Biomechanics of the Knee

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ESSENTIAL BASIC SCIENCES FOR ORTHOPAEDICS

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REVIEW OF ORTHOPAEDICS

MILLER
SECOND EDITION
Knee Biomechanics

**Kinematics**
Range of Motion
Joint Motion

**Kinetics**
Knee Stabilisers
Joint Forces
Axes
‘The Mechanical Stresses to which living tissues are subjected under physiological conditions’

Maquet 1976
Knee Motion

Not a simple hinge joint

4 Degrees of Motion:

1. Flexion-Extension Rotation
2. Axial (Internal-External) Rotation
3. Anterior-Posterior Translation (Roll Back)
4. Ad-Abduction (Varus-Valgus) Rotation
Flexion-Extension

(-10° extension - 130°)

Functional ROM: 0-90°
117° squatting/lifting
110° sitting from TKR
18-20° / 30° stance phase
75° / 90° swing phase
Knee Motion

Radius of curvature of femoral condyles not circular

Complex series of movements about a changing instant centre of rotation (i.e. polycentric rotation)

Cam-shaped curve about femoral condyle
Knee Motion

Franckel et al (1971)

Structural knee derangements can displace instantaneous centre of rotation along its path. Motion about that altered point cannot be accommodated without ligament stretching +/- compressive loading to articular surfaces.

N.B. BH MM tears
ACL injuries
post-traumatic OA
Axial Rotation

Axis around MFC
Varies with Flexion
“Screw Home” action of cruciates at full extension
Normal maximum rotation:
+/~30° at 90°
(45° ER / 30° IR)(6-25°)
‘Screw-Home Mechanism’

Femur internally rotates
during last 15° extension
(external tibial rotation maximal with full extension just prior to heel strike)
Related to size & convexity
of MFC & musculature
Anterior-Posterior Translation

‘Rollback’ phenomenon

PCL (in flexion)

ACL (in extension)

Med condyle: ~5mm
Lat condyle: ~15mm
Rollback Phenomenon

Implements function of Quadriceps
Increases lever arm in flexion
Rollback Phenomenon

Posterior Rollback of the femur on the tibia during knee flexion increases maximum knee flexion

N.B. PCL sacrificing TKR
Ad~Abduction

Normal during many human activities
Abduction during Normal walking $\sim 8^\circ$
Medial Lateral Translation

Inhibited by:
Medial cruciate ridge
Ligament resistance
Patellofemoral Motion

Rotation during walking is

~ 6° of IR and ~ 8° of ER

Can >x2 for other activities
Kinetics

Extension: Quadriceps Mechanism

Flexion: Hamstrings

Stabilisers: (Bony contours) Ligaments Musculature
# Knee Stabilizers

<table>
<thead>
<tr>
<th>DIRECTION</th>
<th>STRUCTURES</th>
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</thead>
<tbody>
<tr>
<td>Medial</td>
<td>Superficial MCL (1°), joint capsule, MM, ACL/PCL</td>
</tr>
<tr>
<td>Lateral</td>
<td>Joint capsule, IT band, LCL (mid), LM, ACL/PCL (90°)</td>
</tr>
<tr>
<td>Anterior</td>
<td>ACL (1°), joint capsule</td>
</tr>
<tr>
<td>Posterior</td>
<td>PCL (1°), joint capsule; PCL tightens with IR</td>
</tr>
<tr>
<td>Rotatory</td>
<td>Combinations~MCL checks ER; ACL checks IR</td>
</tr>
</tbody>
</table>
ACL

Peak Loads: 170 N during walking
500 N during running

Ultimate Strength: ~ 1750 N

Failure due to:
Serial Tearing at 10-15% elongation
Knee Stabilizers

**Collateral ligaments**
- varus-valgus stability

**Cruciate ligaments**
- A-P stability
- rotational stability
- varus-valgus stability
Knee Stabilizers
Meniscal Action

Reduce effective incongruity of knee articulation
Spread the contact between condyles over an increased area
Joint Forces

Measurement in knee not yet possible by direct means

1° motion of the knee: Flexion~Extension

**Coronal Plane**
Static analysis with knee fully extended

**Sagittal Plane**
Dynamic assessment
Forces in coronal plane
Forces in coronal plane

Two-legged Stance

85% tbw

bw ~ wt of legs below knees

~ 43% bw per knee

Single-legged Stance

tbw ~ mass of leg below knee on supporting side
Forces in the sagittal plane

Tibiofemoral joint force increases with increasing flexion angle

TF jt force is directly proportional to bw
(rarely exceeds x8 bw even in extreme flexion)
Joint Forces

Tibiofemoral Loading

During walking = $3-4 \times \text{BW}$

Peak Forces: $20^\circ$ flexion (stance phase)

Medial Condyle more congruent

High Loading phase assoc. with LCL loading + abduction

Menisci $\frac{1}{3}-\frac{1}{2} \text{BW}$
Forces & Motion in the knee
Patellofemoral Loading

\[ F'p = b \cdot Fg / a \]

Quadriceps anterior subluxing force at 0-45° ROM
Patellofemoral Loading

Thickest cartilage in body

111 N (25 lbs) at 15° (walking) \(1/2\) bw

1557 N (347 lbs) at 30° (Stair ascent)

4003 N (893 lbs) at 110° (knee bends) \(\sim x7\) bw
**Patellofemoral Loading**

In TKR:
- External rotation of femoral component
- Lateral placement of femoral & tibial components
- Medial placement of patellar component
- Avoidance of malrotation of the tibial component (avoid internal rotation)
Axes

Mechanical Axis

Body Center of Gravity

Hip Center

3°

Vertical Axis

Anatomic Axis

Knee Center

6°

Ankle Center

2-3°

9°
The Q-angle
Arthrodesis

0 ~ 7° Valgus

10 ~ 15° Flexion
So, what did I learn?

Complex joint
Flexion-Extension ROTATION
Screw home mechanism
Rollback phenomenon
Tibiofemoral loading 3-4x bw during walking
Patellofemoral joint
Importance of menisci