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Physical Activity Levels in Total Hip Arthroplasty Comparing the Direct Anterior Approach to the Direct Lateral Approach: A Prospective Cohort Study

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Abstract

Total hip arthroplasty (THA) is a cost-effective surgical procedure to treat patients with end-stage hip arthritis with high patient satisfaction. Different surgical approaches to the hip have been used to successfully perform THA. However, the role of these surgical approaches on physical activity and early functional recovery in THA patients remains controversial.

In this thesis, we prospectively evaluated physical activity levels in patients with end-stage hip OA whom are undergoing elective THA. The primary focus was to evaluate the impact of different surgical approaches on physical activity levels as a measure of functional recovery in the immediate post-operative period.

Due to the muscle sparing nature, the DA approach demonstrated faster functional recovery in the immediate post-operative period compared to the DL approach. Further examination regarding the economic implications of the improved early function from the perspective of the patient, caregiver, and care payer may be indicated.

Keywords

Total hip arthroplasty, surgical approach, physical activity, functional recovery

Co-Authorship Statement

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Chapter 2 Abdulaziz Aljurayyan – Sole author

Chapter 3 Abdulaziz Aljurayyan – Study design, patient recruitment, data collection, statistical analysis, manuscript preparation

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Chapter 1

1 Introduction:

Total hip arthroplasty (THA) is a cost-effective surgical procedure to treat patients with end stage hip arthritis with high patient satisfaction. The main goal of THA is to achieve a painless and stable hip range of motion and therefore restore patient's physical activity and functional capacity.(1) Different surgical approaches to the hip have been used to successfully perform THA. However, the role of these surgical approaches on physical activity and early functional recovery in THA patients remains controversial. Therefore, the primary focus of this thesis is to evaluate the impact of different surgical approaches on physical activity levels as a measure of functional recovery following THA.

In this introductory chapter, we will provide an overview of the anatomy of the hip, hip arthritis, and the technical considerations of THA performed by the most common surgical approaches. In addition, we will discuss physical activity levels in THA patients and the use of modern wearable technology this field. In the following chapters, we will present a prospective cohort study evaluating the pre-operative and the early post-operative activity levels comparing the direct anterior (DA) approach to the direct lateral (DL) approach for THA using wearable technology.

1.1 Hip anatomy overview:

The hip joint is a complex ball and socket synovial joint. It is composed of an articulation between the femoral head and the acetabulum, with cartilage lining both surfaces. This joint connects the lower extremity to the axial skeleton, and moves in the coronal, sagittal, and transverse planes providing a wide range of motion.(2) In this section, we will provide an overview of the hip anatomy, focusing on the anatomy of the bone, capsulo-labral complex, and muscle.

1.1.1 Bony anatomy:

The bony architecture of the hip is made of the articulation of two different bones, the femur and the acetabulum (Figure 1.1). Each bone has its own bony prominences and landmarks where various muscles attach.(2, 3)

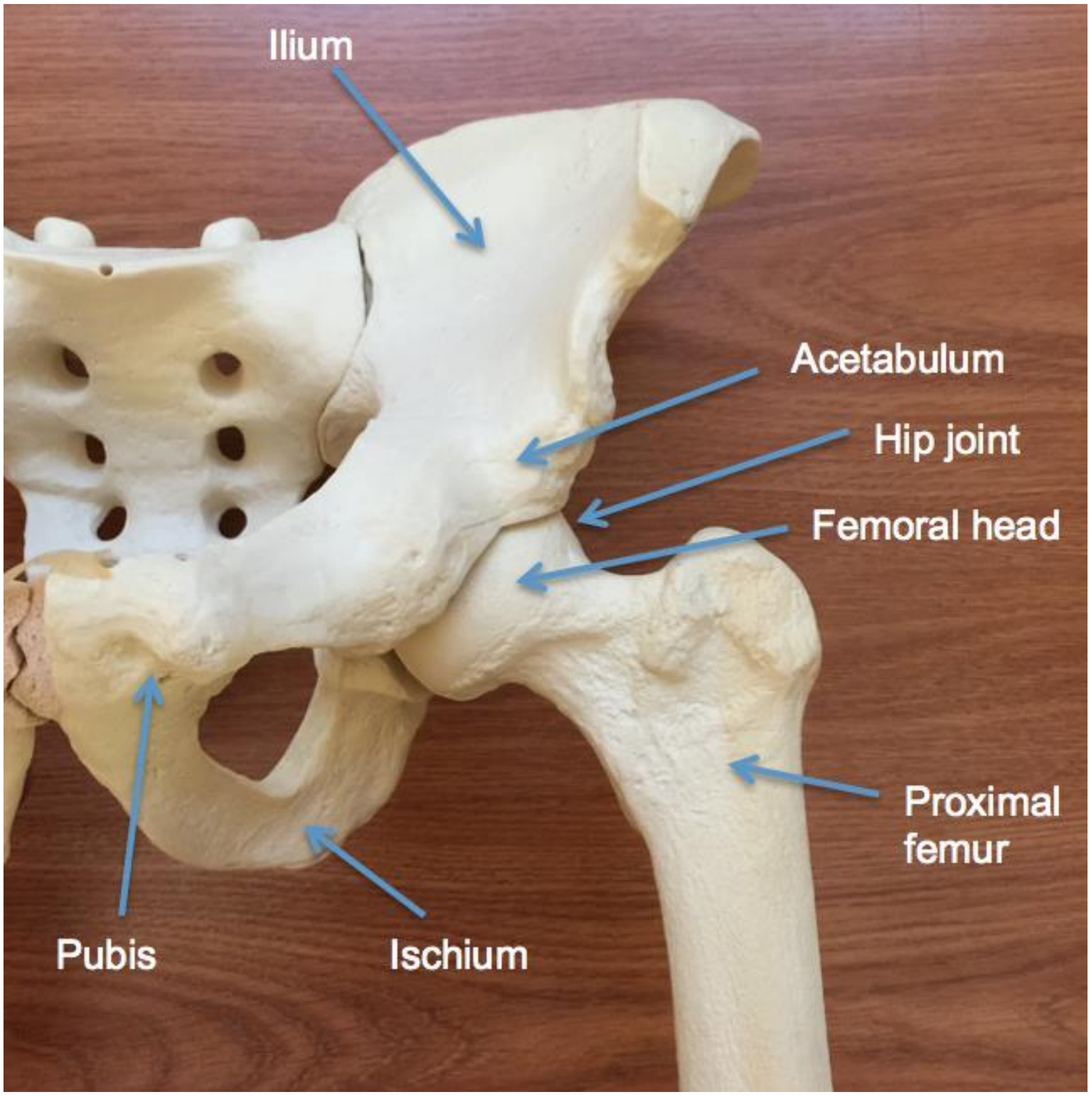

Figure 1.1 Bony anatomy of the hip joint

A sawbone model demonstrating the articulation between the femoral head and acetabulum (A Aljurayyan).

1.1.1.1 Acetabulum:

The acetabulum is a complex bony structure that comprises the socket of the hip joint. Fusion of the growth plates of the ilium, ischium, and pubic bones form the tri-radiate cartilage. The tri-radiate cartilage will ossify and form the bony acetabulum at skeletal maturity.(2) The acetabulum is oriented into 15-23 degrees of anteversion, and 32-45 degrees of abduction.(4-6) Anteversion is the degree of anterior inclination relative to the coronal plane, while the abduction is the degree of lateral inclination relative to the axial plane. The rim of the acetabulum serves as an attachment of the capsulo-labral complex.(7)

1.1.1.2 Femur:

The femoral head, neck, greater and lesser trochanters are the main components of the proximal femur (Figure 1.2). (8) The femoral head is mostly covered with articular (hyaline) cartilage and represents the ball of the hip joint. The femoral neck connects the femoral head to the femoral shaft, and it is oriented into 8-12 degrees of anteversion (Figure 1.3).(9) The femoral anteversion is the anterior inclination of the femoral neck relative to the trans-epicondylar axis, which is an imaginary line connecting the medial and lateral epicondyles of the distal femur in the coronal plane. The greater trochanter is located posterior-lateral on the proximal femur, and numerous muscles attach to it, most importantly the hip abductors. The lesser trochanter is located postero-medial and serves as the insertion of the iliopsoas tendon, which is a powerful hip flexor.(2, 3, 8)

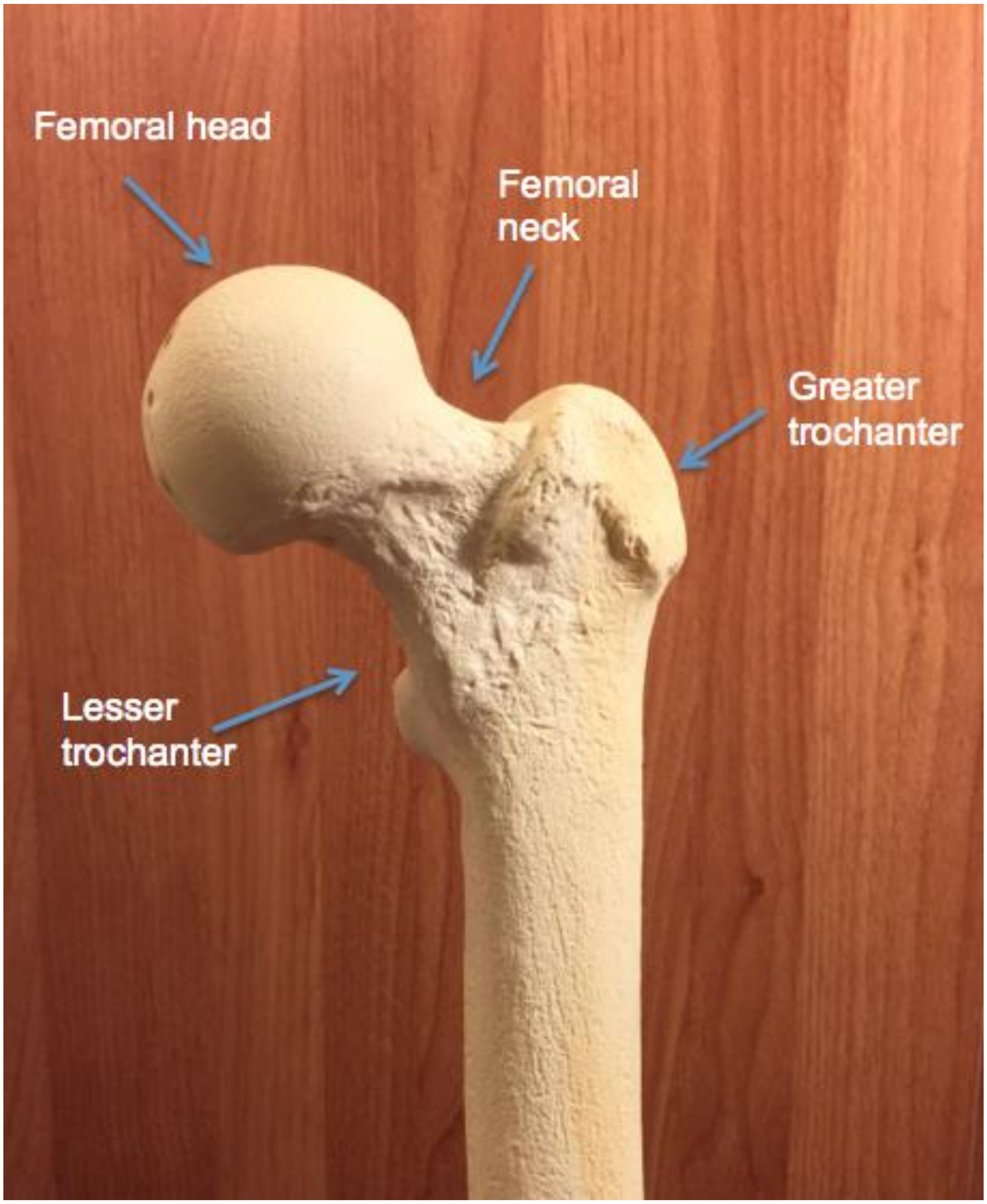

Figure 1.2 Components of the proximal femur

An anterior view of a sawbone model demonstrating the main bony landmarks of the proximal femur (A Aljurayyan).

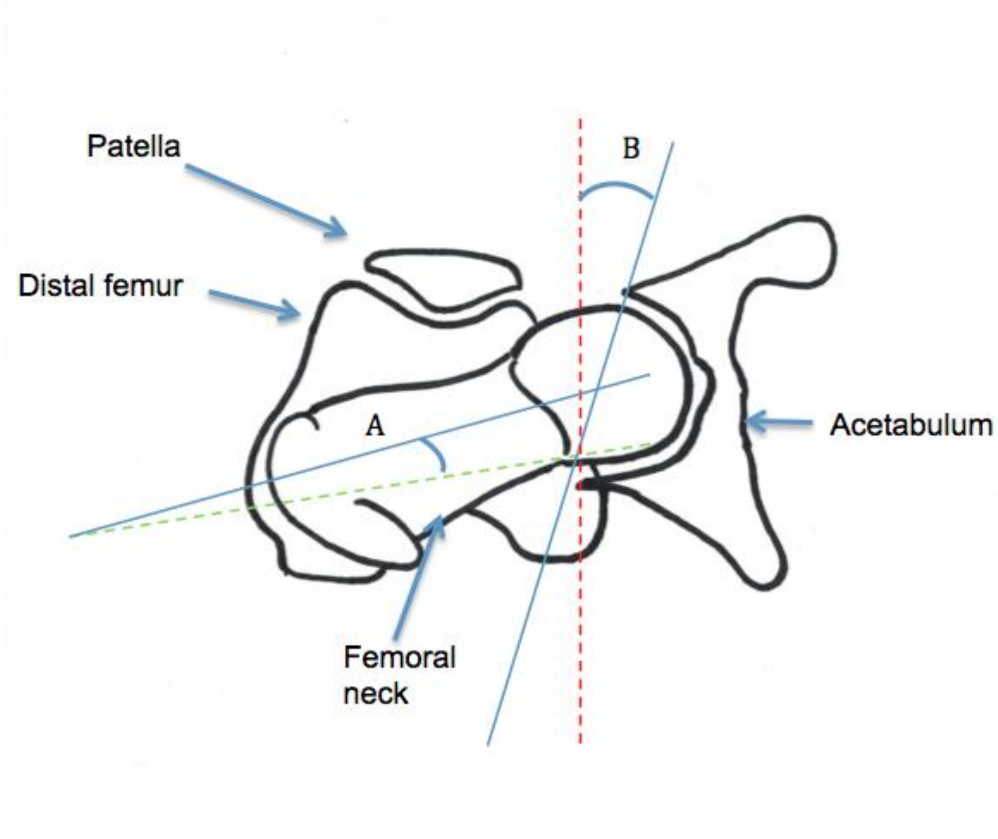

Figure 1.3 Version of the acetabulum and femoral neck

This axial cross-section of the hip joint demonstrates the orientation of the proximal femur and acetabulum. Angle (A) represent the femoral neck anteversion, it is an angle formed by a line along the axis of the femoral neck and the distal trans-epicondylar axis of the distal femur. Angle (B) represents the acetabular anteversion, it is an angle formed by a line along the anterior and posterior columns of the acetabulum intersecting a line in the sagittal plane (A Aljurayyan).

1.1.2 Capsulo-labral complex anatomy:

The acetabular labrum is a crescent shaped fibrocartilage structure that surrounds the acetabular rim; it is opened antero-inferiorly at the acetabular notch.(10, 11) The transverse acetabular ligament spans the two pillars of the acetabular notch forming, with the labrum, a ring that plays a major role is stabilizing the hip joint.(4) The labrum deepens the acetabulum by increasing the articulation surface area by 22% (Figure 1.4).(12) The hip capsule is formed of three important ligaments; the iliofemoral, ischiofemoral, and pubofemoral ligaments. It originates off the acetabular rim with close proximity to the labrum creating what is called the peri-labral recess and inserts on the base of the femoral neck (Figure 1.5).(13) The capsule mainly functions as a static stabilizer of the hip joint. (2)

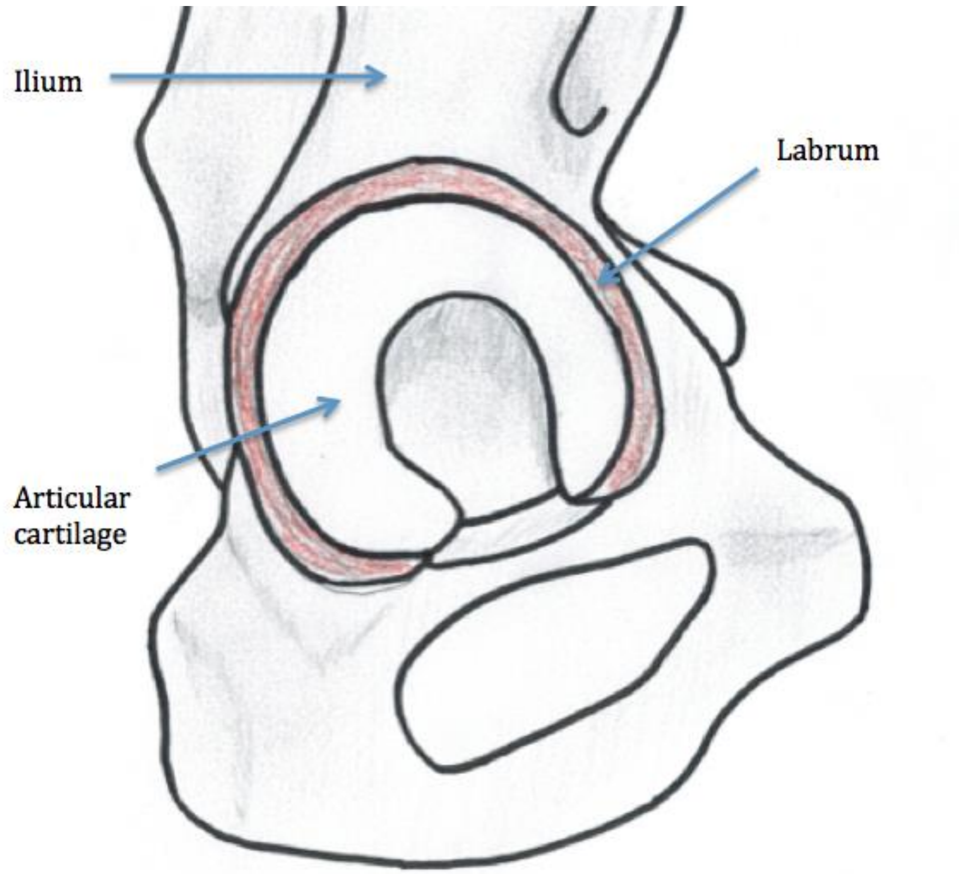

Figure 1.4 The hip joint articular cartilage and labrum

A lateral view of the acetabulum demonstrating the articular cartilage and the attachment of the labrum on the rim of the acetabulum (A Aljurayyan).

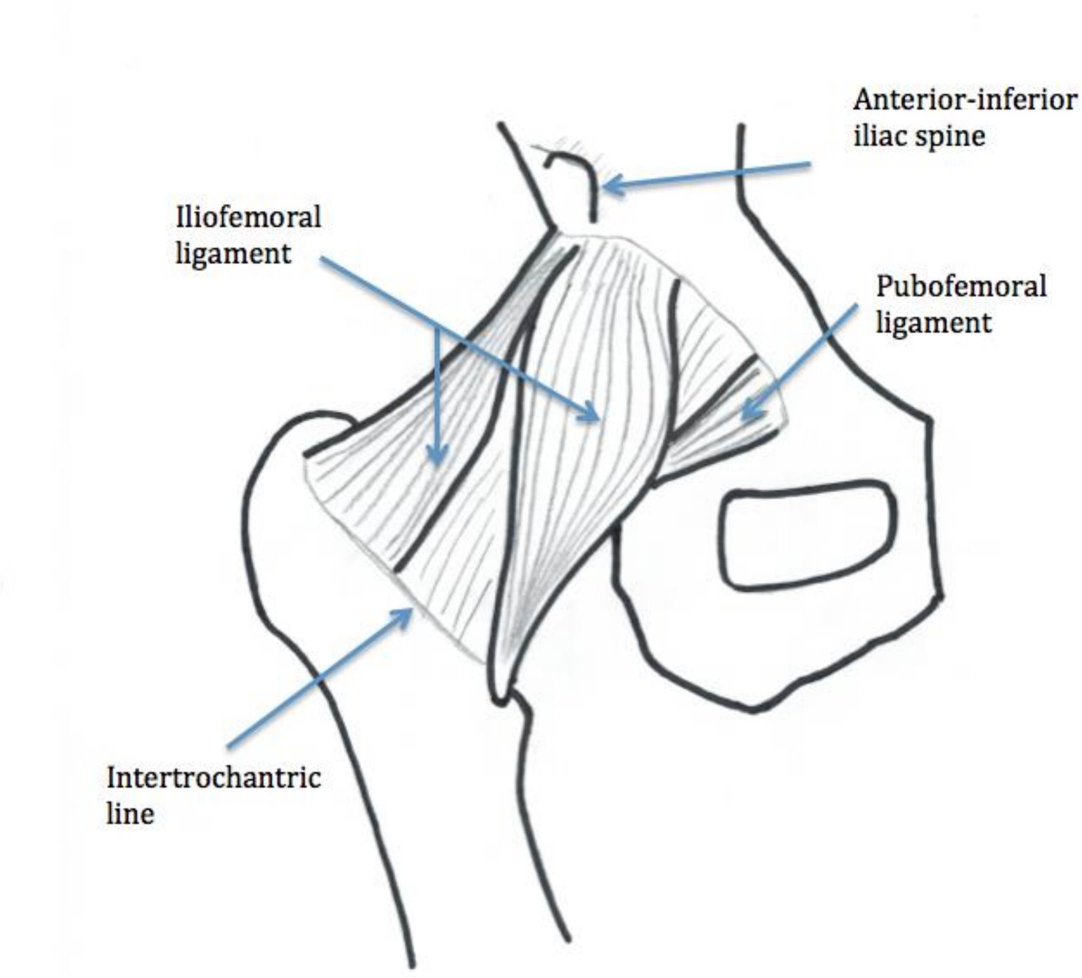

Figure 1.5 Hip joint capsule

An anterior view of the hip joint demonstrating the important ligaments forming the hip joint capsule. The ischiofemoral ligament is located posteriorly; therefore, is not shown in this view (A Aljurayyan).

1.1.3 Hip musculature anatomy:

Detailed knowledge of the muscle anatomy around the hip is fundamental when performing THA. Muscles with different innervations will create a muscular inter-nervous plane that aids safe access to the hip joint.(3) Besides that, it is important to know the origin, insertion, and function of each muscle. In this section, we will discuss the anatomy of relevant muscles to different surgical approaches to the hip.

1.1.3.1 Hip flexor muscles:

Hip flexor muscles include Sartorius, Tensor fascia latae, Rectus femoris, and Iliopsoas. The Sartorius originates on the anterior-superior iliac spine of the pelvis and inserts on the medial aspect of the proximal tibia, with innervation by the femoral nerve. It's main function is as a weak hip flexor and external rotator, but also is a weak knee flexor and internal rotator.(2) The Tensor fascia latae originates on the anterior-superior iliac spine of the pelvis and inserts on the iliotibial band, with innervation by the superior gluteal nerve. It's main function is assisting in abduction, flexion, and internal rotation of the hip.(2) The Rectus femoris is part of the Quadriceps femoris muscle group. It has two different origins, a direct and an indirect head. The direct head originates on the anterior-inferior iliac spine while the indirect head originates on the superior rim of the acetabulum and the anterior hip capsule (Figure 1.6). It inserts on the proximal pole of the patella as part of the Quadriceps femoris muscle tendon. It is innervated by the femoral nerve, and it functions as a hip flexor and a knee extensor.(2, 3) The Iliopsoas has two different origins; the Psoas originates on the transverse process of the lumbar spine and is innervated by the lumbar plexus, while the Iliacus originates on the inner plate of the ilium and is innervated by the femoral nerve. Both muscles share a common insertion on the lesser trochanter. It functions as a strong hip flexor.

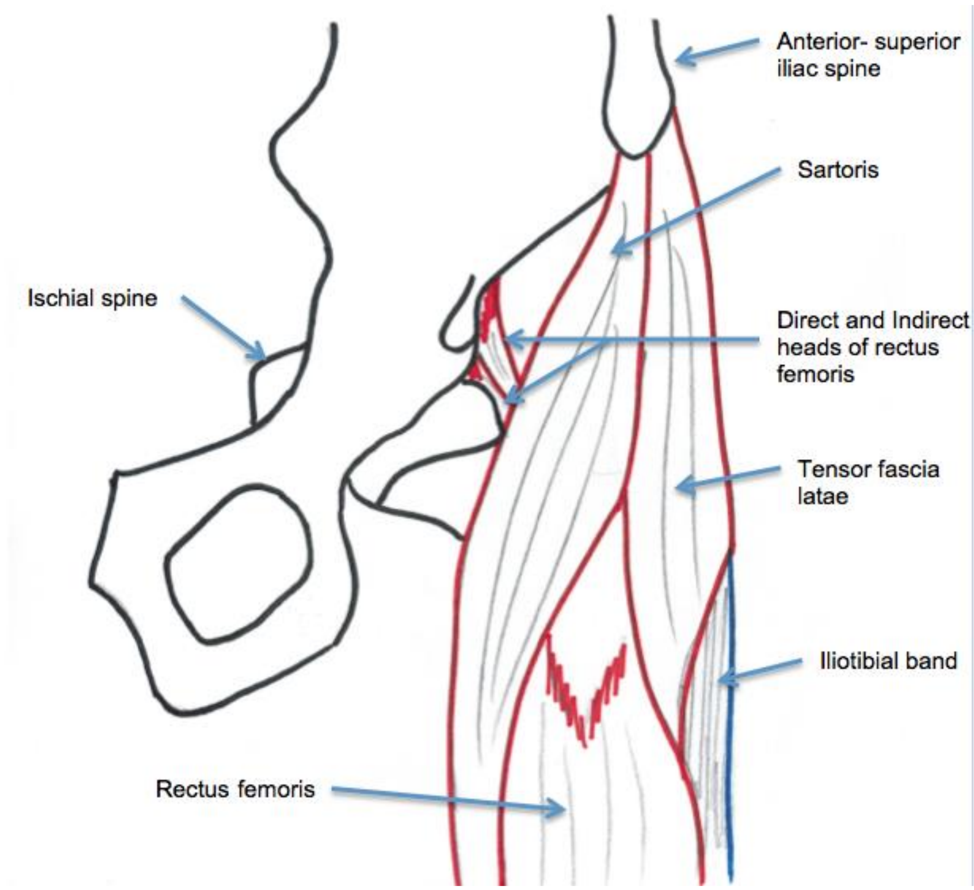

Figure 1.6 Anterior hip muscles

A frontal view of the hip joint demonstrating the anterior hip muscles (A Aljurayyan).

1.1.3.2 Hip abductor muscles:

The hip abductors are mainly composed of two muscles; the Gluteus medius and the Gluteus minimus.(14) The Gluteus medius is considered the primary hip abductor, while the Gluteus minimus is a smaller muscle that lies on the hip capsule itself. The Gluteus medius splits into anterior, middle, and posterior fibers, and it originates on the ilium between the anterior and posterior gluteal lines. It inserts into the tip of the greater trochanter, and is innervated by multiple branches of the superior gluteal nerve. This muscle function as a strong hip abductor, and stabilize the hip joint during gait.(2, 14) The Gluteus minimus originates on the ilium between the inferior and anterior gluteal lines and inserts on the anterior portion of the greater trochanter, and is innervated by the superior gluteal nerve. This muscle abducts and internally rotates the hip.(14, 15)

1.1.3.3 Hip extensor muscles:

The Gluteus maximus is the main hip extensor. It is a large muscle that lies over the Gluteus medius. The Gluteus maximus originates on the sacrum, ilium, and thoracolumbar fascia. It splits into upper fibers that insert into the iliotibial band, and lower fibers that insert into the gluteal tuberosity on the femoral shaft. It is innervated by the inferior gluteal nerve; this large muscle functions as a powerful hip extensor and external rotator.(2)

1.1.3.4 Short external rotator muscles:

The short external rotators include Piriformis, Obturator internus, Superior and Inferior Gemelli, Obturator externus, and Quadratus femoris muscles.(2) Understanding their relation with the sciatic nerve is necessary for identification and protection of the nerve.(3) All these muscles receive innervation by the lumbar and sacral plexuses, and they all function as external rotators of the hip.(2) The Piriformis originates on the anterior aspect of the sacrum and inserts at the apex of the greater trochanter.(2) The Obturator internus originates on the obturator foramen and internal surface the obturator membrane; the Superior and Inferior Gemelli originate on ischial spine and tuberosity, respectively. Both Gemelli join the Obturator internus to form the Conjoint tendon, which inserts into the medial aspect of the greater trochanter.(2) The Obturator externus originates on the obturator foramen and the external surface of the obturator membrane. It inserts on the trochanteric fossa on the medial surface of the greater trochanter.(2)

The Quadratus femoris originates on the lateral margin of obturator ring above the ischial tuberosity. It inserts on the quadrate tubercle and adjacent bone of the intertrochanteric crest of the proximal posterior femur (Figure 1.7).(2)

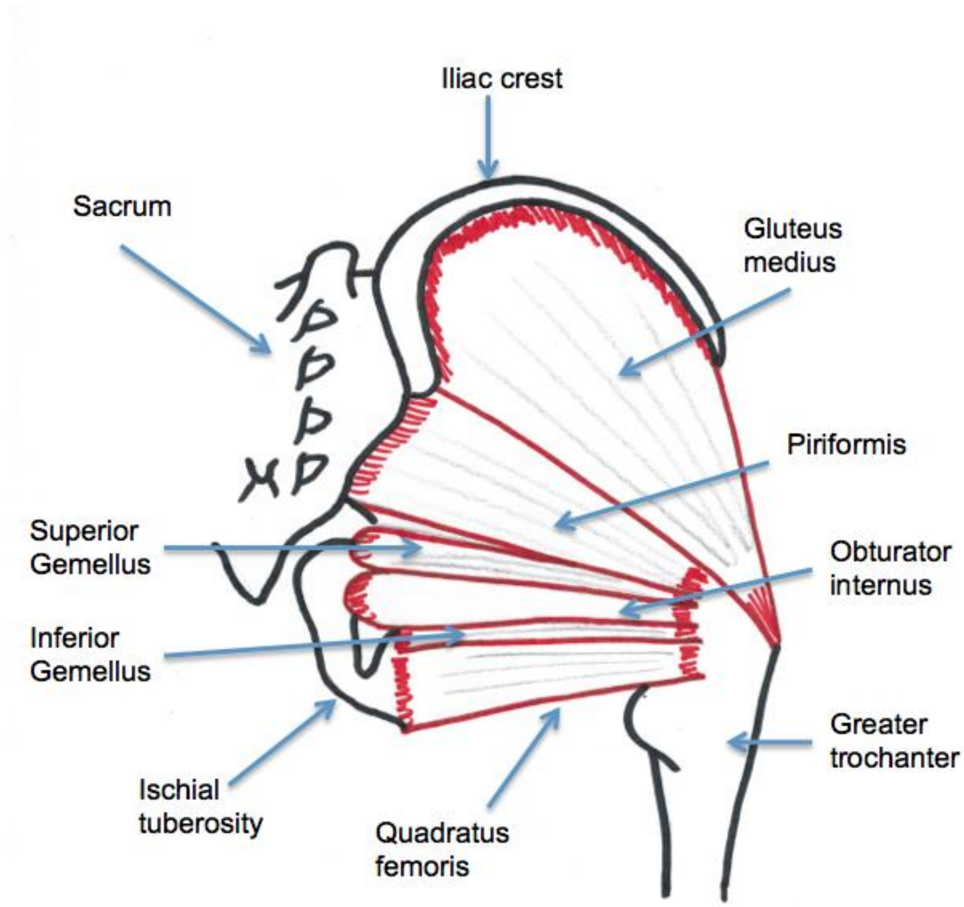

Figure 1.7 Posterior hip muscles

This diagram demonstrates the clinically important muscles that cross the hip posteriorly and laterally (A Aljurayyan).

1.2 Hip arthritis overview:

Arthritis is a common musculoskeletal disorder that results from articular cartilage degeneration.(16) In 2010, the reported prevalence of osteoarthritis in the Canadian population was 15%(17), but owing to the aging population, the prevalence of osteoarthritis is expected to rise. In 2040, it is expected that 25% of the Canadian population (10.5 million) will have osteoarthritis.(17) Severe forms of arthritis can cause debilitating joint pain and psychological distress, if not treated. This can diminish the patient's functional capacity and affect their quality of life.(18) Healthcare providers should be aware of the future increased demand to treat these patients, and invest in developing better tools to improve functional outcomes.

1.2.1 Etiologies of hip arthritis:

Hip arthritis has several etiologies, which can be classified into mechanical, biological, inflammatory or infectious in nature (Table 1.1). Osteoarthritis is the most prevalent cause of hip joint arthritis, and is primarily thought to have a mechanical etiology.(18) In most cases, osteoarthritis can develop with no identified cause; this is called primary osteoarthritis, or idiopathic osteoarthritis. Secondary osteoarthritis refers to cases caused by altered mechanics around the hip joint such as femoral acetabular impingement (FAI), developmental hip dysplasia (DDH), slipped capital femoral epiphysis (SCFE), and trauma.(16, 19-21) Several risk factors have been linked to primary osteoarthritis in the literature.(22, 23) Age, sex, genetics, race and increased bone density are considered non-modifiable risk factors.(24) On the other hand, risk factors such as obesity, sedentary lifestyle, muscle weakness, and joint trauma can be modified to impede the progression of arthritis (Table 1.2).(22)

Biological abnormalities can affect the integrity of the hip joint articulation and, therefore, cause hip arthritis. Disrupting the biology of the hyaline articular cartilage can lead to chondrolysis, a condition of abrupt cartilage loss(16). Interrupted femoral head circulation can cause avascular necrosis (AVN) of the femoral head. This process can progress to subchondral bone collapse leading to significant arthritis and functional limitations.(25)

Inflammatory arthritis of the hip can cause symptoms early in life. Rheumatoid arthritis (RA), ankylosing spondylitis (AS), and systemic lupus erythematous (SLE) are the most prevalent forms.(16) The autoimmune-mediated release of pro-inflammatory cytokines plays a major role in the synovial and articular cartilage destruction in this form of arthritis.(26) Finally, septic arthritis (SA) is an aggressive disease and is considered a surgical emergency. If not treated early, rapid articular cartilage damage and debilitating arthritis can occur within hours.(27) Good understanding of the different etiologies of hip arthritis can help the treating physician to reach the correct diagnosis and treat it accordingly.

Table 1.1 Etiologies of hip arthritis

Mechanical	Femoral acetabular impingement (FAI)
	Developmental hip dysplasia (DDH)
	Slipped capital femoral epiphysis (SCFE)
	Trauma
Biological	Chondrolysis
	Avascular necrosis (AVN) of the femoral head
	Legg-Calvé-Perthes (LCP)
Inflammatory	Rheumatoid arthritis (RA)
	Ankylosing spondylitis (AS)
	Systemic lupus erythematous (SLE)
Infectious	Septic arthritis (SA)

Table 1.2 Primary hip osteoarthritis risk factors

Non-modifiable	Modifiable
Age	Obesity
Sex	Sedentary lifestyle
Genetics	Muscle weakness, and
Race and	Joint trauma
Increased bone density	

1.2.2 Clinical features of hip arthritis:

Advanced hip arthritis can result in disabling symptoms that require medical attention. Hip pain, stiffness, instability, and muscle weakness are the most common complaints. In the vast majority of patients, debilitating hip pain is the chief complaint. A detailed history of pain is required to facilitate diagnosis.(28) Groin pain that is aggravated by activity and alleviated by rest is classic for hip arthritis. In some cases, referred pain to the medial side of the knee through the irritated saphenous branch of the femoral nerve can be misleading.(29) Also, referred pain from the spine or the knee joint should be part of the differential diagnosis and must be eliminated by obtaining a thorough history.(30) Assessing the functional capacity of the patient and the ability to perform activities of daily living is crucial in determining the severity of the disease, and formulating appropriate treatment plans.

The treating physician should start the physical examination with evaluating the patient’s gait. Antalgic gait, and trendelenburg gait are both common findings.(28) The Antalgic gait is an abnormal gait developed by patients to avoid pain in the affected lower limb by shortening the stance phase of walking compared to the swing phase.(28) The trendelenburg gait is another abnormal gait were abductor muscle weakness cause abnormal tilting of the pelvic while walking.(31) Documentation of any leg length discrepancy is necessary and should be corrected when performing THA. Examination of the hip to evaluate the skin for swelling, erythema, deformity, and previous scars is required. The bony prominences around the hip are palpated to rule out any areas of point tenderness, including the relatively common finding of greater trochanter bursitis. The range of motion needs to be evaluated actively and passively and compared to the contralateral side to document any limitation in the different planes of motion. In hip arthritis, internal rotation is usually the first motion to be lost.(30) Documenting the neurovascular status of the limb is vital. When examining for hip arthritis, special tests like the Stinchfield test can be performed to confirm the diagnosis. The Stinchfield test is conducted with the patient supine, resisted hip flexion with the leg in an extended position that elicits groin pain is indicative of hip arthritis.(32)

1.2.3 Non-surgical treatment of hip arthritis:

Treatment of symptomatic hip arthritis ranges from lifestyle modification to THA (Figure 1.8). It is always preferred to begin managing patients with early hip arthritis symptoms by non-operative treatment modalities. There is a broad range of non-operative treatment options including lifestyle modification, physical therapy, walking aids, oral pain medication, and intra-articular injections.(30) The treatment plan can be advanced toward more invasive modalities based on the patient’s symptoms and quality of life.

Lifestyle modifications include weight loss and avoiding impact activities that can exacerbate arthritic symptoms. Christensen et al.(33) demonstrated in a systematic review that weight loss does decrease the symptoms in patients with knee osteoarthritis. Physical therapy can also be effective by strengthening the muscles around the hip and maintaining a good hip range of motion.(34) Using walking aids like canes, crutches, or walkers can offload the arthritic hip and minimize pain.

Oral pain medications can be used if the non-pharmacologic measures fail to provide adequate relief. Acetaminophen and non-steroidal anti-inflammatory drugs (NSAIDS) are commonly used medications to control hip arthritis symptoms. Pain medications should be used with caution to avoid associated adverse effects. Acetaminophen can cause hepatotoxicity, and therefore should be avoided in patients with impaired liver function. NSAIDS also should be avoided in patients with gastrointestinal tract ulcers, hypertension, and renal impairment.(35) Narcotics are effective in cases of intractable pain, but should be utilized as the last option to decrease the risk of addiction and dependence.

Intra-articular injections can be helpful for patients with no or minimal response to oral pain medications or for whom pain medication are contraindicated.(30) This procedure is performed under aseptic techniques using radiographic guidance. Hyaluronic acid is a viscous fluid injected to lubricate the joint, but its efficacy is still controversial.(36, 37) Steroid injections can temporarily suppress the inflammatory process to reduce swelling and decrease pain. Due to its adverse effect on the integrity of surrounding soft tissues, some surgeons prefer to limit its use.(38) It has been also shown that intra-articular cortisone injections shortly before a THA slightly increase the risk of infection.(39) Therefore, intra-articular cortisone injections should be avoided if the patient is considered for surgery.

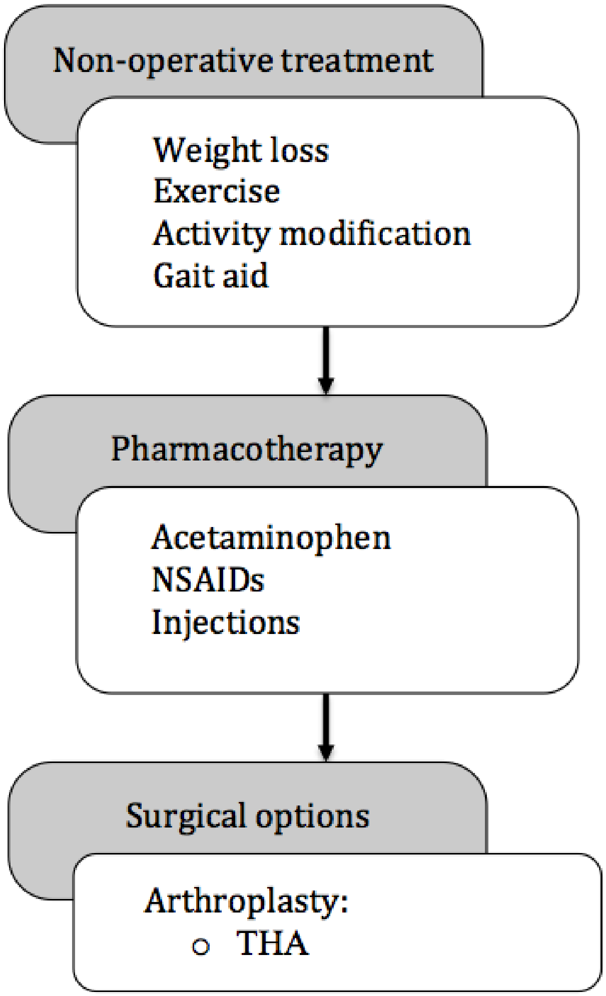

Figure 1.8 Management of hip arthritis

Managing patients with early hip arthritis symptoms should start with non-operative modalities. If this fails, the treatment plan can be advanced toward more invasive modalities based on the patient's symptoms and quality of life (A Aljurayyan).

1.2.4 Surgical treatment of hip arthritis:

Surgical treatment is recommended if non-operative treatment fails to control patient's symptoms. Total hip arthroplasty is the mainstay of surgical treatment for end-stage hip arthritis. Currently, the improved longevity of modern hip replacements and patients desire for maintaining a high level of function makes THA a more attractive option even in very young patients.

1.2.4.1 Total hip arthroplasty:

Total hip arthroplasty is a definitive and very successful option to treat end-stage hip arthritis with high patient satisfaction.(1) Lim et al.(40) and Hamilton et al.(41) demonstrated high patient satisfaction one year after primary THA (91%) compared to other common orthopedic surgical procedures. Haase et al.(42) also evaluated patient-reported outcomes after primary THA in 2,553 patients using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and EuroQol five dimensions questionnaire (EQ-5D). The improvement in function and quality of life and decline in pain was significant at the six months follow up.

The main goal of THA is to achieve a stable, mobile, and pain-free hip joint that restores the patient’s function. To optimize patient outcomes, a number of surgical variables need to be considered, including restoring the anatomical center of rotation of the hip joint and femoral offset, respecting the soft tissues of the hip, and consideration of leg lengths.(28)

The construct of a THA is composed of a femoral stem, a femoral head, and an acetabular cup and a liner (Figure 1.9). The femoral head is firmly engaged to a morse taper at the proximal end of the femoral implant, the head articulates with a liner that is locked into the acetabular cup (Figure 1.10). There are different options of bearing surfaces in THA. The most commonly used bearing surface materials are metal, ceramic and polyethylene.(16) Different bearing surface combinations are available with specific advantages and disadvantages of each construct. Metal on Polyethylene (MoP) is the most commonly used combination. Implant fixation in THA can be performed either using cemented or cementless techniques. Cement fixation is achieved by using Polymethyl methacrylate (PMMA), which acts like a grout and interdigitates with the host cancellous bone. (43, 44) Cementless fixation is used more commonly in North America, and it relies on the biology of the host bone. Bone ingrowth or ongrowth to a rough, porous coated surface on the cementless implants is required for implant fixation.(45)

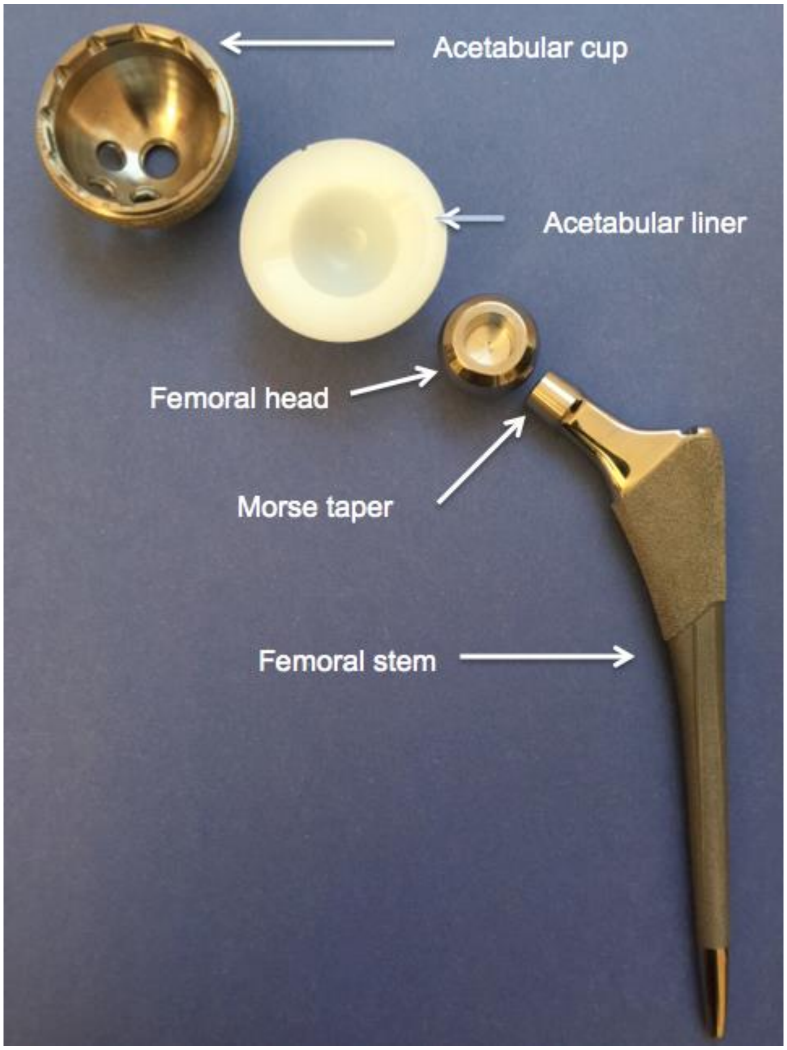

Figure 1.9 Dissembled total hip arthroplasty construct

This is an example of a dissembled cementless total hip arthroplasty. Note the porous coating on the proximal third of the femoral stem (A Aljurayyan).

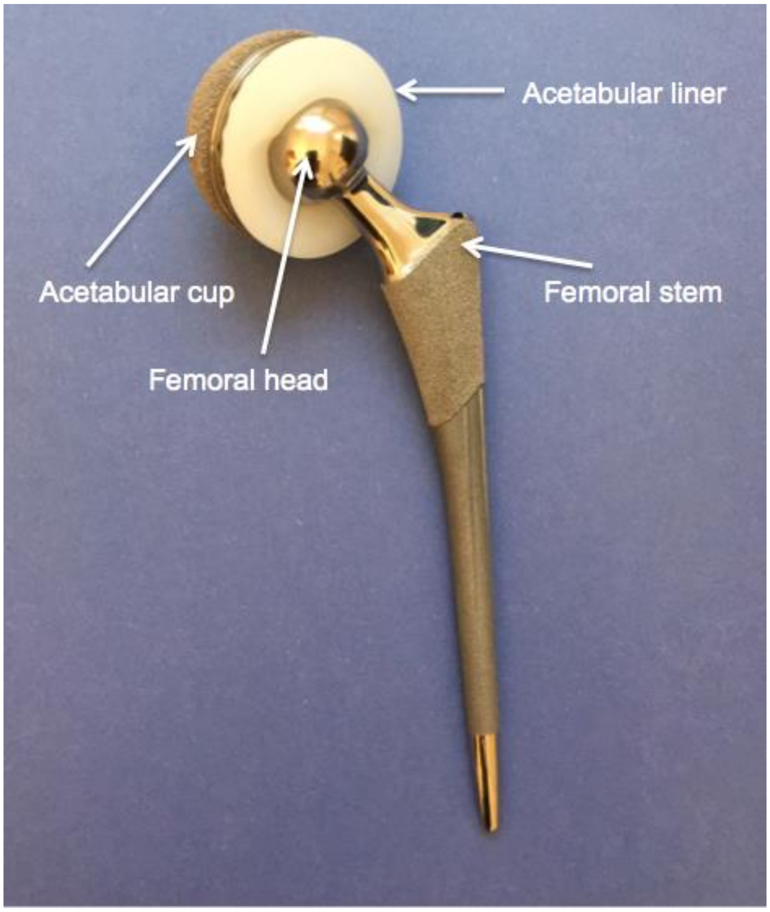

Figure 1.10 Assembled total hip arthroplasty construct

An assembled cementless total hip arthroplasty with a cobalt chromium head articulating with a polyethylene acetabular liner (A Aljurayyan).

1.3 Common surgical approaches in total hip arthroplasty:

When performing a THA, there are multiple approaches to access the hip joint. Each approach has specific advantages and disadvantages, which need to be considered in context of the patient needs. Having a detailed knowledge of human anatomy is necessary to optimize surgical exposure and avoid complications. This section will focus on the technical considerations of the most commonly utilized surgical approaches in THA; the anterior, lateral, and posterior approaches.

1.3.1 Anterior approach to the hip:

In 1881, Heuter(46) first described the anterior approach to the hip. Then in 1917, a publication by Smith- Peterson(47) introduced this approach to orthopedic surgeons in North America. In 1950, Judet(48) published on the use of the direct anterior (DA) approach in hip arthroplasty, popularizing it in Europe. Recently, this approach gained more popularity due its purported muscle sparing nature, early functional recovery and low rate of dislocation.(49-51) This approach is performed with the patient positioned supine on either a regular or a traction operative table. In this section we will describe the surgical technique utilizing a specialized traction operative table that allows for hyperextension, adduction and external rotation of the operative leg.

After positioning the patient supine on a specialized traction operating table, a perineal post is inserted between the legs to act as a point of counter-traction and stabilizes the patient on the table. Then, both feet are securely attached in boots that are connected to lever arms that allow the application of traction, rotation, and angulation to either limb (Figure 1.11). (52) The skin incision starts one fingerbreadth lateral to the anterior-superior iliac spine of the pelvis, and extends toward the lateral border of the patella for approximately 8-12 centimeters (Figure 1.12). The lateral femoral cutaneous nerve is avoided by incising the fascial layer over the muscle belly of the Tensor fascia latae. Blunt dissection is used to develop the interval between the Tensor fascia latae and the Sartorius exposing the underlying interval between the Gluteus medius and Rectus femoris. The Gluteus medius is retracted laterally, and the Rectus femoris is retracted medially, and the ascending branch of the lateral femoral circumflex artery is ligated or cauterized while dissecting through this plane to expose the underlying anterior hip capsule. A capsulotomy is then performed in line with the femoral neck from the ilium to the intertrochanteric ridge. At this point, traction and slight external rotation are applied to the operative limb to aid dislocating the hip joint. Then, a femoral neck osteotomy is performed based on the radiographic pre-operative templating utilizing the piriformis fossa as a landmark. In situ femoral neck osteotomy without dislocating the hip is commonly performed.(3, 52) The acetabulum is exposed, prepared, and component placed in a manner similar to other surgical approaches, although fluoroscopy is also often used.

In this approach, proximal femoral exposure is difficult, which can make preparing the femur a challenge. To optimize the exposure of the proximal femur, the operative limb needs to be positioned in extension, adduction, and external rotation. A special bone hook can be passed around the proximal femur and connected to a motorized lift on the specialized operative table to facilitate the exposure. If the exposure is still inadequate, soft tissue releases can be performed to improve the proximal femur excursion. These releases include releasing the conjoint tendon, piriformis tendon, and part of the tensor fascia latae in a sequential fashion as needed. Once appropriate exposure is achieved, the femur is prepared for implant insertion. The accuracy of the femoral preparation concerning offset and leg length discrepancy can be verified using fluoroscopy or with the limb out of traction.(3, 52, 53)

Figure 1.11 Specialized traction table for the anterior approach

A specialized traction table used for the anterior approach (Hana ™ fracture table, Mizuho OSI, Union City, CA). Both legs are fastened in the boots to allow maneuvering the limb and applying traction (A Aljurayyan).

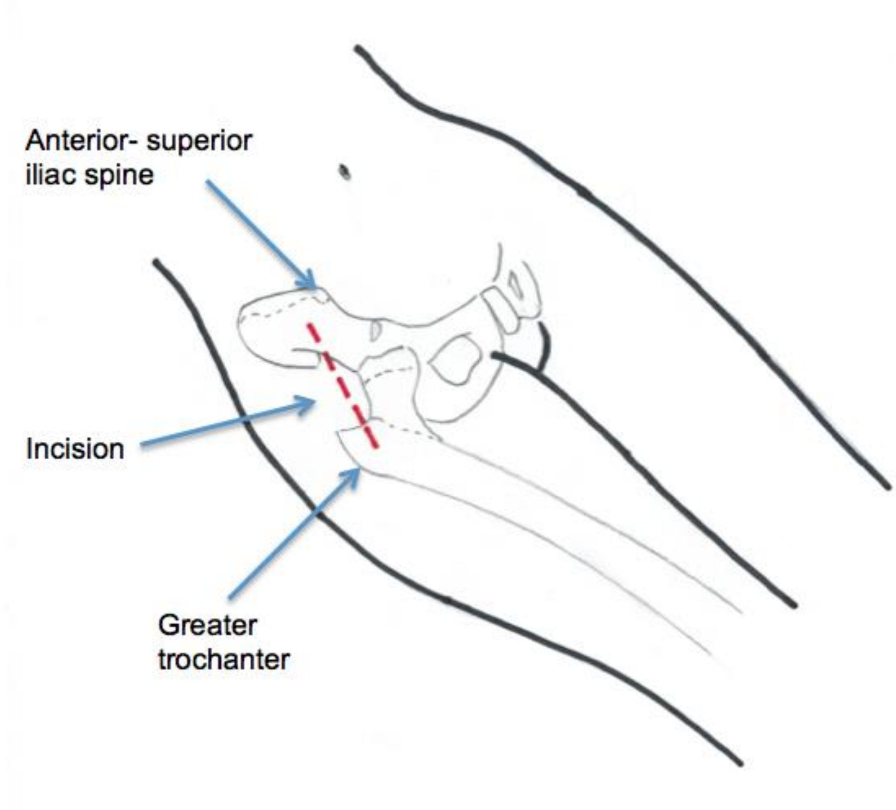

Figure 1.12 Skin incision for the anterior hip approach

The skin incision starts one fingerbreadth lateral to the anterior-superior iliac spine of the pelvis, and extends toward the lateral border of the patella (A Aljurayyan).

1.3.2 Lateral approach to the hip:

In 1980, Hardinge(54) first described the direct lateral approach to the hip. When used for THA, this approach allows excellent exposure and accessibility of the proximal femur and acetabulum in both primary and revision surgeries, and has a low dislocation rate.(55)

In this approach, the patient is placed in a lateral decubitus position where he or she lies on the unaffected side allowing the operative hip to be adequately exposed. The operative limb should be freely draped to facilitate placing the limb in a sterile bag after dislocating the hip. Approximately 10-15 centimeters longitudinal skin incision is centered over the greater trochanter (Figure 1.13). The fascia over the Tensor fascia latae and Gluteus maximus is then split in line with the skin incision, exposing the underlying Gluteus medius muscle and tendon. After identifying the anterior and posterior borders of the Gluteus medius muscle, up to one third of the muscle can be reflected anteriorly off the proximal femur leaving a cuff of Gluteus medius tendon for repair at the end of the procedure. The intact posterior part of the Gluteus medius muscle is retracted posterior revealing the underlying Gluteus minimus and hip capsule. A capsulotomy is made in line with the femoral neck up to the lateral rim of the acetabulum exposing the hip joint articulation. At this point, the hip is dislocated by applying traction, flexion, and external rotation. A femoral neck osteotomy can then be performed based on the radiographic pre-operative templating utilizing bony landmarks. At this stage, the proximal femur and acetabular exposure achieved should be sufficient to complete the femoral and acetabular reconstruction.(3, 54)

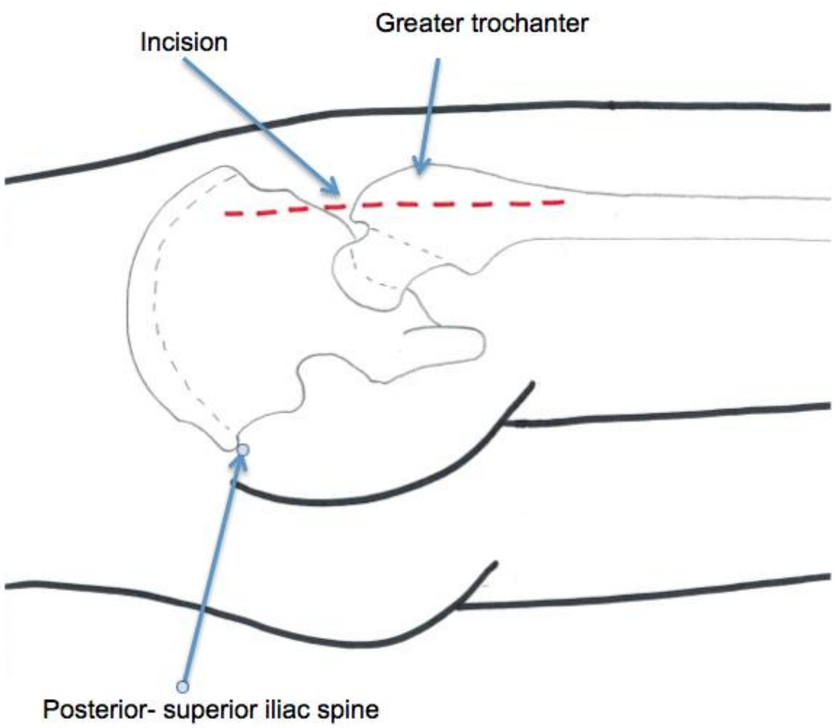

Figure 1.13 Skin incision for the lateral hip approach

Approximately 10-15 centimeters longitudinal skin incision is centered over the greater trochanter (A Aljurayyan).

1.3.3 Posterior approach to the hip:

In 1957, the posterior hip approach (also called southern approach) was first described by Austin Moore.(3) This approach provides clear access to the hip joint.(56) Besides providing excellent exposure of the proximal femur and acetabulum in primary THA, this approach is extensile and facilitates excellent exposure in complex revision surgeries.(3) Furthermore, sparing the abductor muscles may decrease the chance of post-operative gait disturbance and limping. For these reasons, it is the most commonly performed hip approach for THA worldwide.(56)

Like the lateral approach, in this approach, the patient is placed in a lateral decubitus position with the operative hip exposed. The operative limb should be freely draped to allow the surgical assistant to maneuver the limb after dislocating the hip. Approximately 10-15 centimeter skin incision is centered over the posterior one-third of the greater trochanter (Figure 1.14). Proximally, the incision can be curved toward the posterior-superior iliac spine. Distally, the incision is carried out in line with the long axis of the femur. The fascia of the Gluteus maximus is incised in line with the skin incision, splitting the muscle fibers of the Gluteus maximus and exposing the underlying short external rotators. At this point, the surgeon should identify the sciatic nerve and protect it throughout the procedure. The short external rotators are then identified and released off their insertion on the proximal femur. The underlying posterior hip capsule is exposed, and a capsulotomy is performed revealing the articular surface. The hip is then dislocated, and a femoral neck osteotomy is completed based on the radiographic pre-operative templating utilizing bony landmarks. This will provide adequate exposure to complete the femoral and acetabular reconstruction.(3)

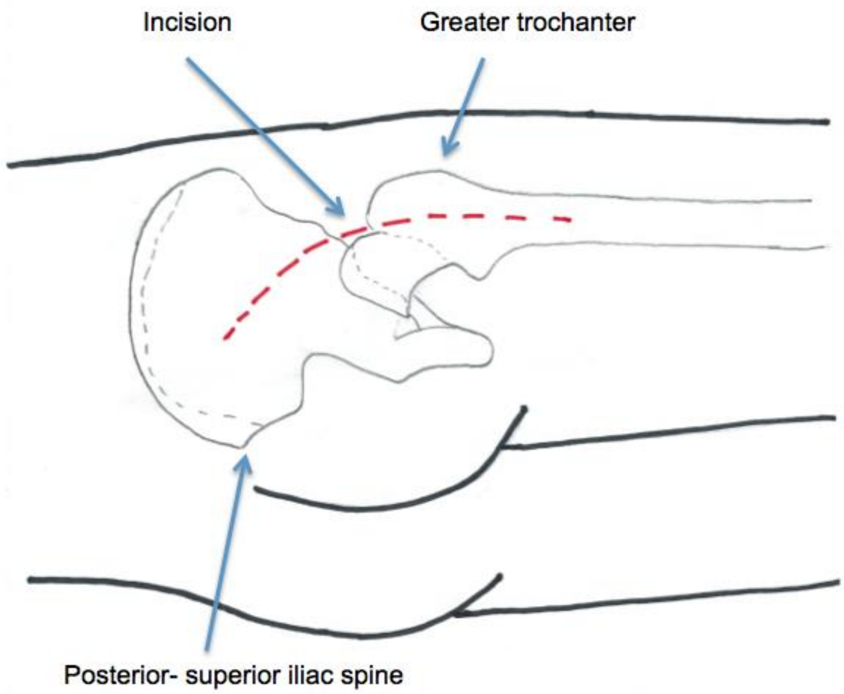

Figure 1.14 Skin incision for the posterior hip approach

Approximately 10-15 centimeter skin incision is centered over the posterior one-third of the greater trochanter (A Aljurayyan).

1.3.4 Component Preparation and Insertion:

After exposing the hip using the preferred surgical approach, the femoral head is dislocated from the acetabulum. A femoral neck osteotomy is performed based on the pre-operative radiographic templating, using the lesser trochanter or the piriformis fossa as surgical landmarks.(16, 45) If it is decided to focus on the acetabulum prior to the femoral preparation, the acetabulum is then exposed. The labrum is removed then from the acetabular rim, and the pulvinar may be cleared from the true floor of the acetabulum. The remaining articular cartilage is reamed away to establish a surface of bleeding subchondral bone to facilitate cup fixation.(28) The cup is inserted using appropriate surgical checks to confirm appropriate anteversion and abduction angles.(57, 58)

The attention is then turned to the femur; the proximal femur is exposed using a combination of retractors and leg positioning. After identifying the long axis of the femoral canal and establishing an appropriate entrance to the femoral canal, the canal is prepared using appropriate instruments until good femoral fit and fill is achieved. While preparing the femur, the surgeon should be cognizant of the position of the broach to achieve the femoral anteversion selected to enable the surgical objectives to be obtained.(59)

A trial reduction is performed by using trial femoral and acetabular components. Using these trial components, the hip is assessed to ensure surgical objectives are achieved; including appropriate leg length, soft tissue tension, joint stability, and range of motion.(28) Once the surgeon is satisfied that the trial hip implants enable an appropriate hip construct, the trial components are substituted with the final implants.

1.3.5 Advantages and Disadvantages of Surgical approaches:

Due to the muscle sparing nature of the direct anterior approach, multiple studies demonstrated improved functional recovery in this approach compared to other surgical approaches.(60, 61) In a meta-analysis comparing the direct anterior approach to the posterior approach Higgins et al.(60) showed the anterior approach improved functional outcomes and had less patient reported post-operative pain and a reduced length of hospital stay. Goebel et al.(61) also retrospectively compared 100 direct anterior THA to 100 direct lateral THA and showed less post-operative pain and decreased length of hospital stay in the direct anterior group. However, some studies showed that the direct anterior approach can be associated with prolonged operative time and increased blood loss early on during the surgeon's learning curve. Spaans et al.(62) compared 46 direct anterior THA to a matched cohort of conventional posterior approach and showed higher operative time and blood loss in the direct anterior group. However, the direct anterior hips were performed during the surgeon's learning curve. Berend et al.(63) in a retrospective review compared 258 direct anterior THA to 372 direct lateral THA; the direct anterior group showed greater estimated blood loss (EBL) but the operative time was equal between the two groups.

It is well known that preserving the hip abductor muscles in THA can prevent post-operative limping and facilitate early functional recovery.(55) Multiple studies evaluated muscle damage in different surgical approaches using different assessment tools. Bremer et al.(64) used magnetic resonance imaging (MRI) one year post-operatively to assess muscle damage in the direct anterior and direct lateral approaches. The direct anterior group showed significantly less damage and fatty atrophy in the Gluteus minimus and medius and significantly less peri-trochanteric bursal fluid compared to the direct lateral group. Bergin et al.(65) also prospectively evaluated muscle damage in THA comparing the direct anterior approach to the posterior approach using inflammatory markers and Creatine Kinase (CK) in the post-anesthesia care unit (PACU). The inflammatory marker levels were slightly decreased in the direct anterior group compared to the posterior approach. However, this difference was not significant. The serum CK, a validated marker of muscle damage, was 5.5 higher in the posterior group with a mean difference of 150.3 units/L. Meneghini et al.(66) also showed less damage to the Gluteus medius and minimus with the direct anterior approach in cadaveric specimens compared to the posterior approach.

Dislocation is a major concern in THA patients. Multiple studies in the current literature showed low dislocation rates in the direct anterior approach.(50, 67) The inherent stability in the direct anterior approach can be explained by the true inter-nervous plane where muscles around the hip joint are not detached.(68) Sheth et al.(67) reviewed 22,237 primary THA in their local Total joint replacement registry. They evaluated the rate of dislocation in the anterior, anterolateral, direct lateral and posterior approaches and showed that anterolateral and anterior approaches had lower dislocation rates (0.8% in the direct anterior group).

Wound complications also have been another concern in THA patients.(69) Christensen et al.(70) in retrospective review compared 1288 posterior THA to 505 direct anterior THA and showed a higher rate of wound complications in the direct anterior group that required re-operation (0.2% to 1.4%, respectively). However, Poehling-Monaghan et al.(71) in another retrospective study showed less wound complication in the direct anterior approach compared to a mini-posterior approach, which can be attributed to skin necrosis from vigorous traction in the mini-posterior group. In the direct anterior approach, the large pannus in patients with central obesity can drape over the incision and provide a suboptimal wound-healing environment. For that reason, it is crucial to assess the patient's body habitus prior to proceeding with an anterior approach.

Intraoperative nerve injuries are not uncommon in THA. With each approach there are certain nerves at risk.(3) In the direct anterior approach the lateral femoral cutaneous nerve in particular is prone to injury with a reported incidence of 67% in one study, however, there was no difference in functional outcome scores in patients with LFCN injury compared to patient without nerve injury in the same study.(72) In the direct lateral approach superior gluteal nerve palsy is the most common reported nerve palsy. Dysfunction of the superior gluteal nerve can paralyze the anterior portion of the Gluteus medius and lead to abductor muscle insufficiency. In the current literature, its prevalence ranges from 2.2-42.5%.(73-75) The risk is higher if the abductor muscle split extends beyond five centimeters proximal to the tip of the greater trochanter where the nerve lies between the Gluteus medius and Gluteus minimus.(3) Sciatic nerve injury can occur while releasing the short external rotators in the posterior approach.(3) In one study, intra-operative sciatic nerve injury was reported to be 1.3%.(76) Most of these injuries result from neuropraxia, a condition where blockage in nerve conduction can lead to temporary loss of motor and sensory nerve function. Fortunately, the majority of these injuries recovers and has no long-term sequelae.(77, 78)

1.4 Physical activity in total hip arthroplasty:

The main goal of THA is to eliminate arthritis-related pain and improve quality of life.(79, 80) Quality of life is determined by multiple factors. The ability to maintain a desired level of physical activity is an important factor in a patient's quality of life. Activity level change following total joint arthroplasty has been evaluated in numerous studies.(81-83) Vissers et al.(84) showed that physical functioning continued to improve up to 4 years following total hip and knee arthroplasty. Although activity levels significantly improve compared to the pre-operative levels, most THA patients will maintain a moderate physical activity, with a minority achieving high levels of activity.(83)

There are different ways to measure activity levels in research. Self-reported methods include activity diaries and questionnaires.(85, 86) Although these measures are simple and easy to implement, it has been shown that patients tend to overestimate their activity when self reporting in a questionnaire.(87, 88) Combining these subjective measures with other objective methods can improve the evaluation of activity levels.(89, 90) The six-minute walk test (6MWT), timed up and go test (TUG), stair measure (ST), and the self-paced walk test (SPWT) are validated and widely used tests in clinical research.(91) Despite being objective measuring tools, these tests measure functional ability and not the actual activity level. Wearable technology devices such as wrist-worn activity trackers have emerged as readily available tools that objectively measure activity levels by counting the number of steps walked.

1.5 Wearable technology and physical activity:

Wearable activity trackers are light, inexpensive, and user-friendly devices that objectively measure activity levels. They function by measuring the number of steps walked then by use of algorithms estimates walked distances; the intensity of activity performed and burned calories.(92, 93) Mechanical activity trackers that relied on gears and mechanical counters were initially used. However, with the increasing utilization of electronics, electronic activity trackers have largely supplanted them.(94) Besides tracking activity levels, some electronic trackers can measure relevant physiologic variables like heart rate and monitor sleep patterns as well.(95, 96)

Wearable technologies have been extensively used in clinical research. Besides its use in different disciplines of medicine, it has been successfully used to monitor physical activity in THA patients.(97, 98) Goldsmith et al.(99) utilized activity trackers to study the relationship between physical activity measured by step counts and polyethylene wear and cup penetration. Other studies have measured steps counts in patients following THA to assess functional recovery compared to their pre-operative state, or compared to a healthy control group.(94, 100) One study assessed the mean steps taken per year in THA patients to establish the number of loading cycles to test implants longevity in the joint simulation labs; this was determined to be 1.56 million loading cycle per year.(97) A variety of activity trackers have been developed and are available for use and numerous studies have validated them for use in clinical research.(96, 101, 102) Evenson et al.(95) performed a systematic review to summarize the evidence for validity and reliability of popular activity trackers from two main manufacturing companies (Fitbit Inc., San Francisco, CA, USA and Jawbone Inc., San Francisco, CA, USA), 22 studies performed on healthy subjects were included in this review; it was found that the validity (Fitbit® and Jawbone®) and inter-device reliability (Fitbit®) of steps counts were overall high. The wrist-worn trackers tend to underestimate step counts and were generally less accurate than the hip-worn trackers. (95) Kaewkannate et al.(103) evaluated the accuracy of 4 popular wrist-worn trackers in the market. The Fitbit® Flex (Fitbit Inc., San Francisco, CA, USA) tracker showed an accuracy of 99.60% when evaluated for step counts and distance travelled when walking straight indoor.

1.6 Purpose and rationale of this thesis:

Earlier functional recovery after surgery certainly concerns both patients and healthcare providers. Any element of the care pathway that detrimentally affects the patient's ability to function in the early post-operative period requires increased resource consumption, including healthcare worker time and energy, patient resources and self-perception, employment, and caregiver effects.(104-106) Early functional recovery and patient independence can decrease the hospital length of stay (LOS) and therefore, lower the overall cost of the procedure.(107, 108) Improved early function also has significant effect on the amount of time off of work required to recover from surgery, and the resultant work force economic impact.(106) How long the patient takes to recover their independence is also important, as it affects the patient's caregivers, and the amount of time they need to dedicate to the care of the patient.(109) If the caregiver is unable to supply the requisite amount of care, these patients need to spend time in a rehabilitation facility during their recovery, facilities that can require substantial healthcare resources. In the current healthcare environment, the reality is that healthcare economics and the resource allocation to specific healthcare elements are increasingly scrutinized to maximize the effect of the healthcare dollars spent.(108)

There are multiple aspects in the peri-operative period that affect the recovery time after a total hip replacement. Multiple studies in the current literature evaluated early functional recovery in THA comparing different surgical approaches. Most of these studies showed faster functional recovery in the direct anterior approach patients when compared to others common surgical approaches like the direct lateral or posterior approaches.(71, 110, 111) Restrepo et al.(112) performed a randomized controlled trial (RCT) in 100 patients undergoing primary unilateral THA. They evaluated early functional recovery in the direct anterior approach compared to the direct lateral approach. Using the Harris Hip Scores (HHS), The Western Ontario and McMaster Universities Arthritis Index (WOMAC), and the 36-Item Short-Form Health Survey (SF-36), they concluded that up to 1 year after surgery, the direct anterior group continued to show significant improvement in functional recovery. In another RCT, Barrett et al.(113) compared direct anterior approach to the posterior approach. Patients in the direct anterior group functioned better regarding climbing stairs normally and walking unlimited at six weeks; they also reported higher Hip disability and Osteoarthritis Outcome Scores (HOOS) at three months. Although these findings evaluated early functional recovery in THA patients, the earliest clinical evaluation started at six weeks post-operatively in most studies, missing the critical period immediately after surgery when the effect of surgical approach may be most profound. Furthermore, besides missing the important immediate post-operative period following surgery, the vast majority of these studies used subjective measures like hip functional scoring systems and questionnaires to evaluate functional recovery.

Wearable technology devices are accurate and reproducible tools to assess physical activity levels in patients after surgery. They can provide real time data in patients about their actual activity levels immediately after they are discharged home. This can allow patients to objectively monitor their level of independence and functionality. We are not aware of any literature estimating the minimum number of steps required to perform ADLs independently, this can be difficult to estimate as patients will have variable stride lengths depending on their body dimensions.

To our knowledge, no studies in the current literature objectively evaluated physical activity levels comparing different surgical approaches in THA using wearable technology devices. Therefore, the primary purpose of this thesis is to examine the influence of surgical approaches on early functional recovery in THA focusing on objectively evaluating physical activity levels in the direct anterior approach compared to the direct lateral approach in the immediate post-operative period.

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Chapter 2

2 Objectives:

1) To measure physical activity levels by means of an objective tool (wearable technology) in patients with end-stage hip osteoarthritis (OA). Then determine whether a correlation exists between the number of steps taken per day with commonly used patient reported outcome scores including the University of California, Los Angeles (UCLA), activity scale, the Western Ontario and McMaster Universities Arthritis Index (WOMAC), the Physical Component Summary of the 12-Item Short Form Survey (PCS SF-12) and the Harris Hip Score (HHS).

2) To determine the change in physical activity levels in a cohort of patients with end-stage hip OA undergoing an elective unilateral primary total hip arthroplasty (THA) in the immediate post-operative period.

3) To explore whether the muscle sparing direct anterior approach provides earlier functional recovery compared to the direct lateral approach in patients undergoing an elective unilateral THA in the immediate post-operative period.

Chapter 3

3 Physical Activity and Quality of Life in Patients with End-Stage Hip Osteoarthritis

3.1 Introduction:

Arthritis is a progressive musculoskeletal condition caused by articular cartilage degeneration that may lead to permanent joint destruction.(1) The prevalence of hip osteoarthritis (OA) is reported to be 10.9% in the general population.(2) Due to a rise in the aging population, this incidence is expected to increase in the future. By 2020, osteoarthritis is expected to become the 4th leading cause of disability.(3) End-stage hip arthritis can cause swelling, debilitating joint pain, and a significant restriction in range of motion. As a result, this can translate into a decline in patient's functional capacity and quality of life.(4)

A patient's quality of life has multiple dimensions. Level of physical activity is a very important variable affecting one's quality of life.(5) According to the World Health Organization (WHO), physical activity is not only limited to exercise. Rather it is defined as "any bodily movement produced by the skeletal muscles, which requires energy expenditure".(6) Besides exercise, bodily movements also include walking, playing, working, performing house-hold chores and any recreational activities.(6) It is also important to maintain a sufficient level of physical activity to prevent chronic diseases that can increase the rate of morbidity and mortality in inactive patients.(7)

Different tools have been developed to assess patient's physical activity in clinical and research settings. These tools include activity scales, questionnaires and wearable technologies.(8) Activity scales and questionnaires are readily available and easy to use, however, they are subjective tools and can be limited by recall bias. Furthermore, patients tend to overestimate their physical activity levels when filling out questionnaires.(9, 10) Conversely, wearable technology is an objective and accurate method to assess physical activity. They function by measuring the number of steps walked then by use of algorithms to estimate walked distances; the intensity of activity performed and burned calories.(11, 12) The use of wearable technology in clinical research has been validated in multiple studies.(13-15) Evenson et al.(16) performed a systematic review to summarize the evidence for validity and reliability of popular activity trackers and demonstrated a high validity for step counts. Despite their accuracy, the use of wearable technology as a measurement tool of physical activity in daily clinical practice is limited. Therefore, it is important to establish whether commonly used patient-reported outcome scores correlate with objective measures of activity to identify outcome scores that can accurately reflect patient's activity levels. There have been limited studies that have validated commonly used patient-reported outcome scores against objective measures of physical activity such as wearable technology.(17, 18) To our knowledge, the University of California Los Angeles (UCLA) activity scale(19), 36-Item Short Form Survey (SF-36)(20), 8-Item Short Form Survey (SF-8)(21) and the Harris Hip Score (HHS)(22) has been correlated to physical activity levels objectively measured by wearable technology where others such as Western Ontario and McMaster Universities Arthritis Index (WOMAC)(23) and 12-Item Short Form Survey (SF-12)(24) have yet to be studied against objective measures.

The purpose of this study is to 1) objectively evaluate physical activity in patients with end-stage hip OA using a wristband activity tracker, 2) to correlate the number of steps taken to a patient-reported physical activity scale, the University of California Los Angeles (UCLA) activity scale(19), as well as other patient-reported outcome scores; specifically the Western Ontario and McMaster Universities Arthritis Index (WOMAC)(23), the Physical Component Summary of the SF-12 (PCS)(24) and the Harris Hip Score (HHS)(22) and 3) to explore the effect of age, body mass index (BMI), and medical co-morbidities measured by the Charlson Co-morbidity Score (CCS) on the mean number of steps taken per day.

3.2 Materials and Methods:

After obtaining research ethics board approval, three fellowship trained arthroplasty surgeons (J.H, B.L, and E.V) in a tertiary academic center prospectively enrolled patients in this study between September 2015 and March 2016. Any patient with hip OA who failed non-operative treatment and in whom a primary total hip arthroplasty (THA) was indicated was considered for inclusion in the study. Exclusion criteria included patients with inflammatory hip arthritis, prior hip surgery, prior infection, contralateral hip pathology that would affect activity, and patients not willing to participate in the study.

Demographics such as, height, weight, age, and medical co-morbidities were collected. The number of steps was recorded using a validated wristband activity tracker, Fitbit® Flex (Fitbit Inc., San Francisco, CA, USA)(16) All patients were asked to wear the wristband for 24 hours a day, except for water activities, on seven consecutive days within the four weeks preceding their scheduled THA. Patients were given clear instruction on how to operate the wristband and wear it, along with a detailed instruction sheet. All patients were also given an information sheet to document the times and reasons they took the wristband off. Data was downloaded as number of steps taken per day. The University of California, Los Angeles (UCLA) activity scale(19), as well as other patient-reported outcome scores including the Western Ontario and McMaster Universities Arthritis Index (WOMAC)(23), the Physical Component Summary of the 12-Item Short Form Survey (PCS SF-12)(24) and the Harris Hip Score (HHS)(22) were obtained during the same time period.

The UCLA activity scale is a simple scale that includes 10 statements covering a range of physical activities, 0 represents no physical activity and 10 represent participation in impact sports.(25) It has been shown to be valid when used to measure physical activity in total joint arthroplasty patients.(25) The WOMAC arthritis index was developed to assess functional outcomes in patients with hip and knee OA.(23) It consists of 24 items divided into 3 main subscales that include pain, stiffness and physical functioning.(23) The PCS SF-12 is part of a short form health survey that covers 4 health related quality of life domains, including physical functioning, role-physical (role limitations due to physical problems), bodily pain and general health.(24) It was initially developed to assess quality of life in the general population; however, its use has been validated in patients with OA.(26) The Harris hip score (HHS) was developed to measure functional outcomes in patients with secondary hip OA who underwent mold arthroplasty.(27) It is a rating scale of 100 points that covers 5 main domains that includes pain, function, activity, deformity, and motion.(27) This score is frequently used to measure functional outcomes after total hip arthroplasty.(28)

Demographics, number of steps taken and patient-reported outcome scores were reported with descriptive statistics including means, standard deviations and ranges. To determine whether a relationship exists between the number of steps taken and patient-reported outcome scores as well as age, BMI and CCS, correlational analysis with Spearman correlation coefficient (rho) was performed. To determine the effect of demographics on activity levels, patient cohorts were categorized by age, gender and BMI. The mean number of steps was compared in patients older than 65 years old to patients aged 65 or younger, male to females, and in patients with BMI ≤ 30 kg/m^2 compared to patients with BMI > 30 kg/m^2 with a Mann-Whitney U test. SPSS® v.22 (SPSS Inc., Chicago, IL, USA) was used for all analyses. Statistical significance was set at $p < 0.05$.

3.3 Results:

Thirty-eight patients were found to meet the inclusion criteria; there were 15 males and 23 females. The mean age at the time of assessment was 65 years (range 48 – 88 years), the mean body mass index (BMI) was 30.3 kg/m^2 (range 20.9 – 49.3 kg/m^2), and the mean Charlson Co-morbidity Score (CCS) was 2.5 (range 0 - 8).

The mean number of steps taken per day was 5883 ± 3841 (range 1511-17876 steps/day). All other outcomes fell within an expected range of a patient with end-stage hip arthritis (Table 3.1).

Table 3.1 Descriptive data of steps per day and other patient-reported outcome scores

	Mean±SD	**Range**
Steps per day	5883 ± 3841	1511-17876
UCLA	4.46 ± 1.70	2- 10
WOMAC	44.08 ± 13.40	18.8 - 80
PCS SF-12	31.40 ± 9.20	20.8 - 53
HHS	51.30 ± 11.60	25 - 72

UCLA=The University of California, Los Angeles activity score, HHS=Harris Hip Score, WOMAC=the Western Ontario and McMaster Universities Arthritis Index and PCS SF-12=the Physical Component Summery of the 12-Item Short Form Survey.

All collected patient-reported outcome scores were correlated to the number of steps walked per day (Table 3.2). The UCLA scale and the HHS demonstrated a statistically significant positive correlation with the number of steps per day with a Spearman correlation coefficient of rho=0.44 (p=0.004) and rho=0.53 (p=0.008) respectively. The WOMAC score and the PCS SF-12 score did not correlate well with the number of steps walked per day with a Spearman correlation coefficient of rho=0.08 (p=0.65) and rho=0.15 (p=0.41) respectively.

Table 3.2 Correlations between steps per day with other patient-reported outcome scores using the Spearman correlation coefficient value (rho)

		Steps/day
UCLA		.441*
	Sig. (2-tailed)	.008
HHS		.538*
(Total)	Sig. (2-tailed)	.004
SF12V1		.158
(PCS)	Sig. (2-tailed)	.412
WOMAC		.086
(Total)	Sig. (2-tailed)	.650

*UCLA=The University of California, Los Angeles activity score, HHS=Harris Hip Score, WOMAC=the Western Ontario and McMaster Universities Arthritis Index and PCS SF-12=the Physical Component Summery of the 12-Item Short Form Survey. * Correlation is significant at the 0.05 level (2-tailed).*

Both age and CCS demonstrated a negative correlation with the number of steps per day with a Spearman correlation coefficient of rho= -0.43 (p=0.01) and rho= -0.45 (p=0.006) respectively. BMI was not found to correlate well with the number of steps walked per day with a Spearman correlation coefficient of rho= -0.20 (p=0.227) (Table 3.3).

Table 3.3 Correlations between steps per day with age, BMI and CCS using the Spearman correlation coefficient value (rho)

		Steps/day
Age	Correlation Coefficient	-.429*
	Sig. (2-tailed)	.010
BMI	Correlation Coefficient	-.209
	Sig. (2-tailed)	.227
CCS	Correlation Coefficient	-.454*
	Sig. (2-tailed)	.006

*BMI=Body Mass Index, CCS= Charlson Co-morbidity Score. * Correlation is significant at the 0.05 level (2-tailed).*

The mean number of steps walked per day in patients older than 65 years old was significantly lower than the mean number of steps for patients aged 65 or younger (p= 0.028). There was no significant difference in the mean number of steps in males compared to the mean number of steps in females (p=0.39). Similarly, there was no difference in the mean number of steps in patients with BMI ≤ 30 kg/m^2 compared to patients with BMI > 30 kg/m^2 (p=0.56) (Table 3.4).

Table 3.4 Comparing the mean steps per day in patients based on age, gender and BMI.

	Steps/day (mean±SD)	**p value**
Total	5883 ± 3841.2	
Male Female	6613.6 ± 4326.4 5451.3 ± 3559.1	p= 0.39
Age ≤ 65 Age > 65	7470.5 ± 4416.5 4202.1 ± 2189.0	p=0.005*
BMI ≤ 30 kg/m^2 BMI > 30 kg/m^2	6318.0 ± 4424.2 5472.2 ± 3274.1	p=0.56

*BMI=Body Mass Index. * Correlation is significant at the 0.05 level (2-tailed).*

3.4 Discussion:

Physical inactivity in patients with hip OA can impact their quality of life, and lead to dire consequences such as increased chronic comorbidity and mortality.(7,29) The primary goal of this study was to objectively evaluate physical activity levels in patients with end-stage hip OA using a wristband activity tracker. The mean number of steps per day in our cohort was 5883 ± 3841 steps/day. Similar results have been reported in the literature. Holsgaard-Larsen A et al.(30) reported the mean number of steps in 26 patients with end-stage hip OA to be 6639 ± 3222 compared to 8576 ± 2872 in a healthy age-matched control group.

Tudor-Locke et al.(31, 32) suggested that values lower than 5000 steps per day would classify patients as sedentary, based on the mean number of steps in a healthy control group with an average age of 69 years old (6000 steps per day, excluding sports activity or exercise). Based on Tudor-Locke's suggested criteria, 51% of the patients in our cohort had a number of steps per day less than 5000 and therefore would be considered sedentary. Harding et al.(33) also reached a similar conclusion when they assessed physical activity levels in a cohort of 63 patients undergoing TKA or THA for end-stage OA using a waist accelerometer. Patients were found to be sedentary 82% of the time pre-operatively when assessed over a 24-hour period. In addition, Fujita et al.(34) found that patients with end-stage hip OA had more sedentary activity levels and walked on average less steps per day (4,632 ± 2246 steps/day) compared to an age-matched healthy control group (7,228 ± 3,132 steps/day).

In our cohort, patients with OA scored low on all patient-reported outcome scores (WOMAC, PCS SF-12 and HHS). This is not surprising, as currently, a large body of literature exists to support these findings.(35, 36) Boutron et al.(35) evaluated disability and the quality of life in 1581 patients with end-stage hip OA in the primary-care setting. These patients reported a high level of disability with a mean WOMAC score of 45.2 ±17.3 and decreased health-related quality of life with a mean PCS SF-36 score of 31.8 ± 8.4. Salaffi et al.(36) also assessed the quality of life in 107 patients with end-stage hip OA using the WOMAC and the SF-36 scores and showed similar results.

The UCLA scale has been found to be the most valid patient-reported activity scale. (8,17, 25) Naal FD et al.(25) concluded that the UCLA scale is the most appropriate patient-reported activity scale in patients undergoing total joint arthroplasty when compared to other patient-reported activity scales. In a systematic review, Terwee et al.(8) evaluated 12 physical activity measurement tools in patients with end-stage hip and knee OA. These tools included five single-item rating scales, six multi-item questionnaires, and one pedometer. The UCLA scale received positive ratings for construct validity that makes it one of the most useful tools to monitoring physical activity levels of populations. In our cohort the UCLA score demonstrated a significant positive correlation with the number of steps per day. Our results support the few studies in the current literature that explored the correlation between the UCLA scale and physical activity objectively measured by wearable technology. Zahiri et al.(19) correlated the UCLA scale to the number of steps as recorded by a pedometer and showed a strong positive correlation between the two variables using linear regression analysis (p= 0.002). Furthermore, Alvarez et al.(17) showed a statistically significant positive correlation between the UCLA scale and physical activity measured by accelerometers using Spearman correlation coefficient (rho= 0.361,p=0.015) in 47 patients following THA. Our findings and the presented literature support the validity of the UCLA scale as physical activity measurement tool. However, the UCLA scale is still a subjective patient-reported outcome score and can be limited by recall bias.(9, 10)

In our cohort, the WOMAC and PCS SF-12 scores did not correlate well with the number of steps taken per day. However, the HHS showed a statistically significant positive correlation. This positive correlation contradicts other studies in the current literature. Alvarez et al.(17) found no correlation between HHS and physical activity levels measured by accelerometers in 47 patients following THA (rho= 0.028,p=0.854). Morlock et al.(18) also did not show a significant correlation between HHS and the number of steps in 31 patients following THA using linear regression analysis (r^2 =0.10, p =0.078). Although both studies used wearable technology, the report by Morlock et al.(18) to our knowledge is the only publication that correlated HHS with the number of steps. However, this study was evaluating patients following THA and was limited by using a heavy pedometer that weighed 1.6kg that theoretically can affect patient's physical activity levels. In addition, they only recorded activities for one day that may not adequately represent a patient's daily activity level.

Although no studies correlated the 12-item short form survey against objectively measured physical activity in patients with OA, limited studies have examined other versions including the 8-item and 36-item short form survey. Fujita et al.(34) showed no correlation between the 8-item short form survey and step counts in 38 female patients with end-stage hip OA awaiting an elective unilateral THA. On the other hand, Brandes et al.(20) correlated the 36-item short form survey against number of steps in 26 patients with end-stage hip and knee OA. They found a positive correlation of physical functioning to step counts with a Pearson correlation coefficient (r) of 0.6 (p=0.02). The 36-item short form survey provides more information compared to shorter forms like the SF-12 and SF-8. Based on the available literature, only SF-36 correlated well to step counts, which can be attributed to the amount of information obtained. However, shorter forms such as SF-12 and SF-8 are more convenient and easier to implement in the daily clinical practice.

In our study, BMI did not correlate with the number of steps per day. In addition, we did not detect a difference in the mean number of steps in patients with BMI ≤ 30 kg/m^2 compared to patients with BMI > 30 kg/m^2. This is similar to the results reported by Alvarez et al.(17) in which they demonstrated no difference in physical activity levels measured by accelerometers between patients with BMI < 30 kg/m^2 (147.7) compared to patients with BMI > 30 kg/m^2 (147.3). It is well documented in the literature that physical inactivity can lead to obesity.(37) However, few studies have assessed whether or not increased BMI could independently lead to physical inactivity and the effect of BMI on physical activity levels remains controversial. On the other hand, both age and CCS demonstrated a negative correlation with the number of steps per day. Similar results have been reported in the literature. Alvarez et al.(17) showed that patients older than 70 years old were significantly less active (105.8) than patients younger than 70 years old (171.1) measured by accelerometers (p=0.02). Marques et al.(38) showed that medical comorbidities significantly reduced physical activity in 60 rheumatoid arthritis patients using Timed Up and Go (TUG) Test and Five-Times-Sit-to-Stand Test.

The lack of a control group is a potential limitation of this study. However, physical activity levels in a similar age-matched control group have been well documented in the current literature and can be compared to patients in our study. Another potential limitation is patient’s compliance with wearing the activity tracker, especially older patients who are not familiar with using such a technology. To our knowledge, this prospective cohort study is the first report to compare the WOMAC and SF-12 scores to step counts in patients with end-stage hip OA. Establishing such a correlation makes this report a valuable clinical study to a wide range of clinicians to help them assess physical activity levels in patients with end-stage OA.

In conclusion, wearable technology devices are becoming more popular among the general population. Healthcare providers should take advantage of the widespread use of this technology by their patients, and inquire about the mean daily steps if the patient happens to record these data. This will allow a more accurate way of evaluating physical activity and will avoid the recall bias and activity overestimation that is associated with patient-reported questionnaires. If access to wearable technology to evaluate physical activity is limited, the use of the UCLA scale is recommended as it showed in our report a significant correlation with the number of steps per day. When considering commonly used outcome scoring systems, the HHS can accurately reflect the level of physical activity as it also demonstrated a significant positive correlation with the mean number of steps. Interestingly, the BMI did not influence the mean number of step per day in our cohort. Further studies exploring the effect of increased BMI on physical activity levels are required in the future.

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Chapter 4

4 Change in Physical Activity Levels in The Immediate Post-Operative Period Following Total Hip Arthroplasty: A Prospective Cohort Study

4.1 Introduction:

End-stage hip osteoarthritis (OA) is a debilitating musculoskeletal disease with high prevalence.(1,2) The incidence of hip arthritis is on the rise. According to the World Health Organization, osteoarthritis is expected to become the 4th leading cause of patient disability in 2020.(3) Articular cartilage damage can cause severe hip pain, swelling and restriction in range of motion. These symptoms will lead to psychological distress, and deterioration in physical functioning and quality of life.(4) Total hip arthroplasty (THA) is a cost-effective surgery that can restore functional capacity and quality of life in this population.(5) The primary goal of a THA is to achieve a painless, mobile, and stable hip joint to improve the patient's functional capacity and quality of life.(6)

Physical activity level is an important dimension of quality of life, and critical prognostic factor following THA.(7) Change in physical activity levels can be measured to assess functional recovery following THA. Various studies have evaluated physical activity levels in THA patients using different measurement tools.(8-10) In addition to utilizing subjective measurement tools of activity levels, wearable technology has been used in several studies as an objective measure. In a systematic review of eight studies that objectively evaluated recovery of physical activity in patients undergoing primary THA for end-stage OA, Arnold et al.(11) found negligible improvement in physical activity levels at six months and limited evidence for larger changes at one year following THA. In the same review, four studies reported healthy control group data; and patients in the THA group showed significantly lower physical activity levels compared to the control group.

Early post-operative functional recovery following surgery remains a major concern for patients and healthcare providers. Considerable effort from healthcare providers, patients, employers, and patient's caregivers is required to facilitate patient's ability to function in the early post-operative period.(12-14) Independence in activities of daily living and improved function following THA can decrease the hospital length of stay (LOS) and therefore, lower the overall cost of the procedure. Recently, the increased demand on THA and limited healthcare budgets represents a major challenge worldwide. In 2013, the mean costs per inpatient day in a local government hospital in the United States were 1,878 US dollars.(15) For that reason, a variety of peri-operative interventions have been introduced recently to minimize the hospital length of stay and reduce the overall costs.(16)

Several studies have evaluated functional recovery after THA using subjective and objective measurement tools.(16) However, few of them evaluated early functional recovery in the immediate post-operative period. Judd et al.(17) evaluated functional recovery in 26 patients undergoing elective THA for hip OA. At one month post-operatively, patients demonstrated significantly lower performance on the stair climb test, timed up and go test, single-limb stance, and 6-minute walk test compared to pre-operatively. However, patients had significantly improved the Hip disability and Osteoarthritis Outcome Score (HOOS) in all subscales ($p=0.01$) except for sports and recreational activities ($p= 0.08$). In another study, Holm et al.(18) evaluated functional recovery in 35 patients undergoing elective unilateral THA in the first week after surgery. The pain, symptoms and activities of daily living subscales of the HOOS significantly improved on post-operative day 7 compared to pre-operatively ($p<0.01$). The time up and go test was also used to assess performance-based function. The performance significantly improved on post-operative day 7 (11.7 ± 3.4 sec) compared to post-operative day 2 (18.3 ± 6,5), however, did not reach the pre-operative level (9.5 ± 2.7 sec).

Several studies in the current literature objectively evaluated functional recovery after THA; however, most of them used performance based tests (such as TUG) that evaluate what the patient can do but not the actual activity level. Activity trackers are validated to measure step counts and provides real time evaluation of patient's activity level.(19) The purpose of this study is to evaluate the patient's immediate post-operative functional recovery following THA by measuring the change in the number of steps taken per day and the UCLA activity scale.(19)

4.2 Materials and Methods:

After obtaining research ethics board approval, three fellowship trained arthroplasty surgeons (J.H, B.L, and E.V) in a tertiary academic center prospectively enrolled patients in this study between September 2015 and March 2016. Any patient with hip OA who failed non-operative treatment and in whom a primary THA was indicated was considered for inclusion in the study. Exclusion criteria included patients with inflammatory hip arthritis, prior hip surgery, prior infection, contralateral hip pathology that would affect activity, and patients not willing to participate in the study. We also excluded patients who developed any post-operative complication that can affect their physical activity.

Demographics such as height, weight, age, and medical co-morbidities were collected. The physical activity level was objectively measured by recording the number of steps walked per day using a validated wristband activity tracker, Fitbit® Flex (Fitbit Inc., San Francisco, CA, USA).(19, 20) All patients were asked to wear the wristband for 24 hours a day, except for water activities, on seven consecutive days within four weeks preceding their scheduled THA and the first two weeks post-operatively in entirety. Patients were given clear instruction on how to operate the wristband and wear it, along with a detailed instruction sheet. All patients were also given an information sheet to document the times and reasons they took the wristband off. Data was downloaded as number of steps taken per day. The University of California, Los Angeles (UCLA) activity scale(21)was also obtained in the same time period. The UCLA activity scale is a simple scale that includes 10 statements covering a range of physical activities, 0 represents no physical activity and 10 represent participation in impact sports.(22) It has been shown to be valid when used to measure physical activity in total joint arthroplasty patients.(22) Two of the surgeons (J.H and B.L) used the direct anterior approach, whereas the third surgeon (E.V) used the direct lateral approach. All patients received a cementless total hip arthroplasty. One of the following porous-coated hemispherical acetabular cups were used to reconstruct the acetabulum: R3® (Smith and Nephew, Warsaw, IN), Trident® (Stryker, Warsaw, IN), or Pinnacle® (DePuy, Warsaw, IN). All patients received a hydroxylapatite-coated cementless Corail® femoral stem (Depuy, Warsaw, IN) to reconstruct the proximal femur. There was no hip precautions following surgery and all patients were allowed weight bearing as tolerated immediately after surgery. The same physiotherapy group cared for all patients.

Demographics, the number of steps, and the UCLA score were reported with descriptive statistics including means, standard deviations, and ranges. A Wilcoxon signed rank test was used to compare patients post-operative step counts and UCLA scores to their pre-operative values. SPSS® v.22 (SPSS Inc., Chicago, IL, USA) was used for all analyses. Statistical significance was set at p value < 0.05.

4.3 Results:

Thirty-eight patients were found to meet the inclusion criteria; there were 15 males and 23 females. The mean age at the time of assessment was 65 years (range 48 – 88 years), the mean body mass index (BMI) was 30.3 kg/m^2 (range 20.9 – 49.3 kg/m^2), and the mean Charlson Co-morbidity Score (CCS) was 2.5 (range 0 - 8). Twenty-six patients underwent a direct anterior approach, and 12 patients underwent a direct lateral approach.

The mean number of steps per day pre-operatively was 5883 ± 3841 (range 1511-17876 steps/day). The mean number of steps per day during the first two weeks post-operatively was 1928 ± 1932.3 (range 0 - 10461 steps/day) (Table 4.1). The mean number of steps per day for post-operative day 13, the last day of the evaluated post-operative period, was 2995.5 ± 2777.4 (range 386 -10461). The mean number of steps taken during each post-operative day is presented in Table 4.2. The mean number of steps taken per day during the first two weeks post-operatively was significantly lower than the mean number of steps taken during the pre-operative period (p=0.0001). However, patients showed steady progressive improvement in their post-operative physical activity levels (Figure 4.1). On post-operative day 13, patients recovered 50.1% of their pre-operative physical activity levels compared to 30.1% on post-operative day 6 and 10% on post-operative day 0 (Table 4.2).

Table 4.1 The mean number of steps per day (steps/day) and UCLA scores pre-operatively and post-operatively with the difference in means (delta)

	Pre-op	Post-op	Delta	p value
Steps/day	5883.0 ± 3841.0	1928.0 ± 1932.3	-4070.1 ± 3172.9	p=0.0001*
UCLA	4.46 ± 1.70	3.43 ± 1.32	-1.10 ± 1.65	p=0.001*

*UCLA= The University of California, Los Angeles activity scale. * Correlation is significant at the 0.05 level (2-tailed).*

Table 4.2 The mean number of steps per day (steps/day) for each post-operative day and the percentage of recovery of the pre-operative activity level

POD	Mean ± SD	Range	Percentage of recovery (%)
0	638.7 ± 577.9	0 - 2123	10.8%
1	821.7 ± 769.4	0 - 2953	13.9%
2	1182.4 ± 1100.0	7 - 4937	20%
3	1551.3 ± 1359.3	141 - 4981	26.4%
4	1802.2 ± 2003.1	386 - 8343	30.6%
5	1944.6 ± 1881.9	122 - 7076	33.1%
6	1840.1 ± 1715.9	194 - 7897	31.3%
7	2191.1 ± 1846.5	389 - 7729	37.3%
8	2098.8 ± 1699.3	283 - 7274	35.7%
9	2298.3 ± 2161.1	275 - 9173	39.1%
10	2484.6 ± 1979.4	435 - 8938	42.2%
11	2457.1 ± 1916.9	517 - 9050	41.8%
12	2874.9 ± 2631.0	285 - 10277	48.9%
13	2995.6 ± 2777.4	386 - 10461	50.1%

POD= post-operative day.

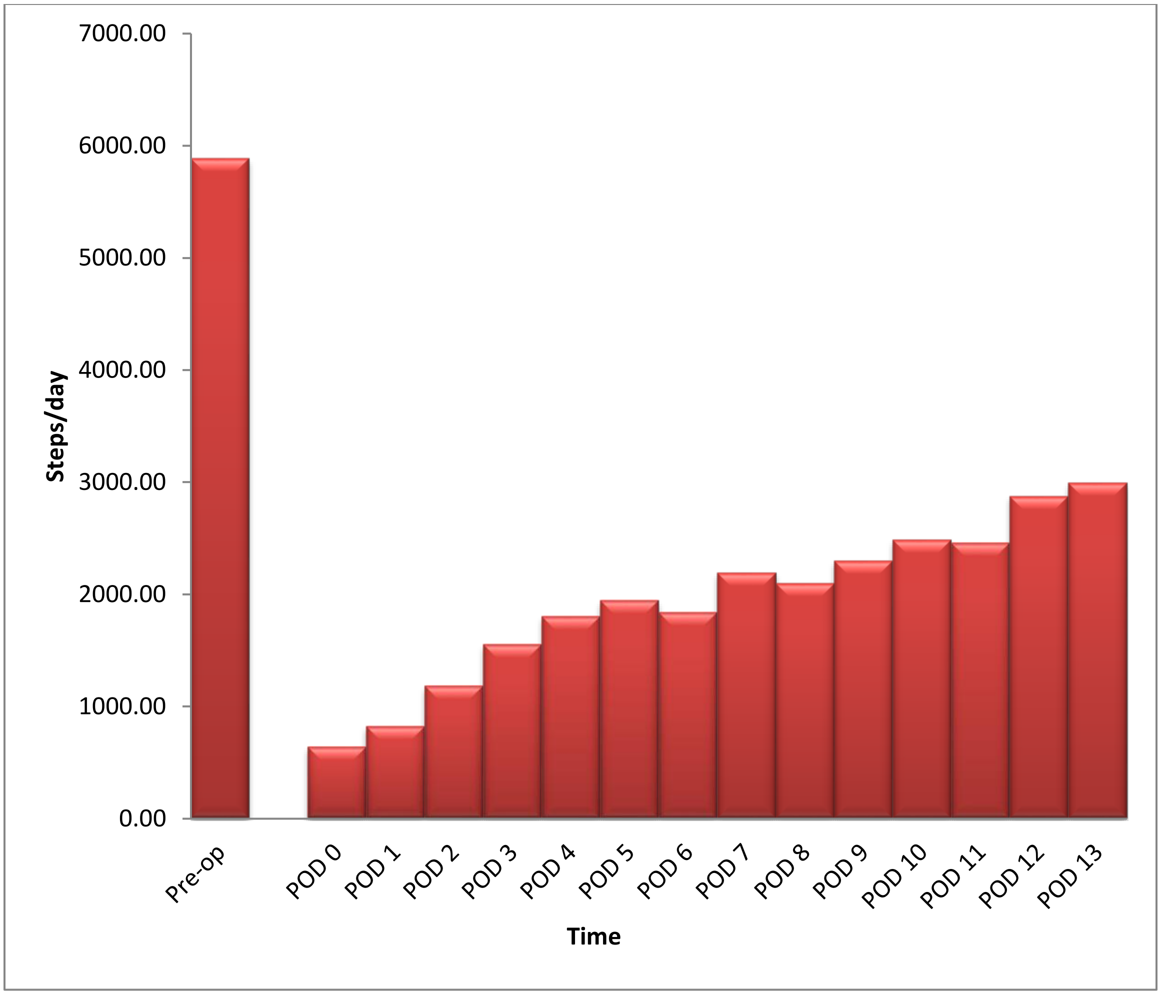

Figure 4.1 The mean number of steps per day in the first 2 weeks post-operatively compared to the mean number of steps pre-operatively. *POD= post-operative day.*

The mean pre-operative UCLA score was 4.46 ± 1.7 (range 2- 10). The mean UCLA score collected at two weeks post-operatively was 3.43 ± 1.32 (range 1-6). The mean UCLA score at two weeks post-operatively was significantly lower than the pre-operative score (p=0.001) (Table 4.1).

4.4 Discussion:

The aim of this study is to determine the physical activity levels in the immediate post-operative period in patients undergoing elective unilateral THA. At the end of the evaluation period (post-operative day 13), the mean number of steps was 2995.5 ± 2777.4 (range 386 -10461), which is only 50.1% of the pre-operative physical activity levels. However, patients showed steady progressive improvement in their post-operative physical activity levels.

Some studies in the current literature indicated that patients do not typically adopt a more active life style following THA. Vissers et al.(23) objectively evaluated physical activity levels in 36 patients after THA performed for end-stage hip OA using accelerometers. At six months post-operatively, patients spent less time walking (1.5 hours) compared to pre-operatively (1.6 hours). de Groot et al.(24) also evaluated physical activity levels in 80 patients after THA and TKA for OA using accelerometers. At six months post-operatively, patients improved the mean percentage of movement-related activity by only 0.7% compared to pre-operatively.

On the contrary, Fujita et al.(25) evaluated 38 patients after THA for OA using pedometers. The mean number of steps walked per day significantly improved at six months (5,657 ± 2,106 steps/day) and one year (6,163 ± 2,410 steps/day) post-operatively compared to pre-operatively (4,632 ± 2,246 steps/day). The discrepancy in the presented data in the literature can be attributed to the outcome measured. Fujita et al.(25) were able to show significant improvement in physical activity by reporting step counts while no difference was found by measuring the time spent walking in other studies. Studies evaluating step counts in the early post-operative period are limited in the current literature. In a study intended to explore the effect of anemia on functional recovery in fast track THA, Jans et al.(26) reported on the step counts in a cohort of 112 patients undergoing elective THA for hip OA. Step counts were measured from day one through six after discharge from the hospital using a 24-hours activity tracker. The mean number of steps after discharge (2163 steps/day) was significantly lower than pre-operatively (5261 steps/day). These findings are similar to the results in our study. However, the recovery rate of the pre-operative activity level was not reported for each evaluated post-operative day. In addition, the step counts assessment was only for six days following patient discharge. The discharge date can vary between patients; therefore, the evaluation period is not consistent in their cohort.

Studies evaluating the rate and pattern of physical activity recovery in the early post-operative period are limited. To our knowledge, this is the first report that objectively explored the rate and pattern of functional recovery reported as step counts in the first two weeks after THA. Therefore, we think the data we presented in this report can guide patients to manage their expectation with regards to recovering their pre-operative physical activity levels in the immediate post-operative period. Furthermore, monitoring and predicting the time patient takes to recover their independence is also important, this can help patient and healthcare providers appropriately plan discharge from hospital and arrange needed resources while recovering from surgery.

Lack of a control group in this study is considered a limitation. Holsgaard-Larsen A et al.(27) reported the mean number of steps in 26 patients with end-stage hip OA to be 6639 ± 3222 compared to 8576 ± 2872 in a healthy age-matched control group. The well documented mean step counts in an age-matched control group in the literature can be used as a reference to our cohort. Another potential limitation is patient's compliance with wearing the activity tracker, especially older patients who are not familiar with using such a technology. At two weeks post-operatively only 50.1% of the pre-operative physical activity level was achieved in our cohort. These findings might indicate that the evaluation period is short and not sufficient to determine the time point where full recovery of the pre-operative physical activity level is achieved. In the future, longer follow-ups including six weeks post-operative follow ups are required to determine the time point of full recovery of physical activity.

In conclusion, although patients continue to improve their physical functioning in the long-term, only 50.1% of the pre-operative physical activity level was reached in our cohort by the end of the first two weeks post-operatively. This can determine the rate of physical activity recovery immediately after THA that can help patients set their expectations and prepare them psychologically and socially for getting through the immediate post-operative period. Evaluating patients for a longer period of time may be needed in the future to identify that point of time where patients reach or exceed their pre-operative physical activity levels and determine whether they can adapt a more active lifestyle as well as return to work timelines. Early functional recovery following THA has significant clinical and socioeconomic impact. Therefore, future research should focus on peri-operative interventions and surgical techniques that can accelerate functional recovery.

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Chapter 5

5 Physical Activity Levels in Total Hip Arthroplasty Comparing The Direct Anterior Approach to The Direct Lateral Approach: A Prospective Cohort Study

5.1 Introduction:

Total hip arthroplasty (THA) is a cost-effective reconstructive surgery to treat patients with end-stage hip arthritis.(1) In 2011, more than 300,000 THA surgeries were performed in the United States with an mean cost of $ 30,124 for each procedure.(2, 3) Despite high patient satisfaction after THA, earlier functional recovery after surgery certainly concerns healthcare providers, patients and caregivers. Different surgical approaches have been successfully used to perform THA.(4) However, the influence of surgical approaches on early functional recovery is still a topic of debate.(5-7) It is proven in the current literature that early functional recovery after TJA will decrease the hospital length of stay (LOS) and therefore, reduce the overall cost of the surgery.(8-12) Furthermore, early independence may affect patient ability to return to work; which can have a significant socioeconomic impact. The expected functional recovery time is also important, as it can significantly influence the time dedicated by caregivers to help patients or the time spent by patients in a rehabilitation facility.

The direct anterior approach has emerged recently as an attractive surgical approach in THA. It has gained more popularity due to its purported muscle sparing nature and use of inter-nervous planes. When compared to the direct lateral (DL) approach, the direct anterior (DA) approach is less invasive and provides faster functional recovery in the early post-operative period. This has been supported by several studies in the current literature.(7, 13-16) However, studies evaluating functional recovery in the DA approach compared to the DL approach in the immediate post-operative period are limited in the current literature. Furthermore, all the studies in the current literature have used primarily subjective measurement tools to assess functional recovery instead of objective measurement tools. Activity trackers have been proven to be valid and accurate objective tools to quantify activity levels by recording the number of steps walked.(17) Therefore, activity trackers may provide a better assessment of functional recovery than subjective measures. Crouter et al.(17) evaluated the accuracy of 10 different activity trackers and found eight of the ten devices had excellent test–retest reliability and accuracy was >95%. In addition, Evenson et al.(18) evaluated the measurement properties of popular activity trackers and concluded that activity trackers measuring step counts have high validity.

To our knowledge, activity trackers have never been used to measure physical activity levels when comparing the DA approach to the DL approach in THA. We hypothesize that patients in the DA group will have better physical activity levels measured by the number steps per day and the UCLA score compared to the DL group in the immediate post-operative period (defined as the first two week post-operatively).

5.2 Materials and methods:

After obtaining research ethics board approval, three fellowship trained arthroplasty surgeons (J.H, B.L, and E.V) in a tertiary academic center prospectively enrolled patients in this study between September 2015 and March 2016. Any patient with hip osteoarthritis who failed non-operative treatment and in whom a primary THA was indicated was considered for inclusion in the study. Exclusion criteria included patients with inflammatory hip arthritis, prior hip surgery, prior infection, contralateral hip pathology that would affect activity, and patients not willing to participate in the study. We also excluded patients who developed any post-operative complication that can affect their physical activity.

Patient demographics including age, gender, body mass index (BMI), and medical co-morbidities were obtained. Using a validated wristband activity tracker, Fitbit® Flex (Fitbit Inc., San Francisco, CA, USA), the number of steps was recorded.(18, 19) Participating patients were advised to wear the wristband for 24-hours a day, except when showering, on seven consecutive days within four weeks preceding their scheduled THA and the first two weeks post-operatively. Clear instructions on how to use the wristband were given to all patients. In addition to the detailed instruction sheet, patients were also given an information sheet to document the times and reasons they took the wristband off. Then all the data was downloaded as number of steps per day on a secured electronic file. The University of California, Los Angeles (UCLA) activity scale(20) was also obtained in the same time period. The UCLA activity scale is a simple scale that includes 10 statements covering a range of physical activities, 0 represents no physical activity and 10 represent participation in impact sports.(21) It has been shown to be valid when used to measure physical activity in total joint arthroplasty patients.(21)

Two of the surgeons (J.H and B.L) used the direct anterior approach, whereas the third surgeon (E.V) used the direct lateral approach. This established the basis of two groups; those who underwent THA through a direct anterior approach (DA group); and those who underwent THA through a direct lateral approach (DL group). The mean number of steps per day for each post-operative day (POD) as well as the mean UCLA score at two weeks post-operatively was compared between the two groups. All patients received a cementless total hip arthroplasty. One of the following porous-coated hemispherical acetabular cups were used to reconstruct the acetabulum: R3® (Smith and Nephew, Warsaw, IN), Trident® (Stryker, Warsaw, IN), or Pinnacle® (DePuy, Warsaw, IN). All patients received a hydroxylapatite-coated cementless Corail® femoral stem (Depuy, Warsaw, IN) to reconstruct the proximal femur. Neither groups had hip precautions and patients in both groups were allowed weight bearing as tolerated immediately after surgery. Both groups had the same group of physiotherapist caring for them.

A sample size calculation was conducted based on a power of 80%, alpha value of 0.05 and effect size of 0.60. Literature comparing the DA approach to the DL approach demonstrate effect sizes ranging from 0.30 – 0.70 for functional outcome scores at six weeks post-operatively therefore an effect size of 0.60 was selected. This resulted in a required sample size of 45 subjects per treatment arm. We inflated the sample size by 10% to account for withdrawals leading to 50 subjects per treatment arm. This paper will report on the first 38 patients enrolled in this study.

Demographics, the number of steps, and UCLA score were reported by means of descriptive statistics including means, standard deviations, and ranges. An independent student's t-test was used to compare age between the two groups. A Wilcoxon signed rank test was used to determine changes in step counts and UCLA scores from the pre-operative visit to the post-operative follow-up in each group. A Mann-Whitney U test was used to compare BMI, CCS, step counts and UCLA score between the DA and DL cohorts. SPSS® v.22 (SPSS Inc., Chicago, IL, USA) was used for all analyses. Statistical significance was set at p value < 0.05.

5.3 Results:

Thirty-eight patients were prospectively analyzed in this study. Twenty-six patients underwent a direct anterior approach and twelve patients underwent a direct lateral approach. Patient’s demographics including age at time of surgery, gender, body mass index (BMI) and Charlson Comorbidity Score (CCS) are listed in (Table 5.1). There was no difference in gender, age and, CCS in both groups (p=0.73, p=0.67 and p=0.146 respectively). The mean BMI was significantly lower in the DA group compared to the DL group with a mean BMI of 27.7 ± 4 kg/m^2 and 35.8 ± 8.8 kg/m^2 respectively (p=0.002). There was no difference in the mean steps walked per day or the mean UCLA score between the DA and DL groups pre-operatively.

Table 5.1 Patient demographics of the two groups

Approach	Direct Lateral (n=12)	Direct Anterior (n=26)	p value
Female %	66.7%	57.7%	p=0.73
Age (years)	62.9 ± 9.9	66.0 ± 9.1	p=0.67
BMI (kg/m^2)	35.8 ± 8.8	27.7 ± 4.0	p=0.002*
CCS	2.0 ± 1.0	2.8 ± 1.4	p=0.15

*BMI= Body Mass Index, CCS= Charlson Comorbidity Score. * Correlation is significant at the 0.05 level (2-tailed).*

The mean number of steps on post-operative day 13 was significantly less than pre-operatively in both the DA and DL groups (p=0.003, 0.005 respectively). Also the mean UCLA score collected at two weeks post-operatively was significantly less than pre-operative scores in both the DA and DL groups (p=0.009, 0.019 respectively). The patients in the DA group had a higher number of steps in the first two weeks post-operatively and had a higher UCLA score collected at two weeks post-operatively compared to the DL group (p=0.03 and p=0.03 respectively) (Table 5.2).

Table 5.2 Comparing the mean steps per day (steps/day) and the UCLA score in the two groups pre-operatively and post-operatively

Approach	Direct Lateral	Direct Anterior	p value
Pre op steps/day	6033.5 ± 4595.9	5814.1 ± 3551.3	p=0.87
Post op steps/day	1298.5 ± 1033.2	2183.3 ± 1555.6	p=0.03*
Pre op UCLA	3.8 ± 0.8	4.7 ± 0.4	p=0.49
Post op UCLA	2.3 ± 0.8	3.8 ± 1.4	p=0.03*

*UCLA= University of California, Los Angeles activity score. * Correlation is significant at the 0.05 level (2-tailed).*

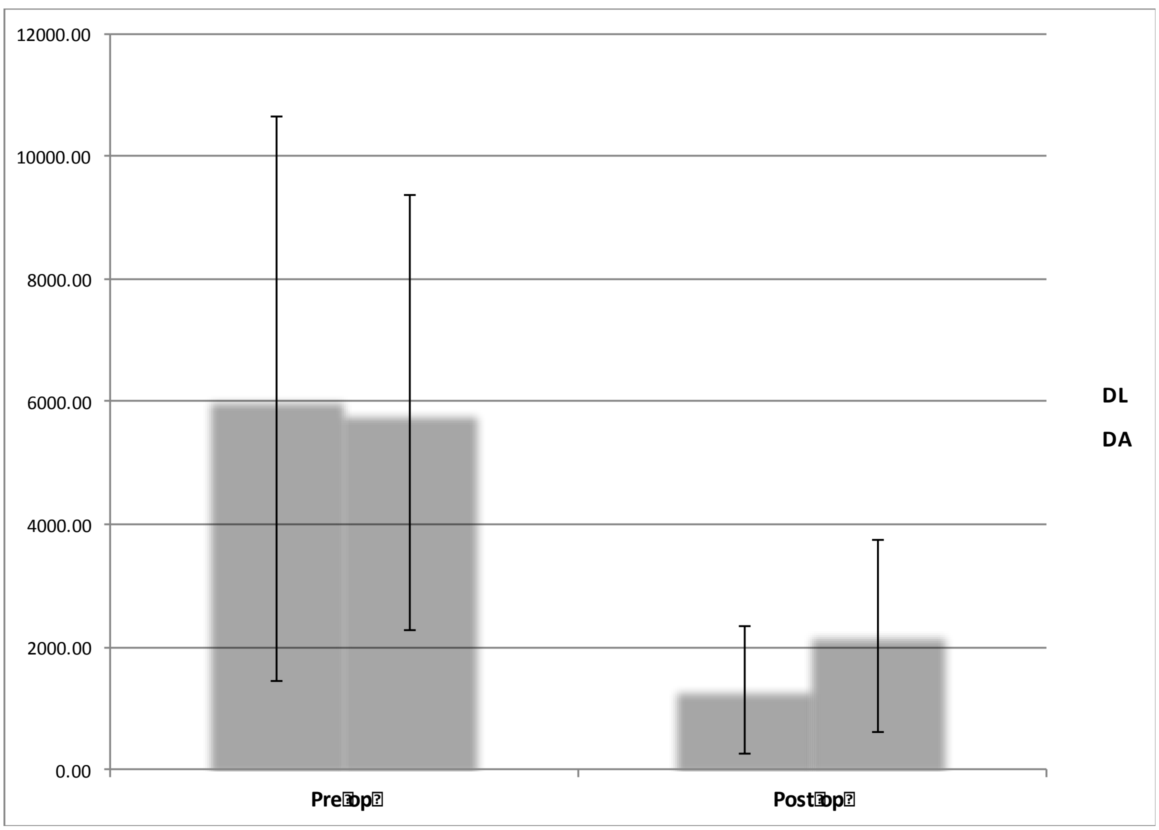

Figure 5.1 The mean number of steps per day pre-operatively and in the first two weeks post-operatively in both groups showing error bars with standard deviation. ** Significant p value (< 0.05).*

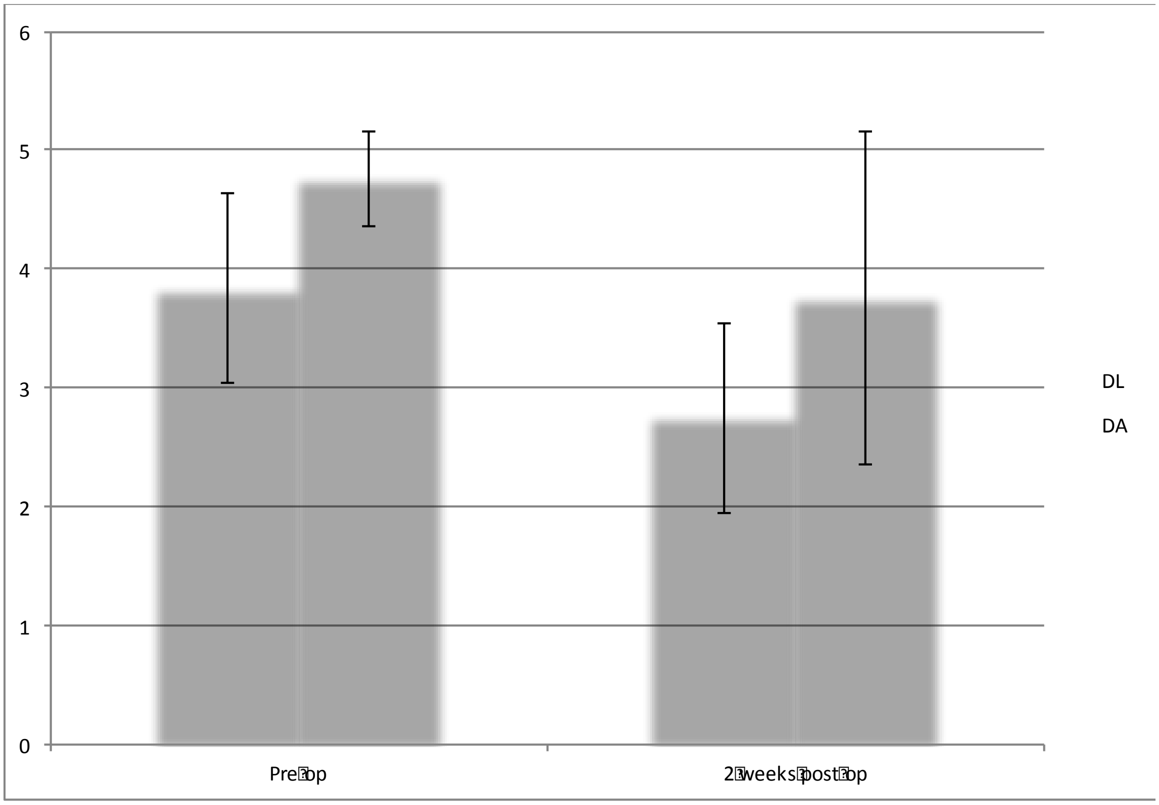

Figure 5.2 The mean UCLA score pre-operative and 2 weeks post-operatively in both groups showing error bars with standard deviation. *UCLA= University of California, Los Angeles activity score. * Significant p value (< 0.05).*

The mean number of steps per day for each post-operative day (POD) in each group is presented in Table 5.3. The DA group showed a statistically significant increase in the number of steps per day compared to the DL group on post-operative days 6, 8, 9,10 and11 ($p=0.004$, $p=0.01$, $p=0.007$, $p=0.008$ and $p=0.03$, respectively). Patients in the DA group reached 60.7% of their pre-operative activity levels on post-operative day 13 compared to only 22.7 % for patients in the DL group.

Table 5.3 Comparing the mean steps per day (steps/day) for each post-operative day in both groups

Post- op days	Direct Lateral (n=12)	Direct Anterior (n=26)	p value
0	628.4 ± 623.2	643.3 ± 570.2	p=0.94
1	698.6 ± 686.4	880.8 ± 812.9	p=0.5
2	1296.4 ± 1031.9	1132.8 ± 1147.1	p=0.38
3	1375.8 ± 1334.6	1560.1 ± 1403.7	p=0.55
4	1360.3± 1149.3	1975.1 ± 2249.9	p=0.74
5	1166.5 ±1227.9	2236.4 ± 2019.8	p=0.10
6	1055.3 ± 1101.7	2154.1 ± 1832.2	p=0.004 *
7	1738.5 ± 1429.9	2372.2 ± 1986.0	p=0.46
8	1289.8 ± 969.8	2422.4 ± 1832.0	p=0.019 *
9	1099.8 ± 533.6	2729.7 ± 2365.1	p=0.007 *
10	1445.9 ± 1026.0	2960.8 ± 2140.5	p=0.008 *
11	1747.5 ± 1684.7	2796.5 ± 1961.9	p=0.034 *
12	1723.4 ± 1752.2	3450.7 ±2836.2	p=0.63
13	1972.5 ± 2022.2	3531.4 ±3005.8	p=0.96

** Correlation is significant at the 0.05 level (2-tailed).*

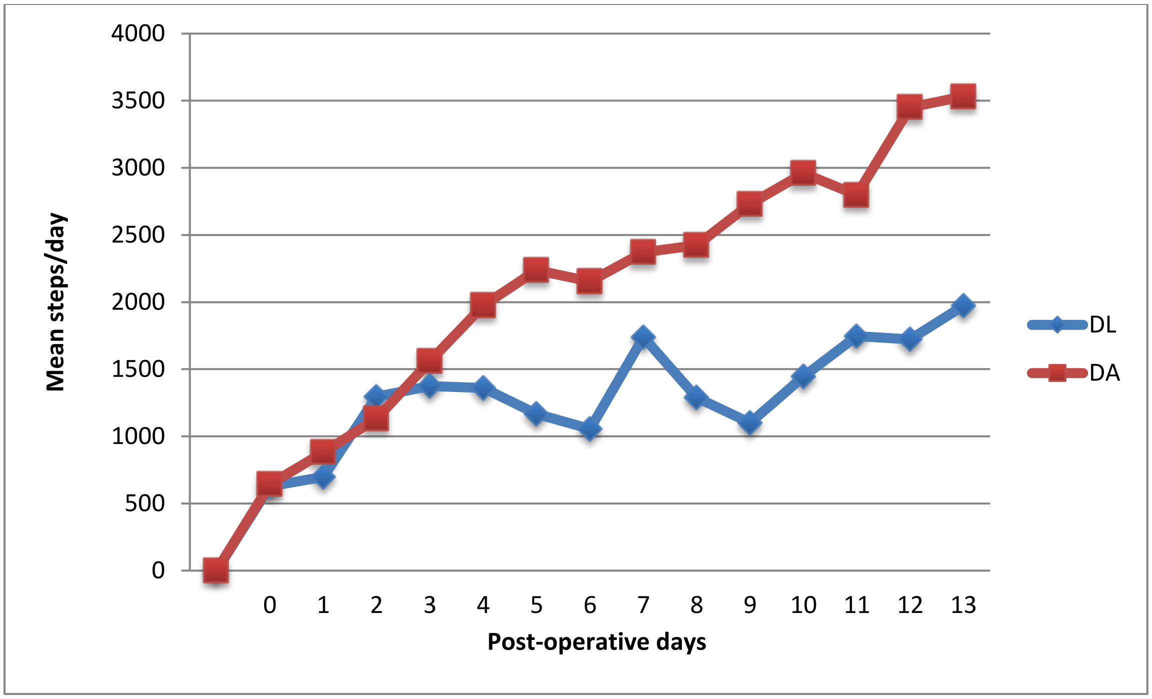

Figure 5.3 A line graph comparing the mean steps per day (steps/day) for each post-operative day in both groups.

5.4 Discussion:

Despite high patient satisfaction in THA, functional recovery and independence in performing activities of daily living (ADL) in the immediate post-operative period is still a primary concern for patients and their caregivers. In this prospective cohort study, the patients in the DA group had a higher number of steps in the first two weeks post-operatively and had a higher UCLA score collected at two weeks post-operatively compared to the DL group. The DA group showed a statistically significant increase in the number of steps per day compared to the DL group in 5 out 14 post-operative days.

It is well documented that patients can fully recover their pre-operative physical activity levels on the long-term after THA. However, we did not expect to see this as early as two weeks post-operatively. In our study, patients in both groups did not reach their pre-operative physical activity levels by the end of the evaluation period (post-operative day 13). However, we were able to demonstrate that patients in the DA group had faster recovery of their physical activity levels compared to the DL group. Patients in the DA group reached 60.7% of their pre-operative activity levels on post-operative day 13 compared to only 22.7 % for patients in the DL group. Furthermore, the mean number of steps taken on post-operative day 13 was 1.7 fold more in the DA group compared to the DL group.

We observed temporary drop in the mean number of steps in both groups, it was more pronounced on post-operative days 5 and 6 for the DL group and post-operative day 6 for the DA group. One potential cause of this drop in steps is tracker malfunction due to low battery charge. The battery lifespan of the activity tracker that we used is 5 days and we clearly advised patients to charge the battery on the fifth day. However, if the patient fails to charge the battery on time or the battery runs out sooner than expected, the recorded number of steps on that day can be inaccurate. Another potential cause of the drop in step count can be related to change in the use of walking aids. Because we did not track the use of walking aids by patients in our cohort, we cannot reach any conclusions.

Change scores are commonly used in the arthroplasty literature. Change score is the change in the outcome variable from baseline to follow-up after a given intervention.(22, 23) The utility of this method has been questioned(22, 23), and therefore, we chose not to report change scores in our analysis. Cronbach and Furby (23)showed that change scores is systematically related to any random error of measurement, therefore lead to invalid conclusions. In addition, other authors showed that change scores lack reliability(22).

In our study, the DA group showed significantly higher number of steps per day on post-operative days 6, 8, 9,10 and 11 compared to the DL group. To our knowledge, no studies in the current literature objectively evaluated functional recovery in the DA approach compared to the DL approach in the first two weeks following THA. However, several studies demonstrated better functional recovery of the DA approach compared to the DL approach at six week post-operatively using subjective measures.(13, 15, 16, 24, 25) Mirza et al.(7) retrospectively reviewed 1690 consecutive primary THA and found the DA group to have a significantly higher HHS when evaluated six weeks post-operatively. Ilchmann et al.(15) in a prospective cohort study also had similar findings at six weeks, twelve weeks and one year post-operatively but not at two years post-operatively. Restrepo et al.(24) performed a randomized controlled trail (RCT) with 50 patients in each group. The DA group had significantly higher SF-36 and WOMAC scores six weeks, twelve weeks, and one year post-operatively but not at two years post-operatively. Some of these studies reported on post-operative pain in the first two week following surgery using the visual analog score (VAS) and patients in the DA group showed significantly less pain compared to patients in the DL group.(26) Studies that have demonstrated less post-operative pain, systemic inflammation and muscle damage in patients who had a DA approach compared to other surgical approaches may indicate reasons for the better function of the DA patient cohort.(27-29)

Early functional recovery can have a significant socioeconomic impact. The expected functional recovery time is very important, as it can influence the time and effort dedicated by caregivers to help patients. Perry et al.(30) in a qualitative study interviewed 11 patients between 6 and 12 weeks after discharge following a lower limb surgery to explore their perceptions on being discharged home. In their study, they reported that many family members arranged time off work to provide the required care particularly in the first few weeks after surgery. In some certain circumstances where caregivers cannot provide the required help, inpatients rehabilitation is required where substantial health care resources are consumed.(31) As the economic burden of THA is increasingly scrutinized to maximize the effect of the healthcare dollars spent, the inter-nervous, inter-muscular DA approach may confer some advantages by enabling better function in the early post-operative period when compared to other surgical approaches.

The BMI was significantly lower in the DA group compared to the DL group ($p=0.002$). However, there was no significant difference in the mean number of steps per day pre-operatively between the two groups ($p=0.87$). Furthermore, as we showed in chapter 3 of this thesis, there was no significant difference in the mean number of steps per day pre-operatively in patients with a BMI ≤30 kg/m^2 compared to patients with a BMI > 30 kg/m^2. The effect of high BMI on physical activity is still a topic of debate. It is hard to draw any conclusions based on our results given the small sample size. There were also more females in the DL group compared to the DA group, which can act as another confounder, however the difference in gender between the two groups was not significant (p=0.73). In this chapter, we did not present an extensive literature review to explore the influence of high BMI or gender on the mean number of steps. Our aim when we reach our target sample size is to have similar demographics in both groups to eliminate any confounding factors.

One of the limitations in this study is the small sample size. Even though current enrolment has not yet reached the target sample size based on our power analysis, a significant difference in the mean number of steps per day was detected in 5 out 14 post-operative days. This may indicate that using step counts, as an objective measure of functional recovery is more sensitive than other subjective methods like functional hip scores and patient reported questionnaires. Another potential limitation is patient's compliance with wearing the activity tracker, especially older patients who are not familiar with such a technology.

The patient's activity level and ability to function in the early post-operative period has important economic and social implications. In this prospective cohort study, we concluded that patients in the DA group had higher physical activity levels measured by step counts and UCLA scores in the early post-operative period compared to the DL group. Further examination regarding the economic implications of the improved early function from the perspective of the patient, caregiver, and care payer may be indicated in the future.

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Chapter 6

6 Conclusions:

Physical activity level is an important dimension of quality of life, and a critical prognostic factor following THA.(1) Measurement of physical activity levels can be used to assess functional recovery following THA. Wearable technology provides an accurate and reproducible measure of physical activity levels.(2) Recently, the utilization of wearable technology to track physical activity levels became more popular in the general population.(3) Healthcare providers should take advantage of the widespread use of this technology by their patients, and inquire about the mean number of daily steps if the patient happens to record these data. However, the use of this technology as a measurement tool of patients' physical activity in the daily clinical practice is still limited. Therefore, it is important to validate patient reported outcome scores against step counts to identify a reliable alternative. Based on our results, the UCLA activity scale is recommended as a validated, simple alternative measurement tool of patients' physical activity. When considering functional outcome scoring systems, the HHS can accurately reflect the level of physical activity as it showed a significant correlation with the number of steps. Although the UCLA and HHS correlated well with the step counts, it is important to count for the recall bias and activity overestimation that is associated with patient-reported questionnaires when assessing physical activity levels.(4)

With the current economics and limited budgets, considerable effort from healthcare professionals is required to provide the appropriate care to patients with end-stage OA with lower costs.(5-7) Early improved function following THA can achieve this goal by reducing hospital length of stay (LOS). The expected functional recovery time is also very important, as it significantly influence the time and effort dedicated by caregivers to help patients. In our study, patients recovered 50.1% of their pre-operative physical activity level only in two weeks. This can determine the rate of physical activity recovery immediately after THA and help patients set their expectations in order to be prepared for the recovery period. Furthermore, this can help healthcare providers appropriately plan discharge from hospital and arrange needed resources while patient recovering from surgery.

When we explored the impact of surgical approaches on early functional recovery, patients in the DA group showed significantly higher number of steps per day in 5 out 14 post-operative days. Also patients in the DA group reached 60.7% of their pre-operative physical activity levels on post-operative day 13 compared to only 22.7 % for patients in the DL group. Therefore, we concluded that DA approach provides faster functional recovery in the early post-operative period compared to the DL approach. This can be explained by the utilization of a true inter-nervous plane in the DA approach that spare the muscles and cause less post-operative pain.(2, 8, 9) On the other hand, the abductor tenotomy performed during a lateral approach produces enough abductor dysfunction that could affect functional activities in the early post-operative period.

In the future, we will complete the data collection to include the entire 100 patients we had proposed as our sample size with 50 patients in each group. This will strengthen our results and allow us to better assess functional outcome in both groups. Also, to be able to determine that time point of full recovery of patient's pre-operative physical activity levels, longer follow-ups including six weeks post-operatively are required. In addition to the clinical advantage of early functional recovery, further examination of the socioeconomic implications of the improved early function from the perspective of the patient, caregiver, and care payer may be indicated in the future.

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Appendix A: Ethics board approval

Western Research | Research Ethics

Western University Health Science Research Ethics Board
HSREB Delegated Initial Approval Notice

Principal Investigator: Dr. Brent Lanting
Department & Institution: Schulich School of Medicine and Dentistry\Orthopaedic Surgery, London Health Sciences Centre

Review Type: Expedited
HSREB File Number: 106742
Study Title: Level of Activity and Sleeping Patterns in Total Hip Replacement Using Direct Anterior Hip Approach Compared to Direct Lateral Approach
Sponsor:

HSREB Initial Approval Date: July 10, 2015
HSREB Expiry Date: July 10, 2016

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Letter of Information & Consent	Informed Consent - Version 23Jun2015 - Clean Copy	2015/06/23
Data Collection Form/Case Report Form	UCLA Activity Score (received May 8/15)	
Western University Protocol	Received June 23/15	

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Appendix B: Informed consent form

London Health Sciences Centre

Title: Level of Activity and Sleeping Patterns in Total Hip Replacement Using Direct Anterior Hip Approach Compared to Direct Lateral Approach.

Study Doctors	**Telephone**
Principal Investigator: Dr. Brent Lanting	
Co-Investigators: Dr. James Howard Dr. Edward Vasarhelyi Dr. Lyndsay Somerville Dr. Matthew Teeter Dr. Aziz Aljurayyan – Orthopaedic Fellow	
Study Coordinators Bryn Zomar Nicole Burke	

You are being invited to voluntarily participate in a research study designed to evaluate the early functional recovery following total hip replacement surgery using direct anterior approach versus direct lateral approach at London Health Sciences Centre.

This letter of information describes the research study and your role as the participant. The purpose of this letter is to provide you with information required for you to make an informed decision regarding participation in this research. Please read this form carefully. Do not hesitate to ask anything about the information provided. Your doctor or the research coordinator will describe the study and answer your questions.

Study Purpose

To evaluate the level of activity and sleeping pattern in the early postoperative period in patients undergoing total hip replacement using direct anterior hip approach compared to direct lateral approach.

Procedure

If you choose to participate in this study, you will be asked to wear a pedometer (an electronic bracelet) to measure your activity level, reported as steps count and sleeping pattern, reported as sleeping hours and the number of times you wake up during your sleep. You will be asked to wear it for 24 hours per day for 1 week prior to your surgery, for 2 weeks immediately after your surgery, and for 1 week after your 6-week follow-up visit with your surgeon. You will receive your pedometer on the day of your last visit before your surgery. Instructions on how to use the pedometer will be provided. You will be asked to bring the pedometer back on the day of your surgery to download the measurements. On the first day after your surgery, you will be given the pedometer again and you will be asked to wear it for another 2 weeks. You will then bring the pedometer back at your first post-operative visit at 2 weeks to download the measurements. You will again be given the pedometer at your 6-week post-operative visit and asked to wear it for one final week. You will be asked to return the pedometer at your next visit with physiotherapy, if you attend University Hospital for your physiotherapy, or to mail it to the study coordinators. During all visits, you will be asked to grade your activity level using a scale from 1-10.

Risks

There are no expected risks other than those expected by undergoing a total hip replacement. There is a potential inconvenience of wearing a pedometer for a total of three weeks during the study period. However, due to the ease of their use, the risk expected is minimal.

Benefits & Compensation

You may not receive direct benefit from participating in this study. Information learned from this study may help lead to improved treatment of total hip replacement for Orthopaedic patients in the future.

There is no compensation provided for participating in this study.

Voluntary Participation

Your participation in this study is voluntary. You may decide not to be in this study, or to be in the study now and change your mind later. You may leave the study at any time without affecting the care being provided. If you decide to withdraw from the study, the information that was collected before you leave the study will still be used in order to help answer the research question. No new information will be collected without your permission.

Alternatives to Study Participation

An alternative to the procedures described above is to not participate in the study and continue on just as you do now. If you choose not to participate in this study, you will undergo the same total hip replacement procedure and post-operative follow-up; however, you will not have to wear the pedometer.

Confidentiality

The study coordinator will keep any personal health information about you in a secure and confidential location for a minimum of 15 years. A list linking your study number with your name will be kept by the study coordinator in a secure place, separate from your study file. All information collected will be stored in a locked office and entered into a secure database, accessible by authorized individuals only. This information will be used solely for the advancement of medical science and any personal information will be kept confidential. Research results will be disseminated through a public presentation, and peer-reviewed publication. These results will be de-identified and presented as averages in order for anonymity to be maintained.

Qualified representatives of the Lawson Quality Assurance Education Program may look at your medical/clinical study records at the site where these records are held, for quality assurance (to check that the information collected for the study is correct and follows proper laws and guidelines).

You will be given a copy of this letter of information and consent form once it has been signed. You do not waive any legal rights by signing the consent form. Representatives of the University of Western Ontario Health Sciences Research Ethics Board may contact you or require access to your study-related records to monitor the conduct of the research.

If you have any questions about your rights as a research participant or the conduct of the study you may contact Dr. David Hill, Scientific Director, c/o Lawson Health Research Institute at [redacted]

If you have any questions about this study or your care please contact Bryn Zomar or Nicole Burke, Clinical Study Coordinators, Department of Orthopaedic, [redacted] or Dr. Brent Lanting, Principal Investigator and Orthopaedic Surgeon, [redacted]

Title: Level of Activity and Sleeping Patterns in Total Hip Replacement Using Direct Anterior Hip Approach Compared to Direct Lateral Approach.

Informed Patient Consent

Agreement of Participating Subject

I have read the accompanying letter of information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

____

Print Participant's Full Name

____

Participant's Signature   Date

____

Name of Person Obtaining Consent

____

Signature of Person Obtaining Consent   Date

Appendix C: Fitbit® instructions sheet

Study ID: _____

The Level of Activity and Sleeping Patterns in Total Hip Replacement Using
Direct Anterior Hip Approach Compared to Direct Lateral Approach

FITBIT INSTRUCTIONS

- Please wear at all times except when showering or swimming.
- When going to bed please put the Fitbit into sleep mode. Do this by tapping the Fitbit until you feel it vibrate on your wrist.
- When you wake up in the morning please take the Fitbit out of sleep mode. Do this by tapping the Fitbit until you feel it vibrate on your wrist.
- Please track your use of the Fitbit with the provided tracking sheet. This includes recording any reason you removed the Fitbit and any difficulties you had.
- Please charge the Fitbit using the provided charger once every five (5) days. The charger plugs into the USB port of a computer. Charge is complete when five (5) lights are visible.

If you have any questions or concerns about using the Fitbit please contact the research coordinator for this study, Bryn Zomar, at

Thank you very much for your participation.

Appendix D: Fitbit® Compliance sheet

Study ID: _____

The Level of Activity and Sleeping Patterns in Total Hip Replacement Using
Direct Anterior Hip Approach Compared to Direct Lateral Approach

<u>FITBIT COMPLIANCE TRACKING SHEET: PREOP</u>

Day 1: Did you remove the Fitbit for any reason?

▯ ☠☐ ▯ ✡♏⧫💻Reason ____

Did you remember to put the Fitbit into sleep mode when you went to bed? ▯ ☠☐ ▯ ✡♏⧫

Day 2: Did you remove the Fitbit for any reason?

▯ ☠☐ ▯ ✡♏⧫💻Reason ____

Did you remember to take the Fitbit out of sleep mode when you woke up? ▯ ☠☐ ▯ ✡♏⧫

Did you remember to put the Fitbit into sleep mode when you went to bed? ▯ ☠☐ ▯ ✡♏⧫

Day 3: Did you remove the Fitbit for any reason?

▯ ☠☐ ▯ ✡♏⧫💻Reason ____

Did you remember to take the Fitbit out of sleep mode when you woke up? ▯ ☠☐ ▯ ✡♏⧫

Did you remember to put the Fitbit into sleep mode when you went to bed? ▯ ☠☐ ▯ ✡♏⧫

Day 4: Did you remove the Fitbit for any reason?

▯ ☠☐ ▯ ✡♏⧫💻Reason ____

Did you remember to take the Fitbit out of sleep mode when you woke up? ▯ ☠☐ ▯ ✡♏⧫

Did you remember to put the Fitbit into sleep mode when you went to bed? ▯ ☠☐ ▯ ✡♏⧫

The Level of Activity and Sleeping Patterns in Total Hip Replacement Using
Direct Anterior Hip Approach Compared to Direct Lateral Approach

Day 5: Did you remove the Fitbit for any reason?

▯ ☠□ ▯ ✡♏⧫💻Reason ____

Did you remember to charge the Fitbit? ▯ ☠□ ▯ ✡♏⧫: How long did it take? ____________

Did you remember to take the Fitbit out of sleep mode when you woke up? ▯ ☠□ ▯ ✡♏⧫

Did you remember to put the Fitbit into sleep mode when you went to bed? ▯ ☠□ ▯ ✡♏⧫

Day 6: Did you remove the Fitbit for any reason?

▯ ☠□ ▯ ✡♏⧫💻Reason ____

Did you remember to take the Fitbit out of sleep mode when you woke up? ▯ ☠□ ▯ ✡♏⧫

Did you remember to put the Fitbit into sleep mode when you went to bed? ▯ No ▯ ✡♏⧫

Day 7: Did you remove the Fitbit for any reason?

▯ ☠□ ▯ ✡♏⧫💻Reason ____

Did you remember to take the Fitbit out of sleep mode when you woke up? ▯ ☠□ ▯ ✡♏⧫

Did you have any problems with the Fitbit?

▯ ☠□

▯ ✡♏⧫💻Please explain: ____

____

____

Appendix E: The UCLA score

UCLA Activity Score	**Hip ID:**
	Study Hip: ☐ Left ☐ Right
	Examination Date (MM/DD/YY): / /
	Subject Initials: |____|____|____|
	Medical Record Number:

Interval: ______________

Check one box that best describes current activity level.
☐ 1: Wholly Inactive, dependent on others, and can not leave residence
☐ 2: Mostly Inactive or restricted to minimum activities of daily living
☐ 3: Sometimes participates in mild activities, such as walking, limited housework and limited shopping
☐ 4: Regularly Participates in mild activities
☐ 5: Sometimes participates in moderate activities such as swimming or could do unlimited housework or shopping
☐ 6: Regularly participates in moderate activities
☐ 7: Regularly participates in active events such as bicycling
☐ 8: Regularly participates in active events, such as golf or bowling
☐ 9: Sometimes participates in impact sports such as jogging, tennis, skiing, acrobatics, ballet, heavy labor or backpacking
☐ 10: Regularly participates in impact sports

Appendix F: Abbreviations list

ANOVA	Analysis of variance
AS	Ankolysing spondylitis
AVN	Avascular necrosis
BL	Brent Lanting
BMI	Body mass index
CK	Creatine kinase
DA	Direct anterior
DL	Direct lateral
DDH	Developmental dysplasia of the hip
EV	Edward Vasarhelyi
FAI	Femoroacetabular impingement
HHS	Harris hip score
HOOS	Hip disability and Osteoarthritis Outcome Scores
JH	James Howard
LHSC	London Health Sciences Centre
MRI	Magnetic resonance imaging
NSAID	Non-steroidal anti-inflammatory drug
PACU	Post-anesthetic care unit

PCS	Physical component summary
RCT	Randomized-controlled trial
SF-36	Short-form 36 questionnaire
SF-12	Short-form 12 questionnaire
SF-8	Short-form 8 questionnaire
THA	Total hip arthroplasty
TUG	Timed up-and-go test
US	United States
UCLA	University of California, Los Angeles
VAS	Visual analogue scale
WOMAC	Western Ontario and McMaster Osteoarthritis Index

Curriculum Vitae

Abdulaziz N. AlJurayyan, M.D, FRCS(c)

Personal

Address: Toronto, Ontario, Canada

Current Appointment

2008-Present	Academic Staff member at the Department of Orthopedic Surgery, College of Medicine, King Saud University, Riyadh, Saudi Arabia.

Education

2016-2017	Trauma and Lower Extremity Reconstruction Clinical Fellowship Sunnybrook Health Sciences Centre, University of Toronto, Ontario,Canada
2015-2016	Bourne- Rorabeck Adult Reconstruction Clinical Fellowship. University of Western, London, Ontario, Canada.
2015-2016	Masters of Science in Surgery –Division of Orthopedics. University of Western, London, Ontario, Canada.
2010 - 2015	Orthopedic Residency Training Program. McGill University, Montreal, Quebec, Canada.
2008 – Present	Demonstrator at the Department of Orthopedics Surgery. Collage of Medicine at King Saud University, Riyadh, Saudi Arabia. King Khalid University Hospital, Riyadh, Saudi Arabia.
2007-2008	Rotating Intern. King Saud University and affiliated Hosptals, Riyadh, Saudi Arabia.
2001-2007	Bahelor of Medicine, Bachelor of Surgery (MBBS). King Saud University, Riyadh, Saudi Arabia.

Academic Honors and Awards

2015	Merit Award of Excellence McGill University, Montreal, Canada

2014	Merit Award of Excellence McGill University, Montreal, Canada
2013	Merit Award of Excellence McGill University, Montreal, Canada
2008	Certificate of Appreciation for The Excellent Intern Department of Surgery, King Saud University, Riyadh, Saudi Arabia
2001	Certificate of Excellence Diplomatic Quarter High School, Riyadh, Saudi Arabia.

Certifications & Examinations

2015	Fellow of The Royal College of Surgeons of Canada.
2015	Canadian Board of Orthopedic Surgery.
2012	Good Clinical Practice (GCP) certificate.
2012	Foundation of Surgery Examination.
2011	Fundamental Critical Care Support Course (FCCS).
2010	Advance Trauma Life Support (ATLS).
2009	Medical Council of Canada Evaluating Examination.
2005	Advanced Cardiac Life Support Provider (ACLS).

Professional Associations

2013 - Present	AO Trauma.
2013 - Present	Canadian Orthopaedic Association.
2010 - Present	Royal College of Physicians and Surgeons of Canada.
2010 - Present	Quebec Orthopaedic Association.
2010 - Present	American Academy of Orthopedic Surgeons.
2007 - Present	Saudi Orthopedic Association.

Research and Publications

Published:

1. Coeliac Disease Presenting as Rickets in Children. *Pediatrics.me* 2009;14(3).
2. Bilateral Simultaneous Anterior Dislocation of the Shoulders: A Case Report. *The Egyptian Orthopedic Journal* 2010;45(3).
3. Pseudohypoparathyroidism Type 1 b; a Rare cause of femoral Neck Fracture: a Case Report. *J T U Med Sc* 2011; 6(1)
4. Rickets and Osteomalacia in Saudi children and adolescents attending endocrine clinic, Riyadh, Saudi Arabia. *Sudanjp*.2012;12(1).
5. Should Pediatrician be Familiar with Osteoporosis? *Primary Health Care*.2012;2(4).
6. Regular Use of Tranexamic Acid in Primary Total Knee Replacement: Are We There Yet? *JBJS Orthop Highlights: Knee Surg,* 2013 Aug 07;3(8):e4. doi: 10.2106/JBJS.KS.M.00356
7. Evaluation of the Orthopedic Residency Training Programs in Saudi Arabia and comparison with a selected Canadian Residency Program. *Adv Med Educ Pract.* 2014 Sep 19;5:315-21. doi: 10.2147/AMEP.S69217. eCollection 2014.
8. Maxillary Suture Distraction: A Rare Complication of Halo Traction in a Scoliosis Patient with Osteogenesis Imperfecta: A Case Report. – Spine Deformity Journal.
9. Abstract publication: What is Safer in Osteoporotic Vertebral Compression Fractures, Kyphoplasty or Vertebroplasty? A Study in Vertebral Analogs. Eur Spine J (2014) 23 (Suppl 5)
10. Does Balloon Kyphoplasty Deliver More Cement Safely into Osteoporotic Vertebrae with Compression Fractures Compared with Vertebroplasty? A Study in Vertebral Analogues. Global Spine J2015 Aug;5(4):300-7. doi: 10.1055/s-0035-1546818. Epub 2015 Feb 26.
11. Acute revision hip arthroplasty: a previously unrecognized risk factor for heterotopic ossification. Eur J orthop Tramatol. 2016 Feb;26(2):183-8. doi: 10.1007/s00590-015-1733-z. Epub 2016 Jan 2.

Submitted:

1. Determining the Validity of Saw Bone L3 Osteoporotic Vertebrae as A biomechanical Model for Vertebroplasty and Kyphoplasty in the Thoracolumbar Anterior Compression Fracture. The Spine Journal
2. The Impact of Living with Unilateral Lower Limb Amputation: A Utility Outcome Score Assessment. Journal Of Trauma.

3. Bilateral Traumatic Quadriceps Rupture in a 24 years Old Healthy Male; a Case Report.
4. Reliability and Concurrent Validity of Elbow Angle Measurement: Comparing Conventional Goniometer, Smart phone app, eye baling and plain radiographs.

Ongoing:

1. A 10-years follow-up comparing "high-flex" vs "standard" posterior cruciate substituting polyethylene tibial inserts in total knee arthroplasy