DIRECT ANTERIOR TOTAL HIP ARTHROPLASTY AND THE RELATIONSHIP
BETWEEN HIP ADDUCTION TORQUE AND EXTERNAL HIP ADDUCTION
MOMENT

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF
THE UNIVERSITY OF HAWAI‘I AT MĀNOA IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE
IN
KINESIOLOGY AND REHABILITATION SCIENCE
MAY, 2012

By:
Sienna Handegard

Thesis Committee:
Iris F. Kimura, Chairperson
Ronald K. Hetzler
Christopher D. Stickley
Acknowledgements

I would like to start off by thanking everyone at UH who helped to make my thesis possible. To Ryan, we helped each other through a lot of this on our own and we are coming out alive and with a degree! To Mel and Dax for always seeming to have an answer to my most random questions, teaching me how to run my stats and then how to interpret them, along with all the tech support (Dax). I would also like to thank Dr. Hetzler and Dr. Stickley for being a part of my committee. A big thank you goes to Dr. Kimura for being my committee chair and helping me through the process. Thank you.

A huge thank you goes to my classmates, past and present. Alex, Karin, Eryn (the THA/TKA team), and Reade were a huge help last year teaching me the ropes of grad school, and of course Liz, I could always count on you for support and encouragement. To the current class we made it!! Ryan, Ko, Morgan, Christina, Tom, and last but not least my old roomie Rich; we had a blast, tried new things, and learned a lot.

Last but definitely not least I need to thank my family for their love, support, and encouragement. Thank you to my parents for not thinking I was crazy to leave everything and go to Hawai‘i for grad school. You pushed me to return to graduate school and it has paid off immensely. You were always there to support me and listen when I just wanted to talk about my frustrations. Mom and Sarah thank you for proof reading when I needed another set of eyes when mine couldn’t take anymore. Another thank you to Kathy Bell, you are a great friend and have been a great mom to Peanut for the last 2 years, we love you!

Love you all and Thank you!!
Abstract

Purpose – The Direct Anterior Total Hip Arthroplasty (DA THA) is a variation of Minimally Invasive Total Hip Arthroplasty procedures. This surgical approach does not transect the abductor musculature and is classified as a muscle sparing procedure. The muscle sparing procedure goal is to limit the damage to the hip abductors and thereby allowing patients faster recovery times. Hip abduction torque as it relates to hip external adduction moment is considered an important factor of THA function before and after surgery. Therefore the purpose of this study was to determine the relationship hip abduction torque had on external hip adduction moment in DA-THA and Control groups.

Methods – Two 2x3 analysis of variance (ANOVA) with repeated measures (RM) were used to compare 16 participants, 8 direct anterior (DA)-THA procedure participants and 8 controls. Pearson’s Correlation was used to test the relationship of hip abduction strength and hip external adduction moment. Pearson’s Chi-square test was used to evaluate the Trendelenburg test grade. External hip adduction moment, function, (Trendelenburg test) and hip abduction torque data were collected at the following three time periods: pre-operation (PRE/initial), three months post-surgery (POST3) and six months post-surgery (POST6).

Results – Results revealed non-significant Pearson Correlation (r = 0.15) between involved hip abduction isometric torque and external hip adduction moments. ANOVA results revealed a decrease in control group hip abduction torque from PRE to POST6.

Conclusion – Within the limitations of the present study DA-THA and control groups failed to demonstrate a significant relationship between hip abductor torque and external hip adduction moment.

Keywords
THA, minimally invasive, direct anterior, abduction moment, external hip adduction moment
List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DA-THA and control group means and standard deviations for Age, BMI, Height, Weight, and Gait Velocity</td>
<td>7</td>
</tr>
<tr>
<td>2. Correlation of Hip Adduction Moment and Hip Abduction Torque in the DA-THA and Control subjects</td>
<td>8</td>
</tr>
<tr>
<td>3. Mean and standard deviations of Hip Adduction Moment at PRE, POST3, and POST6 between a control group and the DA-THA group</td>
<td>9</td>
</tr>
<tr>
<td>4. Mean and standard deviations of Hip Abductor Torque data at PRE, POST3, POST6 between DA-THA and control groups</td>
<td>9</td>
</tr>
<tr>
<td>5. Trendelenburg Test Grade for DA-THA and Control groups at PRE, POST3, and POST6 time periods</td>
<td>10</td>
</tr>
</tbody>
</table>
List of Figures

Figure Page

1. Comparison of DA-THA and control group hip adduction moment at PRE, POST3, and POST6 ................................................................. 13

2. Comparison of DA-THA and control group hip abduction isometric torque measures at PRE, POST3, and POST6 ........................................ 13
Table of Contents

Acknowledgements ........................................................................................................... ii
Abstract ............................................................................................................................... iii
List of Tables ....................................................................................................................... iv
List of Figures ..................................................................................................................... v
Part I ..................................................................................................................................... 1
Introduction ...................................................................................................................... 1
Results .................................................................................................................................. 7
Discussion .......................................................................................................................... 10
Part II .................................................................................................................................... 14
Review of Literature ....................................................................................................... 14
APPENDIX A: RECRUITMENT FLIER ........................................................................... 43
APPENDIX B: MEDICAL HISTORY FORM ................................................................. 45
APPENDIX C: WESTERN IRB THA CONSENT FORM ............................................ 47
APPENDIX D: WESTERN IRB CONTROL CONSENT FORM ................................ 55
APPENDIX E: HARRIS HIP FUNCTION SCALE ......................................................... 62
APPENDIX F: Western Ontario and McMaster Universities Osteoarthritis Index ........ 65
APPENDIX G: SF-36 FORM .............................................................................................. 68
APPENDIX H: ANTHROPOMETRIC FORM ................................................................. 73
APPENDIX I: TRENDELENBURG FORM ...................................................................... 75
APPENDIX J: MANUAL MUSCLE TESTING FORM .................................................. 77
APPENDIX K: WONG-BAKER PAIN SCALE ............................................................... 79
APPENDIX L: DATA SHEET ............................................................................................ 81
APPENDIX M: SPSS SYNTACS ..................................................................................... 83
References ......................................................................................................................... 88
Introduction

Osteoarthritis (OA) currently affects greater than 27 million Americans, of these individuals 31% are patients 65 and older suffering from hip OA (Jordan et al., 2009). The specific cause of OA is unknown, but has been shown to be related to age, family history, and body weight (Felson, 1996). Joint articular cartilage begins to deteriorate over time leading to pain, stiffness, swelling, and decreases in activities of daily living and quality of life (Bhandari et al., 2009). Compensatory gaits develop as OA progresses to decrease pain by limiting weight bearing time on the involved limb (Hurwitz et al., 1997). After conservative measures such as joint conservation, medications, physical therapy, lifestyle changes, and bracing no longer relieve OA symptoms. Surgery is considered the most effective way to manage these patients.

Total hip arthroplasty (THA) is the most effective surgical intervention performed to alleviate symptoms, restore mobility, and allow OA patients to return to previous activity levels (Restrepo et al., 2010, Bender et al., 2009). Minimally invasive THA techniques were first introduced in the 1970s as alternatives to the traditional posterior THA in order to minimalize damage to the underlying soft tissue structures, i.e. muscles and their insertions (Bender et al., 2009, Oinuma et al., 2007, Nakata et al., 2009, Sugano et al., 2009, Berger et al., 2004, Meneghini et al., 2008, Bhandari et al., 2009). Consequently, the Direct Anterior Approach (DA) has become one of the more widely used minimally invasive techniques since it is a muscle sparing procedure (Bergin et al., 2011, Bender et al., 2009), where none of the abductor muscles or the tensor fascia latae are transected (Moskal, 2011, Lugade et al., 2010, Restrepo et al., 2010, Oinuma et al., 2007, Nakata et al., 2009). When the tensor fascia latae is damaged,
dynamic stabilization of the hip is compromised resulting in abnormal hip function until the aforementioned structures have had time to heal (Moskal, 2011).

The Trendelenburg test has long been used as the functional gold standard in determining hip abductor muscle function (Hardcastle and Nade, 1985, Youdas et al., 2010). The inability to maintain a vertical (level) pelvis during single leg stance is viewed as a positive Trendelenburg sign (Hardcastle and Nade, 1985). Abductor muscle function is responsible for maintaining balance control and vertical position of the pelvis during gait. The DA-THA, where no abductor musculature is transected, should reveal a negative Trendelenburg sign post-operatively, along with increases or maintenance of hip abductor muscular torque.

Trendelenburg gait is representative of the gait adaptation used by hip OA patients (Zijlstra and Bisseling, 2004) that results from a decrease in hip abductor torque. The Trendelenburg gait involves dropping the uninvolved pelvis and decreasing the external adduction moment resulting in a lateral trunk lean toward the involved limb associated with weakness in the gluteus medius and abductor muscles (Whittle, 2007, Edmunds and Boscainos, 2011).

Hip abductor musculature damage results in decreases in hip external adduction moment. This decrease in abductor muscle torque (Hurwitz et al., 1997) with its resultant lateral trunk lean toward the involved leg; shifts the center of mass/ground reaction force closer to the involved hip joint (Hurwitz et al., 1997, Chang et al., 2005, Perron et al., 2000). This compensatory gait reduces the torque required by the hip abductors to stabilize the hip, which decreases the external hip adduction moment (Chang et al., 2005, Hurwitz et al., 1997). Hip abduction moment is defined as the torque generated by the abductor muscles during walking that resists external hip adduction moments (Chang et al., 2005). The greater the distance
between the ground reaction force (center of mass) and the hip joint center, the greater the external hip adduction moment, requiring hip abductor muscle torque increases to stabilize the involved hip (Chang et al., 2005, Rutherford and Hubley-Koze, 2009). To our knowledge only Rutherford et al addressed the relationship between hip abductor and gluteus medius torque and frontal plane moments of the hip joint during gait (Rutherford and Hubley-Koze, 2009).

Compared to healthy individuals, THA patients displayed lower hip abduction torque resulting in lower hip external adduction force during level walking (Mayr et al., 2009, Beaulieu et al., 2010).

Therefore the purpose of this study was to determine the relationship between hip abduction torque and external hip adduction moment during gait in DA-THA and control groups at three different data collection time periods.
Methods

Research Design

A longitudinal prospective research design was used to determine the relationship between isometric hip abduction torque and external hip adduction moment during gait. The independent variables in this study include: DA-THA, and control groups, and three data collection time periods. The dependent variables include: external hip adduction moment, isometric hip abduction torque, and Trendelenburg test. External hip adduction moment from now on will be referred to as hip adduction moment.

Subjects

Subjects were eight hip OA patients ranging from 18-85 (62.46 ± 11.80 years, 3 female, 5 males) years of age who elected to undergo DA-THA surgery and eight non-OA control subjects (61.46 ± 4 years, 3 females, and 5 males) (APPENDIX A) who volunteered to participate in this study. Subjects from the DA-THA group were recruited from a pool of hip OA patients undergoing DA-THA surgery by the same board certified orthopedic surgeon specialized in minimally invasive THA. All DA-THA and control group subjects participated in three data collection sessions: 1) pre-operative/initial visit, 2) 3 months, 3) 6 months post-operatively/initial visit. All control group volunteers completed a medical history questionnaire prior to the study participation and were screened by a board certified physician (APPENDIX B). All participants signed informed consent forms, and Health Insurance Portability and Accountability Act authorization forms. The study was approved by the Western Institutional Review Board and the university committee on human subjects (APPENDIX C and D). Subjects with possible contraindications determined during physician screening were excluded from study participation.
Any DA-THA or control subjects who had previous lower extremity joint replacement surgery other than the one being replaced over the course of this study, had a history of rheumatoid or inflammatory arthritis, were unable to walk, or were pregnant were excluded from study participation.

Procedures

All subjects underwent functional testing in the University’s Human Performance and Gait Laboratory. All data were collected by Board of Certification (BOC) nationally certified athletic trainers. The DA-THA participants were tested pre-operatively and at three and six months postoperatively. The control subjects were tested at the initial visit (analogous to the DA-THA pre-operative data collection), and at three, and six months.

Just prior to each data collection period, participants completed the Harris Hip Function Scale (APPENDIX E), the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (APPENDIX F), and the Short Form Health Survey (SF-36) (APPENDIX G) to measure perceived pain and function. Anthropometric data consisting of height measured using a wall-mounted stadiometer, and weight using a Befour PS6600-ST scale (Befour, Inc., Saukville, WI) was collected to assess body mass index (BMI) (APPENDIX H). A three-dimensional (3D) motion capture system (Vicon MX, Vicon, Inc., Centennial, Colorado, USA and Vicon software (Nexus and Polygon, Vicon, Inc., Centennial, Colorado, USA), was used to capture, reduce, and analyze kinematic data. Kinematic data were collected at 240Hz then smoothed using a Woltering filter (MSE 10). The Vicon knee-alignment-device-alike plug-in-gait retroreflective marker set was applied to the participant’s trunk and lower extremities in order to calculate hip adduction moment during gait. Participants were first instructed to perform three practice trials in order to familiarize themselves with the procedures. During testing, participants walked
barefoot at a comfortable, self-selected pace down a 6 meter data collection field. Walking velocity was recorded using infrared timers (Speed Trap II, Brower Timing Systems, Draper, UT, USA). All participants performed the minimum number of trials needed to obtain three successful trials on each leg. A successful trial was determined by placement of the entire foot on the force plate without observed changes in gait or targeting. Trendelenburg data were collected using the procedures of Hardcastle and Nade, and the rating system of Pai (Hardcastle and Nade, 1985, Pai, 1996). Three trials were completed for each leg, and the best grade for each leg was recorded and used for data analysis (APPENDIX I).

Isometric torque data were assessed using the MicroFET 2 hand-held dynamometer (HHD) (Hoggan Health Industries, Draper, Utah, USA). Three BOC Athletic Trainers performed the manual muscle testing (Intratester ICC (2,1) range = 0.89-0.98, 0.84-0.98, 0.86-0.95 for testers 1 to 3, respectively). Hip abduction torque was assessed supine on an adjustable treatment table (high/low table). The HHD was placed on the lateral thigh at 80% of the distance between the greater trochanter and the lateral malleolus. Participants were instructed to perform hold each isometric contraction over a three-second period (Biasca et al., 2009). Following a submaximal familiarization trial, two maximal trials were collected, with 60 seconds of rest between trials, when a greater than 10% difference between trials was measured a third trial was performed, and the average isometric torque of the trials was used for data analysis (Chen et al., 2006, Sharkey et al., 2002, Gartland, 1987, Widler et al., 2009) (APPENDIX J). Pain level was assessed after each trial using a visual analog scale to assess both pain felt in involved joint and at the placement site of the HHD, if the pain was higher than an eight (scale 1-10) that test was no longer performed on the involved limb (APPENDIX K).
**Statistical Analysis**

Descriptive statistics including means, standard deviations and ranges were generated for all demographic characteristics and variables of interest. The statistical model for this prospective study included three 2x3 analysis of variance (ANOVA) with repeated measures (RM) for each dependent variable (walking velocity, kinematic and kinetic gait variables). Pearson’s Chi-square test was used to analyze the Trendelenburg grade data. All statistical analyses were completed using SPSS v 19.0 (IBM, Armonk, NY, USA). The alpha level was set at $p < 0.05$.

**Results**

Demographic characteristics of DA-THA and control group subjects, including age, body mass (BMI), height, weight, and walking gait velocity are provided in Table 1. There were no statistical differences in age, BMI, height, or weight between groups. Significant interaction effects were revealed for walking gait velocity. Subsequent post hoc test results indicated that gait velocity in the DA-THA group increased from the PRE to POST3 and from PRE TO POST6 but not between POST3 AND POST6. $p = 0.003$.

Table 1: DA-THA and control group means and standard deviations for Age, BMI (Body Mass Index), Height, Weight, and Gait Velocity.

<table>
<thead>
<tr>
<th></th>
<th>PRE DA-THA n=8</th>
<th>PRE Control n=8</th>
<th>POST3 DA-THA n=8</th>
<th>POST3 Control n=8</th>
<th>POST6 DA-THA n=8</th>
<th>POST6 Control n=8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>62.25(12.45)</td>
<td>61.25(4.33)</td>
<td>62.50(12.18)</td>
<td>61.38(4.24)</td>
<td>62.63(12.41)</td>
<td>61.63(4.14)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.80(3.07)</td>
<td>26.71(2.56)</td>
<td>26.56(2.91)</td>
<td>26.86(2.53)</td>
<td>26.51(2.84)</td>
<td>26.62(2.65)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.67(0.11)</td>
<td>1.65(0.10)</td>
<td>1.67(0.10)</td>
<td>1.64(0.09)</td>
<td>1.67(0.11)</td>
<td>1.64(0.09)</td>
</tr>
</tbody>
</table>
Weight (kg)

<table>
<thead>
<tr>
<th></th>
<th>74.34(7.45)</th>
<th>72.21(7.26)</th>
<th>73.55(7.28)</th>
<th>72.31(5.81)</th>
<th>73.48(7.26)</th>
<th>71.76(6.10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait Velocity (m/s²)</td>
<td>0.86(0.34)*</td>
<td>1.19(0.27)</td>
<td>1.30(0.18)*</td>
<td>1.32(0.22)</td>
<td>1.34(0.22)*</td>
<td>1.37(0.23)</td>
</tr>
</tbody>
</table>

* Significant difference between PRE, POST3, and POST6 (p<0.05)

Pearson’s Correlation was conducted to assess the relationship between DA-THA and control group hip abduction torque and hip adduction moment. A non-significant Pearson Correlation = -0.154 was revealed (Table 2).

Table 2: Correlation of Hip Adduction Moment and Hip Abduction Torque in the DA-THA and Control subjects

Repeated measures ANOVA means and standard deviations for hip adduction moment among three time periods (PRE, POST3, POST6) between DA THA and Control groups are presented in Table 3. No significant main effects or interactions were seen in hip adduction
moment between the groups and among the data collection time periods Wilks’ Lambda = .942, F (2,12) = .373, p = .412, partial eta squared = .697 (Table 3).

<table>
<thead>
<tr>
<th></th>
<th>PRE</th>
<th>POST3</th>
<th>POST6</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA-THA</td>
<td>0.92 (0.15)</td>
<td>0.99 (0.19)</td>
<td>1.04 (0.19)</td>
</tr>
<tr>
<td>Control</td>
<td>0.99 (0.22)</td>
<td>1.01 (0.15)</td>
<td>1.05 (0.23)</td>
</tr>
</tbody>
</table>

Repeated measures ANOVA means and standard deviations on hip abduction torque among the three time periods (PRE, POST3, POST6) between DA THA and Control groups are presented in Table 4. A significant interaction between group and time, Wilks’ Lambda = .394, F (2, 13) = 9.985, p = .002, partial eta squared = .606 was revealed. Subsequent separate one way repeated measures ANOVAs were conducted to compare torque scores between groups among three time periods (PRE, POST3, POST6). Results indicated a significant difference for time in the control group from PRE to POST6 with p = .008. The DA-THA data indicated no significant effect for time, Wilks’ Lambda = .529, F (2, 6) = 2.673, p = .148, partial eta squared = .471. Although not significant the DA-THA groups mean abduction torque data increased over time (Table 4).

<table>
<thead>
<tr>
<th>Hip Abd (ft-lbs)</th>
<th>PRE</th>
<th>POST3</th>
<th>POST6</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA-THA</td>
<td>18.31 (9.43)</td>
<td>21.36 (12.44)</td>
<td>22.53 (10.59)</td>
</tr>
<tr>
<td>Control</td>
<td>26.07 (9.56)*</td>
<td>24.63 (11.78)</td>
<td>19.93 (9.03)*</td>
</tr>
</tbody>
</table>

* Significant difference between PRE and POST6 (p<0.05)
Pearson’s Chi-square test on Trendelenburg test grade between DA-THA and control groups among three time periods (PRE, POST3, POST6) are presented in Table 5. No statistical interactions were indicated in the Trendelenburg test grade among DA-THA and Control group data among collection time periods or group, Pearson’s Chi-square $x^2 = .307, p = .341$.

Table 5: Occurrence of Trendelenburg Test Grade for DA-THA and Control groups at PRE, POST3, and POST6 time periods

<table>
<thead>
<tr>
<th>Trendelenburg Test Grade</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DA-THA</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Control</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>POST3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DA-THA</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Control</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td><strong>POST6</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DA-THA</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Control</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

Trendelenburg Grade: 1= Maximal elevation of pelvis for 30 sec, 2 = Elevation of pelvis for 30 sec but not maximal, 3 = Elevation of pelvis but not for full 30 sec, 4 = No elevation of pelvis, 5 = Drooping of pelvis, 6 = Non-valid response: presence of hip pain, uncooperative patient

**Discussion**

The most significant finding of the present study was that no relationship was revealed between hip abductor torque and hip adduction moment between the DA-THA and control groups. Hip adduction moment in the DA-THA group of the present study was lower than that reported by Rutherford et al who examined hip adduction moment of healthy subjects and found peak adduction moment to be 1.63 Nm/kg during the initial 20% of gait and 0.8 Nm/kg adduction moment at 20-40% of gait (Rutherford and Hubley-Kozey, 2009). Results of the present study showed that hip adduction moments of the healthy control subjects was comparable to that of the DA-THA at the 6 month data collection period (Figure 1). Rutherford et al also found normative net external adduction moment values in their healthy sample aging...
from 35-55 years. Conversely both the DA-THA and control groups in the present study did not equate normative values reported by Rutherford (Rutherford and Hubley-Kozey, 2009). While the present study’s hip adduction moment values were lower than the Rutherford and Foucher, they exceeded values reported by Lamontagne et al, Shrader et al, and Zijlstra et al (Lamontagne et al., 2009, Shrader et al., 2009, Zijlstra and Bisseling, 2004). Rutherford et al found that strength contributes to 10.5% of the moment however, it is not the sole influencer on that moment (Rutherford and Hubley-Kozey, 2009). Rutherford found that a subject’s mass and gait velocity are the main contributors to frontal plane moments during mid-stance. A possible explanation for this discrepancy between the lack of correlation in the present study and the Rutherford et al study would be the differences in sample size, subjects, and participant age.

A surprising finding was that the control group in the present study demonstrated a significant decrease in abductor torque between the PRE and POST6 data collection period. This decrease in abductor torque of the control group may be attributed to the normal aging process of individuals. The results of the present study are supported by Arokoski et al, who compared a group of healthy males to a group of male non-surgical hip OA patients (Arokoski et al., 2002) who also showed decreased abductor torque values in the hip OA patients. While the DA-THA group in the present study did not demonstrate significant changes in abductor torque during the 6 month data collection period (Figure 2). Conversely, Downing et al, Klausmeier et al, and Jensen et al (Downing et al., 2001, Klausmeier et al., 2009, Jensen et al., 2011) all revealed increases in torque in their post-surgery subjects. Klausmeier et al, compared the minimally invasive DA-THA to the Anterolateral THA and also observed an increase in abduction torque from pre-surgery to 16 weeks (4 months post-surgery) post-surgery (Klausmeier et al., 2009).
Several THA studies used the Trendelenburg test to determine hip abductor musculature function in the post-surgical THA population and the healthy population (Edmunds and Boscainos, 2011, Hardcastle and Nade, 1985, Pai, 1996, Youdas et al., 2010, Kiyama et al., 2010, Nakata et al., 2009). Theoretically, since the DA-THA does not involve abductor musculature damage, subjects should be able to demonstrate a negative Trendelenburg sign/test. Unfortunately, results of the present study failed to demonstrate significant negative or normal Trendelenburg test results in either the DA-THA or control group. Conversely, Nakata et al compared the DA-THA to the minimally invasive posterior approach and revealed a significant difference between groups at three weeks post-operatively. Individuals (n=29) in the DA-THA group displayed a positive Trendelenburg test while the minimally invasive posterior approach group had 64 subjects display positive Trendelenburg test results and continued to have functional weakness when performing the Trendelenburg test (Nakata et al., 2009).

Conclusions

Within the limitations of the present study DA-THA and control groups failed to demonstrate a significant relationship between hip abductor torque and hip adduction moment at three and six months following DA-THA surgery. However, a significant increase in walking gait velocity was revealed in the DA-THA group.
**Figure 1**

*External Adduction Moments for DA-THA and control group at PRE, POST3, POST6*

**Figure 2**

*Hip abduction strength measures of DA-THA and control groups at PRE, POST3, POST6*

*Significant difference from control group PRE*
Part II

Review of Literature

Introduction

The objective of Total Hip Arthroplasty surgery, apart from relief of pain, ideally is to reestablish hip biomechanics to the extent that patients show no apparent functional deficit. Often this does not necessitate returning them to “normal” gait, while normal gait biomechanics is thought to be the goal of surgery.

Direct Anterior Approach

The direct anterior approach demonstrates that minimally invasive surgeries make it possible to replace joints without damaging or detaching the surrounding musculature. Bender et al (Bender et al., 2009) set out to explain in detail the procedure of the direct anterior minimally invasive surgical approach that is performed by William J. Hozack, MD one of the authors. The authors identified multiple indications and contraindications for the surgery. A few of the indications would be for a slender, moderately developed muscle tone and subcutaneous tissue. Obese patients are viewed as a contraindication due to the possibility of soft tissue folds that may prevent the wound from healing; another contraindication is a highly muscular patient making it difficult to expose the joint. In this current surgical approach the use of standard operating table is sufficient, while other approaches require more elaborate surgical tables. All patients are placed supine on the table with the operative leg draped, this position allows for a stable pelvis and easy measurement of the leg length. The location of the start of the incision is determined by locating the anterior superior iliac spine (ASIS) and measuring 3 cm laterally and distally, and
the cut is orientated longitudinally with the axis of the tensor fascia latae (TFL). This site is orientated more laterally than the Smith Peterson approach in the hopes that it will preserve the lateral femoral cutaneous nerve (LFCN). In an attempt to protect the LFCN the authors recommend incising the TFL at its midpoint for the span of the muscle. Using the intramuscular plane between the sartorius and rectus femoris medially and the TFL laterally the hip joint is exposed. Mobilization is possible within 24 hours following surgery with weight bearing determined by the surgeon, with the authors’ inclination for weight bearing as tolerated. The anterior approach has the benefits of preventing damage to muscles and their attachments to the pelvis and femur, improving the dynamic muscular stabilization of the joint (Bender et al., 2009).

The direct anterior is believed to return patients to function earlier and this thought is what Restepo et al (Restrepo et al., 2010) investigated when they compared it to the direct lateral approach. One hundred patients that were diagnosed with osteoarthritis were randomized into two groups, either the direct anterior or direct lateral approach and all followed the same rehabilitation protocol following surgery. Patients functional outcomes, clinical examination, and radiographic evaluations were performed preoperatively, 6 weeks, 6 months, 1 and 2 years following surgery. Preoperative functional outcomes were evaluated by the Harris Hip Score, Lower Extremity Functional Score, Western Ontario McMaster Osteoarthritis Index, the Linear Analog Scale Assessment, Short Form-36, and the mobility and locomotion subscores of the Functional Independence Measure (Restrepo et al., 2010). Additionally all subjects were instructed to keep a daily diary to record their functional recovery as they saw it. The direct anterior group displayed improved physical functioning, role limitations, bodily pain, social functioning, general mental health, vitality energy or fatigue, and post-op physical and mental health dimensions when compared to the direct lateral approach group. Functional outcomes at
the 2 year follow-up were the same between groups as well as neither group displaying a Trendelenburg gait at 2 years. This study confirmed the theory that the direct anterior approach provides early functional outcomes.

Sugano et al (Sugano et al., 2009) compared the anterior approach against the posterior approach with the assistance of a CT-based navigation system in addressing the differences in the direction of cup insertion against the operating table, intraoperative range of motion, joint stability, and the choice of elevated-rim acetabular liners. The posterior group consisted of 39 patients and the anterior group had 33 patients using the Smith Peterson approach. No significant differences were seen in age, sex, diagnosis, height, weight, and body mass within the groups. CT images of all patients were taken pre-operatively at the level of the ASIS down to the femoral condyles. Once all components were placed range of motion and joint stability tests were evaluated using the navigation system. Radiographs were taken immediately post-operatively, 3 months, 6 months, and annually using the standard anteroposterior view, and laterally of the pelvis and femur. Clinical evaluation was done pre-operatively, 6 months, and 2 years after surgery using the Japanese Orthopedic Association hip score and the Oxford hip score. No distinguishable differences were seen when testing flexion, extension, abduction, or separation. In the posterior approach a larger internal rotation at 90° of flexion was seen, while the anterior approach group saw a larger external rotation motion. The anterior group did display a faster recovery time when compared to the posterior group determined by the time taken to be able to walk 20 meters without the use of a cane.

While Sugano et al just addressed the procedures of the two surgeries Nakata et al (Nakata et al., 2009) addressed the clinical aspect of comparing 182 patients who received either the direct anterior or mini-posterior approach, focusing on functional recovery when dealing with
hip stability, ability to walk, and hip function; along with operative invasion and operative accuracy. The authors’ tested hip function with required time up to walking, single-leg stance; Trendelenburg’s sign preoperatively, 5 days and 3 weeks postoperatively, and finally a timed 50 m walk preoperatively and 3 weeks post-surgery. Five days postoperatively 100% of the posterior approach patients exhibited a positive Trendelenburg sign while 97% of the direct anterior patients displayed the positive test. At 3 weeks postop the numbers significantly dropped with the direct anterior group displaying a positive Trendelenburg sign in 29 hips and 64 hips respectively in the posterior approach. Quicker recovery of Trendelenburg’s sign and single-leg stance were appreciably demonstrated in the direct anterior approach patients. When comparing the ability to walk once more the direct anterior approach appeared superior, with 34% of patients returning to walking without assistive devices at 3 weeks postoperatively, while only 19% receiving the posterior approach were able to return to unassisted walking at the 3 week mark. The authors’ results exhibited that the direct anterior approach displayed a faster recovery of hip function and hip stability when compared to the mini-posterior approach. One thought for these results may lie in the surgery itself, with the mini-posterior approach the gluteus maximus and tensor fascia latae are incised. These short external rotators play countless roles in hip function and dynamic hip stabilization. The authors’ contemplate that rapid functional recovery of the direct anterior subjects may be caused by the difference in invasion to the gluteus maximus, hip abductors, and short external rotators. Nakata et al determined that the direct anterior approach to minimally invasive total hip arthroplasty is a more beneficial and more applicable procedure for rapid functional recovery than the mini-posterior approach.

Several researches have looked at the direct anterior approach total hip arthroscopy in comparison to numerous other approaches with relationship to abduction moment and gait.
Klausmeier et al (Klausmeier et al., 2009) addressed recovery rates between the anterior and anterolateral approaches. In this study 10 control patients were compared to 23 patients undergoing total hip arthroscopy, 11 patients receiving the anterolateral approach and 12 patients using the anterior approach. In the anterior approach incisions are made distal and lateral to the anterior superior iliac spine and directed slightly anterior towards the greater trochanter. The tensor fascia latae along with sartorius and rectus femoris muscles are retracted medially; most importantly the abductor muscles are not detached. In the anterolateral approach incisions are made directly over the tensor fascia latae, the anterior one-third of the gluteus medius and minimus tendons are detached to allow exposure of the hip joint. It has been shown that the anterolateral approach affects abductor muscles, which stabilize the pelvis, while the direct anterior approach has shown no damage to the muscle (Mayr et al., 2009). Patients were instructed to begin active abduction against gravity 6 weeks postoperative. Isometric hip abduction strength was assessed using KIN-COM dynamometer on the involved leg of the experimental group while bilateral isometric abduction strength was assessed on the control group. Kinematic and kinetic variables were also tested using an eight-camera motion capturing system (Motion Analysis Corp) with 29 reflective markers where subjects were instructed to walk without shoes across a force plate for 10m at a self-selected speed. The kinetic variables that were assessed were peak hip abduction at both early and late stance phase, internal and external rotation, and flexion/extension moments during each stance phase. Surgical patients were evaluated initially before surgery, six, and 16 weeks postoperatively while the control group was tested initially twice in one month to account for intertester reliability and/or intrasubject repeatability. A mixed model ANOVA was used to evaluate the dependent variable changes between the two surgeries and in comparison to the control group. Data before surgery
showed the THA patients had weaker isometric hip abductor strength as well as a decreased peak abductor moment when they were compared to the control group. At six weeks post-surgery the anterior approach patients did not exhibit an increased return to control levels for either hip strength or mobility when compared to the anterolateral approach patients. They did however show an increased gait velocity, stride length, greater sagittal plane hip range of motion, and greater peak flexor moments when compared to their initial tests. No improvements were seen in the anterolateral group 6 weeks postoperatively. At the 16 week evaluation no changes were seen in hip strength, mobility, or gait temporal distance measures between the two surgery groups. The anterior approach patients did show increased isometric abductor strengths with greater peak abductor moments. When compared to the control group both THA group’s demonstrated weaker isometric hip strength and a lower peak abductor moment during early stance when measured at 16 weeks postoperatively. During second peak hip abductor moment the anterior approach patients showed improvements that matched the control group. Results of this study indicated no differences between surgical approaches in the recovery of hip abductor strength during the 16 weeks. The anterior THA group did exhibit normal magnitudes of the peak abductor moment at six and 16 weeks postoperatively.

Mayr et al (Mayr et al., 2009) performed a randomized assessment of earlier (6 and 12 week follow-up) functional recovery in total hip arthroscopy patients that were treated with the minimally invasive direct anterior and anterolateral approaches focusing on gait analysis. Many THA patients show increased quality of life, an increase in physical function, and had reduced pain, however they often do not return to normal gait one year following surgery. The authors’ hypothesized that patients receiving the direct anterior approach would demonstrate earlier return to normal function when compared to the traditional anterolateral approach. Sixteen patients
were randomly selected to form the direct anterior (DA) group with ages ranging from 55-84 years and an average BMI of 27. Seventeen patients were randomly selected to make up the anterolateral (AL) group; their ages ranged from 59-78 with an average BMI of 29. Joint kinematics were performed one day before surgery, 6 weeks postoperatively, and again at 12 weeks. A six camera VICON system was used at 60hz to track the 15 reflective markers that were placed on each individual as they walked 9m at a self-selected pace in 5 separate trials. The DA group showed significant increases in single support and stride time at 6 weeks. At 12 weeks improvements were seen in cadence and stride length, while no significant differences were seen in the AL group during either follow-up session. Both the DA and AL groups showed an improvement in hip abduction and adduction during stance were seen both at 6 and 12 weeks. Patients in the DA group showed significant increases in the majority of time-distance parameters, with the greatest significance occurring at the 12 week test session. The AL group displayed no significant increases in time-distance parameters in either the 6 or 12 week follow-up. Coronal plane pelvic rotation and hip adduction during stance were observed as possible markers of abductor muscle weakness. These two variables may not be the best discriminators due to the patient-specific compensatory mechanisms were not entirely investigated, for example the trunk kinematics. Using visual inspection no patients showed excessive predisposition of the trunk as a compensatory mechanism for weakened abductors following surgery. The authors’ data showed that the DA patients had noteworthy increases in a larger number of gait parameters than those patients in the AL group, with a large majority of those increases occurring between the 6 and 12 week sessions. Mayr et al concluded that although their study was limited to the overall functional examinations by means of gait kinematic data, patients that received the DA
approach showed an earlier return to near normal gait that those with the traditional AL approach.

Theoretically the direct anterior approach ought to cause less muscle damage than the posterior approach, it is this belief that lead Bergin et al (Bergin et al., 2011) to investigate that the direct anterior approach would display less muscle damage when compared to the posterior approach using biochemical markers. Twenty nine patients with osteoarthritis were in the direct anterior group with 28 patients volunteering to be in the posterior group. Increases in serum creatine kinase (CK) levels were used to determine muscle damage due to surgery, levels were analyzed preoperatively, immediately postoperatively, and on post-op days 1 and 2. Significant differences were seen immediately postoperatively and again on post-op day 1 between the anterior and posterior approaches. Immediately postoperatively the posterior group displayed a 5.5 times higher level than the anterior group. A cumulative rise was also present with nearly twice the level seen in the posterior group. Through multivariate analysis a rise in the CK level was determined to be independently linked with the surgical approach, estimated blood loss, and the transfusion requirements; confirming the relationship between surgical approach and rise in CK levels including an connection between blood loss and muscle damage. In this study there was a clear difference between the anterior and posterior approaches in terms of the rise in serum CK levels at varied time intervals regardless of the preoperative functional and deformity scores. Significantly less muscle damage was seen using the direct anterior approach when compared to the posterior approach when using the evaluation of serum CK levels.

van Oldenrijk et al (van Oldenrijk et al., 2010) was also concerned with muscle damage following MIS-THA as Bergin was. The current authors set out to determine if one MIS-THA approach created less muscle damage than the other when compared to the lateral trans-gluteal
technique on cadavers. Their main primary outcome to the study was the damage done to the gluteus medius muscle, they additionally looked at damage to the gluteus maximus, gluteus minimus, quadratus, rectus femoris, sartorius, and tensor fascia latae. Thirteen fresh frozen adult cadavers were used and distributed into 5 groups, the MIS anterior, MIS posterior, MIS anterolateral, MIS 2-incision, and the trans-gluteal approach for surgery. Five separate surgeons with experience in each approach performed the 5 surgeries using the technique with which they had expertise. Following the operation all cadavers were immediately fixed by submersing them in a 10% formalin solution, making the tissue less vulnerable to decay and handling, allowing for careful dissection of the soft tissue structures. Measurement of muscle damage was normalized by assessing the percent of damage relative to the midsubstance cross-sectional surface area (MCSA) (van Oldenrijk et al., 2010). The affected area was stained yellow and the undamaged tissue stained blue with latex paint. The ratio between yellow and blue was detected using the program MATLAB version 7.0.4.365. The percentage of yellow pixels in comparison to the total number represented the damage done to the muscle at the MCSA level. In 4 out of 5 of the MIS anterior approach the gluteus medius remained fully intact; however none of the approaches were statistically significant when compared to the trans-gluteal approach for gluteus medius muscle damage. Similar findings were seen with the gluteus maximus, gluteus minimus, quadratus, rectus femoris, and tensor fascia latae; with no statistically significant differences between the MIS approaches and trans-gluteal approach. The MIS approaches were found to cause more damage to the quadratus and the tensor fascia latae then the trans-gluteal approach. The authors concluded that they were not able to find statistically significant differences in the amount of muscle damage between different approaches, while the MIS anterior approach preserved the gluteus medius in 4 out of 5 cases.
Trendelenburg Test

The Trendelenburg test has long been used to access hip abductor function, however there is no standard test. Varying versions exist in the orthopaedics, physical therapy, and athletic training. Hardcastle et al (Hardcastle and Nade, 1985) attempted to standardize the test along with access the pitfalls that exist in the test, and reported the responses of the normal person. The authors performed the test by asking patients to balance with their knee flexed at 30 and 90 degrees for 30 seconds. Video imaging, electromyography, and assessment of abductor muscle power strength were all evaluated. Electromyography was performed on the gluteus maximus, gluteus medius, gluteus minimus, tensor fascia latae and adductor magnus muscles to determine their activation during the Trendelenburg test. During the Trendelenburg test on normal individuals when done with the knee flexed at 30 degrees they found three responses within the normal patients. Response one was the “negative” test, where the individuals were able to elevate the pelvis on the non-stance leg for the full 30 seconds. The pelvis remained level in the second response, while the third response demonstrated a drop on the non-stance leg creating a “positive Trendelenburg test”. With the knee flexed at 90 degrees only two responses were seen. The first showed elevation in the non-stance pelvis, however, it was not as significant as when the knee was flexed at 30 degrees. Response two was shown as the pelvis remaining neutral, with no elevation or drop in the pelvis. Electromyography showed that in the third response at 30 degrees of knee flexion no activity was present in gluteus maximus, gluteus medius, gluteus minimus, or adductor magnus; however the tensor fascia latae showed activity (Hardcastle and Nade, 1985). The abnormal subjects when tested displayed false negative results. A false negative is where the individual would shift their trunk over the weight bearing hip reducing the amount of hip abductor muscle activity, in doing so they were able to elevate
the non-stance pelvis. Additional false negatives were seen with individuals supporting themselves on a table or wall with non-stance side arm, where the assistance of the shoulder and back musculature assisted them with elevating the pelvis on the non-stance leg. In the subjects who displayed pain they found that they tended to shift their center of gravity to decrease the strain on the abductors. Subjects who displayed pain were only able to balance for a few seconds before ending the test. In the subjects that leaned over their hip or used musculature above the pelvis displayed little abductor muscle activity during the electromyography testing. A few individuals demonstrated a delayed positive Trendelenburg test, where they initially showed a negative test but as time went on they displayed a dropped pelvis resulting in a positive test. A significant finding was revealed in one individual who had bilateral replacement arthroplasty and showed a normal response when tested three years after surgery. The authors were able to confirm the results of Inman et al that minimal abductor muscle activity is needed to maintain a balance position when the individuals were unable to maintain a level pelvis. In a negative test there was an increase in abductor muscle activity as long as their torso was centered over their hip.

Trendelenburg test grading is also not standardized between examiners. Pai et al (Pai, 1996) in evaluation of three different THA approaches (Hardinge, Liverpool, Transtrochanteric approaches) developed a grading scale that is often used by many examiners to date. Grade one was determined to be normal, if the pelvis on the non-stance leg could be elevated maximally and maintained for 30 seconds. Grade two is defined when elevation of the pelvis is achieved but not held maximally. Grade three and below are graded as positive Trendelenburg tests when the pelvis is elevated but not maintained for a full 30 seconds. Grade four is shown as no elevation of the pelvis, while grade five is defined as drooping of the pelvis. Grade six is
considered a nonvalid response, due to the presence of pain or an uncooperative patients (Pai, 1996). The authors found that abduction function was not affected by the type of the approach when compared to the Trendelenburg test and abductor strength. Of the 264 patients evaluated only 44 displayed a positive Trendelenburg sign. Pai discovered no true difference between the three approaches when comparing functional level, range of motion, and limp. There were no increases seen in positive Trendelenburg gait between the three approaches. They concluded that the Trendelenburg test is a valuable clinical examination test when it is performed and interpreted correctly.

The Trendelenburg test has been used in numerous research studies to determine hip abductor muscle function, but no prior studies have established a relationship of the Trendelenburg test and isometric muscle testing to actual hip abductor function in patients with hip osteoarthritis. Youdas et al looked at addressing this lack of previous research in establishing the validity of the Trendelenburg test and isometric hip abductor muscle strength in identifying patients with hip OA (Youdas et al., 2010). They hypothesized that the Trendelenburg test is a valid examination tool to identify patients with or without hip OA. Ten healthy men and ten women volunteered to be a part of this study and act as the control group, while ten men and ten women diagnosed with hip OA volunteered as well. All subjects with confirmed hip OA were screened by one of the authors and were evaluated on the following inclusionary criteria; a 10% or more reduction in active range of motion when compared to un-injured hip in hip flexion, abduction, and internal/external rotation, along with a positive test on any of the three special screening tests used for hip OA. Those that were diagnosed with hip OA completed a modified version of the Patient Specific Index (PSI), where they rated their degree of difficulty in performing 13 functional activities. These were then in turn used to determine the subjects’ level
of hip impairment. These 13 items were then rated using a seven point Likert-type scaling system, with scores ranging from 91 to 13, where 91 was rated as “unable” to perform the 13 activities and 13 being able to perform all 13 activities without difficulty. Pelvis to femur (P-O-F) position was measured with the use of a universal goniometer (UG) during single leg stance. Adhesive markers were placed on both anterior superior iliac spines to provide consistent placement of the UG when determining P-O-F measurements. The first examiner had three different duties while the subject performed the Trendelenburg test. Their first duty was to time the subject’s single leg balance up to 30 seconds, the second duty was to prompt the subjects to keep an erect posture during the 30 second time, and lastly to record the P-O-F position with the UG. The second examiner was in charge of instructing the subject in the correct performance for the single leg balance test and to accurately measure the P-O-F position. All subjects performed two trials for each leg to obtain an estimate of the error associated with the measurement.

Isometric hip strength was evaluated using a Chatallon dynamometer. Subjects were placed in the supine position and the examiner performed a “make” test to evaluate hip abductor strength. Subjects were instructed to build up to full force over a two second count and sustain it for an additional five seconds. Another examiner braced the subject on their opposite side to maintain a neutral abduction placement. The first examiner performed all isometric hip abduction strength tests and was blinded to the measurement outputs, with two measurements performed bilaterally. Results showed that the control subjects displayed a significantly higher normalized isometric hip strength when compared to the hip OA subjects. The specificity of the Trendelenburg test was 0.70 and the sensitivity was 0.55 for the identifying of subjects with hip OA yielding a positive likelihood ratio of 1.83. When isometric hip strength was normalized the sensitivity was 0.35 and the specificity was 0.90 resulting in a positive likelihood ratio of 3.5 for identifying
patients with hip OA. Patients that have been previously diagnosed with hip OA are 3.5 times more likely to exhibit 30% body weight or less isometric hip abduction strength than those without hip OA. The authors determined that manual muscle testing is more valid in predicting subjects with hip OA than the previous “gold standard” Trendelenburg test.

**Hip Strength/Manual Muscle Testing**

Hip abductor strength is essential to hip function due to its ability to maintain a stable pelvis not only during bipedal motion but most significantly during single leg stance (Inman, 1947). The loss of this strength has shown several compensatory gaits, such as the Trendelenburg gait and Duchenne gait (Widler et al., 2009). Numerous studies have looked at the best way to evaluate not only hip strength but also manual muscle strength in general.

Inman et al (Inman, 1947) examined the functional characteristics of the abductor muscles in 35 healthy individuals. Theoretical torque was determined by multiplying body weight by the distance from the median sagittal plane to the center of rotation of the joint. They then determined the torque experimentally at the hip by myographic recording, with both surface and needle electrodes. Electrodes were placed over the tensor fascia latae, gluteus medius and minimus. All subjects were evaluated by an early Trendelenburg like test where the subject bore their weight on the limb that the electrodes had been placed on. The non-weight bearing limb was flexed at the hip and knee as just to clear the ground. Action potential of the abductors was seen as they exerted the force to keep the pelvis level. Then the subject was instructed to shift their weight to opposite leg, a small block was then placed under the foot so that the leg from which the original recording just cleared the floor without having to flex the hip or knee. A strap was placed around the lateral malleolus that had a spring attached to measure the excursion. A
measurement taken from the femoral head to the middle of the strap was used to determine the abduction power by multiplying the distance to the reading of the spring scale. The author’s determined that they could translate the action potential of the abductor muscles directly into moments of force or torque. The experimental torque was found to be one third to one half lower than the theoretical torque. The author’s set out to determine why this could have happened. So they had all the subjects studied again, but they changed their methods slightly. The subjects were instructed to do a single leg stance but this time they were asked to elevate the pelvis 15 degrees on the non-weight bearing leg. They then determined the action potential of the abductors and found an increase that reached near theoretical values. An additional finding was that the force which inhibits the pelvis from rotation about the supporting hip is not due solely to muscle pull but is affected by the passive tension created by the tensor fascia latae and iliotibial tract. Leading to the assumption that a great muscle mass is not necessary in the abductors, due to the role played by the fascia that assists these muscles. With the torque determined it becomes possible to determine the action of the abductors with the inclusion of finding the angles of action for the individual muscles and fascia, and the length of the lever arm with which they act upon. To evaluate this, dissection of the gluteal muscles was done on cadavers with wires placed along the borders of the muscles to determine their pull on the body. The shadow of the wire was used to determine the exact pull they have. It was found that the gluteus maximus has no action potential when the body is forced to balance on one leg. The author’s determined the magnitude of force for the abductor muscles, fascial tension, and iliotibial tract by again completing the Trendelenburg like test. The three positions are as follows: with the pelvis level, pelvis sagging 15 degrees and elevation of the pelvis by 15 degrees. It was shown that at level pelvis the resistant torque was equally distributed between
the iliotibial tract and the muscles. With 15 degrees of sag the torque lies solely on the fascial tension, and with 15 degrees of elevation the torque is generated by the muscles alone. One clear conclusion is that the force of the abductor muscles and the tension of the iliotibial tract are necessary to hold the pelvis in equilibrium (Inman, 1947).

Hip abductor strength has been evaluated in the supine, side lying, and standing positions; however no one until Wilder et al (Widler et al., 2009) addressed the reliability and validity of each of those positions. The authors included sixteen healthy adults, 8 females and 8 males, in their study. Electromyographic activity of the gluteus medius along with isometric muscle testing were used in determining the validity of each position. Hip abductor strength was measured using a portable dynamometer that was adhered to a custom made frame. All subjects warmed up on a cycle ergometer for five minutes, after this warm up period they were each given standardized instructions and a submaximal familiarization trial for each position was completed. Measurements of the dominant and non-dominant leg were assessed along with randomization of each position. In the side lying position the contralateral leg was placed in 30° of knee and hip flexion, while the tested leg was in full extension at the knee. The weight of the limb was calculated and corrected during the maximal contraction. During the supine position the subject had an abdominal belt placed on them to stabilize the pelvis during testing. In the upright position the subject was placed against the wall for stabilization and the tested limb against the table and the custom made frame. During each positional testing the tested leg was in full extension and 10° abduction. Subjects were asked to complete a full contraction of the muscle for four seconds with sixty seconds rest in between, two trials were performed, a third trial was performed if the first two trials were larger than 10% difference. Electromyographic (EMG) activity was recorded on both the tested and contralateral hip. The highest values of the
two maximal contractions were used. Wilder et al found that the side lying position produced the highest isometric hip abduction strength along with contralateral – to –tested EMG ratio displaying the lowest ratio in the same position. A greater validity of the side lying position was determined when compared to supine and standing. The test retest reliability showed that isometric hip abduction strength is best measured in the side lying position when using a stabilized portable dynamometer.

While Wilder et al addressed the validity of the position during manual muscle testing he used healthy subjects, which can be limited due to the population being tested (Hayes and Falconer, 1992), Hayes et al (Hayes and Falconer, 1992) believed that reliability should be measured on a specific population rather than healthy subjects. This study looked at 43 patients with chronic osteoarthritis of the knee who were participating in a clinical trial for exercise and ultrasound. Knee extension was measured both by manual muscle testing (MMT) and handle held dynamometer (HHD) testing. Subjects were placed in a seated position, staying erect and holding on to the table for stabilization. The manual muscle test was performed by having the subject extend their knee against gravity, and then the examiner performed a break test proximal to the ankle and was graded with the traditional manual muscle testing system. Hand held dynamometer measurements were performed at 80% of the lower leg length with the knee at 65° of flexion. This test was done as a make test for a four second contraction two times with 30-60 seconds rest. The researchers found that during the HHD subjects produced lower strength measurements; during MMT the examiners had a median graded score of good. The test retest reliability between examiners showed little variability with scores of 0.89-0.98. As the mean HHD strength measurements were calculated using the MMT grade, the HHD measurements increased as MMT increased. Hayes et al discussed the idea that if the examiner is weak then the
HHD scores will be lower due to the perceived inability of the subject that the examiner cannot match their strength efforts. In this present study they stated that no examiner conveyed difficulty in matching the efforts of the subjects. The authors concluded that there is sufficient reliability in HHD measurements in patients suffering from OA, while some variability existed in the use of the HHD correctly between examiners.

The cause of abductor weakness after total hip replacement surgery is believed to be caused by numerous factors, such as injury to the superior gluteal nerve, and the incorrect realignment of the fibers of the gluteus minimus and medius that are reflected back to reveal the hip joint. Baker et al (Baker and Bitounis, 1989) investigated the cause of abductor weakness following two different lateral approaches of total hip replacement along with a posterior approach that served as a control group (Baker and Bitounis, 1989). The modified direct lateral approach surgery that took a section of the greater trochanter off with the attachment of the gluteal muscles, the Hardinge approach was considered a soft tissue flap procedure. The authors used a visual analog scale to rate pain and a modified Trendelenburg test as developed by Hardcastle and Nade to evaluate abductor power (Hardcastle and Nade, 1985). The test was graded as either negative or positive with a Grade I or Grade II. The negative test was determined as the subject was able to raise their pelvis on the unsupported leg and maintain for a 30 second time frame. Grade I positive test was when the subject was able to maintain a level pelvis with no elevation. A grade II positive test was determined to be where the subject was unable to maintain a level pelvis and the unsupported pelvis dropped below horizontal. Electromyography was used to determine denervation of the subjects. Three sites of the tensor fascia latae were tested using EMG needle punctures two fingers-breadths anterior and medial to the greater trochanter. Those that had the direct lateral approach with the transection of the
greater trochanter were radiographed imagined three months postoperatively to assess union of the osteotomy. At the two week EMG session denervation was seen in three patients with the modified direct lateral approach, ten in Hardinge’s direct lateral technique, and three additional patients in the posterior approach. After three months postoperatively there were lower incidences of denervation with no significant difference found between the groups. Twenty eight patients with the modified direct lateral displayed malunion or nonunion of the greater trochanter during follow-up radiographs. Four of the patients had their trochanteric wire break, two displayed proximal migration of the trochanter sliver and nine hips showed ununited undisplaced sliver. Abductor function in the seventeen hips with trochanteric union was significantly better than those who displayed malunion or non-union. The difference of denervation between the two week and three months was attributed to the traction of the nerve done in the direct lateral and it was less commonly seen in the modified direct lateral technique. The results of the modified Trendelenburg test had seventeen grade I positive tests and eleven grade II, with only five of those displayed evidence of denervation on the EMG reading. The authors believe that the abductor weakness can be contributed to the detachment of the anterior gluteal flap in the direct lateral approach. Those that had the modified direct lateral approach that had an inadequate fixation of the trochanter displayed abductor weakness while the union osteotomy showed no weakness. On a follow-up session one year later they retested twenty seven of the twenty eight patients that displayed a positive test on the modified Trendelenburg and showed that fifteen of them continued to have a positive test, eight with a grade II positive test, of which six of them had the direct lateral approach performed.

**Hip Abduction Moment**


Previous research addressing moments and forces during movement have used inverse dynamics that use a motion analysis capture system along with force plate data. Zijlstra et al (Zijlstra and Bisseling, 2004) looked at estimating hip joint moments using body fixed sensors with assuming a rigid trunk and a segmented trunk and compared them to the traditional inverse dynamic approach. They used five healthy male participants with a mean age of 23. Three different leg lengths were measured; the first was done with the subject standing on the right leg while maintaining a vertical trunk. The second was instructed again to stand on the right leg with the addition of bending the trunk to the right, the final position was a repeated lateroflexion of the trunk to the right on the right leg. These measurements were taken while standing on a force plate for ten seconds each. Five gait conditions were evaluated, the first was the subjects were asked to walk at their preferred pace, the next two were to walk slower and faster than that preferred pace. They were then instructed to walk at their preferred pace again, however this time they combined with either a maintained adjusted trunk posture or the exaggerated lateroflexion position. The authors looked at only right foot data on the force plate with five successful trials for each condition. The authors acquired data with Elite motion analysis system, force plate, accelerometers, and uniaxial gyroscopes to determine hip abduction moments. The accelerometer and gyroscope data were performed on the dorsal aspects of the upper and lower trunk. They were attached to small light weight plates by elastic neoprene bandages strapped around the pelvis and thorax. Analysis addressed the three different methods in calculating hip abduction moment. Zijlstra determined that while standing with a vertical orientation all three estimations are similar, however the two body fixed sensor estimations were slightly higher in value. While in a lateroflexed position the moment decreased, in part due to the displacement of the trunk, again the body fixed sensors methods showed a higher value. The final posture of
repeated lateroflexion displayed a convincing variation, with the segmented trunk model showing a superior correspondence to that obtained by position and force data than the rigid trunk model. Overall the authors determined that the body fixed sensors method overestimated hip abduction moment, with the segmented trunk model displaying better correspondence with the position and force-based method.

An increased abduction moment in hip OA patients creates increased pain felt in the joint. Chang et al (Chang et al., 2005) however investigated if an increased abduction moment at the hip would decrease ipsilateral medial knee OA progression. Fifty seven individuals enrolled in a previous study entitled Mechanical Factors in Arthritis of the Knee participated in the current study. Six markers were placed on the superior iliac crest, greater trochanter, lateral joint line of the knee, lateral malleolus, lateral aspect of the calcaneus, and the base of the 5th metatarsal to calculate the inverse dynamics of the external moments at the hip, knee, and ankle using the Computerized Functional Testing Corporation system. Ten subjects were evaluated for reliability of hip abduction moment measurements between the two data sessions. The patients knee plain severity was measured using a 1-100 scale, with 100 being the worst possible pain. Radiographs were used to evaluate the severity of the knee OA, with a grading scale of 0=normal, 1=possible osteophytes, 2=definite osteophytes, possible joint space narrowing, 3=moderate osteophytes, definite joint space narrowing with possible attrition, along with some sclerosis, 4= large osteophytes, marked narrowing, severe sclerosis, definite attrition (Chang et al., 2005). Knee OA was determined by using knee radiographs while weight bearing to assess the joint spacing at baseline and again at 18 months. Progression was defined as any worsening of the medial joint spacing grade of none, possibly, definitely, or severely narrowing joint space. The subjects that had a severe grading at baseline were removed from the analysis due to the lack
of progression possible. Peak hip abduction moment was witnessed early in the stance phase of gait, with the patients with a non-progressing knee displayed a greater peak hip abduction moment when compared to the progressing knee. They then examined the relationship of internal hip abduction moment at the baseline session and 18 months after. The authors found that a greater internal hip abduction moment had a protective effect, that is, it decreased the odds of knee OA progression, even after adjusting for the confounding variables of age, sex, gait speed, knee pain severity, physical activity, knee OA severity, hip symptoms, and hip OA presence. The likelihood of medial knee OA progression dropped by 50% with an additional 1 unit of hip abduction moment.

Functional outcomes in THA patients have been studied previously and some studies indicate that normal outcomes are still not seen up to 2 years following surgery. Perron et al (Perron et al., 2000) addressed the comparison of gait patterns between patients receiving either the posterior or anterolateral approach with a total of 18 women to a group of healthy control group of 15 women. All subjects were instructed on walking at a self-selected speed along a walkway with 5 successful trial collected. Peak abduction moment displayed a 15% lower value in the THA group as a whole when compared to the healthy women while in the frontal plane. Weak hip abductor muscles can be seen as the cause of the poor control of balance in the frontal plane. Overall at 46.5 weeks following surgery all THA patients demonstrated gait disability and residual impairments not only seen in the hip but also in neighboring joints (Perron et al., 2000).
Gait Analysis

Recent literature by numerous authors indicates that even after THA surgery patients are not able to return to “normal” gait patterns or even quality of life when compared to the general population. Beaulieu et al (Beaulieu et al., 2010) looked at mobility by comparing hip, knee, and ankle joints, moments bilaterally of the THA patients and a control group. Twenty THA patients and 20 control subjects were matched for age, gender, and BMI and tested between 6 and 15 months post-surgery. The THA patients all received the same lateral approach where the anterior third and posterior two-thirds of the abductors were split and then repaired after the surgery. Each participant was instructed to walk across the walkway at a self-selected speed with three trials each addressing left and right foot strike on the force plate. The modified Plug-in Gait retroreflective marker technique was used with a nine camera digital optical motion capture system (Vicon MX) at 200Hz to measure kinetic and kinematic data. The THA group showed a distinct lower peak flexion angle, peak extension angle, total sagittal-plane ROM, peak adduction angle and peak external rotation angle when compared to the control subjects. Additionally lower peak abduction and external rotation moments were seen in the THA group. The author’s found that THA patients were not able to return to normal gait mechanics. It also confirmed previous studies conclusions that following THA surgery patients yield a smaller hip abduction moment while in a less adducted position, when compared to the general population. By walking in a less adducted position THA subjects necessitated a smaller hip abduction moment to counteract the center of mass. Many have hypothesized that this altered gait is a result of weakened abductor musculature.

Müller et al (Müller et al., 2010) took previously hypothesized thoughts concerning hip abduction strength related to decreased abduction moments when he compared abductor muscle
damage in a minimally invasive anterolateral approach and the more traditional direct lateral approach. It is believed that the minimally invasive techniques are superior to the more traditional techniques when addressing the potential reduction of soft tissue damage. There is much debate as to whether there is an actual decrease in muscle and tendon damage in minimally invasive approach. Previous researchers have shown in all approaches of THA muscle damage exists. The purpose of this study was to examine and compare the two approaches and determine if there was significant difference in soft tissue damage along with analyzing the relevance to postoperative pain and functional recovery. Forty-four patients were randomly assigned either the minimally invasive anterolateral of the modified direct lateral approach via the roll of a dice. During the lateral approach the gluteus medius was cut at a maximum length of 3cm, along with the detachment of the anterior third of the gluteus medius along with the underlying gluteus minimus muscle. The minimally invasive anterolateral approach uses the intermuscular plane between the gluteus medius and the tensor fascia latae to expose the hip and conserve the muscles integrity. The goals postoperatively were for the patients to regain full range of motion, flexibility, regain strength and endurance, and the majority of proprioception. Each patient was assessed preoperatively, 3, and 12 months postop, in Trendelenburg’s sign, hip abduction strength, and MR imaging. Statistical differences were seen in in Trendelenburg’s sign at 12 months in the modified direct lateral group when compared to the minimally invasive anterolateral group. The minimally invasive anterolateral group showed marked higher values in abduction strength of their affected hip at 3 and 12 months, but it was without statistical significance. The MR imaging showed that abductor muscle and tendon damage did occur in both procedures, but pointedly more pathological findings for the gluteus medius muscle were seen in patients with the modified direct lateral approach. Müller et al found that the results
showed that mini-invasive approach showed higher and better values, in scoring systems, and abduction tests. They also determined that the MR images were the most reliable when determining actual muscle damage following either approach. Due to the positive Trendelenburg signs seen in the modified direct lateral approach, the shown gluteus medius damage seems to be echoed in gait pattern, pain and satisfaction of the patients treated.

Antalgic gait patterns are seen in THA patients due to pain of the affected joint and are often displayed after surgery (McCorry et al., 2001). Lugade et al (Lugade et al., 2010) investigated whether the anterior or anterolateral approach to THA or both, would display a “normal” gait following surgery when compared to a control group. Twelve subjects underwent the anterior THA, 11 had the anterolateral approach, and 10 age matched subjects participated as controls. Gait analysis for both THA groups was performed pre-operatively, 6 and 16 weeks post-op, while the control group came in twice within one month. Analysis of gait was taken with a minimum of 5 walking trials at a self-selected pace across a 10m walkway. Step length, single leg support time, pelvic obliquity, vertical GRF, and gait velocity were all addressed in this current study. As assumed the THA subjects displayed a greater gait asymmetry. At 6 weeks post-op the anterolateral group displayed a greater asymmetry, and no improvement in single leg support time was seen 6 weeks post-op. The anterior group showed an improvement in single leg support time at the 6 week data collection session, they also approached levels of “normal” for step length when compared to the control group. The anterior and anterolateral groups moved toward the level of the control group by 16 weeks post-op for temporal-distance indicators, however differences were still seen for pelvic obliquity and step width (Lugade et al., 2010). This finding does not follow previous research by Madsen et al (Madsen et al., 2004), where their subjects did not approach normal gait patterns 6 months post-operatively.
Meneghini et al (Meneghini et al., 2008) investigated whether 3 minimally invasive surgery (MIS) approaches actually have an early recovery and return to function using gait analysis. All subjects were randomly assigned into 3 surgery groups. There were 8 in the 2 incision MIS approach, 8 in the mini-posterior, and 7 in the mini-anterolateral group with data sessions done preoperatively and 6 weeks post-op. All subjects were asked to walk along a 10m walkway at their self-selected speed with five successful trial collected. The variables that were looked at were gait velocity, single-leg stance time, ground reaction force, limb loading rate, and hip abduction moment or abductor torque. All approaches displayed an increase in the mean gait velocity at the 6 week mark. For single-leg stance time all 3 groups displayed a decrease in time when compared to the preoperative means, but the difference was not statistically significant. For ground reaction force only the anterolateral group displayed a decrease when the 6 week post-op was compared to the pre-op. For limb-loading rate the 2 incision and posterior approaches demonstrated an increase in limb-loading rate, while the anterolateral approach displayed a decrease in this rate. Abductor torque increased in the 2 incision approach and decreased in the anterolateral and posterior groups. No differences were found between approaches for the mean percentage change in the abductor torque when comparing the 6 weeks session with the preoperative values. The take home message of the current study is that there is no discernible advantage of the 2 incision approach over the posterior approach.

Rutherford et al (Rutherford and Hubley-Kozey, 2009) wanted to address the relationship between hip adduction moment and hip abduction strength in healthy individuals. The authors recruited 22 injury free, within the last 6 months, subjects to participate in the study. All participants were instructed to walk at a self-selected pace with at least 5 trials using a two optoelectronic motion analysis system along with a single force plate collecting the data.
Surface EMG was also collected on the gluteus medius for the evaluation of muscle activation during walking. Hip abductor muscle strength was measured using a Cybex Isokinetic dynamometer for a series of two maximal isometric muscle contractions with a 60 second rest in between trials. EMG results displayed a peak of 70% maximal voluntary isometric contraction (MVIC) that arose at approximately 8% of the gait cycle followed by a sharp decrease. A subject’s body mass and gait velocity were found to play a significant role in hip adduction moment, while abduction strength only contributed 10.5% to the moment. The current study did not find that the original peak activation of gluteus medius was correlated to the peak hip adduction moment of force during initial stance (Rutherford and Hubley-Kozey, 2009).

While limited long term kinematic data are present, early rates of recovery and gait compensations are currently not well defined. Shrader et al (Shrader et al., 2009) performed a pilot study to facilitate rehabilitation protocols in limitation factors that are associated with specific arthroplasty procedures. Antalgic gait adaptations have long been studied to determine if they can be corrected by early post-op physical therapy (Shrader et al., 2009). A goal of their study was to determine if during gait, dynamic range of motion, peak external moments, temporospatial parameters, and temporal aspects of hip muscle activation will display more significant improvements at three months postoperatively in patients receiving a resurfaced hip arthroplasty when compared to a control, and total hip arthroplasty groups. The authors had seven age matched subjects in each group who volunteered for the present study, with the same surgeon performing all surgeries through a posterolateral approach. A ten cameral passive marker system collecting at 120 frames per second was used to collect gait parameters. Subjects were asked to walk at a self-selected pace along an eight meter walkway, with five clean foot strikes collected for each foot. Surface electromyography was used to record muscle activation.
in the gluteus maximus, gluteus medius, tensor fascia latae, rectus femoris, and hamstring muscles. Data collection was done preoperatively along with three months postoperatively for all subjects. The resurfacing group and THA group both displayed a lower maximum hip abduction angles preoperatively, at three months postoperatively both groups showed improvements in hip abduction moments, with the resurfacing group displaying a more normal pattern than its counterpart THA group. When the authors addressed the complete abduction moment profile shortfalls were evident in both groups when compared to the controls, in initial peak during early stance phase. The gluteus maximus and medius demonstrated a delayed onset and reduction of peak abduction moments suggesting incapacity in force production in the THA group. Hip joint center was also evaluated to determine if any change in offset was the cause of differences in the moment results. Hip joint centers appeared slightly more lateral in the THA group when compared to the resurfacing group and the authors believe that further investigation is needed to determine if this has any influence on moments and subsequently function. If diminished hip abduction angle and moments seen during gait are not addressed, long term Trendelenburg gait often triggers bilateral joint wear as a result of high sheer stress and an increased stance time on the healthy hip and muscle compensations for abductor weakness will be seen.

The authors’ purpose for this study was to assess by means of gait analysis whether normal function is truly achieved one year after surgery or whether their preoperative altered gaits persevered. Foucher et al (Foucher et al., 2007) tested dynamic range of motion and peak external moments during walking with the belief that they would significantly improve and return to normal. Twenty eight subjects were enlisted from patients that had selected to have unilateral hip replacement surgery and were then followed for one year postoperatively. Thirteen
of the 28 subjects had the lateral approach surgery while the remaining 15 received the posterior approach. Subjects were assessed before surgery and then one year following. A control group of people with comparable distribution of body size and age with no previous history of OA were recruited and were assessed in the gait lab. During each visit both the control group and surgery groups were assessed on their passive range of motion, gross abductor strength, and limb length discrepancies, along with objective questions related to functional status. Six retroreflective makers were monitored by four optoelectronic cameras during six trials of ground reaction forces over a force plate. Two trials were performed at a self-selected slow pace, two more at a self-selected normal speed, and the last two at a self-selected fast pace. During preoperatively analysis it was determined that the patients with OA walked with different hip kinematics and kinetics when compared with the control group. Noteworthy improvements were seen in the post-surgery values of the dynamic hip range of motion along with but the frontal plane and external rotation moments. There were no changes seen in abduction, adduction, and external rotation moments. The author’s hypothesis was rejected due to the data showing that was still a significant difference in kinematics and kinetics between the control group and postoperative group. Even though major improvements were made in all parameters except external abduction and adduction moment, gait modifications persisted after surgery. Correlations were found between the preoperative and postoperative values for many parameters. The author indicated that these low moments may be a result of learned patterns before surgery, or possible persistent muscle weakness.
APPENDIX A: RECRUITMENT FLYER
Do you have healthy knees and hips?
Are you interested in assessing your walking gait, functionality, and muscle strength?

The Department of Kinesiology and Rehabilitation Science at the University of Hawai‘i Mānoa is seeking volunteers to participate in a research study: *Functional Recovery and Gait Biomechanics following Total Hip Arthroplasty: a Longitudinal Study*

### What is involved in the study?

3 year follow up after initial session:

- Total of 8 data collection sessions over 3 years
- 60 min for each data collection session

Data to be collected:

- Walking gait
- Functional capacity

### Inclusionary criteria:

- Free from Knee and hip osteoarthritis
- No previous THR or Total Knee Replacement
- No other injuries
- Adult under 85 years of age

### Background Information

The number of total hip replacement (THR) surgeries has been increasing dramatically over the past 10 years. While the posterior THR is a very successful surgical procedure for hip arthritis, the procedure that accesses the hip joint from the front of the body has shown a quicker functional recovery, however neither approach has demonstrated a biomechanical return to normal gait. The purpose of this research is to investigate

### What are the benefits for participants?

You may not receive direct/immediate benefits. However, you will obtain information regarding your walking gait, functional activity capacity, hip muscular strength, and behavioral characteristics. The results of this study will help to maintain and optimize the beneficial effect

For more information contact:
Sienna Handegard ATC, shandega@hawaii.edu

Department of Kinesiology and Rehabilitation Science
1337 Lower Campus Road, Room 231, Honolulu, HI
APPENDIX B: MEDICAL HISTORY FORM
Date ___________________________  ID # ________________________

UNIVERSITY OF HAWAI‘I AT MĀNOA
DEPARTMENT OF KINESIOLOGY AND REHABILITATION SCIENCE
MEDICAL HISTORY FORM

Instructions: Please complete each question to the best of your knowledge/ability. If you have any questions, please ask the investigators.

Part 1. Participant Information

Participant’s Name: ___________________________

Date of Birth: _______________  Age (years) ___________  Sex:  M / F

Home Address: _____________________________________

City/State/Zip: ________________________________  Email: ____________________________

Home/Cell Phone (__) __________________  Emergency Phone (___) ______________

Emergency Contact Person/Relationship: ______________________________________

Hospital Preference _______________________________________________________

Doctor Preference ______________________________  Phone _______________________

Part 2. Medical History

Instruction: Please identify any condition that you have or had that might restrict your participation in physical activity. If you answer yes to any of the following, please describe the proper aid requirements on the next page.

A. General Conditions

1. Fainting Spells  Yes No Past Present
2. Headaches  Yes No Past Present
3. Convulsions/epilepsy  Yes No Past Present
4. Asthma  Yes No Past Present
5. High Blood Pressure  Yes No Past Present
6. Kidney Problems  Yes No Past Present
7. Intestinal Disorder  Yes No Past Present
8. Hernia  Yes No Past Present
9. Diabetes  Yes No Past Present
10. Heart Disease/Disorder  Yes No Past Present
11. Dental plate  Yes No Past Present
12. Poor Vision  Yes No Past Present
13. Poor Hearing  Yes No Past Present
14. Skin Disorder  Yes No Past Present
15. Allergies  Yes No Past Present

Specific ____________________________  Past Present

16. Joint Dislocation Or separations  Yes No

Specify ____________________________  Past Present

17. Allergies  Yes No

Specify ____________________________  Past Present

18. Other ____________________________  Past Present

B. Injuries

1. Toes  Yes No Past Present
2. Feet  Yes No Past Present
3. Ankles  Yes No Past Present
4. Lower Legs  Yes No Past Present
5. Knees  Yes No Past Present
6. Thighs  Yes No Past Present
7. Hips  Yes No Past Present
8. Lower Back  Yes No Past Present
9. Upper Back  Yes No Past Present
10. Ribs  Yes No Past Present
11. Abdomen  Yes No Past Present
12. Chest  Yes No Past Present
13. Neck  Yes No Past Present
14. Fingers  Yes No Past Present
15. Hands  Yes No Past Present
16. Wrists  Yes No Past Present
17. Forearms  Yes No Past Present
18. Elbows  Yes No Past Present
19. Upper Arms  Yes No Past Present
20. Shoulders  Yes No Past Present
21. Head  Yes No Past Present

Specify ____________________________  Past Present

22. Others ____________________________  Past Present

46
APPENDIX C: WESTERN IRB THA CONSENT FORM
RESEARCH SUBJECT INFORMATION AND CONSENT FORM

TITLE: A PROSPECTIVE COMPARISON OF THE BIOMECHANICAL AND FUNCTIONAL GAIT CHARACTERISTICS OF INDIVIDUALS UNDERGOING EITHER A DIRECT ANTERIOR OR MINI-INVASIVE POSTERIOR TOTAL HIP ARTHROPLASTY: A LONGITUDINAL, MULTI CENTERED STUDY.

PROTOCOL NO.: None
WIRB® Protocol #20100778

SPONSOR: University of Hawaii
Honolulu, Hawaii
United States

INVESTIGATOR: Cass Nakasone, M.D.
888 South King Street
Honolulu, Hawaii 96813
United States

SITE(S): Straub Clinic and Hospital Bone and Joint Center
888 South King Street
Honolulu, Hawaii 96813
United States

University of Hawaii, Manoa
PE/A Complex Room 231
1337 Lower Campus Road
Honolulu, Hawaii 96822
United States

Queens Medical Center
Suite 608
1380 Lusitana Street
Honolulu, Hawaii 96813
United States

STUDY-RELATED PHONE NUMBER(S): Cass Nakasone, M.D.
808-522-4232

This consent form may contain words that you do not understand. Please ask the study doctor or the study staff to explain any words or information that you do not clearly understand. You may take home
You are being asked to be in a research study. The purpose of this consent form is to help you decide if you want to be in the research study. Please read this consent form carefully. To be in a research study you must give your informed consent. “Informed consent” includes:

- Reading this consent form
- Having the study doctor or study staff explain the research study to you
- Asking questions about anything that is not clear, and
- Taking home an unsigned copy of this consent form. This gives you time to think about it and to talk to family or friends before you make your decision.

You should not join this research study until all of your questions are answered.

Things to know before deciding to take part in a research study:

- The main goal of a research study is to learn things to help patients in the future.
- The main goal of regular medical care is to help each patient.
- No one can promise that a research study will help you.
- Taking part in a research study is entirely voluntary. No one can make you take part.
- If you decide to take part, you can change your mind later on and withdraw from the research study.
- The decision to join or not join the research study will not cause you to lose any medical benefits. If you decide not to take part in this study, your doctor will continue to treat you.
- Parts of this study may involve standard medical care. Standard care is the treatment normally given for a certain condition or illness.
- After reading the consent form and having a discussion with the research staff, you should know which parts of the study are experimental and which are standard medical care.
- Your medical records may become part of the research record. If that happens, your medical records may be looked at and/or copied by the sponsor of this study and government agencies or other groups associated with the study.

After reading and discussing the information in this consent form you should know:

- Why this research study is being done;
- What will happen during the research;
- Any possible benefits to you;
- The possible risks to you;
- How problems will be treated during the study and after the study is over.

If you take part in this research study, you will be given a copy of this signed and dated consent form.

**PURPOSE OF THE STUDY**

The purpose of this research study is to analyze the walking biomechanical and functional characteristics following a total hip replacement to determine when patients return to normal.

**PROCEDURES**

If you decide to take part in this study:
You will be asked to complete 9 data collection sessions over the next three years: 1.) before surgery, 2.) 2 weeks, 3.) 4 weeks, 4.) 6 weeks, 5.) 3 months, 6.) 6 months, 7.) 1 year, 8.) 2 years, and 9.) 3 years following your total hip replacement.

### Data Collection Time Line

<table>
<thead>
<tr>
<th>HIP Patients (n=100)</th>
<th>Before surgery</th>
<th>2 Weeks After surgery</th>
<th>4 weeks After surgery</th>
<th>6 Weeks After surgery</th>
<th>3 Months After surgery</th>
<th>6 Months After surgery</th>
<th>1 year After Surgery</th>
<th>2 Years After Surgery</th>
<th>3 Years After Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait Analysis</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Trendelenburg</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Up and Go Test</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Isometric Strength</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Functional Scores</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

At each data collection session you will be asked to:

1. Complete 3 questionnaires about your osteoarthritis and your state of mind. These questionnaires include: the Harris Hip Function Score, the Western Ontario and McMaster Universities Osteoarthritis Index, and the Short Form Health Survey.
2. Push as hard as you can into a non-moving strength measuring device in 8 different leg motions: hip flexion, extension, abduction, adduction, internal rotation, external rotation, knee flexion, and extension. This will be done on both legs.
3. Walk 6 meters (about 20 feet) 6 to 10 times at a self-selected (natural) walking speed.
4. Balance on one leg 3 times, and then repeat on the opposite leg.
5. Perform the Timed Up and Go test. This test is a timed test where you will be asked to sit in a chair, then stand, walk 3 meters (about 10 feet), turn around, and return to a seated position in the chair.

One data collection session will take approximately 60 minutes.

Information will also be collected from your medical records and stored on the secured database at Straub Clinic and Hospital. The following items will be reviewed and entered into a data collection spreadsheet:

1. History of total hip replacement surgery and other leg surgeries
2. Age, height, weight, and body mass index at the date of total hip replacement surgery
3. Pre-operative diagnosis
4. Hospital length of stay
5. Discharge disposition
6. Anesthesia physical status and analgesic medications used before and following surgery
7. Arthrotonomy component characteristics
8. Tourniquet time
9. Anesthesia type
10. Hip radiographs
11. Pre-discharge blood transfusions, hematocrit and hemoglobin levels
12. Peri-operative physical therapy outcomes
13. Surgical complications
14. Date of discharge from physical therapy

RISKS AND DISCOMFORTS

Due to the level of physical activity involved, there is a risk of injury. You may have pain in your affected joint during testing. You may also have some discomfort, muscle cramping or soreness during or after test sessions. Although we have a fall prevention system, there is a chance of falling during the gait trials, the balancing test, and the Up and Go test. There is a very remote chance of cardiac arrest and/or death. These risks are comparable to your routine rehabilitation and activities of daily living, and will not affect your recovery from the surgery.

You cannot participate in this study if you are pregnant because the walking biomechanics collected may not accurately represent your normal walking characteristics. If you are unaware that you are pregnant, participation in this study will result in no more danger to the mother or fetus than normal activities of daily living. However, if you become pregnant or think you might be pregnant during the course of this study, you must inform the researchers, and you will be taken out of the study.

NEW INFORMATION

You will be told about anything new that might change your decision to be in this study. You may be asked to sign a revised consent form if this occurs.

BENEFITS

You will not receive direct/immediate benefits from participating in this study. However, you will obtain information regarding your walking gait, functional activity capacity, hip and knee muscular strength, and behavioral characteristics. Results of this study may assist physicians, physical therapists, and athletic trainers to ensure the optimal clinical outcomes following total hip replacement surgery.

PAYMENT FOR PARTICIPATION

You will receive $5 for each data collection session. This money can be applied to your parking and transportation to and from the University of Hawaii Gait Laboratory. You will be paid only for the visits you have completed.

COSTS

You will be responsible for parking and transportation to and from the University of Hawaii, Manoa, Kinesiology and Rehabilitation Science, Human Performance and Gait Laboratory (Sherriff 100). You will be given $5 per data collection session that can be applied toward the parking fee or transportation; however, the money will be given after you arrive at the facility, so it is a reimbursement. The fee for parking at the University of Hawaii, Manoa parking structure is $4 during the week and $5 on the weekends. Any other cost associated with parking/transportation over and above the $5 provided will be your responsibility.

You might have unexpected expenses from being in this study. Ask your study doctor to discuss the costs that will or will not be covered by the sponsor. This discussion should include who will pay the costs of treating possible side effects.
ALTERNATIVE TREATMENT

This is not a treatment study. Your alternative is not to participate in this study. Your follow-up care is the same whether or not you are in this study.

AUTHORIZATION TO USE AND DISCLOSE INFORMATION FOR RESEARCH PURPOSES

What information may be used and given to others?
The study doctor will get your personal and medical information. For example:
- Past and present medical records
- Research records
- Records about your study visits.
- Information gathered for this research about:
  - Data collection sessions
  - Questionnaires

Who may use and give out information about you?
- The study doctor and research assistant that will be reviewing your medical records at Straub Clinic and Hospital.

Who might get this information?
- The research team at the University of Hawaii, Manoa, Department of Kinesiology and Rehabilitation Science
- Representatives of outside groups hired by Straub Clinic and Hospital or the Western Institutional Review Board for audits to make sure studies are done as required.

Your information may be given to:
- The University of Hawaii, Committee on Human Studies
- Hawaii Pacific Health
- Western Institutional Review Board® (WIRB®)

Why will this information be used and/or given to others?
- To do the research
- To study the results, and
- To see if the research was done right.

If the results of this study are made public, information that identifies you will not be used.

What if I decide not to give permission to use and give out my health information?
- Then you will not be able to be in this research study.

May I review or copy my information?
- Yes, but only after the research is over.

May I withdraw or revoke (cancel) my permission?
- Yes, but this permission will not stop automatically.
You may withdraw or take away your permission to use and disclose your health information at any time. You do this by sending written notice to the study doctor. If you withdraw your permission, you will not be able to stay in this study.

When you withdraw your permission, no new health information identifying you will be gathered after that date. Information that has already been gathered may still be used and given to others.

Is my health information protected after it has been given to others?
There is a risk that your information will be given to others without your permission.

COMPENSATION FOR INJURY

The study doctors are National Athletic Trainers’ Association/Board of Certification certified athletic trainers and First Aid/CPR/Automated External Defibrillator (AED) trained. In the event of any physical injury from the research, only immediate and essential medical treatment will be available including an AED. First Aid/CPR and a referral to a medical emergency room will be provided. In the event of any emergency incidence outside the gait lab as a result of this research, contact your medical doctor and inform the study doctor: Dr. Cass Nakasone at 808-522-4232. You should understand that if you are injured in the course of this research process that you alone will be billed for the costs of treating your injuries.

VOLUNTARY PARTICIPATION AND WITHDRAWAL

Your participation in this study is voluntary. You may decide not to participate or you may leave the study at any time. Your decision will not result in any penalty or loss of benefits to which you are entitled.

Your participation in this study may be stopped at any time by the study doctor or the sponsor without your consent for any of the following reasons:
- it is in your best interest;
- you do not consent to continue in the study after being told of changes in the research that may affect you;
- or for any other reason.

If you leave the study before the planned final visit, you may be asked by the study doctor to have some of the end of study procedures done.

SOURCE OF FUNDING FOR THE STUDY

This research study is sponsored by the University of Hawaii, Manoa.

QUESTIONS

Contact Dr. Cass Nakasone at 808-522-4232 for any of the following reasons:
- if you have any questions about this study or your part in it
- if you feel you have had a research-related injury or
- if you have questions, concerns or complaints about the research
If you have questions about your rights as a research subject or if you have questions, concerns or complaints about the research, you may contact:

Western Institutional Review Board® (WIRB®)
3535 Seventh Avenue, SW
Olympia, Washington 98502
Telephone: 1-800-562-4789 or 360-252-2500
E-mail: Help@wirb.com.

WIRB is a group of people who perform independent review of research.

WIRB will not be able to answer some study-specific questions, such as questions about appointment times. However, you may contact WIRB if the research staff cannot be reached or if you wish to talk to someone other than the research staff.

Do not sign this consent form unless you have had a chance to ask questions and have gotten satisfactory answers.

If you agree to be in this study, you will receive a signed and dated copy of this consent form for your records.

CONSENT

I have read this consent form. All my questions about the study and my part in it have been answered. I freely consent to be in this research study.

I authorize the use and disclosure of my health information to the parties listed in the authorization section of this consent for the purposes described above.

By signing this consent form, I have not given up any of my legal rights.

Subject Name (printed)

CONSENT SIGNATURE:

______________________________________________________________  _______________________
Signature of Subject                                              Date

______________________________________________________________  _______________________
Signature of Person Conducting Informed Consent Discussion        Date
APPENDIX D: WESTERN IRB CONTROL CONSENT FORM
A PROSPECTIVE COMPARISON OF THE BIOMECHANICAL AND FUNCTIONAL GAIT CHARACTERISTICS OF INDIVIDUALS UNDERGOING EITHER A DIRECT ANTERIOR OR MINI-INVASIVE POSTERIOR TOTAL HIP ARTHROPLASTY: A LONGITUDINAL, MULTI CENTERED STUDY.

None
WIRB® Protocol #20100778

University of Hawaii
Honolulu, Hawaii
United States

Cass Nakasone, M.D.
888 South King Street
Honolulu, Hawaii 96813
United States

Straub Clinic and Hospital Bone and Joint Center
888 South King Street
Honolulu, Hawaii 96813
United States

University of Hawaii, Manoa
PE/A Complex Room 231
1337 Lower Campus Road
Honolulu, Hawaii 96822
United States

Queens Medical Center
Suite 608
1380 Lusitana Street
Honolulu, Hawaii 96813
United States

Cass Nakasone, M.D.
808-522-4232
You are being asked to participate in this research study as a “control subject” because you are around the same age as the population that we are studying, you do not have arthritis (osteoarthritis) or a joint replacement, and you are able to walk normally. The following information is being provided to help you decide if you would like to participate in this study. This consent form may have words that you do not understand. If you have questions, please ask us. You may take home an unsigned copy of this consent form to think about or discuss with family or friends before making your decision. The purpose of this study is to look at the biomechanical and functional gait (walking) characteristics of subjects who have received a total hip replacement, and compare them to “normal” gait of individuals (control subjects) who do not have a hip or knee replacement.

DESCRIPTION OF PROCEDURES
You will be asked to fill out a medical history questionnaire and four other questionnaires regarding your physical and mental health relative to your ability to participate in this arthritis (osteoarthritis) study as a “control subject” before the first day of data collection. Your responses to the above questionnaires will be screened (reviewed) by a medical doctor. If you are cleared for participation and you choose to participate in this study, you will then be asked to report to the University of Hawaii at Manoa, Kinesiology and Rehabilitation Science Laboratory (Gait Lab) (Sherriff 100) for all testing sessions. When you arrive at the Gait Lab, you will be asked to perform the following four tasks: (1) walk for 6 m (20 feet) at a comfortable speed 6-10 times (Gait Analysis); (2) balance on one leg at a time, 1-3 times each (Trendelenburg); (3) stand up from a seated position in a chair, walk 3m (10 feet), then return to the chair, 1-3 times (Up and Go Test); (4) push your leg into the researcher’s hand and/or muscle testing device (dynamometer) for 3 sec for 8 different leg movements (Isometric Strength). The entire procedure will take approximately 60 minutes. You will be asked to return to the Gait Lab for seven more data collection sessions over the next three years to repeat this procedure (please see Table 1 below).

Table 1. Data Collection Time Line

<table>
<thead>
<tr>
<th>Control Subjects (n=50)</th>
<th>Initial Visit</th>
<th>3 Weeks</th>
<th>6 Weeks</th>
<th>3 Months</th>
<th>6 Months</th>
<th>1 Year</th>
<th>2 Years</th>
<th>3 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait Analysis (test)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Trendelenburg</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Up and Go Test</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Isometric Strength</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Paper/Pencil Tests</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

RISKS
Due to the level of physical activity involved, there is a risk of injury. You may also have some discomfort, muscle cramping or soreness during or after test sessions. Although we have a fall prevention system, there is a chance of falling during the walking test. There is a very remote chance of cardiac arrest (heart attack) and/or death.

NEW FINDINGS
You will be told about any new information that might change your decision to be in this study. You may be asked to sign a revised consent form if this occurs.

BENEFITS
You will not receive direct/immediate benefits. However, you will obtain information regarding your walking gait, functional activity capacity, hip and knee muscular strength, and behavioral characteristics.

57
Results of this study may assist physicians, physical therapists, and athletic trainers to ensure the optimal clinical outcomes (results) following total hip replacement surgery.

PAYMENT FOR PARTICIPATION
You will receive $5 for each data collection session. This money can be applied to your parking and transportation to and from the University of Hawaii Gait Laboratory. You will be paid only for the visits you have completed.

COSTS
You will be responsible for your parking and transportation to and from the University of Hawaii, Manoa, Kinesiology and Rehabilitation Science, Human Performance and Gait Laboratory (Sherrick 100). You will be given $5 per data collection session that can be applied toward the parking fee or transportation; however, the money will be given after you arrive at the facility, so it is a reimbursement. The fee for parking at the University of Hawaii, Manoa parking structure is $4 during the week and $5 on the weekends. Any other cost associated with parking/transportation over and above the $5 provided will be your responsibility.

ALTERNATIVES
This is not a treatment study. Your alternative is to not be in this study.

COMPENSATION FOR INJURY
The study staff are National Athletic Trainers’ Association, Board of Certification certified athletic trainers and First Aid/CPR/AED trained. In the event of any physical injury from the research, only immediate and essential medical treatment is available including an AED. First Aid/CPR and a referral to a medical emergency room will be provided. In the event of any emergency incidence outside the lab as a result of this research, contact your medical doctor and inform the study doctor: Dr. Cass Nakasone at 808-522-4232. You should understand that if you are injured in the course of this research process that you alone will be billed for the costs of treating your injuries.

SOURCE OF FUNDING
Funding for this research study will be provided by University of Hawaii, Manoa.

VOLUNTARY PARTICIPATION/WITHDRAWAL
Your participation in this study is voluntary. You may decide not to participate or you may leave the study at any time. Your decision will not result in any penalty or loss of benefits to which you are entitled.
Your participation in this study may be stopped at any time by the study doctor or the sponsor without your consent for any of the following reasons:
- if it is in your best interest;
- you do not consent to continue in the study after being told of changes in the research that may affect you;
- or for any other reason.

CONFIDENTIALITY
Your research records will be confidential to the extent permitted by law. Agencies with research oversight, such as the University of Hawaii Committee on Human Studies and Western Institutional Review Board® (WIRB®), have the right to review research records.

An identification number will be used to identify you during the study, which will be known only to you and study personnel. In addition, all data and subject (identity) information will be kept under lock and key in the Department of Kinesiology and Rehabilitation Science at the University of Hawaii at Manoa. These materials will be permanently disposed of in a period not longer than 5 years. You will not be personally identified in any publication arising from this study. Personal information about your test results will not be given to anyone without your written permission.

**AUTHORIZATION TO USE AND DISCLOSE INFORMATION FOR RESEARCH PURPOSES**

**What information may be used and given to others?**
The study doctor will get your personal and medical information. For example:

- Research records
- Records about phone calls made as part of this research
- Records about your study visits.
- Information gathered for this research about:
  - Gait lab data collection sessions
  - Questionnaires

**Who may use and give out information about you?**
The study doctor and the study staff.

**Who might get this information?**
The sponsor of this research. “Sponsor” means any persons or companies that are:

- working for or with the sponsor, or
- owned by the sponsor.

**Your information may be given to:**

- The U.S. Food and Drug Administration (FDA),
- Department of Health and Human Services (DHHS) agencies,
- Governmental agencies in other countries,
- Hawaii Pacific Health, and
- Western Institutional Review Board® (WIRB®)

**Why will this information be used and/or given to others?**

- to do the research,
- to study the results, and
- to make sure that the research was done right.

If the results of this study are made public, information that identifies you will not be used.
What if I decide not to give permission to use and give out my health information?
Then you will not be able to be in this research study.

May I review or copy my information?
Yes, but only after the research is over.

May I withdraw or revoke (cancel) my permission?
Yes, but this permission will not stop automatically.

You may withdraw or take away your permission to use and disclose your health information at any time. You do this by sending written notice to the study doctor. If you withdraw your permission, you will not be able to stay in this study.

When you withdraw your permission, no new health information identifying you will be gathered after that date. Information that has already been gathered may still be used and given to others.

Is my health information protected after it has been given to others?
There is a risk that your information will be given to others without your permission.

QUESTIONS

If you have any questions, concerns or complaints related to this study or if at any time you feel you have had a research-related injury, please contact: Dr. Cass Nakasone at 808-522-4232.

If you have questions about your rights as a research subject or if you have questions, concerns or complaints about the research, you may contact:

Western Institutional Review Board® (WIRB®)
3535 Seventh Avenue, SW
Olympia, Washington 98502
Telephone: 1-800-562-4789 or 360-252-2500
E-mail: Help@wirb.com

WIRB is a group of people who perform independent review of research. WIRB will not be able to answer some study-specific questions, such as questions about appointment times. However, you may contact WIRB if the research staff cannot be reached or if you wish to talk to someone other than the research staff.

If you cannot obtain satisfactory answers to your questions, or have complaints about your treatment in this study, please contact: Committee on Human Subjects, University of Hawai‘i at Manoa, 1960 East-West Rd., Biomed Bldg. Ste. B-104, Honolulu, Hawaii 96822, Phone 808-956-5007.

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.

If you agree to be in this study, you will receive a signed and dated copy of this consent form for your records.
CONSENT
I have read this consent form. All my questions about the study and my part in it have been answered. I freely consent to be in this research study.

I authorize the use and disclosure of my health information to the parties listed in the authorization section of this consent for the purposes described above.

By signing this consent form, I have not given up any of my legal rights.

I attest that I do not believe that I am currently pregnant and that should I become pregnant during participation in this study that I will voluntarily withdraw from further participation.

Subject Name (printed)

__________________________________________  ________________
Signature of Subject                       Date

Person Conducting Informed Consent Discussion Name (print)

__________________________________________  ________________
Signature of Person Conducting Informed Consent Discussion                       Date
APPENDIX E: HARRIS HIP FUNCTION SCALE
**Harris Hip Function Scale (Harris, 1969)**

### Pain (44 Possible Points)

<table>
<thead>
<tr>
<th>Description</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. None/ignores</td>
<td>44</td>
</tr>
<tr>
<td>b. Slight, occasional no compromise in activity</td>
<td>40</td>
</tr>
<tr>
<td>c. Mild, no effect on ordinary activity, rarely moderate pain with unusual activity, may take simple pain medication</td>
<td>30</td>
</tr>
<tr>
<td>d. Moderate pain, tolerable, accepts limitations caused by pain. Some limitation of common activities or work. Occasionally takes pain stronger than asprin</td>
<td>20</td>
</tr>
<tr>
<td>e. Marked, serious limitations of activities</td>
<td>10</td>
</tr>
<tr>
<td>f. Totally disabled, crippled, pain in bed, bedridden</td>
<td>0</td>
</tr>
</tbody>
</table>

### Functional Activities (14 Possible Points)

**Gait (walking maximum distance)**

1. **Limp**
   - a. None: 11 points
   - b. Slight: 8 points
   - c. Moderate: 5 points
   - d. Severe/Unable to walk: 0 points

2. **Support**
   - a. None: 11 points
   - b. Cane for long walks: 7 points
   - c. Cane most of the time: 5 points
   - d. One crutch: 4 points
   - e. Two canes: 2 points
   - f. Two crutches: 0 points
   - g. Unable to walk: 0 points

3. **Distance Walked**
   - a. Unlimited: 11 points
   - b. Six blocks: 8 points
   - c. Two to three blocks: 5 points
   - d. Indoors only: 2 points
   - e. Bed and chair: 0 points

4. **Socks and tie shoes**
   - a. With ease: 4 points
   - b. With difficulty: 2 points
   - c. Unable: 0 points

5. **Sitting**
   - a. Comfortably in ordinary chair one hour: 5 points
   - b. On a high chair for 1/2 hour: 3 points
   - c. Unable to sit comfortably in any chair: 0 points

6. **Enter public transport**
   - a. Able to use public transportation: 1 point
   - b. Unable to use public transportation: 0 point
### Harris Hip Function Scale (Harris, 1969)

**Absence of Deformity--4 points are given in the patient demonstrates (requires all four)**

<table>
<thead>
<tr>
<th>Points</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1. Less than 30º fixed flexion contracture</td>
</tr>
<tr>
<td>0</td>
<td>2. Less than 10º fixed adduction</td>
</tr>
<tr>
<td>0</td>
<td>3. Less than 10º fixed internal rotation in extension</td>
</tr>
<tr>
<td></td>
<td>4. Limb length discrepancy less than 3.2 cm</td>
</tr>
</tbody>
</table>

**Range of motion (5 Possible Points)**

1. **Flexion**
   - a. 0º to >90º: 3 points
   - b. 0º--90º: 2 points
   - c. 0º to <90º: 1 point
   - d. 0º: 0 point

2. **Abduction**
   - a. >20º: 2 points
   - b. <20º: 1 point
   - c. 0º: 0 point

**Total Points ___________________**
APPENDIX F: Western Ontario and McMaster Universities Osteoarthritis Index
Western Ontario and McMaster Universities Osteoarthritis Index (Bellamy et al. 1988)

Subject ID#______________    Date_________

Data Collection Period  0  1  2  3  4  5  6  7  8    Center: Control / Straub / Queens

Instructions: Please mark your answers by putting an ✗ in one of the boxes

**Pain:** Think about the pain you felt during the last 48 hours caused by arthritis

<table>
<thead>
<tr>
<th>Question</th>
<th>None</th>
<th>Slight</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. When walking on a flat surface?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. When going up or down stairs?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. At night while in bed?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. While sitting or lying down?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. While standing?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Stiffness:** Think about the stiffness (not pain) you felt during the last 48 hours caused by the arthritis

<table>
<thead>
<tr>
<th>Question</th>
<th>None</th>
<th>Slight</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. How severe has your stiffness been after you first woke up in the morning?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. How severe has your stiffness been after sitting or lying down or while resting later in the day?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Physical Function:** Think about the difficulty you had in doing the following daily physical activities during the last 48 hours caused by the arthritis

<table>
<thead>
<tr>
<th>Question</th>
<th>None</th>
<th>Slight</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. When going down the stairs?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. When going up the stairs?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Getting up from a sitting position?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. While standing?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. When bending to the floor?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
13. When walking on a flat surface?  

ID#_________________

**Western Ontario and McMaster Universities Osteoarthritis Index (Bellamy et al. 1988)**

**Physical Function:** Think about the difficulty you had in doing the following daily physical activities during the last 48 hours caused by the arthritis

<table>
<thead>
<tr>
<th>None</th>
<th>Slight</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
</table>

How much difficulty have you had…

14. Getting in or out of a car?  

15. While going shopping?  

16. When putting on your socks?  

17. When getting out of bed?  

18. When taking off your socks?  

19. While lying in bed?  

20. When getting in or out of the bathtub?  

21. While sitting?  

22. When getting on or off the toilet?  

23. While doing heavy household chores?  

24. While doing light household chores?
APPENDIX G: SF-36 FORM
The SF-36 Short-Form Health Survey (Ware and Sherbourne, 1992)

Subject ID#________________ Date____________

Data Collection Period 0 1 2 3 4 5 6 7 8 Center: Control / Straub / Queens

Instructions: Please mark your answers by putting an * in one of the boxes

1. In general would you say your health is? Excellent Very Good Good Fair Poor
   ☐ ☐ ☐ ☐ ☐

2. Compared to one year ago, how would you rate your health in general now? Better Somewhat better Same Somewhat worse Worse
   ☐ ☐ ☐ ☐ ☐

3. The following are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

   a. Vigorous activities such as running, lifting heavy objects, or participating in strenuous sports
   Yes, limited a lot Yes, limited a little No, Not limited at all
   ☐ ☐ ☐

   b. Moderate activities such as moving a table, pushing a vacuum cleaner, bowling, or playing golf
   ☐ ☐ ☐

   c. Lifting or carrying groceries
   ☐ ☐ ☐

   d. Climbing several flights of stairs
   ☐ ☐ ☐

   e. Climbing one flight of stairs
   ☐ ☐ ☐

   f. Bending, kneeling, or stooping
   ☐ ☐ ☐

   g. Walking more than a mile
   ☐ ☐ ☐

   h. Walking several blocks
   ☐ ☐ ☐

   i. Walking one block
   ☐ ☐ ☐

   j. Bathing or dressing yourself
   ☐ ☐ ☐
The SF-36 Short-Form Health Survey (Ware and Sherbourne, 1992)

Subject ID#________________

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Cut down on the amount of time you spent on work or other activities</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>b. Accomplished less than you would like</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>c. Limited in the kind of work or other activities</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>d. Had difficulty performing the work or other activities</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Cut down on the amount of time you spent on work or other activities</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>b. Accomplished less than you would like</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>c. Didn’t do work or other activities as careful as usual</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors or groups?

Not at all | Slightly | Moderately | Quite a bit | Extremely
---|---|---|---|---
□ | □ | □ | □ | □

7. How much bodily pain have you had during the past four weeks?

None | Very Mild | Mild | Moderate | Severe | Very severe
---|---|---|---|---|---
□ | □ | □ | □ | □ | □
8. During the past 4 weeks, how much did pain interfere with your normal work? (outside and inside?)

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A little bit</th>
<th>Moderately</th>
<th>Quite a bit</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The SF-36 Short-Form Health Survey (Ware and Sherbourne, 1992)

Subject ID#________________

9. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the answer that comes closest to the way you have been feeling. How much of the time during the past 4 weeks…

<table>
<thead>
<tr>
<th>Question</th>
<th>All the time</th>
<th>Most of the time</th>
<th>Sometimes</th>
<th>A little of the time</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Did you feel full of pep?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Have you been a very nervous person?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Have you felt so down in the dumps that nothing could cheer you up?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Have you felt calm and peaceful?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. Did you have a lot of energy?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. Have you felt downhearted and blue?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. Did you feel worn out?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. Have you been a happy person?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Did you feel tired?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives etc.)?

<table>
<thead>
<tr>
<th>All the time</th>
<th>Most of the time</th>
<th>Sometimes</th>
<th>A little of the time</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11. How True or false are each of these statements for you?

<table>
<thead>
<tr>
<th>Definitely true</th>
<th>Mostly True</th>
<th>Don’t know</th>
<th>Mostly false</th>
<th>Definitely false</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. I seem to get sick a little easier than other people.

b. I am as healthy as anybody I know

c. I expect my health to get worse

d. My health is excellent
APPENDIX H: ANTHROPOMETRIC FORM
**Anthropometric Data**

Subject ID#: _______________ Date________
Age_______________ Gender: F / M
Data Collection Period  0  1  2  3  4  5  6  7  8
Center: Control / Straub / Queens
Patient’s Operated leg: L / R Dominant Leg: L / R
Date of Surgery_______________
Weeks after Surgery_______________

**Vicon/Nexus Measurements**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td></td>
</tr>
<tr>
<td>Height (mm)</td>
<td></td>
</tr>
<tr>
<td>Age (yrs)</td>
<td></td>
</tr>
<tr>
<td>Left leg length (mm)</td>
<td></td>
</tr>
<tr>
<td>Left knee width (mm)</td>
<td></td>
</tr>
<tr>
<td>Left ankle width (mm)</td>
<td></td>
</tr>
<tr>
<td>Right leg length (mm)</td>
<td></td>
</tr>
<tr>
<td>Right knee width (mm)</td>
<td></td>
</tr>
<tr>
<td>Right ankle width (mm)</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX I: TRENDELENBURG FORM
**Data Collection Form**

Subject ID#: _______________

Data Collection Period  0  1  2  3  4  5  6  7  8

Patient’s Operated leg: L / R          Dominant leg: L / R

Center: Control / Straub / Queens

<table>
<thead>
<tr>
<th>Trial</th>
<th>Leg Tested</th>
<th>Trendelenburg (s)</th>
<th>Balance Time (s)</th>
<th>Grade (1-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R / L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>R / L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>R / L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>R / L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>R / L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>R / L</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Response Classification:
1. Normal: if the pelvis on the non-stance side can be elevated high up and is maintained for 30 seconds.
2. Elevation of the pelvis is present but not maximal
3. Pelvis is elevated but not maintained for 30 seconds
4. No elevation of the pelvis on the non-stance side
5. Drooping of the pelvis

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX J: MANUAL MUSCLE TESTING FORM
<table>
<thead>
<tr>
<th></th>
<th>Left Leg</th>
<th>Right Leg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial 1 Score (ft-lbₘ)</td>
<td>Pain Score (HHD/Jt)</td>
</tr>
<tr>
<td>Hip extension</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Hip abduction</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Hip adduction</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Hip flexion</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Hip external rotation</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Knee extension</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>
APPENDIX K: WONG-BAKER PAIN SCALE
Several times during the test, we will ask you to rate your pain, according to the pain rating scale. You will be asked to choose a number that describes how much pain you are experiencing. A rating of “0” corresponds to no pain and a rating of “10” corresponds to the worst pain you could possibly experience.

At the end of every functional test, we will ask you to give local muscular ratings for perceived pain in your legs and joints.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Pain is Unbearable—Cannot continue with the activity</td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Pain is Intense—interferes with activity</td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Pain is Troublesome—may interfere with activity</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Pain is Tolerable—able to continue with activity</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Pain is Noticeable—able to continue with activity</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>No Pain</td>
</tr>
</tbody>
</table>
APPENDIX L: DATA SHEET
<table>
<thead>
<tr>
<th>Subject</th>
<th>ID</th>
<th>Group</th>
<th>leg</th>
<th>Strength0</th>
<th>Strength3</th>
<th>Strength4</th>
<th>Add0</th>
<th>Add3</th>
<th>Add4</th>
<th>Trend0</th>
<th>Trend3</th>
<th>Trend4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-001</td>
<td>201</td>
<td>0</td>
<td>1</td>
<td>29.50</td>
<td>27.25</td>
<td>15.00</td>
<td>0.793586</td>
<td>0.782021</td>
<td>0.737212</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>C-002</td>
<td>202</td>
<td>0</td>
<td>0</td>
<td>38.75</td>
<td>44</td>
<td>34</td>
<td>1.014046</td>
<td>1.1078</td>
<td>1.19496</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>C-003</td>
<td>203</td>
<td>0</td>
<td>1</td>
<td>28.33</td>
<td>33.00</td>
<td>23.50</td>
<td>0.914604</td>
<td>0.971341</td>
<td>0.978772</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>C-004</td>
<td>204</td>
<td>0</td>
<td>1</td>
<td>38.50</td>
<td>34.00</td>
<td>32.50</td>
<td>0.954533</td>
<td>1.233517</td>
<td>1.144057</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>C-005</td>
<td>205</td>
<td>0</td>
<td>0</td>
<td>21.67</td>
<td>19.2</td>
<td>15.67</td>
<td>1.11709</td>
<td>1.010057</td>
<td>1.024187</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C-006</td>
<td>206</td>
<td>0</td>
<td>0</td>
<td>18.25</td>
<td>14.6</td>
<td>14.27</td>
<td>0.740013</td>
<td>0.891242</td>
<td>0.817688</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>C-009</td>
<td>209</td>
<td>0</td>
<td>1</td>
<td>22.00</td>
<td>14.40</td>
<td>14.40</td>
<td>1.38051</td>
<td>1.053252</td>
<td>1.415597</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>C-014</td>
<td>214</td>
<td>0</td>
<td>0</td>
<td>11.57</td>
<td>10.6</td>
<td>10.1</td>
<td>1.103693</td>
<td>1.460787</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>THA-S-001</td>
<td>101</td>
<td>1</td>
<td>0</td>
<td>15.00</td>
<td>15.33</td>
<td>13.77</td>
<td>0.904486</td>
<td>1.14953</td>
<td>1.12371</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>THA-S-002</td>
<td>102</td>
<td>1</td>
<td>1</td>
<td>16.80</td>
<td>44.67</td>
<td>36.75</td>
<td>0.817379</td>
<td>0.731628</td>
<td>0.696344</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>THA-S-004</td>
<td>104</td>
<td>1</td>
<td>0</td>
<td>29.33</td>
<td>17.20</td>
<td>28.00</td>
<td>0.788591</td>
<td>1.206777</td>
<td>1.19239</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>THA-S-005</td>
<td>105</td>
<td>1</td>
<td>0</td>
<td>20.70</td>
<td>28.33</td>
<td>29.50</td>
<td>0.824389</td>
<td>0.951931</td>
<td>0.844941</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>THA-S-006</td>
<td>106</td>
<td>1</td>
<td>1</td>
<td>31.67</td>
<td>31.50</td>
<td>33.50</td>
<td>0.941259</td>
<td>0.994777</td>
<td>0.995772</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>THA-S-008</td>
<td>108</td>
<td>1</td>
<td>1</td>
<td>2.27</td>
<td>6.85</td>
<td>10.30</td>
<td>0.911534</td>
<td>1.213647</td>
<td>1.2864</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>THA-S-015</td>
<td>115</td>
<td>1</td>
<td>0</td>
<td>19.10</td>
<td>13.85</td>
<td>17.25</td>
<td>0.881066</td>
<td>0.989828</td>
<td>1.025785</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>THA-S-017</td>
<td>117</td>
<td>1</td>
<td>1</td>
<td>11.60</td>
<td>13.13</td>
<td>11.15</td>
<td>1.265017</td>
<td>0.733761</td>
<td>1.18858</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
GET DATA /TYPE=XLsx
/FILE='G:\thesis\Data\Data sheet 2.xlsx'
/CELLRANGE=full
/READNAMES=on
/ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet1 WINDOW=FRONT.
GET DATA /TYPE=XLsx
/FILE='G:\thesis\Data\Data sheet 2.xlsx'
/CELLRANGE=full
/READNAMES=on
/ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet2 WINDOW=FRONT.
DATASET ACTIVATE DataSet1.
DATASET CLOSE DataSet2.
GET DATA /TYPE=XLsx
/FILE='G:\thesis\Data\Data sheet 2.xlsx'
/CELLRANGE=full
/READNAMES=on
/ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet3 WINDOW=FRONT.
GLM Strength0 Strength3 Strength4
/WSFACTOR=time 3 Polynomial
/METHOD=SSTYPE(3)
/EMMEANS=TABLES(time) COMPARE ADJ(BONFERRONI)
/EMMEANS=TABLES(OVERALL)
/PRINT=DESCRIPTIVE PARAMETER HOMOGENEITY
/CRIERIA=ALPHA(.05)
/WSDESIGN=time.
GET DATA /TYPE=XLsx
/FILE='H:\thesis\Data\Data sheet 2.xlsx'
/CELLRANGE=full
/READNAMES=on
/ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet6 WINDOW=FRONT.
CROSSTABS
/TABLES=Group BY Trend
/FORMAT=AVALUE TABLES
/STATISTICS=CHISQ PHI CORR
/CELLS=COUNT ROW COLUMN TOTAL
/COUNT ROUND CELL.
CORRELATIONS
/VARIABLES=Strength addmomentNmkg
/PRINT=TWOTAIL NOSIG
/STATISTICS DESCRIPTIVES
/MISSING=PAIRWISE.
GET DATA /TYPE=XLSX
   /FILE='G:\thesis\Data\Data sheet 2.xlsx'
   /SHEET=name 'NEW USE ME'
   /CELLRANGE=full
   /READNAMES=on
   /ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet1 WINDOW=FRONT.
GLM Strength0 Strength3 Strength4 BY Group
   /WSFACTOR=time 3 Polynomial
   /METHOD=STYPE(3)
   /EMMEANS=TABLES(OVERALL)
   /EMMEANS=TABLES(Group) COMPARE ADJ(BONFERRONI)
   /EMMEANS=TABLES(time) COMPARE ADJ(BONFERRONI)
   /EMMEANS=TABLES(Group*time)
   /PRINT=DESCRIPTIVE PARAMETER HOMOGENEITY
   /CRITERIA=ALPHA(.05)
   /WSDESIGN=time
   /DESIGN=Group.

GET DATA /TYPE=XLSX
   /FILE='I:\Thesis (UH)\Data\Walking Trials.xlsx'
   /SHEET=name 'Sheet3'
   /CELLRANGE=full
   /READNAMES=on
   /ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet1 WINDOW=FRONT.
GLM Walking_Speed0 Walking_Speed3 Walking_Speed4
   /WSFACTOR=time 3 Polynomial
   /METHOD=STYPE(3)
   /EMMEANS=TABLES(time) COMPARE ADJ(BONFERRONI)
   /PRINT=DESCRIPTIVE PARAMETER HOMOGENEITY
   /CRITERIA=ALPHA(.05)
   /WSDESIGN=time.
References


