Physical Activity after Total Hip Arthroplasty

by

Heather Kattenfeld

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Dedicated to:

My family – Mike, Maren and Maya - for their patience, love and support.

My advisor - Dean Kriellaars - for his patience, support, mentorship and motivation that allowed me to complete my Masters.

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Abstract

Introduction

Pain reduction and functional restoration are often touted as rationale for total hip arthroplasty (THA). It is well established that pain is dramatically reduced, but restoration of function has only been assessed by diminution of disability, rather than regaining ability. Further, disability and function measures have been subjective and self-report. Physical activity is a surrogate for function and can be assessed objectively. Limited studies have objectively examined physical activity after THA.

Purpose

The purpose is to examine physical activity levels of participants after THA and relate physical activity to pain, disability, sleep, and body composition.

Methods

Cross-sectional, observational study of THA patients 1-3 years post-surgery (n=17, male). Seven day triaxial accelerometry (2 second epoch, GT3X) was used to derive step and energy related measures of physical activity along with a daily activity inventory log. Body composition measurements were taken (waist circumference, BMI). Pain was assessed using three visual analog scales related to intensity, function, and provocation. HOOS (Hip Dysfunction and Osteoarthritis Outcome Scale), Oxford Hip, and PSQI (Pittsburgh Sleep Quality Index) were completed.

Results

The participants averaged 9143 (398.2) steps/day. Statistical analysis failed to show a significant difference from the daily step value for the age-matched normative Canadian population. The average stepping time was 142.7 (44.8) minutes/day and average step rate was 61.1 (10.7) steps/minute. The average energy expenditure was 623.9 (270.0) kcal/day. Time spent in

moderate intensity or greater physical activity was 55.8 (22.5) minutes/day. This was higher than the reported value for the age-matched Canadian males at 24 minutes/day. Body composition (WC, BMI) and sleep (PSQI) were not found to be significantly correlated to any PA measure. For the pain measures, VAS function was significantly correlated to step rate ($r=0.483$, $p<0.05$). Subjective disability measures had very limited relation to PA, with step rate being related to Oxford Hip ($r=0.486$, $p<0.05$). When assessing predictors of disability (step wise regression), VAS function was found to account for 80.7% of the variance in the HOOS and 78% of the variance in the Oxford Hip Score but no PA measures were returned.

Conclusion

Activity levels in the male THA population lacking co-morbidities are clinically at par with age-matched peers and near minimum activity guidelines. Traditional PA measures were unrelated to disability measures.

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Introduction

By 2026, it is estimated that just over 20% of the Canadian population will have some form of arthritis (Health Canada, 2003). Osteoarthritis (OA), being the most common form, affects one in ten Canadian adults (Arthiritis Society, 2011). In osteoarthritis, the cartilage erodes in the joint resulting in pain and stiffness of the joint along with functional impairment. Treatment for arthrits may include non-surgical options such as exercise, use of mobility aids or pain medications. As the disease progresses, joint replacement surgery may be required to relieve pain and restore mobility in the patient. Total knee and total hip arthroplasty (THA) are two forms of joint replacement common in people with arthritis. The goal of joint arthroplasty surgery is pain reduction which in turn eliminates this as a barrier to a return to function.

The Canadian Joint Replacement Registry reported degenerative OA as the primary cause for THA in the 2009-10 annual report. In that same time frame, 13,068 THA were performed in Canada (Canadian Institute for Health Information, 2011). Presently in Winnipeg, THA surgeries are performed at two of the city’s hospitals. The total number of hip replacement surgeries performed in the 2011/12 fiscal year in Winnipeg was 999 (Government of Manitoba, 2012). The Concordia Joint Replacement Group (CJRG) performs over half of these hip arthroplasties out of Concordia Hospital. Unlike Total Knee Arthroplasty (TKA), there is no scheduled post-discharge rehabilitation at present for THA patients in Winnipeg.

Recently, the literature has started to focus on function and physical activity (PA) following THA both assessing the patients’ ability to meet PA guidelines (Bauman et al (2007), Stevens et al (2007), Wagenmakers et al (2008), Cukras et al (2007)) and the level of disability present in this population relative to the normative population (McClung et al (2000), Wagenmakers et al (2008), Cukras et al (2007)). To study physical activity in the THA population, most authors have made use of subjective measures of physical activity where clients report activity levels pre-op and at a time (usually 12 months or greater) post-op. However, recent studies using accelerometry, an objective and validated measure of physical activity, have demonstrated that subjective measures of physical activity greatly over-estimate actual physical activity. Troiano et al (2008) objectively measured the physical activity of the adult American population using accelerometry. The objective data concluded that less than 5% of American adults were meeting current activity guidelines. This value was approximately 10 times lower than the self-reported activity in the National Health and Nutritional Examination Survey where 51% indicated they would have met the criteria (defined as accumulating 150 minutes/week of moderate or greater intensity activity). In the Canadian population, Colley et al (2011) found similar results concluding that only 15% of the Canadian adult population was meeting the physical activity guidelines defined by the Canadian Society for Exercise Physiology (2011) using accelerometry. However, 52.5% of Canadian adults indicated being at least moderately active during their leisure time on a self-report questionnaire. Similar findings were reported in a local study using accelerometers to quantify ambulatory performance in patients with lumbar spinal stenosis. Pryce et al (2012) found that pain and disability measures did not correlate strongly with accelerometer based ambulatory activity. Due to these apparent discrepancies, subjective reports of physical activity and disability provide overestimates of actual PA in a population and do not correlate well with objective measures. Objective measures should be used to quantify activity in any research study. Unfortunately, there has been little use of objective measures to quantify activity levels following THA and limited opportunity to study if these clients are meeting activity requirements for healthy living. In fact, it is not even known if patients after THA are actually any more active than they were prior to surgery. Disease specific subjective questionnaires do play an important role in determining perceived function in a population. These questionnaires, including the Hip Dysfunction and Osteoarthritis Outcome Scale (Nilsdotter et al, 2003) and the Oxford Hip Score (Dawson et al, 1996); focus on symptoms such as pain and stiffness and their relationship to the patients' perceived function. The patient reports their current level of disability as determined by hip pain and stiffness. Overall, a well-rounded study should quantify physical activity objectively to avoid over-estimation but also include subjective measures to better understand the perceived disability in relation to actual active participation. This study will look to fill a gap in the literature by using objective measurements to quantify activity levels after THA surgery and compare this to published data for the age-matched normative population. Further, the relationship of objectively measured PA to disability, sleep and pain will be explored.

Literature Review

Scientific literature has begun to focus more on quality of life and functional restoration through participation versus objective clinical means of measuring success of a treatment. This has become the case with osteoarthritis. In the last decade, a focus on quality of life and participation (WHO, 2003) has emerged with increasing use of subjective measures, whether disease specific, domain specific or generic in nature, related to this area. The success of THA surgery is based on the patient's reduction in pain and perceived increased function. General trends have emerged showing that THA is effective in reducing pain, increasing perceived function, and that pre-op condition will influence post-op results (Biring et al (2007), Röder et al (2007)). However, very few studies have objectively measured physical activity in this population to determine levels attainable after surgery. If functional restoration is defined as the return to daily functional activities without pain and with greater ability, this differs from pure physical activity. Physical activity will quantify the amount and intensity of activity the patient participates in and may be a surrogate for functionality. It has been shown that variables such as education, employment and other patient characteristics can influence activity levels (Stevens et al (2007), Hirata et al (2006)). However, a majority of these studies rely on self-reported measures. Actual physical activity measurements and comparisons may help define limitations in current rehabilitation for these clients while giving insight into where rehabilitation should head in the future. The literature discussed below will define recent advances in THA outcomes, activity levels reported in the THA population and limitations in the existing research in the area of physical activity.

Disability and Quality of Life after THA

Many studies have focused on arthroplasty populations with respect to physical function such as mobility and range of motion, pain and perceived levels of disability in pre/post designs. These studies primarily use self-report measures to quantify function or activity. Röder and colleagues (2007), working out of the University of Bern in Switzerland, examined the effect of preoperative pain, walking capacity (categorical based on minutes) and hip flexion (categorical in degrees) on postoperative functioning in people undergoing a total hip replacement. The data was obtained from the IDES (International Documentation and Evaluation System) hip registry that includes information from sixty-five hospitals in eight European countries. The data used included objective ROM measurements, subjective pain, and subjective ambulation tolerance data. Twelve thousand nine hundred and twenty-five patients were included with the earliest data collected in 1967 and the most recent follow up data from 2002. The average number of follow up assessments was 2.1 and mean duration of follow up was 4.3 years. It was found that 57.1% of people who reported they could walk greater than ten minutes pre-operatively reported they could manage greater than 60 minutes post-op compared to only 38.9% in the patients who were limited to less than ten minutes tolerance pre-operatively. Self-reported walking capacity increased up to 3-4 years post-op and then gradually decreased. With respect to hip flexion, 74.7% of patients that had greater than 70 degrees hip flexion pre-operatively achieved greater than 90 degrees post-operatively while 62.6% of patients with less than 70 degrees flexion pre-operatively achieved greater than 90 degrees post-operatively. Unfortunately there were no relationships investigated between age, ambulation tolerance and range of motion. This does not allow for interpretation of these results based on pre-operative activity levels or disability. They concluded that poor mobility and range of motion preoperatively predict a poor functional outcome. Due to the known incongruence between self-reported physical activity and objective measures, the physical activity or tolerance of these patients may be significantly different if measures objectively, therefore altering these relationships significantly. This study suggests that being aware of participants' pre-operative activity level will assist in predicting activity levels following surgery, and that pain is not a good predictor of postoperative limitations.

Biring, et al (2007) from the University of British Colombia investigated quality of life outcomes after total hip revision surgery. This study was populated with 222 patients who underwent a total hip revision surgery between April 2001 and March 2004. The quality of life data was compiled before surgery using the WOMAC and SF-12 and after surgery at a one and two year follow up with the the inclusion of the UCLA activity rating questionnaire. Overall, there was a a significant improvement in the WOMAC function and pain subscales and the SF-12 mental component score ($p<0.001$). In all quality of life scores, the pre-operative functional score (WOMAC) predicted outcomes with relation to function (WOMAC), pain (WOMAC and SF-12) and perceived activity level (UCLA activty questionnaire). Predictors for improved perceived activity post-op were increased WOMAC function score, which of the four surgeons performed the revision surgery, and aspetic loosening as the cause for revision. The single predictor for a poor WOMAC functional score was an age greater than 70. Poor pain-related outcomes after surgery were predicted by a lower pre-op functional score (WOMAC), under 60 years of age, female, increased Charnley classification and a previous revision. Overall, the Charnley class (described below) affected all parameters with increasing classification predicting poor outcomes with relation to function and pain. The Charnley classification used defined the classes as; class A patients have ipsilateral joint replacement; class B1 have an ipsilateral joint replacement with degenerative change in the contralateral hip; class B2 have both hips replaced, and Class C have multiple joint disease or other disabilities leading to problems with ambulation. The rationale for why the authors did not use the UCLA activity questionnaire at time of admission to allow for pre-op and post-op comparisons was not provided. With self-reported activity known to be over-estimated or at best poorly correlated to objective measures, the data presented here may not provide an accurate assessment of the relationships between activity, pain and function.

Finally, Deschartres and colleagues (2007) set out to describe activity limitations and their evolution in persons with THA compared with the general population in France. The data was collected from the Handicap, Disablilty, Dependence Survey taken in 1999 with follow up in 2001. In 1999, 16,945 participants were sampled with 815 having lower-limb arthroplasty. For the follow up survey, 12,350 individuals were re-interviewed; of these 608 of the original 815 with lower-limb arthroplasty were re-interviewed and of these 382 had a THA. Of the general population interviewed in 1999, 145 had had a THA before follow up in 2001. Therefore, there was a total of 527 individuals with THA sampled. Interviews were conducted from October 2001 until January 2002 where respondants were asked to describe changes in health status since 1999 (improvement, worsening, appearance of other chronic conditions including diseases, accidents, problems from birth and due to aging). Disablility was assessed from the participants' reports via computer-assisted personal interviews. Five areas were described; personal care, mobility, housekeeping, cognitive and sensory abilities. A five-point Likert Scale was used from "no disability" to "impossible without help". Walking was divided into specific categories: walking <100 meters, 100-300 meters, 300-500 meters, 500-1000 meters and >1000 meters. Unfortunately, it was not defined whether this distance was attainable throughout the day or in one continuous bout. Conditions were considered improved if the answer decreased by at least one point and worse if the answer increased by at least one point on a Likert scale. If the answers did not differ this was considered no change in disability. Patients with THA reported a higher level of disability in mobility and self-care compared to the general public. Evolution of disability was similar between the two groups, however the use of technical devices for mobility was greater in the THA population. Higher levels of disablility were reported in the more recent compared to remote THA participants with recent THA (2 years or less from surgery) having more difficulty walking >300 meters, washing, shopping, dressing and getting in/out of a chair. The THA participants with surgery within the last two years also reported increased use of a walking aid. The reported impact of the study was that: i) surgeons could better define objectives of Physiotherapy and Rehabilitation, ii) more intensive Rehabilitation is needed sooner to shorten the time of disability, and iii) surgeons will have better information for patients on outcomes of THA and can help patients have more realistic expectations. The reported drawbacks of this study were again using only self-report data and that only the free-living population was sampled. The authors suggest that there may have been a selection bias resulting in under-subscription of a more disabled population. Also, the non-respondents for the follow-up were significantly older than the respondents and had reported significantly more disability in 1999, therefore data may be skewed. Another concern not stated by the authors is the suggestion that surgeons could better define objectives of rehabilitation based on subjective report and based on suggested skewed data. Setting up expectations for patients based solely on reported disability is not ideal. The expectations may set some patients at a disadvantage by undercutting their potential. A range of expectations based on objective assessment of this population may be more prudent.

In conclusion, these studies report perceived function and activity after surgery are influenced by pre-op function. The THA population, especially those in the acute phase of recovery, report decreased function and mobility in comparison to the normative population.

BMI and THA

BMI (body mass index) and its impact on surgery and rehabilation of patients with THA has been explored. There is controversy around whether an increased BMI is associated with increased wear rates of the prosthesis, and if there is a direct relationship between BMI and postoperative activity levels. In the activity data from the Canadian population (Colley et al, 2011) the middle-age (40-59 years) Canadian male and females showed no relationship between BMI and activity levels as measured with accelerometry. This is important to consider when looking at the effects of BMI on activity after THA. Assuming THA patients are at par with their age-matched normative population with respect to activity, only 5.5% of males and 4.7% of females would be meeting activity recommendations for physical activity. Therefore, pre-existing sedentary lifestyle could have a large effect on activity regardless of BMI. However, if it is assumed that activity increases after THA with pain relief, a change in body weight and thus BMI should be expected to follow as well. Donovan, Dingwall and McChesney (2006) examined weight change in 84 patients 1 year after total hip or knee replacement. The BMI of arthroplasty patients was compared between time of pre-admission clinic and their one year follow up. A simple questionnaire was used to determine activity levels, pain relief and weight loss. Only patients who reported increased activity levels were included in the study. Overall, an increase of weight of 0.28 kg was seen which was not significant. However, the individual changes were quite variable. When looking at the different groupings based on weight, none of these groupings showed significant change, either increasing or decreasing. This again points out the limitation of self-report physical activity. With participants being chosen based on self-reported increased physical activity after surgery, it was assumed that this would lead to change in BMI post-op. However, without accurate assessment both of the intensity of physical activity as well as frequency, it is difficult to determine if there was a significant increase in activity following surgery which could lead to a change in BMI. Also, for a change in weight and thus BMI to occur, a study would also have to include a dietary log or component. Regardless of activity levels, if caloric intake exceeds physical activity output, weight will increase or stay stable.

Christian McClung and colleagues (2000) in California examined the relationship between BMI and activity in hip and knee arthroplasty patients. The authors proposed that the previously reported relationship between increased BMI and decreased activity in patients with total joint replacement (TJR) could help explain the reported lack of association between increased weight and implant wear. If patients with a greater BMI are less active as previously shown, there would be less stress on the joint from activity and therefore no increased wear. The purpose of this study was to analyze activity (measured by pedometer) and BMI. This data could be utilized to better understand the association between wear rates, BMI and activity. Data was collected from 209 individuals age 22-82. Of these, 58 participants had no TJR, 24 had a total knee replacement and 127 had a total hip replacement. Unfortunately, the average time after THA was not defined. ANOVA was used to examine the relationship between activity and independent variables such as age, gender, employment status and BMI. Student's t-test was used to examine the difference in distributions between the different groups. Activity was measured with a pedometer worn at the waist for seven days and evaluated as a continuous variable (steps/day). It was also examined as a categorical variable (low, medium, high) based on a division of the distribution at the 25th and 75th percentiles. The participants without TJR averaged 7781 steps/day, which was greater than the 5869 steps/day for the THA group and 4597 steps/day for the TKA group. The non-surgical group was significantly more active than the TJR population, but they were also significantly younger. When examining BMI compared with activity, both the THA and TKA groups had an association between high BMI and reduced activity. This association was not present in participants without TJR. The data presented here supports the consideration of BMI when selecting a study population where physical activity is measured. Also, the numbers here for steps/day help to provide guidelines for a THA study population as well as setting up the assumption that steps taken in the THA population will be lower than non-surgical normals. However, essential information regarding at what stage of recovery the THA population averaged on the continuum would be essential to make comparisons with physical activity parameters.

Busato and colleauges (2008) similarly examined the effect of BMI from the pre-op period until 12 years after THA. Their conclusions indicated that obese patients require THA at a younger age than their normal weight cohorts, and that high pre-operative BMI is associated, in an almost perfect dose-effect relationship, with decreased ambulation over the entire follow up period. Maximal ambulation outcomes were 10-20% lower in the obese patients than their normal weight cohorts. This is similar to McClung's findings, where increased BMI was associated with decreased activity, as were increased age and female gender. The authors state a limitation of their study is that the pedometer may not function as well on obese individuals due to increased soft tissue and may have underestimated the steps in the increased BMI population. The authors conclude that the effect of obesity on activity needs to be considered in studies assessing polyethylene wear and physical activity following total joint replacement. Overall, although BMI is primarily studied in the THA population with reference to wear rate, important information on the negative effect of BMI on physical functioning should be considered in any study focusing on functional restoration after joint replacement surgery.

In conclusion, a relationship between increased BMI and decreased activity has been identified. Also, using steps/day data, the THA population was less active than the normal population. Regardless of increased levels of activity reported after surgery, there was not an associated significant change in weight. Due to these reported associations, it is important to consider BMI of the THA population when assessing physical activity.

Self-Report Physical Activity and THA

Self-report measures are frequently used to quantify physical activity due to the low-cost approach and the ability to manage larger sample sizes. The four studies discussed in this section use self-report measures to quantify physical activity after THA. Shannon Bauman and colleagues (2007) from the Sports Medicine Clinic in Burlington, Ontario examined physical activity after total joint replacement in a cross-sectional survey. This study included 170 THA and 184 TKA patients. These patients were chosen from the arthroplasty database based on good/excellent outcomes determined 1 year post-op using Knee Society Score (KSS) and the Harris Hip Score (HHS) which are, according to the authors, the gold standard objective assessment tools of function following TJR. The HHS is a disease specific measure rating pain, functional ability and evaluates the ability to walk, climb stairs and perform ADL. The inclusion was based on a good/excellent outcomes being a score of 90/100 or greater for the HHS. These tests were administered by a physiotherapist not directly associated with the study to reduce bias. The criteria based on HHS scores were chosen to allow inclusion of participants assumed to have greater potential for functioning at higher activity levels post TJR. The timeline included the Oxford Hip/Knee collected pre-op (1 week prior to surgery) and at 6 and 12 months post-op. Also, clients were mailed the UCLA activity scale in the post-op period. The THA participants included 42.9% males with a mean age of 66.4 years. At 1 year post-op, the THA patients had a mean clinical score of 94.8/100 for the HHS and 16.6/60 for the Oxford Hip. THA patients had a median UCLA score of 6 at a mean follow up time of 40.7 months after surgery, which corresponds to moderate activity. A score of 6-8 on the UCLA activity scale, being moderate intensity using primarily low impact options, was endorsed previously by the Mayo Clinic and the 1999 Hip Society. The study showed a correlation between the UCLA activity score with age, sex (males) and Oxford hip score at 1 year post-op. As shown with previous studies, younger males report being more active post-op. The UCLA acitivy questionnaire was not used in the pre-op period. Bauman et al recognize this as a drawback to their study as it would have allowed for determining rates of return to activity and increase in activity after TJR. There is concern with the authors' claim that the UCLA questionnaire provides an objective view of activity after THA, as the UCLA questionnaire is a self-report measure completed by the patient to quantify activity (the score ranges form 1 (inactive) to 10 (impact sports)). With a moderate activity level reported by participants just over 3 years after THA, this sets the expectation that moderate intensity activity is achieveable once recovered from the surgical process. However, due to the over-estimation with self reported physical activity measures, it would be essential to use objective assessment of activity at this time frame to support these results.

Martin Stevens and colleagues (2007) from the University of Groningen in The Netherlands also used self-report measures when examining the effect of age, education and family status on activity after THA. A cross-sectional design was used with 372 patients who had undergone a primary THA between February 1998 and October 2003. Patient characteristics, education and physical activity were assessed by a self-administered questionnaire. The Short Questionnaire to Assess Health-enhancing physical activity (SQUASH) was used to record participants' perception of their quantity of physical activity. The authors state this questionnaire is both reproducible and has been validated using accelerometry with a Spearmann correlation coefficient between accelerometer readings and total activity score on the SQUASH of 0.45. Patients were considered to meet physical activity guidelines when they spent 30 minutes or more on moderate (3-5 MET) and/or vigorously intense (≥5MET) physical activity on five or more days of the week. There is no discussion of the SQUASH results with relation to time active, intensity of activities or activities particiapted in. The authors only report the relationship between the specific variables tested and the ability to meet physical activity guidelines. The mean age of the study population was 62.7 years with 60.8% females. 50.9% had primary or secondary education. Based on the results, it was concluded that aspects of a patient's characteristics are predictive for the level of physical activity after THA. Increased age, lower education and living alone were predictive of lower physical activity. Results of linear regression showed that 20% of the variance in physical activity could be explained by education, age and family status. The results demonstrated that gender plays a significant role in determining compliance with international guideleines for physical activity. Whereas, joint specific co-morbidities did not predict level of physical activity post-op. This was suggested to support the ideas that patients post-THA are able to function at the same activity level as healthy counterparts by 1 year after surgery. The authors suggest this data can be used to identify those people at risk for decreased activity post-op. With subjective measures being shown to greatly over-estimate actual physical activity, the categorization of patients risk for decreased activity post-op based on social characteristics would need to be reinforced using more accurate objective assessment of PA. This study does further support the trend seen in the literature where males report increased activity after THA. It also lends to the idea that socioeconomic factors also may play a role in affecting physical activity levels and should be considered when selecting future study populations.

The same group of researchers led by Robert Wagenmakers with the addition of their colleague Monique Jacobs (2008) examined the habitual physical activity of THA patients and compared their results to data from a normative population. They further analyzed PA based on age and other functional impairments in the THA group. Lastly, they assessed if the two groups were meeting guidelines set for health-enhancing PA. A questionnaire was sent to 371 patients who underwent a primary THA at the University Medical Center in Groningen between February 1998 and March 2003. The underlying etiology for THA in these patients was primary or secondary OA of the hip. The surgeries were performed or supervised by one of the eight staff surgeons and had to have occurred at least one year prior to this study. A total of 273 usable questionnaires were returned. The normative population consisted of age- and sex-matched people from the same area collected by means of a local helalth survey which was given as part of a larger population survey. Every THA participant was matched with the first appearing healthy counterpart of the same age and sex. The questionnaire sent obtained data on age, sex, general comorbidity and level of PA. The Charnley classification from their records was also obtained. The SQUASH was used to assess the participants perception of their quantity and intensity of PA. The guidelines for health-enhancing PA used here was 30 minutes or more of moderate intensity or vigorous intensity PA at least five days/week. Using the Ainsworth compendium, activities reported can be assigned a MET value. Three intensity categories were established for the two age groups. For the group ≤ 54 years: light intensity = 2 to <4 METs, moderate intensity = 4 to < 6.5 METs, ≥6.5 METs was considered vigorous intensity. For the age group 55 years and older: light intensity = 2 to <3 METs, moderate intensity = 3 to <5 METs, and vigorous intensity = ≥5 METs. Activities with a MET value less than two are not included becasue they do not contribute significantly to habitual activity. Wagenmakers et al (2008), in a separate study, had examined the reliability and validity of the SQUASH to assess PA in the THA population. Here, the SQUASH was administered to participants in the study at one year post-THA; the SQUASH was repeated by the participants involved in determining reliability 2 to 6 weeks after the first questionnaire was completed. The reliability of the SQUASH was determined by calculating Spearmann's correlation coefficient between the activity scores of the separate questions as well as the total activity scores from both administrations of the SQUASH. The correlation coefficient for the total score was 0.57. Although only a modest result, they reported it to be comparable to similar studies looking at the SQUASH in normative populations and also report this value is similar to the reliability of other physical acitvity questionnaires. The validity was determined using the Actigraph GT1M accelerometer worn for a two week period and they reported correlations of $r_{Spearman} = 0.67$ for total activity score and $r_{Spearman} = 0.56$ for total minutes activity The authors do acknowledge the relationship is only modest at best but contribute this to the SQUASH over-estimating activity level or the accelerometer underestimating activity as it does not record activities such as water-based activity, cycling or upper body activities. Based on recent studies using accelerometers to objectively quantify PA, it has been shown that subjective measures substantially over-estimate PA. For the Canadian population the self-reported activity was over 3 times more than the objective assessment using accelerometry and this difference was almost 10 times in the American population. Troiano et al (2008) stated that although accelerometers may underestimate certain types of activity such as water-based exercise and cycling, only 10% of the American population reported any cycling for leisure and 5% reported swimming. Also, Colley et al (2011) reported that when looking at leisure activities Canadians take part in, walking is much more common than swimming and cycling, therefore the accelerometer would have no problem quantifying the most prevalent physical activity. Therefore, it is likely that the SQUASH, alike other self-report measures, over-estimates physical acitivty.

Based on reliability and comparable relative validity, Wagenmakers et al were confident in their use of the SQUASH to estimate physical activity. Based on the previous discussion, one can expect the results to be an over-estimate, however the data does provide a means of comparison for future physical activity studies. The mean age of the THA participants was 62.7 years and the normative group had a mean age of 62.4 years. Both groups were composed of 60.8% females. The researchers found that the total time spent in PA (mean minutes per week) was higher in the THA group (1601.0 minutes) versus the normative group (1501.6 minutes), this was not significant. This increased time for the THA group was mainly due to time spent in leisure activities with 550.8 minutes per week in comparison to 485.6 minutes per week in the normative population. Leisure activities defined by the SQUASH are walking, bicycling, gardening and odd jobs. When examining the time spent in different intensities of activity, the THA group spent more time in light intensity activities and less time in vigorous activities. The authors also categorized the THA group based on age, finding the older group had significantly more women ($p<0.05$) in it and the number of comorbidities was significantlyhigher ($p<0.05$). The older age participants were significantly less active in all types of PA (1083.4 minutes per week incomparison to 2051.3 minutes per week, $p<0.05$), in activities of light intensities (607.7 minutes /week in comparison to 1346.2 minutes/week, $p<0.05$), moderate intensities (231.1 minutes per week in comparsion to 511.2 minutes per week, $p<0.05$) and in overall PA (1083.4 minutes per week in comparison to 2051.3 minutes per week, $p<0.05$). When the number of participants who met Dutch and International guidelines was calculated, 51.2% of the THA participants and 48.8% of the normal participants met the guidelines. Binary logistic regression analysis was used to determine predictors for meeting the guidelines. With the dependent variable set at meeting the guidelines (yes/no) the indepenedent variables studied were age, sex, and total number of comorbidities. Sex was the only variable that significantly influenced the chance of meeting the guidelines. The odds of men meeting the guidelines was about twice that of women. The authors conclude that patients after total hip replacement surgery appear to be at least as active as the normative population, but are insufficiently active based on the national and Dutch guidelines. It can be assumed that this subjective measure overestimates physical activity, therefore it is likely that the number of both THA participants and normal participants meeting the guidelines would be significantly lower. Also, the ability to convert reported activities to METs with accuracy is also questionable as the intensity is determined subjectively. It may be more accurate to ask patients to rate exertion or use a scale such as Borg Rating of Perceived Exertion versus simply asking the participant to circle the intensity. The authors suggest, in lieu of the many benefits to overall health related to physical activity, these patients should be stimulated to become more physically active. This study again concludes that patients at least one year after THA should be at activity levels parallel with the age-matched normative population. However, objective data allowing the comparison would eliminate the known over-estimation with self-report and provide a more accurate picture of physical activity in the THA population.

Cukras and colleagues (2007) from Poland studied physical activity of elderly patients (n=69, mean age 70.4 years) after THA using 7 Day Physical Activity Recall Questionnaire. The authors aimed to describe physical activity for people who have had a THA for primary osteoarthritis of the hip in addition to comparing the PA of the THA population to that of a similar-aged cohort without THA. The control group consisted of 77 citizens age-matched to the THA population. The authors divided physical activity into three divisions: low <1.5 METs, medium ≤4 METs, high ≤6 METs and very high >10 METs. There are two significant sources of error demonstrated here. The first is the known overestimation of physical activity based on subjective questionnaires. The second is the classification of physical activity based on METs. The Metabolic Equivalent value is a general estimation of energy expenditure, however it may over or underestimate actual intensity and energy requirements as it does vary based on the overall fitness of the participants. A generally fit person may find an activity classified as 10 METs (very high/intense activity) not that demanding and if asked to classify the intensity may have said only moderate. Again, the actual objective measure of physical activity allows better determination of overall energy expenditure. These sources of error should be kept in mind when considering the findings presented here. Analysis (Mann-Whitney U and Chi-Square) demonstrated that age and sex data of the two groups were similar. Mean energy expenditure for actual physical activity per week was also similar. Energy expenditure for low intensity PA was less in the THA men then in their age-matched controls. Energy expenditure through medium intensity physical activity was not significantly different as was engagement in high intensity physical activity. Women with THA reported lower energy expenditure from high intensity physical activity than women without surgery. There was no one from either group that reported taking part in very high intensity physical activity. The most popular physical activity after THA were marching, bicycling and general body conditioning. For these three activities in the post-surgery group, women averaged 46.8 kcal/kg/week and men averaged 74.8 kcal/kg/week. Seventy percent of the surgery group reported carrying out medium intensity physical activity for greater than two hours (120 minutes) during the week. The authors suggest studies should focus less on what activities are safe for THA patients and more on what an appropriate level of activity post-op would be. In this study, less than half of the THA participants regularly complied with recommendations regarding physical activity for healthy people with respect to energy expenditure (300 kcal per session, 2000 kcal per week), frequency (at least three times per week) and duration (40 minuites). As 70% reported medium intensity physical activity for >2 hours in 7 days, the authors suggest THA clients could regularly comply with the recommendations if motivated. The authors suggest these recommendations be established at an individual level taking into consideration physical activity in the past. To be able to accurately estimate physical activity both before and changes after surgery, objective measures would be necessary.

In conclusion, use of self-report measures have confirmed the relationship between such factors as age, gender and socioeconomic variables and physical activity. Also, information on physical activity quantities (1601.0 minutes/week active, 70% of participants with > 2 hours moderate intensity PA/week) and ability of this population to meet PA guidelines (approximately 50%) is provided lending to the development of future studies using objective measures of PA.

Guidelines for Physical Acitivity after THA

Chatterji et al (2004) from Australia examined the effect of THA on recreation and sporting activities. The study included 320 patients who had undergone THA 1-2 years prior. All participants had a similar inpatient post-op rehab course and performed their own rehabilitation at home as directed by the therapist in hospital. Data was taken from a self-administered questionnaire to assess outcomes of the THA. This was modified to include information on the

21 different sporting activities, including post-op return to each sport and frequency of participation. Grimby scale, which is a scoring system for post-operative physical activity (1-Hardly any physical activity up to 6-Regular hard exercise), was used to quantify current level of activity in the participants. A visual analog scale was used to quantify patient-perceived effect of THA on their sporting activity. The average for activity using Grimby's score was 3.46 which corresponded best with occasional light to moderate activity. The sports/activities which showed an increase in participation after surgery were walking and aqua aerobics. The sports/activities which saw a decrease in participation were golf, tennis and jogging. Following THA, a beneficial effect on performance was reported by patients using the VAS scale and an overall increase in number of patients active was seen. Those patients who had been more active with sports/activities before surgery tended to continue with more sports/activities after surgery (correlation coefficient 0.612, $p<0.001$). Pre-operatively, men were significantly more active with a score of 2.06 compared to 1.7 in women ($p<0.05$). This trend continued post-operatively with the men's score (2.0) remaining significantly higher than the females (1.4) ($p<0.001$). There was also very little difference in the male participation pre- and post-op compared with women who saw a 17.6 % decrease in participation after surgery. The time for return to activity was variable. The first activities that were returned to were walking and then water-based activities (primarily swimming and aquacise). The authors concluded that patients were returning to lower impact activities post-operatively. Although overall participation increased slightly (188 participants increasing to 196 post-op), the number of sports played decreased. It may be concluded that patients are more cautious with return to activity post-op or may not be given adequate information on safe return to a variety of sports instead of the most common or those deemed most safe. To better quantify physical activity and intensity of the activities, objective measures should be used. This may provide further information on both return to sport as well as changes in intensity of activity pre- versus post-op. It may also be beneficial to have a sub-group in a study where surgeon discussion regarding return to activities would be more individualized considering previous experience to assess how this might change patients perceptions on their ability to return to more varied sports/activities.

A large factor which determines return to physical activity after hip replacement is the surgeon's recommendations. There is variety in opinion around which sports are safe and when more vigorous activities can be safely resumed. Klein et al (2007) utilized a survey format to determine surgeon's recommendations regarding return to athletic activity after THA. The authors used a web-based survey including 30 groups of activities (37 specific sports) that the surgeons were asked to classify for a standard (metal-on-plastic) THA into 4 categories: allow, allow with experience, not allowed or undecided. The surgeons from both the Hip Society and the American Association of Hip and Knee Surgeons were also asked when they would allow return to sports. In total 549 participants were used for analysis. There were no significant differences in recommendations between the two groups. In general, low impact activities were allowed, potentially low impact were allowed with cross-country skiing needing experience, intermediate impact being allowed or needing experience except snowboarding which was not allowed, and high impact activities were not allowed (including jogging, racquetball, contact sports, etc). There were slight variations in when patients should return to sports but the difference was not found to be significant. The authors state it appears that waiting three to six months after surgerey to return to sports is recommended. Thirty-three percent of the AAHKS participants compared to twenty-four percent from the Hip Society had allowed return to sporting activities within the first three months. The authors state this data should be used as guidelines and refined by each individual surgeon. There is no mention of opinions with different implant types and also there was no data available on general age of patients or experience level for the different surgeons. There are obvious limitations to such a method of determining safe activities post-THA, but this study does allow for a guideline based on professional opinion. When proposing a study to objectively assess physical activity after THA, one should consider these recommendations and limitations set by surgeons to see if patients are in fact adhering to the recommendations and if this may affect intensity levels attained.

In conclusion, surgeons are generally recommending low to intermediate impact activities after THA, with some focus placed on previous experience. This carries over into patients' reports after surgery showing the most common activities to be low impact (walking, water aerobics). However, this data also suggests previous activity level, gender and time line after surgery should be considered when planning research to objectively assess PA in this population.

Objective Assessment of Physical Activity and THA

More recently, studies have shifted their focus to objective measures of physical activity in the THA population. Physical activity is measured and commented on, but often related back to wear rate of the prosthesis as the main concern. An example is the study by Sechriest and colleagues (2007), out of the University of Minnesota, who investigated activity levels in young patients with a primary total hip arthroplasty. Previous studies cited by the authors had indicated that younger patients are more active which leads to earlier prosthetic failure. These researchers purported to quantify activity post-operatively while measuring linear polyethylene wear rates. They hypothesized that younger patients would have increased walking activity after THA when compared with the older population, and that polyethylene wear rates would be increased relative to the rate reported for the older population (approximately 0.1 mm/year). Thirty-four patients were examined with a total of forty-one primary THAs. All patients were 50 years or younger at the time of the initial procedure. Data collected included demographics, pre-operative Harris Hip Score, presence of other artificial joints and history of contralateral hip surgery. The 34 patients were contacted by phone or at time of their follow up. Information was updated where appropriate and a Harris Hip Score was completed. Activity level was measured via a digital pedometer (Sportline) as well as the UCLA activity score. The pedometer was provided along with a pedometer-based activity log. Patients measured and recorded their average step length and their daily mileage for a one week period. From this data the gait cycles per year were calculated. The polyethylene wear was estimated using radiographs at one year post-op and at the time of the study. The data showed that the average number of gait cycles for this younger population was 1.2 million/year which was consistent with and comparable to that reported by older patients after THA (approximately 1 million gait cycles per year). The authors suggest that younger patients have developed an inactive lifestyle preoperatively and lifestyle remains unchanged after surgery regardless of better hip function leading to little difference in gait cycles compared to the older population. Also, the authors notes that the younger patients are told to modify activity to prevent premature failure. Patients may be self-limiting their return to more vigorous physical activity due to fear of failure of the joint replacement. Lastly, they suggest the pedometers could underestimate activity. The data also showed that each diagnostic group other than Rheumatoid Arthritis demonstrated a trend toward weight gain over time. UCLA scores were significantly lower in patients with more than one artificial joint and/or with contralateral hip surgery. Also, UCLA scores of men were significantly higher than women. These scores did correlate with perveived pain and function on the HHS but did not correlate with gait cycles per year as measured with the pedometer. Lastly, walking activity measured with the pedometer did not correlate with polyethylene wear rates. This study again questions if self-report measures accurately demonstrate the activity levels of this population. This study stresses the importance of objective measurement of physical activity, as the subjective report (UCLA Activity Score) did not correlate well with the objective (pedometer) data collected.

A similar study to Sechriest's was conducted by Bennett and associates (2008) in Ireland looking at polyethylene wear of patients ten years after THA. One hundred participants were included with activity levels measured by a digital pedometer (Fit Pro) and wear rates determined using radiographs at time of surgery and at follow up. The significant differences from the previous study include the length of time the pedometer was worn (fourteen days compared to seven in Sechriest's), all ages were included (mean age 70.3 years compared to 50.3 years at time of follow up for Sechriest), and the time of follow up (ten years compared to 6.3 years for Sechriest). Due to the variation in age seen in this study, the participants were stratified based on this variable. The groups were divided into: 55-64 years, 65-69 years, 70-74 years, 75-79 years and ≥80 years. A wide range of activity levels were seen, varying from 1005 steps/day to 13,366 steps/day. The 55-64 year group demonstrated significantly increased activity level (4873 steps/day) when compared to the age 70-74 group (3440 steps/day)($p<0.05$). There was no significant difference in activity level between the two youngest age groups. There was also no significant difference between the 70-74 and 75-79 year age groups. The >80 years group had significantly less activity (2213 steps/day) when compared to the age 55-64 (4873 steps/day) and 65-69 (4892 steps/day) age groups ($p<0.05$). Significant decreases in activity level is evident from the 55-69 age group to the 70-79 age group and again to the ≥80 year group. Average wear rate calculated was 0.14 mm/year. The two younger groups displayed similar activity levels; 4873 and 4892 steps/day (.889 and .892 million gait cycles/year) as did the two middle groups with 3440 and 3428 steps/day (.627 and .626 million gait cycles/year). The authors suggest due to the low variation present, 4800 steps/day for ages 55-70 and 3400 steps/day for ages 70-80 could act as reference activity levels for these groups. There was a poor Pearson correlation coefficient between activity levels and age (r^2=0.089, NS). This may be due to non-medical factors such as individual choice, occupation and motivation. No distinct relationship was found between activity level and wear rates. The authors suggest more than just activity will effect wear rates such as walking pattern, loading and tribological conditions. Although no direct relationships were found between activity and wear rates, it is suggested that this study was the first to examine wear rates and activity levels in the ≥80 year population, and this information may provide insight into implant selection and rehabilitation focus in this group. The use of objective measures provide more concrete data to base predictions for future studies as well as expectations for physical activity in patients after THA.

The use of accelerometers is becoming more common when examining physical activity in a population. There are not many studies which have made use of the accelerometer to quantify physical activity in the osteoarthritis or THA populations. In 2006, Hirata and colleagues in Japan used an accelerometer to allow comparison of ambulatory physical activity, disease severity and employment status in adult women with OA of the hip. They also proposed to identify the physically inactive patients from the activity monitor data and determine associations between joint function, gait function, disease severity and employment status with physical activity. Seventy-one females with OA of the hip, based on radiographs, were recruited from an outpatient hip clinic. Overall function of the hip was determined using the Harris Hip Score. Walking speed was measured using a step watch on a 10 meter straightaway with the use of mobility aid if needed. The severity of the disease on radiographs was determined using the Kellgren-Lawrence Scale. Lastly, ambulatory physical activity was measured using an activity monitor with a uniaxial accelerometer sensor (Lifecorder). This device is able to estimate energy expenditure as well as steps taken and was supplemented by an activity log kept by the participant detailing the time the monitor was worn. The clients were instructed to wear the activity monitor for seven days. Activity intensity was grouped into three categories: light, moderate and vigorous intensity to estimate MET equivalents. The participants had a mean age of 50 years and a mean BMI of 21.4 kg/m^2 . The median walking speed was 1.16 meters/second. Of the 65 participants, 25 were unemployed, and of the 40 who were employed, 18 had a sitting occupation and 22 had a standing/walking occupation. There was a large variation seen in time spent in moderate intensity activities, from 1.1 to 42.1 minutes/day. It was shown that employed women had greater energy expenditure and time spent in moderate intensity activities than the unemployed. Standing/walking occupations versus sitting had increased step counts (2018 more steps/day, $p<0.05$), energy expenditure (0.9 kcal/kg/day more , $p<0.05$), total activity time (22.7 minutes/day more, $p<0.05$) using ANOVA. Inactive patients were significantly older, had lower medians for BMI, hip scores and walking speeds and a higher prevalence of stage 4 arthritis than the more active cohort. The results showed that most participants (>85%) did not meet current activity recommendations of at least 30 minutes of moderate-intensity activity on most, preferably all, days of the week. With respect to employment, there was an interrelationship present with disease severity, and both were also independently associated with physical inactivity. The authors suggest that those participants who were employed were more active and that the physical activity may slow the decline in function associated with end-stage OA. The highest prevalence of inactivity based on occupation was in the women who reported being homemakers. The authors address the limitations of their study including a small sample size and that activity monitors are known to not accurately quantify activities such as cycling or those involving primarily the upper body. The authors also warn against generalization as the participants had mild to moderate joint loss of function and loss of gait function and were all Japanese. This study suggests employment should be considered in the pre- and post-op populations as it was related to inactivity and to time spent in physical activity.

A comparable study to the one proposed here was completed in The Netherlands by de Groot and colleagues (2008). The authors examined the change in actual physical activity from pre-op until 6 months post-op for total knee and total hip arthroplasties. The authors hypothesized that patients' actual physical activity, body function, capacity and self-reported physical function would be markedly different after surgery. Physical activity was measured using an activity monitor; body function was measured using the subscales for pain and function from the WOMAC; capacity was measured using the 6 minute walk test, rising from a chair test and stair walk test. Also, the self-reported physical activity from the WOMAC's function subscale and the SF-36 function subscale were used in conjunction with the Physical Activity Scale for Individuals with Physical Disabilities (PASIPD). The study followed 84 patients awaiting THA or TKA whose surgeries were scheduled between April 2004 and May 2006. All data was collected before surgery and at 3 and 6 months after surgery. The mean age of participants was

61.8 years. Pre-operative radiographs were graded using the Kellgren-Lawrence grading system. An activity monitor was worn for 48 hours (2 consecutive weekdays). To avoid bias, the principles behind the use of the activity monitor were not discussd with participants until after the measurements were taken. Data was calculated per day and as an average of the two days. The level of actual physical activity expressed as % activity/24 hour period. Lastly, the function of the hip/knee was assessed by the Harris Hip Score or the Knee Society Score. All patients underwent routine post-op rehabilitation, with therapy being limited to the first six weeks post-op. Normal distributions for the variables was estimated with the Kolmogorov-Smirnov test. Means and standard deviations or medians and range were determined. An independent t-test was used to compare pre- and post-op measurements or Wilcoxon test if the variables were not distributed normally. The authors found that in the total group the mean percent of movement-related activity was 0.7% higher 6 months after compared with before surgery. Patients with THA or TKA had more sit-to-stand movements by 6 months after surgery. There was an expected decrease in pain ($p<0.001$) and stiffness ($p<0.001$), and there was an improvement in six minute walk test ($p<0.001$) at both three and six months post. Less time was needed for stairs and rising from a chair and patients reported their physical function and physical activity as improved. The effect of pain and stiffness was greater in the THA group. THA patients also saw greater change at 3 and 6 months post on rising from a chair and self-reported functioning from the WOMAC (both $p=0.03$). The authors do acknowledge their study used a small sample size and suggest the study may have been underpowered for the two subgroups in relation to activity monitoring. They also suggest the follow up may have been too short, even though previous studies had suggested change would be seen within this time frame. Other factors that may have confounded the data was a higher BMI in the TKA group, number of physical therapy sessions, if the patient resides alone and if pain medication was used. Overall, the influence of surgery on actual physical activity was less than expected (the mean percentage of movement-related activity was 0.7% higher 6 months after surgery compared with pre-operatively). Also, there is a discrepancy between self-reported physical activity and objective measurements of physical activity. The use of the accelerometer allows for comparison to future studies data and also supports the conclusion set forth by authors in this area such as Sechriest et al (2007) who suggested that patients have developed an inactive lifestyle preoperatively and lifestyle remains unchanged after surgery regardless of better hip function. This would help to explain the minor increase in activity after THA regardless of pain reduction and self-reported improvement in function and activity. It would also be beneficial to have a look at a different population bases (Canada versus the Netherlands) as it is known activity, BMI and even surgery and rehabilitation can vary in different countries and across cultures.

In conclusion, when physical activity is quantified objectively, there is no correlation between this data and subjective measures. Using a pedometer, THA populations ranging from 5-10 years post-op averaged 4873-6575 steps/day. A relationship between employment and PA was reported for female participants with osteoarthritis of the hip, and only 15% of this population met the suggested PA guidelines. Lastly, there was a slight increase in physical activity pre- to post-op (0.7%) seen in the TJA population using accelerometry. Therefore, it is important to objectively measure PA to provide a true representation of activity levels in a population and employment should be considered when selecting the study population.

Summary of Literature Review

The literature has clearly shown an improvement in perceived function through the use of self-report measures (Biring et al (2007), Bauman et al (2007)). Studies that have examined physical activity by using pedometers and accelerometers have demonstrated that the actual physical level of these patients may not match the perceived. Sechreist et al (2007) found this discrepancy when comparing gait cycles to the UCLA Acitivty Score following THA. This was also demonstrated in the THA population with the use of accelerometers by de Groot et al (2008) when subjective reported function was compared with the accelerometer findings. Generally an over estimation of physical acitivity is seen in subjective measures. This was also demonstrated in more general American (Troiano, 2008) and Canadian (Colley, 2011) populations when actual PA using accelerometers was compared with self-reported activity. In the THA population, patients may perceive better function due to decreased or absent pain with activity, but may not actually increase activity post-op. In research, it is difficult to completely eliminate all underlying factors that may affect the variable studied, in this case physical activity. The preceeding literature review has shown that there are numerous factors outside of the hip replacement surgery that will influence physical activity after hip replacement surgery. Therefore, it is wise to intiate studies in this area by limiting these extraneous variables by selecting a more controlled study population. In this population, there are a few trends that should be considered. The first of these is the relationship between a higher BMI and a decreased activity level after hip replacement (McClung et al, 2000, Busato et al, 2008). A benefit of considering a population with a lower BMI would be to eliminate the known loss of accuracy for activity monitors in the obese population. Since this study's focus is physical activty, it is essential to obtain accurate data from these devices. Another common trend seen with the use of self-report measures in the THA population is males reporting higher levels of PA after surgery and more consistently meeting activity guidelines in comparison with their female counterparts (Bauman et al, 2007, Wagenmakers et al, 2008, Chatterji et al, 2004, Sechriest et al, 2007). Lastly, younger patients are more active after hip replacement surgery (Stevens et al, 2007, Wagenmakers et al, 2008 and Bennett et al, 2008). Previous literature has also addressed the importance of factors such as education and living situation as playing a role in activity after surgery. With this information in mind, it would be expected that the most significant increase in activity after surgery would occur in a younger male population. Therefore, this study will examine the physical activity of younger males with a moderate BMI to control for the extraneous variables as well as setting an expectation to find optimal activity levels after surgery for the THA population. There has been a shift toward quantifying physical acitivity in the Canadian population as a whole as well. With the increasing rate of obesity, there has been a push toward stressing Physical Activity Guidelines for the Canadian population. CSEP (Canadian Society for Exercise Physiology) in agreement with the American College of Sports Medicine guidelines (Garber, 2011) updated the Canadian Physical Activity Guidelines in January 2011. For adults age 18-64, there should be an accumulation of at least 150 minutes of moderate-to vigorous-intensity aerobic physical activity per week in bouts of ten minutes or more (CSEP, 2011). In March 2011, Colley, et al. released their accelerometer data for the Canadian adult population. In the age 40-59 male subset of the population, the authors found that on average there was 26 minutes daily spent in moderate-to vigorous activity. Only 5.5% of this group attained the suggested 30 minutes of moderate-to-vigorous activity on at least five days and 15.1% attained more than 150 minutes of moderate to vigorous activity in at least ten minute bouts per week as suggested previously by the CSEP guidelines. This subset averaged 9996 steps/day with 46.9% averaging more than 10000 steps per day. (Colley, et al., 2011). With comparison to this existing accelerometer data on the Canadian population, the data collected can be directly compared to age-matched accelerometer data as well as to the existing physical activity recommendations as outline by CSEP. The results may set the standard for achievable activity levels after surgery which could be used in future studies when examining the group as a whole or more specific subsets after THA. It will also allow for a better understanding of accurate physical activity patterns after THA and emphasize this area of research.

Purpose

The purpose is to characterize physical activity levels of participants 1-3 years after THA and relate physical activity to pain, disability, sleep, and body composition.

Objectives

Objective 1. To examine the physical activity patterns in patients after THA and relate this physical activity to age-matched normative data and age-matched activity guidelines.

Objective 2. To examine the relationships between PA and pain, body composition, sleep and self-reported disability.

Methods

Design

This is an observational, cross-sectional study of patients 1-3 years after THA using accelerometer based physical activity data collection over a seven-day period concurrent with self-reports of disability, pain and sleep.

Subjects

Participants were recruited from the Concordia Joint Replacement Group's database. All participants included were 1-3 years post a unilateral primary total hip replacement or hip resurfacing surgery. Inclusion criteria for this study are as follows; 1) primary unilateral THA or resurfacing, 2) age ≤60 years at time of surgery, 3) male, 4) no substantial co-morbidities that would limit activity, 5) english as the primary language (spoken/read), and 6) no cognitive limitations.

Of the 140 THA patient names provided by the CJRG database who met the initial criteria of being a male ≤ 60 years at the time of a unilateral THA or hip resurfacing surgery, less than one third (46) were suitable once screened for all inclusion criteria and proximity to assessment site. A significant number of potential participants declined or were excluded due to time constraints, issues with other joints limiting function and/or new medical conditions affecting physical activity. As expected with this means of recruitment, there were also issues with contacting clients by telephone as contact information provided was incorrect or there was no response. Of the participants where contact was initiated, information was provided regarding the study and participation required. 17 of the 46 potential participants were recruited successfully who met all inclusion criteria. This study was approved by the HREB at the University of Manitoba under Ethics Reference Number H2009:085.

Overview of Measurements

Physical activity was measured using accelerometry (GT3X, Actigraph, Pensacola, FL) for 7 days. An activity log was completed detailing the types of physical activities participated in concurrent with the accelerometry recording period. Body composition was assessed with BMI (using measured height and weight) and waist circumference. Participants completed the Hip Dysfunction and Osteoarthritis Outcome Score (HOOS), Oxford Hip score, and the Pittsburgh Sleep Quality Index. Pain was assessed using three visual analog scales (VAS) examining pain intensity, pain effect on function and pain after provocation.

Age, last level of education completed, employment status and marital status were also collected.

Physical Activity

The triaxial accelerometer (GT3X, Actigraph, Pensacola, FL) was worn on the right hip by means of an elastic strap. The participant replaced the device each morning and removed when going to sleep for the night. The participant was requested to wear the device during the waking hours for a minimum of seven consecutive days. The accelerometer was set to record the summed acceleration (activity counts) at 2 second epochs and the sampling rate of the acceleration data during the epoch was 100 Hz. The accelerometer data (see Table 1) was downloaded via manufacturer’s software (Actilife™ software, version 4.0.4). Each epoch of data is time stamped and contains the acceleration for each of the three axes, the step count, and the orientation of the accelerometer. The resultant vector of the three axes can be readily computed using the Pythagorean Theorem (see Figure 1). Energy expenditure (kcals/min) for each epoch was calculated using body mass (kg) and the vector magnitude. This algorithm uses the Work-Energy Theorem for low level activity, and then employs a modified Freedson equation for triaxial accelerometry (Actilife™ software, version 4.0.4).

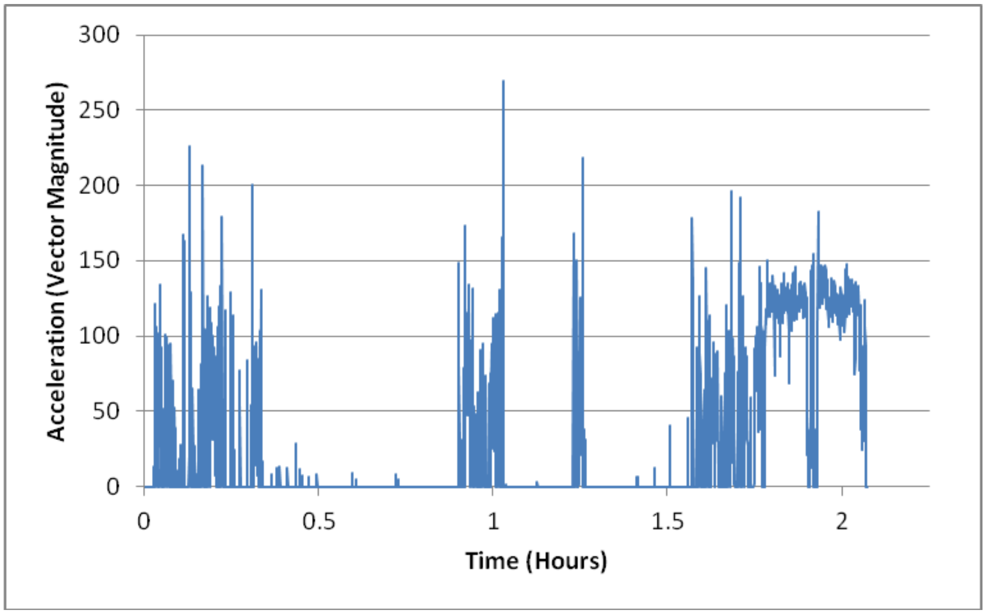

Figure 1 . Accelerometry data for a two hour period from a THA participant.

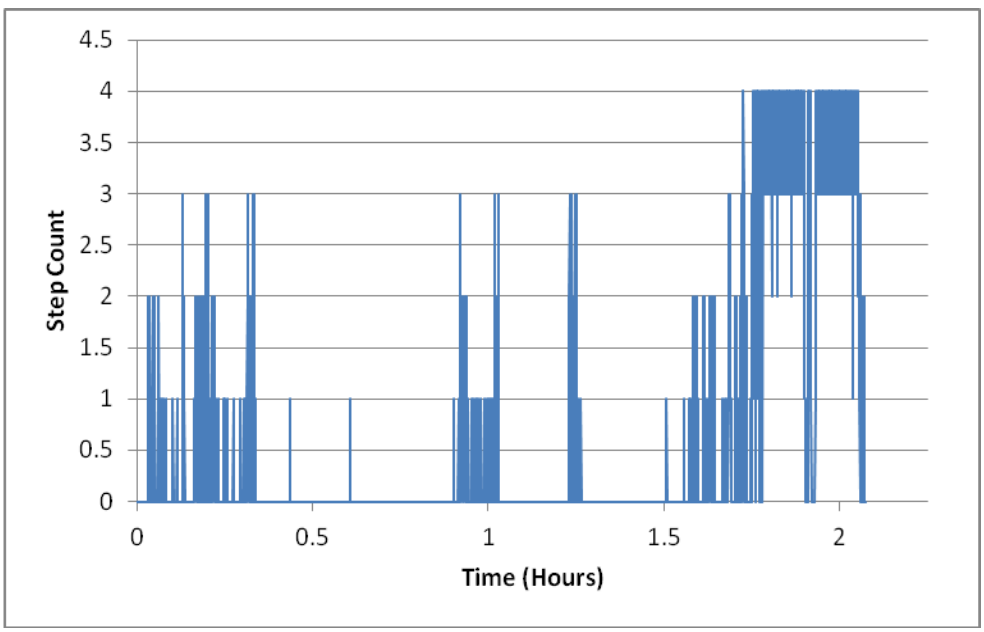

Figure 2. Accelerometry derived step data (steps/epoch) for a two hour period (corresponds to Figure 1).

A custom designed algorithm was used to determine total wear time per day. Wear time is determined as the total time in a 24 hour period where there was no greater than 30 minutes of inactivity. This algorithm effectively keeps periods of inactivity (sedentary time) but removes time when the device is not worn, or periods of excessive inactivity (greater than 30 minutes). This would reduce the ability to detect periods of sedentarism, but this was not an objective of the study. Wear time will necessarily be longer than active time (see below) as it includes periods of inactivity (no accelerometer activity data during an epoch). A minimum of 8 hours wear time was deemed suitable for inclusion for subsequent analysis so as to avoid inclusion of partial days of wear, or periods where the participants forgot to wear the device. For each valid day, the total number of hours active per day (sum of time where the resultant acceleration >0) and the total minutes spent in each activity category moderate (>3 METs) vigorous (>6 METs) and intense (>9 METs) activity were calculated. The total daily caloric expenditure was derived as the sum of all energy expenditure per day.

The accelerometer is also equipped with a step detection system which records steps per epoch interval (See Figure 2). The steps per epoch data was used to derive total daily step count, stepping time (total number of epochs with non-zero step counts), and average daily cadence or step rate (total daily steps / total daily step time). Average daily cadence has not been reported previously.

Body Composition

Body composition was assessed using two methods. The first method was calculating the participant's BMI. The BMI is the body mass index which is calculated using the participant's height and weight. Height was measured using a wall mounted stadiometer and body mass was measured using a medical grade platform scale. All participants had their heights and weights taken without footwear. The BMI was used to classify the participants into subgroups of underweight (<18.5), normal (18.5-24.9), overweight (25-29.9), and obese (30.0 and above) (Hopman et al, 2007).

Waist circumference was taken using the method described by Sowers and colleagues (2008). Waist circumference was measured using a non-stretching tape at the narrowed point of the mid-torso at maximum inhalation.

Disability, Sleep and Pain

HOOS

The HOOS is a self-report measure of disability consisting of 40 questions and taking approximately 10 minutes to complete. The HOOS has five sub scales: pain, other symptoms, function in ADL, function in sport and recreation and hip-related quality of life (QOL). The scores can range from 100 (no symptoms) to 0 (extreme symptoms) for each subscale. This measure asks the patient to take into account the previous week when answering versus the previous 48 hours (Klassbo, 2003).

HOOS Expectations

Participants were also instructed to complete the HOOS detailing where they expected to be by 1-3 years after hip replacement or resurfacing surgery. Being cognizant of patients' expectations allows for a better understanding of whether the surgery and subsequent rehabilitation had met the goals and expectations of the surgical process.

Oxford Hip Score

The Oxford Hip Score was developed in 1996 by Dawson et al to provide a short questionnaire that is reliable, reproducible, valid and sensitive to change in the total hip replacement population. The scoring system used in this study allows ranges from 12 (least symptoms) to 60 (most severe symptoms). The Oxford Hip Score is one of the measures routinely used by the CJRG surgeons as part of their follow ups and included in their database.

Sleep Quality

The Pittsburgh Sleep Quality Index (PSQI) is used to measure both quality of sleep and sleep patterns for the study population. The PSQI is comprised of seven subcomponents looking at subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, use of sleep medication and daytime dysfunction. Each subcomponent is scored separately and the sum of the scores for the different components is the total score. A score of greater than 5 is indicative of sleep disturbance. Pain and lack of sleep can both be independently linked to reduction in quality of life, psychiatric morbidity, medical morbidity and disability (Cole, 2007). Based on this information, reduction of pain through THA surgery should have a positive effect on sleep. Cole et al determined that the PSQI would document aspects of sleep disturbance in the chronic disease population and that it has shown both reliability and validity (Cole, 2007).

Pain Scales

Three visual analog scales were used to quantify pain post-op for the THA study population. Visual analog scales have been shown to be a satisfactory measure of pain (Huskisson, 1974). Nicola Crichton summarizes the use of the VAS as follows, “A VAS is usually a horizontal line, 100 mm in length, anchored by word descriptors at each end. The patient marks on the line the point that they feel represents their perception of their current state. The VAS score is determined by measuring in millimeters from the left hand end of the line to the point that the patient marks” (Gould, 2001). Based on this, the mark indicating the pain level was measured to the nearest mm on the 100 mm visual analog scale, and the value was converted to cm (a score out of 10). The intensity of pain was assessed with the anchors “no pain” and “worst imaginable pain”. The functional VAS was assessed with the anchors “no effect” and “incapacitated” with the question stating “To what extent does pain limit your ability to function in activities of daily living?”. Ian McDowell (2006), in the review of pain measurements, states that the VAS has been used in many aspects of quality of life and has the advantage of being more sensitive and precise than verbal scales and avoid the clustering effects of numerical rating scales due to digit preference. The provocation VAS looked at the change in pain after a brisk 80 foot walk. The time for completion was determined to assess the participants’ “brisk walking” pace.

Statistical Analysis

An alpha level of 0.05 was used and all statistical analysis was conducted using SPSS 16.

Descriptive statistics

To provide descriptive statistics for participant characteristics, subjective measures (HOOS, Oxford Hip Score, PSQI, VAS scales), accelerometer data, activity log data, and comparison to previously published values and scales.

- The mean and standard deviation was calculated and the minimum and maximum values provided for each measure.
- Frequencies or percentages were provided to describe participants in relation to previously reported norms or classifications.

Paired comparisons

Paired comparisons were performed on the HOOS expected to the HOOS current scores. Paired t-tests were utilized to detect differences. Due to small sample size there is increased chance of type 2 error (the failure to detect differences that are real); non-significant differences may be due to the test being underpowered. Although repeated pair t-tests were employed no correction was made for multiple comparisons, these multiple comparisons would slightly increase the risk of showing a difference due to chance.

Correlations

Correlations were performed for the examination of the inter-relationships between disability, pain and physical activity measures. Pearson product moment correlation was employed. A limitation of Pearson correlation is that it normally requires interval or ratio data for both variables. Also, it is only useful for detecting linear relationships between variables. When aggregate scores are derived from a number of categorical scales (like the HOOS or Oxford), the Pearson correlation can be employed. Its utility for a single 5 point categorical question however is highly suspect. Further, the quantification of pain on a 100 mm scale has been shown to be suitable for use in Pearson correlation. Spearman Rank Correlation is the method used for data which is ordinal and is capable of detecting any monotonic relationship – so it can detect more than just linear covariance. Pearson and Spearman coefficients were computed in all cases. Ostensibly, the same results were obtained with both methods for this data set so Pearson was only reported.

- When examining bivariate relationships using correlation it is important to examine the scatterplots of the variables to insure that they exhibit variance over a range. In other words, correlation is not suitable to apply to data which is clustered, or has non-uniform distributions such as a cluster and a single point, or two clusters. Scatterplots were reviewed for each bivariate relationship examined for these violations. No violations were observed.
- When performing correlation, as the sample size decreases the ability to detect significant correlation coefficients with of lower magnitude is reduced. This is illustrated for the sample size of the study, and the set alpha (0.05) and power (0.8) levels in the calculation shown in Table 1 below. This calculation indicates that correlation coefficients below 0.64 would be difficult to detect with a sample size of 17, in other words this study would be powered to detect r values for bivariate relationships above 0.64, a priori. Statistical packages like SPSS report the two-tailed significance with each correlation reported, and can report significant p values with r values below 0.64. So if a relationship is detected with a small sample size, generally it can be thought to be bona fida as the likelihood of this relationship being created by chance is low. However caution must be exercised and the result must be interpreted in context of other results, and the clinical meaning of the strength of correlation (low r values, less than 0.2, in THA research may offer little clinical relevance).

Table 1: Smallest correlation coefficient (r) acceptable to delineate a linear bivariate relationship given the sample size, and with alpha set to 0.05, and power to 0.8.

Smallest acceptable correlation coefficient	Error Rate (%)		Sample size
	Type I	Type II	
0.64	**5**	**20**	**17**

Regression

Regression is a natural extension of bivariate correlation. Regression with multiple independent variables with low sample size has substantially reduced ability to detect weaker predictors of the dependent variable. Regression was performed for exploratory purposes. Based on the small sample size, non-significant findings are considered as the model failing to show a significant relationship, rather the absence of a predictive relationship; however, clinical inferences can be made.

Comparison to Population Data

Comparison of the population physical activity (mean daily steps) to existing age matched Canadian values and values from relevant literature.

- A one-sample t-test was utilized. Due to small sample size and increased chance of type two errors, non-significant findings may be due to the test failing to show a significant difference as underpowered; however clinical difference can be inferred. In the case of PA measures, clinically relevant differences can be established. For instance, for daily step counts a minimum of 2000 steps was determined as clinically relevant based upon the Tudor Locke criteria (Tudor-Locke et al, 2004).

When performing a comparison to a population mean or normative values. The variance of your sample is supplied in the computation; with low sample sizes variances can be small or large due to random sampling. When variance is large the ability to detect real differences from population is limited. So, the mean difference observed between the sample and the population mean must be considered.

Results

The characteristics of the seventeen participants recruited are summarized in Table 2. The average time from surgery (total hip replacement or resurfacing) was 27 months. Of the seventeen participants, 14 were THA and 11 of those were right sided THA. THA and resurfacing surgeries spanned January 2008 to June 2010 and were performed by the four CJRG surgeons. 65% of the participants (n=11) had completed post-secondary education. 88% of the participants (n=15) reported being married or in a common-law relationship

Table 2: Participant characteristics

	Mean	Standard Deviation	Minimum	Maximum
Age (years)	57	4.11	47	61
Height (cm)	177.4	6.33	162.6	187
Body mass (kg)	93.1	18.95	74.9	149.2
BMI	29.5	5.02	22.5	44.6
Waist Circumference (cm)	99.3	14.7	86.4	138
Time after surgery (months)	27.2	8.7	14	44

Using BMI classification, 9 (56.3%) of the participants would be classified as overweight and 6 (35.3%) would be classified as obese. Further classification within the category as per Hopman et al (2007) would categorize 4 of the participants as obese class I, 1 as obese class II and 1 as obese class III. Only 2 (11.8%) of the participants were classified as normal weight. With reference to waist circumference and the accepted healthy published values, 6 of the participants would be considered at increased risk for heart disease and diabetes based on a waist circumference greater than 102 cm (Sowers, et al, 2008). As expected, a strong correlation existed between BMI and waist circumference ($r = 0.91$, $p<0.01$).

Subjective Reports of Disability, Sleep and Pain

Table 3 summarizes the scores for the subjective reports of disability, sleep and pain.

Table 3: Descriptive statistics of subjective reports

	Mean	Standard Deviation	Minimum	Maximum
HOOS (100 = no symptoms)	91.0	12.4	56.4	100
Oxford (12 = least symptoms)	14.6	4.8	12	31
PSQI (≤5 associated with good sleep quality)	4.53	2.8	1	11
VAS I (0 = no pain 10 = worst pain imaginable)	0.44	0.74	0	3
VAS F (0= no effect 10 = incapacitated)	0.21	0.31	0	1
VAS P (0 = no pain 10 = worst pain imaginable)	0.19	0.30	0	1.2

The HOOS total score is composed of the five subscales. Overall, the score is quite high 91.0 (12.4) with the best possible score being 100. More detail is provided on the individual subscales scores in Table 4. It is difficult to comment on the improvement in these scores in the study population as the HOOS was not administered in the pre-op period. The average Oxford Hip score seen here is 14.6 (4.8) with the best possible score being 12. Field et al (2005) reported the average Oxford Hip Score of their study population to be 20 when looking at a cross-sectional comparison of changes in the Oxford Hip Score from pre-op until 4 years post-op. The mean score for the PSQI was just below 5, which is the threshold used to indicate a significant sleep disturbance. The average score for the normal or “good sleepers” reported in the development of the PSQI was 2.67 (1.70) (Buysse, et al, 1989). A tally of the individual scores revealed that five of the seventeen participants exceeded the disordered sleep threshold. The Pittsburgh Sleep Quality Index only includes one question specific to pain limiting sleep. This question asks how often the subject has had difficulty sleeping due to pain. Fifteen of the seventeen participants reported that pain had not affected sleep in the last month. The two participants who reported difficulty sleeping due to pain reported pain affected sleep 1-2 times per week. When looking at the VAS pain values for these two participants, they reported the second and third highest pain scores for intensity and one had the highest pain score reported for function. The subject with the highest reported pain on the VAS function also reported the highest level of disability on the Oxford Hip Score and the HOOS. Only one of the participants where pain affected sleep was part of the subset of the study population defined as having sleep disturbance as per the PSQI.

Three visual analog scales were used to assess pain. The first application quantified pain intensity (VAS intensity). Fifteen of the seventeen participants reported pain intensity less than 1 cm out of 10. The highest VAS for pain intensity reported was 3. Brokelman et al (2003) assessed satisfaction in patients in comparison to surgeons at a mean of 5.9 years post-op and their study population (mean age 73 years at time of surgery) reported an average VAS intensity of 0.79 at rest. The second application of the VAS quantified the extent to which pain limited the ability to function in daily activities (VAS function). The highest VAS reported was 1 with the remaining participants reporting a score of 0.5 or less. The last application of the VAS quantified pain after provocation (VAS provocation). The provoking event chosen for this study was a brisk 80-foot walk. The time in seconds to complete the walk and Borg Rating of Perceived Exertion following the walk were recorded along with the VAS pain value. The highest VAS indicated in this application was 1.2 with the remaining participants indicating a pain level of 0.5 or less. Brokelman et al (2003) also published a value of VAS intensity with movement. Here the average score was 1.4. The average time to complete the 80-foot walk was 16.8 (3.2) seconds. The average speed was 1.49 m/sec (0.2) or 3.3 mph. The Borg RPE scores varied from 6-9 with average being 6.76 (1.1) reflecting a perceived intensity of “No exertion” to “Very light exertion”. The brisk walk test failed to statistically increase the VAS pain levels. In fact, the mean VAS was reduced from 0.44 to 0.19. However, when considering the walking speed of the study population, the “brisk walk” at 1.49 m/sec is faster than the preferred median velocity of patients 1 year after THA at 1.18 m/sec but slower than the "fast" median velocity of 1.74 m/sec (Hodt-Billington et al, 2011). Therefore, this speed of walking may not provoke an increase in pain.

Comparison of Disability to Expectations

Table 4 provides a comparison of the HOOS overall score (and sub-domain scores) to the expectation scores. The paired t-test failed to show a significant difference between the current HOOS and the expected HOOS ($p=0.23$) total scores. For all five subscales of the HOOS, the mean expectation score for the population was less than the present scores. When comparing the HOOS to HOOS expectation subscale scores, the one significant difference detected was between the Sports and Recreation components ($p<0.05$) reflecting that the participants had lower expectations for what they could be doing 1-3 years after surgery than what they are actually undertaking in the sports and recreation domain.

Table 4: HOOS present versus expectations

			Mean	Standard Deviation	Minimum	Maximum	Published Post-op Scores +
Hip Osteoarthritis Outcome Scale	Pain	Current	94.0	9.22	72.2	100	82.3
		Expected	90.6	13.27	55.5	100	
	Symptoms	Current	88.5	21.34	15	100	73.9
		Expected	86.8	16.00	50	100	
	ADL	Current	92.8	11.31	64.7	100	75.5
		Expected	90.2	14.05	50	100	
	Sports and Recreation	Current	89.7*	12.28	56.3	100	56.3
		Expected	82.7*	16.90	43.8	100	
	Quality of Life	Current	83.1	16.93	56.3	100	66.2
		Expected	81.6	19.45	31.3	100	
	Total Score	Current	91.0	12.36	56.4	100	-
		Expected	88.2	13.91	48.7	100	

* significantly different $p<0.05$

+ previously published data from Nilsdotter et al (2003) – patients 6 months post-op

Comparison between Disability Measures

The total HOOS score and the score for each component were compared to the Oxford Hip Score (Table 5). As expected, there is a strong correlation between the two subjective measures of disability. There was a weak, non-significant correlation (r=0.162) between the HOOS total expected score and the Oxford Hip Score.

Table 5: Correlation of HOOS current and subscales to Oxford Hip Score (correlation coefficient (p value))

		Oxford
	HOOS	0.94 (p<0.001)
HOOS Sub-Components	Pain	0.87 (p<0.001)
	Symptoms	0.96 (p<0.001)
	ADL	0.89 (p<0.001)
	Sports and Recreation	0.62 (p<0.004)
	Quality of Life	0.65 (p<0.003)

Disability and Pain Scales

The HOOS and Oxford Hip Score were compared to the VAS pain measures (Table 6).

Table 6: Correlation of pain to disability measures (correlation coefficient).

		Oxford	HOOS
VAS	Intensity	0.560*	0.700*
	Function	0.883**	0.898**
	Provocation	0.096	0.006

* significant p<0.05

** significant p<0.01

A strong correlation was found between both the HOOS and VAS function (r=0.898, p<0.01) and between the Oxford and VAS function (r=0.883, p<0.01). It is interesting to note that a simple visual analog scale that takes less than a minute to have patients complete is strongly correlated to more involved, detailed disability assessments.

Physical Activity

Each participant was instructed to wear the accelerometer for seven consecutive days at the time of the assessment. The average number of days that the accelerometer was worn was 6.5 (1.4) of 7. The average wear time per day was 13.0 (2.0) hours. For both Troiano et al (2008) for the American population and Colley et al (2011) for the Canadian population, participants with greater than 4 days of data were accepted for data analysis. These authors considered 10 hours or greater wear time to be adequate to represent a normal day, and both studies had a very similar average wear time of around 14 hours.

The accelerometer provides energy related measures as well as step related measures simultaneously but with different internal algorithms. Table 7 summarizes the energy or caloric expenditure related measures, while Table 8 reports on the step related data.

Table 7: Energy expenditure related physical activity data

	Mean	SD	Minimum	Maximum
Energy Expenditure from PA (kcal)	623.9	270.0	47.7	1546.5
Active Time (hours)	4.85	1.3	2.6	7.1
Daily duration (minutes) > 3 METs	55.8	22.5	42.8	162.7
Daily duration (minutes) > 6 METs	8.7	10.5	2.5	71.50
Daily duration (minutes) > 9 METs	2.7	6.18	0.63	43.97

When assessing the daily duration in minutes above each MET cutoff point the moderate category included all activity greater than 3 METs in intensity. It is not limited to values >3 METs but <6 METs. Therefore, the value provided in the >3 MET or moderate category should actually be referred to as time spent in any activity of moderate or greater intensity and the category with >6 METs could be defined as vigorous-intense activity.

Table 8: Step related physical activity data

	Mean	SD	Minimum	Maximum
Daily Steps (steps/day)	9143	3982.0	4464	16279
Stepping Time (minutes/day)	142.7	44.8	72.9	215.5
Step Rate (steps/minute)	61.1	10.7	44.4	79.4

Pearson correlations were performed to examine the relationships between the two types of objective physical activity data obtained, step data and energy expenditure. Table 9 summarizes these results.

Table 9: Correlations between step and energy expenditure physical activity data

		Energy Expenditure				
		Active Time (hours)	Energy Expenditure (kcal)	>3 METs (minutes)	>6 METs (minutes)	>9 METs (minutes)
Pedometry	Steps/day	.738**	.783**	.815**	.519*	.480
	Step Time (minutes/day)	.883**	.803**	.793**	.479	.377
	Step Rate (steps/minute)	.326	.523*	.685**	.406	.429

* significant at the p<0.01 level

** significant at the p<0.05 level

As expected, there were significant correlations seen in general between the two types of activity data. The >6 METs and >9 METs categories that quantified time spent in vigorous to intense and intense activity failed to show a correlation to step data, however there was very limited time spent in these intensity categories (see Table 7), and the activities performed to reach high intensity PA as recorded by the accelerometer may not involve stepping activity.

Activity Logs

Activity logs completed by participants help to provide an inventory of activities of the participants as well as partially confirming data collected by the accelerometer. The most common activities reported for this study population were walking, yard work/house work and golf.

A factor that may affect activity levels, especially in a variable climate as seen in Manitoba, is weather. Across participants data was collected from three of the four seasons. The average steps for the summer subset of the population (n=5) was 8383.5 (2824.25). For the participants where data was collected in the fall (n=9), the average steps per day was 9573.6 (4513.95). Lastly, the average steps per day for the participants where data collection occurred in the winter (n=3) was 9117.3 (5207.84). Overall, these values do not show much clinical variation in step values between the three seasons. It is interesting to note that the highest value for steps/day is seen in the fall, and that the winter values exceed that of the summer participants. It is difficult to draw any conclusions about seasonal activity due to the limited sample size and uneven distribution of participants across the different seasons.

As expected, golf was prevalent in the summer months with 4 of the 5 participants taking part in this activity. In the fall season, yard work/shoveling and house work were reported with more frequency with 5 out of the 9 participants in this subset reporting time spent in these activities. There was no regular pattern of activity noted between the three participants where data was collected in the winter months (n=3). Walking was seen regularly across all seasons, although participants did not distinguish outdoor versus indoor walking or if the activity was for leisure or exercise. Another activity recorded by 7 of the 17 participants was work/occupation. This was not included in activities/sports as the type of work and physical demands were not defined.

Comparison of Physical Activity to Population Norms and Guidelines

Pedometry

The daily step count has been used to indicate activity levels in the population with the most recognized guideline being >10,000 steps per day (Tudor-Locke et al, 2004). This value has been reported to indicate the cut-off for defining a person as "active". In this study, the number of days each subject accumulated greater than 10,000 steps was tabulated. On average, this population accumulated 2.8 (2.9) days with greater than 10,000 steps. The minimum number of days above 10,000 steps was zero for four of the participants, and the maximum was 7 days for one subject. Refer to Table 10 for the frequency of participants per Lifestyle Indices based on steps per day based on the work of Tudor-Locke et al (2004).

Table 10: Categorization of daily step counts based upon Lifestyle Index

	Number of Subjects	Percentage
Lifestyle Indices		
<5000 steps/day – sedentary	3	17.6%
5000-7499 steps/day – low active	3	17.6%
7499-9999 steps/day – somewhat active	4	23.5%
≥10000 steps/day – highly active	7	41.2%

In January 2011, Statistics Canada issued a health report looking at the physical activity of Canadian adults using an accelerometer. In this report, step and activity data was reported for the different age groups in both males and females. For use with this project, the data from males 40-59 years of age was used to compare the hip replacement population to the general Canadian population for age-matched males. Statistics Canada reported the average steps/day for 40-59 year old males as 9996 (Colley et al, 2011). This study population had an average of 9143 steps/day. A one sample t-test failed to show a significant difference between these values. With a mean difference of only 9996-9143, this difference was not considered as clinically relevant reduction. Tudor-Locke et al (2010) reported that American adults averaged 6564 (107) steps/day based on the National Health and Nutrition Examination Survey, however this value included all ages and both sexes and therefore does not allow for a direct comparison to the relatively younger male population reported here, and the Canadian context..

Table11: Comparison of participants' mean daily step count to previously published values

Current Study 9143 (3982)			
Study	**Mean** **Mean Difference**	**95% CI**	**p value**
THA, mechanical pedometer, n=4	5552 3591	(1543,5638)	p=0.0019
THA, Accelerometer Kinkel et al (2009)	12288 -3085	(-1037,-5132)	p=0.0056
THA, Systematic Review (Naal and Impellizzeri 2010)	11250 -2107	(-59,-4154)	p=0.044

Comparisons were made between the average daily step count for the study population and previously reported data for the TJA population. The mean daily step count of 5552(3951) was calculated from the pedometer based studies (Schmalzreid (1998), McClung (2000), Sechriest (2007), Bennett (2008)) and was found to be significantly lower (p=0.0019) than the average for the study population. Kinkel et al (2009) reported an average of 12288 steps/day for the THA population 1 year post-op which was significantly higher (p=0.0056) than the average for the study population. Similarly, the average daily step count reported by Naal and Impellizzeri (2010) based on accelerometer based studies in the TJA population was significantly higher (p=0.044) than the current study population as well.

Vissers et al (2011) in a review of literature on recovery of physical functioning after THA reported that cadence or step rate had only been reported in three of the studies reviewed. The cadence during a clinical gait test at 6-8 months post-op was 80.4 steps/minute. This is slightly higher than the steps/minute value reported here of 61.1 (10.7) steps/minute which is averaged throughout the entire day.

Energy Expenditure

The other area examined in the Canadian population was minutes per day spent in the activities of different intensity. Colley et al (2011) used this data to extrapolate if the new Canadian Physical Activity Guidelines were being met. The age-matched Canadian males spent an average of 24 minutes per day in moderate intensity activity. This was similar to the age-matched (50-59) males in the U.S. who were active 26.4 minutes/day (Troiano, 2008). The study population spent an average of 55.8 minutes per day in moderate intensity activities. When looking at the Physical Activity Guidelines, the Canadian population subset of males 40-69 only met the guidelines 5.5% of the time when defining that thirty minutes of moderate-intensity activity should be accumulated in at least 10-minute bouts on 5-7 days of the week. For the U.S. adult population only 5% met the guidelines considering 10 minute bouts as well (Troiano, 2008). However, that number increased to 15.1% of the age-matched Canadian males when defining the guideline as the accumulation of more than 150 minutes per week of moderate-to vigorous physical activity (Colley et al, 2011). Based on the participants' average minutes of moderate intensity or greater activity per day (55.8 minutes), it can be extrapolated that all of the participants in this subset of the THA population would meet the physical activity guideline of greater than 150 minutes of moderate to vigorous intensity activity per week not considering bouts.

Relationship between Physical Activity and Self-reports of Disability, Pain and Sleep

Correlation and regression were used to examine the relationship between physical activity measures (step and energy related) and the subjective measures used to assess disability, sleep disturbance, body composition and pain. The following PA measures were used in the correlation analysis; steps/day, step rate, energy expenditure, time in moderate, vigorous, intense activity.

Pain and PA: The analysis failed to show any significant relationships with the exception of the significant correlation found between step rate and VAS function (r=-.483, p=0.05).

Body Composition and PA: The analysis failed to show any significant relationships between body composition and physical activity

Sleep and PA: The analysis failed to show any significant relationships between sleep and physical activity.

Disability and PA: The correlation coefficients are summarized in Table 12.

Table 12: Correlation between disability and objective physical activity data

	Steps/day	Step Time (minutes)	Step Rate (steps/minute)	Energy Expenditure	>3 METs (minutes)	>6 METs (minutes)	>9 METs (minutes)
HOOS total score	.255 p=.324	.144 p=.583	.424 p=.090	.113 p=.665	.284 p=.270	.207 p=.425	.198 p=.447
Oxford Hip Score	.280 p=.276	.135 p=.606	**.486** **p<0.05**	.134 p=.609	.306 p=.233	.184 p=.480	.158 p=.544

The analysis failed to show any significant relationships between these variables with the exception of the significant correlation found was between the Oxford Hip Score and stepping rate ($r=.486$, $p<0.05$). Overall, there was a lack of relationship observed between the self-reported disability in the THA participants and their objective physical activity.

Regression

Prediction of PA

Regression analysis was used to assess the ability of disease specific measures and body composition to predict physical activity. Full model regression was performed with daily step count as the dependent and the following independents (HOOS, Oxford, PSQI, months since surgery, BMI, and WC). The regression failed to return a significant model using the supplied independent variables.

Prediction of Disability

The HOOS total score was set as the dependent variable and the independent variables were months since surgery, age, BMI, PSQI, VAS intensity, VAS function, daily steps and energy expenditure. The full model returned a significant prediction ($r^2= 0.903$, $p<0.05$).

The regression was repeated but substituting the Oxford Hip Score for the HOOS as the dependent variable and with the same independent variables. A significant r^2 of 0.950 was revealed.

Finally, stepwise regression was then used to delineate the essential predictors from the independents (Table 13). For HOOS only one significant model was returned, whereas for the Oxford two models were provided.

Table 13: Stepwise regression results for HOOS total and Oxford Hip Score

	r^2	p value
Dependent: HOOS total; Model: VAS function	0.807	p<0.001
Dependent: Oxford Hip; Model: VAS function	0.780	p<0.001
Dependent: Oxford Hip; Model: VAS function + VAS intensity	0.857	p<0.001
Independents: months since surgery, age, BMI, PSQI , VAS intensity, VAS function, daily steps and daily energy expenditure		

Based on the results of the stepwise linear regression, VAS function can account for 80.7% of the variance in the HOOS. Similarly, VAS function could account for a substantial variance (78%) of the Oxford Hip Score.

Summary of Results

The study population consisted of 17 male participants with an average age of 57 years following THA (mean 27 months post-op). A majority of the participants were obese (56.3%) and 35% had a waist circumference above the healthy range.

Subjective reports of disability, sleep and pain were completed during an in clinic assessment. The average disability scores were 91.0 (12.4) for the HOOS and 14.6 (4.8) for the Oxford Hip Score. There was a strong correlation between the two subjective disability measures. The mean PSQI score (4.53(2.8)) was just below the threshold used to indicate sleep disturbance (>5), and 29% of the subjects exceeded the sleep disorder threshold. Pain was reported using three VAS scales looking at intensity, function and provocation. Overall, the pain scores were quite low. Of interest, there was a strong correlation between the disease specific disability scores and VAS function.

The HOOS was completed both to report disability at the time of assessment as well as to capture expectations of the participants regarding disability at 1-3 years after THA. In general, the HOOS expected score was lower than the present score for all subscales and for the total score. The only significant difference detected was between the scores in the Sports and Recreation component.

Physical activity was represented by two different types of data from the accelerometer, energy expenditure related data and step related data. The average energy expenditure was 623.9 (270.0) kcal/day and the average time spent in moderate intensity or greater activity was 55.8 (22.5) minutes/day. The average daily step count was 9143 (3982.0). Activity logs were used to provide an inventory of activities participated in and to assist in confirming accelerometer data. The most common activities reported were walking, yard work and golf.

The daily step count was used to divide the participants into lifestyle indices proposed by Tudor-Locke et al (2004). 41.2% of the participants were considered highly active obtaining ≥10,000 steps/day. The physical activity data was also compared to that of the age-matched normal population. The one sample t-test failed to detect a significant difference in steps/day values between the study population and the age-matched male Canadian population. However, the study population had a significantly high daily step value compared to previously reported pedometer based values. When compared to relevant literature using accelerometers to quantify daily steps, the study population's daily step value was significantly lower. The study population had a greater time spent in moderate and greater intensity activity then the age-matched normative population (Canadian and American).

The statistical analysis failed to return any significant relationships between PA and body composition or sleep. For pain, VAS function was significantly correlated with stepping rate, no other significant relationships were detected. For the disability scales, the only significant relationship found was between the Oxford Hip Score and stepping rate. When regression analysis was used, the analysis failed to return a significant model to predict PA based on the independents (HOOS, Oxford Hip Score, pain, PSQI, months since surgery, body composition). However, VAS function was able to account for 80.7% of the variance in the HOOS and 78% of the variance in the Oxford Hip Score.

Discussion

One of the current topics of interest in joint replacement research is the assessment of physical activity and function in patients both before and after hip replacement surgery. Previously, outcomes of joint arthroplasties focused on subjective reports of function and disability to assess patient satisfaction and disease specific outcomes of the surgery. Due to the importance of physical activity in maintaining health and its impact on the prosthesis, research has started to include measures of physical activity. However, many studies continued to utilize subjective measures to report activity (e.g. UCLA Activity Index, SQUASH). More recently, the limitations of using self-reported measures to quantify physical activity have been demonstrated (Sechriest et al, 2007, de Groot et al., 2008) including two large populations studies (Troiano et al, 2008, Colley et al, 2011). Despite this knowledge, limited objective assessment of PA has been performed in this population (de Groot et al, 2008, Kinkel et al, 2009). Accurate characterization of physical activity in the THA population will help to determine if the well-established pain reduction actually manifests into functional restoration. It would also allow for decisions to be made regarding expectations of THA surgery and outcomes of surgery based on activity such as wear rate of the prosthesis. Lastly, it would assist in determining the focus of future studies assessing if current rehabilitation protocols are aggressive enough. The purpose of this study was to provide objective physical activity data for the younger, healthy male subset of the THA population. The inclusion criteria of this study, based on the findings of previous research, served to select the subset of the THA population with the most potential to be active following surgery.

Inclusion criteria act to assist in defining the best population subset to meet the objectives of research with the introduction of as few confounding variables as possible. As discussed in the literature review, previous work in the area of physical activity in the THA population reported variables such as age, sex, BMI and socioeconomic variables influenced physical activity. To control for these variables, participants were chosen with characteristics that would maximize physical activity outcomes 1-3 years after THA. These strict inclusion criteria introduced two areas of bias into this study. The first is selection bias. The data collected will only be representative of a younger male subset of the population. Also, the participants were recruited from only one site in Winnipeg and may not be representative of the outcomes in the city as a whole, even for this subset of the THA population. The second type of bias is recruitment bias. As the purpose and objective of the study was revealed at the time of contact with potential participants, it may have lead to recruitment of participants accepting of or satisfied with their current level of physical activity. In general, the participants reported remaining fairly active or were grateful for their positive outcome and agreed based on this. Therefore, the physical activity patterns described here cannot or should not be used as a generalization for all THA patients, but as an indication of the upper limit of PA possible after surgery.

The primary objective of this research was to characterize physical activity in the THA population. Accelerometry was utilized to quantify physical activity. The first accelerometer derived measures were step related. Recent literature has provided guidelines that allow classification of participants into different activity indices. Based on the indices proposed by Tudor-Locke and Bassett (2004), 41.2% of the participants would be classified as highly active (≥10000 steps/day). Only 17.6% were classified as sedentary. Another of the stepping variables reported was stepping rate. This quantified the average step/minute taken. Vissers et al (2011), based on a review of literature investigating recovery of functioning after THA, reported the post-op cadence for a THA population 6-8 months after surgery as 80.4 steps/minute. This is greater than the value for the current population (61.1 steps/minute). However, the age and sex of this population was not reported for direct comparison. Also, this study provided a new measure of step rate or cadence by providing the daily average for this measure. Vissers et al (2011) found only three studies that provided data on cadence. All three studies were assessing gait analysis. Therefore, the data provided from these studies would be measured in a clinical setting, not considering changes in gait speed throughout the days depending on if the participant is involved in obligatory or peregrinating behavior. Therefore, this daily average step rate is a more accurate representation of cadence in this population.

The daily step count also allowed for direct comparison to previously published values for age-matched Canadian males. A one sample t-test was unable to detect a significant difference between the daily step values for these two groups. As the difference between these values (853 steps) would not be considered clinically significant, male patients 1-3 years after THA are capable of returning to activity levels at par with their age-matched normative cohort. Clinical difference for daily step counts could be set at a value of 2000 up to 2500 steps. This value can be extrapolated from the work of Tudor-Locke et al (2004) who based the different lifestyle indices on a daily step value difference of 2500 steps, therefore this has been reported as a significant difference when looking at activity levels in the general population. This daily step rate was also compared to previously published data for the TJA population. When compared to the average daily step count from pedometer based studies (Schmalzreid (1998), McClung (2000), Sechriest (2007), Bennett (2008)), the study population had a significantly higher (p=0.0019) daily step rate. The drawback of comparison to these pedometer based studies is related to the type of pedometer used. It is likely that mechanical pedometers were used due to the low step values and timeline of these studies. Mechanical pedometers are known to have decreased sensitivity to BMI and gait speed as well as being less accurate when worn on the right hip. Therefore, it is likely these pedometers underestimate daily step values for this population. The daily step value of the study population (9143) was found to be significantly lower that published accelerometer daily step values from Kinkel et al (2009) (12288, p<0.0056) and Naal and Impellizzeri (2010) (11250, p<0.044). A higher than average value would have been expected based on the age and lack of co-morbidities in this population. A potential explanation for this discrepancy could be lack of rehabilitation in Winnipeg for this population. Without follow up to provide input on advancing exercise during recovery as well as more individual based recommendations based on previous experience and fitness level, this population may not be meeting activity levels possible and seen in their THA cohorts.

Energy expenditure was calculated for the study population. On average, just over 650 kcals were expended with physical activity per day. An accepted value to categorize a person as active based on energy expenditure is >3.0 kcal/kg/day, which is equivalent to a walk ≥ 1 hour per day (CDC, 2011). Using the average value for energy expenditure per day as well as average body mass (623.9 kcal/day/93.1 kg = 6.7 kcal/kg/day), this population would qualify as active for adults.

A common parameter reported is time spent in moderate intensity (>3 METs) activity per day. A number of recent studies have focused on not only quantifying physical activity but also reporting if the study population was meeting physical activity guidelines. The goal for health-inducing PA proposed by CSEP in accordance with the American College of Sports Medicine and the WHO states that a person should take part in 150 minutes of moderate intensity activity/exercise in at least ten minute bouts per week. The limitation of the present study is that moderate intensity activity was not calculated based on ten minute bouts. On average, the participants accumulated 55.8 minutes of moderate intensity activity/day. Based on the average minutes/day in moderate or greater intensity activity, it can be extrapolated to just under 400 minutes/week. Therefore, this subset of the THA population would be meeting the guideline of 150 minutes of moderate or greater intensity activity per week without considering bouts. In comparison to age-matched Canadian (24 minutes/day) and American males (26.4 minutes/day), the study population spent significantly more time in moderate to intense activity. Potential reasons for this discrepancy could include the study population spent a majority of time at or around the cut-off for moderate intensity. With a slight change in threshold, there would be a significant change in time in this category. Therefore, this value may be an over-estimation. However, it is important to consider that this cohort was chosen based on age and lack of co-morbidities, so they may be spending more time in moderate to intense activities than the age-matched normative sample. Also, this study used 2 second epochs to sample acceleration and store data versus longer sampling periods (1 minute epochs) in these larger population studies. As the longer epoch length will cause estimation of acceleration over this time period, brief bouts of activity less than one minute in length would be underestimated as an average over the full minute. For example, if the participant completed 10 jumping jacks in 15 seconds and then rested for the remaining 45 seconds, the average acceleration of the full minute would not truly represent the intensity of the jumping jacks. Whereas, if the acceleration is sampled and averaged over a 2 second epoch, the actual intensity of the activity would be represented, impacting time in different intensities of activities. Therefore, this study was better able to represent time in different activity levels using the shorter epoch time.

Activity logs provide an inventory of activities participated in by a population and allow comparison to accelerometer data. Chatterji et al (2004) looked at the effect of THA on sporting and recreational activity. They reported a change in sporting activities chosen after THA: with lower impact options becoming more prevalent. Similar to their findings, the study population's activity logs showed walking to be the most common activity, with 8 of the seventeen participants reporting regular walking. The other common activities seen in the study population included yard work (n=5), golf (n=4), and bicycling (n=2). Unlike the reported data from Chatterji and colleagues, none of the study population reported any water-based exercise. Chatterji had reported swimming as the second most common activity following a THA. This difference may be due to the inclusion of only male subjects. Males may be less likely to take part in water-based activities than females or age as well could play a role in determining activities chosen. Unfortunately, accelerometers are limited in quantifying low impact options such as swimming/water-based activity and are known to underestimate cycling. Due to these low impact options being prevalent after THA, future studies may want to look into a better way to quantify energy expenditure with these activities to ensure all forms of physical activity are represented in this population. For this data set, none of the participants reported having to remove the accelerometer for aquatic activities and cycling was only reported by two of the seventeen participants, so it is likely there was not a significant underestimation of PA due to this limitation.

The second objective was to describe the relationship between physical activity and self-report of pain, disability and sleep. These variables include pain, body composition, sleep disturbance and self-report disability measures. The subjective measures used to assess disability in the present population were the HOOS and Oxford Hip Score. As expected, the scores indicated low levels of disability. The mean Oxford Hip Score 14 (4.8) was similar to the Oxford Hip Score reported by Bauman et al (2007) in THA patients 1 year post-op (16.6). The correlation between the two disability scales (HOOS to the Oxford Hip Score) was strong ($r=0.94$, $p<0.001$). However, when comparing the self-reported disability measures to actual physical activity, the analysis was unable to detect significant correlations between these variables with the exception of that found between the Oxford Hip Score and average daily stepping rate ($r=.486$, $p<0.05$). This low to moderate correlation between the self-reported disability and objective physical activity data was expected as disease specific research has reported that subjective assessment of function through disability measures is not reflective of actual PA behavior (Sechriest et al, 2007, de Groot et al., 2008,). This study clearly supports the separation of perception of function from actual behavior.

When considering joint replacement surgery, the expectations of the patient and the surgeon can influence the outcome. To investigate the expectations of this subset of the total hip arthroplasty population, a variation of the HOOS questionnaire was administered. This allowed the participant to indicate not only their current level of disability but also where they expected to be at 1-3 years after THA. At this point in the recovery process, the expected scores were all lower than the current scores, indicating that this subset of the population was functioning at a better than expected level. The only significant difference detected in the current versus expected scores was seen in the Sports and Recreation component of the questionnaire. The expected score was significantly lower than the current. Jourdan et al (2012) investigated the relationship between patients' and surgeons' expectations prior to THA. They reported that overall both surgeons and patients' expectations were high, which is reflective of the positive outcomes of this surgery with relation to pain reduction. However, the concordance was poor between surgeons and patients. The greatest divergence between scores was found in the exercise/participation in sports category where patients' expectations were more optimistic than the surgeons. The surgeons' rating of expectations seemed to be significantly related to clinical data whereas the patients' expectations were mainly psychological and non-hip related. They also noted that patients with lower function before surgery had higher expectations and are at higher risk of decreased satisfaction after surgery. The current study population reported lower expectations than their current function. This may be in part due to the inclusion criteria focusing on healthy, younger males who were likely higher functioning pre-op as well. As reported in Jourdan's study, these patients report a more moderate level of expectations in comparison to the lower functioning patients. Also, after surgery there ample education and focus placed on hip movement restrictions during the acute recovery phase and longer term restrictions with relation to higher impact sports. It may follow that expectations after surgery have changed considerably from the first meeting with an orthopedic surgery due to further education during the surgical process. Future studies should include a measure of expectations both before and after surgery to investigate this relationship further. Also, surgeons should focus on setting more realistic expectations with patients before surgery, especially in relation to sports and recreation, to improve overall satisfaction after surgery.

Previous studies have shown a significant negative relationship between body composition measures such as BMI and physical activity (McClung et al (2000), Busato et al (2008)). As expected, the correlation between BMI and waist circumference was strong ($r=0.91$, $p<0.01$). The analysis was unable to detect any significant relationships when comparing body composition to any of the physical activity parameters. There was an adequate range of BMI and WC values for comparison purposes, however the small population size may have underpowered this calculation. It is important to note that in the Canadian male and female age-matched cohort (40-59 years) there is no relationship between physical activity measured by accelerometry and BMI. The BMI values for the study population ranged from 24.1 to 44.6 kg/m^2. 11.8% of the study population was classified as normal weight, 52.9% were classified as overweight, and the remaining 35.3% were classified as obese. The Canadian Joint Replacement Registry reported in their Annual Statistics from Clinical Data (CIHI, 2011) that of the males in Canada requiring THA in 2009-2010, 18.4% were normal weight, 39.4% were overweight and 41.9% were categorized as obese. Compared to this data, the study population had a similar distribution. It would be beneficial to reassess this relationship with a larger sample size to allow for increased number of participants in each range of BMI. Also, this relationship may be influenced by gender as well; therefore including females may cause a change in correlation between these factors. It may also be prudent to consider other factors (socioeconomic, etc.) that influence activity level other than BMI. The THA studies reporting the presence of this negative correlation between BMI and activity primarily used pedometers to quantify PA. The drawback of mechanical pedometers was previously reviewed. Due to the decreased sensitivity to BMI, this negative correlation may be due to the pedometer underestimating the number of steps/day in the higher BMI population, not that this population is less active due to increased BMI. This relationship should be further examined using accelerometers or accelerometer based pedometers to quantify activity levels.

Pain is considered in the disability specific measures such as the HOOS and Oxford Hip Score. However, VAS pain scales assess pain in a more domain specific, rather than disease specific, manner. The participants were asked to quantify pain in their current state, the impact of pain on their activities of daily living and pain after provocation. The majority of the participants reported a pain score of less than one cm out of ten cm for the three different scales. This low level of pain would be expected at 1-3 years following THA. When comparing these three scales to the physical activity data obtained, the only significant correlation detected was found between step rate and VAS function. Although disability is related to pain, the objective physical activity is not. This may be due to limited variation in pain scores or due to the length of time from surgery. A stronger relationship between pain and physical activity would be expected prior to surgery and during the acute recovery phase when pain is known to be a limiting factor to function.

Regression was used to examine the ability to predict disability using physical activity, body composition, sleep quality, age, months since surgery, as well as pain. Step wise regression revealed that VAS function was able to account for 80.7% of the variance in the HOOS total score, and 78% of the variance in the Oxford Hip total score. It is interesting that a measure considering a domain-specific role of pain and its effect on function can so strongly account for the variability in more involved disease specific measures. Both its relationship to the disability measures as well as it being the only pain measure related to physical activity (step rate); the utility of the simple VAS function question to assess perceived disability in the THA population is confirmed. These relationships also reveal that the impact of pain on perceived function is a principal determinant of how the participants responded in the disability questionnaires. This relationship should be further investigated as a VAS function scale may provide a quick, patient-friendly measure that provides a reliable prediction of disease-specific functioning.

Another variable that may be expected to affect physical activity in a chronic disease population would be sleep disturbance (Cole et al, 2007). In the hip arthritis population, sleep disturbance secondary to pain is a common occurrence. A well-reported outcome of joint replacement surgery is, of course, pain reduction. Therefore, one would expect that a measure that quantifies sleep quality could be correlated to physical activity due to a decrease in pain post-op. However, statistical analysis was unable to detect a relationship between the PSQI scores and the various physical activity parameters reported. The measure used, the Pittsburgh Sleep Quality Index, is not a disease specific measure but a more generic measure of sleep quality. Therefore, poor sleep quality is likely related to factors other than pain. Due to the higher than expected prevalence of sleep disturbance in the participants (29%, n=5), sleep intervention in conjunction with THA may be beneficial in patients identified as having sleep disturbance to improve overall quality of life.

With analysis unable to show any significant relationships between the disease specific measures and physical activity, it may be essential to consider more domain specific measures to investigate which factors influence physical functioning following THA. Davis et al (2011) investigated the recovery and inter-relationships of symptoms, activity and participation in the first year after total hip and knee replacement. The authors felt there should be more focus on domain specific outcomes looking at areas such as return to higher demand activities and participation in social roles, leisure pursuits and community interactions. Participants with THA had rapid recovery in physical impairment, minimal change in mood, more gradual improvement in activity, and early worsening of participation with rapid improvement following through 3 months post-op. Similarly, Singh and Lewallen (2010) investigated predictors of activity limitation and dependence on walking aids after THA. They found that older age, female sex, depression and higher BMI were associated with higher odds of moderate to severe activity limitation and with moderate to complete dependence on walking aids two years after THA. They suggest that screening for depression before surgery may help identify older adults at risk for poor functional outcomes. Therefore, if further studies were to assess physical activity in the THA population with less stringent inclusion criteria than the present study, a general or domain specific measure to assess depression may be necessary when determining factors that may predict decreased physical activity following THA. Also, future studies assessing possible interventions to improve physical activity after THA should consider depression diagnosis and treatment depending on the study population used.

The present objective closely parallels other recent research in the area of physical activity in patients following THA. Robert Wagenmakers and colleagues (2011) assessed the physical activity behaviors of patients 1 year after THA using self-report measures. The objectives of their work parallels the objectives of the current research, however the primary means of quantifying physical activity was the Short Questionnaire to Assess Health-enhancing physical activity (SQUASH). Using previously published MET values, physical activity was quantified and time spent in different intensities of activities was tabulated. The participants aged $\leq$ 75 years spent 1632.6 minutes on total physical activity during the week. This value is lower than the 2037 minutes spent on total physical activity during the week in the younger male population. 72.0% of the participants $\leq$75 years of age adhered to the recommendation of 30 minutes or more of moderate or vigorous intensity activity on at least 5 days per week. Younger, male patients with no other lower extremity complaints met the guidelines more often. This might help to explain the 100% adherence to the guideline for 150 minutes of moderate intensity per week in the study population as this subset (younger males) has been reported to be more active. Unfortunately, Wagenmaker's data should be compared with caution as the correlation between accelerometer data and the SQUASH data for physical activity is only 0.45 in younger population (mean age=44 years) and 0.67 in older adults (mean age=71 years). Therefore, although this self-report physical activity data provides better comparison than disease specific measures in determining physical activity post-op, there is still room for error.

A more accurate means of assessing physical activity is the use of a basic physical activity monitor, the pedometer. The pedometer has been used frequently in studies assessing wear rates in THA prostheses, as walking is the most important physical activity affecting the wear (Sechriest et al (2007), Bennett et al (2008)). So, well these studies provided information on walking in relation to wear rates, they also provide information on physical activity in this population. Schmalzried et al (1998) used pedometers to quantify walking activity in patients at least 6 months post-THA or TKA. Although the average step count was 4988 steps per day, the variation was extreme with the lowest value being 395 steps/day up to 17718 steps/day. As with previous studies, the most active participants were those under the age of 60 and male. Bennett et al (2008) found similar findings when assessing wear rate at 10 years post-THA. There was a large variability seen in steps taken, 1005 to 13366 steps per day, and again age was found to be negatively correlated with the step data. The age 55-64 cohort averaged 4873 steps/day. McClung et al (2000), also using the pedometer to look at wear rates, found the THA population to average 5869 steps/day. There was a negative relationship found between BMI and activity (steps/day). Lastly, Sechriest et al (2007) found an average of just over 6500 steps/day in younger (mean age 42 years at time of surgery) THA patients approximately 6 years after surgery. There was a significant negative correlation reported between BMI and gait cycles but no correlation between gait cycles and the UCLA score (self-report activity measure). The present study found a higher value for average steps/day at 9143, however, as with these previous studies, there was a large amount of variability (4464 to 16298 steps/day).

When determining the best method to assess physical activity, there are multiple factors to consider. The use of self-report measures allows ease of data collection and timely access to a larger study population. Pedometers provide more accurate physical activity data and are relatively inexpensive. However, the most accurate physical activity data can be obtained by using an accelerometer. The limitations of such a device are cost and increased man power required to download and interpret data. Naal and Impellizzeri (2010) found through their systematic review of physical activity in TJA patients, that steps measures in studies using pedometers were less than half of the steps measured in studies using accelerometers. They suggest the reason for the large discrepancy may be due to walking velocity, gait biomechanics and amount of soft tissues, rendering the pedometer less effective. Due to this discrepancy, they suggest accelerometers are the more appropriate instruments to objectively assess physical activity in patients undergoing TJA. The limitations of mechanical pedometers may explain some of the discrepancy in the number of steps recorded in the present study in comparison to the pedometer studies discussed previously. When interpreting the steps/day data using only accelerometry, Naal and Impellizzeri (2010) reported the average to be 11250 steps/day, much higher than previous pedometer based studies and significantly higher than the accelerometer driven steps/day in the present study. Another factor to consider is that although walking may be the primary activity reported by Canadians and seen in this study population, pedometers are unable to quantify other activities that the accelerometer may pick up. For example in the present study population, after walking the primary activities reported were yard work/house work and golf. The accelerometer has the sensitivity to pick up body movement with these activities whereas the pedometer would only be able to report on stepping behavior, therefore underestimating overall activity.

There are a limited number of accelerometer based physical activity studies done in the TJA population for comparison. Ingrid de Groot and colleagues (2008) in the Netherlands looked at physical activity before and at 3 and 6 months after THA. At 6 month following TJA, the average was 9.1(3.9) % of a 24 hour period was spent active. This value was much higher in the younger male subset at 20.6 (5.71) % of a 24 hour period active. There was one subject with a value of 10.9%, however a majority of the participants (n=12, 71%) were at greater than 15% of the day (24 hour period) active. Unfortunately, de Groot and colleagues did not report any step data or energy expenditure data for further comparison. The difference observed in activity percentage could in part be due to the difference in post-operative assessment period (6 months versus 1-3 years), as well as differences in the populations. The relatively short wear time for the accelerometer in de Groot's research (48 hours) in comparison to 7 days in the present study could also account for this discrepancy. Overall, de Groot found a relatively small increase in physical activity from pre-op to the 6 month follow up (0.7%) despite significant improvements in self-reported pain and disability. The current study has also indicated a poor relationship between self-reported disability and physical activity.

Kinkel et al (2009) utilized accelerometers to assess physical activity with respect to age in patients at least 1 year after THA. The accelerometer has been shown to accurately quantify walking behavior. Participants averaged 6144 stride cycles per day which is equivalent to 12288 steps/day. In accordance with previous studies, they found that increased age negatively correlated to physical activity, higher BMI is related to decreased activity and men were more active than women. The steps/day they reported is significantly higher than the value from the current study. Comparison is essential in research to determine if different populations are exhibiting similar trends in data. For this reason, studies incorporating accelerometers to quantify physical activity should provide more extensive data sets including both step and energy expenditure data to facilitate these comparisons. Unfortunately, most of the research objectively quantifying physical activity in the THA population provides partial data sets for comparison purposes.

Limitations

The primary limitation of this study is the small sample size. Although significant trends were noted and the accelerometer data does provide insight into the physical activity of this population, the sample size obtained could cause some of the statistical comparisons to be underpowered. Possible causes for limited participation may be due to the strict inclusion criteria and access to patients at only one site in Winnipeg. It is also likely that the participants obtained may be more active, and therefore more willing, to participate in a study quantifying PA. This may skew the results. This issue was reported by Kinkel et al (2009) who contacted 215 patients but only 105 agreed to participate. They state that this approach, as with the current study, may lead to selection of satisfied and motivated patients, therefore leading to the potential to overestimate activity in a population.

When calculating time spent in moderate intensity activity there is the potential for over-estimation due to the activity level of this population. The cut off point for determining light to moderate intensity activity is based on an equation provided by the manufacturer. There is some room for error using an equation such as this, and this error may be magnified due to the large amount of time spent at or just around the moderate intensity threshold level. A slight change in the threshold value could cause a significant change in the amount of time spent in different intensities of PA. Due to this potential for error, the data may over-estimate the time spent in moderate intensity activity, which may in part account for the difference reported between the study population and that of the age-matched Canadian and U.S males. This over-estimation is further stressed by the information provided in the activity logs completed where walking is the most common activity. Walking for leisure (under 2.5 mph) is not categorized as a moderate intensity activity (MET value >3). Also, moderate activity was not considered in bouts of ten minutes. To be able to accurately assess the participants' adherence to the current physical activity guidelines, this measure would have been necessary.

Lastly, the most accurate means to assess physical activity in a population is to measure change over time. The best design to meet his goal would be a longitudinal study which would effectively provide information on participants' pre-op physical activity levels as well as physical activity during recovery.

Conclusion

The present study quantifies physical activity including energy expenditure and step-based data for the younger male subset of the THA population without significant co-morbidities. Physical activity data for this subset (steps/day) was not clinically different than that of the age-matched normative population. In general, analysis was unable to detect a relationship between pain, sleep and body composition measures to PA. However, although the small sample size limited analysis of linear bivariate relationships, had there been a moderate or above relationship (r>0.65) the analysis we would have detected it. The activity data provided can be used as a guideline when establishing PA levels possible after THA. The accelerometer allowed objective assessment of physical activity with minimal impact on the participants and yields useful data related to step based activity, time active and energy expenditure. Future studies using accelerometry to asses

PA in this population should include a domain specific measure to better understand factors that affect PA after surgery to maximize outcomes in these patients.

Recommendations & Future Studies

Based on the limitation of the present study, it would be recommended that future research focuses on physical activity in a more generalized group following THA. This may allow for easier time with recruitment and provide more information on the THA population as a whole. Also, using multiple sites for recruitment may decrease bias. The best approach may be to introduce the accelerometer during surgeon initial consults and follow up appointments which may increase compliance and provide set time frames for data collection. This will allow for a longitudinal approach to assessing physical activity and better represent change over time. Due to this population having on average 2000 steps/day less than other accelerometer based studies following THA likely including more extensive rehabilitation following surgery, it may be beneficial to include a subset of a THA study population to investigate if the introduction of a more intense rehabilitation program following surgery improves physical activity in the long term. As reported by Birgitte Espehaug in a study with colleagues looking at the effect of body weight on physical activity (Flugsrud et al, 2007), when asked, 64% of participants who exercised before having THA continued after. This differed greatly from only 34% of those who did not exercise regularly prior to THA started regular exercise after. Therefore, it is important to consider not only the change in activity over time but also if regular exercise was part of the participants' lifestyle before surgery.

As the results demonstrate, utilizing a physical activity monitor is essential to accurately quantify physical activity; however self-report measures do play a significant role in showing change in disability over time based on patients' perceptions of pain and function. It has also been shown that studies looking at activity may want to include more domain specific measures to assess the effect of diagnoses such as depression on physical activity. If future studies plan to assess need for increased intervention after THA, sleep intervention should also be assessed due to the high prevalence of participants with disordered sleep in this population despite low pain scores.

When using a provoking event to assess change in pain after surgery, walking is an appropriate activity to use as it causes low impact stresses to the joint, is a regular daily activity and is restricted before surgery due to pain and limited range of motion. For provocation during the in clinic assessment, participants were asked to walk at a brisk, yet comfortable pace. None of the participants required the use of a mobility aid for walking during the in clinic assessment. This differs from the data presented by Deschartres et al in France (2007) who found increased use of mobility aids in the THA population. However, this may be due to the inclusion criteria with focus on the younger, more active population. Hodt-Billington, et al (2011) looked at gait velocity both pre- and post-op THA. They used a 7-meter walkway to look at slow, preferred and fast gait velocities. The "fast" median velocity at 12 months post-op for their study population was 1.74 m/sec. The preferred median velocity was 1.18 m/sec. In the present study, the mean walking speed for the brisk walk used for pain provocation was 1.49 m/sec. Therefore, the term used "brisk, yet comfortable" in the present study may not have elicited the faster speed required to provoke a pain response. In future studies, it is recommended that participants be asked to walk as fast as possible to see if changes in pain are noted due to the awareness that the post-op preferred pace is quite a bit lower than their potential "fast" pace.

VAS function was found to correlate to PA data (step rate) as well as being able to account for 80.7% of the variance in the HOOS total score, and 78% of the variance in the Oxford Hip total score. Due to the versatility of this domain specific, simple measure, future studies may want to investigate these relationships further. It would be beneficial to have a simple domain specific measure for surgeons and researchers to use to obtain information on disability in this population. This study further validates this domain specific question.

Lastly, specific recommendations can be made to the different parties invested in the outcome after THA. Surgeons should better define goals both for and with patients having a hip replacement related to function and physical activity. This would allow for better determination of the outcome measures needed to assess these goals as well as allowing the surgeon to provide more realistic expectations to the individual patient. Surgeons should consider not only the patients' condition in relation to the surgery itself, but also their fitness level and previous experience when determining goals and activities possible following surgery. As physical activity is essential for the maintenance of overall health, surgeons should motivate their patients to remain active with safe exercise options before surgery as well as including activity monitoring during follow up to address any limitations observed. A safe timeline to return to various activities should also be discussed. Therapists involved in the patients' rehabilitation should also consider the limitations and strengths of the patient to best determine an individualized program to address not only generalized goals with relation to range of motion and strength, but also patient specific goals for return to sport. Working alongside the surgeon, the therapist can help maximize each patient's outcome based on their fitness level as well as surgical and medical restrictions. Finally, the patient should be fully aware of the limitations in place after THA. Goals for return to work and sporting activities should be discussed with the surgeon prior to their THA to improve satisfaction and decrease anxiety around return to activity post-op.

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