Driving Related Leg Movements in Older Adults with and Without a Right Knee Replacement

By
Aman Bajwa

A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE

School of Medical Rehabilitation
University of Manitoba
Winnipeg, Manitoba

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

*****

COPYRIGHT PERMISSION

Driving Related Leg Movements in Older Adults with and Without a Right Knee Replacement

BY

Aman Bajwa

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

MASTER OF SCIENCE

Table of Contents

Abstract

The purpose of this study was to measure driving-related movement time in older adults age $\geq$60 years with (TKR group; n=16) and without (No-TKR group; n=22) a total knee replacement (TKR). Movement time was recorded while participants used two foot-shifting strategies, a pivot and a lift, as they shifted their right foot from a simulated gas pedal/switch to a simulated brake pedal/switch. Participants used their preferred foot shifting method first (either a pivot or a lift), and the alternative strategy second (either a pivot or a lift) in all trials. In addition, active range of motion (AROM), the Timed Up and Go (TUG) test, a foot tap test, three gait parameters (walking speed, cadence and step-length), and a domain specific quality of life instrument, the Knee Injury and Osteoarthritis Outcome Score (KOOS scale) were also assessed.

Overall, women had consistently slower movement time (compared to men) for both preferred and alternative foot shifting strategy. There were no differences in movement time between individuals with and without a TKR. Regression analysis revealed that significant predictors for longer preferred and alternative movement time were height (being shorter) and having more ADL difficulties. Individuals with a TKR reported (significantly) more symptoms in their right knee, had reduced AROM in right hip flexion and extension, knee flexion, and ankle dorsiflexion, had shorter step length compared to the No-TKR group, and had longer TUG times. This study demonstrates a unique method of assessing movement time in individuals with and without a TKR and provides direction for future research in this area.

Acknowledgements

I would like to thank my advisor, Dr. Leah Weinberg, for her continuous support and advice. She was always there to encourage and guide me during the course of my degree and dissertation. In addition to my advisor, I would like to acknowledge my thesis committee members: Dr. Dean Kriellaars, Dr. Michelle Porter and Dr. Barb Shay. I want to thank them for their time and valuable suggestions during the completion of this thesis. A special thanks goes to Sandra Webber for helping me in the process of data management and data collection. I wish also to thank all the participants who participated in this research.

Last, but not least, I thank my family: my parents, Ajaib S. Bajwa and Narinder K. Bajwa, and my siblings, Preeti Purewal and Deepinder S. Bajwa for their unconditional support and encouragement.

List of Tables

List of Figures

Introduction

Osteoarthritis (OA) is the most common form of arthritis (Scott & Hochberg, 1998; Flores & Hochberg, 2003). In Canada, 3,000,000 people are affected by OA (The Arthritis Society, 2005). Because the knee joint is the body's primary weight-bearing joint, it is commonly affected by OA. Knee OA is one of the most common causes of pain and functional disability in older adults (Ndongo, Ka, Leye, Diallo, Niang, Sy, & Moreira, 2003). Treatment for this condition may be conservative (e.g., involving medication, physical therapy, etc.) or surgical. Surgical treatment often involves a total knee replacement (TKR) for patients with advanced osteoarthritis of the knee (Hawker et al., 1998). In Canada, 24,815 TKRs were performed in 2001-2002 (Canadian Joint Replacement Registry, 2004). However, some studies indicate that for some individuals, substantial residual pain and disability remain after a TKR (Jinks, Lewis & Croft, 2003; Jones, Voaklander, Johnston, & Suarez-Almazor, 2000). In turn, this may affect mobility and compromise knee function, including the knee function required to safely operate the gas and brake pedals of an automobile.

According to the Canada Safety Council (2000), about one-half of seniors living in private households (1.7 million) drove a vehicle in the year 1996. Following TKR, patients often inquire when they may be able to resume driving; but there is very limited scientific data to assist the formation of guidelines for the resumption of driving following TKR (Pierson, Earles & Wood, 2003). Therefore, this study examined driving-related functional movements: those involved when moving the right foot from a (simulated) gas pedal to a (simulated) brake pedal. Driving conditions often require unexpected braking, especially in an emergency situation (Spalding, Kiss, Kyberd, Turner-Smith, & Simpson, 1994). In addition to muscle strength, cognitive, and sensory functions, shifting the foot quickly from gas to brake pedal requires functional range of motion at the hip, knee and ankle joints (Anstey et al., 2005). The ability to perform a quick brake reaction might be impaired after a TKR, hence affecting the ability to stop quickly in an emergency and compromising the safety of the driver and others on the road.

Based on earlier studies of brake reaction time (BRT) and movement time after TKR, an individual may be advised to resume driving six to eight weeks following surgery (Pierson et al., 2003; Spalding et al., 1994). However, none of these studies examined factors that may influence movement time. For example, the time taken to shift one's foot quickly from the gas to the brake pedal has not been examined in relation to different strategies (e.g., lifting or pivoting the foot) that individuals may use when braking. Moreover, extant research did not examine the hip, knee and ankle joint angles involved when people shift the right foot from gas to brake pedal. These parameters may be related to movement time and foot-shifting strategy. Another method of evaluating TKR outcomes involves the use of self-report, quality of life measures such as the WOMAC or KOOS scales (Jones et al., 2000; Marx, 2003; Roos & Toksvig-Larsen, 2003) that examine knee-specific quality of life factors such as pain, stiffness, and function in activities of daily living after TKR and these may also be related to movement time. In sum, a number of factors may influence return to safe driving after TKR, such as foot-shifting strategy, AROM, self-reported pain/symptoms and difficulties in ADL. By assessing how these variables relate to movement time, this research provided direction for future research to help determine when TKR patients may recommence driving.

A review of the above literature has led to the formation of the following research question: Are there differences in driving-related functional performance measures, and in quality of life, of individuals with and without a right total knee arthroplasty? Therefore, the purpose of this study, the "Driving-related Leg Movements in Older Adults With and Without a Right Knee Replacement" (referred to hereafter as the Knee Replacement Study) is to examine any potential differences in driving-related functional performance measures involving the right leg, and in quality of life, between two groups of individuals: those with a right TKR (TKR group, n = 17) and those without a right TKR (No-TKR group, n = 22).

This study assessed movement time (defined as the time taken to shift the right foot from a simulated gas pedal to a simulated brake pedal), by using two foot-shifting strategies: a lift and a pivot. Movement time was recorded using a Lafayette reaction/movement timer apparatus, which was connected to a gas and brake switch (i.e., simulated pedals). In addition, the groups were assessed for measurement of hip, knee and ankle joint angles and range of motion (ROM) using a Vicon Motion Analysis System (VMAS) when the braking strategy was performed. Additional physical measures included: assessment of gait parameters using VMAS, AROM using a goniometer, mobility using the Timed Up and Go test (TUG) (Podsiadlo, & Richardson, 1991), and an adapted foot tap test (hereafter referred to as the tap test) (Staplin et al., 2003). Finally, a knee-related quality of life measure, the Knee Injury and Osteoarthritis Outcome Scale (KOOS) (Roos, Roos, Lohmander, Ekdahl, & Beynnon, 1998), was also administered. The descriptive statistics of the study are presented. Univariate and multivariate methods were used to examine between-group differences in movement time for the two foot-shifting strategies and regression was employed to examine determinants of preferred and alternative movement time. Correlation analyses were performed to examine relationships between movement time, age, gender, physical measures, quality of life measures, and functional performance variables.

Literature Review

Osteoarthritis and Total Knee Replacement

Osteoarthritis (OA) is a degenerative joint disease and is reported to be the most common type of arthritis (Scott & Hochberg, 1998; Flores & Hochberg, 2003). The joints usually affected by OA are knees, hands, hips and spinal joints (Felson, 2003). According to the Arthritis Society of Canada (2005), OA affects 3,000,000 Canadians. Some of the common symptoms of OA are pain, stiffness, alteration in the shape of the joint, and functional impairment. In particular, it affects two thirds of adults who are age sixty-five or older (Cushnaghan & Dieppe, 1991; Dodge, Mikkelsen, & Duff, 1970). Disability associated with OA may include poor mobility, difficulty performing daily activities, social isolation and loss of work opportunity, leading to serious financial concerns (O'Reilly & Doherty, 2003). OA contributes significantly to overall disability in the community. Among the different joints affected by OA, the knee is affected most often (Adams & Hamblen, 2001), and knee OA leads to the greatest decrease in mobility and quality of life (Badley, 1995; O'Reilly & Doherty, 2003).

The knee joint is a major weight-bearing joint of the human body and is thus more prone to age-related degeneration. In OA of the knee joint, cartilage is gradually worn and this may lead to hypertrophy of the bone at joint margins and formation of osteophytes (Flores & Hochberg, 2003). This results in pain, loss of function, and a reduced quality of life (Downe-Wamboldt, 1991). Hawker et al., (1998) state that conservative treatment, such as medication and physical therapy is often used to relieve symptoms in patients with mild to moderate severity. However, in cases of severe pain and deformity, operative treatment may be considered. Frequently used operative measures for OA knee joint include the following: removal of loose bodies; upper tibial osteotomy; excision of the patella; arthrodesis, and joint replacement (Adams & Hamblen, 2001).

Total knee replacement (TKR) is the surgical replacement of a painful, damaged or diseased knee joint with an artificial joint (Harwin, 2002). In this surgical procedure, the damaged and diseased parts of the tibia and femur are removed, or femoral and tibial condyles are resected. The new artificial joint is then fixed on the resected surface to maintain the normal functional and anatomical position of the joint. Joint replacement is increasingly used as one of the methods of treatment for advanced OA of the knee (Brazier, Harper, Munro, Walters, & Snaith, 1999). Most knee replacements are performed for individuals age ≥ 65 years, who have severe osteoarthritis of the knee (Coyte et al., 1994; Hawker et al., 1998). TKR is often the treatment of choice for individuals with chronic knee joint destruction caused by OA specifically in people who have severe pain, instability, deformity and restricted ROM in the affected knee (Harwin, 2002; Hawker et al., 1998; Chang, Pellissier, & Hazen, 1996).

In Canada, 24,815 total knee replacements were performed in 2001-2002 (Canadian Joint Replacement Registry [CJRR], 2004). According to these statistics, in 2001-2002, the number of total knee replacements increased by 61.6%, as compared to 1994-1995. In addition, total knee replacements increased 7.3% in 2001-2002 over the previous year (CJRR, 2004). Furthermore, in 2001-2002, Manitoba and Ontario had the highest TKR rates, with 96.0 and 90.5 joint replacements per 100,000 people, respectively (CJRR, 2004). The majority (70.7%) were performed on patients age ≥ 65 years, with a mean age of 69.0 years (69.2 years for females and 68.7 years for males) in

2001-2002 (CJRR, 2004). After undergoing TKR, many individuals experience improvement in pain and disability/mobility, while others do not experience these positive changes and may have persistent pain and functional difficulties after TKR surgery (Jinks, Lewis & Croft, 2003).

Outcomes after Total Knee Replacement

The main goals of performing TKR surgery are to relieve pain and disability, and to restore normal function of the knee joint (Hawker et al., 1998; Chang, Pellissier, & Hazen, 1996). Studies show that the level of post-operative pain and disability is lower when compared to the pre-operative level (Drewett, Minns & Sibly, 1992; Griffiths et al., 1995). However, a number of studies show that the level of pain and disability is higher in individuals with TKR when compared to controls in the general population (Jinks, Lewis & Croft, 2003; Jones et al., 2000). Individuals with a TKR may present qualitative and quantitative deficits in functional activities (Mizner & Snyder-Mackler, 2005). Jones, Voaklander, Johnston, & Suarez-Almazor (2000), conducted a study to assess participants pre- and post- arthroplasty. Their study included 228 and 276 participants age 40 and older; the former participants had total hip replacements, and the latter had total knee replacements. Participants were assessed one month pre-operatively and six months post-operatively. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (Bellamy et al., 1988) and the Medical Outcome Survey Short Form SF-36 (McHorney, Ware, & Raczek, 1993) were used to assess health-related quality of life. Results of this study revealed that 15% to 30% of patients with TKR reported little or no improvement after surgery or were unsatisfied with the results of surgery. Although some participants reported a significant improvement in pain, social function, physical function and general health after undergoing TKR, the quality of life experienced by these TKR patients did not match the quality of life measures experienced by the study's control group (i.e., people who did not have surgery).

In another study, Walsh, Woodhouse, Thomas and Finch (1998) compared a group of individuals one year post-TKR surgery (n = 29), with age and gender-matched controls (n = 40). Comparisons concerned walking speed, stair-climbing ability, knee torque and AROM (age of the participants was not mentioned in the article). The study demonstrated that men with TKR had a 17% slower walking speed and a 51% slower stair-climbing ability. Similarly, women with TKR had an 18% slower walking speed, and were 43% slower in stair climbing. In terms of total work of the knee extensors, individuals with a TKR performed 29% to 37% less work when compared to the control group. These results indicated that physical and functional impairments persisted for one year following TKR, as compared to age-matched controls.

Ouellet and Moffet (2002) assessed the extent of post-operative locomotor deficits in individuals with a TKR (n = 16), comparing the values with a group of control subjects (n = 21). The former group had a mean age of 66.8 years and the latter group, 60 years. Individuals within the TKR group were compared pre- and post-operatively. The mobility of participants was examined using a) gait and stair-climbing evaluations, b) the Timed Up and Go test (Podsialdo & Richardson, 1991), and c) the six-minute walk test (Guyatt et al., 1985). The results showed that two months following TKR, participants had large functional deficits compared to the control group. Individuals with TKR had 54% slower gait speed and significantly increased double-limb support during ambulation. In addition, TKR individuals took 58% longer to complete the TUG and walked significantly shorter distances in the six-minute walk test. Moreover, the researchers reported that two-month post-operative mobility was reduced, as compared to the pre-operative level. Post-TKR participants had 20% slower gait speed, took 29% longer to climb stairs, 30% longer to complete the TUG, and covered a 19% shorter distance in the six-minute walk test.

These studies suggest that the functional performance of individuals post-TKR, may not bring them to the same level of function and quality of life as experienced by control subjects. However, the studies that measured brake-reaction time of individuals with a TKR did not examine objective measures that may be associated with driving-related leg movements. Therefore, this study examined individuals with and without a TKR, using measures that may be associated with driving performance. Specifically, this study examined potential differences in the following variables: movement time; hip, knee, and ankle joint angles when shifting the right foot from the gas to the brake switch using the VMAS; active range of motion; the TUG; the foot tap test and gait parameters of gait speed, cadence and step length, and knee-specific quality of life using the KOOS scale (Roos et al., 1998).

Functional Performance Measures

A performance measure is one in which an individual is asked to perform a specific task that is evaluated using predetermined criteria, such as counting repetitions or timing the activity (Guralnik et al., 1989). Physical performance measures usually tend to assess only a single aspect from the domain of interest (Stratford et al., 2003). They provide an objective measurement of a person's physiological and functional status and are sensitive to change over time (Cress et al., 1995).

Movement Time

Driving a vehicle is an activity valued by many older adults (Ganz, Levin, Peterson & Ranawat, 2003). Anstey et al. (2005) propose that three factors, cognition, sensory function and physical function/medical condition help to predict driving ability. Reductions in muscle strength, endurance and flexibility may also impair driving ability (Anstey et al., 2005). In addition, slower and inaccurate initiation and execution of movement may affect driving skills (Porter, & Whitton, 2002). If people have residual pain and restricted ROM, it may cause slower initiation and difficult movement when braking. The result may affect the ability to depress the brake pedal quickly. According to Spalding et al. (1994), a vital requirement for safe driving is the ability to stop quickly in an emergency.

Shifting the foot quickly from the gas to the brake pedal requires movement of the hip, knee and ankle joint. One important, objective measure of driving ability is brake reaction time (BRT) (Ganz, Levin, Peterson & Ranawat, 2003; Morrison, Swope & Halcomb, 1986; Spirduso, 1975). Previous research divided total brake reaction time into perception or reaction time, and movement time (Lister, 1950; Spalding et al., 1994; Green, 2000). Reaction time was defined as the time from presentation of a red light stimulus until the foot starts to move off the gas switch/brake pedal, whereas, movement time was defined as the time taken from the start of the movement off the gas pedal until the foot depresses the brake switch (Lister, 1950; Spalding et al., 1994; Green, 2000). Some studies recorded perception time and movement time separately; other studies measured total brake reaction time, and some examined only movement time (Green, 2000). In general, previous studies employed the following protocol: Individuals were seated in front of a red light stimulus and they were instructed to respond by moving their right foot from the gas to the brake switch of a reaction timer when the stimulus was presented (Green, 2000).

While a number of studies focus on measuring brake reaction time, there is limited research examining BRT in individuals who have received a TKR. One study by Spalding et al. (1994) examined BRT in individuals with a TKR in order to develop guidelines to help determine when people can safely resume driving after surgery. Their study population consisted of 29 participants (mean age, 74 years) with a TKR who were assessed pre-operatively and at 4, 6, 8 and 10 weeks, post-operatively. These participants were compared to 20 control group participants (mean age, 67 years). A simulated car set-up with a reaction/movement timer was used to record the BRT. The results of the study showed that the mean BRT of drivers was .72 seconds for the TKR group (pre-operatively) and .71 seconds for the control group. Based on the results of the study, the authors suggest that because BRT returned in their study to pre-operative values by the eighth week following TKR, it is safe to resume driving at eight weeks post-TKR. However, in the above study, the researchers recruited individuals with a TKR who were both drivers and non-drivers, and also included individuals with a left TKR. Therefore, the lack of appropriate inclusion and exclusion criteria likely influenced the study results. Accordingly, the suggested timeframe involved for the resumption of driving may be underestimated.

In a similar study by Pierson et al. (2003), researchers investigated pre- and post-operative BRT among patients with a TKR. The purpose of the study was to determine when participants could resume driving, and to discern if gender affects BRT.

Researchers recruited 31 participants undergoing TKR with a mean age of 68.5 years. BRT was examined 3 weeks before and at 3, 6 and 9 weeks after surgery. According to study results, BRT improved, post-operatively, by 12.5% at 6 weeks and by 17.5% at 9 weeks, when compared to the pre-operative level. In addition, the mean BRT for men was 200 milliseconds (ms) faster than women's mean BRT. The authors of this study advised that surgeons can recommend a return to driving at six weeks post-TKR. A major drawback of this study was that there was no control group. Instead, the authors compared pre- and post-operative BRT of individuals with knee osteoarthritis. These individuals might have had a slower pre-operative BRT, owing to knee pathologies, than those in a control group. Therefore, in order to determine acceptable post-operative brake response times, it would be important to compare brake reaction times of individuals with and without a TKR to determine any potential differences in BRT or movement time between the two groups.

Although the few previous studies examining BRT in individuals with a TKR recommended that one can resume driving anywhere from 6-12 weeks post-operatively, none of the studies examined factors that may influence movement time. For example, a study conducted by Meikle, Devlin, & Pauley (2006) examined brake response time after right transtibial amputation, in order to assess safety when operating foot pedals. It also examined different techniques associated with foot-shifting. To measure brake response time, the above researchers used brake and gas pedals (Logitech Inc, CA) in addition to Vericom reaction timer software (version 1.00). Their study measured brake response time, using the following four foot pedal arrangements:

1) Prosthesis operating both the accelerator and brake pedals;

2) Prosthesis operating the accelerator and left foot operating the brake;

3) Left foot operating both the accelerator and brake, and

4) Left-sided accelerator with the left foot operating both the accelerator and brake.

The main outcome measures of the study were the following: reaction time; movement time; brake response time, and pedal configuration preference. The authors found that using the prosthesis to operate the accelerator pedal while using the left foot to operate the brake pedal, resulted in slower reaction time, movement time and brake response time. The fastest times for each measure resulted when the left foot operated both the accelerator and brake pedal. The study's results led the authors to advise that right transtibial amputees should not drive using both feet on the pedals.

However, none of the studies involving TKR patients examined different foot-shifting strategies and the potential influence these strategies have on BRT. Moreover, none of the studies examined other functional parameters such as the hip, knee, and ankle joint ROM (following TKR), which may interfere with foot-shifting and thus affect brake response time. Therefore, to address these gaps in the literature, this study compared participants with and without a right TKR and examined movement time according to two different foot-shifting strategies: a pivot and a lift strategy. A Lafayette movement timer (Model number 63017) was used to record reaction time and total movement time. In addition, joint angles during the foot shifting strategy were examined using a Vicon 460 Motion Analysis System (Vicon Motion Systems Inc., Lake Forest, CA).

Motion Analysis

Three-dimensional (3-D) motion analysis systems are frequently used to examine gait or lower limb joint parameters, such as range of motion. This process usually involves the use of two or more specialized cameras and the placement of reflective markers on anatomical landmarks, which define the area of the body under examination. Light is reflected off the markers and into the camera lens; a resulting stick image is computed with specialized software and is displayed on a computer screen (McGinnis, 2005). The software computes a mathematical model that predicts the joint centre (e.g., the hip, knee or ankle joint centre, in this study). This is done from data recorded by the camera in three planes and from an individual's anthropometric measurements, such as weight, height, leg length, and width of ankle and knee joints. The computer software is then able to generate a stick figure and to compute gait parameters or joint angles that are of interest to the researcher. The anatomical motion analysis data can be used for both research and clinical purposes (Schwartz & Rozumalski, 2005). This 3-D reproduction has many uses, such as for medical assessment of movement disorders, and for understanding athletic techniques.

While a motion analysis system has been used to study gait in individuals with a TKR (Fuchs, Floren, Skwara, & Tibesku, 2002; Webster, Wittwer, & Feller. 2003), there are no extant studies that examine hip, knee, and ankle joint angles during the performance of such functional tasks as shifting one's foot from gas to brake pedal. Similarly, no studies compared these functional tasks in individuals with and without a TKR. Therefore, this study examined hip, knee, and ankle joint angles during the aforementioned two shifting maneuvers, using a Vicon 460 Motion Analysis System, while, at the same time, recording movement time.

Active Range of Motion

Post-operative active and passive knee joint range of motion (ROM) is considered one of the most important indicators of patient satisfaction and functional performance after TKR (Kawamura & Bourne, 2001; Rowe & Nutton, 2005). Tew, Forster, & Wallace (1989) conducted a review of 724 clients with TKRs one year after surgery and found that nearly half of the clients could not flex their knee joint beyond 90°. In another study, AROM and functional knee movement were assessed pre- and post-TKR (Rowe & Myles, 2005). Researchers used an electrogoniometer to examine knee ROM (n=50) when participants performed 11 activities of daily living (ADL). Results revealed that 83% of subjects, who had more than 90° of knee flexion before surgery, demonstrated significantly reduced knee flexion after undergoing TKR.

Restricted knee flexion might affect the ability to shift the foot quickly from the gas to the brake pedal while driving a vehicle. No existing research examines the association of AROM with movement time. Therefore, in this study, active hip flexion and extension, knee flexion and extension, ankle plantarflexion and dorsiflexion joint range of motion were assessed using a universal goniometer. These measurements permitted examination of any potential joint ROM restrictions and of a possible association between ROM restrictions and movement time.

Traditionally, AROM has been measured using a universal goniometer. This device is reported to have high criterion-related validity and content validity (Clarkson, 2000). Validity is "the degree to which an instrument measures what it is supposed to measure (Currier, 1990). Reliability is the extent to which the instrument yields similar results on repeated use by the same observer or by different observers (Sim & Arnell, 1993). Because intra-tester reliability is reported to be better than inter-tester reliability when using a universal goniometer, it is recommended that the same therapist should perform all measures when possible (Youdas et al., 1991; Low, 1976). Joint measurement can be recorded reliably when ROM is assessed using a "single standardized protocol" of measurement (Dijkstra et al., 1994). The previous research indicated that averaging repeated measures makes no difference to the reliability of the goniometer recordings (Elveru, Rothstein, & Lamb, 1988; Boone et al., 1978). Therefore, in this study, AROM was measured by one tester using a universal goniometer and a standardized protocol, as recommended by Clarkson (2000).

The Timed Up and Go test

One of the performance measures used in studies examining functional performance after TKR is the Timed Up and Go (TUG) test (Freter & Fruchter, 2000; Ouellet & Moffet, 2002). The TUG is reported to be a reliable and valid screening and assessment tool for measuring functional mobility and the risk of falling in older adults (Podsiadlo and Richardson, 1991). The authors suggest that older adults who take less than 20 seconds to complete the test are likely to be independent in mobility and transfers. In constrast, they suggest that individuals taking more than 30 seconds to complete the test are more likely to require assistance with transfers and mobility.

In a study by Ouellett & Moffet (2002), individuals (n = 16) with a mean age of 66.8 years were compared before and two months after a TKR. In addition, the TKR group was compared to a No-TKR control group. The authors report that before TKR, participants took 30% less time to complete the TUG, as compared to individuals in the No-TKR group. The results of the study revealed that participants with a TKR took 21% and 58% longer than the control group to complete the TUG pre- and post-operatively, respectively.

Freter & Fruchter (2000) examined the relationship between the TUG and gait time in a group (n = 79) of inpatients admitted either for a TKR (n = 29), total hip replacement (THR) (n = 30) or hip fracture (n = 20). Researchers used the TUG and a 10 meter walk test as the outcome measures. The mean age of the participants was 73.4 years. Researchers noted a strong correlation between gait time and the TUG; however, they suggest that these two measures are not redundant and differ by diagnosis, mobility and status of the patient. For example, the authors reported that the above correlation at the time of admission and discharge was r = .74 and r = .81, respectively. The correlation between TUG and gait time was strong at admission and discharge for patients with TKR and total hip replacement (THR). However, the above authors reported that correlations were weaker for patients with a fracture of the hip joint.

The TUG has been used as one of the functional outcome measures in numerous clinical studies involving a geriatric population. For example, it was used as an assessment tool for a rehabilitation program in a geriatric hospital (Hershkovitz, Gottlieb, Beloosesky, & Brill, 2003) with 353 patients who had either a stroke or joint replacement surgery (TKR and THR). Results revealed that at the time of discharge, there was significant improvement in the TUG, regardless of diagnosis. The researchers reported that, at the time of discharge, the average TUG time was 33% faster as compared to the average TUG time at admission. Therefore it was included in this study to examine the relationship to movement time and other functional parameters, and to examine if this sample population had similar TUG times reported in previous research.

Foot tap test

In addition to the TUG, a foot tap test was used in this study to assess a performance task that simulated the movement of shifting the foot from a gas to a brake pedal. This test was adapted from studies using similar tests. For example, Nguyen, Hau, & Bartlett (2000) conducted a study to evaluate BRT before and after surgery in individuals with anterior cruciate ligament (ACL) instability. Participants (n = 73) were examined before surgery and at 2, 4, 6 and 8 weeks after surgery. In addition to BRT, researchers used a foot stepping test. This consisted of the participant seated on a chair with a paper box (length = 30 cm, breadth = 2.5 cm and height = 2.5 cm) placed on the floor along his/her right foot. The participant was instructed to step on either side of the box without touching it, and to move as fast as possible; the number of steps was recorded for 10 seconds. This test was used to simulate the leg movements used while shifting the right foot between gas and brake pedal. Researchers reported a strong correlation between the stepping test's results and reaction time of participants. Moreover, six weeks after surgery, 37.5% of participants reached their pre-operative level in the stepping test and 75% reached their pre-operative level for reaction time.

In 2003, the U.S. department of transportation developed a driver screening and evaluation program (Staplin, Lococco, Gish, & Decina, 2003) and used a foot tap test as one of the physical performance measures. They used a 75 mm (3 inch) binder for the test. Participants were instructed to sit on a chair with the open binder placed on the floor in front of the participant. In this test, individuals were instructed to place their left foot under the chair and asked to move their right foot on either side of binder as quickly as possible for ten taps. An administrator manually recorded the time taken to complete the test. The movement pattern used in the foot stepping and tap tests may be similar to the foot-shifting pattern used when driving a vehicle. Because of the potential relationship to movement time, an adapted foot tap test, described in the methods section (below), was included in the current study.

Gait

Another important parameter that may be altered after a TKR is walking ability (or gait). Gait is described as the manner or style of walking (Whittle, 1996) and the gait cycle is defined as a single series of events between two sequential initial contacts by the foot of same limb on the floor (Perry, 1992). Gait analysis is the systematic measurement, description, and assessment of the parameters characterizing human locomotion (Davis et al., 1991). Various methods are used for gait analysis: observational gait analysis; electrogoniometers; cameras (still photography), and motion analysis systems (using video cameras) (Perry, 1992).

Gait analyses included the following measurements: step length; cadence (number of steps per minute); velocity (distance per unit of time in a particular direction); swing-stance time, and single or double limb support time (Chen et al., 1991). The gait cycle is divided into two phases: stance phase (the period during which the foot is on the ground) and swing phase (the period during which the foot is in the air) (Perry, 1992). The reported normal interval of time during which the foot is on the floor is 60% for stance and 40% for swing phases (Murray et al., 1964). The single limb support and double stance interval are 40% and 10%, respectively (Perry, 1992). However, the precise duration of these gait cycle intervals varies with a person's walking velocity (Andriacchi, 1977). Gait may be altered due to various factors that restrict joint motion. For example, it may be related to joint abnormalities, quadriceps weakness, osteoarthritic changes and pain (Perry, 1992). Osteoarthritis of the knee often leads to changes in gait and mobility function that affect walking, stair-climbing and activities of daily living (Ouellet & Moffet, 2002). Individuals with osteoarthritis (OA) are reported to have slower walking speed, decreased cadence, shorter step length and shorter single stance phase of the involved leg, when compared to individuals without OA (Berman, Zarro, Bosacco, & Israelite, 1987; Chao, Laughman, & Stauffer, 1980).

Although "one goal of knee replacement is to improve function, that is, gait" (Berman et al., 1987, p. 1340), patients may not achieve a normal walking pattern, post-surgery. Several studies evaluated the gait cycle after knee replacement. For example, Lee, Tsuchida, Kitahara & Moriya (1999) assessed gait variables in 20 individuals, pre- and post-TKR (average age, 68 years), and compared the gait parameters of those with a TKR ($n = 20$) and of a control group ($n = 35$). The mean age of the former groups was 68 years; the mean age of the latter group was 69 years. The authors reported that patients with a TKR one year or more post-surgery, had significantly ($p \leq .05$) slower gait velocity than those in the control group. In addition, step length was shorter, and step width was wider, in those with a TKR, when compared to the control group. Furthermore, single-leg support time was shorter and bilateral support time was longer among their subjects who had a TKR.

In another study, Chen, Cheng, Shang and Wu (1991) examined individuals ($n = 13$) who had a TKR, by using a computerized Vicon motion analysis system and force plates. Results from their gait analysis showed a slower velocity, shorter step-length and reduced cadence in individuals with a TKR (mean age, 64.8 years), when compared to a group of younger, control subjects (mean age, 26.8 years). In addition, participants with a TKR had longer double-limb support time and reduced single-leg support time. One of the drawbacks of the study was that the TKR individuals were not compared to an age-matched control group. It was possible that gait unsteadiness experienced after TKR may have been related to pain and decreased range of motion in the joints (Sinaki et al., 2004), factors that may also be associated with one's ability to shift the foot quickly from gas to brake pedal when driving a vehicle. This study used the Vicon motion analysis system to objectively measure kinematic gait parameters.

Health-Related Quality of Life Measures

Quality of life refers to an overall sense of well-being, with a strong relation to a person's health perceptions and ability to function (O'Sullivan, 2001). It included all aspects of community life that have a direct and great influence on the physical and mental health of people (Centre for Disease Control and Prevention, 2005). Health-related quality of life includes the physical, psychological, and social domains of health that are influenced by an individual's experiences, beliefs, expectations, and perceptions (Irrgang & Anderson, 2002). Health-related quality of life measures are divided into two categories: generic and domain-specific. The focus of domain-specific quality of life instruments is on a primary condition or a population of interest; it is therefore reported to be more responsive to changes in perceptions over time (Guyatt, Feeny and Patrick, 1993). Moreover, domain-specific quality of life instruments are reported to be easier to administer and interpret (McSweeny and Creer, 1995).

Generally, knee surgery is performed to reduce pain and disability and to improve functional ability, mobility, and knee-related quality of life (Marx, 2002). Therefore, an instrument that is used to measure knee-related quality of life should cover such important components as pain, symptoms, the ability to carry on activities of daily living, and one's own perceptions of quality of life. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) is a well validated outcome measure developed to assess pain, stiffness, and physical function in elderly patients with hip or knee OA (Bellamy et al., 1988). It includes three subscales: pain, symptoms, and activities of daily living. The WOMAC is the most frequently used outcome instrument for assessing the effects of patient-relevant treatment associated with osteoarthritis (Roos and Toksvig-Larsen, 2003). For example, Lingard, Katz, Wright and Sledge (2001) conducted a study to compare responsiveness of the Knee Society Clinical Rating Scale (Insall, Dorr, Scott and Scott, 1989) and the WOMAC. Based on the study's results the authors concluded that the WOMAC has high internal consistency and was a responsive outcome measure following TKR.

However, some patients eligible for TKR may have expectations of engaging in more demanding physical functions, such as those required for sports and recreational activities, as well as for daily living (Roos et al., 2002). To address these functions, Roos, Roos, Lohmander, Ekadahl, and Beynnon (1998) developed the Knee Injury and Osteoarthritis Outcome Score (KOOS), that has also been used to assess outcomes after TKR surgery (Roos and Tokswig-Larsen, 2003). The KOOS is a knee-specific questionnaire that includes the WOMAC in its original form, with all subscales (i.e., pain, stiffness and ADL function). Two additional subscales were developed and included in the KOOS questionnaire, knee-related quality of life (QOL) and sports and recreational activities (Roos, Roos, Lohmander, Ekadahl, and Beynnon, 1998).

Garratt, Brealey & Gillespie (2004) studied 16 patient-administered, knee-specific QOL health instruments and compared them according to reliability, validity and responsiveness. All the instruments were identified through literature searches, and the relevant information regarding the instrument content, patient population, reliability, validity and responsiveness was extracted from peer-reviewed, published papers. The authors concluded that the KOOS instrument has good evidence of reliability, responsiveness, and content and construct validity.

Paxton and Fithian (2005) reviewed and evaluated general health instruments in order to identify appropriate measures to examine knee arthroplasty outcomes. The authors considered psychometric properties (i.e., validity, reliability and responsiveness) and practical considerations of various instruments, such as the following: the Short Form-36 (SF 36) (McHorney, Ware, & Raczek, 1993), Short Form-12 (Ware, Kosinski, & Dewey, 2000), and specific knee scales, such as the Knee Society Clinical Rating System (Insall, Dorr, Scott, & Scott, 1989), Knee Outcome Survey (Irrgang et al., 1998), International Knee Documentation Committee scale (Irrgang et al., 2001), WOMAC (Bellamy et al., 1988), and KOOS (Roos et al. , 1998). Based on an extensive review of the literature, the researchers suggest using the SF-36 (as a health-related QOL measure) and the KOOS as a knee-specific quality of life outcome instrument for complete evaluation following knee arthroplasty. In summary, the KOOS is a valid, reliable and responsive instrument for patient-relevant outcomes, following TKR (Roos & Toksvig-

Larsen, 2003) and as such, this instrument was chosen as a knee-specific quality of life outcome measure in this study, for comparing the TKR and No-TKR groups.

Summary of the Literature Review

Many individuals with advanced OA of the knee receive a TKR. It is performed to relieve pain, disability and to restore normal function of the knee joint (Hawker et al., 1998; Chang, Pellissier, and Hazen, 1996)—all of which have an impact on QOL. Whereas a majority of people report improvement following TKR, a substantial number of people may report significant physical and functional impairments following a TKR (Walsh, Woodhouse, Thomas and Finch, 1998). TKR may lead to residual pain and impaired functional capacity (Mizner and Snyder-Mackler, 2005) and may potentially affect an individual's quality of life. Driving a vehicle is an activity valued by many older adults (Ganz, Levin, Peterson and Ranawat, 2003); therefore, driving capability may be regarded as a valued component of quality of life.

The ability to stop a vehicle quickly requires acceptable brake reaction and movement time (Spalding et al., 1994). However, there is limited research examining BRT in individuals after TKR surgery. Moreover, there is no research that focuses on different foot-shifting strategies during a braking response or on the association of foot-shifting strategy with BRT after TKR.

In order to shift one's foot quickly from a gas to a brake pedal, functional ROM in the hip, knee and ankle joint is required. Following TKR, an individual's movement time may be increased, possibly owing to restricted range of motion and residual pain—thus likely affecting the ability to brake quickly. Therefore, in this study, movement time of individuals with and without a right TKR was compared when they used two foot-shifting strategies: a pivot and a lift. In addition to comparing movement time between groups, this study examined relationships between movement time and movement – related variables (e.g., gender, age, body mass index, height, weight, hip, knee ankle joint angles and active range of motion). Furthermore, this study compared the TKR and No-TKR groups on performance-based measures that may be related to movement time, namely hip, knee and ankle joint angles when participants perform the braking action. In addition, the study included a knee specific quality of life measure and performance based measures that have been used in previous TKR studies (e.g., active range of motion (AROM), the Timed Up and Go test (TUG), gait parameters) and a foot tap test.

Objectives

The purpose of this study was to examine any potential differences in driving-related functional performance measures and in one quality of life measure between two groups of individuals: those with a right TKR (TKR group) and those without a right TKR (No-TKR group). This study had the following five, major objectives:

1. To examine between-group differences in movement time for each foot-shifting strategy (a lift and a pivot).
2. To examine between-group differences in hip, knee and ankle joint angles and range of motion using the VMAS.
3. To investigate between-group differences in functional performance measures using the Timed Up and Go test, the foot tap test, active range of motion measured by a universal goniometer, and three gait parameters, step-length, cadence and gait speed.
4. To examine between-group differences in quality of life with the knee-specific KOOS scale.
5. To examine associations (i.e., correlations) between movement time, VMAS hip, knee, and ankle joint angles and range of motion, the five subscales of the knee-specific KOOS scale, and functional performance measures (TUG, tap test, AROM and gait parameters).

Hypotheses

In relation to objectives 1-4, it was hypothesized that:

A. Individuals <u>with</u> a right TKR (TKR group) compared to those <u>without</u> a TKR (No-TKR group) will demonstrate:

1. Longer movement time when shifting from the gas to brake switch (i.e., individuals with TKR will be slower)
2. Reduced total ROM, flexion-directed movement and extension-directed movement at the right knee joint when shifting the right foot from gas to brake switch (as measured by VMAS)
3. Decreased AROM in the right hip, knee, and ankle joint
4. Longer time to complete the Timed Up and Go test
5. Decreased number of taps in the foot tap test
6. Decreased gait speed, cadence (i.e., number of steps in one minute) and step-length in the right leg
7. Individuals with TKR will report more pain, more symptoms, reduced quality of life, more difficulties in function in activities of daily living, and reduced function in sports and recreational activities.

In relation to Objective 5, it was hypothesized that:

A. 1. Longer movement time will be significantly associated with more restricted joint angles and range of motion as measured by VMAS

2. Longer movement time will be significantly associated with reports of more pain, symptoms, more difficulties with ADL, more problems with function in sports and recreational activities, and lower QOL as measured by the KOOS subscales

3. Longer movement time will be significantly associated with more restricted active range of motion (measured by goniometer)
4. Longer movement time will be significantly associated with fewer number of taps in the foot tap test
5. Longer movement time will be significantly associated with slower right leg gait speed, fewer steps per minute (cadence) and shorter step length
6. Longer movement time will be significantly associated with longer time to complete the Timed Up and Go test and fewer taps in the foot tap test.

Clinical Relevance

This study extends the existing literature regarding the assessment of brake response time and movement time in individuals following TKR surgery. It does so by including two different foot-shifting strategies, by examining functional performance measures that may be related to movement time, and by assessing domain-specific, TKR-related quality of life. No previous studies examined braking movement time when considering different foot-shifting strategies. The information from this study may help to improve understanding of any potential differences in driving-related leg function in individuals with and without a right TKR. As a result, this study may also provide direction for the development of a rehabilitation program, specifically designed to assess and improve leg function following TKR and in relation to the safe operation of a motor vehicle (especially regarding specific movements associated with braking). For example, the foot tap test used in this study simulates the movement used when shifting between the gas and brake pedal and future research may examine the psychometric properties of this particular test as both an outcome measure and a rehabilitation exercise.

Limitations

This is a laboratory-based study and accordingly, it has several limitations:

1. The simulated gas and brake pedal/switches that were attached to the Lafayette timer apparatus and used to record movement time were not equivalent to the devices used for an actual driving situation. In the laboratory setting, these switches were attached to a board. The participant sat in front of the switches on an ordinary chair (not a car seat), which had the centre of the back removed. This was done to be able to capture the VMAS markers placed on the posterior superior iliac spine (bilaterally). In addition, there was no

steering wheel in front of the participants that would help them to stabilize their body while shifting the right foot, thereby possibly influencing movement time. Instead, the participant was told to hold onto the side to the chair seat to keep the arms from blocking the capture of the markers placed on the anterior superior iliac spines (see Figure 2, showing the participant seated in front of the red light stimulus).

2. There was some predictability about responding to the red light stimulus as participants were anticipating the red light to go on for the testing procedure. In contrast, in a real driving situation, braking is often a response to an unanticipated event.

3. The participants were allowed to use one, two or three wooden boards (height 1.5 cm each) under their right foot, if they had difficulty reaching the switches while shifting from gas to brake switch. This tended to occur with individuals of short stature. This might have led to some discrepancy in recorded joint angles when participants shifted their right foot from gas to brake switch.

4. Control group participants were not asked to report if they had any knee-related problems, such as osteoarthritis. Pre-existing right knee problems in this group may potentially cause slower movement time and thus may have influenced study results.

5. Some participants in the TKR group voluntarily reported that they also had a left knee replacement. However, this information was not systematically documented for all participants.

Methods

Participant Recruitment/Screening

This was a cross-sectional study and included community-dwelling adults, aged 60 years and older. Ethical approval for the study was received from the University of Manitoba, Bannatyne Campus Health Research Ethics Board. Data for this thesis were collected during the larger research study outlined in the ethics approval document and in the participant information and consent form (see Appendix A). Several strategies were used for participant recruitment. Posters (see Appendix B) were placed at various hospital physiotherapy departments, senior's apartment buildings and senior centres. A notice about the study was also placed in the "Growing Older" column of the Winnipeg Free Press, and a notice was placed in the Seniors' Resource Network website (www.seniors.cimnet.ca). All posters and notices asked individuals to contact the principal investigator, Dr. Weinberg, if they were interested in participating in the study.

All those who contacted Dr. Weinberg by phone or e-mail received a follow-up telephone call from the research assistant who screened each person over the phone to determine if she or he met the eligibility criteria (See Appendix C for screening instrument).Those who expressed interest in participating in the study and who were eligible for participation received by mail a written "Participant Information and Consent Form", which described the study and the activities that each participant was asked to complete in the study (see Appendix A), as well as a driving questionnaire (not included in this thesis but which is included in other aspects of the larger study).

Participants were phoned a second time by the research assistant, 3-5 days after the package was mailed, in order to determine the following: if the individual received the information package, if he or she had a chance to review the information, and to discuss any questions he or she had in relation to the study. At this time, two appointments were also scheduled for those who agreed to participate.

The first appointment lasted on average two hours and the second appointment lasted approximately one hour. Both appointments were held at the School of Medical Rehabilitation, on the 3rd floor of the Rehabilitation Hospital. Appointment one took place in Dr. Weinberg's Aging, Social Cognition, and Rehabilitation Laboratory, and appointment two in Dr. Shay's Pain Research Laboratory where the Vicon apparatus is housed. All the participants were requested to bring a pair of (tight) shorts and walking shoes for both appointments.

Eligibility Criteria

Individuals were eligible to participate in the Knee Replacement Study if they met the following inclusion criteria:

1. Aged 60 years or older
2. English speaking
3. Regular drivers (people who drive at least once per week)
4. Ambulatory (with or without assistive devices)
5. Mini Mental State Examination (MMSE) score of > 24. The Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975) is a brief standardized screening test of cognition. It assesses orientation, attention, immediate and short-term recall, language, and ability to follow verbal and written commands. The cut-off score for normal cognition is 24/30 (Folstein, Folstein, & McHugh, 1975). The MMSE was used to

screen participants for their ability to follow instructions for the various tasks performed in the study.

6. For the TKR group, individuals who had a right TKR three months to one year prior to the date of participation in the study.

Measures

Equipment Description

Lafayette Reaction and Movement timer

Movement time was recorded using the Lafayette Reaction and Movement timer (Model Number 63017) (see Figure 1 on page 36). The apparatus consisted of the timer recording system, a visual stimulus box, and the gas/brake foot switches. The Lafayette Reaction and Movement timer has two digital clock timers that measure reaction time and total movement time in seconds. An operator controls the timing of the visual stimulus box and records the time as registered on the two digital clocks. The first digital clock (shown in Figure 1 on the left) shows reaction time, that is, the time taken to lift the foot off the gas switch after the red light visual stimulus is turned on. The second clock on the right shows the total movement time (i.e., the sum of reaction time and movement time). The time taken to shift the foot from gas to brake switch and to depress it fully is called movement time. The movement time used for this study was calculated by subtracting reaction time from the total movement time (i.e., Movement Time = Total Movement Time – Reaction Time). The total movement time is referred to as brake reaction/response time in some studies.

Two switches, one for the gas and one for the brake were fixed on a wooden board (for dimensions, see Table 1 on page 35). The switches were attached to the movement timer machine. A chair was placed on the wooden board (height from floor to top of seat was 18 inches) and participants were seated on this chair during the trials. The chair did not have any armrests and the back of the chair was removed, so that the visibility of the reflective markers used with the motion analysis system was not restricted (see Figure 2 on page 36). Participants were asked to place the chair at a distance from the switches, according to their comfort level. For each participant, the distance between the switches and the front legs of the chair was recorded.

The movement timer was attached to a visual stimulus box that was placed at a height of 68 cm (see Figure 2). The visual stimulus box had two small lights: one red and one white. The white light was turned on as the movement time operator started the trial and turned off automatically after one second. This white light was designed so that the participant could prepare himself/herself for the trial. The white light on the visual stimulus box was shielded using a 2 cm long cardboard, to avoid interference with the VMAS.

The red light appeared on the visual stimulus box after the white light was displayed. The delay time between the white and red light was controlled by the operator and was designed to make the red light response less predictable. In other words, to avoid a learning effect, the time delay between white and red light changed before each trial and was sequenced as 1, 2, 3, 2, 1, 1, 2, 3 (and so on) seconds. There was a rest period of approximately 30 seconds to one minute between the trials, in order to reduce fatigue. The protocol for recording the movement time is described in the section "Appointment Two."

***Table 1.* Configuration of wooden board and gas/brake switches**

Width of wooden board = 30 inches
Length of wooden board = 50 inches
Distance between the base of the gas and brake switches = 3.5 inches
Angle of inclination of gas switch = 30°
Angle of inclination of brake switch =30°
Height of gas switch = 5.2 inches
Height of brake switch = 6 inches

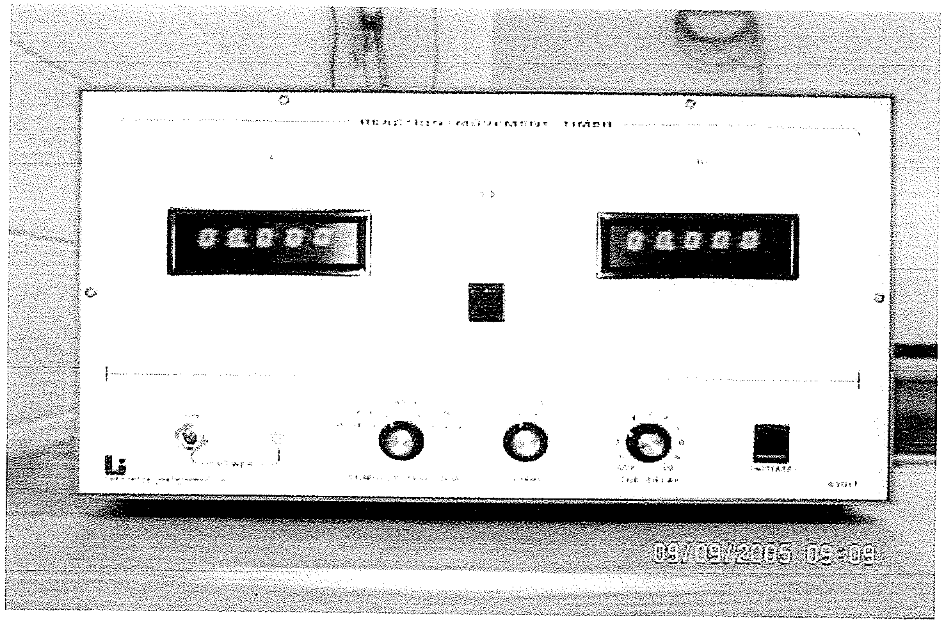

Figure 1. **Lafayette Reaction/Movement Timer**
Note: Digital clocks A (on the left) and B (on the right) record the reaction and total movement time, respectively. The circular control on the bottom (right) is used to adjust the time interval between the white and red light.

Figure 2. **Experimental set up showing the visual stimulus box**
Note: The back of the chair was open in order to display markers for the Vicon Motion Analysis System. The red light on the visual stimulus box is on.

Figure 3. **Experimental set up showing the gas switch**
Note: The gas switch is on the right and the brake switch is on the left of the board. The participant's right foot is on the gas switch and his hands are holding onto the side of the chair. The timing operator is seated in front of the Lafayetter movement timer. Two of the Vicon motion analysis cameras are in the top of the picture.

Vicon Motion Analysis System (VMAS)

The Vicon 460 Motion Analysis System was used first to record gait, and, second, to record the right hip, knee, and ankle joint angles and range of motion when participants moved their right leg from the gas to the brake switch in response to the red light stimulus, attached to the Lafayette reaction and movement timer. The Vicon 460 (Vicon Motion Systems Inc., Lake Forest, CA) is designed to perform three-dimensional motion analysis. The Vicon Motion Analysis System (VMAS) used in this study consisted of six cameras, a software station, and the software program that controls the cameras and computes the captured data. Each camera of the VMAS is surrounded by a ring of Light Emitting Diode (LED) lights. A number of reflective markers were attached to the specific anatomical landmarks on the individual whose motion/movement was recorded. When an individual moved in the designated recording area (about 8 feet long and 3 feet wide), termed, the 'capture volume,' light from the LED reflected back from the reflective markers to the camera lens. The cameras recorded at the frequency of 120 Hz. A video signal was created by using the information from the markers, and the signal was sent to the computer software for analysis.

Certain anthropometric body measurements were also entered into the computer in advance of recording the movement, in order for the system to be able to calculate and establish joint coordinates, angles, range of motion, and to produce an animated or moving stick figure on the computer screen. The measurements recorded in the computer include height, weight, knee-width, ankle-width, and leg-length. As noted, the computer software converted the raw information from the cameras into a three-dimensional figure on the computer screen, and this figure was used to check if all the reflective markers were captured at each trial. If all markers were not captured, then adjustments to the markers were made and the system was re-checked. After the conversion, the data was saved as an ASCII file, and then further joint analysis was performed by transferring the information to the Sigma Plot statistical package.

In order to identify and label lower-limb joints, the reflective markers were attached to pre-defined anatomical points. For this study, the markers were applied bilaterally to the lower limbs at the following anatomical locations:

1. Anterior Superior Iliac Spine

2. Posterior Superior Iliac Spine

3. Lateral middle aspect of thigh
4. Lateral epicondyle of femur
5. Lateral aspect of shin
6. Lateral malleolus
7. Back of the heel
8. Base of second metatarsal.

The markers on the right shin and thigh were placed higher than the left side, so that the left and right side could be distinguished easily, as recommended in the Vicon instruction manual. Double-sided tape was used to stick the reflective markers to the anatomical landmarks. The participants were wearing tight-fitting shorts and shoes for all the trials so that the markers did not shift about on the clothes or on shoes when performing the braking task.

The intention was to use the Vicon motion analysis system for both gait analysis and for calculation of joint angles and joint range of motion in the seated position during recording of reaction time/movement time. However, after examining the Vicon data it was evident that the data was not reliable and/or valid for the reaction time/movement time procedure. Accordingly, analysis of the Vicon data for reaction time/movement time could not be included in these analyses.

Gonimeter

Active Range of Motion was measured using a universal goniometer. Each participant's active hip flexion and extension, knee flexion and extension, and ankle plantarflexion and dorsiflexion joint range of motion were recorded. All the range of motion measurements were recorded in accordance with Clarkson (2000). The participants were asked to perform each movement only once. The positions used for the measurement of ROM are described as follows:

1. Hip Flexion: Each participant was positioned in a supine position, lying with knees extended and hips at 0° abduction, adduction and rotation. The pelvis was stabilized to prevent posterior tilting or rotation of pelvis. The participant was instructed to actively flex his/her hip by lifting the thigh off the plinth and was allowed to bend the knee joint to reduce tension in the hamstring muscles.

Goniometer Alignment: The fulcrum of the goniometer was placed over the lateral aspect of hip joint, and the greater trochanter of the femur was used as the reference point. The proximal arm of the goniometer was aligned with the lateral midline of the pelvis, and the distal arm was aligned with the lateral midline of the femur, using the lateral epicondyle as reference.

2. Hip Extension: The participant was instructed to lie in a prone position and both knees were placed in an extended position. The pelvis was stabilized to avoid any rotation of the pelvis. The participant was asked to extend the hip joint by raising the lower extremity from the table. The knee was maintained in extension throughout the movement.

Goniometer Alignment: The fulcrum of the goniometer was centered over the lateral aspect of hip joint, using the greater trochanter of the femur for reference. The proximal or the stationary arm was aligned with the lateral midline of the pelvis. The distal arm of the goniometer was aligned with the lateral midline of the femur.

3. Knee Flexion/Extension: The participant was lying in a supine position on the plynth, with the knee joint in full extension and hips in 0° abduction, adduction and rotation. The participant's thigh was stabilized by the therapist's hand to prevent rotation, abduction and adduction of the hip. The participant was asked to bend the knee joint to the end range for flexion and extend the knee joint for AROM in extension.

Goniometer Alignment: The fulcrum of the goniometer was placed over the lateral epicondyle of the femur. The proximal arm was aligned with the lateral midline of the femur, using the greater trochanter for reference and the distal arm was aligned with the lateral midline of the fibula.

4. Ankle Dorsiflexion/Plantarflexion: The participant was placed in a supine position with the ankle off the edge of the treatment table. The foot was maintained in 0° of inversion and eversion. The leg was stabilized manually by the examiner to prevent knee motion and hip rotation. The participant was instructed to pull the foot upwards for dorsiflexion and downwards for plantarflexion.

Goniometer Alignment: The goniometer was placed over the lateral aspect of the lateral malleolus. The proximal arm of the goniometer was aligned with lateral midline of the fibula and the distal arm was aligned parallel to the lateral aspect of fifth metatarsal.

Timed Up and Go test

The Timed Up and Go test (Podsiadlo & Richardson, 1991) has been used as an outcome measure in studies examining function and mobility in people who have received a TKR. To measure the TUG, a standard armchair (seat height, 18 inches) was used. Participants were allowed to use a walking aid, if desired. Participants were instructed to complete the test as quickly as possible but at a safe and comfortable pace.

They were instructed that on the word 'go,' they were to get up from the chair, walk a distance of 3 meters, turn around, and walk back to the chair and return to a sitting position. The point at the distance of three meters was marked using a bright colored marking/tape on the floor. The time for each trial was recorded using a stopwatch. Each person was timed from the time they were given the verbal cue (i.e., 'go') until they returned back to the chair and were seated again. Participants were asked to perform the test twice, with a rest period of approximately one minute between trials. The fastest test trial (i.e., the trial in which the participant used the shortest time period to complete the TUG) was used for analysis purposes.

Foot tap test

The foot tap test (Staplin et al., 2003) simulates the movement one would use when shifting from a gas to a brake pedal. The participant was seated on a chair with a book (twelve inches long, eight inches wide and three inches in height) placed on the floor between the feet. Participants were then instructed to move the left foot under the chair so that it did not interfere with the movement of the right foot. Participants were instructed to use their right foot to tap the floor (with the whole foot) on each side of the book as quickly as possible on hearing the word 'go.' The number of taps completed in ten seconds was recorded. Participants were asked to perform the foot tap test once.

Knee Injury and Osteoarthritis Outcome Score

The Knee Injury and Osteoarthritis Outcome Score (KOOS) is a 42 item, domain-specific, quality of life instrument consisting of five subscales (Roos et al., 1998). All questions refer to experiences during the "last" week. The first subscale, called symptoms (7 questions) asks about knee symptoms such as swelling, grinding or clicking, ability to straighten and bend the knee, and knee stiffness. The pain subscale (9 questions) includes questions about amount of knee pain experienced during different knee movements, walking on a flat surface, going up or down stairs, lying in bed or sitting in a chair, and when standing. Function in daily living (17 questions) asks about the degree of difficulty experienced when going up and own stairs, rising from sitting, standing, bending to floor, walking on a flat surface, getting in and out of a car, shopping, putting on socks/stockings, rising from bed, moving in bed, getting in/out of bath and getting on/off a toilet, and heavy and light domestic activities. Function in sport and recreational activities (5 questions) asks the degree of difficulty when squatting, running, jumping, twisting/pivoting, and kneeling. The quality of life subscale (4 questions) asks how often the person is aware of the knee problem, modification of lifestyle to avoid activities that would be potentially damaging to the knee, and general difficulty with the (TKR) knee. A Likert scale is used for each question that ranges from 0 (no problems) to 4 (extreme problems). Each subscale is analyzed and scored separately.

The score of all the items in each subscale is added and transformed to a 0-100 scale, with zero representing extreme knee problems and 100 representing no knee problems. Roos et al. (1998) suggest that missing values in each subscale can be substituted with the average value for the specific dimension but if more than two items are missing, the score should be considered invalid for that particular subscale, for that individual. The formula used to convert the raw score of the subscale to the 0 – 100 scale is:

$$\text{Transformed scale} = \frac{100 - \text{Actual raw score} \times 100}{\text{Possible raw score range}}$$

Data Collection - Appointment Protocols

A detailed and chronological description of the protocol for each appointment is outlined below:

Appointment 1

1. Participant information and consent form for the study was discussed and signed.
2. The Driving-related questionnaire was reviewed and completed (not a part of this thesis, as noted).
3. The Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975) was administered to assess cognitive status.
4. The KOOS scale (Roos et al., 1998) was administered as a face-to-face interview.
5. Bilateral AROM of hip flexion and extension, knee flexion and extension, and ankle plantarflexion and dorsiflexion were measured using a universal goniometer.
6. The Timed Up and Go (Podsiadlo & Richardson, 1991) test was administered.
7. The foot tap test was conducted.
8. A computerized driving test, developed by the American Automobile Association, was administered.

Appointment 2

At the time of the second appointment, the Lafayette movement timer was used to record the brake response time and the Vicon Motion Analysis System (VMAS) was used to record the gait cycle, and hip, knee, and ankle joint angles and joint range of motion during the simulated braking strategies (a lift or a pivot). The sequence of events is outlined below:

1. The participant changed into shorts.

2. The individual's height, weight, bilateral knee and ankle width, and leg length were measured. Height was measured with a yardstick fixed to the wall. Weight was measured using a digital weighing scale and leg length was measured manually using a measuring tape. All measures were entered into the computer.

3. Next, reflective markers were placed on the following anatomical landmarks: anterior superior iliac spines; posterior superior iliac spines; lateral lower one-third thigh; lateral epicondyle of femur; lateral lower one third shank of tibia; lateral malleolus; posterior side calcaneous; and head of second metatarsal bone.

4. Before starting the gait cycle trials, a static trial was captured to check if the cameras captured the markers, and to label the markers in the computer software.

5. The gait cycle was then recorded. Each participant was asked to walk for a distance of 6 meters at his/her usual walking speed along a marked pathway. One practice trial and three regular trials were recorded. The average of the three regular trials was used for data analysis.

Simulated braking activity

The next set of activities involved the simulated braking activity as follows:

1. Each participant was instructed to sit on the chair placed on the board where the gas and brake switches were attached (see Figure 3). When the participant was seated, in addition to the Vicon reflective markers that were still attached to the same anatomical locations, electromyography (EMG) surface electrodes were placed over the vastus lateralis, lateral gastrocnemius, and tibialis anterior. Thus, EMG recordings were simultaneous with the Lafayette timer and Vicon recordings. Please note that EMG analysis is not included in this thesis.

2. Before the movement trials started, a static VMAS trial was recorded in the sitting position to check if the cameras captured the markers in this position, and to label the markers in the computer software. The markers were readjusted, if required, and the static trial repeated as necessary.

3. Before the beginning of the trials, each participant was asked which strategy they used while shifting from gas to brake pedal in his/her own vehicle: a lift or a pivot strategy. This strategy was called 'the preferred or usual strategy' and the strategy that was not usually employed was called 'the alternate' or 'alternative strategy'. The 'preferred shifting strategy' was used first during trials, followed by the 'alternative strategy.' Thus, the 'preferred' and 'alternative strategy' could be either a lift or a pivot. In this study, a lift was defined as the movement of the right foot from gas to brake switch, with the heel lifted from the ground during the movement. A pivot was defined as the right foot pivoting from gas to brake switch, without lifting the heel from the ground.

4. The participant was allowed to adjust the distance from the chair to the switches according to their comfort level. If the participant had difficulty reaching the switches, he/she was allowed to use (one, two or three) wooden boards under his/her feet (each 1.5 cm high) to maintain a comfortable foot position.

5. Participants were instructed to shift the right foot as quickly as possible from gas to brake switch upon seeing the red light (see Figure 2). The time, measured in seconds, was recorded on the Lafayette apparatus. The VMAS was activated simultaneously to record the movement while the participant performed the procedure.

6. Five practice trials and ten regular trials were recorded for the usual or preferred foot shifting strategy; next, three practice trials and ten regular trials were recorded for the

alternative foot shifting strategy. The period between the trials varied from approximately 30 seconds to two minutes while the VMAS computer was reset to record the next trial or markers adjusted as needed. The three fastest movement time trials were used for data analysis.

Data Management

1. Movement time: The reaction time and total movement time of each trial were recorded from the Lafayette movement timer. Movement time (i.e., time taken to shift the foot from the gas to brake switch and depress it) was calculated by subtracting the reaction time from the total movement time. The mean of three fastest trials for each of the preferred and alternative braking strategies was used for statistical analysis.

2. Gait analysis: The Vicon 460 Motion Analysis System (Vicon Motion Systems Inc., Lake Forest, CA) automatically computed gait speed, cadence (number of steps per minute) and step length of the right leg. The mean of the three regular walking trials was calculated using SPSS (Version 12) and used for subsequent analysis.

Statistical Analysis

Statistical analysis was performed using SPSS Version 12.0 and Version 15.0 (Basic) for Windows. Results have been divided into preliminary and main analyses. Preliminary analyses include descriptive statistics and sample characteristics (see Tables 2 and 3). Preliminary analysis was conducted that compared characteristics by group (TKR and No-TKR) and by gender (male/female) using t-tests for continuous variables. Preliminary analyses also included between group analyses of KOOS scales, active range of motion, gait characteristics, and performance measures of the TUG and tap test and correlation analyses.

The main analyses focused on movement time. Between group analyses using t-tests are presented first. Two-way ANCOVA was employed to examine gender and group differences in preferred and alternate movement time while controlling for age. Regression analyses was used to examine determinants of preferred and alternate movement time. The regression models included TKR (dummy coded no = 0, yes = 1), gender, age, height, weight, BMI, ADL –KOOS scale. The final model included TKR, ADL, and height.

Results

Preliminary analysis

A total of 39 individuals participated in the Knee Replacement Study; 17 were in the TKR group and 22 in the No-TKR group. One outlier (person) was removed from the analysis due to extreme scores in movement time leaving a total of 38 persons included in the analyses. Preliminary analyses were conducted to determine if there were preexisting differences between the two groups. Using alpha = .05 there were no significant between group differences in age, or height. The mean MMSE score for the TKR group and the No-TKR group was 28.69/30 and 29.64/30 respectively. Although this difference was significant both groups were well within the normal range and above the cut-off score of ≤ 24 for cognitive impairment. The average age of the participants (n = 39) was 70.6 years (range, 60-86 years); the mean age of participants in the TKR group was 72.1 years (range, 60-83) and 69.4 years (range, 60-86) in the No-TKR group (see Table 2). There were nine females in the TKR group and fourteen females in the No-TKR group; eight males were in each group. Chi square analysis revealed no significant gender differences between the two groups. There was a significant between group differences in weight and BMI. Individuals with a TKR weighed, on average, 14.2% more than those in the control group and had a BMI 16.8% higher than No-TKR participants (see Table2).

Between-gender analysis revealed a significant difference in height; men were on average taller than women (see Table 3). In the TKR group men were 176 cm (SD 5.5 cm) and women 162.1 (SD 4.4 cm); within the No-TKR group men were 177.2 cm (SD 7.9 cm) and women 166.6 cm (SD 8.3 cm).

Table 2. **Means and standard deviations of participant characteristics by group**

	No-TKR (n = 22)		*TKR (n = 17)*	
	Mean	SD	Mean	SD
Age (years)	69.4	6.6	72.1	7.2
Height (cm)	170.48	9.51	167.81	8.14
Weight (kg)	76.41	14.07	87.90	12.60**
Body Mass Index (BMI) (kg/m^2)	26.35	4.82	31.44	5.67**

Note: ** = p≤ .01 SD = Standard Deviation

Table 3. **Means and standard deviations of participant characteristics by gender**

	Males (n = 15)		*Females (n = 23)*	
	Mean	SD	Mean	SD
Age (years)	73.13	6.97	68.52	6.30*
Height (cm)	176.23	6.71	164.87	7.25**
Weight (kg)	83.73	11.82	79.62	16.04
Body Mass Index (BMI) (kg/m^2)	26.95	3.43	29.50	6.75

Note: * = p≤ .05 ** = p≤ .01 SD = Standard Deviation

The KOOS Scale: between-group analyses

The KOOS scale consists of five subscales: 1) symptoms; 2) pain; 3) function in daily living or ADL; 4) function in sports and recreational activities; and 5) QOL (Roos et al., 1998). The score for each subscale was calculated according to the user's guide for the KOOS scale (www.koos.nu). All the participants were asked to answer the questions in the KOOS scale with respect to their right leg only. Significant between-group differences exist for one subscale: the symptom subscale (see Table 4). Participants with a TKR (mean score = 76.9/100) reported significantly more symptoms compared to the

No-TKR group (mean score = 85.1/100) indicating that individuals with a TKR reported 10.1% more symptoms (e.g., swelling, stiffness, etc.) when compared to the No-TKR group. Overall, there was a tendency for those with a TKR to have lower scores in all the KOOS subscales (see Table 4); the lower the score the more problems or difficulties. The results are based on 38 participants.

In the function in sports and recreation activities subscale, only 27 participants answered all the questions. Participants stated they were not performing the activities that are listed in the sports and recreational activities scale (e.g., running, kneeling, jumping and twisting). Cronbach's alpha was calculated for each subscale (see Table 4) to determine if Chronbach's alpha for this sample was similar to reported values. The values of Cronbach's alpha for each subscale were acceptable based on previous research.

Table 4. **Means and standard deviations of KOOS subscales by group**

KOOS subscales	*Cronbach's Alpha*	*No-TKR*		*TKR*	
		Mean	SD	Mean	SD
Pain (n = 38)	.906	89.3	15.8	80.5	13.1
Symptoms (n = 38)	.629	85.1	14.6	75.9	12.5*
ADL (n = 38)	.944	88.1	17.1	83.6	9.6
QOL (n = 38)	.824	71.3	24.9	60.9	14.9
Sports & Recreation (n =27)	.946	77.4	29.8	63.1	25.2

Note: * = p≤.05 ADL = Activity of Daily Living QOL = Quality of Life
Score of 100 = No Problems Score of 0 = Extreme Problems SD = Standard Deviation

Active Range of Motion: between-group analyses

AROM was examined using a universal goniometer. The two groups were compared for right hip flexion and extension, knee flexion and extension, and ankle plantarflexion and dorsiflexion. There were significant between-group differences in AROM of the right leg. Specifically, the TKR group had reduced AROM in hip flexion and extension, knee flexion, and ankle dorsiflexion when compared to the control group (see Table 5).

Table 5. **Means and standard deviations of AROM by group (n = 38)**

Active Range of Motion (AROM) in degrees	*No-TKR (n = 22)*		*TKR (n = 16)*	
	Mean	SD	Mean	SD
Right Hip Flexion	117.2	6.3	108.9	9.2**
Right Hip Extension	17.9	3.6	12.6	4.5**
Right Knee Flexion	122.8	9.5	110.9	7.0**
Right Knee Extension	0.7	1.8	1.9	3.8
Right Ankle Dorsiflexion	13.1	1.7	11.8	1.8**
Right Ankle Plantarflexion	46.9	5.1	48.1	6.8

Note: ** = $p \leq .01$ SD = Standard Deviation

Gait analysis: between-group analyses

The results of kinematic gait analysis revealed that participants with a TKR had significantly shorter step-length when compared to the No-TKR group (Table 6). There was no significant difference in cadence or walking speed between groups.

Table 6. **Means and standard deviations of gait parameters by group (n = 38)**

Gait Parameters	*No-TKR (n = 22)*		*TKR (n = 16)*	
	Mean	SD	Mean	SD
Right walking speed (m/s)	1.24	.22	1.11	.21
Right cadence (steps/min)	110.90	8.50	109.25	10.98
Right step length (m)	.68	.16	.62	.08*

Note: * = $p \leq .05$ SD = Standard Deviation m/s = Meters per second m = Meters min = Minute

TUG and foot tap test: between-group statistical analyses

The groups were compared using two performance measures, the TUG test (Podsiadlo and Richardson, 1991) and the foot tap test (Nguyen et al., 2000; Staplin et al., 2003) (see Table 7). Participants in the TKR group took significantly more time to complete the TUG when compared to the No-TKR group (see Table 7). Specifically, individuals with a TKR took 23.5% more time than individuals without a TKR to complete the TUG. With respect to the foot tap test, there was no significant difference between groups although the No-TKR group achieved a greater number of taps compared to the TKR group.

Table 7. **Means and standard deviations of foot tap test and TUG test by group**

	No-TKR (n = 22)		*TKR (n =16)*	
	Mean	SD	Mean	SD
Foot tap test (taps/second)	10.7	2.4	9.8	1.8
TUG test (seconds)	6.1	2.0	7.6	1.8*

Note: * = p≤.05 SD = Standard Deviation

Correlation analyses

Correlation analyses were conducted to examine potential relationships between movement time and key variables. The summary tables of significant correlation analyses are presented in Tables 8 and 9 for preferred movement time and alternative movement time respectively. Significant associations revealed that preferred movement time was moderately correlated with gender (being female), height (being shorter), greater BMI, having more ADL difficulties (KOOS ADL scale), longer time in performing the TUG, and performing fewer taps in the tap test. In addition, longer movement time was moderately associated with slower right leg walking speed and shorter step length and moderately strongly associated with preferred (longer) reaction time and strongly correlated with longer pivot preferred movement time.

Similarly, alternate movement time (see Table 9) was moderately correlated with gender (being female), height (being shorter) having more ADL (KOOS) right leg difficulties, longer time in performing the TUG, and performing fewer taps in the foot tap test. In addition alternative movement time was perfectly correlated with alternative pivot and lift movement times. In other words, slower pivot and lift movement time was associated with the alternative foot shifting strategy. Longer alternative movement time was also moderately associated with slower walking speed and shorter step length.

Examination of KOOS subscales revealed that all subscale were moderately to moderately strongly correlated (see Table 10). Thus, having less pain was associated with reporting fewer symptoms, better ADL function, higher quality of life, and better function in sports and recreational activities. Moreover, reporting more pain was associated with a longer TUG time whereas reports of less pain was associated with better cadence, walking speed, and step length, and greater AROM in the knee. Similar results emerged for the symptoms subscale, but in addition, reporting less symptoms was associated with better performance in the tap test and reporting more symptoms was associated with having a TKR. Reporting fewer ADL difficulties was significantly associated with better tap test performance, faster gait speed, longer step length, greater AROM in hip and knee flexion whereas having more ADL difficulties was associated with longer TUG time. Reporting better quality of life was associated with better walking speed and greater step length and AROM of the knee and reporting better function in sports and recreation was associated with faster walking speed and greater knee and ankle dorsiflexion.

Table 8. **Correlations between preferred movement time and selected variables [1](n =38)**

Measures	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1. PMT	--													
2. Age	-.16	--												
3. Gender	.39*	-.33*	--											
4. Height	-.45**	.18	-.63**	--										
5. Weight	.12	-.17	-.14	.15	--									
6. BMI	.35*	-.25	.22	-.42**	.84**	--								
7. ADL	-.39*	.27	-.12	.21	-.49**	-.55**	--							
8. TUG	.37*	.21	.09	-.25	.41*	.48**	-.42**	--						
9. Tap test	-.39*	-.05	-.14	.22	-.29	-.35*	.50**	-.61**	--					
10. TKR	.14	.17	-.08	-.15	.40*	.44**	-.16	.36*	-.22	--				
11. PPMT	.99**	-.45*	.62**	-.58**	-.03	.34	-.30	.09	-.31	-.08	--			
12.PRT	.52**	.01	.07	-.19	.09	.17	-.47**	.50**	-.43	.40	.30	--		
13. Speed	-.42**	-.13	-.08	.30	-.31	-.42**	.51**	-.79**	.57**	-.29	.21	-.57**	--	
14. SL	-.40*	-.18	-.26	.45**	-.26	.46**	.27	-.69**	.54**	-.33*	-.31	-.38*	.84**	--

Note: *p ≤.05 **p≤.01 [1](n = 38 except n= 20 for PPMT)

BMI = Body mass index
TKR = Total knee replacement
Speed = Right Gait Speed
ADL = Activities of daily living (KOOS)
PPMT = Pivot preferred movement time (n = 20)
SL = Right Step Length
PMT = Preferred movement time
TUG = Timed Up and Go
PRT = Preferred reaction time

***Table 9.* Correlations between alternate movement time and selected variables [1] (n =38)**

Measures	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1. AMT	--														
2. Age	-.14	--													
3. Gender	.37	-.33*	--												
4. Height	-.44**	.18	-.63**	--											
5. Weight	.18	-.17	-.14	.15	--										
6. BMI	.41*	-.25	.22	-.42**	.84**	--									
7. ADL	-.55**	.27	-.12	.21	-.49**	-.55**	--								
8.TUG	.41*	.21	.09	-.25	.41*	.48**	-.42**	--							
9. Tap test	-.37*	-.05	-.14	.22	-.29	-.35*	.50**	-.61**	--						
10. TKR	.21	.17	-.08	-.15	.40*	.44**	-.16	.36*	-.22	--					
11. ART	.25	.08	-.13	-.08	.25	.26	-.23	.29	-.20	.03	--				
12.APMT	1.0**	-.02	.14	-.44	.53*	.61**	-.66**	.49*	-.39	.30	.65**	--			
13.ALMT	1.0**	-.28	.55**	-.41	-.03	.25	-.27	.21	-.31	.25	[2]	[3]	--		
14. Speed	-.48**	-.13	-.08	.30	-.31	-.42**	.51**	-.79**	.54**	-.29	-.26	-.62**	-.20	--	
15. SL	-.50**	-.18	-.26	.45**	-.26	.46**	.46**	-.69**	-.33*	-.33*	-.16	-.68*	-.32	.84**	--

Note: *p ≤.05 **p≤.01
BM I= Body mass index
TKR = Total knee replacement
(n=18)
(n=20)

[1](n = 38 except n= 18 for APMT, n=20 for ALMT)
ADL=Activities of daily living (KOOS)
Speed = Right Gait Speed
ART = Alternate reaction time
SL = Right Step Length

AMT= Alternate movement time
TUG = Timed Up and Go
APMT = Pivot alternate movement time
ALMT = Alternate lift movement time
AMT = Alternate movement time

***Table 10.* Correlations between KOOS subscales and selected variables[1] (n =38)**

Measures	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1. Pain	--													
2. Symp	.65**	--												
3. ADL	.57**	.72**	--											
4. QOL	.51**	.66**	.77**	--										
5. Sports	.43*	.59**	.72**	.69**	--									
6. TKR	-.27	-.32*	-.16	-.24	-.23	--								
7. TUG	-.45**	-.47**	-.42**	-.28	-.26	.36*	--							
8. Tap test	.27	.33*	.50**	.30	.27	-.22	-.61**	--						
9. Cadence	.43**	.19	.25	.21	.16	-.09	-.51**	.27	--					
10.Walk	.39*	.40*	.51**	.47**	.39*	-.29	-.79**	.57**	.63*	--				
11.Step	.29	.35*	.46**	.44**	.28	-.33*	-.69**	.54**	.18	.84**	--			
12.HFAROM	.31	.37*	.35*	.25	.01	-.49**	.52**	.25	.25	.38*	.31	--		
13. KFAROM	.35*	.41*	.40*	.39*	.38*	-.58**	-.43**	.36*	.08	.36*	.38*	.52**	--	
14. ADAROM	.16	.18	.14	.11	.47*	-.33	-.28	.11	.07	.32	.34*	.16	.37*	--

Note: $^{*}p \leq .05$ $^{**}p \leq .01$

[1](n = 38 except n= 27 for Sports)

Pain = KOOS pain subscale

ADL = KOOS Function in activities of daily living subscale

QOL = Quality of life subscale

Sports = KOOS Function in sports and recreational activities subscale

TKR = Total knee replacement

TUG = Timed up and go

Cadence = Right leg steps per minute

Walk = Right leg walking speed

Step = Right leg step length

HFAROM = Hip flexion active range of motion (right leg)

KFAROM = Knee flexion active range of motion (right leg)

ADAROM = Ankle dorsiflexion active range of motion (right leg)

Main analysis

The focus of the main analysis was on movement time (i.e., average right foot preferred strategy movement time and average right foot alternative strategy movement time). One (TKR) participant was removed from all movement time analyses because of extreme movement time values; therefore, movement time analyses are based on n = 38.

Foot-shifting strategy was examined first for all participants. All participants were asked to state their preferred method of shifting their foot from the gas to the brake switch, in the manner they would do in their own vehicles when using gas and brake pedals. Nineteen participants preferred a lift strategy and 20 participants preferred a pivot strategy. A pivot was the preferred strategy for 11 men and 9 women; a lift was the preferred strategy for 5 men and 14 women (see Table 11).

Table 11. **Preferred foot-shifting strategies (n = 38)**

	Lift	*Pivot*
TKR	6	10
No-TKR	12	10
Males	4	11
Females	14	9

Note: Lift: Shifting the right foot from the gas to brake switch, when lifting the heel off the ground
Pivot: Shifting the right foot from the gas to brake switch, when the heel is in touch with the ground

In the TKR group five men and five women preferred a pivot strategy, whereas a lift was the preferred method by 3 men and 4 women. In the No-TKR group a pivot was the preferred method of foot-shifting for 6 men and 4 women; a lift was the preferred strategy for 2 men and 10 women.

Movement time analyses

Means and standard deviations for movement time and reaction time are presented in Table 12 for preferred and alternative movement strategies (n = 38). No significant differences emerged using paired t-tests.

Table 12. **Movement time and reaction time: means and standard deviations for preferred and alternative strategies (n = 38)**

Strategy	*Movement time*		*Reaction time*	
	Mean	SD	Mean	SD
Preferred	.194	.049	.384	.061
Alternative	.201	.056	.389	.071

Note: Both preferred and alternative strategies include both pivot and lift strategies
Preferred Strategy = Foot-shifting strategy that an individual uses while driving his/her own vehicle
Alternative Strategy = Foot shifting-strategy alternative to preferred strategy
SD = Standard Deviation

Table 13 presents movement time means and standard deviations for preferred and alternative foot-shifting strategies for each group (No-TKR and TKR). Reaction time means and standard deviations are presented in Table 14 for each strategy for both groups. No significant differences emerged using paired t-tests to compare preferred and alternative reaction time.

Table 13. **Movement time: means and standard deviations for preferred and alternative strategies for No-TKR and TKR groups**

Foot shifting strategy	*No-TKR*		*TKR*	
	Mean	SD	Mean	SD
Preferred	.188 (n = 22)	.047	.202 (n = 16)	.053
Alternate	.190 (n = 22)	.056	.214 (n = 16)	.054
PPivot	.192 (n = 10)	.045	.183 (n = 10)	.050
PLift	.186 (n = 12)	.050	.233 (n = 6)	.046
APivot	.202 (n = 12)	.068	.243 (n = 6)	.058
ALift	.177 (n = 10)	.037	.197 (n = 10)	.046

Note: PPivot =Preferred Pivot PLift = Preferred Lift SD = Standard Deviation
APivot = Alternate Pivot ALift = Alternate Lift
Pivot = When the right foot is shifted from gas to brake switch without lifting the heel off the floor
Lift = When the right foot is shifted from gas to brake switch by lifting the heel off the floor

Table 14. **Reaction time: means and standard deviations for preferred and alternative strategies for No-TKR and TKR groups**

Foot shifting strategy	*No-TKR*		*TKR*	
	Mean	SD	Mean	SD
Preferred	.376 (n = 22)	.051	.393 (n = 16)	.073
Alternate	.387 (n = 22)	.086	.391 (n = 16)	.048
PPivot	.371 (n = 10)	.063	.353 (n = 10)	.037
PLift	.381 (n = 12)	.040	.461 (n = 6)	.069
APivot	.357 (n = 12)	.069	.398 (n = 6)	.070
ALift	.423 (n = 10)	.093	.387 (n = 10)	.032

Note: PPivot =Preferred Pivot PLift = Preferred Lift SD = Standard Deviation
APivot = Alternate Pivot ALift = Alternate Lift
Pivot = When the right foot is shifted from gas to brake switch without lifting the heel off the floor
Lift = When the right foot is shifted from gas to brake switch by lifting the heel off the floor

Gender means and standard deviations in movement time and reaction time are presented in Table 15. There were no significant gender differences in reaction time. However, movement time was significantly different for both preferred and alternative movement time; males were faster than females. Table 16 presents means and standard deviations for pivot and lift preferred and alternative movement time by gender. Both pivot preferred movement time and lift alternative movement time were significantly different between males and females. Males were faster for both movement times.

***Table 15.* Movement time and reaction time: means and standard deviations for preferred and alternative strategies by gender (males = 15, females = 23)**

Foot shifting strategy	*Males*		*Females*	
	Mean	SD	Mean	SD
Preferred movement time	.170	.054	.379	.089*
Alternative movement time	.176	.047	.400	.085*
Preferred reaction time	.210	.039	.387	.035
Alternative reaction time	.217	.056	.400	.085

Note: Participants used either a pivot or lift in both the preferred and alternative strategies
* = $p \leq .05$ SD = Standard Deviation

***Table 16.* Movement time: means and standard deviations for pivot and lift preferred and alternative strategies by gender**

Foot shifting strategy	*Males*		*Females*	
	Mean	SD	Mean	SD
Pivot Preferred	.169 (n = 11)	.038	.233 (n = 9)	.048**
Lift Preferred	.199 (n = 4)	.092	.202 (n =14)	.041
Pivot Alternative	.199 (n = 4)	.083	.220 (n =14)	.064
Lift Alternative	.167 (n =11)	.026	.212 (n = 9)	.045*

Note: * = $p \leq .05$ ** = $p \leq .01$ SD = Standard Deviation

Ancova analyses

Two-way Ancova analyses were performed for preferred movement time (n = 38) and for pivot preferred (n = 20) and lift preferred (n = 18) movement time. All analyses used TKR (0 = no and 1 = yes) and gender (0 = males and 1 = females) while controlling for age to examine potential TKR and gender differences in movement time.

The first analyses examined right foot preferred movement time (n = 38). The strategy used could have been either a pivot or a lift. Table 17 shows a main effect for gender. Overall, males (M = .170, SD = .05) had significantly faster preferred movement time compared to females (M = .210, SD = .04), p =.01.

***Table 17.* Ancova summary table for preferred movement time (n = 38)**

Source	*SS*	*Df*	*MS*	*F*
Model	1.45	5	.29	132.76***
Age	.000	1	.000	.659
TKR 01	.003	1	.003	1.525
Gender	.011	1	.011	4.816*
TKR 01* Gender	.001	1	.001	.543
Error	.072	33	.002	

Note: * = p≤.05 *** = p≤.001

A significant gender main effect again emerged for the pivot preferred movement time (n = 20). Table 18 indicates that overall, males (M = .169, SD = .04) had significantly faster pivot preferred movement time compared to females (M = .233, SD = .05), p = .01.

***Table 18.* Ancova summary table for pivot preferred movement time (n = 20)**

Source	*SS*	*df*	*MS*	*F*
Model	.80	5	.161	79.787***
Age	.002	1	.002	.899
TKR 01	.001	1	.001	.270
Gender	.012	1	.012	6.016*
TKR 01* Gender	6.16E-006	1	6.16E-006	.003
Error	.030	15	.002	

Note: * = p≤.05 ***p = ≤.001

Right foot lift preferred movement time (n = 18) results are shown in Table 19. There was a significant interaction effect (p = .027) for TKR and gender. However, the only post-hoc comparison that approached significance (p = .06) was in the No-TKR group with women having longer lift preferred movement time. There was insufficient power (cell sizes) to detect any other post hoc differences.

***Table 19.* Ancova summary table for right foot lift preferred movement time (n = 18)**

Source	*SS*	*Df*	*MS*	*F*
Model	.755	5	.151	83.685***
Age	.001	1	.001	.689
TKR 01	.016	1	.016	8.939**
Gender	.000	1	.000	.179
TKR 01* Gender	.011	1	.011	6.251*
Error	.023	13	.002	

Note: *p = ≤.05 ***p = ≤.001

Two-way Ancova analyses were also performed for alternative movement time (n = 38) and for alternative pivot (n = 18) and alternative lift (n = 20) movement time. All analyses used TKR (0 = no and 1 = yes) and gender (0 = males and 1 = females) while controlling for age.

The only significant results for alternative movement time are presented in Table 20. There was a main effect for gender (p = .04). Overall, males (M = .176, SD = .05) had significantly faster alternative movement time compared to females (M = .217, SD = .06), p = .024.

Table 20. **Ancova summary table for right foot alternative movement time (n = 38)**

Source	*SS*	*Df*	*MS*	*F*
Model	1.550	5	.310	109.940***
Age	.000	1	.000	.132
TKR 01	.007	1	.007	2.445
Gender	.013	1	.013	4.682*
TKR 01* Gender	1.13E-005	1	1.13E-005	.004
Error	.093	33	.003	

Note: *p = ≤.05 ***p = ≤.001

Regression analysis results

Stepwise regression analysis was performed to examine predictors of both preferred movement time and alternative movement time as the dependent variables (n = 38). Predictor variables for the analyses included total knee replacement dummy coded 0 = no and 1 = yes, age, gender, height, BMI, weight, and ADL (KOOS). The final models that explained the greatest amount of variance in preferred and alternative movement time included ADL and height. Regression analyses results for preferred movement time are presented in Table 21. Significant predictor variables were height and the ADL (KOOS) subscale. Being shorter and having more ADL difficulties were significantly associated with longer movement times. Overall, 25 percent of the variance in preferred movement time was explained by these two factors.

***Table 21.* Summary of stepwise regression analysis for variables predicting right foot preferred strategy movement time (n = 38)**

Factors	*Model 1* β	*Model 2* *B*
Height	-.45**	.38*
ADL-KOOS		-.30*
Adjusted R^2	.18	.25

Note: *p = ≤.05 ** = p≤.01

A second stepwise regression analysis was performed using the same predictor variables to examine predictors of alternative movement time. Results are presented in Table 22. Similar to preferred movement time, having more ADL difficulties, and having a shorter height were significantly associated with longer alternative movement time.

Overall, these two factors accounted for 37 percent of the variance in alternative movement time.

Table 22. **Summary of stepwise regression analysis for variables predicting right foot alternative strategy movement time (n = 38)**

Factors	*Model 1* *B*	*Model 2* *B*
Height		-.34*
ADL-KOOS	-.55***	-.48***
Adjusted R^2	.28	.37

Note: * = $p \leq .05$ ** = $p \leq .01$ *** = $p \leq .001$

Summary of Significant Results

Preliminary analyses

1. The TKR group had significantly greater weight and BMI compared to the No-TKR group.

2. Men were on average taller than women.

3. Individuals with a TKR reported significantly more symptoms in their right knee (KOOS) compared to No-TKR individuals.

4. Individuals with a TKR had reduced AROM in right hip flexion and extension, knee flexion, and ankle dorsiflexion compared to participants in the No-TKR group.

5. Participants with a TKR demonstrated shorter right leg step-length when compared to individuals without a TKR.

6. Compared to their counterparts, participants with a TKR took significantly longer to complete the TUG.

7. Correlation analyses revealed moderate correlations between (longer) preferred movement time and gender (being female), height (being shorter), greater BMI, having more ADL difficulties, longer time in performing the TUG, and performing fewer taps in the foot tap test. In addition, longer movement time was moderately associated with slower right leg walking speed and shorter step length, and longer reaction time. A strong correlation was noted between longer movement time and longer pivot preferred movement time. Longer alternative movement time was associated with shorter height, greater BMI, more ADL difficulties, longer time to complete the TUG, fewer taps in the tap test. Slower alternate pivot and lift movement time, and slower walking speed and shorter step length.

Main Analyses

1. Ancova results :

- Overall, males had significantly faster preferred and alternative movement time and pivot preferred movement time compared to females.
- There were no main effects for TKR on movement time (i.e., there was no significant difference between TKR and No-TKR groups for preferred or alternative movement time).

2. Regression results:

- Significant predictors for longer preferred and alternative movement time were height (being shorter) and having more ADL difficulties.

Discussion

This pilot study has shown the feasibility and utility of examining two different foot shifting strategies in a laboratory setting when assessing movement time after total knee replacement. The study provided objective information about the relationships between movement time, foot shifting strategy, gender, height, and other variables, and compared these variables amongst those with and without a TKR. The study compared two groups of individuals—those with a right TKR (the TKR group) and those without a right TKR (No-TKR group)—and focused on movement time and selected TKR and driving-related variables. Currently, there are no studies that examine the relationships between movement time (time taken to shift the right foot from gas to brake pedal), foot shifting strategy, knee specific quality of life, physical characteristics, and specific functional performance measures that may be related to movement time such as right knee active range of motion. In addition, foot shifting strategy was examined in relation to movement time—a factor that has not been considered in previous studies.

Previous studies did not examine individual differences in foot-shifting strategies and the potential influence these strategies may have on brake responses or predictors of movement time. The distinctiveness of this study is that movement time was examined in association with two foot shifting strategies. Results of the current study indicate a gender difference in movement time but surprisingly, no between group differences in movement time (i.e., there was no significant difference between TKR and No-TKR groups for preferred or alternative movement time).

Main analyses discussion: Movement time

Ancova

Ancova was used to examine the effects of TKR or no TKR and gender on preferred and alternative movement time as well as for pivot and lift preferred and pivot and lift alternative movement time, while controlling for any possible age effects. There was a main effect for gender in the preferred movement time, pivot preferred movement time, and for alternative movement time. Overall, women had slower movement time compared to men in these analyses. In other words, being female consistently resulted in having longer movement time. These results support previous studies outlined in the review by Green (2000) who noted that no studies of movement time have reported women as faster than men in movement time. Although there was a significant interaction effect for TKR and gender on lift preferred movement time, post-hoc analyses again confirmed the effect of gender on movement time. These results support previous research that reported faster mean brake response time for men than for women (Pierson et al., 2003). Contrary to expectations, the ANCOVA analyses demonstrated no differences in movement time between the TKR and No-TKR groups in movement time. None of the studies in the past compared movement time of individuals with and without a TKR. Therefore, this study provides an extension of the previous literature available on movement time in individuals with a TKR.

Regression

Stepwise regression analysis was undertaken to examine predictors of preferred and alternative movement time. The final model included TKR, gender, age, height, and the ADL KOOS scale. For both analyses being shorter and having more ADL difficulties accounted for 25% of the variance in (longer) preferred movement time and 37% of the variance in (longer) alternative movement time. Height may have been an influencing factor in movement time in relation to the laboratory set-up of the movement time apparatus.

The simulated driving apparatus used in this study does not represent an actual driving situation. Although there were two foot switches (one for the gas and one for the brake), there was no steering wheel. Individuals were asked to keep their arms on the side of the chair, a position that does not approximate a real driving situation. In addition, participants were tested in a seated position with the distance between the chair and pedal adjusted for comfort, thus attempting to simulate the individual's normal driving position. However, the seat could not be adjusted in any other direction; the height of the chair could not be adjusted (as it can in most recent car models), according to participants' own height. In some instances, as reported earlier, boards were placed under the feet of those who had difficulty navigating the foot switches. In addition, some participants complained about the angle of inclination and height of the foot switches, and this may also have influenced movement time (Morrison et al., 1986) especially among women who are shorter than men. Consequently, we cannot generalize the results of movement time in this study to an actual driving situation. Future research examining brake reaction time/movement time should use a type of apparatus that more effectively simulates a real car with a steering wheel, and an adjustable seat that compensates for height differences so that the experiment more accurately represents an actual driving situation (Green, 2000).

Other factors may also have influenced movement time in this study. It is possible that the left leg may act as a support during a foot shifting strategy (Pierson et al, 2003). If there is pain in the left knee this may interfere with movement of the right leg and cause longer movement time. However, we did not record pain or other symptoms in the left leg. The effect of left leg pain, stiffness, osteoarthritis, whether or not the participant had a left TKR or had expectations of receiving a left leg TKR as they relate to movement time requires further examination.

The ability to shift one's foot from a gas to a brake pedal may also be influenced by muscle strength which may be reduced following a TKR. Macdonald and Owen (1988) suggest that the force of 100 N may be necessary for adequate brake reaction time (BRT). However, the current study did not measure muscle strength or braking force. Therefore, future research should examine these factors when evaluating movement time post-TKR, as muscle strength may be compromised post-surgery.

Moreover, brake reaction/movement time was measured in the laboratory, in a stationary situation, and with the participant anticipating the red light stimulus and the need to respond quickly to the stimulus. In a real life driving situation, the need for brake response is often unexpected. Although the results of the current study are supported by previous research, Ganz et al. (2003) note that there is no safe or optimal driving reaction time score established or recommended on a driving reaction time test. Thus future research examining movement time must first establish pre- and post TKR norms for movement time as well as norms for individuals without a TKR. In addition, a consistent methodology must be established to ensure comparison of movement time results between studies. This would involve using both pre- and post- operative measures of movement time, quality of life measures, functional performance measures, and driving patterns such as distance and frequency of driving, as well as time since surgery (Ganz et al., 2003).

It would also be prudent to use more stringent post-operative time periods. In this study, participants were recruited if they had undergone a TKR three months to one year prior to the date of participation in the study. However, there may be a significant difference between movement time of individuals who have undergone TKR three months prior to testing and individuals who have had a TKR one year prior to testing. Given that individuals are advised to return to driving within the first three months after a TKR, functional comparisons could be made in relation to driving ability at 1, 3, 6 and 12 months, post-TKR. This type of comparison may provide more clear results of objective function in relation to movement time. Because this study's sample size was small and included people from 3-12 months post-TKR, it is possible this restricted observation of significant results.

The literature indicates that one of the questions most frequently asked by patients after TKR is when he/she may return to driving. The advice given by orthopedic surgeons is provided with little empirical guidelines. It is based primarily on brake response time or brake movement time measured in a laboratory setting with a stationary brake response methodology when the participant is presented with a red light stimulus (Pierson et al., 2003). Based on these studies, individuals may be advised to resume driving anywhere from 6 to 8 weeks after surgery.

For example, a study by Pierson et al. (2003) compared BRT (referred to as total movement time in this study) pre- and post-TKR. These authors reported that six weeks after surgery, BRT reached pre-operative level. Based on these results, they suggest that it is safe to resume driving six weeks after receiving a TKR. These researchers assume that all individuals can achieve pre-surgical brake response times six weeks following surgery, but they do not consider individual differences in leg function or brake response times before surgery. More specifically, the researchers assume that pre-surgery BRT is appropriate for safe braking. They overlooked the possibility that individuals undergoing TKR might already have delayed movement time prior to surgery, owing to severe knee OA, for example. Therefore, it is reasonable to question the above authors' recommendations that individuals with a TKR should resume driving six weeks post-TKR.

In another study by Spalding et al (1994), BRT was compared between a control group (mean age 67 years) and a surgical (TKR) group, pre-operatively and again at 4, 6, 8, and 10 weeks, post-operatively (mean age, 74 years). Although the researchers concluded that individuals may return to driving eight weeks following TKR, this suggestion is questionable because of one of the limitations of the study was that not all the participants in the study were regular drivers. Their results show that the individuals who are not drivers have significantly longer brake response times. This result is not unexpected, as people with no driving experience would likely take longer than others to perform an unfamiliar task.

Spalding et al. (1994) also included participants with a right or left TKR. Participants with a left TKR may not demonstrate results similar to ones with a right TKR because movement time (when shifting the right foot from the gas to brake switch) may not be affected by a left TKR as usually people use the right leg for both gas and brake pedal. In the present study, participants were regular drivers and were recruited specifically with a right TKR because, in the country of this study (Canada), the right foot is usually used for a braking response.

Furthermore, average preferred movement time was .202 seconds and .188 seconds (s) in the TKR and No-TKR group, respectively. However, in the study by Spalding et al. (1994), average movement time was .38 seconds in the TKR group and .37 seconds in the control group. The difference in recorded movement time between our study and Spalding's study may be due to the apparatus and method used. Spalding et al. (1994) defined movement time as the time recorded from when the foot is taken off the gas pedal to when the brake pedal is depressed to a point that achieves a brake pressure of 100 N (Newton), which may take longer than the type of movement time measured in this study (above). On the other hand, there is not much difference in reaction time (the time between the initiation of a red light stimulus and when the foot is taken off the gas pedal) recorded in the two studies. Average reaction time was .34 seconds and .39 seconds in the Spalding et al. study and in our study, respectively.

Green (2000) reviewed studies related to brake response time, movement time and reaction time. He reported that some normalized values of BRT have been established in past studies but that results often vary because of different testing apparatus, types of signals (e.g., red light stimulus box, computer screen, etc.) and owing to how responses are measured (e.g., analyses were performed either using reaction time, movement time or total movement time). In his review, Green states that average BRT under conditions of high expectancy and little uncertainty is about .70 to .75 seconds and that .2 seconds of that value is movement time (Green, 2000).

In this study, the average BRT was slightly faster at .60 $\pm$ .11 and .57 $\pm$ .08 seconds in the TKR and No-TKR group, and preferred movement time .202 $\pm$ .5 and .188 $\pm$ in the TKR and No-TKR group, respectively. These results support the premise advanced by Green that simulator studies have faster total movement / reaction times and may be influenced by the expectancy of the stimulus. Moreover, Green notes that the absence of an age effect on movement time may be related to sample bias, that is, older adults in better health are more likely to be driving and may be more likely to participate in driving studies. He also notes that no studies have found that women are faster than men, supporting the results in our study that found men have faster movement time in all conditions.

Previous studies examined outcomes of individuals with a TKR at various time periods, for example, from three months to many years after receiving a TKR (Oulett and Moffet, 2002; Kreibich et al., 1996; Otsuki, Nawata, and Okuno, 1999). However, only a few studies focused on driving-related function post-TKR. These laboratory studies concentrated exclusively on braking and movement time pre- and post-TKR, and did not relate movement time to self-report or functional performance measures.

Recommendations about when it is appropriate to resume driving after TKR, has been based on the time it takes to achieve pre-TKR brake response times. However, these studies provide no consensus on the time period, post-TKR that a typical individual must wait before being capable of performing an acceptable brake/movement time. For example, various time periods are recommended, indicating that individuals may resume driving anywhere from six to eight weeks following TKR (Pierson et al., 2003; Spalding et al., 1994). However, none of these studies examined movement time in relation to other parameters, such as foot-shifting strategy, knee range of motion, or post-TKR quality of life measures which have been used in many studies to assess TKR outcomes. For example, the ADL KOOS scale addresses the degree of difficulty a person experienced within the last week with function in daily living - activities such as going up and down stairs, rising from a sitting position, getting in and out of a car require functional ROM in hip, knee, and ankle range of motion, similar to the range of motion that may be required for safe braking. In sum, the results of the current study illustrate the utility of examining linkages between movement time and knee-related quality of life, anthropometric measures, and functional performance measures and provides direction for future research.

Preliminary analysis discussion

The present study consisted of 39 participants: 17 in the TKR group, and 22 in the No-TKR group. The mean age of the participants in the TKR group was 72.1 years (range, 60-83). According to Canadian Joint Replacements Registry (CJRR, 2004), the mean age of patients undergoing TKR is 69 years. Therefore, the age of participants in the current study is slightly older and may thus reflect accurately the increasing population of this age group in Canada, as well as the fact that Manitoba has one of the highest proportions of people aged 65 and older in Canada (Manitoba Fact Book on Aging, 2005).

The characteristics of TKR participants involved in this study are consistent with previous research, in that individuals with a TKR weighed significantly more (88.02 ± 12.21 kg) and had significantly greater BMI (31.19 ± 5.67 kg/m^2) compared to individuals without a TKR (Hirvonen et al., 2006; Harms, Larson, Sahmoun, and Beal, 2006).

KOOS Scale

Various QOL instruments have been used to measure knee specific outcomes after TKR. The KOOS scale is an extension of the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) (Bellamy et al., 1988), a disease specific quality of life instrument that is a widely used and is reported to be the instrument of choice for examining knee related quality of life after TKR (Brazier et al., 1999; Kriebich et al., 1996). The WOMAC has three separate subscales originally designed to assess pain, stiffness and function of daily living among older adults with osteoarthritis but has been used extensively as an outcome measure after TKR. For example, Quintana et al. (2006) conducted a study to determine changes in health-related quality of life after TKR in 624 patients who completed the WOMAC pre- and six months post-TKR (mean age = 71.9 years). Post-TKR participants reported significant improvement in symptoms, pain and function.

This study examined knee-specific quality of life post-TKR using the KOOS scale. In general, there was a tendency for participants with a TKR to report more pain and symptoms, more difficulty with ADL, more difficulty with function in sports and recreational activities, and reduced QOL when compared to their counterparts. However, the only significant differences emerged for symptoms (Table 4). The scores in our study are similar to those reported in previous research by Roos and Toksvig-Larsen (2003). The relationship of the KOOS subscales were examined with respect to movement time but only the ADL subscale was significantly correlated with both preferred and alternative (longer) movement time. Considering the range of activities the KOOS ADL scale examines, such as difficulty in getting in and out of a car, future research needs to explore more fully the relationship of this measure to objective functional outcomes (e.g., hip, knee, or ankle active range of motion) and domain specific functions, such as movement time.

Active Range of Motion

Active range of motion is considered an important outcome measure following TKR (Ritter, Harty, Cavis, Meding, & Berend, 2003). For example, Schurman and Rojer (2005) assessed knee ROM among 358 subjects (mean age, 69 years), using a goniometer before and after TKR. They used five different types of prostheses to examine AROM. These researchers reported that the average range of knee flexion was 111 degrees, pre-operatively, and that it was 113 degrees, post-operatively. Similarly, in our study, average active right knee flexion was 111.3 degrees and active knee extension was 1.9 degrees in participants with a right TKR.

In addition, in our study we measured AROM at the hip, knee and ankle joints, using a goniometer. The results showed that participants with a right TKR have significantly less right hip flexion and extension, knee flexion, and ankle dorsiflexion, when compared to the No-TKR group (see Table 5). This suggests that although TKR may help with pain reduction individuals may still have reduced range of active and functional knee range of motion (Jones et al., 2005). The reduced ROM post-operatively could be attributed to the reason that individuals undergoing TKR surgery have restricted ROM even prior to the surgery and the TKR surgery may have improved the ROM but, not comparable to the control group individuals.

Previous research has reported a modest correlation between knee mobility and functional items of the WOMAC (Jones et al., 2005) and this is evident in the correlation between ADL and hip and knee AROM in our study (see Table 5). Although we did not measure AROM before surgery, and, therefore, we do not know if AROM is reduced post-TKR, the TKR group, in contrast to the No-TKR group, demonstrated a significantly smaller AROM in knee flexion. Although these results cannot be generalized to all people with right TKR, they provide direction for future research that examines hip, knee, and ankle movements pre- and post-operatively, in relation to movement time pre- and post-operatively.

Gait analysis

Gait analysis has often been used to examine function after TKR surgery and the results of this study support previous gait analysis studies. Previous research by Lee et al. (1999) compared gait between those who had undergone TKR one year prior to the study date (n = 20, mean age = 68 years) with control subjects who had not undergone a TKR (n =35, mean age = 69 years). Force plates were used to gather all the data. The researchers used stepwise linear regression for statistical analysis, and reported that gait speed was reduced and that step length was shorter in individuals with a TKR, when compared to control subjects.

In another study Chen, Cheng, Shang and Wu (1991), examined functional status of patients (mean age = 64.8 years) with a TKR, using gait analysis. The data were collected using a Vicon motion analysis system. Data from participants with a TKR was compared with a control group of participants who were younger (mean age = 27 years). These researchers reported that participants with a TKR demonstrated slower velocity, shorter step-length and reduced cadence, when compared to those without a TKR. Although the researchers recruited a younger group of individuals in the control group, the findings in this study, using groups of like age, were similar to findings of Chen et al. (1991).

In the current study, individuals with a TKR have significantly shorter step-length, when compared to the No-TKR group and there is a tendency for TKR subject to have slower walking speed and less cadence (see Table 6). The results of the gait analysis (in the current study) were supported by the results from the TUG test, which shows that individuals with a TKR take longer to walk the three meters in the TUG the test. In addition, shorter step length and slower gait speed was associated with longer preferred and alternative movement time whereas shorter movement time was associated with better self-report of function in the KOOS scales (see Table 4). As such, future research needs to extend gait analysis following TKR and examine the relationships with other self-report and functional outcomes in order to elucidate the relationships between these variables.

Performance tests: The Timed Up and Go Test and the foot tap test

The TUG and tap test have been used to measure leg strength, endurance, and coordination. Specifically, the U.S. Department of Transportation - National Highway Traffic Safety Administration in the report on Model Driver Screening and Evaluation Program, Volume 11: Maryland Pilot Older Driver Study (Chapter 3: Pilot Study Data Collection, 2003) stated that "the physical abilities targeted in these tests were those needed to sustain pedal control without fatigue and to quickly and accurately shift back and forth from the accelerator to the brake pedal when circumstances demand it" (page 7).

In this study, there was a significant difference in TUG scores between the TKR and No-TKR groups (see Table 7). The TUG test has been used frequently as an outcome measure after undergoing a TKR. For example, Rossi et al. (2006) compared mobility between participants with a TKR (mean age 70.7 years) and participants in an age-matched control group (mean age, 69.6 years) using the TUG. These researchers reported that 10-26 months after TKR, participants were 28% slower when compared to their control group counterparts: TKR group participants took, on average, 7.3 seconds, and control group participants take, on average, 5.6 seconds, to complete the TUG. The findings of this study are similar to Rossi et al. (2006), in that individuals with TKR are significantly slower when compared to their control group counterparts. In this study, the TKR group took 7.6 seconds and the non-TKR group took 6.3 seconds to complete the TUG (see Table 7).

In another study by Mizner & Mackler (2005) 14 participants were tested three months after TKR surgery. The mean age of participants was 62 years and the mean BMI was 29.7kg/m^2. Participants took 7.37 seconds on an average to complete TUG and their gait speed was 1.34 meter/second. Similarly, in this study, participants with TKR completed the TUG in 7.6 seconds and their average gait speed was 1.12 meter/second.

Although the TKR participants in this study took longer to complete the TUG, when compared to the No-TKR group, the results of both groups fall within a normal range for the TUG. A cut-off score of 20 seconds or less to complete the TUG was considered to indicate independence in mobility and transfers (Podsiadlo and Richardson,

1991) whereas individuals who took more than 30 seconds to complete the test were considered to require assistance with transfers and mobility.

Although the participants were able to demonstrate a good score/time in the TUG test, this does not indicate that the participants can walk for long distances. It is possible that an outcome measure demonstrating endurance and strength such as the six minute walk would be a superior indicator of endurance and mobility (Parent & Moffet, 2002) and should be used in addition to the TUG test as an outcome measure following TKR. In addition, the correlation with movement time (longer movement time is correlated with longer TUG time) provided an additional perspective on outcome measurements following TKR and the relationship to movement time.

The tap test used in this study differs from the study mentioned above in that participants were timed for ten seconds and the numbers of taps achieved in that time were counted, whereas other methods time the individual while they complete a specified number of taps. Regardless of the method used, this test may be a useful method for examining an approximation of movement time in a clinical setting. In this type of test, the person shifts the right foot, from right to left, across a book or binder, such that the movement performed imitates the movement that is used when shifting the right foot from a gas to a brake pedal. Therefore, TKR individuals may demonstrate reduced functional performance in this test at different time periods post-TKR, especially if they have pain or restricted ROM in the hip, knee, or ankle.

The tap test has not been used in previous studies related to TKR and/or movement time. However, it has been used as an outcome measure in patients before and after right knee arthroscopy (mean age = 42 years). The results in these studies compared individuals pre- and post-arthroscopy, and the authors reported that participants reached their pre-arthroscopy levels (14 taps in 10 seconds) four weeks after arthroscopy. The results from this study, although not significant, demonstrated a tendency for individuals with a TKR to perform fewer number of taps (mean = 9.6) when compared to participants in the No-TKR group (mean = 10.6). Future research should examine the psychometric properties of the tap test, and validate the use of this test in individuals with and without a TKR to determine if the test can be used as a proxy of movement time in a clinical setting post-TKR. That is, to use it as a clinical test that may discriminate between slower and faster movement time post-TKR so that it could be used as an outcome measure in future TKR research. In addition, future research should examine the psychometric properties of this test as a rehabilitation exercise specifically designed to improve movement time following TKR, prior to return to driving.

Correlation analysis

Correlation analyses were performed to explore relationships between preferred and alternative movement time and selected variables. Although the preferred strategy was the one the individual was most expected to use in a real driving situation, we presented correlations for both preferred and alternative strategy movement times. Contrary to our expectations, age and having a TKR were not associated with preferred or alternative movement time. However, correlation results do support our hypotheses related to movement time and the KOOS scale. Results revealed that (slower) preferred movement time was significantly correlated with being female, being shorter, having a greater BMI, and having more ADL difficulties. These factors may explain the longer movement time observed in women compared to men and supports previous research that links self-report outcome measures, physical performance measures, and gender post-TKR (Kennedy, Stratford, Pagura, Walsh, & Woodhouse, 2002). In addition, (longer) movement time was significantly correlated with taking longer to complete the TUG and fewer taps in the tap test, which may also reflect reporting more ADL problems. Thus height appears to influence preferred movement time, possibly making it more difficult for women (who are shorter than men) to both reach the pedals and to shift between the pedals in this laboratory study.

Similar to preferred movement time, longer alternative movement time was significantly associated with being female, having greater BMI, reporting more ADL difficulties, taking longer to complete the TUG and performing fewer taps in the tap test, having a slower walking speed and shorter step length. Alternate pivot preferred movement time was associated with greater weight and BMI and more difficulties with ADL. Thus, being female, reporting more ADL difficulties, having a longer TUG time and slower walking speed are consistent with previous research examining outcomes following TKR (Kennedy et al., 2002; Parent & Moffet, 2002). It has been suggested that further research is needed to examine the relationships between the WOMAC scores and performance measures across the pre- and post-operative spectrum (Parent & Moffet, 2002). As such, this study provides additional insight to the relationship between the ADL subscale of the KOOS (and by proxy the WOMAC) and movement time, which can be considered a domain specific performance outcome measure following TKR.

Vicon joint angles and range of motion

Due to inexact placement of the knee and tibial markers, the data from the Vicon joint angle and ROM analysis proved to be unreliable and could not be used for these analyses. There are significant challenges in marker placement when using the Vicon system to record lower extremity movements from a seated position. The standard Plug in Gait model requires accurate placement of markers over anatomical landmarks such as the anterior superior iliac spines, posterior superior iliac spines and the centre of knee joint rotation. A different model may have been able to compensate for possible inaccurate marker placement, especially with more obese individuals where the abdomen often obscures the anatomical reference points.

It is possible that during the foot shifting movement camera detection of these markers became partially obscured, providing inaccurate recording. Others have also noted this problem, and various devices have been developed to compensate for these problems that help to reduce error in recording the joint angles and ROM (Baker, 2006; Deluzion, Wyss, Li, & Costigan, 1993; Manal, McClay, Stanhope, Richards, & Galinat, 2000; Schache, Baker, & Lamoreus, 2006).

Whereas gait analysis using the Vicon system has been well established after TKR (Chen, Cheng, Shang, & Wu, 1991; Dennis, Komistek, Mahfouz, Walker, & Tucher, 2004; Fuchs, Toauffs, Plaumann, Tibesku, & Rosenbuam, 2005; Munderman, Dyrby, & Andriacchi, 2005), in addition to gait analysis, this study attempted to use the system to analyze joint parameters specifically related to movement that may be used during a foot shifting strategy that imitates movement used in a driving situation. Future methodology must address how to best record the data from a seated position, including marker placement and calculation of results using the Vicon system.

Conclusions

This study was designed to examine movement time when older adults performed a lift or a pivot foot-shifting strategy, while moving their right foot from a simulated gas pedal (switch) to a simulated brake pedal (switch). The foot shifting strategies were categorized as preferred or alternative. The preferred method was the one that participants normally used in their own car. Two groups of participants were examined: a TKR group and a No-TKR group. Main analyses of movement time ANCOVA results demonstrated a gender difference in movement time with males having faster movement time compared to females, but no differences in movement time between TKR and No-TKR groups. Based on regression analysis of movement time, height (being shorter) and reporting more ADL difficulties explained a moderate amount of the variance in both preferred and alternative foot-shifting strategy movement time.

With respect to AROM, there was a smaller range of motion in right hip and knee flexion and ankle dorsiflexion among TKR participants who also performed more poorly on physical performance measures of the TUG, tap test, and gait parameters compared to the No-TKR group. There was a tendency for TKR individuals to report more pain, symptoms (the only significantly different between group scale), ADL difficulties, poorer function in sports and poorer quality of life, and having more ADL difficulties was correlated with longer movement time.

The results of this pilot study extend previous research on movement time and provide new directions for future movement time research with older adults receiving a TKR. The study demonstrated the unique approach of examining movement time with two foot shifting strategies, a familiar or preferred strategy and an unfamiliar or alternative strategy as well as examining the linkages between movement time and anthropometric characteristics, quality of life measures and physical performance measures. It also provides direction for future rehabilitation related research among health care professionals who are concerned with older adults' driving ability, especially after TKR.

References

Adams J.C., & Hamblen, D. L. (2001). *Outline of Orthopedics* (13th ed.). London: Churchill Livingstone.

Andriacchi, T.P., Galante, J.O., & Fermier, R.W. (1982). The influence of total knee-replacement design on walking and stair climbing. *Journal of Bone and Joint Surgery, 64(9), 1328-1335.*

Andriacchi, T.P., Ogle, J.A., & Galante, J.O. (1977). Walking speed as a basis for normal and abnormal gait measurements. *Journal of Biomechanics, 10(4), 261-268.*

Anstey, K. J., Wood, J., Lord, S., Walker, J. G. (2005). Cognitive, sensory and physical factors enabling driving safety in older adults. *Clinical Psychology Review, 25(1), 45-65.*

Badley, E.M. (1995). The effect of osteoarthritis on disability on health care use in Canada. *Journal of Rheumatology, 22(43), 19-22.*

Baker, R. (2006). Gait analysis methods in rehabilitation. *Journal of Neuroengineering Rehabilitation., 3(4),* 4.

Barck, A. L. (1998). Minimise outcome measures after knee replacement. *Archives of Orthopaedic and Trauma Surgery, 117 (8), 461-463.*

Barker, S., Craik, R., Freedman, W., Herrmann, N., & Hillstrom, H. (2006). Accuracy, reliability, and validity of a spatiotemporal gait analysis system. *Medical Engineering & Physics, 28(5), 460-467.*

Bellamy, N., Buchanan, W. W., Goldsmith, C.H., Campbell, J., & Stitt, L. W. (1988).

Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of hip or knee. *Journal of Rheumatology, 15(12), 1833-1840.*

Berman, A. T., Zarro, V. J., Bosacco, S. J., & Israelite, C. (1987). Quantitative gait analysis after unilateral or bilateral knee replacement. *Journal of Bone and Joint Surgery, 69(9), 1340-1345.*

Bischoff, H. A., Stahelin, H. B., Monsch, A. U., Iverson, M. D., Weyh, A., Dechend, M., Akos, R., Conzelmann, M., Dick, W., & Theiler, R. (2003). Identifying a cut-off point for normal mobility: a comparison of the timed 'up and go' test in community-dwelling and institutionalised elderly women. *Age and Aging, 32(3), 315-320.*

Bombardier, C., Melfi, C. A., Paul, J., Green, R., Hawker, G., Wright, J. & Coyte, P. (1995). Comparison of a generic and a disease-specific measure of pain and physical function after knee replacement surgery. *Medical Care, 33 (4), 131-144.*

Boone, D.C., Azen, S.P., Lin, C-M, Spence, C., Baron, C., & Lee L. (1978). Reliability of goniometric measurements. *Physical Therapy, 58(11), 1355-1360.*

Brazier, J.E., Harper, R., Munro, J., Walters, S.J., & Snaith, M.L. (1999). Generic and condition-specific outcome measures for people with osteoarthritis of the knee. *Rheumatology (Oxford), 38(9), 870-877.*

Canadian Joint Replacement Registry (CJRR). CIHI (Canadian Institute for Health Information) provides aggregate level data for Canadian Joint Replacement Registry. Retrieved March 29, 2005, from http://secure.cihi.ca/cihiweb/.

Centre for Disease Control and Prevention (2005). *Healthy Places Terminology.*

Retrieved May 10, 2005, from www.cdc.gov/healthyplaces/terminology.htm

Chang, R. W., Pellissier, J.M., & Hazen, G. B. (1996). A cost effectiveness analysis of total hip arthroplasty for osteoarthritis of the hip. *Journal of American Medical Association, 275(11), 858-865.*

Chao, E.Y., Laughman, R. K., & Stauffer, R. N. (1980). Biomechanical gait evaluation of pre and post operative total knee replacement patients. *Archives of Orthopedic and traumatic surgery, 97(4), 309-317.*

Chen, P., Cheng, C., Shang, H., & Wu, J. (1991). Gait analysis after total knee replacement for degenerative arthritis. *Journal of Formosan Medical Association, 90(2), 160-166.*

Clarkson, H.M. (2000). Musculoskeletal Assessment: Joint range of motion and manual muscle strength (second ed.). Philadelphia: Lippincott Williams & Wilkins.

Coyte, P. C., Wright, J.G., Hawker, G. A., Bombardier, C., Dittus, R. S., Paul, J. E., Freund, D. A. & Ho, E. (1994). Waiting times for knee-replacement surgery in the United States and Ontario. *New England Journal of Medicine, 331(16), 1068-1071.*

Cress et al. (1995). Relationship between physical performance and self- perceived physical function. *Journal of American Geriatric Society, 43(2), 93-101.*

Currier, D.P. (1990). Elements of research in physical therapy. 3rd ed. Baltimore: Williams & Wilkins.

Cushnaghan, J., & Dieppe, P. (1991). Study of 500 patients with limb joint osteoarthritis: Analysis by age, sex, and distribution of symptomatic joint sites. *Annals of Rheumatic Disease, 50(1), 8-13.*

Davis, R.B. III, Ounpuu, S., Tyburski, D., & Gage, J.R. (1991). A gait analysis technique data collection and reduction. *Human Movement Science, 4, 575-587.*

Deluzio, K. J., Wyss, U. P., Li, J., & Costigan, P. A. (1993). A procedure to validate three-dimensional motion assessment systems. *Journal of Biomechanics, 26(6), 753-759.*

Dennis, D. A., Komistek, R. D., Mahfouz, M. R., Walker, S. A., & Tucker, A. (2004). A multicenter analysis of axial femorotibial rotation after total knee arthroplasty. *Clinical Orthopaedics Related Reearch, 428 (November), 180-189.*

Dijkstra, P.U., deBont, L.G.M., van der Weele, L.Th., Boering, G. (1994). Joint mobility measurements: reliability of standardized method. *Journal of Craniomandibular Practice, 12(1), 52-57.*

Dodge, H. J., Mikkelsen, W. M., & Duff, I. F. (1970). Age-sex prevalence of radiographic abnormalities of the joints of the hands, wrists and cervical spine of adult residents of Tecumseh, Michigan community health study area, 1962-1965. *Journal of Chronic Diseases, 23(3), 151-159.*

Downe-Wamboldt, B. (1991). Coping and life satisfaction in elderly women with osteoarthritis. *Journal of Advanced Nursing, 16(11), 1328-1335.*

Drewett, R.F., Minns, R.J., & Sibly, T.F. (1992). Measuring outcome of total knee replacement using quality of life indices. *Annals of the Royal College of Surgeons of England, 74(4), 286-289.*

Elveru, R.A., Rothstein, J.M., & Lamb, R.L. (1988). Goniometric reliability in a clinical setting: Subtalar and ankle joint measurements. *Physical Therapy, 68(5), 672-677.*

Felson, D.T. (2003). Epidemiology of osteoarthritis. In K.D. Brandt, M. Doherty & L.S.

Lohmander (Eds.), *Osteoarthritis* (pp. 9-16). Oxford: Oxford University Press.

Flores, R.H., & Hochberg, M.C. (2003). Definition and classification of osteoarthritis. In K.D. Brandt, M. Doherty & L.S. Lohmander (Eds.), *Osteoarthritis* (pp. 1-8). Oxford: Oxford University Press.

Folstein, M.F., Folstein, S. E., McHugh, P. R. (1975). Mini-mental state: A practical method for grading the cognitive state of patients for the physician. *Journal of Psychiatric Research, 12, 189-198.*

Fowler, N. K., & Nicol, A. C. (1999). Measurement of external three-dimensional interphalangeal loads applied during activities of daily living. *Clinical Biomechanics (Bristol, Avon), 14(9) 646-652.*

Freter, S.H. & Fruchter, N. (2000). Relationship between timed "up and go" and gait time in an elderly orthopedic rehabilitation population. *Clinical Rehabilitation, 14(1), 96-101.*

Fuchs, S., Rolauffs, B., Plaumann, T., Tibesku, C. O., & Rosenbaum, D. (2005). Clinical and functional results after the rehabilitation period in minimally-invasive unicondylar knee arthroplasty patients. *Knee Surgery, Sports Traumatology, Arthrosccopy, 13(3),* 179-186.

Ganz, S.B., Levin, A.Z., Peterson, M.G., & Ranawat, C.S. (2003). Improvement in driving reaction time after total hip arthroplasty. *Clinical Orthopaedics and Related Research, 413(August), 192 – 200.*

Garratt, A. M., Brealey, S., & Gillespie, W. J. (2004). Patient-assessed health instruments for the knee: a structured review. *Rheumatology, 43(11), 1414-1423.*

Gotlin, R.S., Sherman, A.L., Sierra, N., et al. (2000). Measurement of brake response time after right anterior cruciate ligament reconstruction. *Archives of Physical Medicine and Rehabilitation, 81(2), 201-204.*

Green, M. (2000). "How long does it take to stop?" Methodological analysis of driver perception-brake time. *Transportation Human Factors, 2(3), 195-216.*

Griffiths, G., Bellamy, N., Baily, W.H., Baily, S.I., McLaren A.C., & Campbell, J.A. (1995). A comparative study of relative efficacy of the WOMAC, AIMS and HAQ instruments in evaluating the outcome of total knee arthroplasty. *Inflammopharmacology, 3(1), 1-6.*

Guralnik, J.M., Branch, L.G., Cummings, S.R., & Curb, J.D. (1989). Physical performance measures in aging research. *Journal of Gerontology (5), 44, M141-146.*

Guyatt, G.H., Sullivan, M. J., Thompson, P. J., Fallen, E. L., Pugsley, S. O., Taylor, D. W., et al (1985). The 6-minute walk: a new measure of exercise ability in patients with chronic heart failure. *Canadian Medical Association Journal, 132(8), 919–923.*

Guyatt, G.H., Feeny, D.H., & Patrick, D.L. (1993). Measuring health-related quality of life. *Annals of Internal Medicine, 118(8), 622-629.*

Harms S., Larson R., Sahmoun A. E., & Beal, J. R. (2006). Obesity increases the likelihood of total joint replacement surgery among younger adults. *International Orthopaedics, 31(1), 23-26.*

Harwin, S.F. (2002). Indications and Patient Selection. In G. R. Scuderi & A.J. Tria Jr. (Eds.). Surgical Techniques in Total Knee Arthroplasty (pp 3-8). New York: Springer.

Hau, R., Csongvay, & Barlett, J. (2000). Driving reaction time after right knee arthroscopy. *Knee Surgery, Sports Traumatology, Arthroscopy, 8(2), 89-92.*

Hawker, G. et al. (1998). Health-related quality of life after knee replacement. *Journal of Bone and Joint Surgery, 80A (2), 163-173.*

Hershkovitz, A., Gottlieb, D., Beloosesky, Y. & Brill, S. (2003). Programme evaluation of a geriatric rehabilitation day hospital. *Clinical rehabilitation, 17(7), 750-755.*

Hirvonen, J., Blom, M., Tuominen, U., Seitsalo, S., Lehto, M., Paavolainen, P., Hietaniemi, K., Rissanen, P., & Sintonen, H. (2006). Health-related quality of life in patients waiting for major joint replacement: A comparison between patients and population controls. *Health and quality of life outcomes, 4 (3).* Retrieved November 15, 2006, from: http://www.pubmedcentral.nih.gov.proxy1.lib .umanitoba.ca/picrender.fcgi?artid=1373609&blobtype=pdf

Hooper, K., & McGee, H. (1983). Correction to driver characteristic specifications and standard formulations for intersection sight distance. *Transportation Research Record, 904(a), 30-32.*

Hooper, K., & McGee, H. (1983). Driver perception-reaction time: Are revisions to current specification values in order? *Transportation Research Record, 904(b), 21-30.*

Insall, J. N., Dorr, L. D., Scott, R. D., & Scott, W.N. (1989). Rationale of The Knee Society Clinical Rating System. *Clinical Orthopedics, 248(November), 13-14.*

Irrgang, J. J., & Anderson, A. F. (2002). Development and validation of health-related quality of life measures for the knee. *Clinical Orthopedics and Related Research, 402(September), 95-109.*

Irrgang, J. J, Snyder-Mackler, L., Wainner, R. S., Fu, F. H., Harner, C. D. (1998). Development of a patient-reported measure of function of the knee. *Journal of Bone and Joint Surgery, 80(8), 1132-1145.*

Irrgang, J. J., Anderson, A. F., Boland, A. L., Harner, C. D., Kurosaka, M., Neyret, P. Richmond, J. C., & Shelborne, K. D. (2001). Development and validation of the international knee documentation committee subjective knee form. *The American Journal of Sports Medicine, 29(5), 600-613.*

Jackson B. D., Wluka, A. E., Teichtahl, A. J., Morris, M. E., & Cicuttni, F. M. (2004). Reviewing knee osteoarthritis--a biomechanical perspective. *Journal of Science and Medicine in Sport, 7(3), 347-357.*

Jinks, C., Lewis, M., & Croft, P. (2003). Health status after hip or knee arthroplasty. *Annals of Rheumatic Disease, 62(8), 700 – 701.*

Jones, C. A., Voaklander, D. C., Johnston, D. W., & Suarez-Almazor, M. E. (2003). Determinants of function after total knee arthroplasty. *Physical Therapy, 83(8), 696-706.*

Jones, C. A., Voaklander, D. C., Johnston, D. W., & Suarez-Almazor, M. E. (2000). Health related quality of life outcomes after total hip and knee arthroplasties in a community based population. *Journal of Rheumatology, 27(7), 1745-1752.*

Kawamura, H. & Bourne, R. B. (2001). Factors affecting range of flexion after total knee arthroplasty. *Journal of Orthopedic Science, 6(3), 248-252.*

Kennedy, D., Stratfoed, P. W., Pagura, S., M., C., Walsh, M., & Woodhouse, L. J.

(2002). Comparison of gender and group differences in self-report and physical performance measures in total hip and knee arthroplasty candidates. *The Journal of Arthroplasty, 17(1), 70-77.*

Kreibich et al. (1996). What is the best way of assessing outcome after total knee replacement? *Clinical Orthopedics, 331(October), 221-225.*

Law Commission of Canada (2002). Using "Age" as a Fitness-to-Drive Criterion for Older Adults. Retrieved June 15, 2006, from http://www.lcc.gc.ca/research_project/02_age_3-en.asp

Lee, T. H., Tsuchida, T., Kitahara, H., & Moriya, H. (1999). Gait analysis before and after unilateral total knee arthroplasty: study using a linear regression model of normal controls-women without arthroplasty. *Journal of Orthopedic Science, 4(1),13-21.*

Lingard, E. A., Katz, J. N., Wright, R. J., & Sledge, C.B. (2001). Validity and responsiveness of the Knee Society Clinical Rating System in comparison with the SF-36 and WOMAC. *Journal of Bone and Joint Surgery, 83(12), 1856-64.*

Lister, R. D. (1950). The reaction time of drivers in moving stationary vehicles. *Road Research Laboratory, Great Britain, RN/1324/RDL.*

Low J. (1976). The reliability of joint measurement. *Physiotherapy, 62, 227-229.*

Macdonald, W. & Owen, J. W. (1988). The effect of total hip replacement on driving reactions. *Journal of Bone and Joint Surgery, 70(2), 202-205.*

Macdonald, W. & Owen, J. W. (1988). The effect of total hip replacement on driving reactions. *Journal of Bone and Joint Surgery, 70(B), 202-205.*

Manal, K., McClay, I., Stanhope, S., Richards, J., & Galinat, B. (2000). Comparison of surface mounted markers and attachment methods in estimating tibial rotations during walking: an in vivo study. *Gait Posture, 11(1),* 38-45.

Marks, R. (1994). Reliability and validity of self-paced walking time measures for knee osteoarthrosis. *Arthritis Care Research, 7(1), 50-53.*

Marx, R.G. (2002). Knee rating scales for clinical outcome. In: Calaghan, J.J., Rubash, H.E., Simonian, P.T., Wickiewicz, T.L., Rosenberg, A.G., eds. The adult knee. Philadelphia: Lippincott Williams & Wilkins, 2002: 367-378.

McHorney, C. A., Ware, J. E., & Raczek, A. E. (1993). The MOS 36-Item Short-Form Health Survey (SF-36): II. Psychometric and clinical tests of validity in measuring physical and mental health constructs. *Medical Care, 31(3), 247-263*

McSweeny A.J., Creer, T.L. (1995). Health-related quality of life assessment in medical care. *Disease Month, 41(1), 1-71.*

Meikle, B., Devlin, M., & Pauley, T. (2006). Driving pedal reaction times after right transtibial amputations. *Archives of Physical Medicine and Rehabilitation, 87(3), 390-394.*

Mizner, R. L. & Snyder-Mackler, L. (2005. Altered loading during walking and sit-to-stand is affected by quadriceps weakness after total knee arthroplasty. *Journal of Orthopaedics Research, 23(5), 1083-1090.*

Morrisson, R. W., Swope, J. G., & Halcomb, C. G. (1986). Movement time and brake pedal placement. *Human Factors, 28(2), 241-246.*

Mundermann, A., Dyrby, C. O., & Andriacchi, T. P. (2005). Secondary gait changes in patients with medial compartment knee osteoarthritis: increased load at the ankle, knee, and hip during walking. *Arthritis and Rheumatism, 52(9), 2835-2844.*

Murray, M.P., Drought, A.B., & Kory, R.C. (1964). Walking pattern of normal men. *Journal of Bone and Joint Surgery, 46A (2), 335-360.*

Nagano, Y., Takahashi, T., Ishida, K., Hirose, D., Okumiya, K., Matsubayashi, K., Doi, Y., & Yamamoto, H. (2003). Knee pain in people aged 80 years and older is not associated with gait parameter and functional performance. *International Journal of Rehabilitation Research, 26(2), 131-136.*

Ndongo, S., Ka, M. M., Leye, A., Diallo, S., Niang, E. H., Sy, M. H., & Moreira Diop, T. (2003). Epidemiological and clinical features of the knee osteoarthritis. *Dakar médical, 48(3), 171-175.*

Nguyen, T., Hau, R., & Barlett, J. (2000). Driving reaction time before and after anterior cruciate ligament reconstruction. *Knee Surgery, Sports Traumatology & Arthroscopy, 8(4), 226-230.*

O'Reilly, S. & Doherty, M. (2003). Signs, symptoms, and laboratory tests. In K.D. Brandt, M. Doherty & L.S. Lohmander (Eds.), *Osteoarthritis* (pp. 197-210). Oxford: Oxford University Press.

O' Sullivan, S., & Schmitz, T. (2001). *Physical Rehabilitation: Assessment and Treatment* (4th ed.). Philadelphia: W.B. Saunders Company.

Otsuki, T., Nawata, K., & Okuno, M. (1999). Quantitative evaluation of gait pattern in patients with osteoarthrosis of knee before and after total knee arthroplasty: Gait analysis using a pressure measuring system. *Journal of Orthopedic Sciences, 4(2), 99-105.*

Ouellet, D., & Moffet, H. (2002). Locomotor deficits before and two months after knee arthroplasty. *Arthritis & Rheumatism, 47(5), 484-493.*

Paxton, E. W. & Fithian, D.C. (2005). Outcome instruments for patellofemoral arthroplasty. *Clinical Orthopaedics and Related Research, 436(July), 66 -70.*

Perry, J. (1992). *Gait Analysis; normal and pathological function.* Thorofare, NJ: Slack Inc.

Pierson, J.L., Earles, D.R., &Wood, K. (2003). Brake response time after total knee arthroplasty: When is it safe for patients to drive? *The Journal of Arthroplasty, 18(7), 840-843.*

Podsiadlo, D., & Richardson, S. (1991). The timed "Up and Go": A test of basic functional mobility for frail elderly person. *Journal of American Geriatrics Society, 39(2), 142-148.*

Porter, M.M., & Whitton, M.J. (2002). Assessment of driving with the global positioning system and video technology in young, middle-aged, and older drivers. *Journal of Gerontology: Medical Sciences, 57A (9), 578-582.*

Quintana, J.M., Escobar, A., Arostegui, I., Bilbao, A., Azkarate, J., Goenaga, J. I., & Arenaza, J.C. (2006). Health-related quality of life and appropriateness of knee or hip joint replacement. *Journal of Internal Medicine, 166 (2), 220-226.*

Redelmeier, D. A., Bayoumi, A. M., Glodstein, R. S., & Guyatt, G. H. (1997). Interpreting small differences in functional status: the six minute walk test in chronic lung disease patients. *American Journal of Respiratory Critical Care Medicine, 155(4), 1278- 1282.*

Rheault, W., Miller, M., Nothnagal, P., Strassle, J., & Urban, D. (1988). Intertester reliability and concurrent validity of fluid-based and universal goniometers for active knee flexion. *Physical Therapy, 68(11), 1676-1678.*

Ritter, M. A., Harty, L. D., Davis, K. E., Meding, J. B., & Berend, M. E. (2003). Predicting range of motion after total knee arthroplasty. *The Journal of Bone and Joint Surgery, 85-A (7), 1278-1285.*

Roos, E. M., Roos, H. P., & Lohmander, L. S., Ekdahl, C., Beynnon, B. D. (1998). Knee Injury and Osteoarthritis Outcome Score (KOOS)- development of a self-administered outcome measure. *Journal of Orthopedics and Sports Physical Therapy, 28(2), 88-96.*

Roos, E.M. & Toksvig-Larsen, S. (2003). Knee Injury and Osteoarthritis Outcome Score (KOOS) – validation and comparison to the WOMAC in total knee replacement. *Health and Quality of Life Outcomes, 1(1), 17-27.*

Rowe, P. J., Myles, C. M., & Nutton, R. (2005). The effect of total knee arthroplasty on joint movement during functional activities and joint range of motion with particular regard to higher flexion users. *Journal of Orthopaedic Surgery, 13(2), 131-138.*

Rossi, M. D., Hasson, S., Kohia, M., Pineda, E., & Bryan, W. (2006). Mobility and perceived function after total knee arthroplasty. *The Journal of Arthroplasty, 21(1), 6-12.*

The Canada Safety Council (2000). Seniors behind the wheel. *Safety Canada.* Retrieved on January, 2007 from http://www.safety-council.org/news/sc/2000/Eng-1-00.pdf

Salaffi,F., Carotti, M., & Grassi, W. (2005). Health-related quality of life in patients with hip or knee osteoarthritis: comparison of generic and disease-specific instruments. *Clinical Rheumatology, 24(1), 29-37.*

Schache, A. G., Baker, R., & Lamoreux, L. W. (2006). Defining the knee joint flexion-extension axis for purposes of quantitative gait analysis: an evaluation of methods. *Gait Posture, 24(1), 100-109.*

Schurman, D. J. & Rojer, D. E. (2005). Total Knee Arthroplasty. *Clinical Orthopaedics and Related Research, 430(January), 132-137.*

Scott, J. C. & Hochberg, M. C. (1998). Arthritis and other musculoskeletal diseases. In R. C. Brownson, P. L. Remington, and J. R. Davis (Eds). *Chronic Disease Epidemiology and Control, 2nd edition* (pp.465-489). Washington DC: American Public Health Association.

Sim, J.,& Arnell, P. (1993). Measurement validity in physical therapy research. *Physical Therapy, 73(2), 102-110.*

Sinaki, M., Brey, R. H., Hughes, C. A., Larson, D. R., & Kaufman, K. R. (2005). Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. *Osteoporosis International, 16(8), 1004-1010.*

Spalding, T.J., Kiss, J., Kyberd, P., Turner-Smith, A. & Simpson, A.H. (1994). Driver reaction times after total knee replacement. *The Journal of Bone and Joint Surgery, 76 (5), 754-756.*

Spirduso, W. W. (1975). Reaction and movement time as a function of age and physical activity level. *Journal of Gerontology, 30(4), 435-440.*

Staplin, L., Gish, K. W., Wagner, E. K. (2003). MaryPODS revisited: Updated crash analysis and implications for screening program implementation. *Journal of Safety Research, 34(4), 389-397.*

Staplin, L., Lococo, K.H., Gish, K.W., & Decina, L.E. (2003). Model driver screening and evaluation program final technical report: Vol.2.. Maryland Pilot Older Driver Study (Report No. DOT HS 809 583). Washington, DC: National Highway Traffic Safety Administration. Retrieved 12/08/2004 from http://www.nhtsa.dot.gov/people/injury/olddrive/modeldriver/2_chap_3.htm

Stratford, P.W., Kennedy, D., Pagura, S., & Gollish, J.D. (2003). The relationship between self-report and performance-related measures: Questioning the content validity of timed tests. *Arthritis & Rheumatism, 49 (4), 535-540.*

Tew, M., Forster, I. W., & Wallace, W. A. (1989). Effect of total knee arthroplasty on maximal flexion. *Clinical Orthopaedics and Related Research, 247(October), 168-174.*

The Arthritis Society (2005, March 29). *Osteoarthritis: How common is osteoarthritis?* Retrieved May 11, 2005, from http://www.arthritis.ca/types%20of%20arthritis/osteoarthritis/default.asp?s=1

Walsh, M., Woodhouse, L. J., Thomas, S. G., & Finch, E. (1998). Physical impairments and functional limitations: a comparison of individuals 1 year after total knee arthroplasty with control subjects. *Physical Therapy, 78(3), 248-258.*

Whittle , M. C. (1996). Gait Analysis 2nd edition . Oxford: Buttereorth-Heinman, a division of Reed Educational and Professional Publishing Ltd.

Woolhead, G. M., Donovan, J. L., & Dieppe, P. A. (2005). Outcomes of total knee replacement: a qualitative study. *Rheumatology (Oxford), 44(8), 1032-1037.*

Youdas, J.W., Carey, J.R., & Garrett, T.R. (1991). Reliability of measurements of cervical spine range of motion-comparison of three methods. *Physical Therapy, 71(2), 23-29.*

Appendix A

Participant Information and Consent Form

RESEARCH PARTICIPANT INFORMATION AND CONSENT FORM

Research Project Title: Leg Movements During Driving Among Older Adults With and Without a Total Knee Replacement

Principal Investigator: Dr. Leah Weinberg, Ph.D., R106-771 McDermot Ave., Wpg., MB., R3E 0T6. Phone:

Co-Investigator: Dr. Michelle Porter, Ph.D., 207A Max Bell Centre. Phone:

You are being asked to participate in a research study. Please take your time to review this consent form and discuss any questions you may have with the study staff. You may take your time to make your decision about participating in this study and you may discuss it with your friends, family or (if applicable) your doctor before you make your decision. This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand.

<u>Purpose of Study</u>

The purpose of this study is to examine driving related leg movements in older drivers with and without a total knee replacement (TKR). This study will involve a series of laboratory exercises as well as measuring the flexibility and strength of your hip, knee and ankle joints. Prior to conducting the laboratory part of this study, we will ask you to complete several questionnaires that relate to your driving habits, your health and functional ability, your knee function, and your beliefs and attitudes about falls and exercise. We have included one questionnaire with this information package. You will be asked to respond to the other questionnaires during your first appointment.

A total of 60 individuals will participate in this study.

<u>Study Procedures</u>

Participation in the study will involve two appointments. The first appointment will last on average two hours and the second appointment approximately one and one-half hours. We ask that you bring a pair of shorts to wear at each appointment.

The appointments will take place in the Aging, Rehabilitation, and Social Cognition Research Laboratory in the School of Medical Rehabilitation at the University of Manitoba. The laboratory is located on the third floor of the Rehabilitation Hospital, 800 Sherbrook St, Winnipeg, MB., in Room RR309C. Laboratory tests during the second appointment will take place in Room RR355, also on the third floor of the Rehabilitation Hospital.

If you take part in this study, you will have the following procedures administered by a trained research assistant:

1. At the **first appointment**, in Room RR309C in the Rehabilitation Hospital, you will be asked to take the Mini Mental State Exam which is a simple, brief test of your thinking ability in terms of orientation, memory, attention, language, and planning. You will be asked a series of questions which may require you to look at objects or draw, so you should make sure to bring your reading glasses.

You will also be asked to provide a short health history and to answer some questionnaires. The questionnaires will ask about your activities, any pain you may be experiencing, and your ability to do certain activities. Other questions will ask about how you rate your health and functional ability, and your attitudes and beliefs about your health, functional ability, exercise, and falls. For example, you will be asked the extent to which you feel you control your future health, or if you agree or disagree with certain statements such as "The main thing which affects my health is what I myself do".

Next, the research assistant will measure the flexibility in your right hip, knee, and ankle. You will be asked to bend and straighten your hip and a measurement is taken in each position. Similarly, you will be asked to bend and straighten your knee as far as you can comfortably, and bend and straighten your ankle while a measurement is taken in each position. You will be lying down for the hip and knee movements, and seated for the ankle movements. We ask that you bring a pair of shorts to wear while we take these measurements. We will also record your height and weight, and measure your leg length as well as the width of your knees and your ankles.

This will be followed by a short walking test. You will start from a seated position, you will get up, walk to a point 9 metres away, turn around and walk back to the chair and sit down. You will be timed as you walk as quickly and safely as you can from the word start until you sit down again.

Next, you will take a foot tapping test. You will sit in a standard chair and will move your right foot from right to left and back again over an open book as many times as possible in 10 seconds.

Finally, the research assistant will assist you with a computer test called "Roadwise Review ™, A Tool to Help Seniors Drive Safely Longer" produced by the American Automobile Association (AAA). This is an easy-to-use computer program that allows you to check visual, mental and physical responses a person needs when driving. The computer program has a series of exercises that allows you to perform a self-evaluation based on the accuracy and speed of your responses. The research assistant will help you with the exercises. For example, head/neck flexibility is assessed by having you sit on a chair facing away from the computer. You will then be asked to turn and look at the computer screen and identify a figure that is on the screen. Visual acuity is measured by having you sit in front of the computer screen and identify which letter on the screen is different from the others. This is done first with high contrast between the letters and the background, and then with low contrast between the letters and the background, similar to what you may see when you are driving during a bright day and during periods of low visibility such as in fog or rain. Other exercises ask you to match certain whole figures with ones that have parts missing but could be completed to match the whole figure. Another task is to quickly identify figures at the edge of the computer screen that match the figure in the middle of the screen, similar to being able to recognize and anticipate a hazard when you are driving. A different task asks you to scan the driving environment on the computer screen and to recognize traffic signals and driving threats at the edge of your field of view. At the end of the program, you will receive feedback on each area, together with suggestions to keep you driving safely longer. You will receive a print out of the results of this test at the end of your second appointment.

2. At your **second appointment**, lasting approximately one and one-half hours, we again ask that you bring a pair of shorts to wear. This is so we can clearly see how you walk and how you move your leg. The following tests will be administered by two research assistants.

Foot reaction and movement time will be measured with two foot switches mounted on a wood base such that the angle and distance between switches are similar to what would be found in a standard vehicle gas and brake pedals. You will be seated and asked to respond to a light signal as quickly as possible, moving your right foot from the right switch to the left switch, similar to moving from the gas to the brake pedal in a car. Reaction time is the time of releasing the right switch. Movement time is the time to hit the left switch. You will perform several practice trials and test trials.

You will have special markers attached to areas over your hip, knee, and ankle joints so that our motion analysis cameras can analyse your movements as you place your foot on the "gas pedal switch" and move it to the "brake pedal switch". At the same time, we will measure the muscles that are activated as you perform the movements, with special electrodes attached to the skin over your knee muscles, and your muscles on the front and back of your lower leg. You will also be asked to walk a short distance with the markers on so that our motion analysis camera can analyse how you walk. This camera does not take conventional pictures. Rather, it records your movements based on the reflection of the markers and produces "stick" figures that can be analysed. These activities will take place on the third floor of the Rehabilitation Hospital, 800 Sherbrook St., in room RR355.

Risks and Discomforts

There are risks associated with any type of physical activity. We have tried to minimize risks to you by asking you questions about your health status. The likelihood of injury from this type of testing is low. You do not have to do any test if you feel that it will cause you discomfort or pain.

In addition, if you are uncomfortable answering any of the questions on the questionnaires, you are free not to answer them.

Benefits

There may or may not be direct benefit to you from participating in this study. However, you will learn useful and valuable information about your driving skills by taking the "Roadwise Review ™, A Tool to Help Seniors Drive Safely Longer". In addition, you will receive information on your own abilities from the laboratory tests (reaction and movement time and other physical tests). At the end of the study, after all the data is analysed we will provide you with general results from the study.

Costs
All the procedures which will be performed as part of this study, are provided at no cost to you.

Payment for participation
You will be given $10.00 for parking or bus/transportation costs after each appointment.

Confidentiality
Information gathered in this research study may be published or presented in public forums, however your name and other identifying information will not be used or revealed. Your information will be assigned a study number and all study related documents will have only your assigned study number.
Your identity will be treated as confidential in accordance with the Personal Health Information Act of Manitoba (PHIA) guidelines. No results will be released in any way that could identify you personally.
Driver and Vehicle Licensing or Autopac (MPI) will NOT be given any information.

The University of Manitoba Health Research Ethics Board may review records related to the study for quality assurance purposes.

All records will be kept in a locked secure area and only those persons identified by the study investigators (e.g., project coordinator, research assistants) will have access to these records.

Voluntary Participation/Withdrawal from the Study
Your decision to take part in this study is voluntary. You may refuse to participate or you may withdraw from the study at any time. Your decision not to participate or to withdraw from the study will not affect you in any way. You can stop participating in the study at any time. However, if you decide to stop participating in the study, we encourage you to talk to the study staff first.

If the study staff feel that it is in your best interest to withdraw you from the study, they will remove you without your consent.

Questions

You are free to ask any questions that you may have about any of the activities you are asked to participate in and your rights as a research participant. If any questions come up during or after the study, contact the study principal investigator Dr. Leah Weinberg at or the study coordinator Ms. Aman Bajwa, at .

For questions about your rights as a research participant, you may contact The University of Manitoba, Bannatyne Campus Research Ethics Board Office at (204) 789-3389.

Do not sign this consent form unless you have had a chance to ask questions and have received satisfactory answers to all of your questions.

Statement of Consent

I have read this consent form. I have had the opportunity to discuss this research study with Dr. Leah Weinberg and/or her study staff. I have had my questions answered by them in language I understand. The risks and benefits have been explained to me. I believe that I have not been unduly influenced by any study team member to participate in the research study by any statements or implied statements. Any relationship I may have with the study team has not affected my decision to participate. I understand that I will be given a copy of this consent form after signing it. I understand that my participation in this study is voluntary and that I may choose to withdraw at any time. I freely agree to participate in this research study.

I understand that my identity will be treated as confidential in accordance with the Personal Health Information Act of Manitoba (PHIA) guidelines. No results will be released in any way that could identify me personally.

I authorize the inspection of any of my records that relate to this study by The University of Manitoba Research Ethics Board for quality assurance purposes.

By signing this consent form, I have not waived any of the legal rights that I have as a participant in a research study.

I agree to be contacted for future follow-up in relation to this study. Yes ____ No ____

Participant signature: ______________________________ Date: __________
(Day/month/year)

Participant printed name: ____________________________________

I, the undersigned, have fully explained the relevant details of this research study to the participant named above and believe that the participant has understood and has knowingly given their consent.

Printed Name: ___________________________________ Date: ___________
(Day, month, year)

Signature: ____

Role in the study: ____

Appendix B

Study Poster

UNIVERSITY OF MANITOBA

RESEARCH STUDY EXAMINING LEG MOVEMENTS IN OLDER ADULTS WITH and WITHOUT A RIGHT KNEE REPLACEMENT

Men and women, 60 years of age and over,
with or without a right knee replacement are eligible.

The study involves participating in two sessions lasting approximately one and a half hours each.

You will be asked to perform some simple laboratory exercises and answer some questionnaires.

There will be reimbursement for bus/parking costs for each appointment

For information please contact:
Dr. Leah Weinberg,
University of Manitoba
Phone:

E-mail:

Appendix C

Phone Tracking Sheet

LEG MOVEMENTS DURING DRIVING AMONG OLDER ADULTS WITH AND WITHOUT A TOTAL KNEE REPLACEMENT

PHONE TRACKING SHEET

DATE OF PHONE CALL: ______/______/________ ID #: ________________
DD MM YYYY

LAST NAME: ________________ **FIRST NAME:** ________________

ADDRESS: ____

POSTAL CODE: ________________

PHONE NUMBER: ________________ *HOME* ☐ *WORK* ☐

GENDER: ☐ **Male** ☐ **Female**

DATE OF BIRTH: ______/______/______ **AGE:** ☐
DD MM YYYY

SELECTION CRITERIA:

I. Right knee replacement: ☐ **Yes** ☐ **No** *If Yes, when?*
(If greater than one year, disqualified)

II. Regular driver: ☐ **Yes** ☐ **No**

III. Where did you hear about the study?

Newspapers/ newsletter (Which one?) ____________ ☐
Poster (Where?) ____________________ ☐
Friend(s)/ Relative(s) ☐
Are the friends or Relatives taking part in study too? ☐ ***Yes*** ☐ ***No***

VI. Qualified to participate? ☐ **Yes** ☐ **No**

If no, interested in future study? ☐ Yes ☐ No

PACKAGE SENT OUT: ☐ **Yes** Date: ____________________
☐ **No** Why: ____________________

FOLLOW-UP DATE: ________________

Response after reading package:
Willing to participate ☐ Unwilling to participate ☐

Date of Appointment 1: Date: Time: Why?
Date of Appointment 2: Date: Time:
Other Comments
________________________ ________________________
________________________ ________________________
____
____