CHAPTER 1

INTRODUCTION
1.1. ANATOMY AND BIOMECHANICS

Knee joint is a compound joint with compromised stability owing to its shallow articular surface. The stability of the knee is provided by the surrounding musculature which are huge and the strong ligaments that are present intra articularly as well as extra articularly. Adding to the non-congruent articular surface the compound nature of the joint adds to the problem. There are three intra articular ligaments namely anterior cruciate ligament, posterior cruciate ligament, meniscal ligament and three extra articular ligaments namely medial collateral ligament, lateral collateral ligament and the Ligamentum patellae that provide stability for the joint. The ligaments provide predominant stability when there is a static load or static forces acting on the joint which is termed the passive stability. The ligaments and the muscle combines to provide stability to the joints when there is a dynamic task is performed.

In humans and other primates, the knee joins the thigh with the leg and consists of two joints: one between the femur and tibia (tibiofemoral joint), and one between the femur and patella (patellofemoral joint). It is the largest joint in the human body. The knee is a modified hinge joint, which permits flexion and extension as well as slight internal and external rotation. The knee is vulnerable to injury and to the development of osteoarthritis.

It is often termed a compound joint having tibiofemoral and patellofemoral components. (The fibular collateral ligament is often considered with tibiofemoral components.) The knee is a modified hinge joint, a type of synovial joint, which is composed of three functional compartments: the patellofemoral articulation, consisting of the patella, or "kneecap", and the patellar groove on the front of the femur through which it slides; and the medial and lateral tibiofemoral articulations linking the femur, or thigh bone, with the tibia, the main bone of the lower leg. The joint is bathed in synovial fluid which is contained inside the synovial membrane called the joint capsule. The posterolateral corner of the knee is an area that has recently been the subject of renewed scrutiny and research.

The knee is the largest joint and one of the most important joints in the body. It plays an essential role in movement related to carrying the body weight in horizontal (running and walking) and vertical (jumping) directions. At birth, the kneecap is just formed from cartilage, and this will ossify (change to bone) between the ages of three and five years. Because it is the largest sesamoid bone in the human body, the ossification process takes significantly longer.
The main articular bodies of the femur are its lateral and media condyles. These diverge slightly distally and posteriorly, with the lateral condyle being wider in front than at the back while the medial condyle is of more constant width. The radius of the condyles' curvature in the sagittal plane becomes smaller toward the back. This diminishing radius produces a series of involute midpoints (i.e. located on a spiral). The resulting series of transverse axes permit the sliding and rolling motion in the flexing knee while ensuring the collateral ligaments are sufficiently lax to permit the rotation associated with the curvature of the medial condyle about a vertical axis. The pair of tibial condyles are separated by the intercondylar eminence composed of a lateral and a medial tubercle.

The patella also serves an articular body, and its posterior surface is referred to as the trochlea of the knee. It is inserted into the thin anterior wall of the joint capsule. On its posterior surface is a lateral and a medial articular surface, both of which communicate with the patellar surface which unites the two femoral condyles on the anterior side of the bone's distal end. The articular capsule has a synovial and a fibrous membrane separated by fatty deposits. Anteriorly, the synovial membrane is attached on the margin of the cartilage both on the femur and the tibia, but on the femur, the suprapatellar bursa or recess extends the joint space proximally. The suprapatellar bursa is prevented from being pinched during extension by the articularis genus muscle. Behind, the synovial membrane is attached to the margins of the two femoral condyles which produce two extensions similar to the anterior recess. Between these two extensions, the synovial membrane passes in front of the two cruciate ligaments at the center of the joint, thus forming a pocket direct inward.

Numerous bursae surround the knee joint. The largest communicative bursa is the suprapatellar bursa described above. Four considerably smaller bursae are located on the back of the knee. Two non-communicative bursae are located in front of the patella and below the patellar tendon, and others are sometimes present. Cartilage is a thin, elastic tissue that protects the bone and makes certain that the joint surfaces can slide easily over each other. Cartilage ensures supple knee movement. There are two types of joint cartilage in the knees: fibrous cartilage (the meniscus) and hyaline cartilage. Fibrous cartilage has tensile strength and can resist pressure. Hyaline cartilage covers the surface along which the joints move. Cartilage will wear over the years. Cartilage has a very limited capacity for self-restoration. The newly formed tissue will generally consist of a large part of fibrous cartilage of lesser quality than the original hyaline cartilage. As a result, new cracks and tears will form in the
cartilage over time.

The articular disks of the knee joint are called menisci because they only partly divide the joint space. These two disks, the medial meniscus and the lateral meniscus, consist of connective tissue with extensive collagen fibers containing cartilage-like cells. Strong fibers run along the menisci from one attachment to the other, while weaker radial fibers are interlaced with the former. The menisci are flattened at the center of the knee joint, fused with the synovial membrane laterally, and can move over the tibial surface. The menisci serve to protect the ends of the bones from rubbing on each other and to effectively deepen the tibial sockets into which the femur attaches. They also play a role in shock absorption, and may be cracked, or torn, when the knee is forcefully rotated and/or bent. The ligaments surrounding the knee joint offer stability by limiting movements and, together with the menisci and several bursae, protect the articular capsule.

The knee is stabilized by a pair of cruciate ligaments. The anterior cruciate ligament (ACL) stretches from the lateral condyle of the femur to the anterior intercondylar area. The ACL is critically important because it prevents the tibia from being pushed too far anterior relative to the femur. It is often torn during twisting or bending of the knee.

The posterior cruciate ligament (PCL) stretches from medial condyle of femur to the posterior intercondylar area. Injury to this ligament is uncommon but can occur as a direct result of forced trauma to the ligament. This ligament prevents posterior displacement of the tibia relative to the femur. The transverse ligament stretches from the lateral meniscus to the medial meniscus. It passes in front of the menisci. It is divided into several strips in 10% of cases. The two menisci are attached to each other anteriorly by the ligament. The posterior and anterior meniscofemoral ligaments stretch from the posterior horn of the lateral meniscus to the medial femoral condyle. They pass posteriorly behind the posterior cruciate ligament. The posterior meniscofemoral ligament is more commonly present (30%); both ligaments are present less often. The menisco-tibial ligaments (or "coronary") stretches from inferior edges of the menisci to the periphery of the tibial plateaus.

The patellar ligament connects the patella to the tuberosity of the tibia. It is also occasionally called the patellar tendon because there is no definite separation between the quadriceps tendon (which surrounds the patella) and the area connecting the patella to the tibia. This very
strong ligament helps give the patella its mechanical leverage and also functions as a cap for the condyles of the femur. Laterally and medially to the patellar ligament the lateral and medial retinaculum connect fibers from the vastus lateralis and medialis muscles to the tibia. Some fibers from the iliotibial tract radiate into the lateral retinaculum and the medial retinaculum receives some transverse fibers arising on the medial femoral epicondyle.

The medial collateral ligament (MCL a.k.a. "tibial") stretches from the medial epicondyle of the femur to the medial tibial condyle. It is composed of three groups of fibers, one stretching between the two bones, and two fused with the medial meniscus. The MCL is partly covered by the pes anserinus and the tendon of the semimembranosus passes under it. It protects the medial side of the knee from being bent open by a stress applied to the lateral side of the knee (a valgus force). The lateral collateral ligament (LCL a.k.a. "fibular") stretches from the lateral epicondyle of the femur to the head of fibula. It is separate from both the joint capsule and the lateral meniscus.

It protects the lateral side from an inside bending force (a varus force). The anterolateral ligament (ALL) is situated in front of the LCL. Lastly, there are two ligaments on the dorsal side of the knee. The oblique popliteal ligament is a radiation of the tendon of the semimembranosus on the medial side, from where it is direct laterally and proximally. The arcuate popliteal ligament originates on the apex of the head of the fibula to stretch proximally, crosses the tendon of the popliteus muscle, and passes into the capsule.
(A) Quadriceps tendon
(B) Patella
(C) Lateral Collateral Ligament
(D) Articular Cartilage
(E) Patellar Tendon
(F) Meniscus
(G) Femur
(H) Posterior Cruciate Ligament
(I) Anterior Cruciate Ligament
(J) Medial Collateral Ligament
(K) Tibia

(FIG: 1.1. Overview of Knee Joint)

(COURTESY: https://www.drugs.com/healthguide/images/204695.jpg)
(A) Quadriceps Muscles
(B) Femur
(C) Articular Cartilage
(D) Lateral Condyle
(E) Posterior Cruciate Ligament
(F) Anterior Cruciate Ligament
(G) Lateral Collateral Ligament

(H) Tibia
(I) Tibia
(J) Quadriceps Tendon
(K) Patella
(L) Medial Collateral Ligament
(M) Meniscus
(N) Patellar Tendon Ligament

(FIG: 1.2. Inside parts of Knee joint)

(COURTESY: https://upload.wikimedia.org/wikipedia/commons/thumb/0/09/Knee_diagram.svg/1200px-Knee_diagram.svg.png)
<table>
<thead>
<tr>
<th><strong>Muscle</strong></th>
<th><strong>Origin</strong></th>
<th><strong>Insertion</strong></th>
<th><strong>Artery</strong></th>
<th><strong>Nerve</strong></th>
<th><strong>Action</strong></th>
<th><strong>Antagonist</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Articularis genus</td>
<td>Distal and anterior femoral shaft</td>
<td>Proximal extension of the joint capsule of the knee</td>
<td>Femoral artery</td>
<td>Femoral nerve</td>
<td>Pulling the suprapatellar bursa during extension of the knee</td>
<td></td>
</tr>
<tr>
<td>Quadriceps femoris</td>
<td>Combined rectus femoris and vastus muscles</td>
<td>Patella and Tibial tuberosity via the patellar ligament</td>
<td>Femoral artery</td>
<td>Femoral nerve</td>
<td>Extension of the knee; flexion of the hip</td>
<td>Hamstring</td>
</tr>
<tr>
<td>Rectus femoris</td>
<td>Anterior inferior iliac spine and the exterior surface of the bony ridge</td>
<td>Patella and Tibial tuberosity via the Patellar ligament</td>
<td>Femoral artery</td>
<td>Femoral nerve</td>
<td>Extension of the knee; flexion of the hip</td>
<td>Hamstring</td>
</tr>
<tr>
<td>Vastus lateralis</td>
<td>Greater trochanter, Intertrochanteric line, and Linea aspera of the femur</td>
<td>Patella and Tibial tuberosity via the patellar ligament</td>
<td>Femoral artery</td>
<td>Femoral nerve</td>
<td>Extends and stabilizes knee</td>
<td>Hamstring</td>
</tr>
<tr>
<td>Vastus intermedius</td>
<td>Antero/lateral femur</td>
<td>Patella and Tibial tuberosity via the patellar ligament</td>
<td>Femoral artery</td>
<td>Femoral nerve</td>
<td>Extension of the knee</td>
<td>Hamstring</td>
</tr>
<tr>
<td>Vastus medialis</td>
<td>Femur</td>
<td>Patella and Tibial tuberosity via the patellar ligament</td>
<td>Femoral artery</td>
<td>Femoral nerve</td>
<td>Extension of the knee</td>
<td>Hamstring</td>
</tr>
<tr>
<td><strong>MUSCLE</strong></td>
<td><strong>ORIGIN</strong></td>
<td><strong>INSERTION</strong></td>
<td><strong>ARTERY</strong></td>
<td><strong>NERVE</strong></td>
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<tr>
<td>Biceps femoris</td>
<td>Long head: tuberosity of the ischium, short head: linea aspera on the femur</td>
<td>The head of the fibula which articulates with the back of the lateral tibial condyle</td>
<td>Inferior gluteal artery, perforating arteries, popliteal artery</td>
<td>sciatic nerve</td>
<td>Flexion of knee, laterally rotates leg at knee (when knee is flexed), extends hip joint (long head only)</td>
<td></td>
</tr>
<tr>
<td>Semitendinosus</td>
<td>Tuberosity of the ischium</td>
<td>Pes anserinus</td>
<td>Inferior gluteal artery, perforating arteries</td>
<td>Sciatic (tibial, L5, S1, S2)</td>
<td>Flexes knee, extends hip joint, medially rotates leg at knee</td>
<td></td>
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<tr>
<td>Semimembranosus</td>
<td>Tuberosity of the ischium</td>
<td>Medial surface of tibia</td>
<td>Profund a femoris, Gluteal artery</td>
<td>Sciatic nerve</td>
<td>Flexes knee, extends hip joint, medially rotates leg at Knee</td>
<td></td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>Medial and lateral condyle of the femur</td>
<td>Calcaneus</td>
<td>Sural artery</td>
<td>Tibial nerve</td>
<td>Minor flexion of knee</td>
<td></td>
</tr>
<tr>
<td>Muscle</td>
<td>origin</td>
<td>Insertion</td>
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<td>Nerve</td>
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<tr>
<td>Gracilis</td>
<td>Inferior pubic</td>
<td>Pes</td>
<td>Obturator</td>
<td>Anterior branch of</td>
<td>Flexion and medial rotation of</td>
<td></td>
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<tr>
<td></td>
<td>ramus</td>
<td>Anserinus</td>
<td>Artery</td>
<td>obturator nerve</td>
<td>knee; Adduction of hip, flexion Of</td>
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<td>hip;</td>
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(1.1. MUCLES OF THE KNEE JOINT)

The femoral artery and the popliteal artery help form the arterial network or plexus, surrounding the knee joint. There are six main branches: two superior genicular arteries, two inferior genicular arteries, the descending genicular artery and the recurrent branch of anterior tibial artery. The medial genicular arteries penetrate the knee joint. The knee permits flexion and extension about a virtual transverse axis, as well as a slight medial and lateral rotation about the axis of the lower leg in the flexed position. The knee joint is called "mobile" because the femur and lateral meniscus move over the tibia during rotation, while the femur rolls and glides over both menisci during extension-flexion.
(FIG: 1.3. Posterior view of knee)

(A) Fibula  (G) Posterior Cruciate Ligament
(B) Lateral Collateral Ligament  (H) Articular Surface Of Tibia
(C) Lateral Meniscus  (I) Medial Collateral Ligament
(D) Red Zone  (J) Medial Meniscus
(E) White Zone  (K) Tibia
(F) Anterior Cruciate Ligament

The center of the transverse axis of the extension/flexion movements is located where both collateral ligaments and both cruciate ligaments intersect. This center moves upward and backward during flexion, while the distance between the center and the articular surfaces of the femur changes dynamically with the decreasing curvature of the femoral condyles. The total range of motion is dependent on several parameters such as soft-tissue restraints, active insufficiency, and hamstring tightness. With the knee extended both the lateral and medial collateral ligaments, as well as the anterior part of the anterior cruciate ligament, are taut. During extension, the femoral condyles glide and roll into a position which causes the complete unfolding of the tibial collateral ligament. During the last 10° of extension, an obligatory terminal rotation is triggered in which the knee is rotated medially 5°. The final rotation is produced by a lateral rotation of the tibia in the non-weight-bearing leg, and by a medial rotation of the femur in the weight-bearing leg. This terminal rotation is made possible by the shape of the medial femoral condyle, assisted by contraction of the popliteus muscle and the iliotibial tract and is caused by the stretching of the anterior cruciate ligament. Both cruciate ligaments are slightly unwound and both lateral ligaments become taut.

In the flexed position, the collateral ligaments are relaxed while the cruciate ligaments are taut. Rotation is controlled by the twisted cruciate ligaments; the two ligaments get twisted around each other during medial rotation of the tibia — which reduces the amount of rotation possible — while them become unwound during lateral rotation of the tibia. Because of the oblique position of the cruciate ligaments at least a part of one of them is always tense and these ligaments control the joint as the collateral ligaments are relaxed. Furthermore, the dorsal fibers of the tibial collateral ligament become tensed during extreme medial rotation and the ligament also reduces the lateral rotation to 45-60°.
(FIG: 1.4. inside view of knee joint)

(FIG: 1.5. inside view of knee joint)

(A) Medial femoral condyle
(B) Posterior cruciform ligament
(C) Medial meniscus
(D) Medial collateral ligament
(E) Tibia
(F) Anterior cruciate ligament
(G) Lateral femoral condyle
(H) Posterior Cruciate Ligament
(I) Posterior Meniscofemoral Ligament
(J) Lateral Meniscus
(K) Lateral Collateral Ligament
(L) Posterior Ligament Of Head Of Fibula
(M) Head Of Fibula
(N) Interosseus Membrane

Main biomechanical roles of the knee joint complex to allow locomotion with (a) minimum energy requirements from the muscles and (b) stability, accommodating for different terrains to transmit, absorb and redistribute forces caused during the activities of daily life.

**Arthrokinematics of the knee**

Rotation and translation in knee joint
- **Rotation**: - Flexion-extension: upto 160 degree of flexion (upto 5 degree flexion-hyperextension)
  - varus-valgus: 6-8 degree in extension
  - Internal-external rotation: 25-30 degree in flexion
- **Translation**: - Anterior-posterior: 5-10mm
  - Compression: 2-5mm
  - Medio-lateral: 1-2mm

*(FIG: 1.6. Centre of rotation for femur motion during flexion-extension)*

(COURTESY - [http://2.bp.blogspot.com/-qWzv8Ijibw/U3h1d06HIdI/AAAAAAAAABTU/XbXRMNbdueg/s1600/movement-of-knee.gif](http://2.bp.blogspot.com/-qWzv8Ijibw/U3h1d06HIdI/AAAAAAAAABTU/XbXRMNbdueg/s1600/movement-of-knee.gif))
Knee joint kinematics in the sagittal plane during gait

- Extension: contact is located centrally.
- Early flexion: posterior rolling; contact continuously moves posteriorly.
- Deep flexion: femoral sliding; contact is located posteriorly; the unlocking of the ACL prevents further femoral roll back.

Normal Biomechanics of Knee and Movements

Knee Joint produces Functional shortening and lengthening of extremity. The knee is comprised tibiofemoral joint and patellofemoral joint.

(FIG: 1.7. Motions present in knee joint)

(COURTESY: http://2.bp.blogspot.com/-qWcz88IjJiBw/U3h1d06HiI/AAAAAAAAABTU/bXRMNb0UEg/s1600/movement%3Dof+knee.gif)
(FIG: 1.8. Biomechanics of knee joint)

(COURTESY https://www.researchgate.net/profile/Chsrinivasa_Rao/publication/280216011/figure/fig2/AS:305728851070979@1449902846352/figure-fig2_Q320.jpg)
(FIG: 1.9. Tibial on femoral extension)

COURTESY: https://images.app.goo.gl/GwYBj3fLEmcz9HND

The knee joint is a modified hinge joint with gliding function too. It has got six degrees of freedom

- 3 rotations
- 3 translations

In sagittal axis it has flexion-extension movement, in frontal axis, it has a varus-valgus rotation and whereas in transverse axis there is internal-external rotation)

- Flexion-Extension: 3 degrees of hyperextension to 155 degrees of flexion
- Varus-valgus: 6-8 deg in extension
- Internal-external rotation: 25-30 deg in flexion
- Translation
  - Anterior-posterior: 5-10 mm
- Compression: 2–5 mm [patellar compression]
- Medio-lateral: 1-2 mm

Anatomic Axis of Knee

A line is drawn along the shaft of the Femur and shaft of tibia form angle of 170 to 175 degree. When the angle is less than 165 degree an abnormal condition called genu valgum. This subjects the medial aspect of the knee is subjected to distraction force. When the angle is more than 180 degree an abnormal condition called genu varum. The medial aspect of the knee is subjected to increase compression loading.

(A) Anterior Superior Iliac Spine
(B) 'Q' Angle
(C) Midpoint Of Patella
(D) Tibial Tubercle

(FIG: 1.10. Measurement of Q-angle)

(COURTESY: https://www.physio-pedia.com/images/thumb/f/f2/Q_angle_2.png/250px-Q_angle_2.png)
It is the angle formed by a resultant vector of Quadriceps and the pull of ligamentum patella.

It is found by drawing two lines

- From anteroposterior iliac spine to the midpoint of Patella
- From Tibial tubercle to the midpoint of Patella

The normal angle is about 13 degrees. When the angle is large, lateral pull on patella is increased.

**Patellofemoral Joint**

It transmits tensile forces generated by the quadriceps to the patellar tendon and increases the lever arm of the extensor mechanism. Removal of patella decreases extension force by 30%. The motion of the patellofemoral joint is sliding articulation. In full flexion, the patella moves 7cm caudally. Maximum contact between femur and patella is at 45 degrees of flexion.

**Forces acting on patella are**

- Laterally – Lateral retinaculum, vastus lateralis, iliobibial tract
- Medially – Medial retinaculum and vastus medialis
- Superior – Quadriceps via quadriceps tendon
- Inferior – patellar ligament

Passive restraints to lateral subluxation are medial patellofemoral ligament [60% of the restraining force], medial patellomeniscal ligament [13% of the restraining force] and retinaculum [10%]. Dynamic restraint is by quadriceps muscles.

**Tibiofemoral Joint**

Tibiofemoral joint functions to transmit the body weight from femur to tibia. The tibiofemoral joint reaction force is three times body weight with walking and four times body weight with climbing. The range of motion of knee is 3 degrees of hyperextension to 155 degrees of flexion. The flexion is limited by the size of thigh-calf becomes contact is usually the limiting factor to full flexion. Normal gait requires a range of motion from 0 to 70 degrees.
**Posterior Rollback**

Instant center of rotation is the point at which the joint surfaces are in direct contact. Posterior rollback is a phenomenon whereas the knee flexes, the instant center of rotation on the femur moves posteriorly. This occurs due to the unique shape of the femoral condyle.

Rollback allows knee flexion by avoiding impingement.

**Change in center of Rotation**

- Extension: contact is located centrally
- Early flexion: posterior rolling – contact continuously moves posteriorly.
- Deep flexion: femoral sliding – contact is located posteriorly

The unlocking of the ACL prevents further femoral rollback

**Screw home mechanism**

During the last 20 degrees of knee extension- anterior tibial glide persists on the tibia’s medial condyle because its articular surface is longer in that dimension than the lateral condyle’s. Prolonged anterior glide on the medial side produces external tibial rotation, the “screw-home” mechanism. This locks knee and serves to decrease the work of the quadriceps while standing.

**Range of Motion at the Knee in Different Activities**

The patellofemoral joint reaction is one-half of body weight during normal walking, increasing up to over three times body weight during stair climbing and descending.
Knee joint loading in Different Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Tibiofemoral joint Flexion in degrees</th>
<th>Load (X body weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycling</td>
<td>60-100</td>
<td>1.2</td>
</tr>
<tr>
<td>Walking</td>
<td>15</td>
<td>3.0</td>
</tr>
<tr>
<td>Stairs</td>
<td>45-60</td>
<td>3.8-4.3</td>
</tr>
<tr>
<td>Squat-rise</td>
<td>140</td>
<td>5.0</td>
</tr>
<tr>
<td>Squat-down</td>
<td>140</td>
<td>5.6</td>
</tr>
</tbody>
</table>

(1.2. Knee joint loading in Different Activities)

Range of motion at the knee in Different Activities

<table>
<thead>
<tr>
<th>Activities</th>
<th>Knee flexion in degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal gait level surfaces</td>
<td>60</td>
</tr>
<tr>
<td>Stair climbing</td>
<td>80</td>
</tr>
<tr>
<td>Sitting/rising from most chairs</td>
<td>90</td>
</tr>
<tr>
<td>Sitting/rising from toilet seat</td>
<td>115</td>
</tr>
</tbody>
</table>

(1.3. Range of motion at the knee in Different Activities)

Role of Menisci

Menisci have following functions

- Load bearing
- Stability
- Joint lubrication
- Prevent capsule, synovial impingement
- Shock absorbers

As the femur compresses through the meniscus onto the tibia, it pushes the meniscus out of the joint cavity. The meniscus deforms to conform with the femoral condyle and allows for the contact to be distributed over a larger area. Also, the meniscus increases its circumference and moves radially outwards and posteriorly with knee flexion, following the rolling and sliding of the femoral condyle with flexion. During radial deformation, the meniscus is anchored by its anterior and posterior horns. During loading, tensile, compressive, and shear forces are generated.

**Ascending and Descending Stairs**

During ascending of stairs, the actual degree of knee flexion required to ascend stairs is determined not only by the height of the step but also by the height of the patient. For the standard 7" step approximately 65° of flexion will be required. Lever arm during climbing the stairs can be reduced by leaning forward. Also, in stair climbing, the tibia is maintained relatively vertical, which diminishes the anterior subluxation potential of the femur on the tibia.

Descending stairs also required 85° of flexion. The tibia is steeply inclined toward the horizontal, bringing the tibial plateaus into an oblique orientation. The force of body weight will now tend to sublux the femur anteriorly. This anterior subluxation potential will be resisted by the patellofemoral joint reaction force and the tension which develops in the posterior cruciate ligament.
Restrains excessive forward movement of the Tibia in relation to the femur. Limits rotational movements of the knee.

(FIG: 1.11. Anterior cruciate ligament)

(COURTESY: - http://image.wikifoundry.com/image/1/1-0l-rEiySMDR61yOXpQtw95952/GW1225H416)
A powerful ligament extending from the top-rear surface of the tibia to the bottom-front surface of the femur. This ligament prevents the knee joint from posterior instability.

(FIG: 1.12. Posterior cruciate ligament)

(COURTESY: - http://image.wikifoundry.com/image/1/f-0\-rEiySMDR61yOXpQtw95952/GW1225H416)
Stabilizes the joint and prevents the knee from buckling inwards. The ligament attaches to the femur and the tibia and runs across the inside medial of the knee.

(FIG 1.13. Medial collateral ligament)

(COURTESY: - http://image.wikifoundry.com/image/1/f-0l-rEiySMDR61yOXpQtw95952/GW1225H416)
The lateral collateral ligament extends from the top-outside surface of the fibula to the bottom-outside surface of the femur. The ligament stabilizes the knee on the outside of the joint.

(FIG: 1.14, Lateral collateral ligament)

(COURTESY: - http://image.wikifoundry.com/image/1/f-0lrEiySMDR61yOXpQtw95952/GW12251416)
STABILITY OF KNEE

Stability is provided by ligaments and other structures. Main ligaments in different stresses, important for stability as follows

Varus stress

Lateral collateral ligament

Valgus stress

Superficial portion of the medial collateral ligament

Anterior translation

The anterior cruciate ligament is a primary static restraint to anterior translation and also plays a role in axial rotation

It has two components

- Anteromedial bundle
  * tight in flexion
- Posterolateral bundle
  * tight in extension

Posterior Translation

The posterior cruciate ligament is the primary static restraint to posterior translation and external rotation. Posterolateral corner is the primary stabilizer of external tibial rotation. This ligament originates from anterolateral medial femoral condyle and inserts on the tibial sulcus. It has an anterolateral component which tightens in flexion and a posteromedial component that tightens in extension. In 2004, a research group at the University of Connecticut let by Michelle Devan decided to try to figure out the effect of “structural abnormalities” on repetitive strain injuries of knee like iliotibial band syndrome (ITBS) and patellofemoral syndrome (PFPS). In particular, they wanted to study women.
So, they did one of my favourite kinds of studies: they measured a bunch of stuff that every therapist in world "knows" is a risk factor for various knee problems, the usual structural suspects. In fifty young women athletes, they checked:

- the tightness of iliotibial bands
- the angles of knee joints
- the strength of their hamstrings and quadriceps

And then they waited to see who got what kinds of knee injuries over the course of the season. Most health care professionals would fully expect the women with tight iliotibial bands to get more ITB syndrome, and the ones with some wacky knee angles to get patellofemoral pain syndrome.

The biomechanics and kinematics of the patellofemoral joint are the result of a complex assortment of static and dynamic conditions. This article will present a review of our basic understanding of these conditions and place them in the context of necessary information required when considering surgical interventions. The importance of this information becomes highlighted when one considers that the knee is a coupled mechanical system, and changes in any single component of the system can affect any of the remaining parts of the system.

(FIG: 1.15. LATERAL VIEW OF PATTELO-FEMORAL JOINT)
(COURTESY: http://static.squarespace.com/static/52994853e4b0a6ba0e3606be/52994bbfe4b0e9e09bdec1e6/530e72e
Articulating Surfaces

The articular cartilage of the patella is similar to that of other joints in that it contains a solid phase and a fluid phase that is mostly composed of collagen and glycosaminoglycans. The solid phase is somewhat permeable and when the articular surface is under load, the fluid gradually redistributes itself within the solid matrix. Therefore, the pressure within the fluid is strongly associated with the cushioning effect of the articular cartilage and the low friction coefficient of articular surfaces. Any damage to the articular surfaces causes a loss of pressure within the fluid phase, which subsequently results in higher stresses on the collagen fibers and more vulnerability leading to possible breakdown.

Ligaments

The patellar retinaculum is an important stabilizer of the patellofemoral joint, mainly its medial and lateral components.

The Medial Patellofemoral Ligament (MPFL) - originates on the medial femur and has a “sail-shaped” attachment on the patella and quadriceps tendon. Because of its wider attachment than its origin, several authors have promoted the technique of using a double-bundled graft to recreate the anatomy of this complex. Kang and colleagues described two components of MPFL fibers, using the term superior-oblique bundle and inferior-straight bundle. The clinical significance of this is not yet known, but the authors suggested the bundles may vary in their roles as dynamic versus static stabilizers. Furthermore, length differences between the two bundles or attachment sites have been described. Mochizuki and colleagues showed the length of the MPFL fibers from the origin to the medial patella was 56.3±5.1 mm vs. 70.7±4.5 mm to the quadriceps tendon.

The Lateral Patellofemoral Ligament (LPFL) - is an important lateral stabilizer of the patella against medial subluxation or dislocation. Some authors describe the lateral patellofemoral ligament as a palpable thickening of the joint capsule between the patella and femoral epicondyle. Medial movement of the patella is controlled by the vastus medialis oblique (VMO) muscle. Lateral tracking is guided by both the vastus lateralis and the iliotibial band. Patellar motion is further constrained by the patellofemoral ligament, the patellotibial ligament, and the retinaculum.
(FIG: 1.16. Ligaments of patello-femoral joint)


The patella lies within the quadriceps tendon and thereby increases the mechanical advantage of the quadriceps mechanism. Not only does the patella increase the force of knee extension by 50%, but it also provides stability to the patellar tendon and minimizes the forces placed on the femoral condyles. Tracking of the patella begins with the lower patellar
border lying in contact with the suprapatellar fat pad when the knee is fully extended. With knee flexion, the patella moves proximally with a lateral shift. During normal patellar tracking, the patella engages in the trochlea at around 30° of knee flexion and remains stable then after due to the bony constraints of the trochlea. As the knee continues to flex, the tibia internally rotates and the patella moves upward. The patella is engaged with the trochlea at 20-30° of knee flexion. At 90° the patella contacts the lateral and medial femoral facets within the condylar fossa. At 130-135° of knee flexion, the medial facets of the patella contact the articulating surface of the femoral condyles.

Compression at the patellofemoral joint:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Force</th>
<th>%Body weight</th>
<th>Pounds of force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>850 N</td>
<td>½ × BW</td>
<td>100 lbs</td>
</tr>
<tr>
<td>Bike</td>
<td>850 N</td>
<td>½ × BW</td>
<td>100 lbs</td>
</tr>
<tr>
<td>Stair Ascend</td>
<td>1500 N</td>
<td>3.3 × BW</td>
<td>660 lbs</td>
</tr>
<tr>
<td>Stair Descend</td>
<td>4000 N</td>
<td>5 × BW</td>
<td>1000 lbs</td>
</tr>
<tr>
<td>Jogging</td>
<td>5000 N</td>
<td>7 × BW</td>
<td>1400 lbs</td>
</tr>
<tr>
<td>Squatting</td>
<td>5000 N</td>
<td>7 × BW</td>
<td>1400 lbs</td>
</tr>
<tr>
<td>Deep Squatting</td>
<td>15000</td>
<td>20 × BW</td>
<td>4000 lbs</td>
</tr>
</tbody>
</table>

(1.4. Compression at the patellofemoral joint)

Examination of the patellofemoral joint involves:

- **Observation of the position of the patella with the knee in 90° of flexion**: patella alta, patella baja, or patellar lateralization may be present.

- **Observation of patellar tracking in terminal extension (30-0°)**: a J-curve may be present.

- **Assess the patellar glide**: a tight lateral retinaculum can decrease the medial glide, a medial glide of less than 5 mm (1 quadrant) can indicate a tight retinaculum. If a
positive apprehension sign (fear of the patella popping out of position) is elicited with assessment of the patellar glide, suspect a patella subluxation or dislocation.

- **Palpate the pain** tenderness is often found on the patellar facets, the trochlea, and the peripatellar soft tissue. Tenderness to palpation at the superior or inferior poles of the patella usually indicates pathology.

- **Assess the patella compression test** Compress and push the affected patella distally. Pain is a positive test associated with anterior knee pain. An active test, in which the patient contracts the quadriceps tendon against a compressed patella, has a high false-positive rate.

- **Assess the Q-angle**. The Q-angle is the angle formed by a line created from the ASIS to the mid patella intersecting with a line created from the mid patella to the tibial tubercle with the knee in full extension. The average Q-angle for males is 14°, and the average for females is 17°. An increase in this angle can indicate abnormal patellar tracking.

  The torsional stability is provided by the cruciate ligaments which help in stabilizing the knee joint when the person performs a pivoted movement using one leg. These ligaments are most often injured in case of Sporting injuries which involves kicking, jumping and running in a bizarre manner. The Anterior cruciate ligament (ACL) is more injured in female athletes compared to male with a 9 fold increase in vulnerability (Myklebust G, 2003) . Most of the ACL injuries in athletes occur during a noncontact period, during deceleration phase, lateral pivoting, or landing tasks which are often associated with high knee external joint loading. (Besier TF, 2001)

Meniscus is a ligament that is attached to the tibial condylar plateau intra-articularly. The main function of the meniscus is to increase the congruency of the knee joint and thereby increasing the articular surface and increase the contact are of the articulation. The meniscus works hand in hand with the cruciate ligaments particularly the ACL. There are studies which states that the bilateral removal of the medial and lateral meniscus resulted in sublimation of the tibia even though the ACL were intact which clearly states that the medial and the lateral meniscus provide anterior stability in addition to the ACL and the Ligamentum patellae.
The meniscus does not augment the function of posterior cruciate ligament (PCL) in maintaining the posterior stability. The bilateral removal of the medial and the lateral meniscus did not resulted in any sublimation or even altered loading pattern by additional load on the PCL which clearly explains the scenario. (Shoemaker SC, 1986) Posterior cruciate ligament is less injured when compared to ACL in athletes.

It most often occurs as an combination injury with ACL or collateral ligaments. Often high velocity injuries injure both ACL and PCL. Chronic postero-lateral or posteromedial instability often resulted in laxity of posterior cruciate ligament. The ligaments which are positioned in the extra articulate region are medial collateral ligament, lateral collateral ligament which provides stability on the lateral aspect. These ligaments prevents the lateral translation of the tibia when non-weight bearing and prevents the lateral translation of femur when the limbs are weight bearing. The medial collateral ligament (MCL) is the commonly injured ligament and is injured either in isolation or along with other knee ligament in 40 % of the patients (Schein A, 2012).

MCL injuries occur when there is a valgus stress across the knee joint plateau from a direct blow to the lateral knee. The injury also happens during noncontact injuries that result in tibial external rotation and during valgus forces along the knee joint (Phisitkul P, 2006). Lower-grade MCL injuries usually occur in isolation, but the high-grade injuries are always accompanied by parallel injury to the anterior cruciate ligament, or the meniscus (Jacobson KE, 2006). The MCL is the known primary restraint to all valgus stress across the medial aspect of the knee joint at all flexion angles.

There are other structures that contribute to the same stability, which are postero medial corner (PMC), which is a collection of structures that include posterior oblique ligament, oblique popliteal ligament, posterior horn of the medial meniscus, and the tendinous expansion of the semimembranosus insertion. (Sims WF, 2004) There are reported injury to both the MCL and PMC which are resultant of both valgus and anteromedial rotator instability (AMRI) (Azar MA, 2006).

Ligamentum patellae, which is a ligament formed by the extension of insertion of the quadriceps muscles, positioned in the anterior aspect also provide stability to the knee joint anterior translation of Tibia and femur. The ligament also provides leverage for the
better performance of the quadriceps muscle in extending the knee joint. Ligament’s
stability of the knee joint is reinforced by the muscles passing through the knee joint. The
muscles which are passing through the knee joint are designed in such a manner that they
become slender and do not obstruct the movement at the knee joint at the same time do not
compromise the stability. Quadriceps and hamstring are the predominant muscles which
protect the knee from anterior and posterior destabilization forces.

There are three components of the knee joint namely the medial tibio-femoral,
lateral tibio-femoral and the patella-femoral joint. The stability of a joint is maintained
mainly by the ligaments and the huge musculo-tendinous structures passing through the joint.
Because of this fact, the knee joint is vulnerable to many soft tissue injuries as the soft tissues
are the one which maintains the stability. The nature of the muscles which are passing
through the knee joint also contribute to the injury proneness of the joint the quadriceps and
hamstrings muscles are two entirely different functional muscles which crosses the knee
joint.

There is often an imbalance between the quadriceps and hamstrings that results in
shortening of hamstring and lengthening of the quadriceps. The quadriceps strengthening
invariably results into abnormal positioning of the patella which results in wide range of
disorders. So, knee rehabilitation becomes a daunting task for physiotherapist.

Out of three joints in the knee complex, the patella femoral joint is most vulnerable
in all age group compared to the other two. There are various conditions affecting the Patello
femoral joint but the most common one is Patello-femoral pain syndrome. Patello-femoral
pain syndrome (PFPS) is a common disorder of the knee joint, and occurs in both athletes and
the general population. It is a painful musculoskeletal condition, which is characterized by
knee pain located in the anterior aspect and retro-patellar region of the knee joint. The
prevalence of PFPS has been reported across several age groups, with females 2.23 times
more likely to develop PFPS compared with males (Boling M, 2010). PFPS is shown to have
a very high incidence i.e. 25% in the age group of 10-35 years with over all incidence of
22/1000 person. It is also shown to occur more in young individuals with high physical
activities. It can cause significant pain leading to limitations in societal participation and
physical activity.

Patello-femoral pain syndrome has a multi-factorial nature and multiple parameters
have been proposed as potential risk factors, classified as intrinsic or extrinsic. Some of the
intrinsic risk factors are modifiable and may be approached in treatments which are muscle imbalances at hip, knee & ankle, foot over-pronation, limb length discrepancy, patellar malalignment and hyper mobility. Whereas extrinsic risk factors include the type of sports activity, environmental conditions, and the surface and equipment used.

Biomechanical studies have proven association of Hamstring flexibility, quadriceps or iliotibial band, strength deficit in hamstring, quadriceps, hip abductors & external rotators, abnormal VMO/ VL reflex timing, an excessive quadriceps (Q) angle, patellar mal-tracking & dynamic valgus, patellar compression or tilting; and weakness in functional testing with development of PFPS. Other causes may include Poor mechanics with activities such as weight lifting, a change in shoes or bike fit, Incorrect or worn out footwear.

There are many outcome measures which are used for functional assessment of patellafemoral pain syndrome namely, Anterior Knee Pain Scale (AKPS) introduced by Kujala in 1993 (Kujala UM, 1993), Lower Extremity Functional Scale (LEFS) introduced by Binkley in 1999 (Binkley JM), Visual Analog scale (VAS), Function Index Questionnaire (FIQ), and Modified Functional Index Questionnaire (MFIQ) Whereas pain severity is usually assessed by Patello-femoral pain syndrome severity scale which is a valid and reliable tool.

Tendinopathy is a common musculoskeletal disorder affecting both recreational and elite athletes potentially leading to disability lasting several months. Numerous athletes who run and jump as in volleyball (44%) and basketball (32%) (Marsha Rutland, 2010) Similar activity occurs in soccer and dancers, who also participate in repetitive kicking, jumping, and landing. A higher prevalence is noted in sports with high impact ballistic loading of the knee extensors.

Patellar tendon overuse is also seen in military recruits, accounting for 15% of all of their soft tissue injuries 5 and up to 22% incidence in the overall athletic population. Many factors, both intrinsic and extrinsic, contribute to patellar tendinopathy. Intrinsic factors such as strength imbalance, postural alignment, foot structure, reduced ankle dorsiflexion, and lack of muscle strength or flexibility may play a role. However the primary cause appears to relate to the extrinsic factor of overuse. Microtrauma or “overuse” injury develops from repetitive mechanical loading of the tendon through excessive jumping and landing activity.

A study of 760 adolescent athletes across 16 different sports revealed a prevalence of 5.8% of athletes with patellar tendon pain. 22.8% incidence of patellar tendon pain in a
sample of 407 elite volleyball players, (Mark F, 2016) and Taunton et al in 2003, found that 48% of 2000 runners had patellar tendon pain. However, multiple histopathologic studies have indicated that the primary pathologic process in most painful tendons is degenerative rather than inflammatory. Based on histopathology, several authors have suggested that the term “tendinitis” be abandoned in favor of the term “tendinosis”, which describes a degenerative tendon condition.

Other tissue research has shown the presence of proinflammatory chemical agents such as cyclooxygenase, growth factors, and prostaglandin in painful patellar tendons as well as macrophages and lymphocytes in chronic tendinopathy, suggesting that there may be an inflammatory component in patellar tendon pain. The intervention plan for patellar tendon pain should be based on an evidence-based approach which incorporates the clinical judgment of the clinician, the patient’s values, and the best available evidence.

The term patella femoral pain was first used to describe an inspectional tendinopathy. This pain is often caused by over use or strain on the patellar ligament. The patellar ligament joins the patella to the shin bone, or tibia. It is very strong and facilitates straightening the leg by the quadriceps muscles. The quadriceps muscles straighten the knee in jumping, running and other movements in which the individual needs to be propelled from the ground these muscles also function to stabilize the body during landing. The patellar ligament endues a great deal of stress during these movements this is especially true when the individual frequently changes direction performs jumping movements, or uses the ligament repeatedly for long periods of time as in running with repeated over use constant inflammation micro-tears as well as collagen degeneration may occur.

Knee joint is a most unstable joint in the list of weight bearing joints in the body. Its non-congruent articular surface contributes towards instability. The stability of a joint is maintained mainly by the ligaments and the huge musculo-tendinous structures passing through the joint. Because of this fact, the knee joint is vulnerable to many soft tissue injuries as the soft tissues are the one which maintains the stability. The nature of the muscles which are passing through the knee joint also contribute to the injury proneness of the joint the quadriceps and hamstrings muscles are two entirely different functional muscles which crosses the knee joint.
There is often an imbalance between the quadriceps and hamstrings that results in shortening of hamstring and lengthening of the quadriceps. The quadriceps strengthening invariably results into abnormal positioning of the patella which results in wide range of disorders. So, knee rehabilitation becomes a daunting task for physiotherapist. One of the major problems faced during knee rehabilitation is the presence of three joints namely the medial and lateral tibio femoral joint and the patella femoral joint. The patella femoral joint is most vulnerable in all age group compared to the other two. There are various conditions affecting the Patello femoral joint but the most common one is Patello-femoral pain syndrome.

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1.2 Evaluation strategies adopted in PFPS

Evaluation and conformation of the condition is vital in any musculo skeletal problem. Evaluation is to differently diagnose between conditions affecting the Patella. A comprehensive evaluation includes detailed examination of both intrinsic and extrinsic factors. A detailed history of a patient’s workout schedule and duration of a symptom is paramount to making a correct diagnosis. If symptoms have lasted longer than 6 weeks, tendinopathy should be suspected. Evaluation of chronic patellar tendinopathy should include the utilization of Blazina’s knee scale 22 or Kennedy’s scale. Pain in the patellar tendon may be reproduced with resisted knee extension. Functional tests of ascending or descending stairs, performing single leg declining squats, jumping or hopping will most likely reproduce patellar pain symptoms. The evaluation should include history, age and any recent growth spurts, location of pain, and special tests. The rehab professional should be able to differentiate between patellar tendinopathy and additional diagnoses of patellofemoral dysfunction, Sinding-Larsen-Johansson Syndrome, Osgood Schlatter’s disease.
1.3 Management strategies adopted in PFPS

Typical non invasive treatment includes resting, icing, and eccentric strengthening of the quadriceps muscles. The KT tape application is excellent for providing pain relief as well as taking strain off of the ligament. Promoting blood flow to the area, and providing proprioceptive (body awareness) confidence. Rehabilitation incorporates three stages ranging from limited partial weight bearing loaded exercise to a sports specific return to play protocol. Overuse is a primary contributor to patellar tendinopathy, it is important to avoid rapid progression in frequency, intensity, and duration in rehabilitation and functional progression. Most athletes with patellar tendinopathy are treated non-operatively, it is imperative to understand rehabilitation protocols and implement them wisely. Eccentric exercise has been promoted as an important conservative treatment choice for patellar tendinopathy. Prior to initiating exercise, a warm-up and stretching period is recommended. Cycling on a stationary bicycle for 5-10 minutes with minimal resistance is suggested as an active warm-up. Next, stretching should be incorporated into the program before and after the exercise routine in order to address any flexibility imbalances. Hip flexor, quadriceps, hamstring, and gastrocnemius and soleus tightness.

The population most at risk from PFPS is runners, cyclists, basketball players and other sports participants. Onset can be gradual or the result of a single incident and is often caused by a change in training regime that includes dramatic increases in training time, distance or intensity, it can be compounded by worn or the wrong type of footwear. Symptoms include discomfort while sitting with bent knees or descending stairs and generalized knee pain. Treatment involves resting and physical therapy that includes stretching and strengthening exercises for the legs. PFPS is one of a handful of conditions sometimes referred to as runner's knee, the other conditions being Chondromalacia patellae, Iliotibial band syndrome, and Plica syndrome. A chondromalacia patella is a term sometimes treated synonymously with PFPS. However, there is general consensus that PFPS is a term that applies only to individuals without cartilage damage, thereby distinguishing it from chondromalacia patellae, a condition characterized by softening of the patellar articular cartilage. Despite this academic distinction, the diagnosis of PFPS is typically made clinically, based only on the history and physical examination rather than on the results of any medical imaging. Therefore, it is unknown whether most persons with a diagnosis of PFPS have cartilage damage or not, making the difference between PFPS and chondromalacia theoretical rather than practical. It is thought that only some individuals with anterior knee pain will have true chondromalacia patellae.
1.4 Statement of problem

In pain assessment, Severity of pain plays a vital role in determining the physiotherapy treatment protocol. Although several studies exists showing association of above biomechanical factors in development of PFPS, yet no study is done to see whether this factors have any relation with pain severity. Hence, the purpose of this study is to evaluate the association between selected biomechanical features with pain severity in individuals with patello-femoral pain syndrome there by device a better treatment protocol for PFPS.
1.5. Significance of research

This study pivots around the severity of pain. Severity of pain is a major indicator of the chronicity and its pathogenesis of the condition. In treatment planning severity of pain using a visual analogue scale is major factor in goal setting and treatment planning as for a physiotherapist is concerned. A physiotherapist takes the severity of pain as a major indicator of prognosis, sometimes based upon the seniority of the pain the therapist may refer a patient to a physician. Hence severity of pain is a very important criterion determining every aspect of Physiotherapy delivery to the patient. This study tries to find out whether the bio-mechanical factors mentioned in this study do have a significant role to play with the severity of pain or not. Many studies which are done to prove that there is an association between these bio-mechanical factors and the Patello femoral pain syndrome, yet no study is done to see whether this factor have any relationship with pain security. If any of the factors is found to be associated more with pain severity then this knowledge could be used in future for clinical decision making.