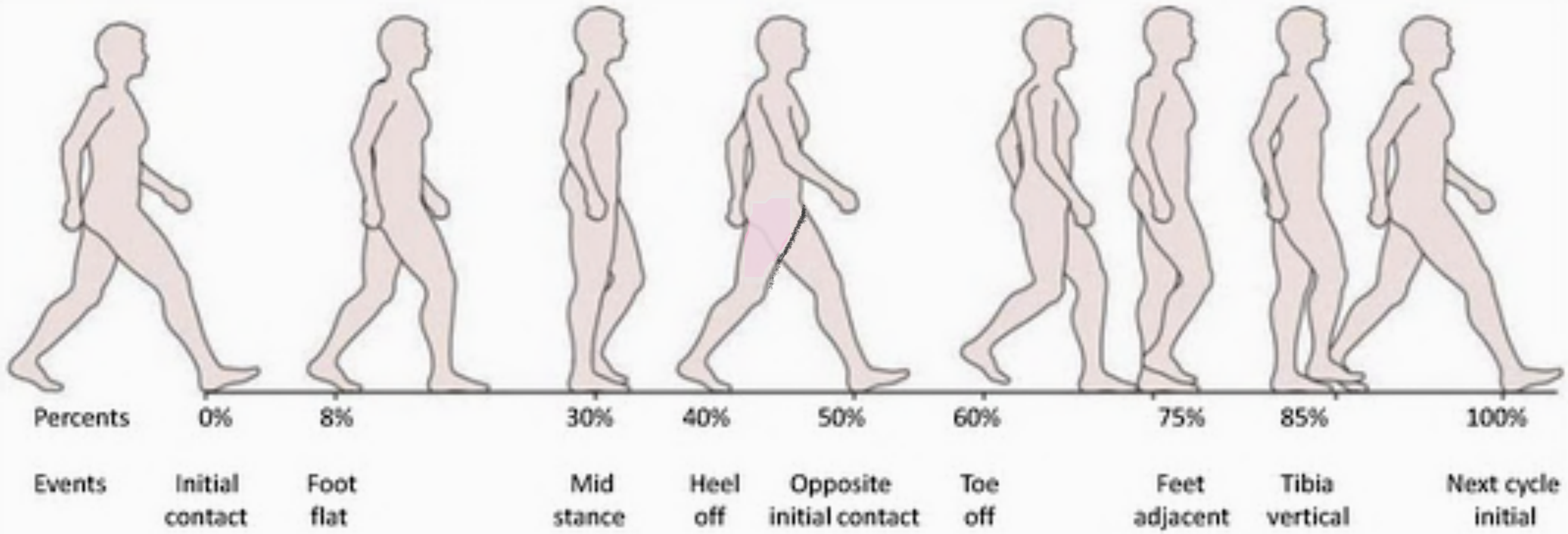
# Kinematics and kinetics of gait

OLDEN Theresa
Formation FMH de chirurgie orthopédique et traumatologie
13.02.2020

# GAIT CYCLE

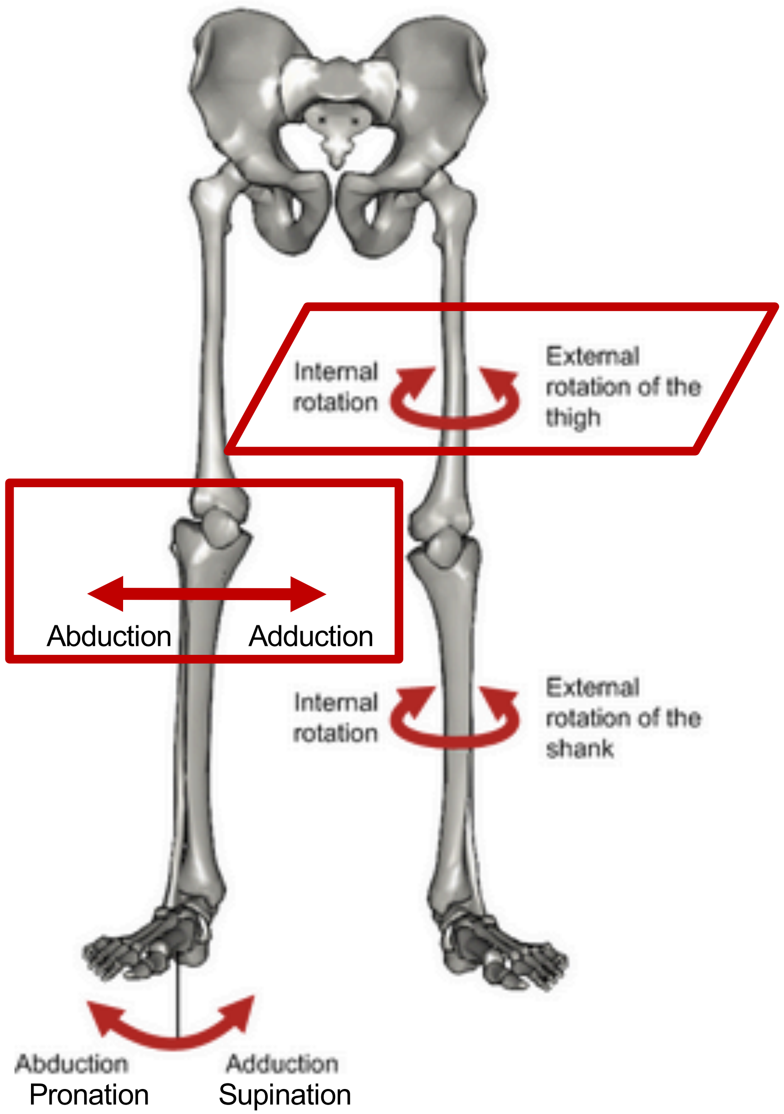
MEDICOL

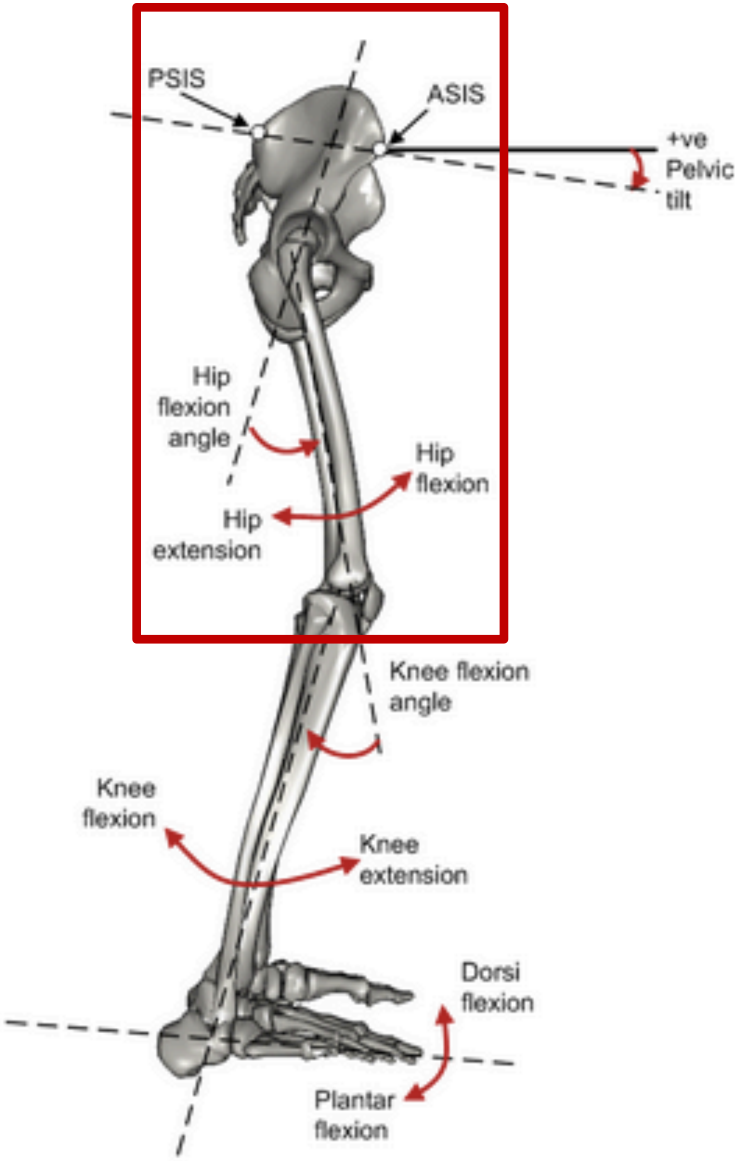



| Periods | Loadding response | Mid stance | Terminal stance | | Pre swing | Initial swing | Mid swing | Terminal swing |
|---|---|---|---|---|---|---|---|---|
| Tasks | Initial double limb support | Initial single limb support | | | Second double limb support | Second single limb support | | |
| Phase | Statique<br>Stance phase | | | | | Dynamique<br>Swing phase | | |
| Per | | | | Push off | | | | |
| Cycle | One cycle | | | | | | | |

# FRONTAL, TRANSVERSE AND SAGITTAL PLANE JOINT ANGLES

MEDICOL

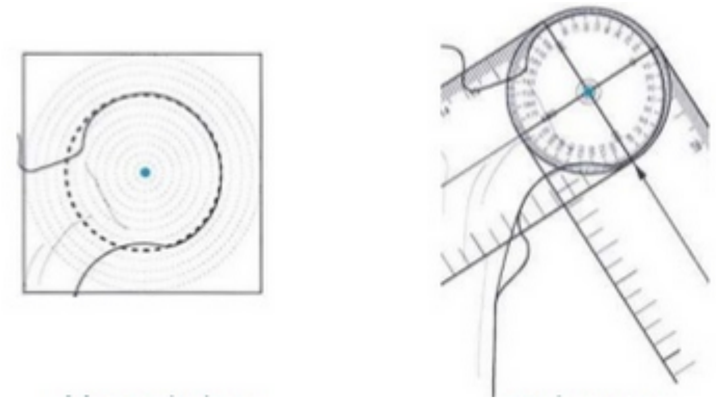


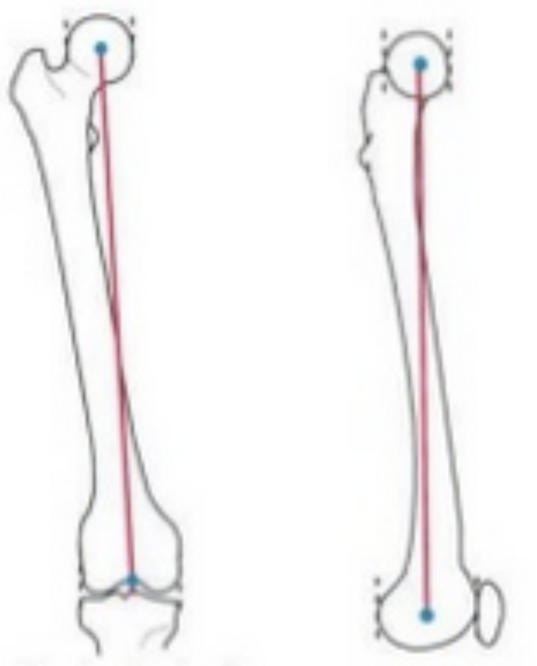

PSIS=Posterior superior iliac spine

ASIS=Anterior superior iliac spine

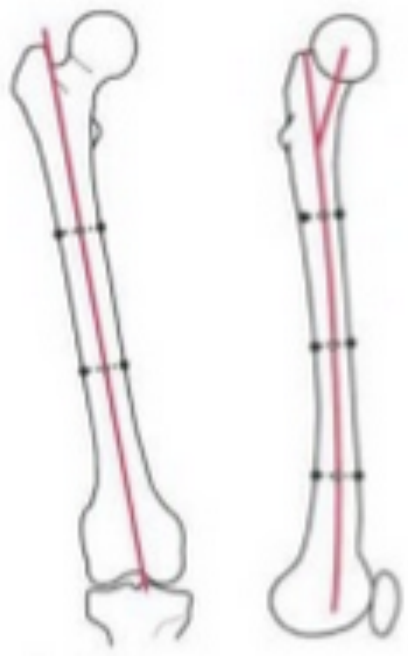
# MECHANICAL AND ANATOMICAL AXIS



Joint center



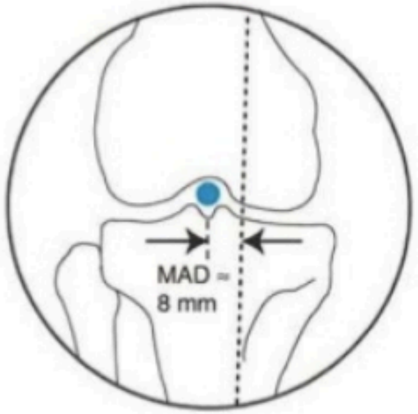
Mechanical axis



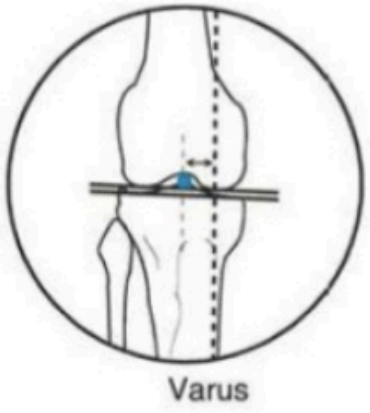
Anatomical axis

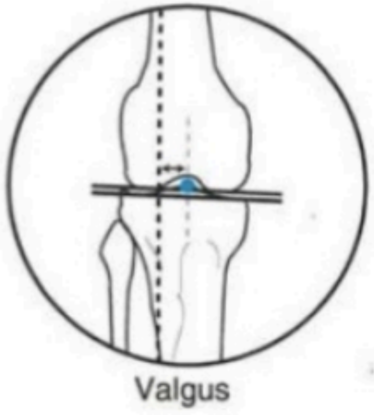
# JOINT ALIGNEMENT

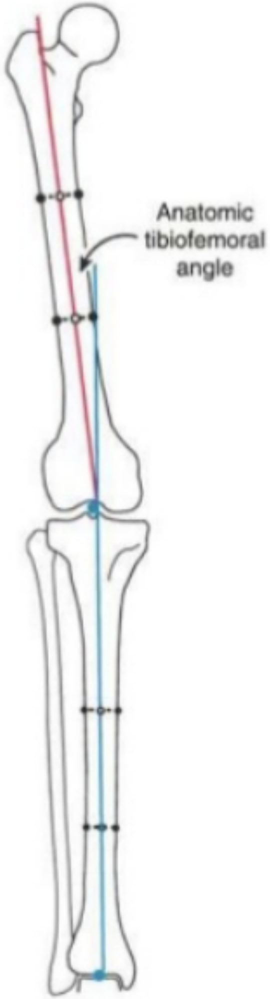
Mechanical axis of the lower limb

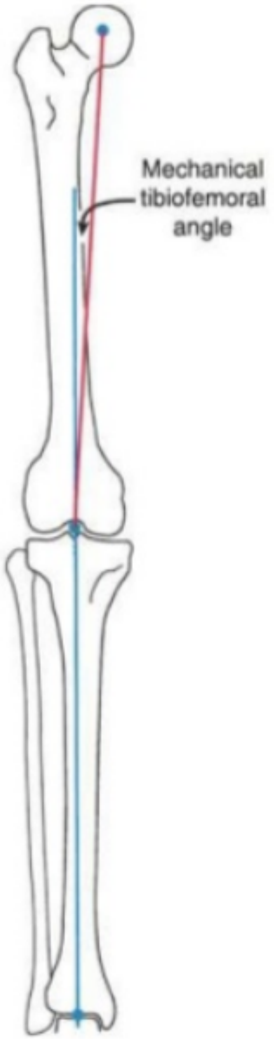



*MAD* - mechanical axis deviation (mm)

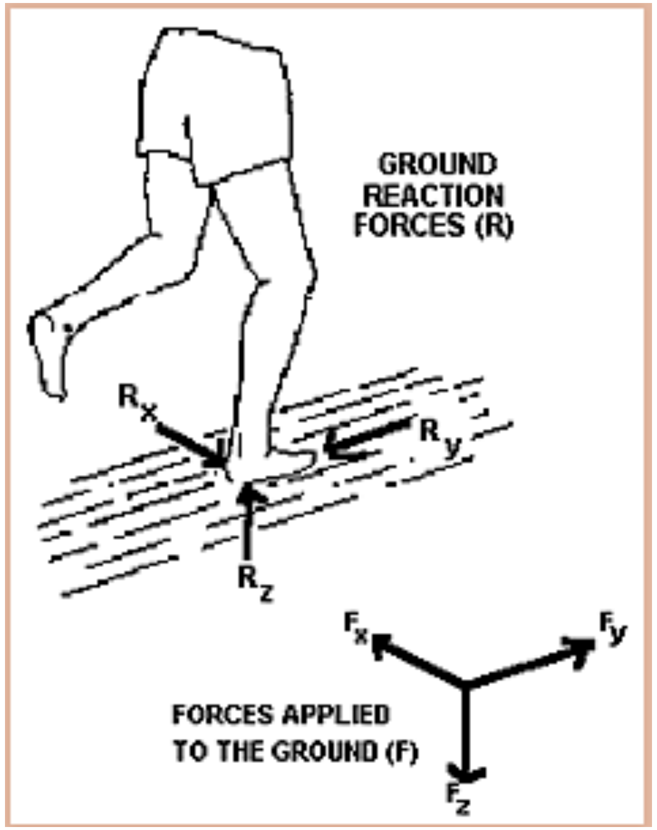


# GROUND REACTION FORCE



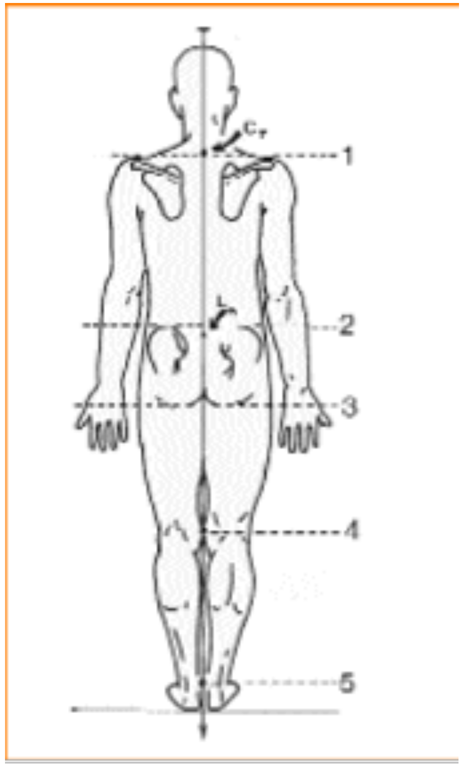
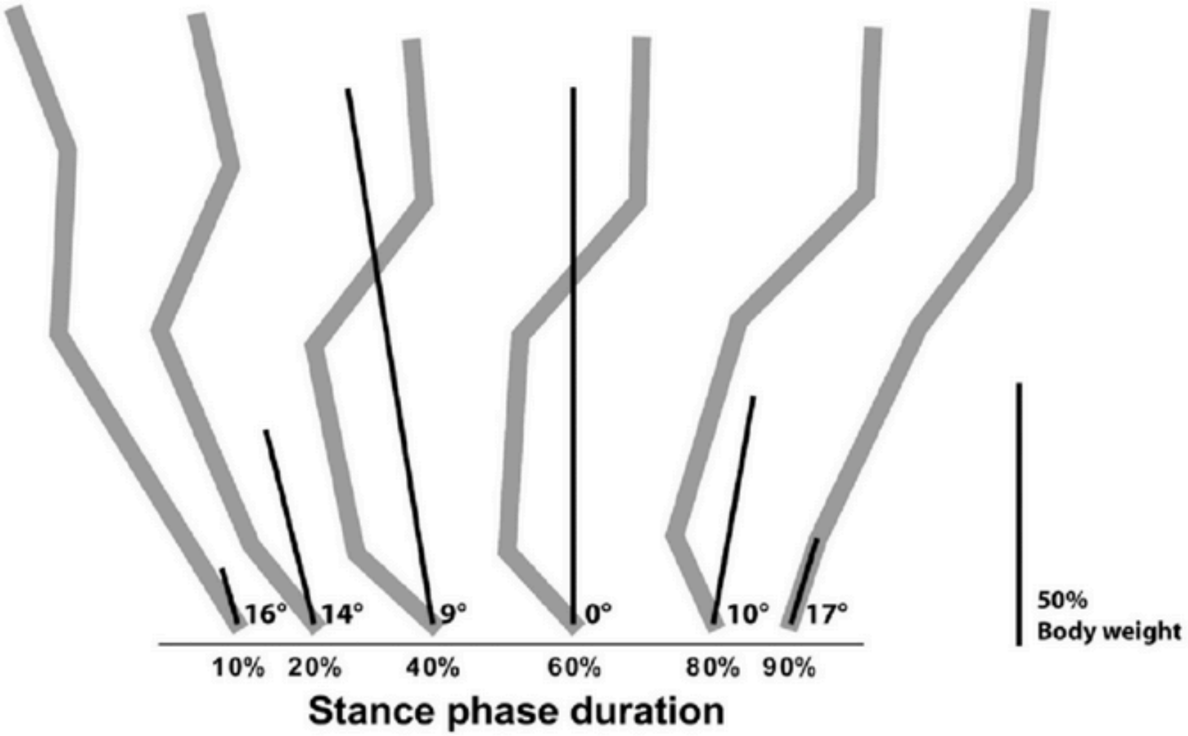




**Fig. 1. Schéma des conditions mécaniques normales de la posture bipède (plan frontal).**

La ligne de gravité suit les apophyses épineuses de C7 à S1, elle tombe dans la ligne inter-fessière et arrive au sol entre les deux malléoles. Les épaules sont horizontales (1), le bassin (2) et les plis fessiers (3) également. Les condyles internes du genou (4) et les malléoles (5) se touchent.



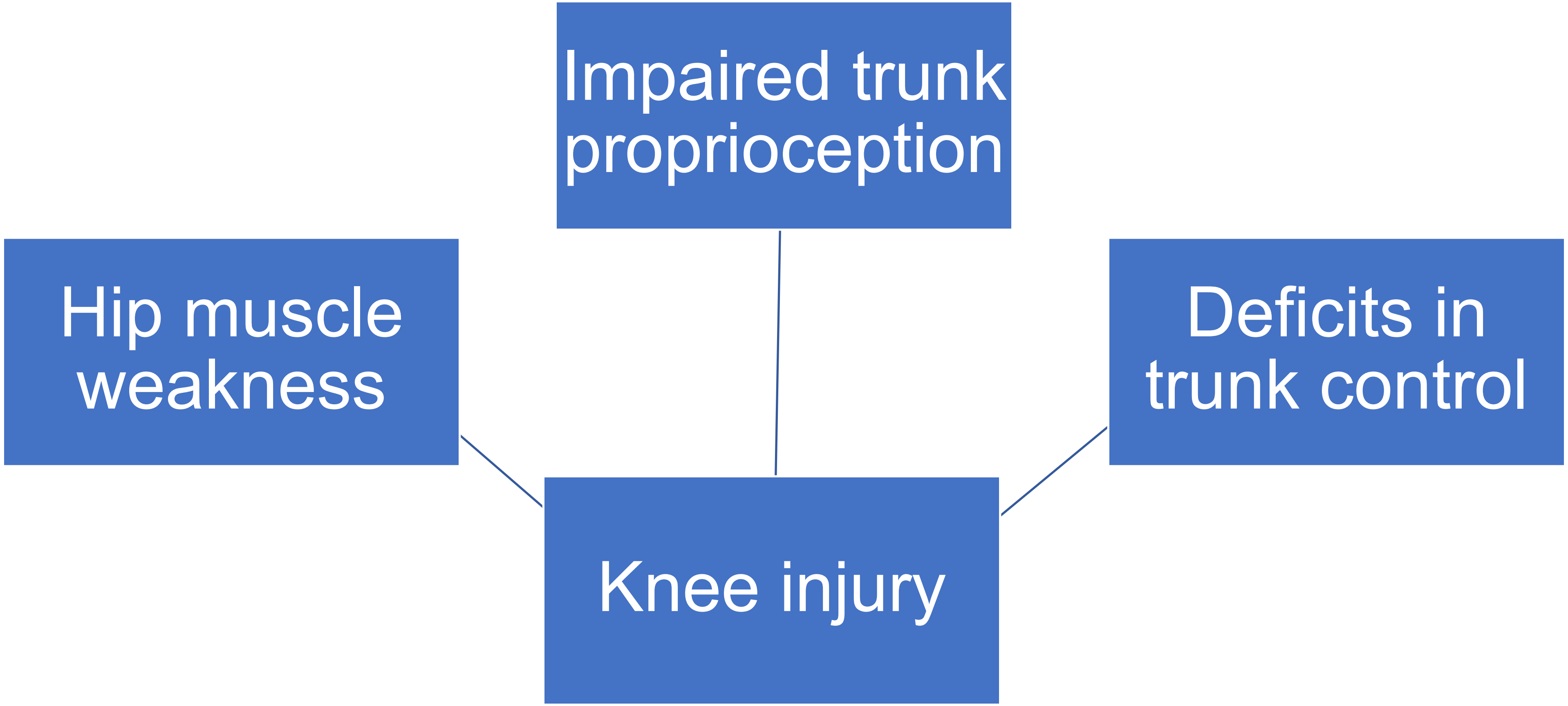
## CHRISTOPHER M.POWERS

# THE INFLUENCE OF ABNORMAL HIP MECHANICS ON KNEE INJURY: A BIOMECHANICAL PERSPECTIVE

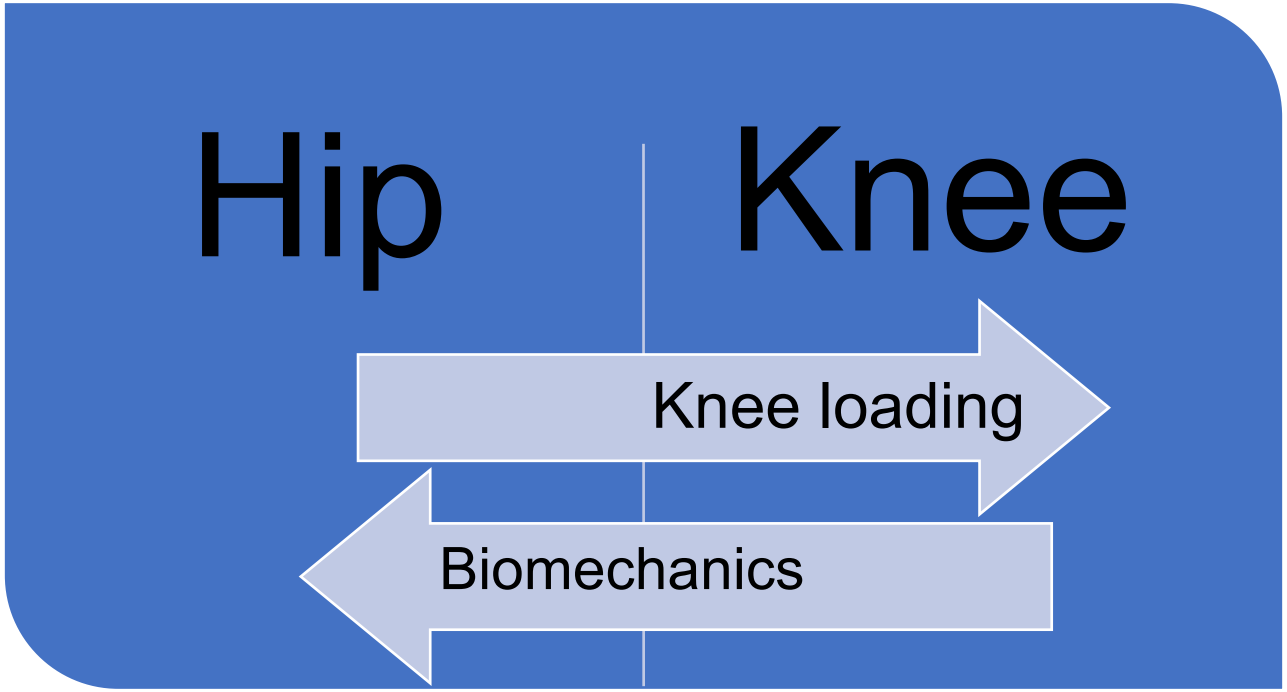
- Journal of orthopaedic Sports Physical Therapy
- February 2010
- Review: Level of evidence 5

| Strength | Level | Design | Randomization | Control |
|---|---|---|---|---|
| High | Level 1 | Randomized control trial (RCT) | Yes | Yes |
| | | Meta-analysis of RCT with homogeneous results | No | |
| | Level 2 | Prospective comparative study (therapeutic) | No | Yes |
| | | Meta-analysis of Level 2 studies or Level 1 studies with inconsistent results | No | |
| | Level 3 | Retrospective Cohort Study | No | Yes |
| | | Case-control Study | No | Yes |
| | | Meta-analysis of Level 3 studies | No | |
| | Level 4 | Case Series | No | No |
| | Level 5 | Case Report | No | No |
| | | Expert Opinion | No | No |
| Low | | Personal Observation | No | No |

# Synopsis


Impaired trunk proprioception
Hip muscle weakness
Deficits in trunk control
Knee injury

MEDICOL



# DYNAMIC KNEE VALGUS

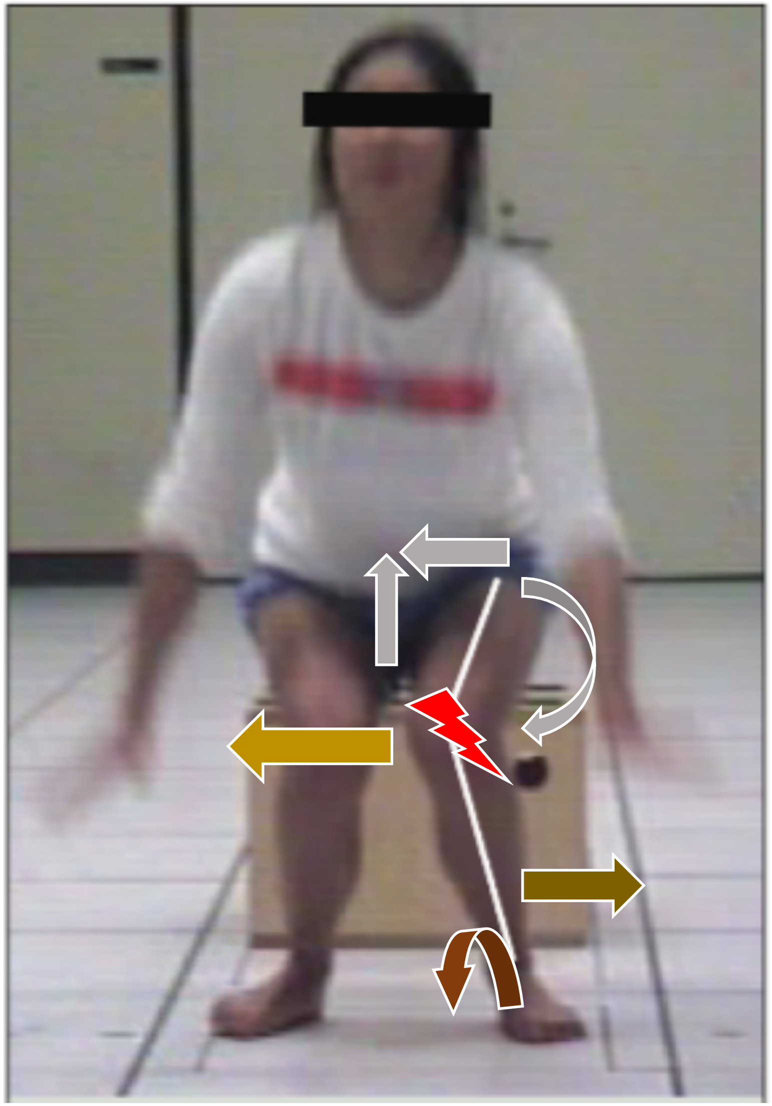
MEDICOL

Loading response phase

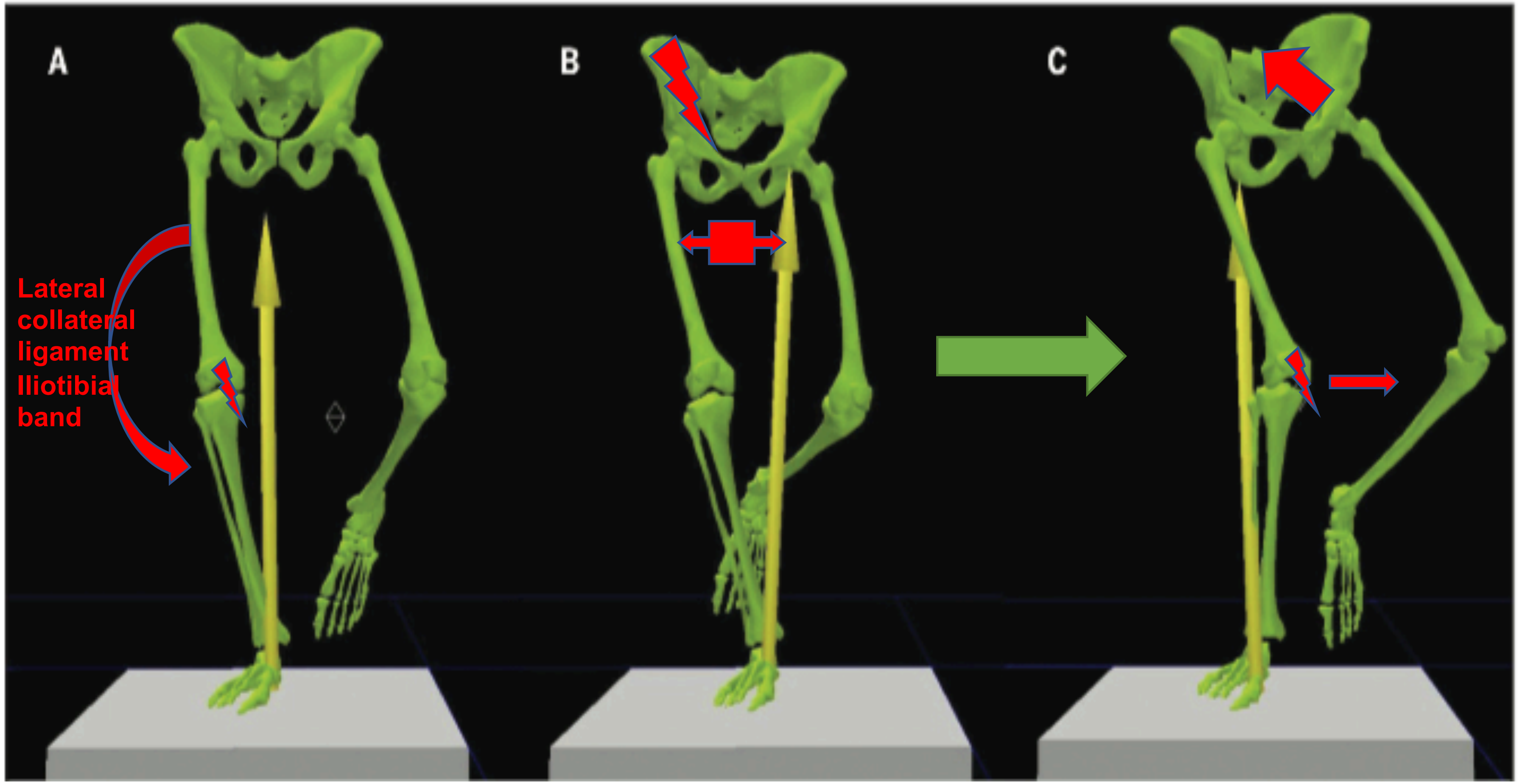
- 10%

Hip
-Flexion
-Adduction
-Internal rotation

→ Medial collapse → Tibia abducts / Foot pronates → ACL injury / Patello femoral joint dys function



# FRONTAL PLANE
# PROXIMAL CONTRIBUTIONS TO ABNORMAL TIBIOFEMORAL JOINT KINETICS




Initial contact of the heel
Varus

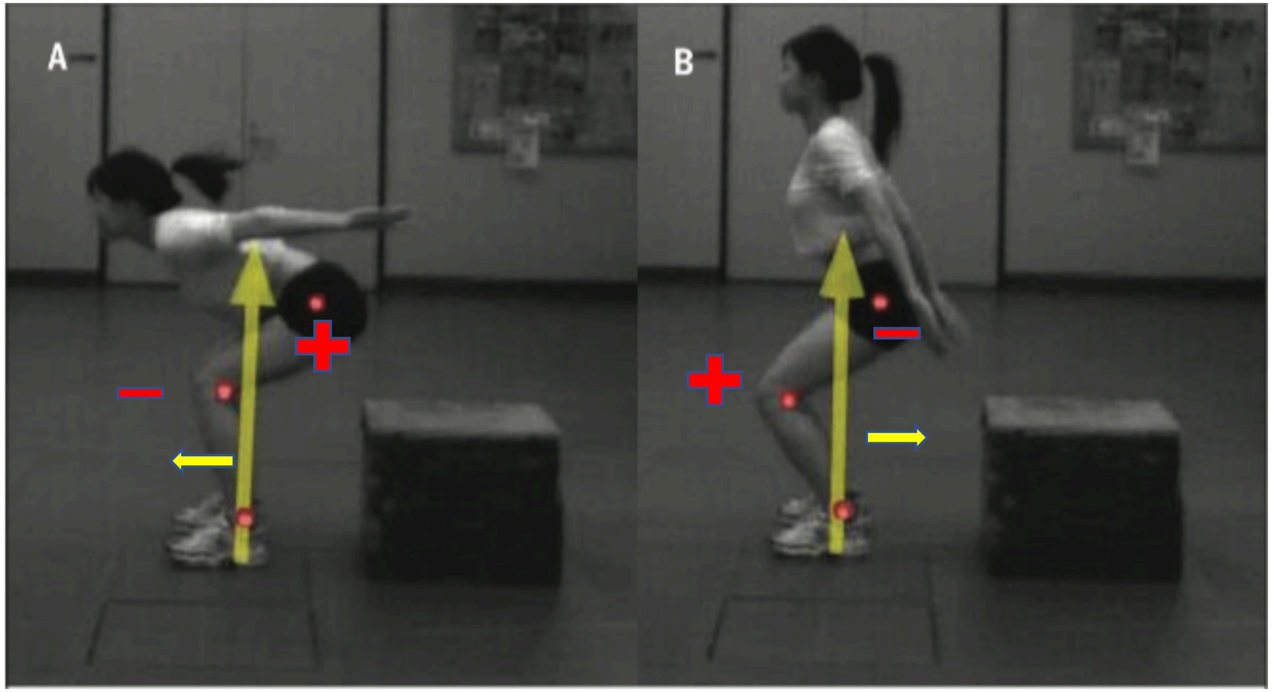
Hip muscle weakness
>Varus
*Trendelenburg*

Shifting center of mass
=> Valgus collapse
*Compensated Trendelenburg*

## SAGITTAL PLANE

MEDICOL

## ORIENTATION OF THE TRUNK → MUSCULAR DEMAND



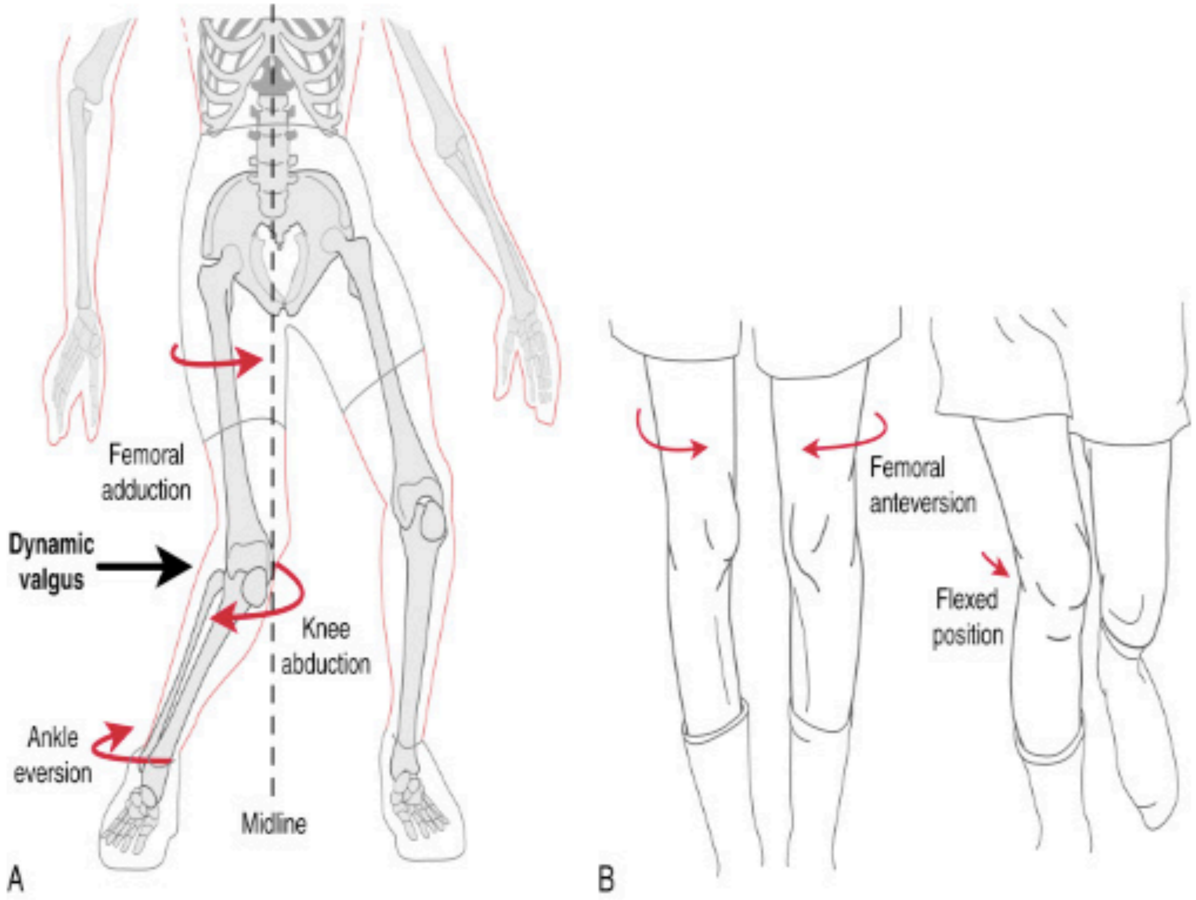
# ACL INJURY

Predictive factors

1. <40° of flexion
2. Females biomechanical profile
   1. Decreased hip and knee flexion
   2. Increased quadriceps activation
   3. Greater knee valgus angles and moments

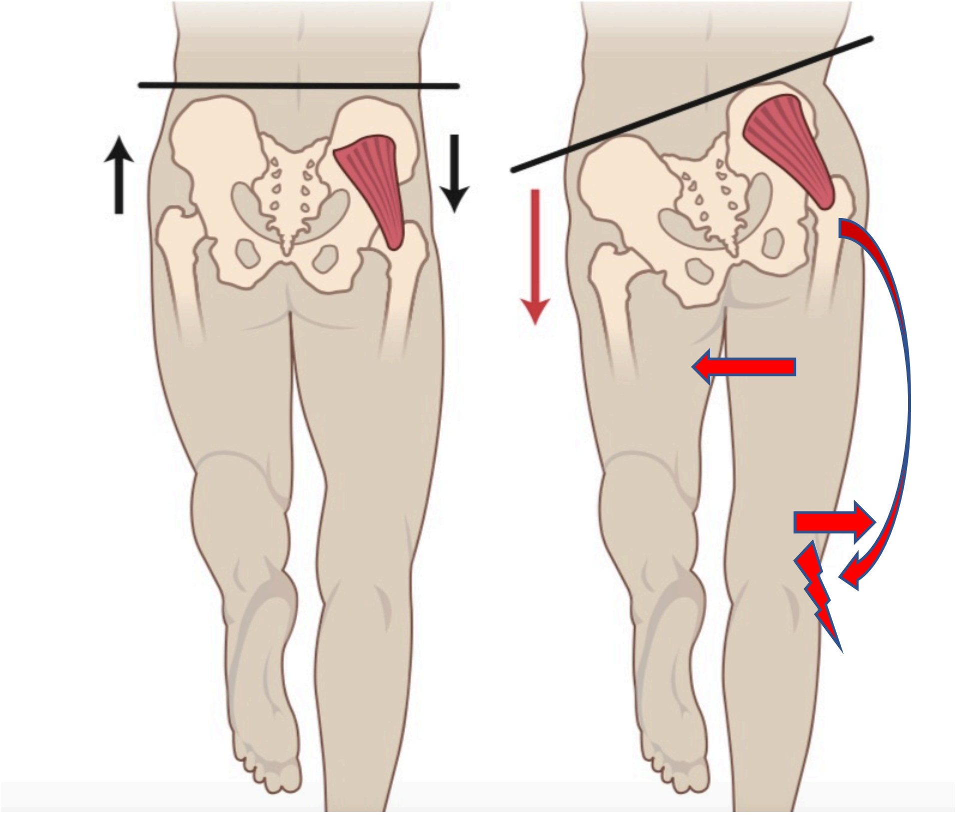
Insufficient deceleration of body center of mass by hip extensors
⇒ Quadriceps and ligaments
⇒ Valgus

Impaired motor control?

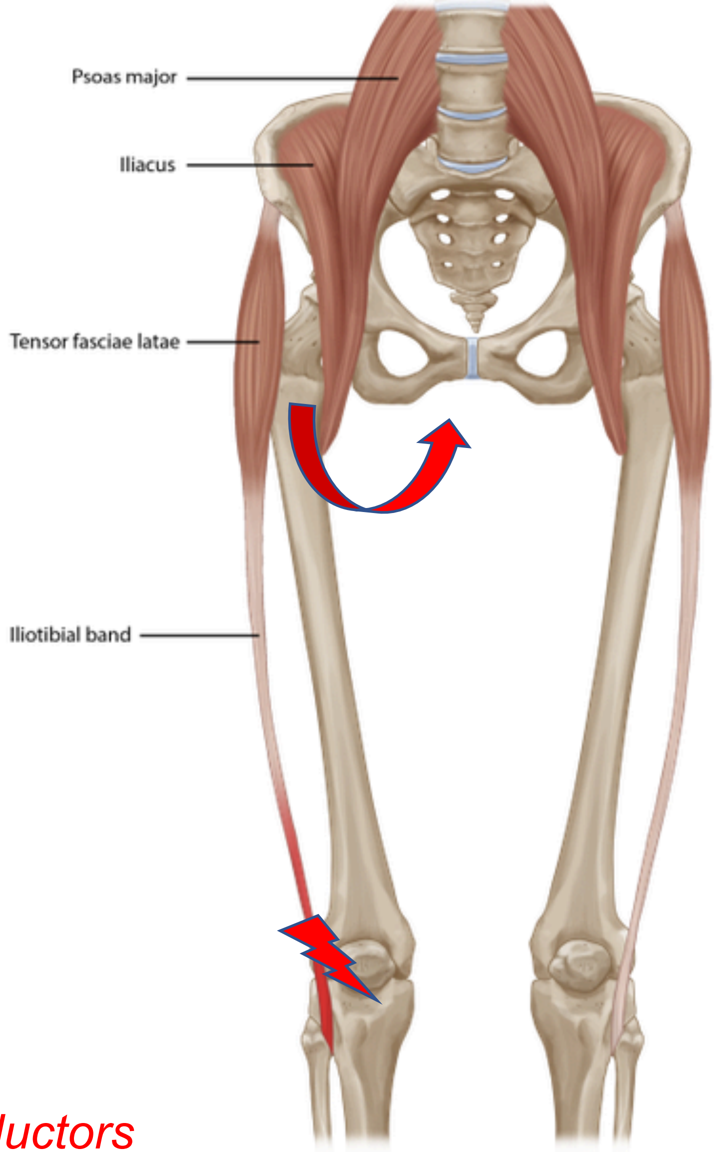


# ILIOTIBIAL BAND SYNDROME

Frontal plane



Transverse plane




**Strengthen hip abductors*

# PATELLOFEMORAL JOINT DYSFUNCTION

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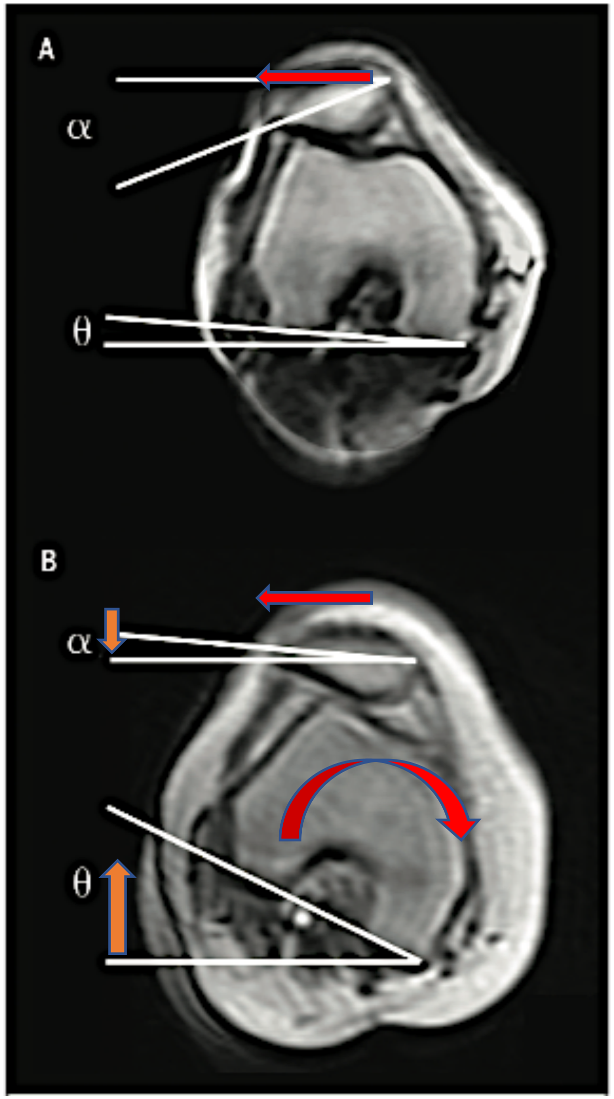
Lateral patellar subluxation




Non-weight-bearing

Weight-bearing

Transverse plane: Internal rotation

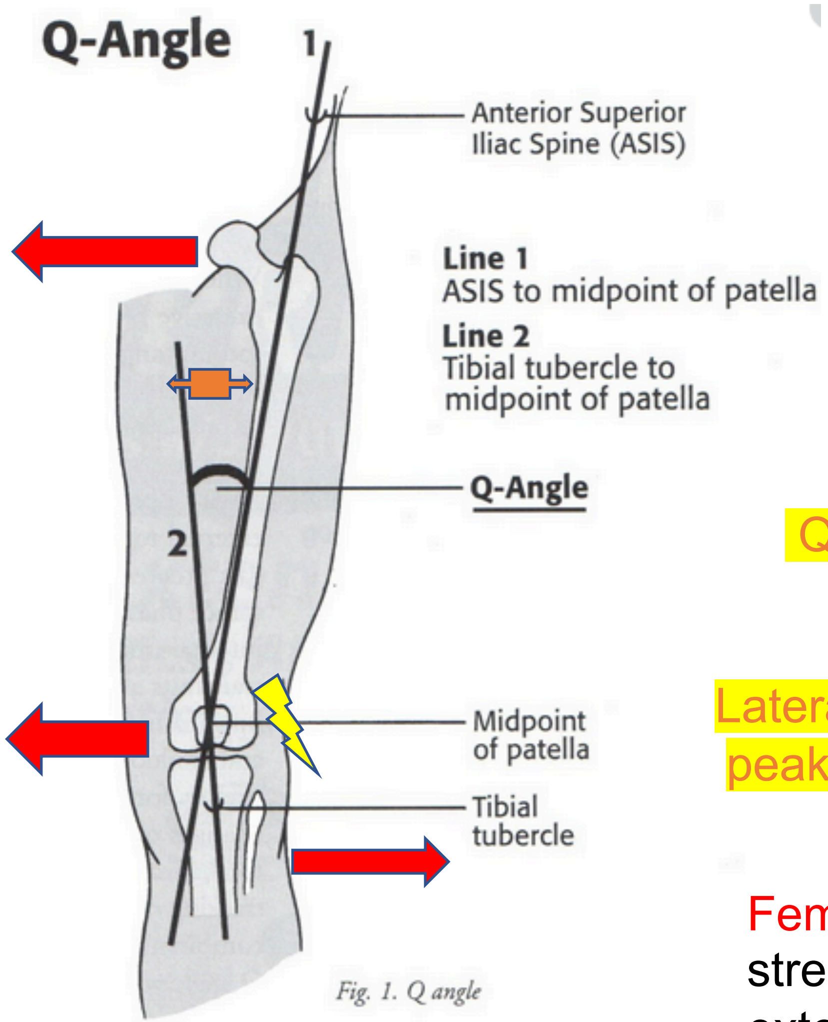



*Fig. 1. Q angle*

Frontal plane: Valgus orientation
=> Increased Q angle

Q angle+10°

Lateral compartment peak pressure+45%

Femmes: Impaired strenghth of hip extensors, abductors and external rotators

# CLINICAL IMPLICATIONS

Frontal plane: hip abductors

Sagittal plane: weakness of posterior rotators, tightness of hip flexors

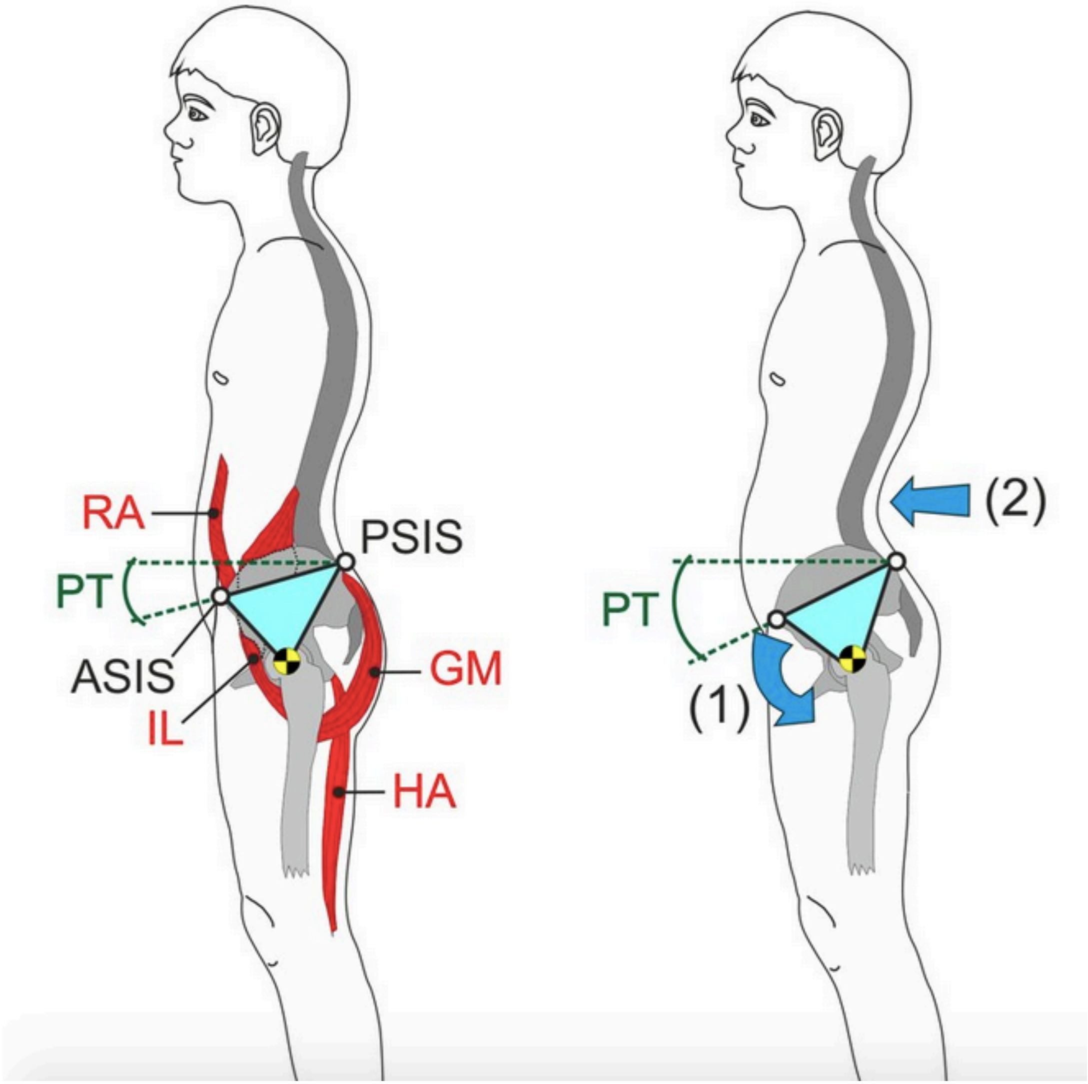
⇒ Compensatory lumbar lordosis

⇒ posterior shift in the trunk position

⇒ Increase of knee flexion moment

⇒ Increase of demand on the knee extensors

⇒ Decreasing hip flexion moment




Anterior pelvic tilt

# DYNAMIC HIP JOINT CONTROL
# GLUTEUS MAXIMUS PERFORMANCE

MEDICOL

<u>Gluteus maximus</u>

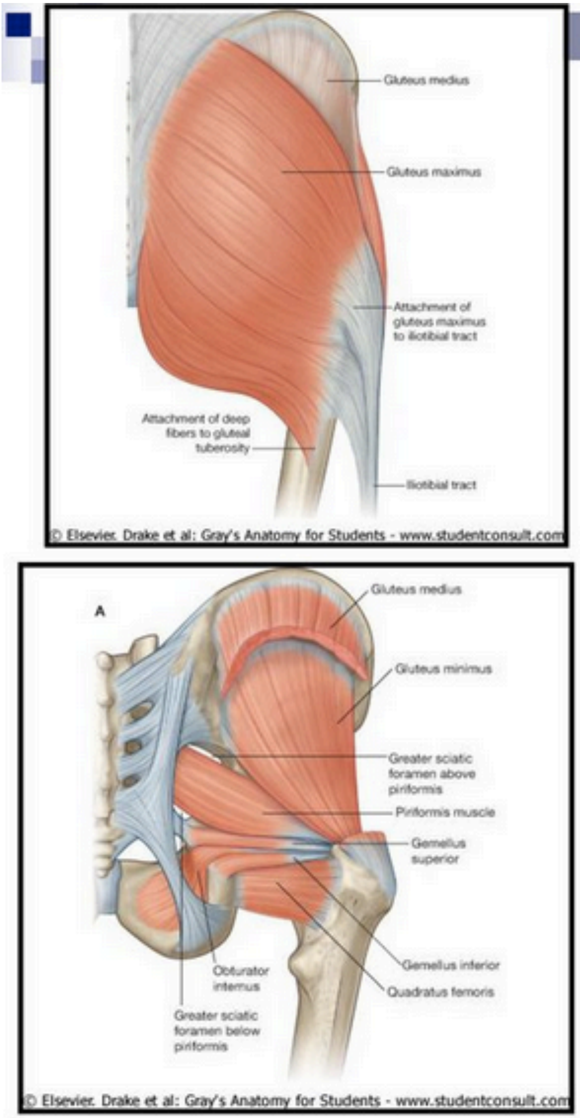
3-dimensional stability→ resisting to:

1. Hip flexion
2. Hip adduction
3. Hip internal rotation

<u>Gluteus medius</u>

Frontal plane stabilization of the femur and pelvis

*Flexion<60°*




## Gluteals

- Gluteus maximus
  - Origin - Ilium, sacrum and coccyx
  - Insertion - Gluteal tuberosity of femur, iliotibial tract
  - Action - Extends thigh, some lateral rotation and abduction
  - Innervation - Inferior gluteal nerve
- Gluteus medius
- Gluteus minimus
  - Origin - Ilium
  - Insertion - Greater trochanter of femur
  - Action - Abduction, medial rotation
  - Innervation - Superior gluteal nerve
- **Lesser Gluteals help stabilize hip to allow fluent bipedal walking**

# Gender differences in gait kinematics for patients with knee osteoarthritis

Angkoon Phinyomark[1], Sean T. Osis[1,3], Blayne A. Hettinga[1,3], Dylan Kobsar[1] and Reed Ferber[1,2,3*]

MEDICOL

- BMC Musculoskeletal Disorders (2016)
- Prospective group-control study, level 1
- Purposes:

  examine

  1. Gender differences in gait biomechanics for patients with mild to moderate knee osteoarthritis (OA) and for healthy individuals
  2. Differences in gait kinematics between healthy gender-matched subjects as compared with their knee OA counterparts

## INCLUSION CRITERIA

1. Clinical criteria for mild-moderate OA according to the American Colllege of Rhumatology
2. Radiograph+
3. Kellgren-Lawrence (K-L) grade<3
4. 100mm Visual pain analog scale (VAS) > 20mm on most days of the previous week
5. Ability to walk on a treadmill without the use of handrails

## EXCLUSION CRITERIA

1. Severe OA (K-L>3)
2. Any kind of treatment
   1. Conservative
   2. Chirurgical
3. OA on any other weight-bearing joint
4. Systemic arthritic condition

# Idiopathic OA of the Knee

MEDICOL

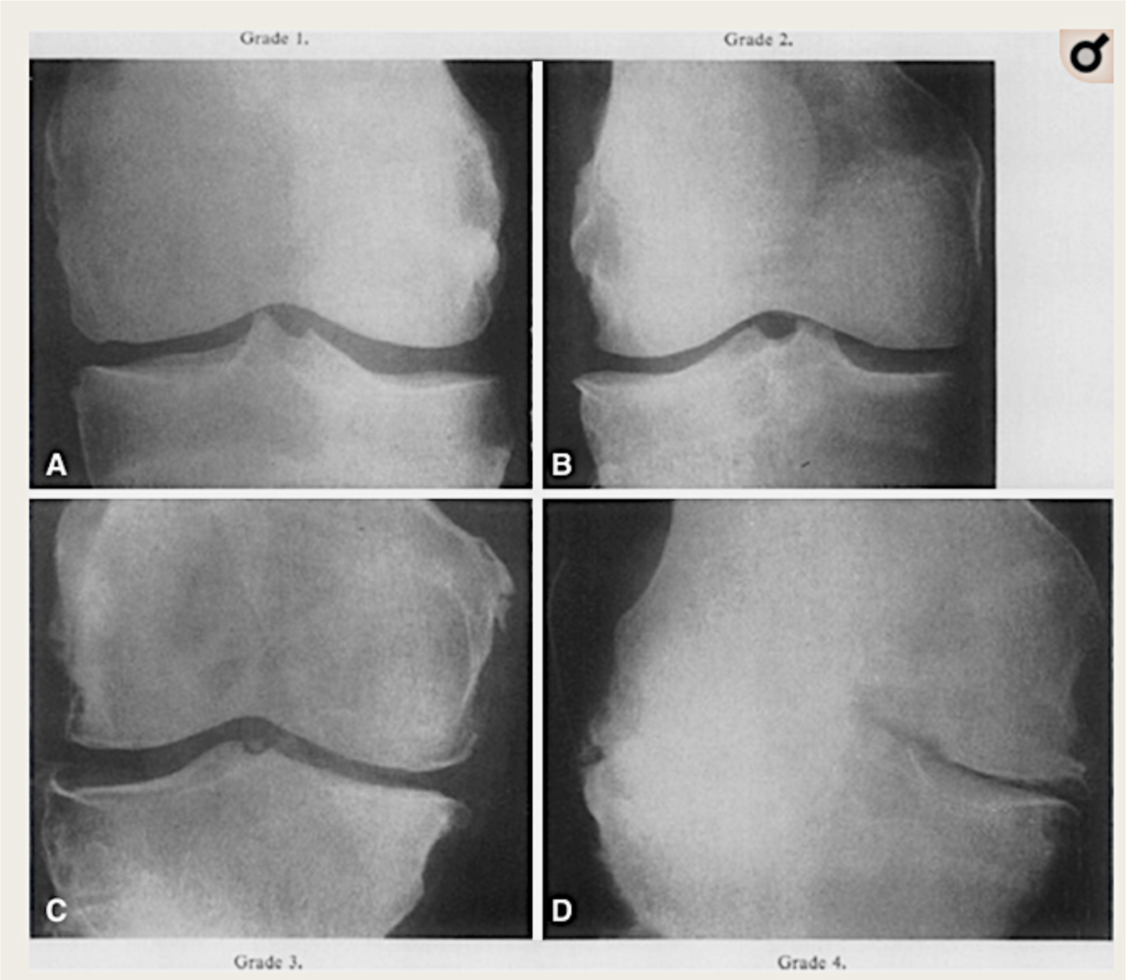
## American College of Rhumatology

| Clinical and laboratory | Clinical and radiographic | Clinical [1] |
|---|---|---|
| Knee pain | Knee pain | Knee pain |
| + at least 5 of 9: | + at least 1 of 3: | + at least 3 of 6: |
| - Age > 50 years | - Age > 50 years | - Age > 50 years |
| - Stiffness < 30 minutes | - Stiffness < 30 minutes | - Stiffness < 30 minutes |
| - Crepitus | - Crepitus | - Crepitus |
| - Bony Tenderness | + Osteophytes | - Bony Tenderness |
| - Bony enlargement | | - Bony enlargement |
| - No palpable warmth | | - No palpable warmth |
| - ESR <40 mm/hour | | |

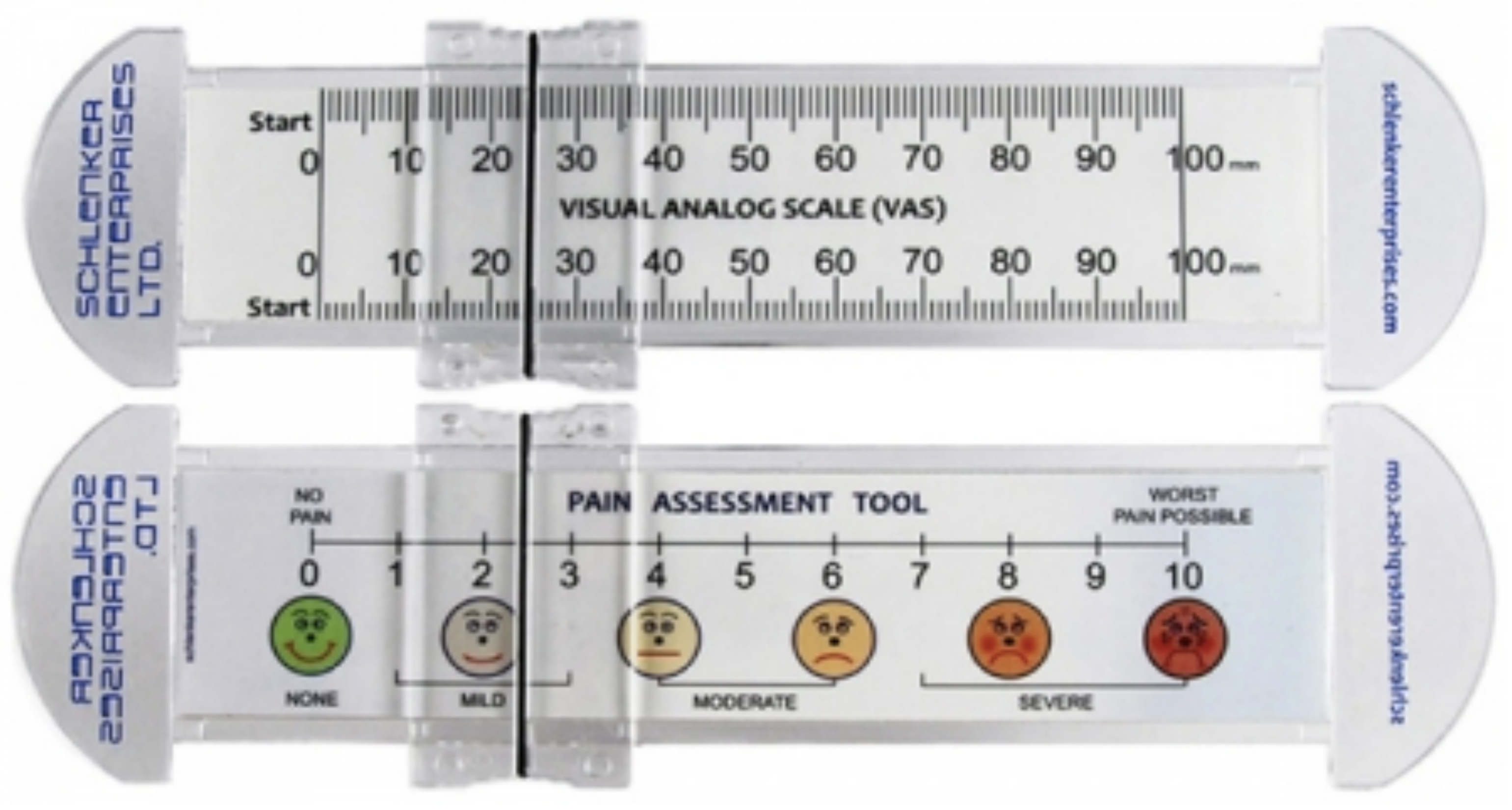
# Kellgren-Lawrence scale

AP knee radiograph

(A) Grade 1: doubtful narrowing of the joint space with possible osteophyte formation
(B) Grade 2: possible narrowing of the joint space with definite osteophyte formation
(C) Grade 3: definite narrowing of joint space, moderate osteophyte formation, some sclerosis, and possible deformity of bony ends
(D) Grade 4: large osteophyte formation, severe narrowing of the joint space with marked sclerosis, and definite deformity of bone ends



# 100MM VISUAL PAIN ANALOG SCALE



# PARTICIPANTS

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## 100 OA+

33-72 years
45 males
55 females
Categories according to BMI

1. 18-25: Normal weight
2. 30-40: obese
3. >40: severly obese

Symptomatic unilateral or bilateral knee OA

## 43 OA –

40-79 years
18 males
25 females
Categories according to BMI
No musculoskeletal injuries during the prior 6 months
No clinical signs/symptoms of knee OA

# DATA COLLECTION

VICON motion capture system

3-dimensional kinematic data

Walking treadmill

14 anatomic landmarks: removed after static trial=> 11 markers for walking kinematic data

2 markers on each shoe: toe-off events

30sec, 20-30 consecutive strides, 1.0-1.3 m/s

Standard shoes

**Fig. 1** Photograph of the clinical laboratory used in this experiment

# DATA PROCESSING



<u>8 discrete variables for each waveform :</u>

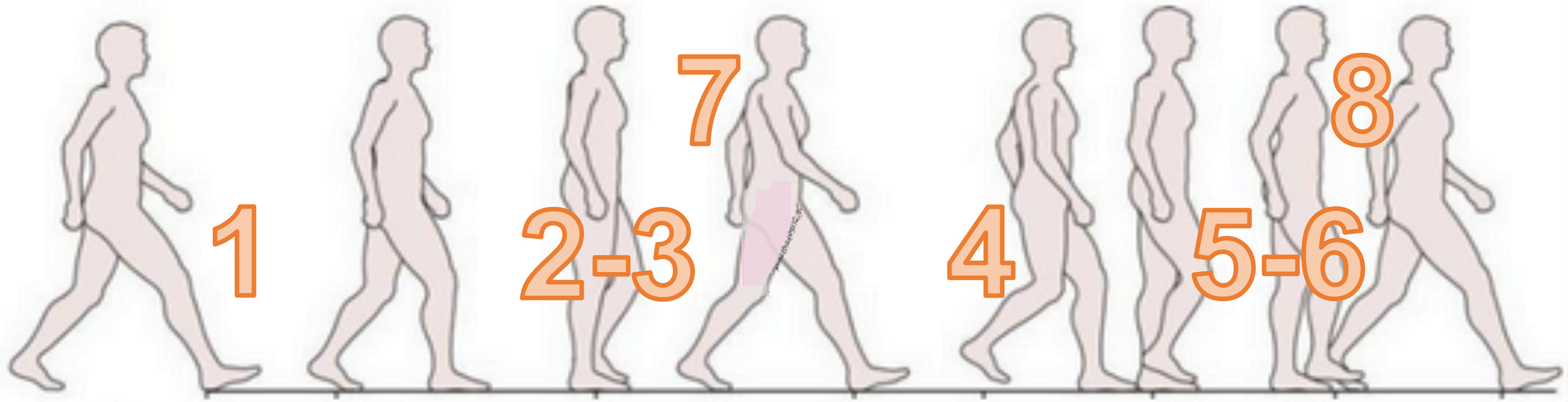
(1) angle at touchdown

(2–3) maximum and minimum peak angles during stance phase

(4) angle at toe-off

(5–6) maximum and minimum peak angles during swing phase

(7–8) ROM angles during stance phase and swing phase




| Percents | 0% | 8% | 30% | 40% | 50% | 60% | 75% | 85% | 100% |
|---|---|---|---|---|---|---|---|---|---|
| Events | Initial contact | Foot flat | Mid stance | Heel off | Opposite initial contact | Toe off | Feet adjacent | Tibia vertical | Next cycle initial |

| Periods | Loadding response | Mid stance | Terminal stance | | Pre swing | Initial swing | Mid swing | Terminal swing |
|---|---|---|---|---|---|---|---|---|
| Tasks | Initial double limb support | Initial single limb support | | | Second double limb support | Second single limb support | | |
| Phase | Stance phase | | | | | Swing phase | | |
| Per | | | | Push off | | | | |
| Cycle | One cycle | | | | | | | |

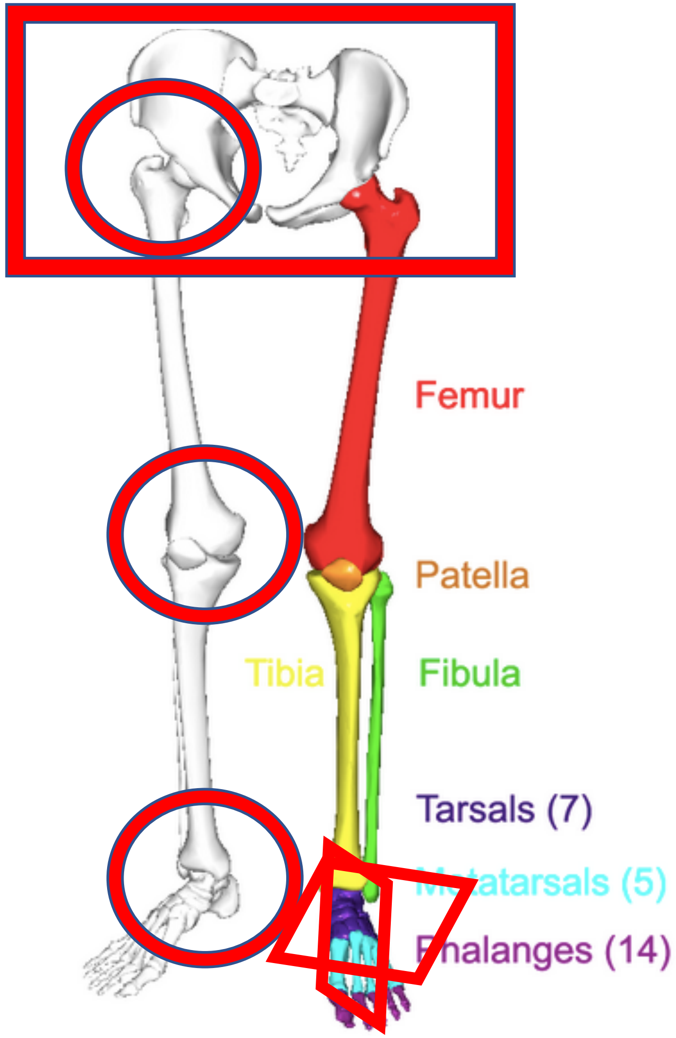
MEDICOL

# DATA PROCESSING

8 averaged variables from 10 consectutive strikes => mean for all 3 planes of motion
3 lower extremity joints: ankle, knee, hip
1 Pelvic segment
Transverse and sagittal-plane positions of the foot segment = 2
1 Selected side
→ Bilateral OA: most affected side
→ Control subjects: randomly extracted

8 discrete variables × {[(3 joints + 1 pelvis segment) × 3 planes] + [1- foot segment × 2 planes]} × 1 selected side

**112 discrete variables**



# DATA ANALYSIS

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| | |
|---|---|
| OA+ male and female<br>n=100 | Healthy male and female<br>n=43 |
| OA+healthy males<br>n=63 | OA+healthy females<br>n=80 |

↓ Discrete variables

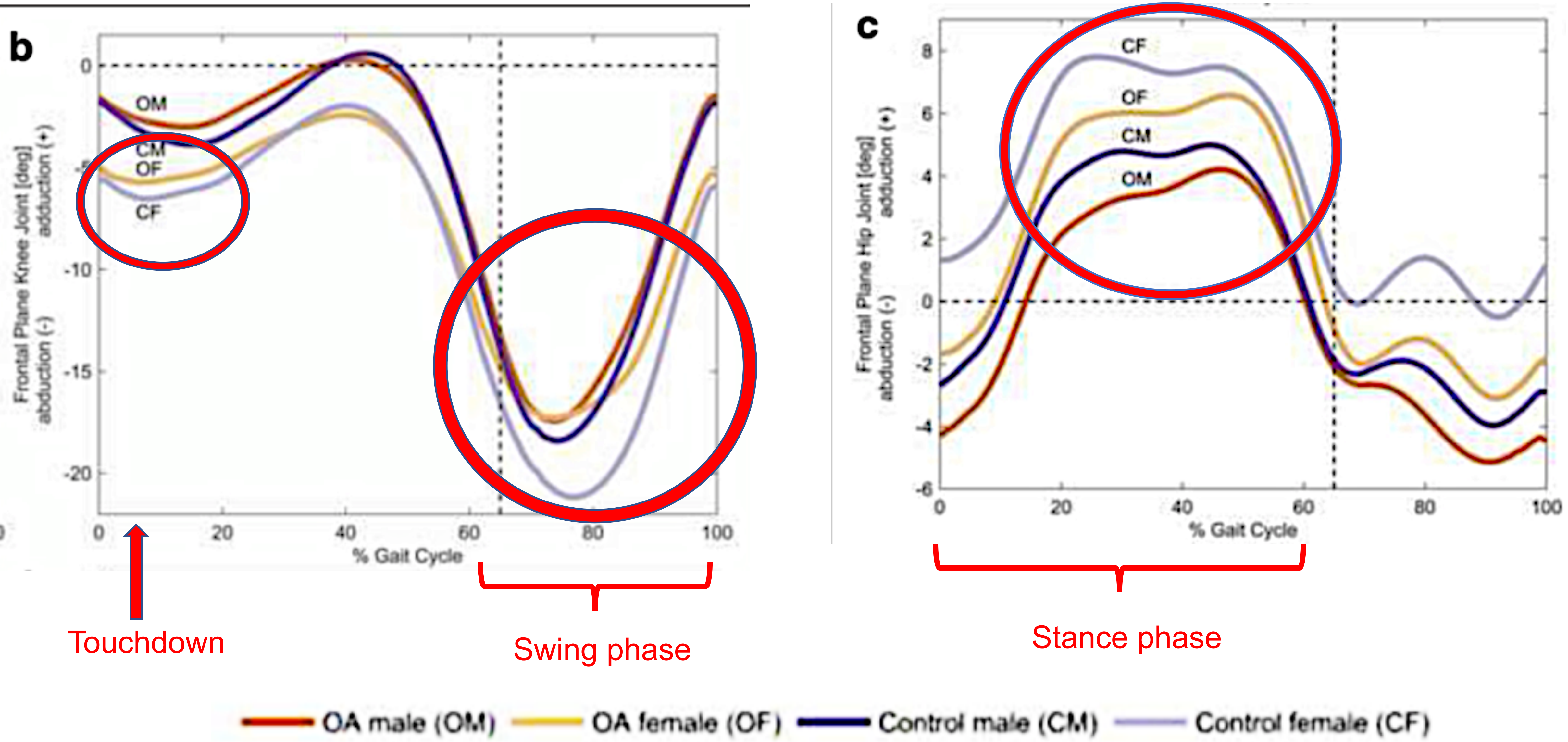
Original feature Matrix X → Normalization → PRINCIPAL COMPONENT ANALYSIS

= creation of maximal variability

# RESULTS

1. Anthropometrics
    1. BMI of OA+ males and females > healthy males and females
        1. Significant for females
2. Kinematic differences
    1. OA+ females
        1. Greater knee abduction at touchdown and during swing
        2. Greater maximum peak hip adduction angle during stance
    2. Healthy subjects
        1. same differences

# RESULTS



b
Frontal Plane Knee Joint [deg]
abduction (-) adduction (+)
0
-5
-10
-15
-20
OM
CM
OF
CF
0
20
40
60
80
100
% Gait Cycle
Touchdown
Swing phase
c
Frontal Plane Hip Joint [deg]
abduction (-) adduction (+)
8
6
4
2
0
-2
-4
-6
CF
OF
CM
OM
0
20
40
60
80
100
% Gait Cycle
Stance phase
OA male (OM)
OA female (OF)
Control male (CM)
Control female (CF)

# DISCUSSION

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1. Nouvel finding: frontal plane hip and knee kinematics are different between males and females
    1. Differences persist in healthy and OA-symptomatic individuals
2. No differences in gait kinematics between healthy gender-matched subjects and their OA couterparts
3. Limitations
    1. Missing ground reaction force data and joint kinetics
    2. Confounding factors
        1. Pain
        2. Walking speed
        3. BMI
            1. Known confounding factor (hip+knee frontal plane kinematics)

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