoarthritis and 13 control subjects. Aquino and Leme, (2006) compared the nondominant knee of female volunteers with the OA knee of those who were undergoing knee surgery. The results showed no significant differences between the values of maximum torque of the nondominant side in the control group and the OA knee in a group of women with knee OA. This was equally true for the peak flexor torque and the peak extensor torque. The findings suggest that weakness of the quadriceps muscles may not be a determinant factor for physiological deterioration in those individuals with knee OA. Arokoski et al., (2002) is the only available study about weakness of muscles associated
with OA of the hip. However, the authors did not obtain the isokinetic muscle strength of the hip muscles using a Biodex machine, therefore the data obtained in their study can not be compared with the present study results. In spite of the aforementioned studies, muscle weakness was a common complaint among individuals with hip OA in the present study, and among individuals with knee OA in these previously cited studies (Yamada et al. 2001; Aquino and Leme, 2006). This indicates that subjects perceive themselves as weakening and therefore may choose to curtail their activity based on this perception, however actual weakness has not been demonstrated.

5.1.4. The VO$_2$peak – submaximal test

The submaximal exercise test estimates an individual’s aerobic capacity. The higher the aerobic capacity of individuals the less fatigued they became during activities. Consequently, those who presented higher levels of predicted VO$_2$peak tend to be more active and independent than those who demonstrated lower levels of predicted VO$_2$peak. It was hypothesized that subjects with hip OA within four weeks prior to surgery would demonstrate lower estimated VO$_2$peak than those who were at the time of referral and those at the time of consultation. There was a significant difference between the three groups ($p = 0.001$). Subjects at the time of referral demonstrated significantly higher ($p = 0.002$) aerobic capacity compared to subjects at the time of consultation. Similarly, the
estimated aerobic capacity of subjects at the time of referral was significantly higher \( (p = 0.002) \) than subjects within four weeks prior to surgery.

According to Fisher et al. (1994) and Hollenberg et al. (2006) maximal aerobic power scores tend to decrease with the aging process and this tends to be worse in individuals with OA. The authors suggested that the more sedentary individuals become due to the aging process, the worse their aerobic capacity. Fisher et al. (1994) also reported an increase in VO\(_{2}\)\(_{\text{peak}}\) in individuals with OA who underwent an exercise program. These findings may indicate that due to progressive worsening of OA, subjects engage in fewer activities such as walking or bicycling, which reduces their cardiovascular fitness. Therefore the level of oxygen capacity of those individuals with hip OA tends to decrease over time. In the current study, it was found that peak oxygen capacity was higher at the time of referral compared to both time of consultation and the time of surgery. However, there was no significant difference between subjects in the CON group and subjects in the PREOP group. Therefore, our results suggest that individuals who have been in the continuum of care for longer period of time may demonstrate decreased aerobic capacity. However, these results are based on group differences only and can not determine what happens at the level of the individual.
5.2. Limitations of the Current Study

The current study was susceptible to limitations that affect the results and limit potential conclusions. Initially, the power calculation indicated that 25 subjects per group (a total of n=75) were needed to detect differences, if they were present. This assumption was not met and the sample size was too small. There were only seven subjects per group with a total of 21 individuals, which can affect all results and any findings cannot be considered generalizable. The strategy of recruiting subjects with hip OA did not meet our expectations. Subjects were recruited from the caseload of three orthopedic surgeons in Kingston, Ontario. The subjects were identified using the current waiting list of these surgeons. However, not all the candidates for hip replacement were residents of Kingston, Ontario. Consequently, many were dependent on a family member or a friend to travel to Kingston to attend to the testing session and therefore they were unable to participate in the study. Other individuals, who were living in Kingston, could not manage with their level of pain during activities. This may suggest that only those who were higher functioning or who had greater social support networks participated in the study.

Finally, the subjects in this study came to the laboratory for testing at different times of the day. It is recognized that at the end of a working day one may be more fatigued than at the start of the day. Therefore, those who came to the laboratory at the end of the day, after finishing their job, may have had some
fatigue which could have influenced all the measures obtained during the testing session.

5.3. Directions for Future Research

The present study provides new insight into understanding the differences in functional and physiological outcome measures in individuals with hip OA, despite the limitations that need to be taken into account. In order to advance the knowledge obtained in the current study, future studies need to include a larger sample of subjects with hip OA and potentially a control group of matched healthy individuals. Further investigations are needed to determine deterioration in hip flexion and extension muscle strength as well as in hip abduction and adduction muscle strength occurs among those individuals who are waiting for total hip replacement. Additionally, a longitudinal design would be preferable to a cross sectional one in order to observe changes in functional and physiological status of individuals with hip OA. A longitudinal study would provide data about the same group of individuals at different points in time allowing the researcher to track change at the individual level.
CHAPTER 6

Conclusion

Individuals with hip OA at three different points in the continuum of care (at time of referral to a surgeon, at the time of consultation with the surgeon and within four weeks prior to surgery) demonstrate differences in both functional (6MWT and TUG) and physiological ($\text{VO}_2\text{peak}$ – submaximal arm ergometer test) status. It was observed that individuals at the time of referral generally tend to walk longer distances, demonstrate better balance control and mobility, and show greater aerobic capacity than the individuals at the time of consultation or those within four weeks prior to surgery. These findings suggest that individuals who are at a further point along the continuum of care for hip OA show poorer outcomes in both functional and physiological status.

Hip muscle strength was not significantly different between the three groups. Therefore, it remains to be investigated whether the strength of hip muscles are different between Individuals with hip OA at different points in the continuum of care. Therefore, the present data will be useful for guiding a better evaluation of the functional and physiological status of subjects with hip OA.
REFERENCES


Shumway-Cook, A., Brauer, S., Woollacott, M. (2000). Predicting the Probability for Falls in Community Dwelling Older Adults Using the Timed Up & Go Test; *Physical Therapy*, 80 (9), 896-903.


Appendix I

Letter of Information

You are invited to participate in a study entitled “Change in Objective Functional Tests While Waiting for Total Joint Replacement”. This is a research project being conducted through the Department of Surgery at Kingston General Hospital and the School of Rehabilitation Therapy at Queen’s University. The principal investigators are Dr. Mark Harrison and Dr. Alice Aiken. This study is being conducted to collect objective measures of physiological and psychological function while patients are waiting from referral to initial consultation and from consultation to surgery for total hip or total knee joint replacement surgery.

In this study you will be asked to fill out several questionnaires, perform some strength tests for your legs, do a cardiovascular test on the exercise bicycle or arm ergometer, and do some simple functional tests that involve walking and sitting. The test will take approximately 90 minutes of your time. If you have just been referred to the orthopedic surgeon, you will be contacted again at the time of your consultation with him to see if you would like to repeat the battery of tests. There are no benefits from your participation in this study. There is a minor risk of fatigue while you are performing the test; however the research assistant will allow you to rest as much as you like, and you may refuse to continue if you get too fatigued. Your medical chart from this clinic will be reviewed by the researchers or their assistants to look at the results of any diagnostic tests (eg. X-rays) and to determine any medical conditions you may have. The information from your questionnaires and tests will be kept strictly confidential, identifiable only by a code. All test data and surveys will be kept in a locked filing cabinet and will be available only to the principle investigators and the research team. Any data collected will be presented as group data only, so your individual responses will not be identifiable.

Your participation in this study is voluntary. You may refuse to answer any questions that you do not feel comfortable answering. You may withdraw from the study at any time and this will not affect your care in the orthopedic clinic. If you have any questions about your participation in this study, or would like to have your data removed
from the study you may do so by contacting the principal investigators, Dr. Mark Harrison at (613) 549-6666 or harrisom@post.queensu.ca, or Dr. Alice Aiken, at (613) 533-6710 or alice.aiken@queensu.ca, or the department head of the Department of Surgery, Dr. Dale Mercer at (613) 533-2660. If you have any questions regarding your rights as a research subjects, you may contact Dr. Albert Clark, Chair, and Research Ethics Board at (613) 533-6081.

If you agree to participate, please sign the attached consent form and submit it to the research assistant. Please keep this letter so you have all the appropriate contact information.

Thank you very much for taking the time to participate in this study.

Sincerely,

Mark Harrison
Appendix II

Consent Form

I have agreed to participate in a study entitled “Change in Objective Functional Tests While Waiting for Total Joint Replacement”.

I understand that:

1) This is a research project being conducted through the Department of Surgery at Kingston General Hospital and the School of Rehabilitation Therapy at Queen’s University. The principal investigators are Dr. Mark Harrison and Dr. Alice Aiken.

2) This study is being conducted to collect objective measures of physiological and psychological function while patients are waiting from referral to initial consultation and from consultation to surgery for total hip or total knee joint replacement surgery.

3) I am being asked to fill out several questionnaires, perform some strength tests for my legs, do a cardiovascular test on the exercise bicycle or arm ergometer, and do some simple functional tests that involve walking and sitting. The test will take approximately 90 minutes of my time.

4) There are no anticipated benefits from my participation in this study, and there is a minor risk of fatigue but I can rest or stop testing if I become fatigued.

5) My medical charts will be reviewed by the researchers and their team to look at the results of any diagnostic tests (eg. X-rays) and to determine any medical conditions I may have.

6) My testing and survey information will be kept strictly confidential, identifiable only by a code.

7) All surveys and testing information will be kept in a locked filing cabinet and will be available only to the principle investigator and her research team. Any data collected will be presented as group data only, so my individual responses will not be identifiable.

8) My participation in this study is voluntary. I may refuse to answer any questions that I do not feel comfortable answering. I may withdraw from the study at any time without penalty and this will not affect my care in the orthopedic clinic.

9) If I have any questions about my participation in this study, or would like to have my data removed from the study I may do so by contacting:
   a) the principal investigators, Dr. Mark Harrison at (613) 549-6666 or harrism@post.queensu.ca, or Dr. Alice Aiken, at (613) 533-6710 or alice.aiken@queensu.ca, or
   b) the department head, Dr. D. Mercer at (613) 533-2660, or
   c) If I have any questions regarding my rights as a research subjects, I may contact Dr. Albert Clark, Chair, Research Ethics Board at (613) 533-6081.

________________________________________________________________________  ____________________________________________________________________
Signature of Patient                                            Date
# Appendix III

## DATA COLLECTION SHEET

<table>
<thead>
<tr>
<th>Code number</th>
<th>Gender</th>
<th>Date</th>
<th>Side</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
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</table>

**Assessment**

Duration of Symptoms: ________ yrs ________ mths

Different From Normal Today?

Better / worse / normal

Date of referral to ortho: dd_______ mm_______ year _________

Past Joint Surgery: Joint? ________ Date: ______________

History of Low Back Pain: ____________________________ Diagnosis: ________ Duration: ________

**Medication**

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<tr>
<th>Pain</th>
<th>NSAIDS</th>
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<tr>
<td>Acetaminophen</td>
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<td>Ibuprofen</td>
<td>Naproxyn</td>
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<td>Voltaren</td>
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**Supplements**

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<td>Glucosamine</td>
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<td>Shark Cartilage</td>
<td>Chondroitin</td>
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Specify type: ____________________________

Dose: ____________________________

---

88
### Pain in other Joints that limits activity:

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<th>Joint</th>
<th>Right</th>
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### Previous Surgery

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### Other Conditions Limiting Mobility

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### Active Hip Range of Motion (supine)

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<td>Flex</td>
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### Submaximal VO2
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**Biodex**

**Knee Flexion/Extension**

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**Hip Flexion/Extension**

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**Timed up and Go Test**

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Average pain /10

RPE

**6-min Walk**

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Distance walked

Extra Steps

Total m

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Appendix IV

Borg rating of perceived exertion scale

Please indicate heavy and strenuous the exercise feels to you:

6............... No exertion at all
7............... Extremely Light (7.5)
8
9............... Very Light
10
11............... Light
12
13............... Somewhat hard
14
15............... Hard (heavy)
16
17............... Very hard
18
19............... Extremely hard
20............... Maximal exertion
Appendix V

Calculation of peak oxygen uptake in upper body:

**FEMALES**

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<tr>
<th>HR</th>
<th>300g (21 watt)</th>
<th>VO_{peak} 600g (42 watt)</th>
<th>(L·min⁻¹) 900g (63 watt)</th>
<th>1.2kg (84 watt)</th>
<th>1.5kg (105 watt)</th>
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*Accuracy expressed as Standard error of the estimate (% VO_{peak}) is 10.7 % for the women.*

Divide the liter·min⁻¹ value from the table by body weight to express the peak oxygen uptake in upper body in mL·kg⁻¹·min⁻¹:

**Peak oxygen uptake in mL·kg⁻¹·min⁻¹ = (L·min⁻¹) × 1000 / BW⁻¹**
## MALES

<table>
<thead>
<tr>
<th>HR</th>
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<th>VO&lt;sub&gt;2 max&lt;/sub&gt; 600g (42 watt)</th>
<th>(L·min&lt;sup&gt;-1&lt;/sup&gt;) 900g (63 watt)</th>
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Accuracy expressed as Standard error of the estimate (% VO<sub>2 max</sub>) is 11.8 % for the men.

Divide the liter value by body weight to express the peak oxygen uptake in upper body in mL·kg<sup>-1</sup>·min<sup>-1</sup> (<VO<sub>2 max</sub>):

Peak oxygen uptake in mL·kg<sup>-1</sup>·min<sup>-1</sup> = L·min<sup>-1</sup>·1000/ BW<sup>-1</sup>