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Analysis of Human Locomotion

BSc Surgery & Anaesthesia

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Imperial College
London

Learning Objectives

By the end of the session, you will be able to:

- ➢Understand how muscles function to generate motion
- ➢Describe the basic functions of human locomotion
- ➢List the levels of biomechanical assessment that can be applied to assess human motion and function
- ➢Give examples of how biomechanical assessment are used in real life applications

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The biomechanics of human movement

To describe, analyse and assess human movement

WHY?

Measure – Describe – Analyse – Assess

PART I: HUMAN LOCOMOTION

PART II: MOTION CAPTURE

PART III: APPLICATIONS & RESEARCH

PART I

HUMAN LOCOMOTION

Human Locomotion

Repetitive sequence of limb motions to:

move the body forward (mobility)

Maintain stability

"Normal" Gait.....

co-ordinated

efficient

effortless

Pathological gait disrupts.....

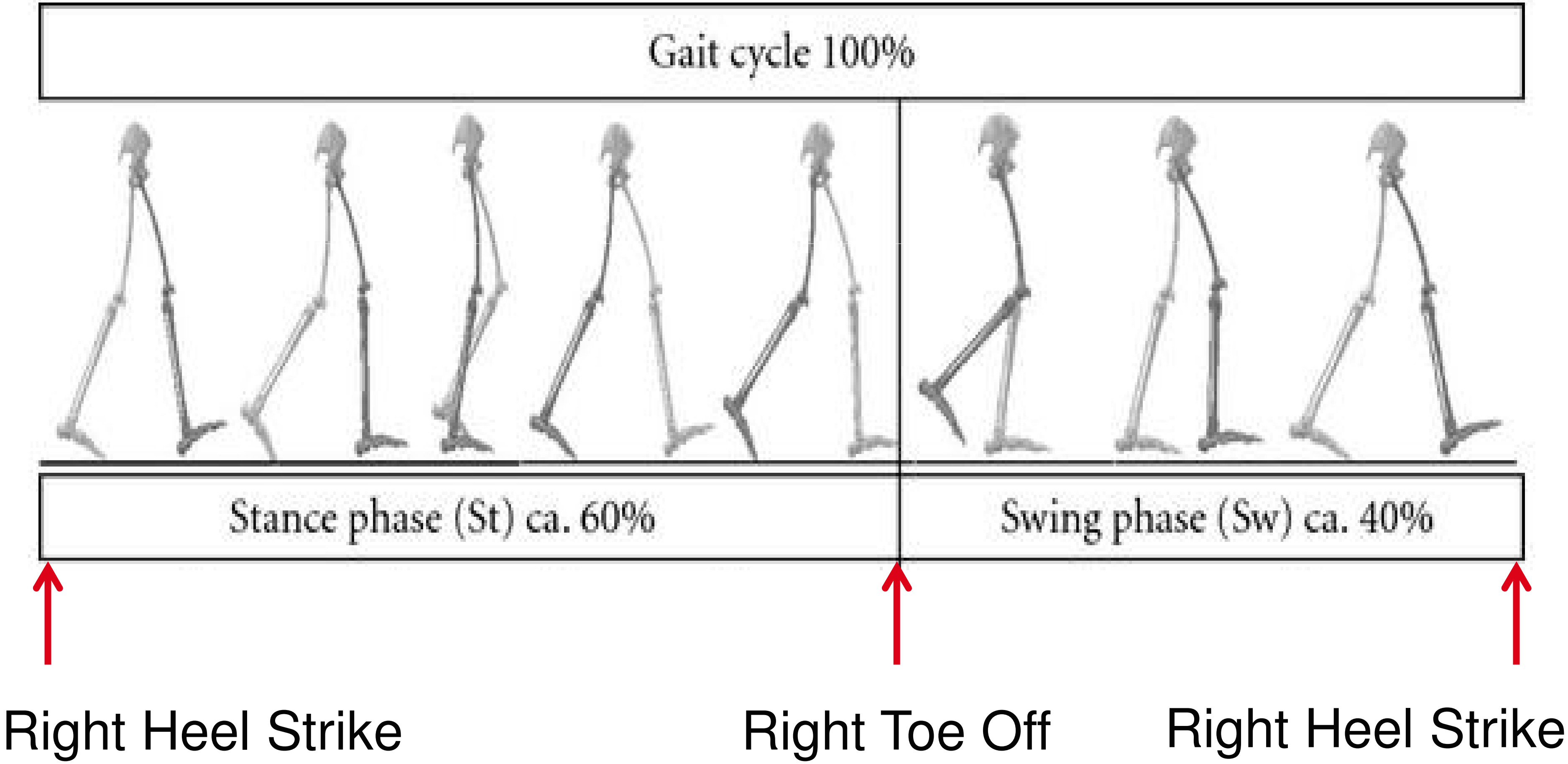
precision

co-ordination

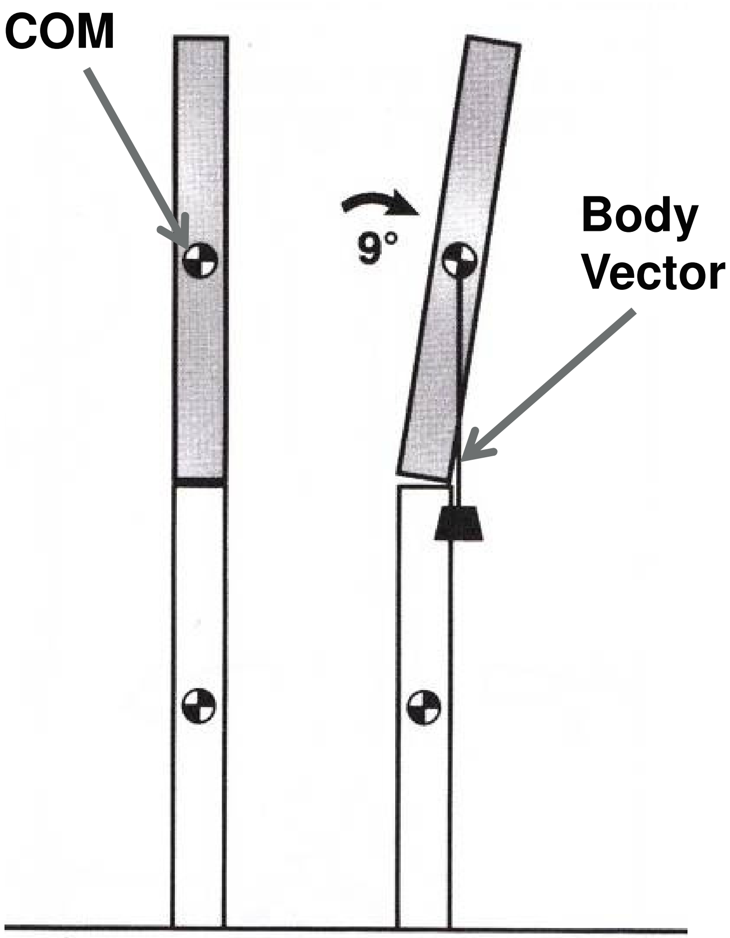
speed

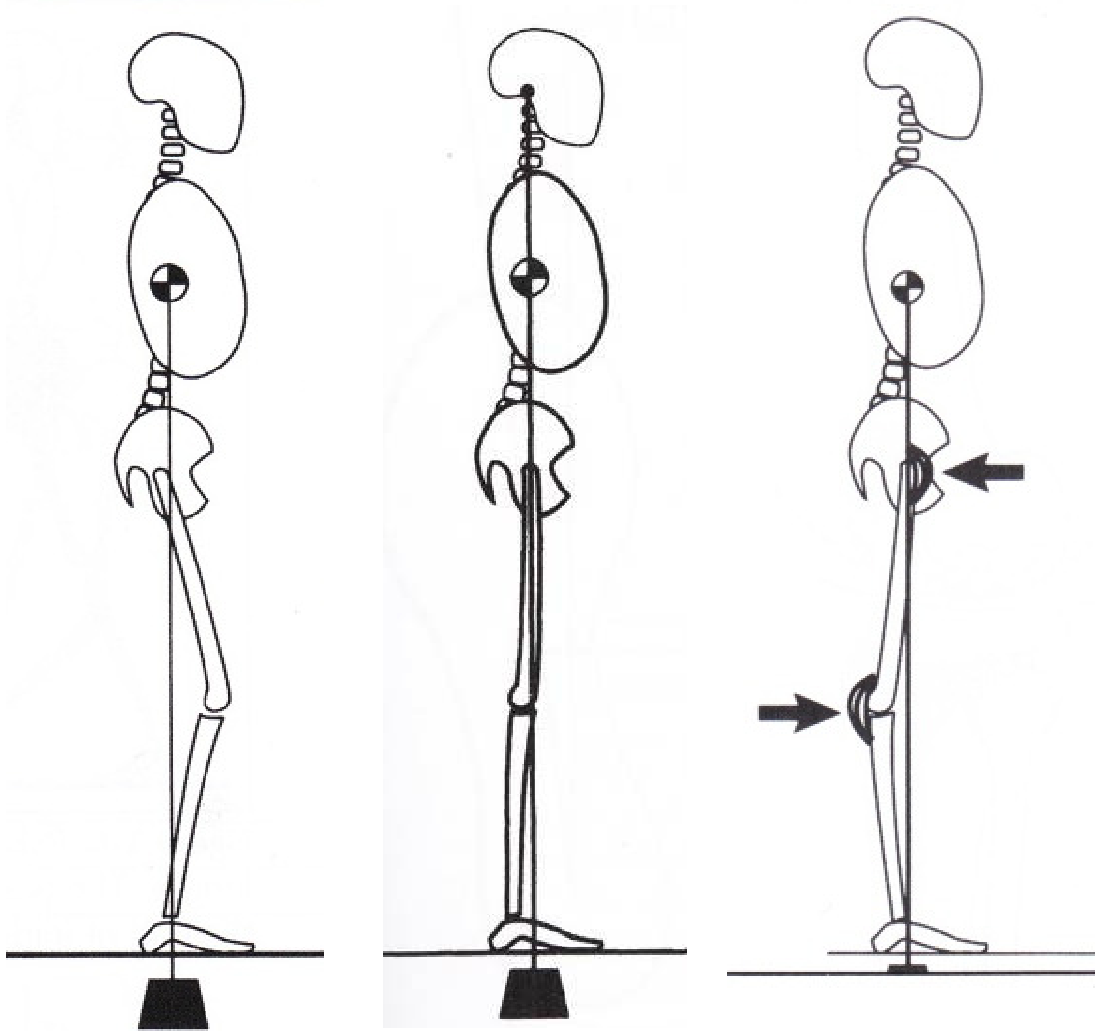
versatility

Human Locomotion: THE GAIT CYCLE

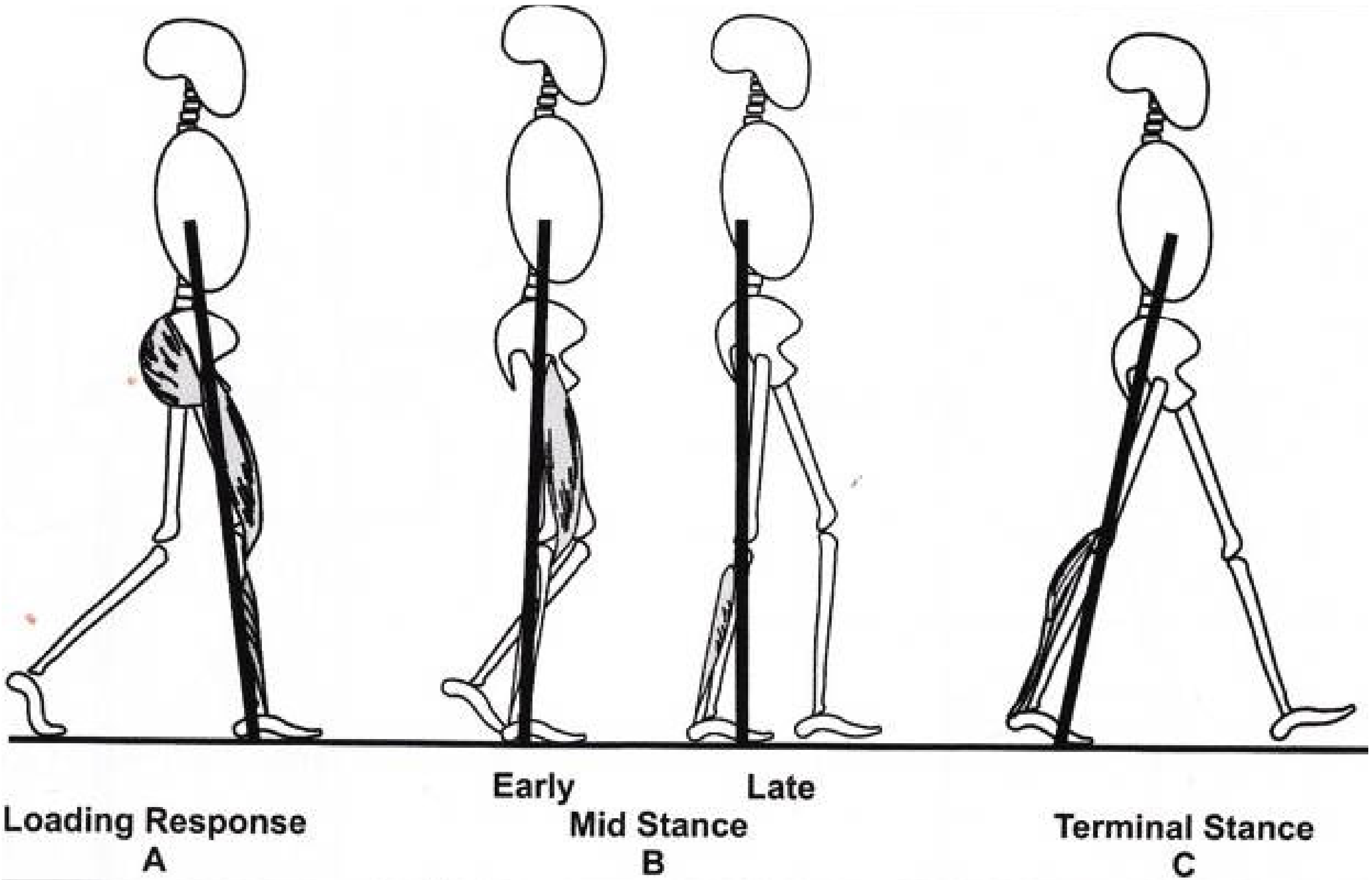


STATIC STABILITY: Alignment of bodyweight





DYNAMIC STABILITY



Muscle mechanics

Concentric Force:
Muscle actively shortening

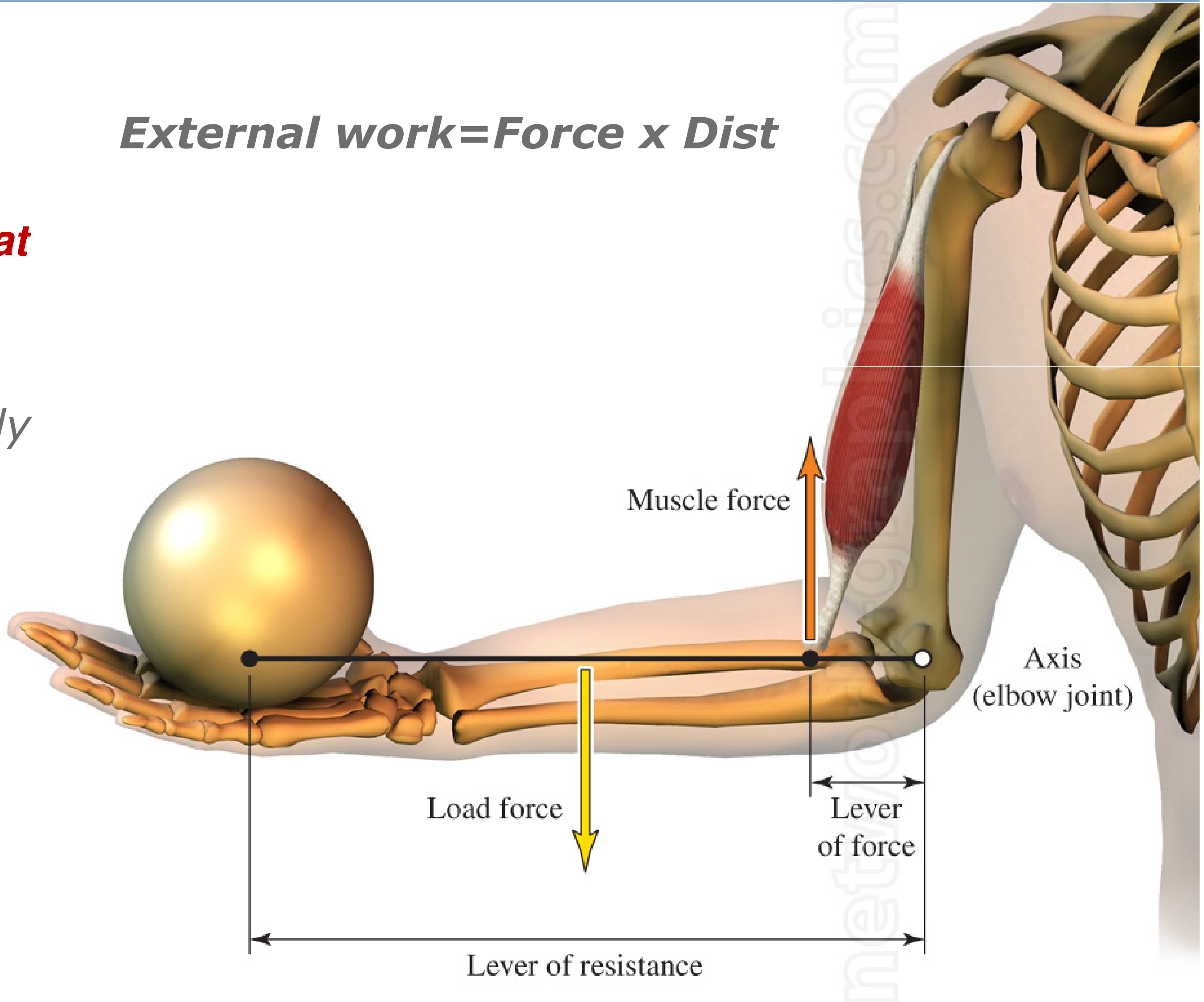
Energy → Kinetic + Heat

Isometric Force:
Muscle held actively at fixed length

Eccentric Force:
Muscle actively lengthening

Energy → Heat

External work=Force x Dist

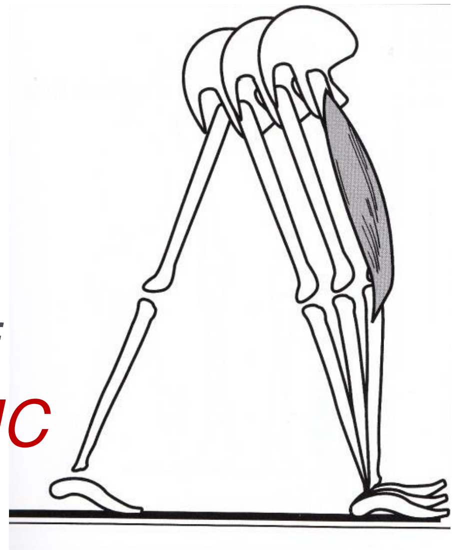


Locomotor Functions:

1) Propulsion *for progression*

CONCENTRIC

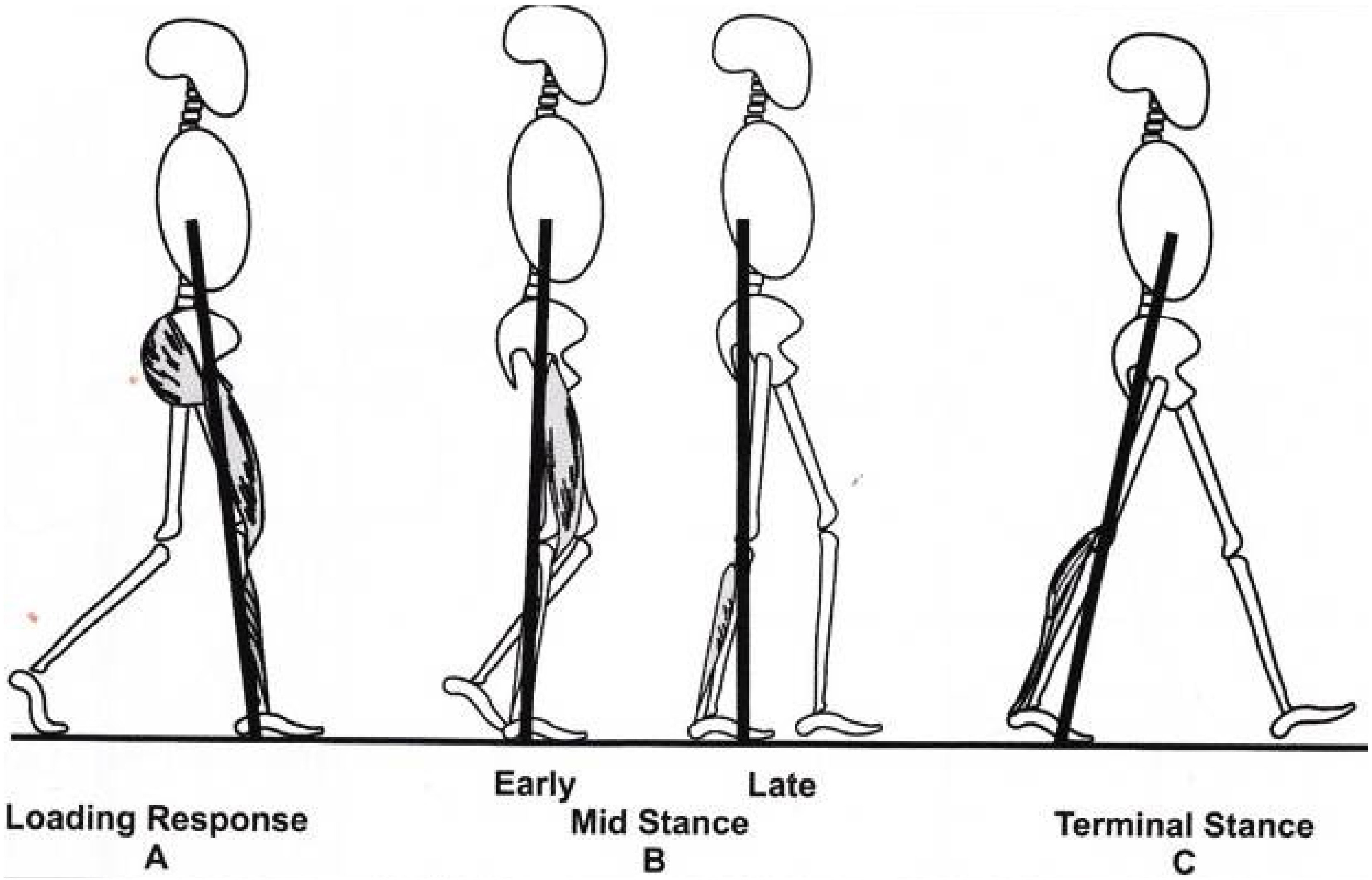
2) Stability *ISOMETRIC*



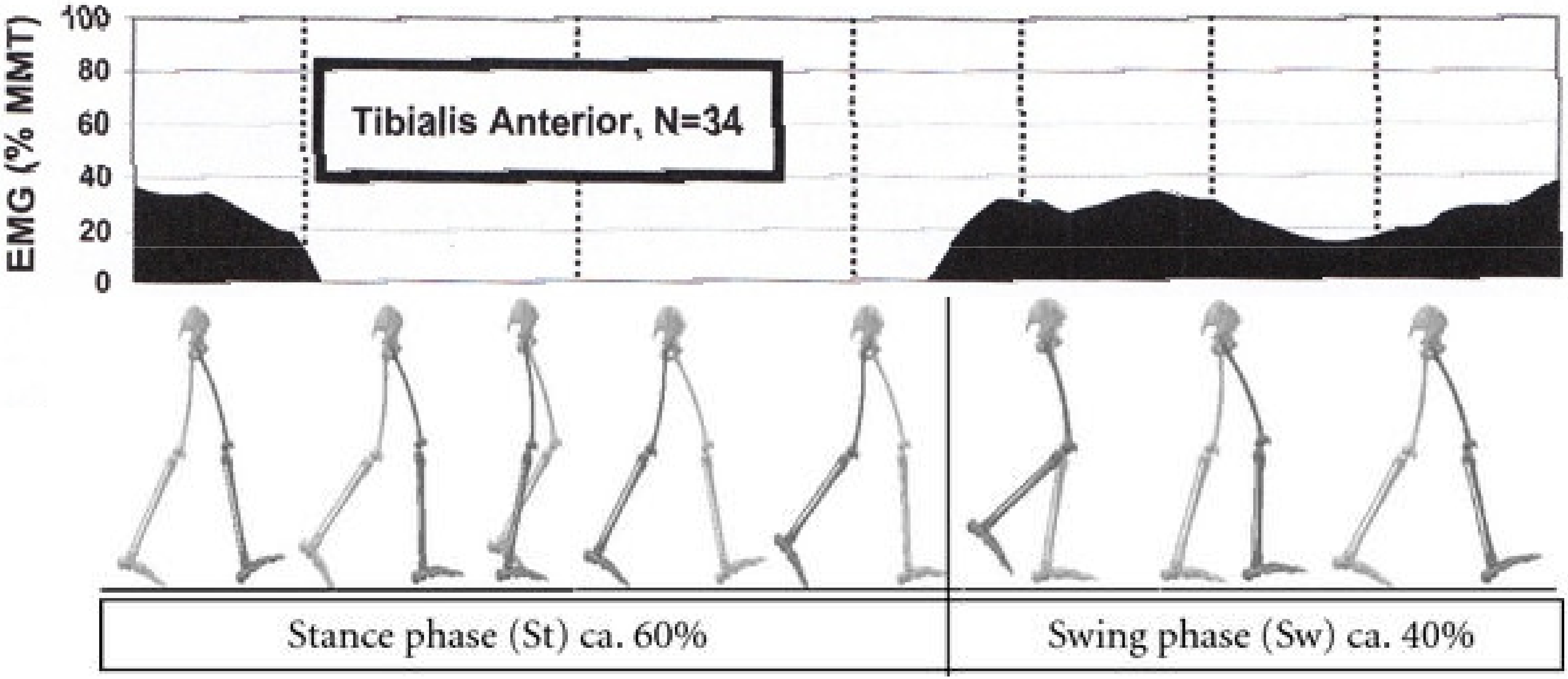
3) Shock absorption *to minimize the shock of floor impact: ECCENTRIC*

4) Energy conservation *to reduce the muscular effort required*

DYNAMIC STABILITY



Example: Tibialis Anterior



Pathological Gait: Foot Drop

PART I: HUMAN LOCOMOTION
Summary

Human locomotion aims to achieve mobility and stability in the most efficient way

The Gait Cycle is composed of stance (60%) and swing (40%) phases

During walking, the alignment of the body vector to the joints is continually changing

Each muscle functions to achieve progression, shock absorption and stability

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PART II

MOTION CAPTURE

Biomechanical conventions

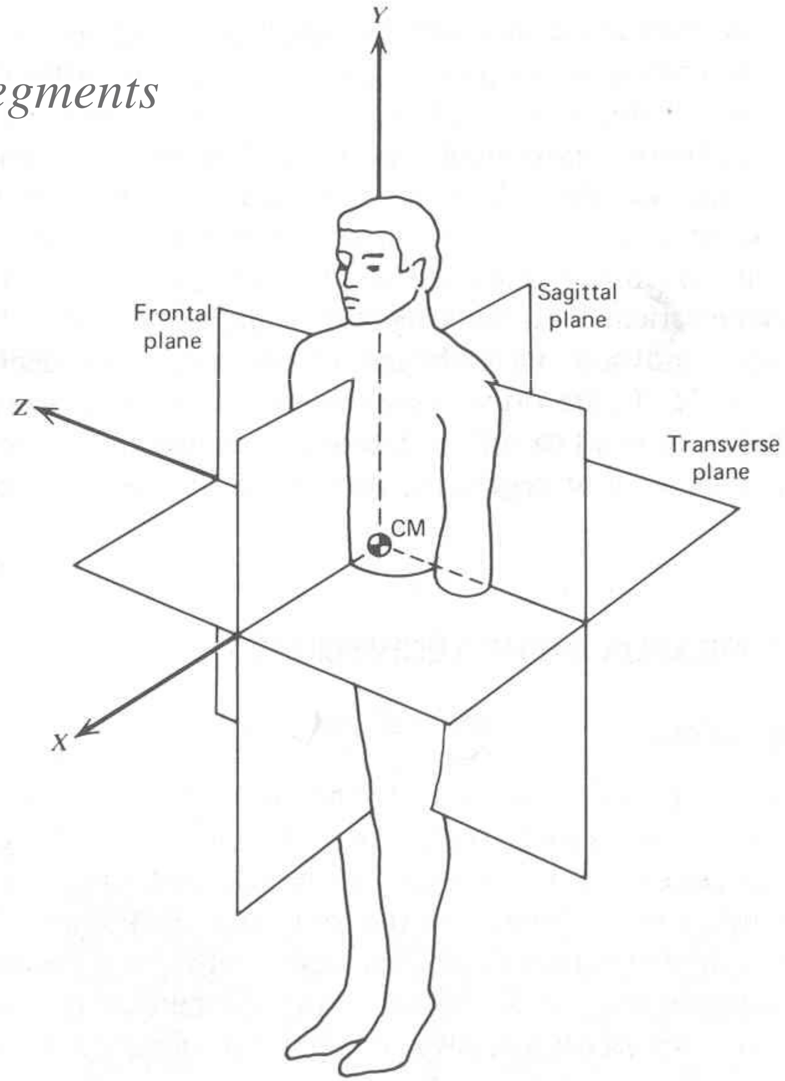
Kinematics *= describes the motion of points or segments without consideration of the forces that cause it*

Kinetics *= the study of motion and its causes*

Sagittal = Flexion/extension

Frontal (or coronal) = Abduction/adduction

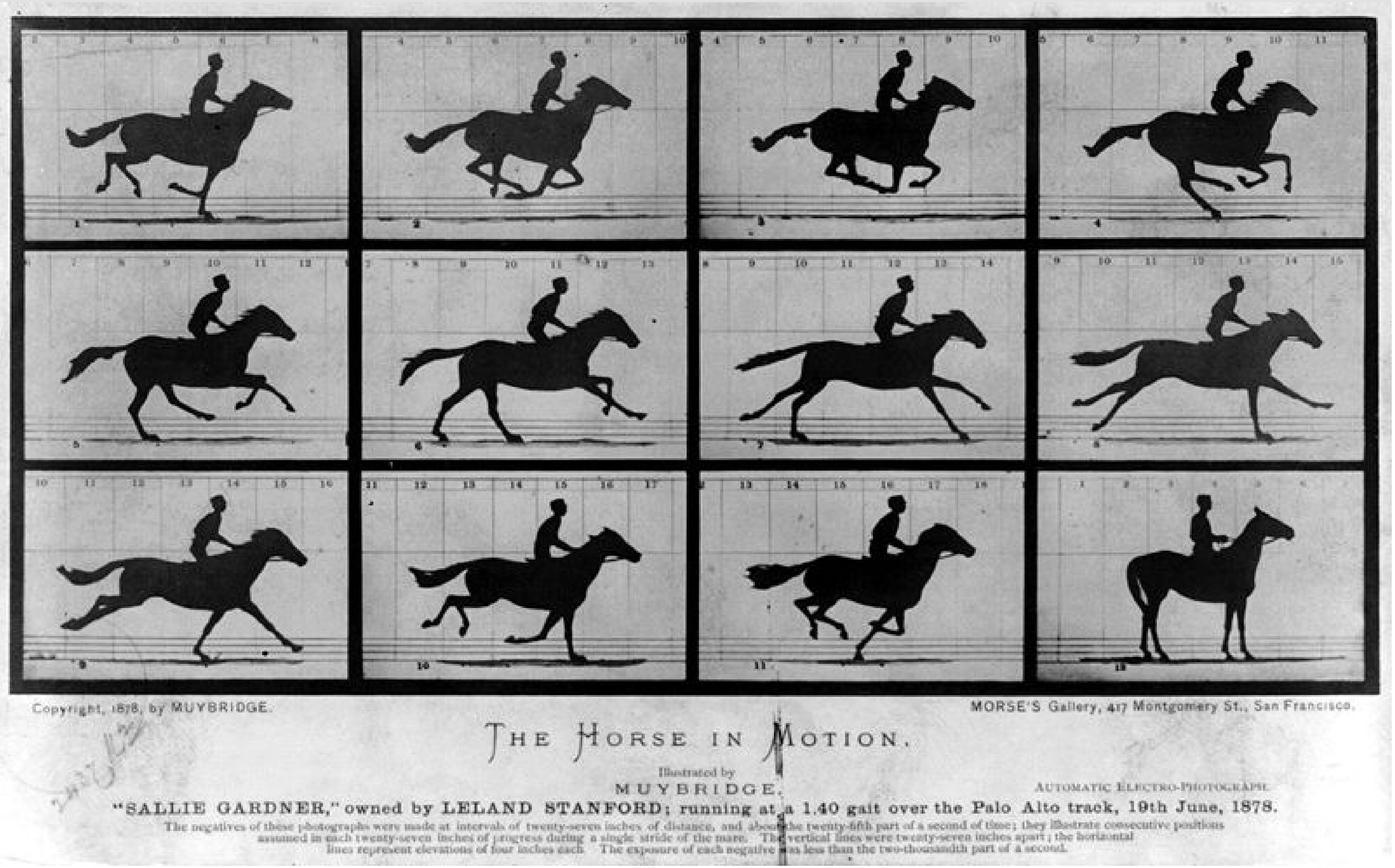
Transverse = Internal/external rotation



What is motion capture?

The process of recording movement and translating that movement on to a digital model

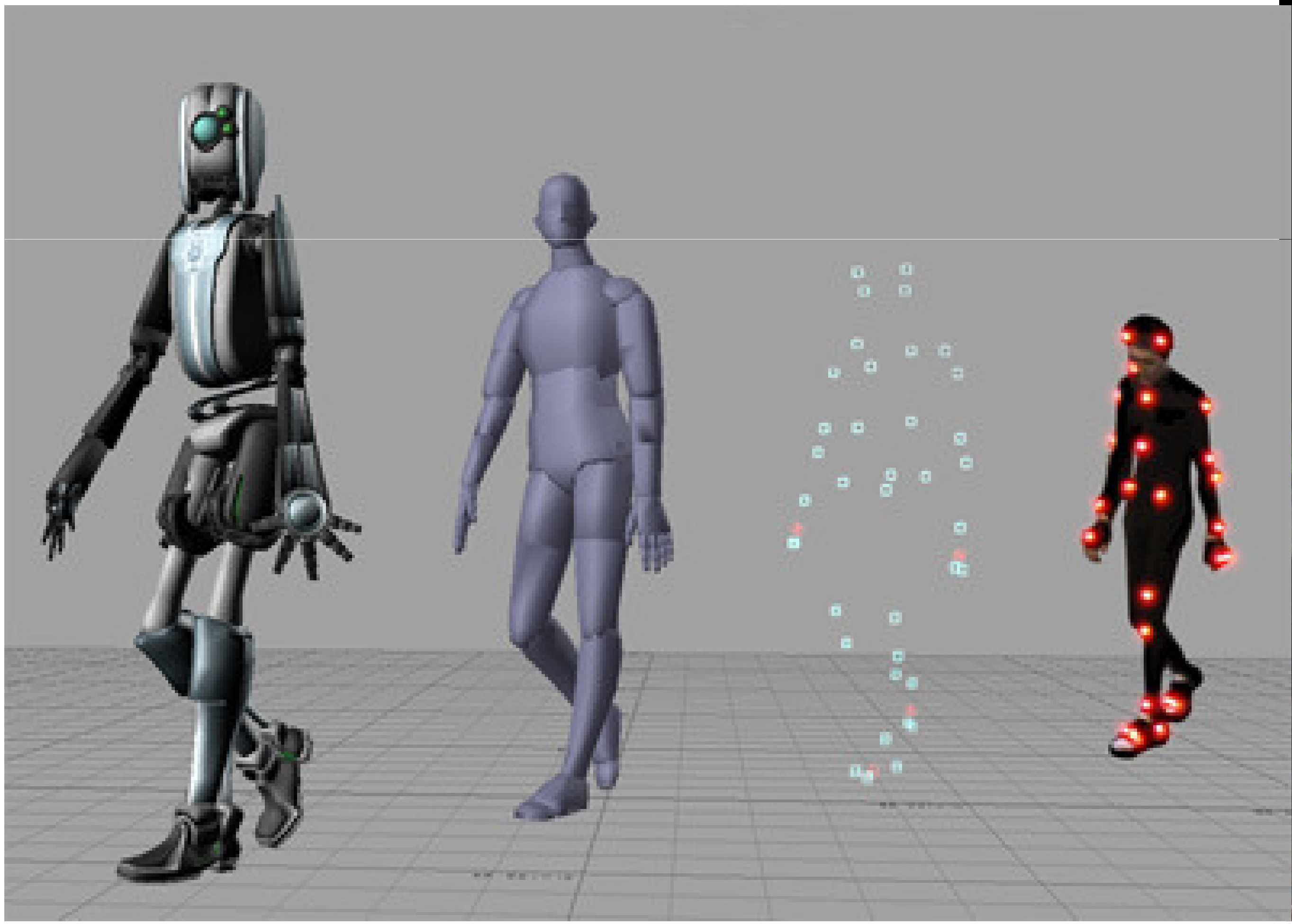
Edweard Muybridge (1830-1904)

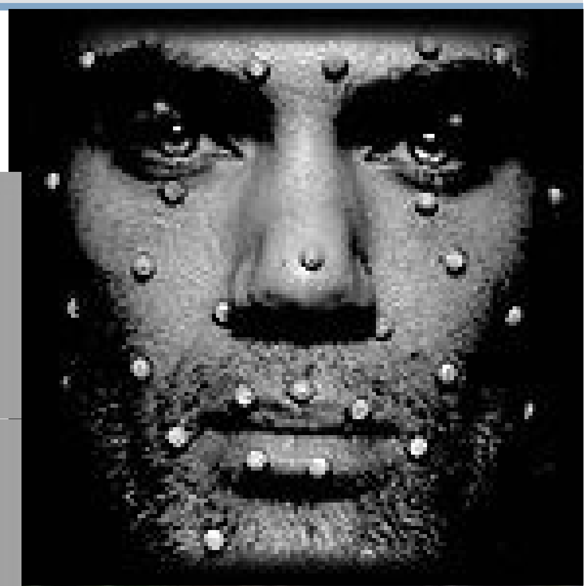


Muybridge's experiments proved conclusively for the first time, that a horse while galloping lifted all four hooves off the ground

21st Century Motion Capture

Computer-generated imagery (CGI)



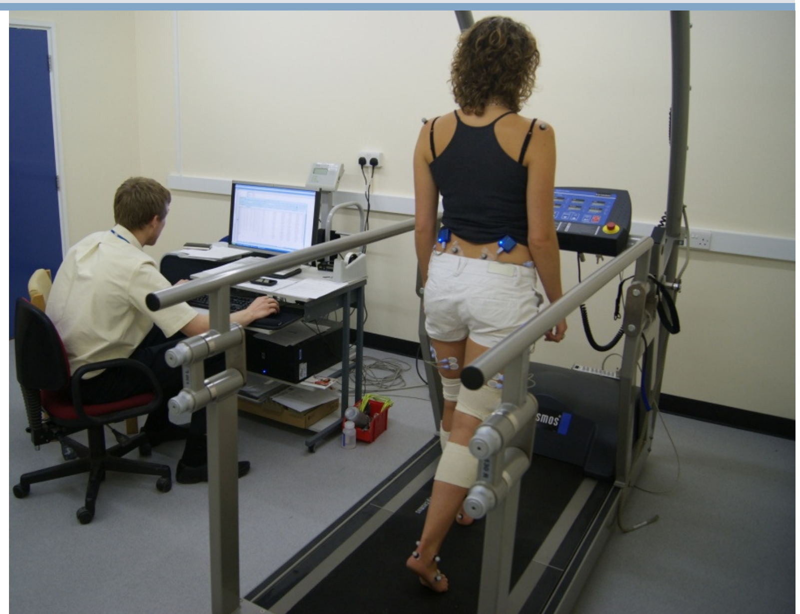


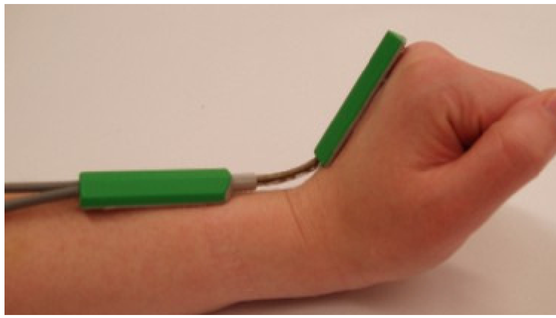
Levels of Motion Capture

- Force Plates (GRF)
  - Temporal parameters
  - Symmetry

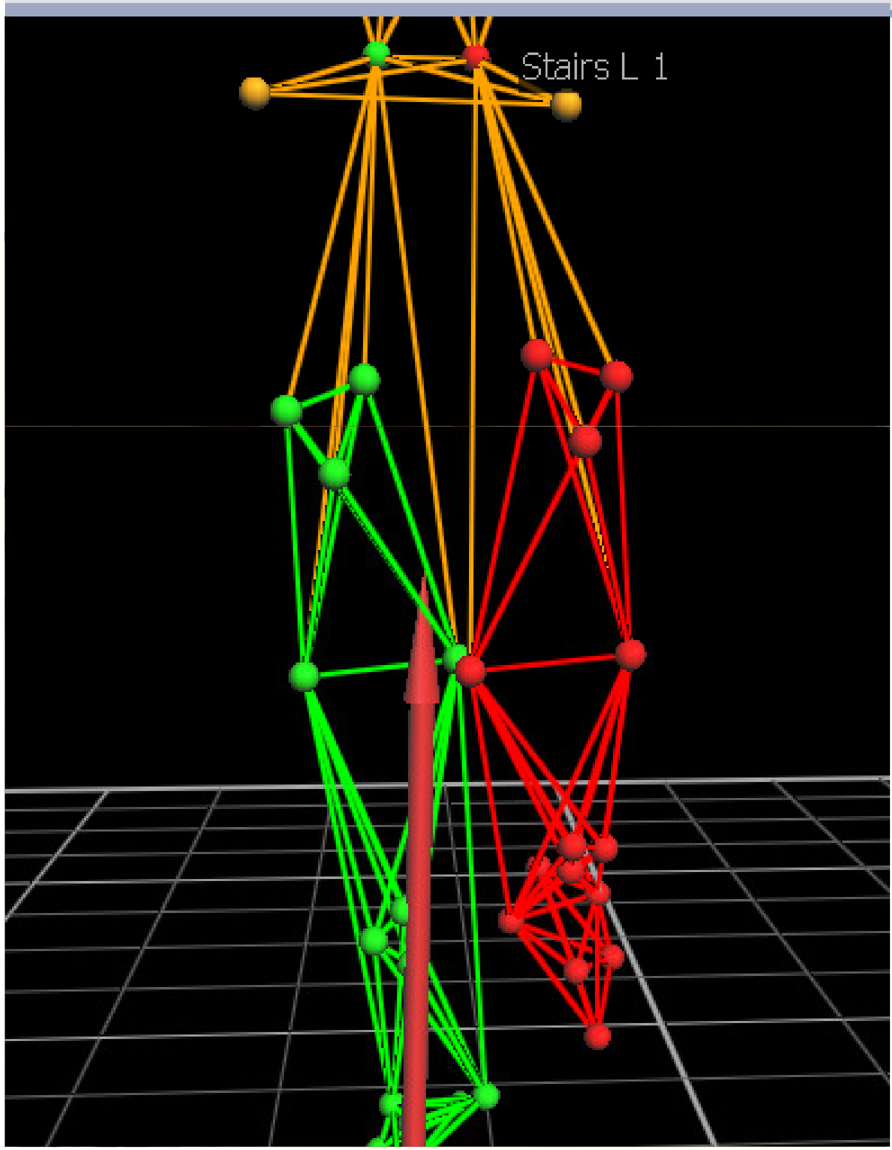
- Motion Analysis
  - Observation
  - Goniometry
  - 2D/3D motion capture

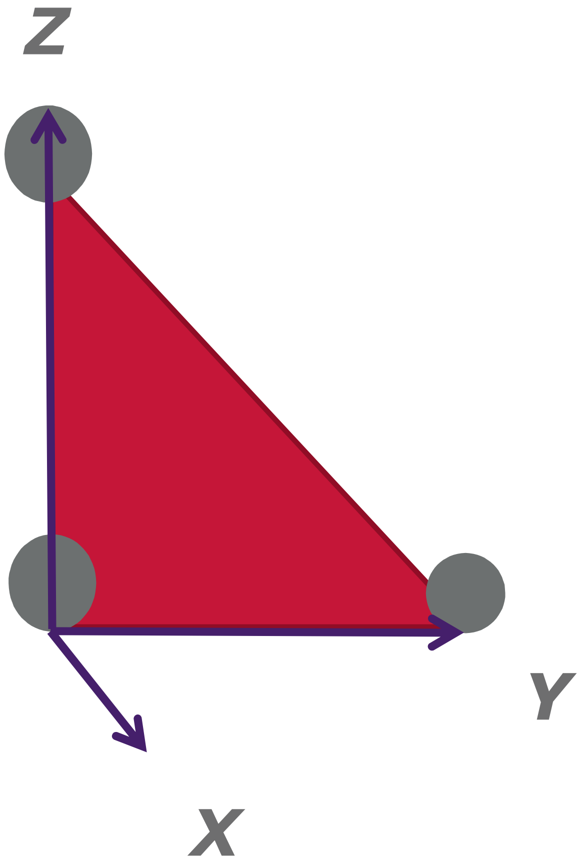
- Body worn sensors
  - Electrogoniometry
  - Accelerometry



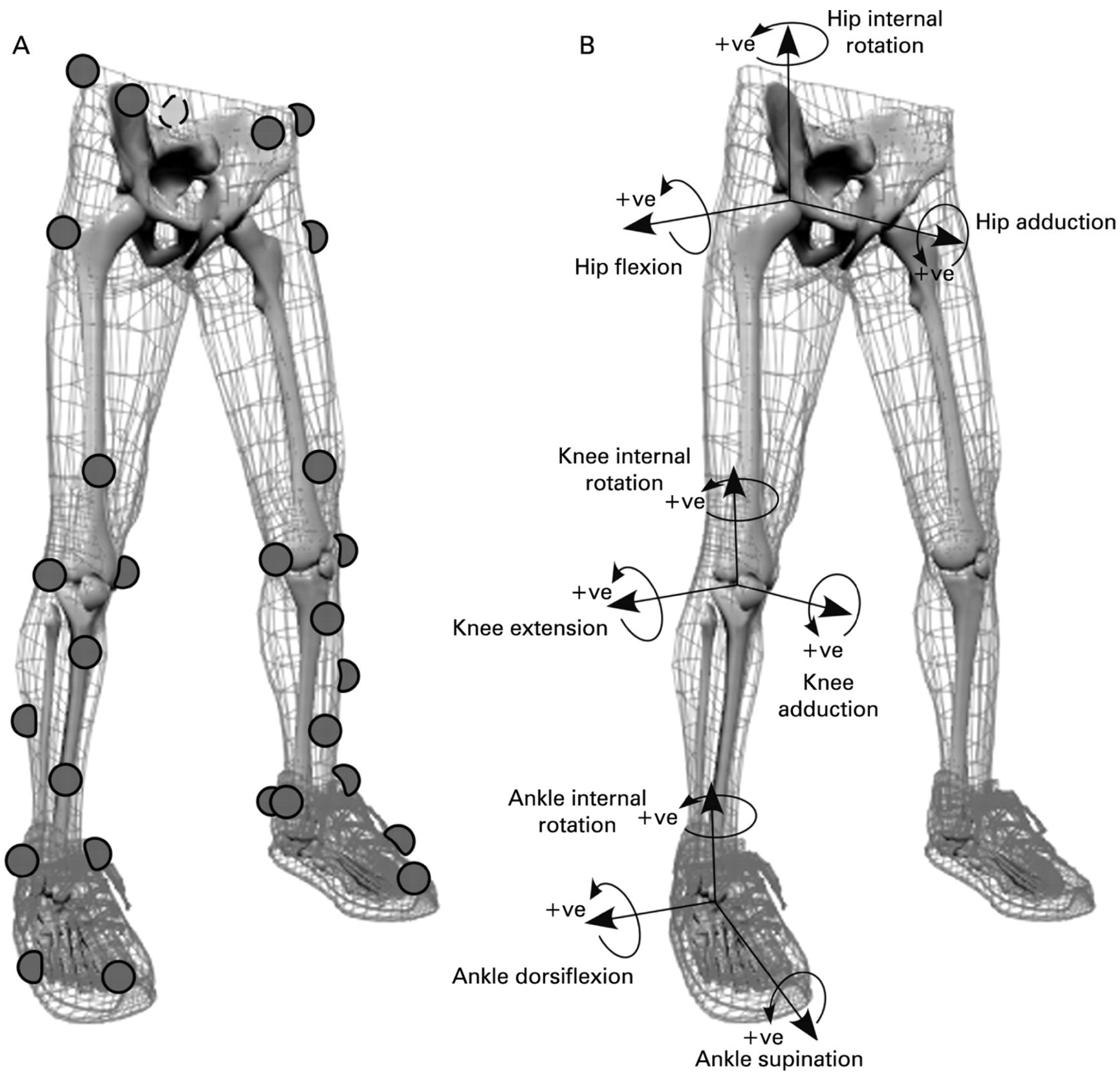


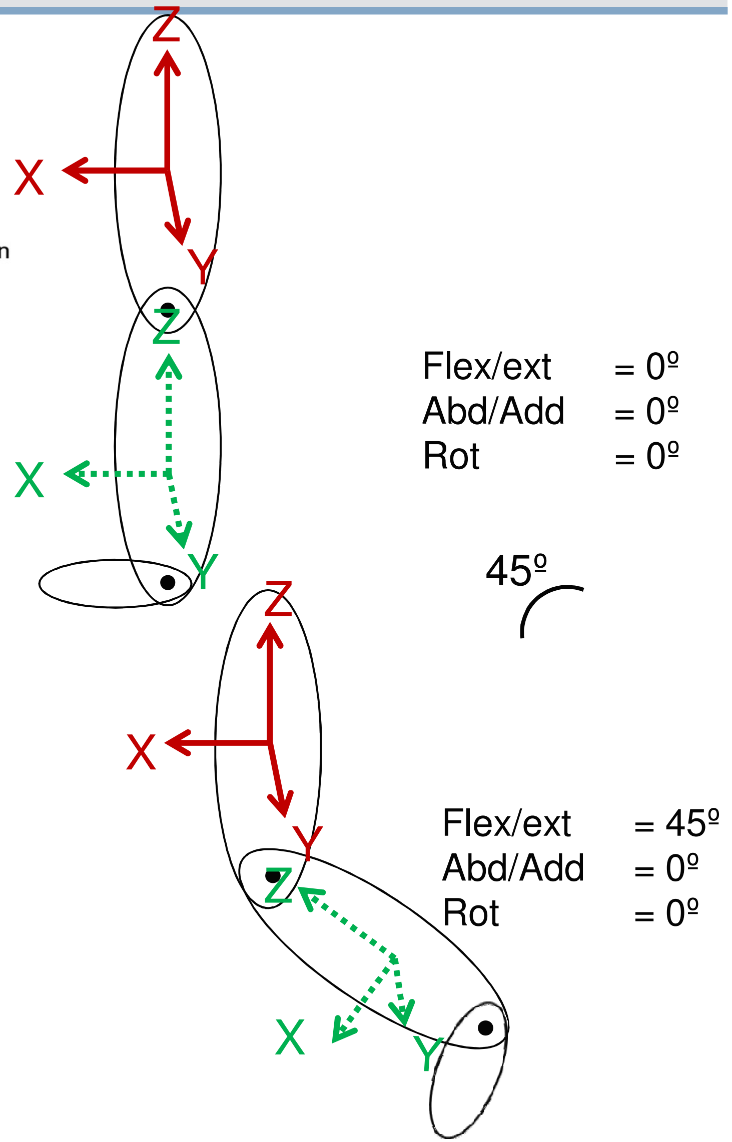
3D Motion Capture



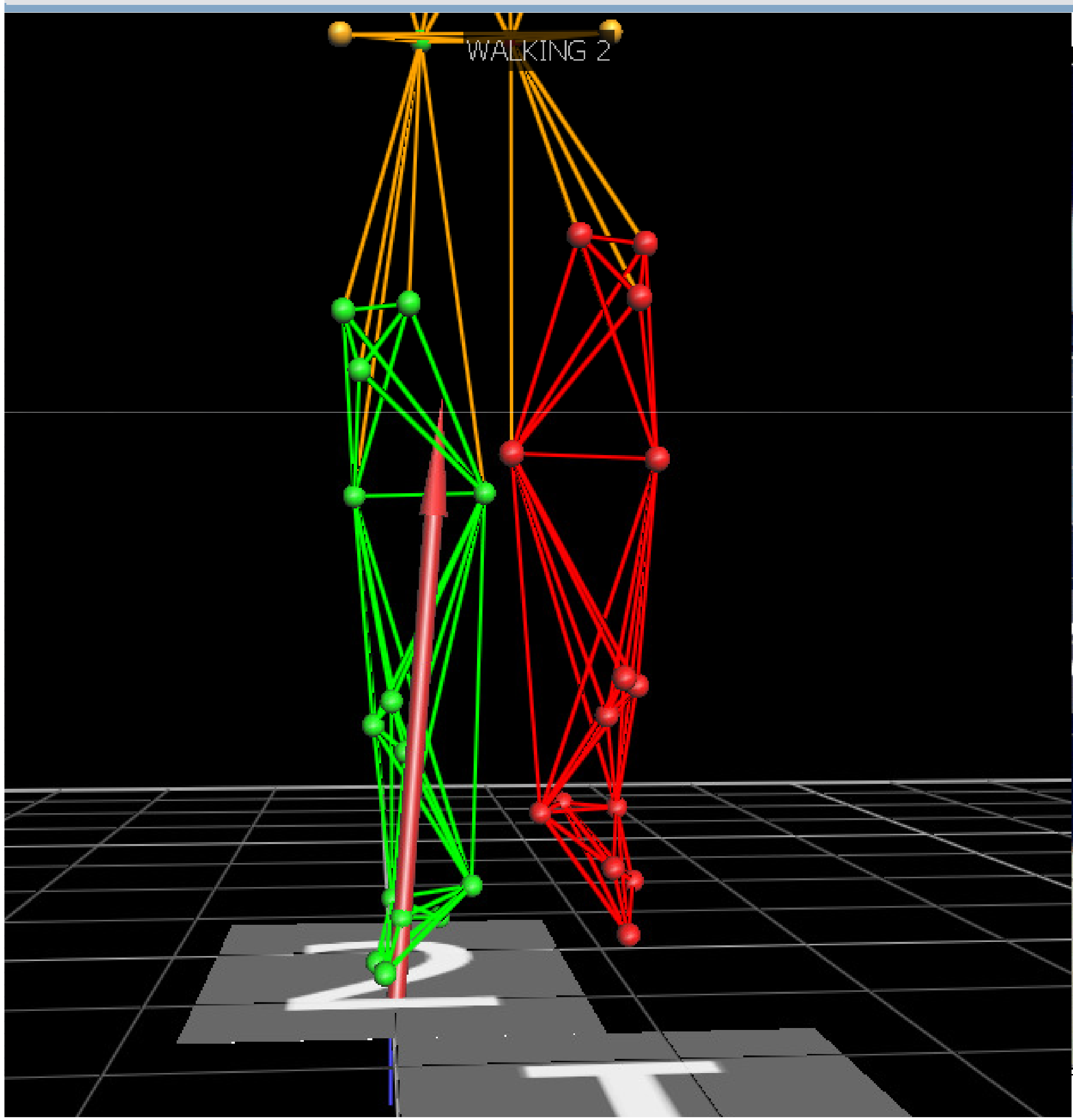


Joint angle measurements

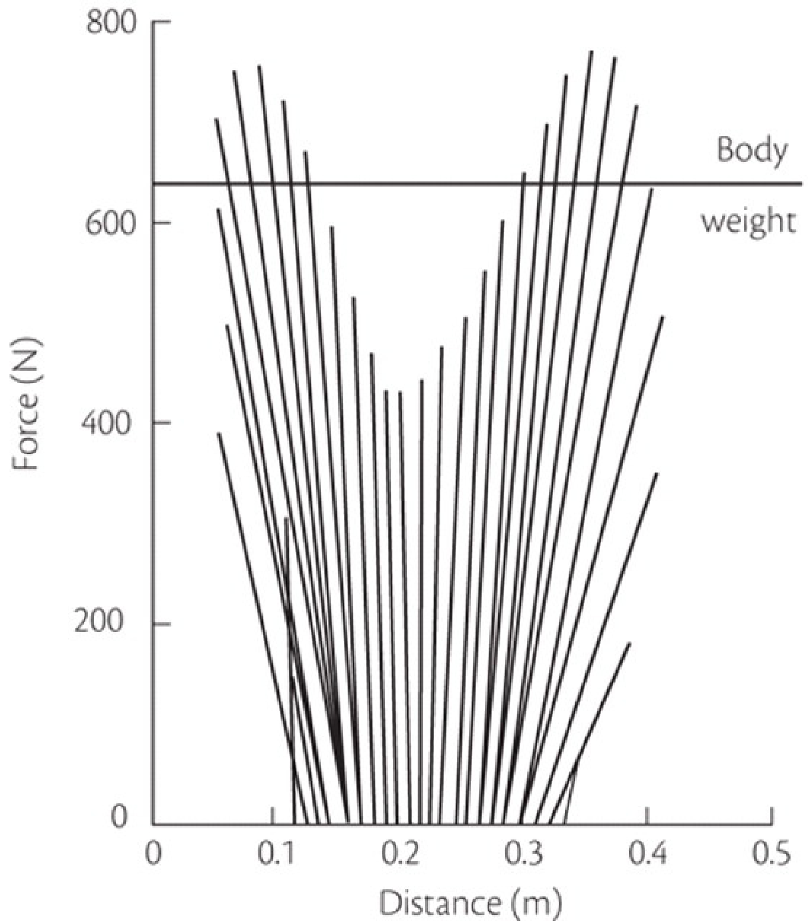




Ground reaction force vector & inverse dynamics

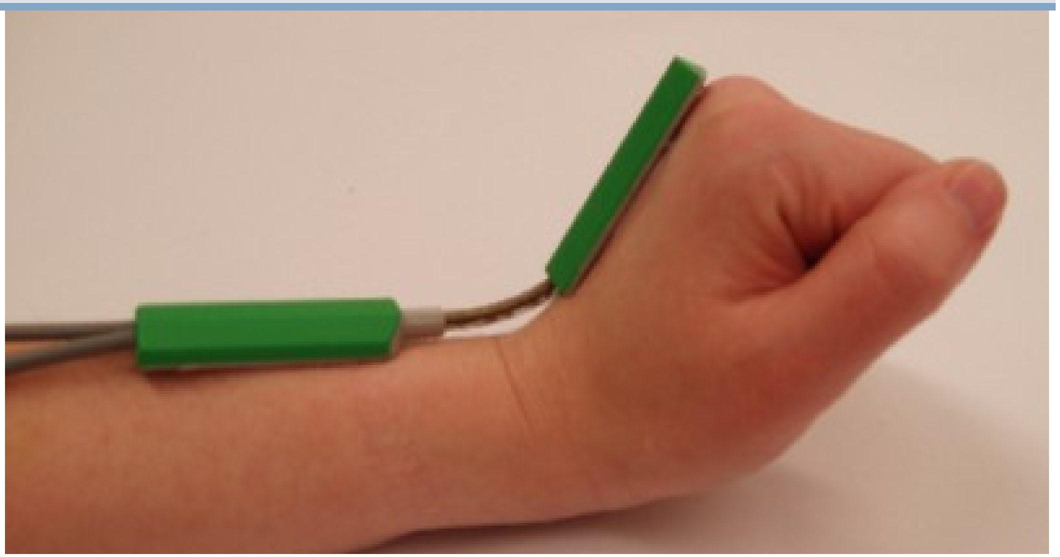


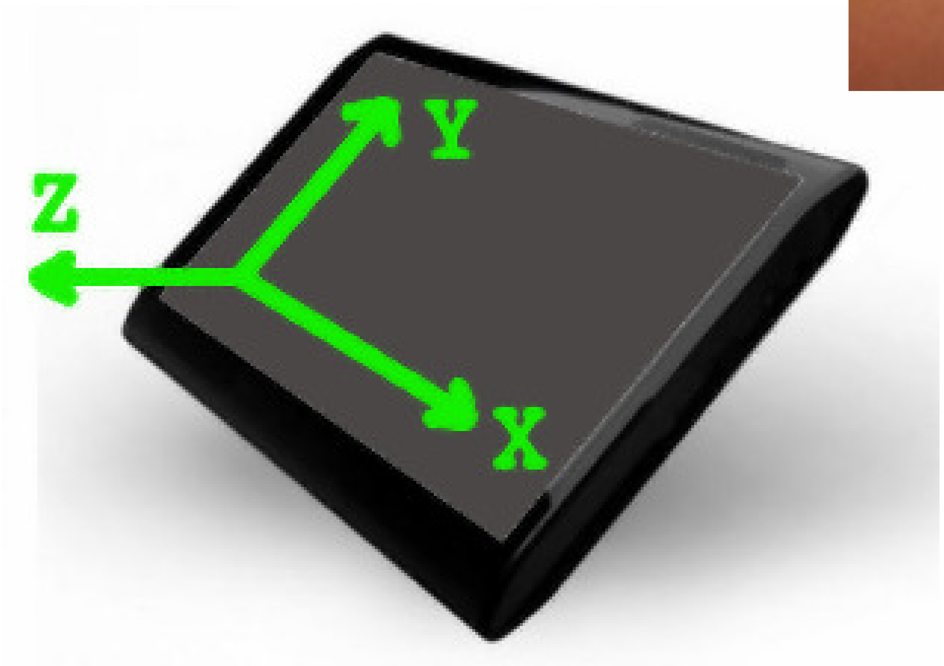
Net muscle & gravitational forces
(acceleration) x (mass)



Body Worn Sensors

Electrogoniometry





Accelerometry

PART II: Summary

- Kinematics & Kinetics

- Planes of motion

- Levels of Motion capture

  - 3D motion capture provides the most complete analysis
  - Motion parameters are derived from markers attached to the subject and the ground reaction force vector

  - Body worn sensors are increasingly being utilised

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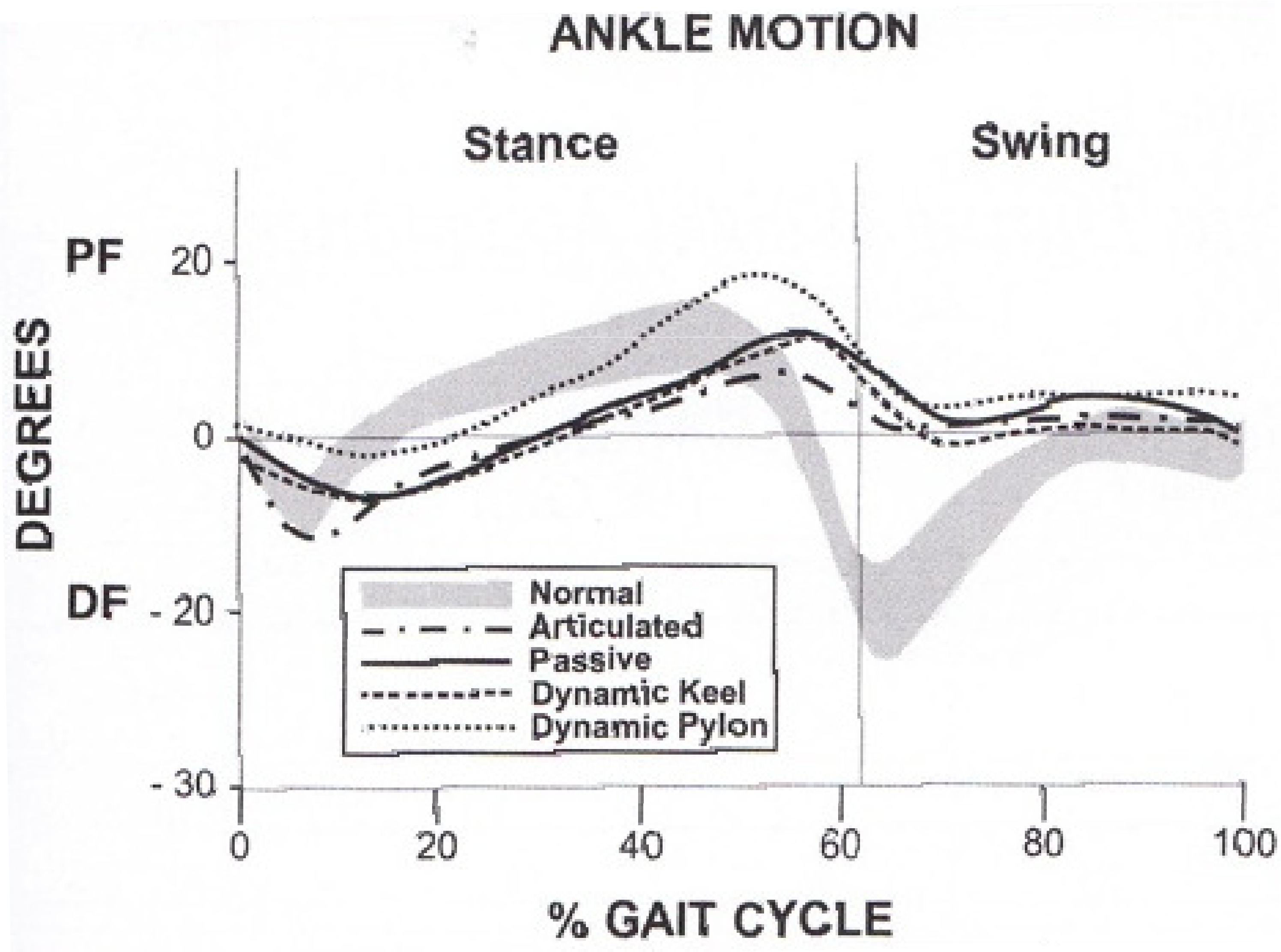
PART III

APPLICATIONS & RESEARCH

Clinical assessment of gait



Clinical Application: considerations

- Cost
- Space
- Time
- Data analysis/interpretation
- Patient behaviour
- Direct benefit to patients..?

Oliver Pistorius

Amputee *vs* intact-limb subjects

Running at top speed on an instrumented treadmill

<u>Measured</u>
ground reaction force
Metabolic cost

<u>Results</u>
Similar top speed attained
Physiologically similar
Mechanically dissimilar
- ↓ aerial & swing times in amputee
- ↓ vertical GRF in amputee

Slender limbs of animals adapted to run
Limitation of speed by low GRF

Weyand et al. (2009) *J Appl Physiol*

Osteoarthritis Study: what is 'normal' gait?

"an inevitable consequence of aging"
"wear and tear"
"Repeated loading on the joints during exercise causes OA"

Aim: To develop a database of knee joint functioning during activities of daily living

We all have different walking patterns

Do our walking patterns match up with patterns of wear in the joint?

Cartilage is a metabolic tissue and can repair itself.

Can we identify people at risk of osteoarthritis before cartilage damage becomes too advanced?

PART III: Summary

Pathological gait can be compared with normal gait to quantify differences and interventional effects

Gait analysis is used widely in the world of research and increasingly so in the clinic

There are a number of considerations in the clinical application of gait analysis

The true motion of the skeleton and forces within the joints are difficult to measure, therefore data interpretation should be cautious and critical.

SUMMARY AND READING

Human locomotion is complex:

A number of muscles work synchronously using the bony segments as levers to achieve mobility and stability

It can be measured in different ways and on different levels

This can provide us with insight into pathologies, effectiveness of interventions, performance etc through research and clinical application.

Skeletal Muscle from Molecules to Movement (Jones, De Haan & Round)

Research Methods in Biomechanics (Robertson, Hamill, Caldwell, Kamen & Whittlesey)

Gait Analysis Normal and Pathological Function (Perry & Burnfield)

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Thank You for listening!

Questions?

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