CHAPTER 2

REVIEW OF LITERATURE
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The PubMed, MEDLINE, Cochrane, Science direct and EMBASE medical literature databases were searched from January 1980 to December 2016. The search was made with the key words total knee replacement, quadriceps exercises, knee rehabilitation, knee strengthening exercises, hip abductor muscles, quality of life, functional outcome and performance based outcome measures retrieved 1916 articles with 56 RCTs, ten systematic review and three meta-analysis on physical therapy interventions following TKR for those who diagnosed with knee osteoarthritis.

This review delivers the information about the osteoarthritis of the knee joint, role of the hip abductors in knee osteoarthritis and total knee replacement. This review also provides the evidence regarding the commonly used outcome measure such as self-reported questionnaires on pain, function, quality of life, and also on performance-based physical functional outcome measure following TKR. The later section of the review emphasizes the evidence-based management on strengthening of hip abductor muscles following OA and its need after total knee replacement.

2.1 Osteoarthritis

Osteoarthritis (OA) is a foremost cause of joint pain, increasing its prevalence with age and an important cause of disability during functional activities, affecting all the structures of the joint.\textsuperscript{35} Knee OA affects the articular cartilage and subchondral bone of a synovial joint and increases the stress of the joint leading to the additional cartilage loss (Figure 1).\textsuperscript{35,36} The OA diagnosed with no apparent cause has classified as 'primary' and if triggering factors present for joint pathology termed as 'secondary'.\textsuperscript{37} The OA of the knee joint is the commonest, and it’s rare before the age of 40 years and increases its
prevalence each decade thereafter. In India, the OA of the knee is the commonest joint disease and rheumatologic problem with a prevalence of 22-39%.

A recent epidemiological study done across five sites of India by Pal et al. found that the overall prevalence of knee OA is (28.7%) with higher prevalence rate reported in big cities like south Bangalore (33.1%), big villages (31.1%) when compared to towns (17.1) and small cities (17.2%). In the year 2020, global estimate predicts the prevalence of knee OA would increases twice and expected to increase intensely over next two decades.

![Healthy Knee Joint and Osteoarthritic Knee Joint](image)

**Figure 1:** The appearance knee Joint.

a. Normal knee Joint. b. Osteoarthritic knee joint

In early stages of knee OA, arthritis pain is deep, intermittent and aching in nature, which increases with the activities stressing the joint. The stresses on the articular cartilage increased during walking, stair climbing and squatting, which further progress the disease by increasing the joint load and altered biomechanics. As OA, progress patients commonly experience pain at rest, night pain, early morning stiffness, limitation of knee range of motion and crepitus during movements.
Well-established or end-stage OA regarded in terms of articular cartilage involvement with findings of articular cartilage attrition. The subject with end-stage arthritis commonly classified with clinical and radiological observations, the radiological observation of a reduction in joint space, usually in relation to the loss of articular cartilage is a universal feature of end-stage knee OA. The presence of radiological findings like bone spurs (osteophytes) formation, reduction of joint space, subchondral sclerosis (eburnation) and the existence of subchondral cysts following (Figure 2) are other common features of OA.

![Figure 2: The radiological appearance knee Joint.](image)

The subjects with 40%-80% of these radiological findings with symptomatic OA have difficulties in performing walking, stair climbing and other activities of daily living. Almost 80% of individuals diagnosed with OA have reduced knee ROM of movement, with 25% have difficulty in performing daily activities and transformed quality of life.

Despite, the radiological findings with articular cartilage involvement in diagnosing OA; other tissues also to be considered as an initiator of OA, mainly the subchondral bone, muscles and other joint structures. The muscle dysfunction could
possibly lead and accelerate the cartilage attrition; this could be the primary cause for functional impairments. The reduced force generating capacity and the weakness of the quadriceps may attribute to reduced physical function in subjects diagnosed with knee OA. Recent studies suggested that knee OA cannot be considered as a pathology of the articular cartilage alone, the management of the OA should also focus on the impairment of the lower extremity muscles especially the quadriceps.\textsuperscript{42-44}

The quadriceps strengthening exercises, self-management programs, low impact aerobic exercises, and neuromuscular re-education exercises for subjects with symptomatic OA have shown to be effective.\textsuperscript{45} Irrespective of age, functional limitations, pain perception and other co- morbidities these exercises have shown to be an effective treatment for knee OA. Patel et al. \textsuperscript{41} in his study concluded that the level of improvements in outcomes is not depending on the radiographic grading of the osteoarthritis. Moreover, they showed that patients with mild to moderate OA had improvements in patients reported outcome measures at one-year duration following education and exercises.\textsuperscript{41}

The knee OA is not curable, clinicians and researchers focused on the modifiable factors, which could enhance physical function following OA.\textsuperscript{39} Quadriceps strength deficit could be an important variable for the cause and progression of the knee OA that may alter physical function. Studies on knee OA proven that subjects diagnosed with knee OA had a 20 \% of quadriceps strength deficit when compared to their healthy age-matched controls.\textsuperscript{46} Quadriceps muscle function is a modifiable factor, which could enhance physical function following knee OA. Studies aiming at exercise training addressing these impaired muscle function of the quadriceps proven effective, and it is preferred as the first line of management.\textsuperscript{47}
The quadriceps exercises enhance or maintain the muscle strength and could possibly relieve symptoms of OA.\textsuperscript{48} Studies have shown that the observed improvements in exercises following OA were less and it is comparable to the reported estimates of non-steroidal anti-inflammatory drugs.\textsuperscript{49, 50} The land-based therapeutic exercises have strong evidence in short-term pain reduction and improvements physical function.\textsuperscript{51} However, there is no evidence supporting the effect of exercises on disease progression in symptomatic knee OA patients.\textsuperscript{52} Total knee replacement surgery is an optimal treatment for those who fails conservative management following end-stage knee OA.\textsuperscript{1, 2}

### 2.2 Total knee replacement

Total knee replacement (TKR) also termed as total knee arthroplasty is the surgical replacement of the affected knee joint with prosthetic components (Figure 3), which can improve functional status, relieve pain, enhanced quality of life and result in relatively low perioperative morbidity of the participants.\textsuperscript{16} TKR introduced in the late 1950s, and it has been associated with high complications and failure rates due to its lack in implant design and mimic of normal knee kinetics and kinematics of the knee. Advances in the prosthetic design in the last decade enhanced the patient's functional performance and quality of life. TKR is proven to be the most renowned surgical procedure for patients with severe knee pain and altered physical function following osteoarthritis of the knee. TKR is a safe treatment for those who do not respond to non-surgical therapies aiming to alleviate pain, improve function to regain their activity and quality of life.\textsuperscript{53-55}
2.2.1 Surgical approaches and prosthesis for total Knee replacement

Total knee replacement surgical procedure consists of replacing the diseased or damaged weight-bearing articular surfaces of the joint with metal and plastic components (Figure 4). TKR aims to restore the normal anatomical alignment of the knee joint by replacing the affected weight bearing surfaces of the cartilage on femur, tibia, and patella with artificial bearings. The prime indication for the TKR is severe pain and functional disability. Restoration of normal alignment of the knee joint allows continued motion at the knee, and improving normal sliding and gliding mechanism of the femur on the tibia during knee flexion prevents the impingement of the femur. This phenomenon can be achieved in the knee which has a normal tibiofemoral contact in knee flexion. \(^{16, 53, 54}\)

TKR prosthesis designed with the obliteration of the knee posterior cruciate ligament produce excessive stress on the anterior surface and tension on the posterior part of the prosthesis due to more anterior migration of the contact points, this could lead mechanical failure of the prosthesis with excessive wear and tear. \(^{55, 56}\) Proponents of the posterior cruciate ligament retaining prosthesis have theorized that preservation of the
cruciate ligament improves joint sensation and thus patient functional outcome.\textsuperscript{57, 58} The heightened functional scores have been obtained following posterior cruciate retaining prosthesis, however, the best knee design posterior cruciate ligament retaining or removal is still controversial.\textsuperscript{57-59}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{surgical_components.png}
\caption{Surgical components of total knee replacement.}
\end{figure}

\textbf{a. Femoral component. b. Tibial component.}

\subsection*{2.2.2 Less Invasive total knee replacement}

Less invasive surgery is a technique used in recent years in various procedures to minimize the tissue damage during the surgery. Reduced length of stay after surgery, less postoperative pain, and early rehabilitation are the advantages of the minimal invasive TKR following sub vastus approach (Figure 5).\textsuperscript{16} Minimally invasive TKR studied by Lin et al.\textsuperscript{60} found the effects using the subvastus approach on twenty-two patients and found the patients had a good prognosis and functional recovery. The participants who underwent unilateral TKR shown a reduction in isometric muscle strength at one-month
after TKR, no significant differences observed at 12 months when compared with a healthy knee. However, the study found a change in functional score at 12 months postoperatively from the baseline score. 60

Kelly et al. 61 compared vastus splitting approach and medial parapatellar approaches in forty-two consecutive patients undergoing primary TKR. The authors concluded that vastus-splitting approach preserves the quadriceps function by reducing the lateral retinacular release and it is a viable alternative surgical technique. 61 Knee osteoarthritis patients may have diminished joint sensation, which could possibly precipitate the degenerative changes. The mechanoreceptors present over the posterior cruciate ligament of knee detect the joint position and kinesthesia. There is a strong association between decreased proprioception and function in patients with osteoarthritis. 55, 56

McAllister and Stepanian 62 found reduced postoperative pain and increased range of motion of the knee joint following minimal invasive TKR. The same authors well-defined that when TKR surgery performed without cutting up the tendon of quadriceps, dislocation of the knee joint and patella eversion were labeled as minimal invasive TKR. 62 Leopold S 6 in his commentary recommended that following TKR emphasis should focus on patient’s expectation like perioperative and immediate postoperative period. The participants should be well-versed about substantial postoperative pain and the need for aggressive physical therapy regimen for successful outcome in pain relief and enhanced physical function. 16
2.3 Rehabilitation following TKR

The World Health Organization (WHO) defines rehabilitation as “a progressive, dynamic, goal-oriented and often time-limited process, which enables an individual with impairment to identify and reach his/her optimal mental, physical, cognitive and/or social functional level.” 63

Physiotherapy rehabilitation aims to improve function, maximize independence and reduce post-operative complications, it's widely accepted as a gold standard treatment for those who underwent TKR. However, there are variations in the mode of
delivery, when to start rehabilitation following TKR. Physiotherapy rehabilitation may be started before the operation (preoperatively), immediate post-operative (Inpatient) and following discharge (outpatient) mainly focusing on enhancing the muscle strength to improve function and quality of life.\textsuperscript{64}

2.3.1 Rehabilitation focusing mainly on quadriceps strength for TKR following OA

Lenssen et al.\textsuperscript{65} compared exercise regime delivered two sessions per day versus exercises once daily following total knee replacement. The study findings revealed that observed improvement in knee range of motion, pain, passive knee extension at four days, six weeks and three months following surgery found no significant difference. The self-reported functional recovery of the patient measured using WOMAC questionnaire and knee society scale showed similar improvement at all the time period.\textsuperscript{65}

Petterson et al.\textsuperscript{23} in their prospective cohort study with 200 participants assessed the effect of progressive resistance exercises for quadriceps muscle with and without neuromuscular electrical stimulation. The six-weeks of progressive strengthening exercise group with or without neuromuscular electrical stimulation showed clinical improvements in functional outcome measure in both short-term and long-term follow-up. However, the standard rehabilitation does not yield any improvements at 1 year following TKR in both the groups.\textsuperscript{23}

Mizner et al.\textsuperscript{49} hypothesized that strength of the quadriceps muscle can be strongly correlated with the performance based physical function rather than knee range of motion or pain following TKR. Their study findings supported the hypothesis with a higher functional performance followed by the improvement in the quadriceps strength. Hence, the author’s established the quadriceps strength could be an imperative factor for the heightened recovery of functional performance after TKR. Forty patients who
underwent TKR shown a declined functional performance at one month following surgery, the patients attained the preoperative functional level at 6 months post-surgery. The author recommended intensive rehabilitation should be incorporated in the early stages after TKR for the enhanced functional recovery in the initial stages.49

Moffet et al.24 studied the intensive rehabilitation effectiveness following TKR on functional capacity and quality of life. Seventy-seven participants with a diagnosis of knee OA were randomly assigned to intensive rehabilitation or control group and followed up for 2 months post-TKR. The intensive functional rehabilitation group walked faster during six-minute walk test at all the three post outcome measures following TKR. The authors further recommend more intensive rehabilitation in the sub-acute phase post-surgery for the enhanced the long-term functional recovery and quality of life.24

2.3.2 Strength deficits in quadriceps muscle compared to pre-operative level after surgery

Quadriceps weakness is abundant in patients with advanced knee osteoarthritis, strength deficits in quadriceps assessed by isometric or slow isokinetic tests. More than 50% of strength deficits documented at one month following TKR when compared to pre-operative levels. These deficits in quadriceps strength could possibly due to the surgical approach involving extensor mechanism and failure of voluntary muscle activation. The quadriceps muscle strength increases steadily at 6 to 12 months, however, residual weakness in the muscle is significant when compared to their age-matched controls.24

Michael J. Bade et al. 21 in his prospective cohort study compared their outcomes with healthy age matched controls to find the changes observed in quadriceps muscle strength, the knee range of motion, and function at two weeks before the TKR and six
months later. Seventeen healthy adults were compared to twenty-four patients who underwent unilateral TKR. The electromechanically designed dynamometer was used to assess the isometric quadriceps torque and the active and passive range of motion were measured. The stair-climbing test, timed up-and-go test, SMWT, and single-limb stance time was used in their study to assess the functional performance and concluded that impairment persists on functional limitations even at six months after TKA. The study further recommended that to improve function following TKR, more intensive therapeutic approaches may be essential.\textsuperscript{21}

Knee OA and impairment in the quadriceps strength are associated with functional impairments. This impairment undoubtedly addressed in rehabilitation approach and commended long-term aggressive strengthening exercises after TKR. Ample number of studies assessed the strengthening of quadriceps post TKR and found strength increments at 6 months and 1 year following surgery.\textsuperscript{23, 42, 43}

\subsection*{2.3.3 Quality of life following Total knee replacement}

Fitzgerald et al.\textsuperscript{36} in their study determined whether preoperative characteristics influenced the quality of life following TKR at one month, 6 months, and 12 months. A total of 222 patients diagnosed with OA assessed for preoperative outcome measure and post outcome measure at three time points for those underwent primary joint replacement using SF-36 questionnaire. Significant improvements were observed in their study in the subscales of bodily pain and physical function after joint replacement. However, at 1 month post replacement, the reduction in the physical function was observed, which suggests a need for an informal or formal assistance for participants for doing basic physical function following replacement surgery. The improvements in bodily pain and physical function outcomes were directly associated with more preoperative social support.\textsuperscript{36}
Allyson Jones et al. \(^{66}\) evaluated pain, physical function, and health-related quality of life in 454 patients who received either a primary total hip or knee arthroplasty. The Older patient group aged more than 80 years compared with a younger group aged between 55 to 79 years. The outcomes were analyzed at month prior to surgery and six months post-surgery and study found that only age, not a factor that will affect the outcome of after total hip and knee joint arthroplasty. The age can’t be a limiting factor when considering the replacement surgeries and it can be related to other comorbidities.\(^{66}\)

Kennedy et al. \(^{67}\) in their study assessed the effect of preoperative functional status and the changes in the lower-extremity functional status of patients over a 1-year period after TKA. Eighty-four patients diagnosed with knee OA participated in their study and the outcomes of lower extremity functional scale and SMWT taken over a 1-year period. The study findings established that following TKR, first 3 months patients had more improvement and from 3 to 6 months improvement was slower and continued to occur, however, after 6 months, there was only little improvement observed. The physical therapists should focus on the expected rate of improvement and make judgments to the expected total amount of improvement following TKR.\(^{67}\)

Nunez M et al.\(^{68}\) in their prospective study on patients with OA who underwent TKR evaluated health-related quality of life at 36-month post-surgery. The influence of variables such as socio-demographic, clinical, intraoperative and postoperative care on health-related quality of life was established in 90 patients. The study findings showed that enhanced health-related quality of life especially in the pain dimension at 36 months after TKR was significant in patients with severe OA. Lower preoperative WOMAC scores, longer duration of pain unrelated to knee OA and high BMI were negatively influenced postoperative WOMAC scores.\(^{68}\)
Minns Lowe et al.\textsuperscript{25} in their systematic review and meta-analysis evaluated the effectiveness of physiotherapy rehabilitation following elective total knee replacement for those who diagnosed with knee OA. The review found 6 RCTs met their study criteria which directed rehabilitation on physiotherapy exercise compared with usual or standard physiotherapy care following discharge from the hospital. Six trials with a total of 614 patients were identified in their review and five were included in their meta-analyses.\textsuperscript{25} The authors found the physiotherapy functional exercises following elective TKR showed short term benefit in functional outcome and knee ROM. The meta-analysis of the 5 included RCTs shown superior effects of physical therapy exercises at 3 months following TKR, however, the differences observed at 12 months was not significant between the supervised physiotherapy exercises and non-supervised home exercises. The study findings revealed no long term benefit was observed with small to moderate effect size.\textsuperscript{25}

Arnold et al.\textsuperscript{27} in their recent systematic review found the changes observed in the physical activity at 6 months following TKR is not significant, also the existing evidence is limited for larger changes at 1 year postsurgery. The authors further recommended to find the approaches to improve the physical function and patients expectations following TKR.

Bade et al.\textsuperscript{69} in a recent study found that high-intensity rehabilitation program focusing on quadriceps strengthening following unilateral TKR showed better improvement in functional performance measures when compared to low-intensity rehabilitation program with age matched and sex matched controls.\textsuperscript{69} There were eight participants in high intensity group and age matched controls group, the high intensity group showed improvements in functional outcome and quadriceps strength at 52 weeks.
2.3.3.1 Quality of life following total knee replacement in Asian patients

Ko Y et al. \(^{70}\) examined health-related quality of life on Asian adult patients following total or unicompartmental knee replacement. Health-related quality of life score was measured using the self-reported instruments like SF-36 and the Oxford Knee Score. The study findings determined that both total and unilateral knee replacement patients experienced significant improvements in role physical and pain domains of health-related quality of life.\(^{70}\)

Xie F et al. \(^{71}\) in their prospective observational study aimed to quantify the improvement in health outcomes for Asian patients after TKR at two-years of duration. Their study included a total of 298 at baseline and analysis was done for 176 patients at six months, and 111 patients followed for two-years. Changes in quality of life were observed in all the scores with the exception social functioning, vitality, and mental health domains of SF-36. The magnitude of changes in the SF-36 subscales scores was similar to those without the adjustment of covariates. The authors concluded both the general questionnaires and knee-specific physical functioning has significantly improved after TKR.\(^{71}\)

2.3.4. Physical function

Physical function is interrelated to the patient’s or subject’s ability to move around for the performance of activities of daily living. Physical function measured using the performance-based tests or self-reported measures using the questionnaires, both measures quarantine different forms of physical functioning. The performance-based measures were often assessor observed by totaling distance covered, timing or the number of repetitions, these tests evaluate what participants can do rather than what they perceive they can do. Performance-based tests may show better differences in pain and
function than familiar patient-reported questionnaires, however, studies have shown that both the measures are seen as amenable rather than challenging when appraising physical functional for individuals with OA and also following hip and knee arthroplasty. \(^{72-76}\)

### 2.3.4.1 Functional outcome following TKR

Dobson et al. \(^{77}\) established an international, multidisciplinary expert group for the study via an online survey to identify and select the best performance based functional measures. Five performance-based tests identified by the experts and recommended by the Osteoarthritis Research Society International (OARSI). The performance based test of 30-s chair raise test, 40-m paced fast walk test, a stair climb test, timed up and go test and six-minute walk test is the best recommended functional tests for people diagnosed with hip or knee OA and following joint replacement of the hip or knee. The authors concluded these tests support in clinical practice and recommended as a potential outcome in the future trials on OA. \(^{77}\)

Ko et al. \(^{70}\) hypothesized that patients after the one-year duration of TKR will walk slower when compared to healthy aged-matched controls in extended walk test. The participants able to walk 30 minutes after the 1-year duration of TKR, however, they walked with the slower speed when compared with their healthy age-matched peoples. The study has confirmed that six-minute walk test is an excellent predictor of longer duration ambulation after TKR. The authors reinforce the use of SMWT, timed up and go test along with the self-reported outcome measures for assessing the physical function recovery following the TKR. \(^{70}\)

Recent studies on rehabilitation showed improvements in arthritis pain but a varied physical function with 30 % of patients not satisfied with 1 year after TKR. \(^{78, 79}\) Despite more advanced and excellent surgical procedure, declined functional tasks were
reported following TKR when compared to their healthy age-matched controls.\textsuperscript{20, 21} The reason for the participants having unexplained poor function following TKR is currently one of the unanswered conundrums of physiotherapy rehabilitation.

A contemporary systematic review recognized that there are small and mixed changes in functional outcome at 6 months and at 1 year following TKR. The observed improvement was considerably lower when compared with their age-matched healthy adults.\textsuperscript{26} Declined functional tasks of 15\% reduced walking speed, 50\% more time taken to complete stair climbing tasks and 20\% less distance covered during the six-minute walk test were reported following TKR when associated with age-matched healthy controls. Franklin et al.\textsuperscript{17} suggested demographic and clinical variables predicts the functional improvement especially the quadriceps strength.\textsuperscript{17}

Therefore, it is skeptical whether exercises steering quadriceps strengthening alone will improve physical function after TKR. It is unlikely that quadriceps strengthening alone could contribute to physical function following OA of the knee; the contribution of proximal muscle weakness could possibly lead to discrepancies in physical function.\textsuperscript{28} Recent studies have proven that proximal muscle weakness especially hip abductors play a vital role in knee joint function and a significant reduction in hip abductor strength observed in knee OA.\textsuperscript{29,30} The hip abductors are well renowned for the stabilization of trunk and hip during walking, maintaining the femoropelvic alignment, and transferring the forces from the lower limbs to the pelvis.\textsuperscript{31,32} Hip abductor weakness can lead to contralateral pelvic drop, this, in turn, will shift the center of mass with increased load medially to the medial tibiofemoral joint.\textsuperscript{80}

Thus, an increased medial joint loading could progress to the advancement of knee OA and also an increase in the strength of hip abductors might have a disease-
modifying effect by reducing the medial joint loading. Deasy et al. in a recent systematic review concluded that significant hip strength deficits observed in knee OA patients and recommended that hip strength assessments may assist with targeted rehabilitation.

### 2.4 Hip abductors

The primary hip abductor (HA) muscle is well-organized as gluteus medius muscle with a cross-sectional area of around 60% of the total hip abductor muscle. The hip abduction movement also needs an essential contribution from all the fibers of gluteus minimus and the tensor fasciae latae. The secondary hip abductors were identified as the muscles of piriformis, sartorius and the rectus femoris. The HA mainly provides the stability of the hip in frontal plane by producing a torque equal to body weight during stance limb support of walking. The increase in the strength of HA could increase the pelvis stability by reducing the magnitude of the pelvis drop and thereby enhancing the pelvis maintain horizontal.

Gluteus medius (Figure 6a) originates at the upper surface of the ilium above the anterior gluteal line and inserts on the greater trochanters lateral and superior- posterior aspect. This is a broad fan-shaped muscle with three anatomic and functional sets of fiber, the anterior, middle and posterior subdivisions, all fibers contract to contribute abduction. The hip abductors, yield a compressive force on the acetabulum and femoral head during the walking at single limb support phase which could possibly enhance the frontal plane stability.

The gluteus minimus (Figure 6b) lies slight anterior and deep to the gluteus medius muscle, with occupying 20% of the total hip abductors cross-sectional area. The gluteus minimus muscle originates between the anterior and the inferior gluteal line of
the ilium and attaches to the greater trochanter on its anterior surface. This muscle act similar to gluteus medius especially in generating abduction movement; expect the role of flexion by the gluteus minimus anterior fibers.\textsuperscript{32, 82}

The smallest muscle among the three abductors is the tensor fasciae latae with a total cross-sectional area of about 11\% only. The tensor fasciae latae originates from the iliac crests outer lip and with a blend insertion to the iliotibial band.\textsuperscript{82}

The hip abduction torque was mainly produced by the muscles of gluteus medius, gluteus minimus and the tensor fasciae latae. At 10 degrees of adduction, the hip abductors are at the maximum elongated position and peak torque of the muscle occurs at this point. This position matches the position of single limb support during walking and generates extreme frontal plane stability of the hip which was required. During stance limb support phase of gait, the opposite leg lifts off the ground and starts swinging forward. If the HA torque production is inadequate in the stance limb the pelvis and trunk may drop towards the swing leg.\textsuperscript{31}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{hip_abductors.png}
\caption{Hip abductors.}
\begin{itemize}
\item a. Gluteus medius
\item b. Gluteus minimus
\end{itemize}
\end{figure}
In light of the above-mentioned findings, the frontal plane stabilizing the function of the hip abductor muscles is important for walking; the abductor produces more compressive force instance at the hip and thereby augmenting walking. The forces may increase in running, stair ascent or descent about 5 to 6 times of body weight. Even normal day-to-day functional activities or exercises may produce excessive compressive force, which could exceed the body weight. All the muscles of hip abductors theoretically, through the attachment and lines of forces provide stability of the hips and pelvis during gait in healthy individuals.

There is evidence for OA of the knee joint was associated with hip abductor weakness and internal adduction moment. It has been hypothesized that the progression of knee OA could also be due to the contralateral drop in the pelvis and shift in the center of mass which may lead to the excessive medial side knee joint loading. The recent systematic review findings by Deasy et al. findings revealed a 24% reduced isometric strength of hip muscles in knee OA participants and the authors recommended hip strengthening exercises can be targeted for the management of osteoarthritis participants.

### 2.4.1 Hip abductor role in knee kinematics

Knee joint pathology rarely present with isolated dysfunction of the knee joint alone, the hip joint dysfunction might also influence the knee joint pathologies. The assessment for identifying knee pathologies or intervention targeting knee joint may focus on the more proximal aspects of the kinetic chain especially the hip joint. The hip muscles strength deficit due to altered firing pattern of the muscle, central inhibition, or unidentified compensatory strategies might be a risk for knee pathology. The hip muscle strength deficits can be predicted in the knee pathologies like anterior knee pain, syndrome, and ligament injuries especially the anterior cruciate ligament, iliotibial band friction syndrome and the knee osteoarthritis.
The participants diagnosed with knee osteoarthritis (OA) demonstrated pain with several hip clinical tests. Cliborne et al.\textsuperscript{74} found a single session of hip mobilization has increased knee range of motion and reduction of pain for those who diagnosed with knee OA.\textsuperscript{74} Currier et al.\textsuperscript{18} developed a clinical prediction rule for knee OA patients who may improve with hip mobilization on knee pain and function. Amongst the five predicted variables identified in their study, if a patient is present with two variables the probability of success with hip mobilization is \textit{97\%}. There is no clear evidence to support their study findings because the relationship between the lumbopelvic-hip complex and the knee OA is not clear. However, the relationship does appear to exist, with respect to reduced motion, altered muscle activation, varied function and improvements in pain, knee range of motion when treating the proximal joint.\textsuperscript{18}

\textbf{2.4.2 Hip abductor weakness progression to OA}

Chang et al.\textsuperscript{85} found the weakness in hip abductors during stance limb could further increase the load on the same side medial tibiofemoral joint and lead to medial knee OA (Figure 7). During walking the weakness in the hip abductor leads to the pelvic drop on the stance limb when the contralateral limb starts the swing phase. The shift of the center of mass created on the swing limb will increase the load on the medial compartment of stance knee. Their study also found that the slower walking speed might accompany the OA progression by increasing the hip and knee joint moments.\textsuperscript{85}

Tevald et al.\textsuperscript{86} in his cross-sectional study revealed that targeting the hip abductor is an imperative factor for the conservative management of OA. Both knee extensor strength and the hip abductor strength are associated with the functional performance of get up and go test, stair climb and descent test and five-time chair raise test. The study also showed that a hand-held dynamometer is a reliable tool for the hip abductor strength assessment.\textsuperscript{86}
The above studies have shown that the hip abductor weakness is mainly allied to the advancement of knee OA and it is closely associated with the physical function measures.

![Figure 7: Hip abductor weakness progression to knee OA.](image)

### 2.4.3 Hip abductor strengthening following OA Knee

Hinman et al. 87 compared hip muscles strength in people with symptomatic medial knee OA to the asymptomatic healthy group. Participants diagnosed with symptomatic knee OA had significant hip muscle strength deficits when compared with healthy age matched controls. The strength deficits observed was 16%, 27% in hip extensors and hip external rotators respectively. The authors concluded people diagnosed with symptomatic knee OA demonstrate reduced hip musculature strength when compared with the asymptomatic controls. The authors are not clear whether the weakness observed in the hip muscle leads the onset of knee OA and recommended the inclusion of hip strengthening exercises for Osteoarthritis of the knee patients.87
Sled et al.\textsuperscript{88} investigated the role of hip abductors on knee joint loading, quadriceps strength, physical function and pain in individuals with diagnosed with medial knee OA. Forty OA patients demonstrated significant improvement in hip abductor strength following 2 months of home strengthening exercise for hip abductors, but not in the knee adduction moment. The knee OA group showed significant changes in functional performance of sit-to-stand test when compared to the control group. The knee pain reported in OA group after hip abductor strengthening exercises, however, the reduced the knee joint loading shown an improvement in functional performance.\textsuperscript{88}

2.4.4 Role of Hip abductor strengthening in total knee replacement

The hip Abductor strength contribution to physical function following total knee replacement

Karvannan et al.\textsuperscript{89} in their recent pilot trial showed that hip abductor strengthening exercise improved functional performance of six minute walk test and single leg stance at one year follow up. The experimental group participants who underwent hip abductor strengthening exercises walked much faster than the knee strengthening group participants at 3 months and one year with a mean difference of 54 and 88 meters respectively. The functional measure of single leg stance was observed with a statistically significant change of 4.2 sec at 3 months and 3.9 sec at 1 year. However, the study hasn’t found significant changes of timed up and go test and numeric pain rating scale at all the outcome measure. The findings of the study revealed the participants with strong hip abductors walked further and showed improvements in functional outcome and suggested hip abductors could be potential contributors to the performance based functional outcomes following the total knee replacement surgery.
Karvannan et al.\textsuperscript{90} in their commentary recommended that strengthening of hip abductor could be imperative for the enhanced physical function following TKR. Hip abductor strengthening exercises could be used as an adjunct to conventional knee extensor strengthening exercise following TKR to improve the performance based outcome measure.

Sara R. Piva et al.\textsuperscript{29} in their cross-sectional study with thirty-one patients who underwent TKR, evaluated the hip abductors contribution on performance based physical function. The findings of their study were hip abductors associated with enhanced performance on the tests like stair ascend-descend test, 5-chair rise test, and the figure-of-8 walk test. The authors established that hip abductor strength influenced physical function measures more than quadriceps strength following the knee replacement. The study revealed that hip abductor strength can be an independent correlate for the improved functional performance measures for participants who underwent TKR.\textsuperscript{29}

In a study by Alnahdi et al.\textsuperscript{30} the physical function following unilateral TKR was associated with hip abductor strength and revealed that it contributes to the improvement in performance-based test and not in the self-reported functional measure. Hip abductor strength could possibly share a contribution similar to quadriceps strength in improving functional performance. In view of the above findings, we postulated that hip abductor strengthening exercises are likely to be the catalyst for the improvement in the physical function following TKR.\textsuperscript{30}

As a corollary, the hip abductor strengthening exercises established a favorable path for targeted rehabilitation to enhance physical function for those who undergo TKR.\textsuperscript{90} We believe studies should use hip abductor strengthening exercises as an adjunct to quadriceps strengthening exercise following TKR for the enhanced performance based
functional measure. Future trials should investigate whether hip abductor exercise provides enhanced self-reported and performance-based functional outcome measure when added to the quadriceps exercise with proven efficacy or when applied over a longer period to consider it as clinically important or relevant.

2.5 Summary of evidence for hip abductor rehabilitation

Knee pain related to daily activities is common findings of in patients diagnosed with knee OA. Exercise therapy was proven to be a cornerstone in treating knee OA, especially the strengthening exercise for the quadriceps muscle has been shown to be important in enhancing the functional activities following knee OA. The patient who fails the conservative treatment for advanced knee OA can be a potential candidate for total knee replacement. Less invasive knee replacement, rehabilitation following TKR focusing on early rehabilitation, strengthening of quadriceps was proven effective in pain reduction and enhanced function following TKR for those who diagnosed with knee OA. However, there is limited evidence in changes in physical activity, quality of life following TKR and the physical activity is lesser than the age matched healthy controls.

Recent studies have shown that the physical activity doesn’t necessarily improve with quadriceps exercise alone and the quadriceps strength could not be a single predictor for functional performance following the TKR. The role of proximal muscle especially the hip abductors can also be a facilitator for functional enhancement following TKR. Significant reduction in hip abductor strength was observed in knee OA participants and studies has recommended the assessment of hip abductor strength should be consider for the management approaches of knee OA.
It’s possible that strengthening of hip abductors may optimize the functional performance for the participants who undergo total knee replacement following knee OA. Our review suggests that there is a paucity of studies on hip abductor strengthening alone or with an addition of knee strengthening may benefit the participants who undergo TKR. To the best of our knowledge, the effects of hip abductor strengthening exercises on the quality of life, hip abductor strength, knee specific self-reported outcome of KOOS and performance based measure of six-minute walk test, TUG, pain and knee ROM could not be retrieved in the literature.