Biomechanic of the knee joint
<table>
<thead>
<tr>
<th>Plane</th>
<th>Motion</th>
<th>Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagital</td>
<td>Flexion/extension</td>
<td>Frontal</td>
</tr>
<tr>
<td>Frontal</td>
<td>Abduction/abduction, Side flexion, Inversion/eversion</td>
<td>Ant-Post</td>
</tr>
<tr>
<td>Transverse</td>
<td>Int rotationn/ext rotation, Horizontal flexion/extension, Supination/pronation</td>
<td>Vertical</td>
</tr>
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</table>
1- Tibiofemoral joint

2- Patellofemoral joint
Tibiofemoral joints
Lower end of femure
Upper end of tibia
The Tibial Plateau has two articular facets that articulate with the Condyles of the Femur.
Kinetic/Biomechanical Chain
**Closed-chain motion**

Movement of a proximal segment against a fixed distal segment is referred to as a closed-chain motion.
Open-chain motion

Movement of the distal segment when the proximal segment is fixed is referred to as an open-chain motion.
Osteokinematics
and
Arthrokinematics
Movement
Osteokinematics:

Gross movements of bones at joints

- flexion / extension
- abduction / adduction
- internal rotation / external rotation

These terms describe the movements that occur around a center of rotation, namely the joint axis.
Arthrokinematics:

- Small amplitude motions of bones at joint surface.
  - Roll
  - Glide (or slide)
  - Spin

ARTHROKINEMATICS is the general term for the specific movements of joint surfaces.

Joint surfaces move with respect to one another by simultaneously (1) rolling, (2) gliding, and (3) spinning. This discussion focuses on how joint surfaces roll and glide with respect to one another, and largely ignores the spin component.
Osteokinematics Movement of Knee Joint
Tibiofemoral Joint

I. Flex-Ext

II. Rotation

III. Add-abd
Knee Flex-Ext

- Axis: Frontal axis/Oblique
- Plan: Sagital plan
Flex

X > 140°

130° - 140°

140°

120°

Hip Flex

Hip Ext
squatting position  →  Knee flex  →  160°
Active knee Extension $\rightarrow 0^\circ$

Passive Knee Extension $\rightarrow 5^\circ-10^\circ$

EXT $> 5^\circ-10^\circ$
Genue Recurvatum

Knee Hyperextension
In close kinematic chain (OKC) – flexion / extension range is limited by ankle range.

Limited Dorsi flex → knee flex

limited plantar flex → knee EXT
Tibiofemoral joint

I. Flex-Ext

II. Rotation

III. Add-abd
Knee Rotation

- **Axis:** Vertical axis
- **Plan:** Transvers plan

I. **Automatic** rotation of knee

II. **Nonautomatic** rotation of knee
Nonautomatic (Axial) Rotation of Knee

- Knee flex
- Max range is available at 90° knee flex

- Range of motion: 35°
  - Med rot: 0° - 15°
  - Ext rot: 0° - 20°
Automatic Rotation of Knee

- Knee locking (Screw Home Locking Mechanism)
- CCK: Femoral ROT
- OCK: Tibial ROT

- The beginning of the flexion
  - Med rot of tibia/ Ext rot of femure

- End of the extension
  - Ext rot of tibia/ Med rot of femure
Tibiofemoral joint

I. Flex-Ext

II. Rotation

III. Add-abd
Valgus (Abduction)/Varus (Adduction)

- **Axis:** Ant-Post
- **Plan:** Frontal plan
- **Passive**

Frontal plane ROM is typically only 8° at full extension, and 13° with 20° of knee flexion.

Excessive frontal plane motion could indicate ligamentous insufficiency.
Arthrokineamatics Movement of the Knee Joint
Tibiofemoral Joint

- Roll
- Glide (or slide)
- Spin
If the moving joint surface rolls on its partner without simultaneously gliding, the surfaces would separate (gap or subluxate) in some places and impinge in others. Roll and glide must occur simultaneously to preserve joint integrity.
SO WHEN WE STABILIZE THE CONCAVE TIBIA...
Closed-Chain Motion
TF CKC Flexion

- Early 0° - 25° knee flexion –
  - *Posterior rolling* of femoral condyles on the tibia

- As flexion continues –
  - *Posterior Rolling* accompanied by simultaneous *Anterior glide* of femur
TF CKC EXTENSION

- Extension from flexion is a reversal of flexion motion.
- Early extension –
  - *Anterior rolling* of femoral condyles on tibial plateau
- As extension continues –
  - *Anterior Rolling* accompanied by simultaneous *Posterior glide* of femur
Opened-Chain Motion
TF OCK FLEXION / EXTENSION

- When tibia is flexed on a fixed femur –
  - The tibia performed *Both Posterior Rolling & Gliding* on relatively fixed femoral condyles.

- When tibia is Extended on a fixed femur –
  - The tibia performed *Both Anterior Rolling & Gliding* on relatively fixed femoral condyles.

Elongating ACL

Elongating PCL
Screw-home Mechanism
Medial condyle of tibia and femur is larger than lateral condyle
- The femur must **intrnally** rotate for knee Extention in a closed chain.

- The femur must **externally** rotate for knee flexion in a closed chain.
- The tibia must **externally** rotate slightly to allow for knee **extension** in an open **chain**.

- The tibia must **internally** rotate slightly to allow for knee **flexion** in an open **chain**.
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Femur on tibia

Closed-chain movement

Lateral view of right lower extremity
Patellofemoral joints
Patellofemoral joint

- "sliding" articulation
  - patella moves 7cm caudally during full flexion
- maximum contact between femur and patella is at 45 degrees of flexion

- The primary function of the patella is to **increase the lever arm** of the extensor mechanism around the knee, improving the efficiency of quadriceps contraction.
Patella movement

- Flex-EXT
- Tilt of patella
- ROT
- Shift of patella
- Rotation around the vertical axis

- **Medial tilt:**
  - 30 Flex
  - Flex > 100

- **Lateral tilt**
  - Flex 30-100
- Rotation around the Ant-Post axis

- Flex: 25-130

**FIGURE 11-34.** (a) Medial rotation of the patella. The diagram shows the proximal end of a right tibia and fibula and a right patella. The femur has been removed to emphasize patellar motion. The inferior pole of the patella follows medial rotation of the tibia during both automatic and axial rotation. (b) Lateral rotation of the patella. The inferior pole of the patella follows the lateral rotation of the tibia during both automatic and axial rotation.
Flex: medial shift

Ext: lateral shift

30 flex: no shift
Axis of knee joint

I. Mechanical axis

II. Anatomical axis

III. Vertical axis

IV. Transvers axis

V. Anterior-posterior axis
Diagram showing anatomical and mechanical axes of a leg bone. Key angles and axes are labeled:
- Knee joint plane
- Mechanical axis
- Anatomical axis
- Vertical axis

Angles and measurements:
- 6°
- 81°-85°
- 58°-85°
- 95°-99°
Torsion of the lower limb

I. Femoral neck torsion

II. Tibial torsion
Femoral neck torsion
Normal Femoral Neck Anteversion

Increased Femoral Neck Anteversion

Femoral Neck Retroversion

15° Angle of FNA

45° Angle of FNA

0° Angle of FNA
Tibial torsion

I. External tibial torsion

II. Internal tibial torsion
External tibial torsion
Internal tibial torsion

Prone exam: foot-thigh angle

Internal tibial torsion
2) In-toeing: Tibial Torsion

Supine position

Sitting position
- Retroversion, Ext Rot of Tibia  ➔  toe out
- Anteversion, Int Rot of Tibia  ➔  toe in
Angles of lower limb:

- Valgus angle
- Q angle
Valgus angle

- anatomical axis
- 170-175
Valgus angle

Figure 1. Knee alignment can be categorized as genu valgum (knock-knee), normal or genu varum (bow legged).
Line 1 is from asis to patella
Line 1 represents the pull of the quad

Line 2 is from tubercle to patella
Line 2 represents the patellar tendon and the passive direction of the patella
Q - Angle of the Knee

15 degree

MALE

angle 12°

FEMALE

angle 16°
Q Angle of the Knee

- **Normal**: < 15°
- **Knock-kneed**: > 20°
- **Bow-legged**: < 10°
Thank you
Three mechanisms are commonly held to be responsible for automatic knee rotation.

1) The anterior cruciate ligament becomes 'too short' during terminal extension (Fick, 1911) and the ligament is hence taut prior to maximal extension, causing rotation with further extension (Braus, 1921).

✓ This statement was limited to the anterior fibre bundles by Sieglbauer (1930). The articular surfaces were held responsible for the other 2 mechanisms.

1) 2) The laterally oriented curvature of the (hence 'longer') medial femoral condyle (Langer & Toldt, 1902; Cunningham, 1939) causes automatic rotation in sliding past the medial tubercle of the intercondylar eminence (Gerrish, 1899).

2) 3) The lateral 'shorter' femoral condyle was 'used up' before the 'longer' medial one, resulting in rotation
PFJ FUNCTION

- It works primarily as an anatomical pulley.
- It reduces friction between quadriceps tendon & femoral condyle.
- The ability of patella to perform its function without restricting knee motion depends on its mobility.
PFJ ARTICULATING SURFACE

- The triangular shape patella is the largest sesamoid bone in the body and is a least congruent joint too.
- Posterior surface is divided by a vertical ridge into medial & lateral patellar facets.
- The ridge is located slightly towards the medial facet making the smaller medial facet.
- The medial & lateral facet are flat & slightly convex side to side & top to bottom.
- At least 30% of patella have 2nd ridge separating medial facet from the extreme medial edge known as Odd Facet of Patella.
FEMORAL ARTICULATING SURFACE

- Patella articulate in femur with intercondylar groove or femoral sulcus on anterior surface of distal femur.
- Femoral surface are concave side to side & convex top to bottom but lateral facet is more convex then medial surface.
PFJ congruence

- The vertical position of patella in femoral sulcus is related to length of patellar tendon, approximately 1:1 is (referred to as Insall-Salvati index)
- An excessive long tendon produce an abnormally high position of patella on femoral sulcus known as patella alta.
- In neutral or extended knee, the patella has little or no contact with the femoral sulcus beneath.
At 10° – 20° of flexion – contact with inferior margin of medial & lateral facet.

By 90° of flexion – all portion of patella contact with femur except the odd facet.

Beyond 90° of flexion – medial condyle inter the intercondylar notch & odd facet achieves contact for the first time.

At 135° of flexion – contact is on lateral & odd facet with medial facet completely out of contact.
PATELLO FEMORAL JOINT STABILIZER
MEDIAL-LATERAL PFJ STABILITY

- PFJ is under permanent control of 2 restraining mechanism across each other at right angle.
  - Transvers group of stabilizer
  - Longitudinal group of stabilizer
Transvers stabilizer –

- Medial & lateral retinaculum
- Vastus Medialis & Lateralis
- The lateral PF ligament contributes 53% of total force when in full extension of knee.
LONGITUDINAL STABILIZATION

- Patellar tendon – inferiorly
- Quadriceps tendon – superiorly
MEDIAL-LATERAL POSITIONING OF PATELLA/PATELLAR TRACKING

- When the knee is fully extended & relax, the patella should be able to passively displaced medially or laterally not more then one half of patella.
- Imbalance in passive tension or change in line of pull of dynamic structures will substantially influence the patella.
- Abnormal force may influence the excursion of patella even in its more secure location within intercondylar notch in flexion.
MEDIAL & LATERAL FORCE ON PATELLA

- Since the action line of quadriceps & patellar ligament do not co-inside, patella tend to pulled slightly laterally & increase compression on lateral patellar facets.

- Larger force on patella may cause it to subluxation or dislocate off the lateral lip of femur.

- Genu valgum increase the obliquity of femur & oblique the pull of quadriceps.
Femoral anteversion & tibial torsion creates an increased obliquity in patella predisposing to excessive lateral pressure or to subluxation or dislocation.

Excessive tension in lateral retinaculum (or weakness of VMO) may cause the patella to tilt laterally.

Insufficient height of lateral lips of femoral sulcus may create patellar subluxation or fully dislocation, even with relatively small lateral force.
PATELLAR INFLUENCE ON QUADRICEPS FUNCTION

- Patella lengthens the MA of quadriceps by increasing the distance of quadriceps tendon & patellar tendon from the axis of the knee joint.
- The patella, as an anatomic pulley, deflects the action line of quadriceps away from the joint centre, increasing the angle of pull & enhancing extension torque generation.
- Pull of quadriceps also creates anterior translation of tibia on femur increasing ACL restraint.
QUADRICEPS ACTIVITIES DURING WEIGHT-BEARING

- **When an erect posture is attained** –
  - Minimal activity of quadriceps because the LOG passes just anterior to knee axis results in a gravitational extension torque that maintains the joint in extension.

- **In weight-bearing with the knee slightly flexed** –
  - The LOG pass posterior to knee joint axis
  - As the gravitational torque tend to promote knee flexion, the activity of quadriceps is necessary to counterbalance the gravitational torque and maintain the knee joint in equilibrium.
LOG & MOVEMENT ARM (MA) DURING SQUATTING
QUADRICEPS ACTIVITIES DURING NON-WEIGHT-BEARING

- The *MA of resistance is minimal* when the knee is flexed to 90° but increases as knee extension progresses.
- Therefore, greater quadriceps force is required as the knee approaches full extension.
- The *opposite* happens during weight-bearing activities.
LOG & MOVEMENT ARM (MA) DURING NON-WEIGHT BEARING
QUADRICEPS STRENGTHENING: WEIGHT-BEARING VERSUS NON–WEIGHT-BEARING

- Weight-bearing quadriceps exercises as squat & leg press resulted in a posterior shear force at knee throughout the entire ROM.
- There was *No Anterior Shear* anywhere in the ROM.
- In contrast, anterior shear force in a non–weight bearing knee extension exercise maximal anterior shear occurring between 20° and 10°.
Quadriceps Strengthening: Weight-Bearing Versus Non-Weight-Bearing Cont...

- A *Posterior Shear Force* was also found during *Non-Weight-Bearing Exercise*, only between $60^0$ and $101^0$ of flexion.

- *Weight Bearing Exercises* are often prescribed after *ACL or PCL injury* because of less stressful, more like functional movements & safer than non-weight-bearing exercises.
OTHER MUSCLES HELPING KNEE EXTENSION

- The actions of the *Gluteus Maximus & Soleus Muscles* can influence knee motion in weight-bearing.
- Although they do not cross the knee joint, these muscles are capable of assisting with knee extension.
ILIOTIBIAL BAND OR IT TRACT

- **Proximally** –
  - The IT band is from Tensor Fascia Lata (TFL), Gluteus Maximus & Gluteus Medius muscles.

- **Distally** –
  - Attach to lateral intermuscular septum & inserts into the Anterolateral Tibia (*Gerdy’s Tubercle*).
  - IT band also attaches to patella via lateral PF ligament of lateral retinaculum.
AXN:

- Reinforcing anterolateral aspect of knee joint
- Assisting ACL in checking posterior femoral or anterior tibial translation when the knee joint is nearly full extension.
- With the knee in flexion, the combination of IT band, LCL & popliteal tendon increases the stability of lateral knee.
AXN LINE FOR ITB

- In extended knee –
  - IT band moves anterior to the knee joint axis.

- In flexed knee –
  - IT band moves posteriorly over the lateral femoral condyle as the knee is flexed.

- The IT band, therefore, remains consistently taut, regardless of hip or knee’s position.