POLITECNICO
MILANO 1863

# Technologies for motor behavior analysis and virtual modelling (C.I.) [2]

Prof. G. Baroni

## Course teaching team (Human Motion Virtualization)

Main lecturer:

Prof. Guido Baroni

3349, 9011

Seminars:

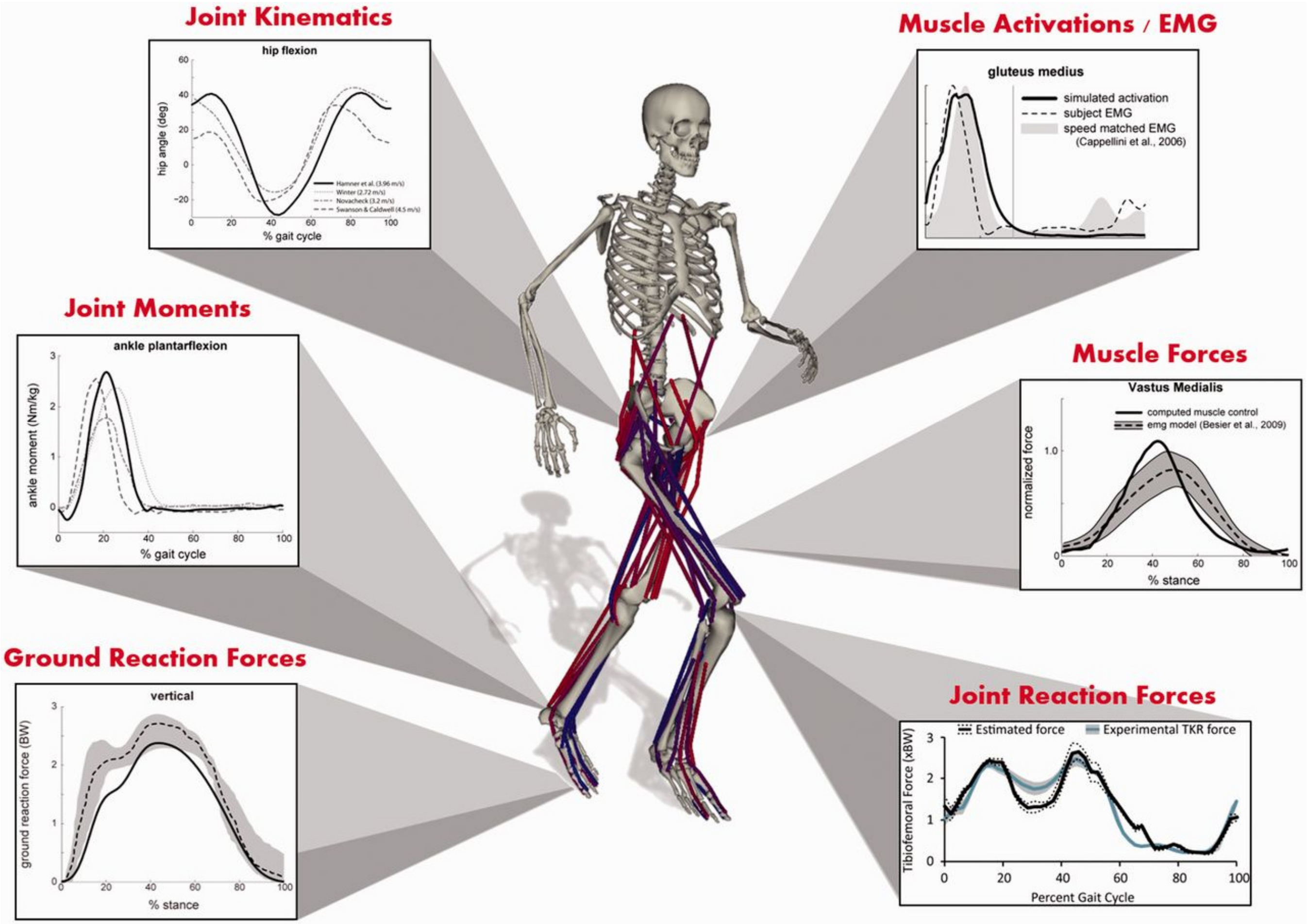
Giulia Buizza, M.Sc. giulia.buizza@polimi.it

# Course hours and classrooms

| Date | Topic | Time | Room |
|---|---|---|---|
| Tuesday 7 November | II module introduction (GB+GBu) | 10.15-13.15 | T.03 |
| Wednesday 8 November | Lecture Advanced Camera Calibration (GB) | 8.15-11.15 | S1.4 |
| Thursday 9 November | OpenSIM SW introduction, download and installation (GBu) | 15.15-18.15 | 9.0.3 |
| Sabato 11 November-Wednesday 15 November - No lectures | | | |
| Thursday 16 November | Presentazione OpenSIM. Scaling (Tutorial 1)(GBu) | 15.15-18.15 | 9.0.3 |
| Tuesday 21 November | Lezione Surface acquisition processing and rendering + Assegnazione progetti (GB) | 10.15-13.15 | T.03 |
| Wednesday 22 November | Presentazione OpenSIM. Scaling (Tutorial 2) - Tendon Transfer Surgery (GBu) | 8.15-11.15 | S1.4 |
| Thursday 23 November | Presentazione OpenSIM. Scaling (Tutorial 3) - IK (GBu) | 15.15-18.15 | 9.0.3 |
| Tuesday 28 November | Lezione Advanced motion tracking e Markerless Motion Capture (PC) | 10.15-13.15 | T.03 |
| Wednesday 29 November | Projects presentation and Assignment (GB+GBu) | 8.15-11.15 | S1.4 |
| Thursday 30 November | Seminario wearable (GA) | 15.15-18.15 | 9.0.3 |
| Tuesday 5 December -Thursday 7 December - No lectures | | | |
| Tuesday 12 December | Lezione Eye tracking (RV) | 10.15-13.15 | T.03 |
| Wednesday 13 December | Seminario Deformable image registration (CP) | 8.15-11.15 | S1.4 |
| Thursday 14 December | Global Motion modelling (CP) | 15.15-18.15 | 9.0.3 |
| Tuesday 19 December | Update Progetti (GBu) | 10.15-13.15 | T.03 |
| Wednesday 20 December | Lectures on advanced skin motion artifacts compensation (GB) | 8.15-11.15 | S1.4 |
| Thursday 21 December | No lessons - Graduation | | |
| Tuesday 16 January | Project presentations (GB) | 10.15-13.15 | T.03 |
| Wednesday 17 January | Project presentations (GB) | 8.15-11.15 | S1.4 |

8.45

# Course topics: Human Motion Virtualization



# Course topics: Human motion virtualization

- Course introduction
- Technologies for human motion virtualization
- The OpenSIM software
- Advanced spatial localization
  - Advanced camera calibration
  - 3D surface acquisition
  - Markerless human motion analysis
- Unconventional human motion analysis
  - Motion modeling for time resolved therapy
- Wearable sensors / ergonomics

at the time of surgical you want to capture motion (as any deviation of composition of the patient to respect the programmazione della chirurgia). Also ct scan + rebuilding what his configuration was at the time of the scan. Whole anatomical conf., it's easy if I can do a MRI, but not always is possible, so models + motion models to predict of the internal conf. of the patient at the time of the treatment

# Practice: Human motion Virtualization

- OpenSIM cases
- Projects (small groups):
  - In-house motion analysis technologies (video, inertial)
  - Advanced applications (OpenSIM)

*Groups are expected to be equipped with at least one laptop with OpenSIM installed and ancillary software (Mokka, VideoDIGIT)

# Course material

Course slides

Practice slides and documentation

Course Beep channel (articles, practice exercises)

# Exam modalities

Interview with Course Teachers

dura fino a gen2019
se fai un modulo poi devi dire "accetto il voto" o "non accetto il voto"

# Human motion virtualization (simulation with real data)

1) Prevention of injuries

2) Prediction of rehabilitation/surgical treatment outcomes

3) Design and a-priori evaluation of prostheses

4) Virtual/augmented reality

5) Surgical exploration/simulation

6) Optimization of human-machine interfaces design

7) Entertainment

Concept to fix in our mind

# Human motion virtualization (simulation with real data)

- ✓ Human motion virtualization makes the most of multifactorial motion captured data (kinematics, EMG, reaction/contact forces) as input to simulated environment and human models

- ✓ Virtual environments (software) represent the tools where new situations can be explored (muscle displacement for functional planning, interaction with the environment)

- ✓ Environment design is optimized as a function of virtualized human motion data

read everything

- ✓ Rehabilitation programs / surgical interventions can be planned more appropriately on a patient specific basis

- ✓ External motion data can be used as a surrogate to predict internal anatomo-pathological modifications (breathing motion models) on biomedical image dataset

# Human motion virtualization (simulation with real data)

- ✓ Or... Use real human data to drive robots

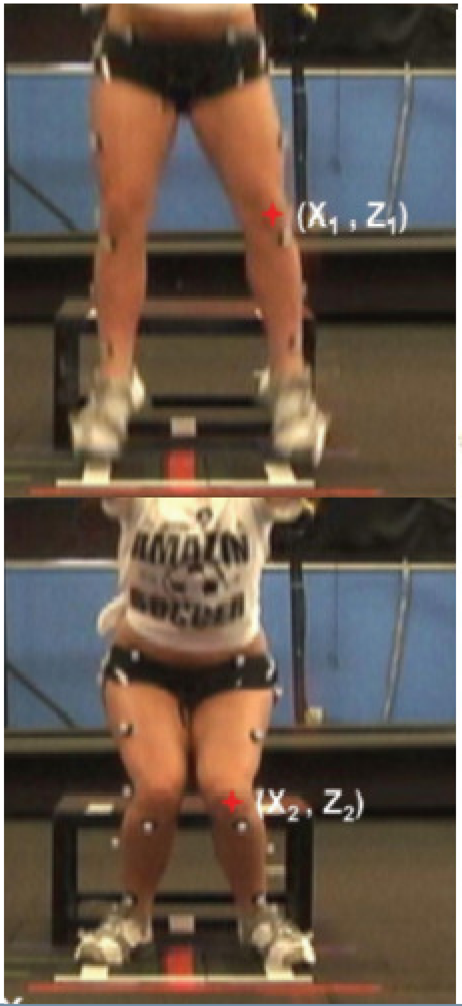
real data to plan motion of the robot.

they must move like humans to make the interaction with humans better.So you can interact with it better

# Applications: Prevention of injuries

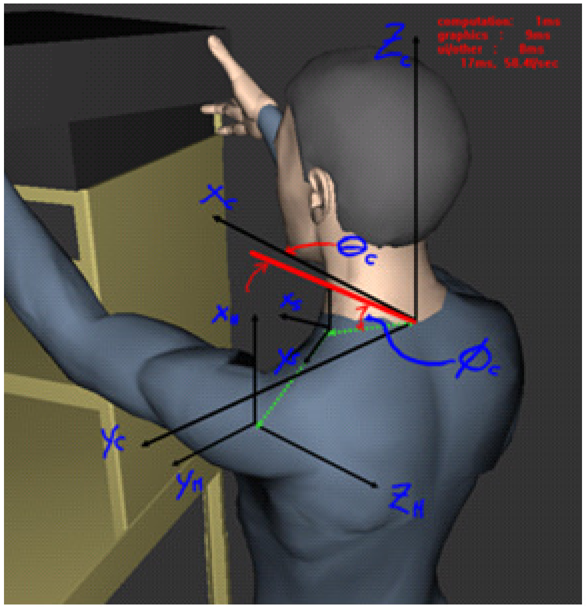
- ✓Kinematics data are fed to a human model which estimates loads
- ✓The effects of compensatory motion/gesture can be simulated on joints load for injury prevention

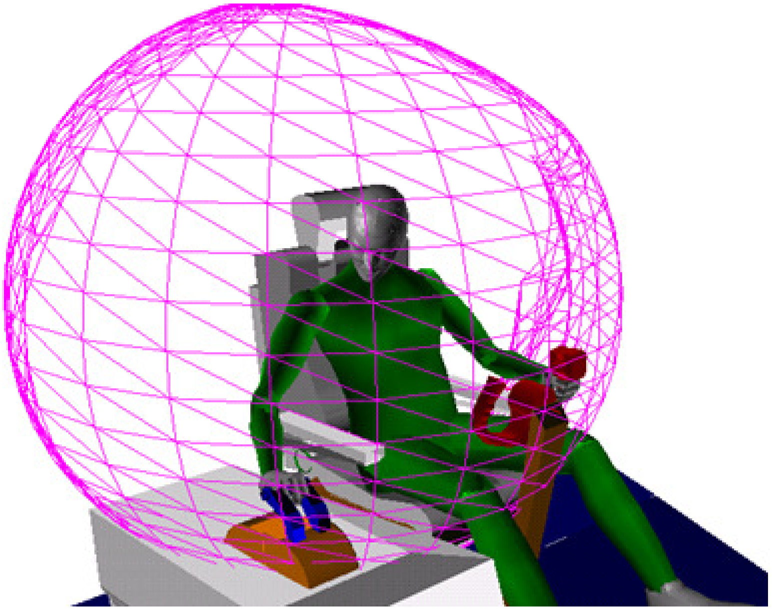
Real data from squat/jump, understanding and calculating the loads on joints, prevent injuries. It allows to try to correct the gesture, correct and compensate injury dangers the subject is going through!! How he should correct the movement in order to unload, or balance the load distribution on all the specific joints involved in the process. You can train the patient and re-abilitate him.




# Application areas: ergonomics and human factors

Optimization of cockpit, workspace …

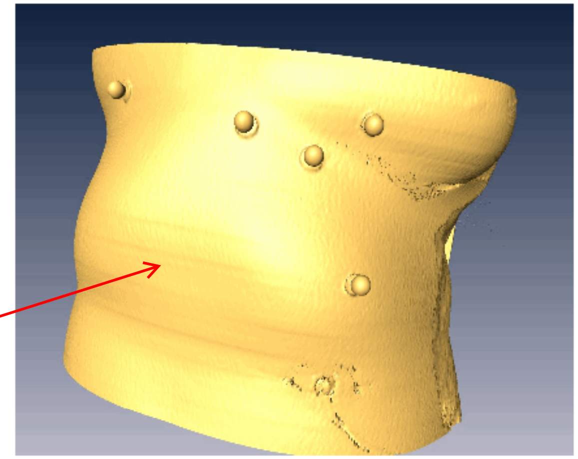


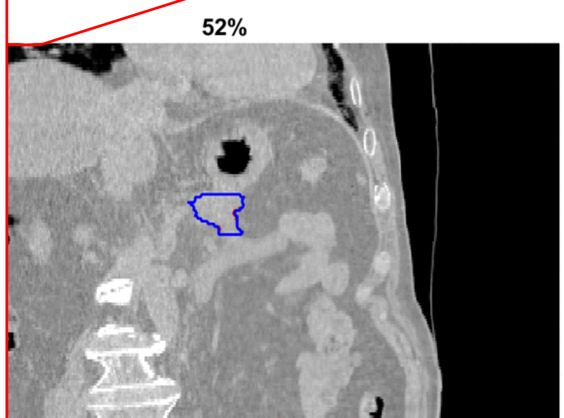


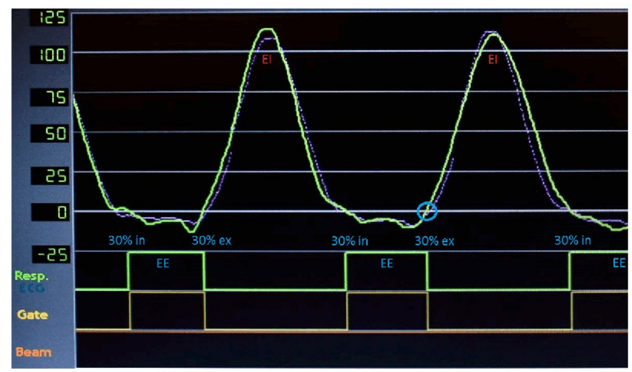
# Application: anatomical modeling (4D)

markers used to capture respiratory motions, it can be combined with acq of each spefici slides of CT scan, so that you can undesrtand at which instant of resp. phase that image was acquaired. You can link the time of the image with the phase of respiratory moment. You can have a volume at end of respiration, at the beginning, etc. You subdivided in phases (windows) and you have each volume for each subdvd. Which represents the anat. conf. of the sbj at that moment. This is how motion is captured and virtualized in order to produce representation of the inside motion. You can quantify what's the variation that comes into place from one phase and another. You can quantify the displacement, produce motions modules, which are basically maps of the deformations. They can be used as basis for predicting how the patient will be at the time of the surgery WICH WILL BE DIFFERENT FROM THE MOMENT WHERE CT WERE ACQUIRED!!! I'm not sure if it will still be valid when im doing surgery :( maybe he's breathing differently,higher freq... so I need to adapt the motion I have captured to that moment. In order to estimate this I need to use the motion model that I am able to extract and work on it, to adapt to what im seeing during the surgery. I cant do CT during that time, but I can track the motions. I can use this data + the model in order to adapt that motion model to the real case in surgical, and estimate a new conf of the patient. Real time data + model. High precision targeting surgery (radiotherapy)

otion data applied to
s based on
age registration to
omical configurations
spiratory phases and





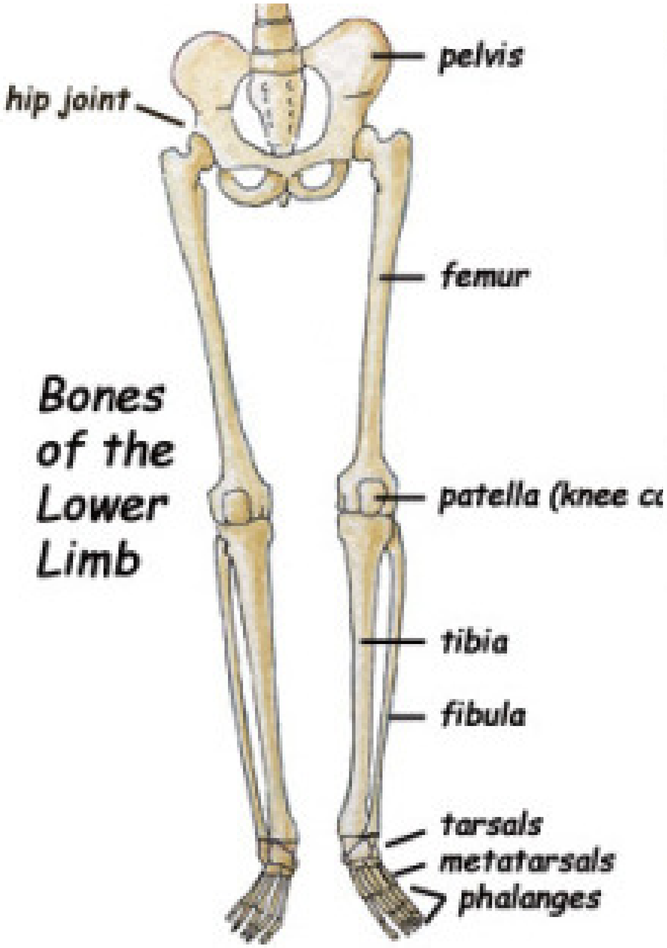
# Basic biomechanics concepts needed

- ✓ Biomechanical reference systems
  - ✓ axes
  - ✓ planes
  - ✓ reference systems
- ✓ Kinematic variables
  - ✓ position
  - ✓ angles
  - ✓ velocity
  - ✓ acceleration
- ✓ Kinetics variables
  - ✓ masses
  - ✓ Inertias
  - ✓ COM / COG / COP
  - ✓ Reactions

# Basic biomechanics concepts needed

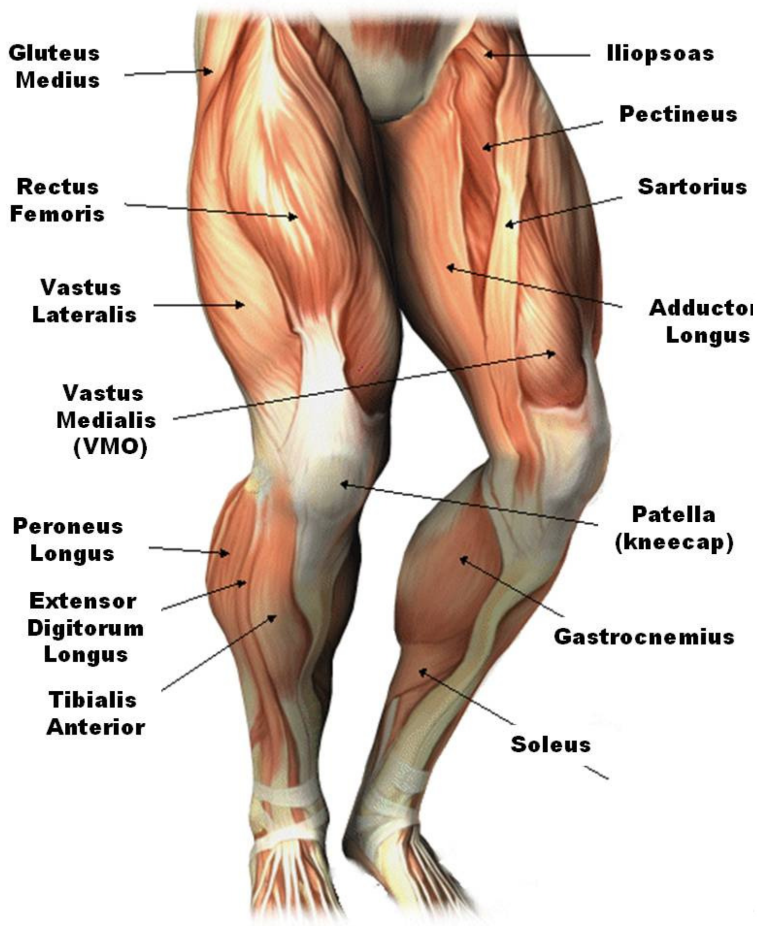
- ✓ Kinematics chains
  - ✓ segments / joints / reference systems / base / end-effector
- ✓ Direct /Forward kinematics
  - ✓ given joints configuration find position and orientation of the end effector
- ✓ Inverse kinematics
  - ✓ given a goal (reaching) find joint configuration(s)
- ✓ Direct/Forward Dynamics
  - ✓ estimate segments motion from known applied joint torques and external forces
- ✓ Inverse dynamics
  - ✓ given a motion and applied external forces, estimate joints loads (net forces and torques)

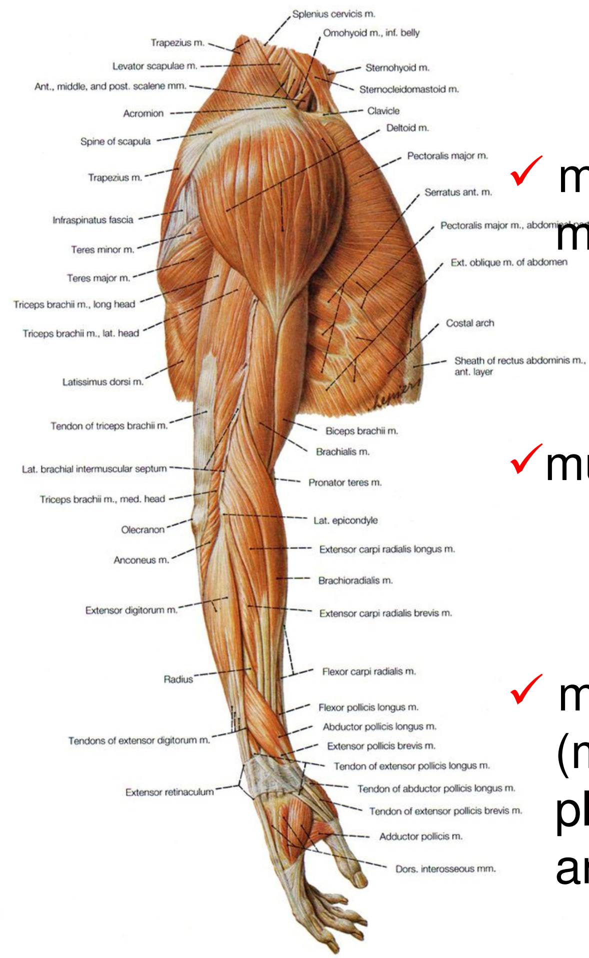
# Basic biomechanics concepts needed




- ✓ bones/joints names
- ✓ joints degrees of freedom
- ✓ reference system origin and orientation
- ✓ Classification of joint rotations on anatomical planes

# Basic biomechanics concepts needed

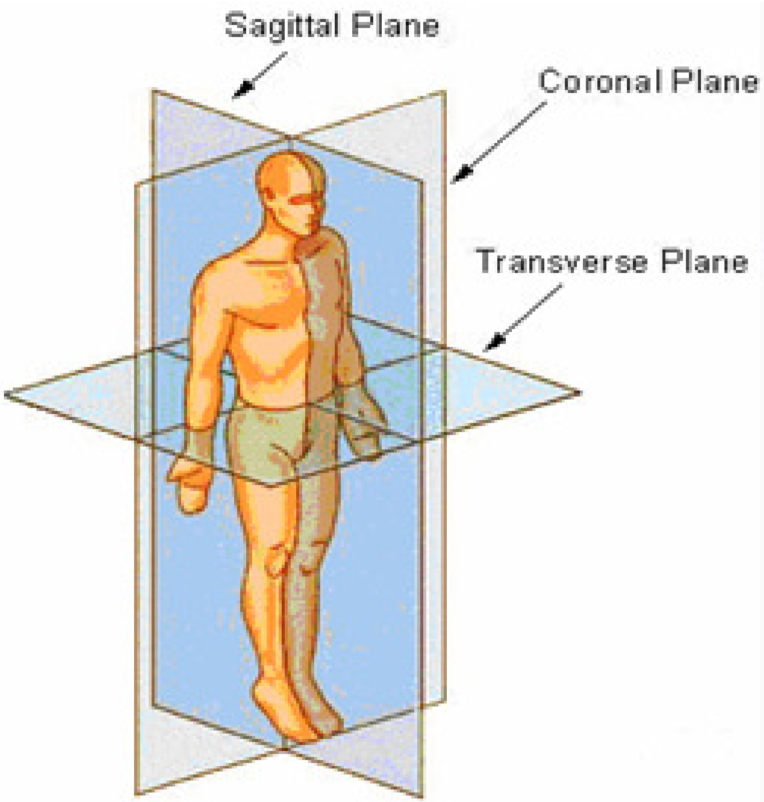


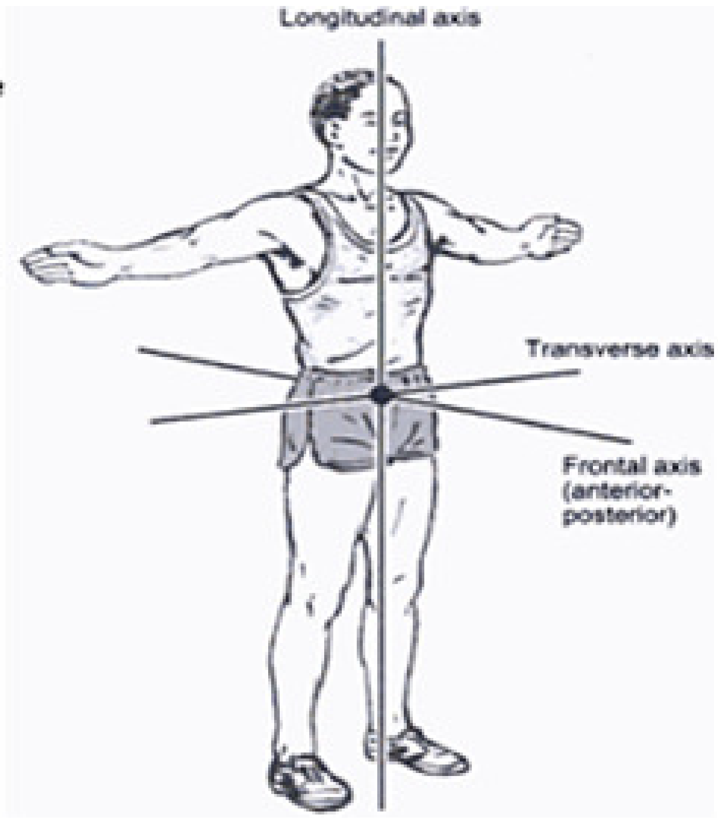




biarticular, pluriarticular, action of biceepts (flexor at elbow level, antagonist: tricepts, which is the extensor)

- ✓ muscle names (at least major muscles)
- ✓ muscle insertion points
- ✓ muscle characteristics (monoarticular, biarticular, pluriarticular, agonist, antagonist)

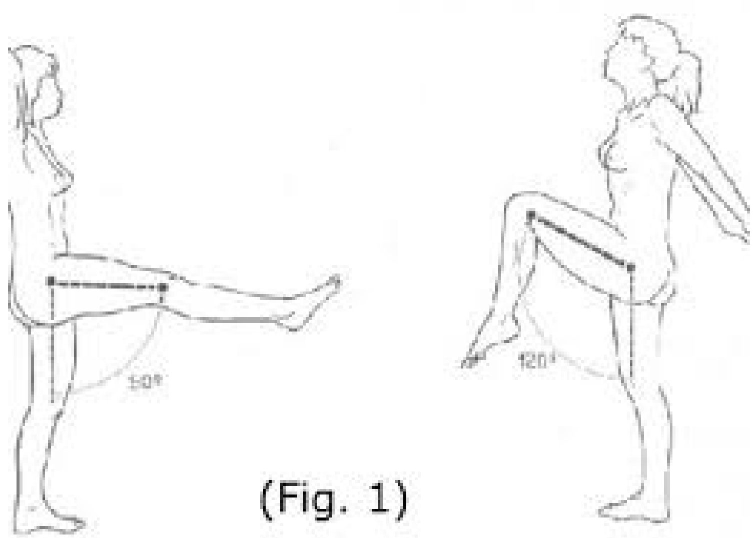
# Basic biomechanics concepts needed



# Basic biomechanics concepts needed

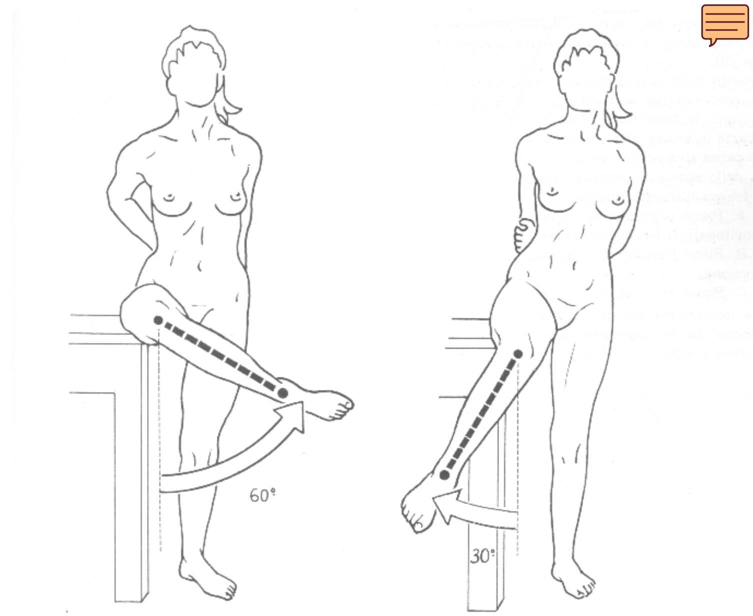
On sagittal plane (around transverse axis):




Hip flexion
Knee extension

Hip flexion
Knee flexion

On frontal plane (around frontal axis) :

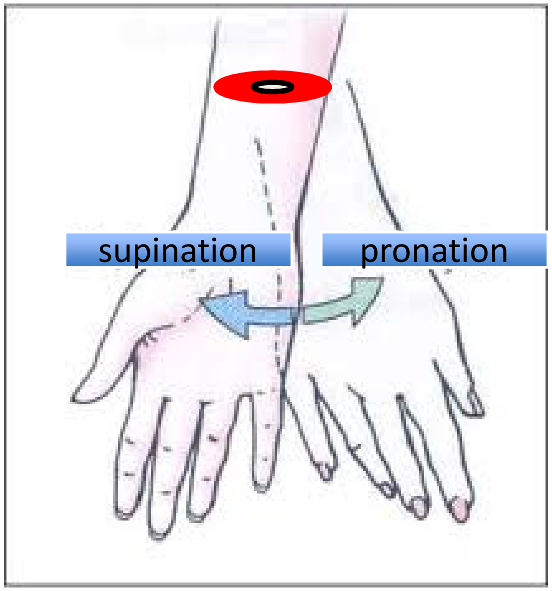


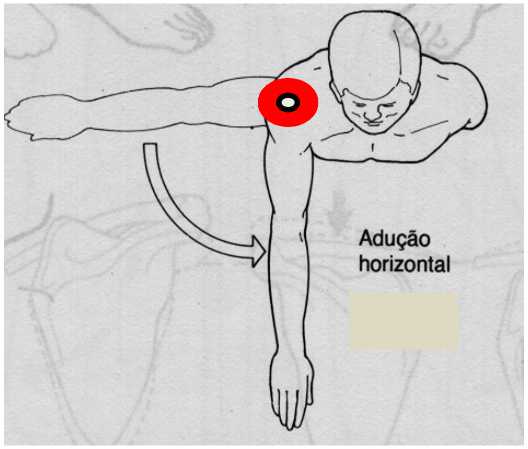

Adduction

Abduction

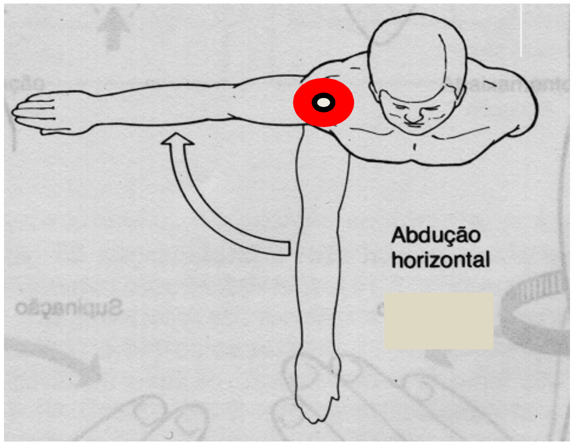
# Basic biomechanics concepts needed

On transverse plane (around longitudinal axis):



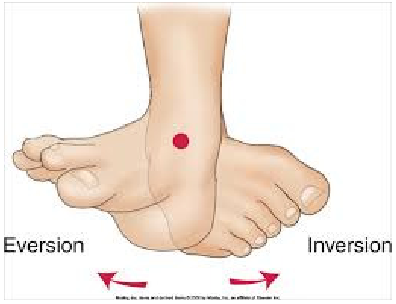




Horizontal
Adduction




Horizontal
Abduction

For the foot:
- Eversion
- Inversion



# Basic biomechanics concepts needed

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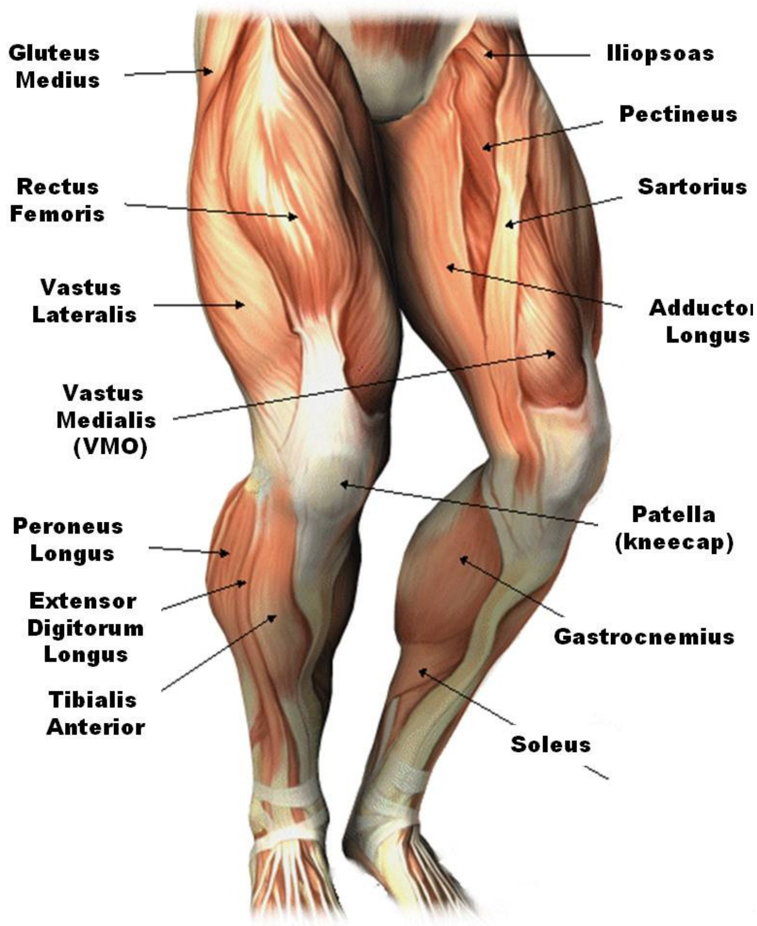
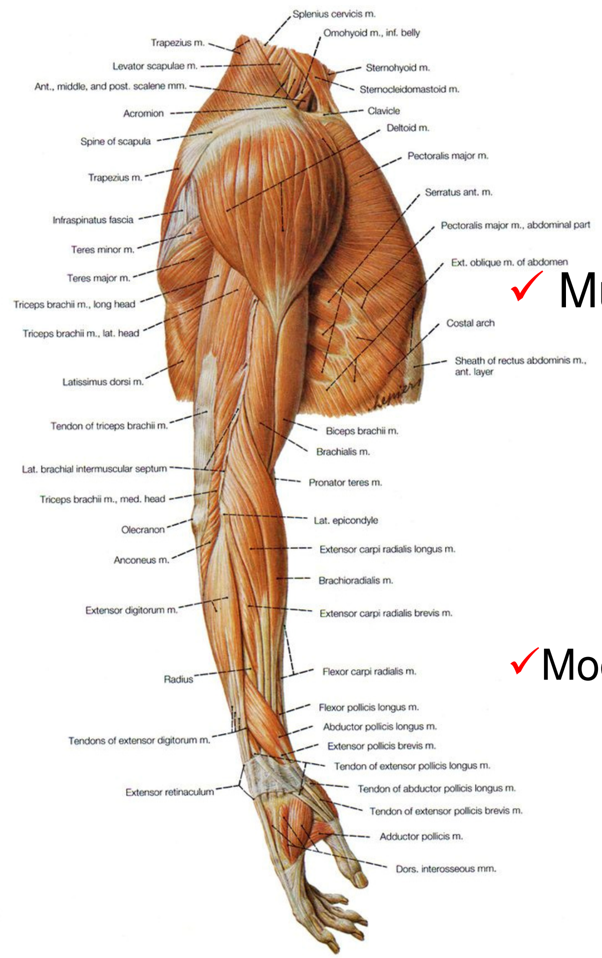



- ✓ Muscle function:
  - ✓Flexor
  - ✓Extensor
  - ✓Abductor
  - ✓Adductor
  - ✓Supinator
  - ✓Pronator
- ✓Modes of contractions:
  - ✓Isotonic (excentric, concentric)
  - ✓Isometric
  - ✓Isokinetic

# Basic biomechanics concepts needed

HIP

| Muscoli | Flessione | Estensione | Rotazione mediale | Rotazione laterale | Abduzione | Adduzione |
|---|---|---|---|---|---|---|
| Bicipite femorale | | X | | | | |
| Semitendinoso | | X | | | | |
| Semimembranoso | | X | | | | |
| Sartorio | X | | | X | | |
| Ileo-psoas | X | | | X | | |
| Reto da coxa | X | | | | | |
| Piccolo Gluteo | | | X | | X | |
| Medio Gluteo | | | X | | X | |
| Grande Gluteo | | | | X | X | |
| Tensore della fascia lata | | | X | | X | |
| Gracile | X | | | | | X |
| Adduttore lungo | | | | | | X |
| Adduttore magno | | | | X | | X |
| Adduttore minimo | | | | | | X |
| Pettineo | X | | | | | |
| Otturatore esterno e interno | | | | X | | |
| Piriforme | | | | X | X | |

# Basic biomechanics concepts needed

KNEE

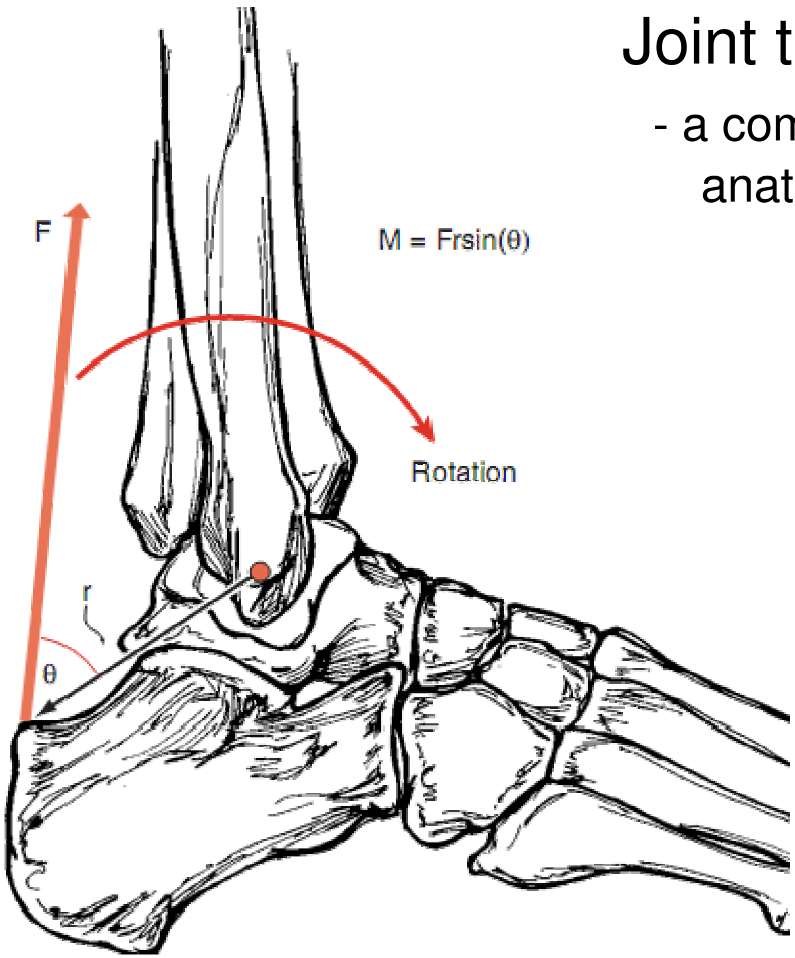
| Muscoli | Flessione | Estensione | Rotazione mediale | Rotazione laterale |
|---|---|---|---|---|
| Quadricipite | | X | | |
| Bicipite femorale | X | | | X |
| Semitendinoso | X | | X | |
| Semimembranoso | X | | X | |
| Sartorio | X | | X | |
| Gracile | X | | X | |
| Popliteo | X | | X | |
| Gastrocnemio | X | | | |
| Plantare | X | | | |

# Basic biomechanics concepts needed

## ANKLE /Foot

[new slides]

| Muscoli | Flessione Plantare | Dorsi flessione | Inversione | Eversione | Abduzione | Adduzione |
|---|---|---|---|---|---|---|
| Gastrocnemio | X | | | | | |
| Soleo | X | | | | | |
| Plantare | X | | | | | |
| Tibiale anteriore | | X | X | | | X |
| Tibiale posteriore | X | | X | | | X |
| Fibulare lungo | X | | | X | X | |
| Fibulare breve | X | | | X | X | |
| Fibulare terzo | | X | | X | | X |
| Estensore lungo del dito | | X | | X | | |
| Estensore lungo dell’alluce | | X | X | | | |
| Flessore lungo del dito | X | | X | | | X |
| Flessore lungo dell’alluce | X | | X | | | |

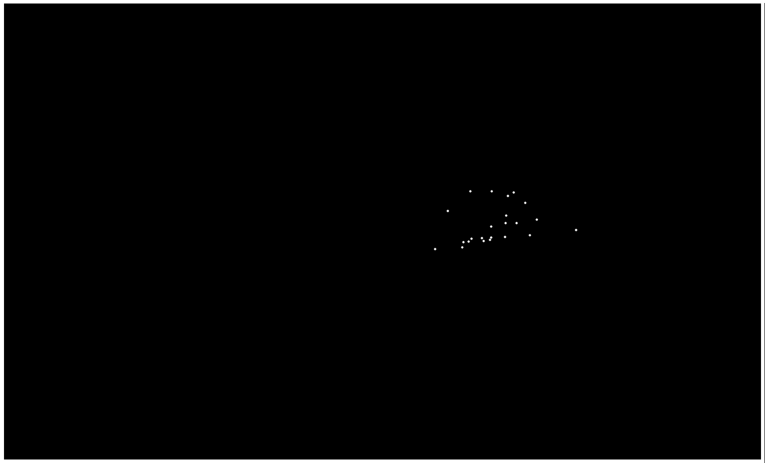



## Joint torque

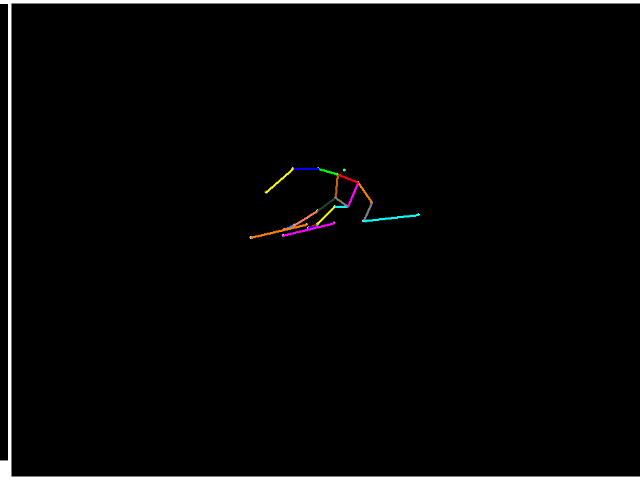
- a combination of muscle force and anatomy (moment arm)

# Basic biomechanics concepts needed

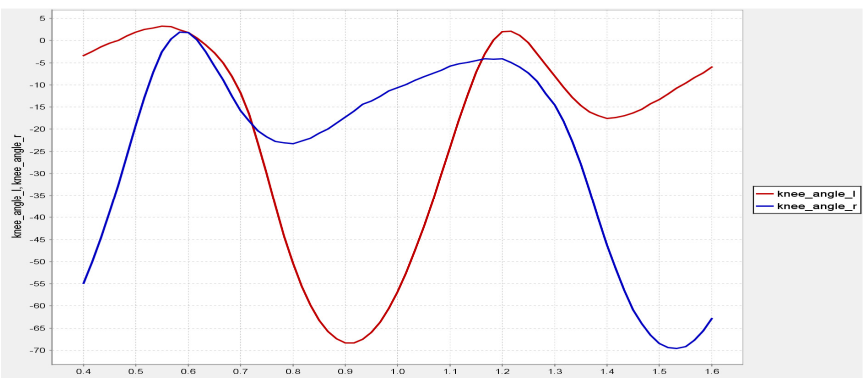
trajectories



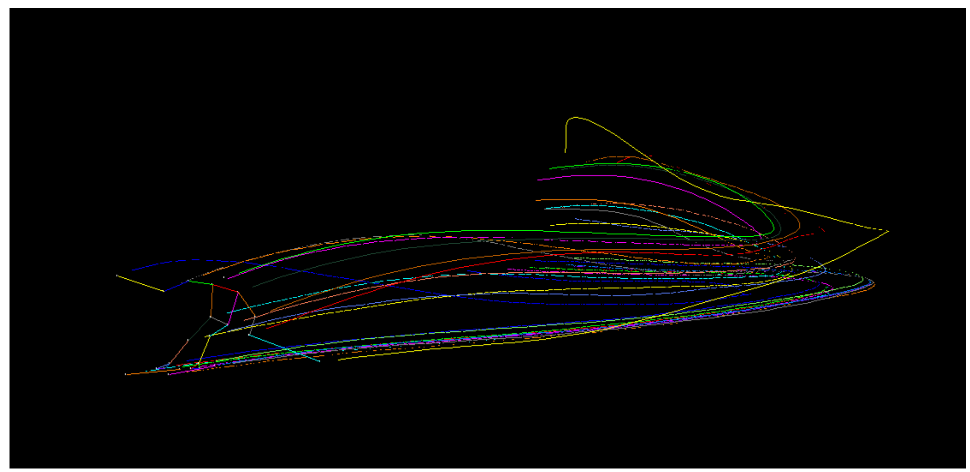
Points / markers



Links (model)

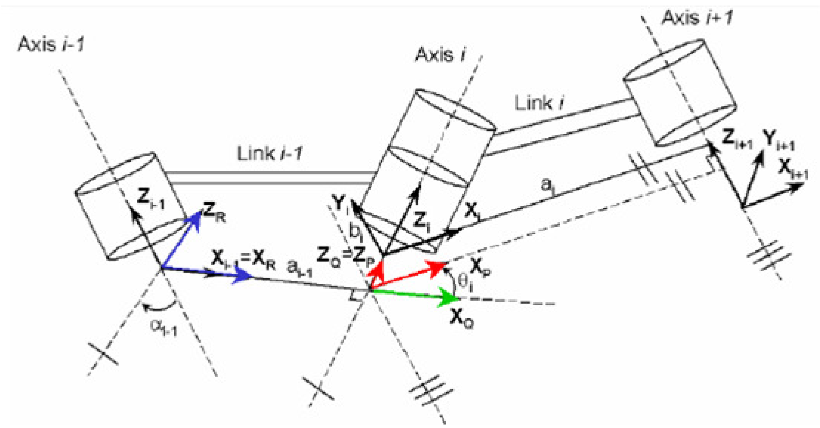



Joint angles

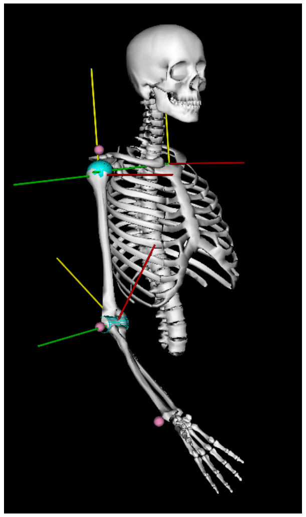


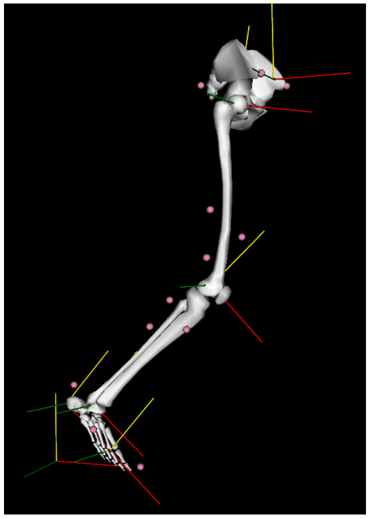
Trajectories

# Basic biomechanics concepts needed

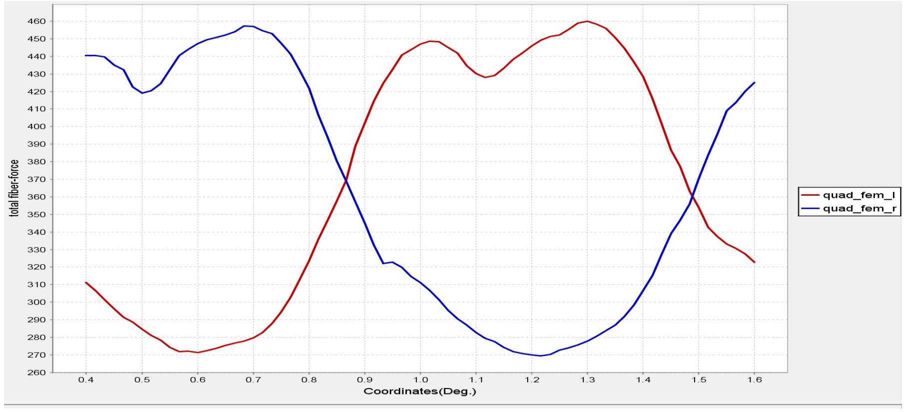



Kinematic chains

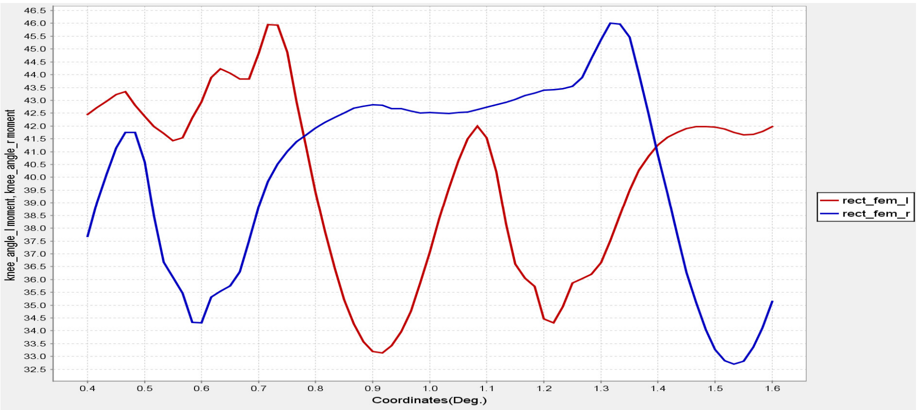




kinematics chains

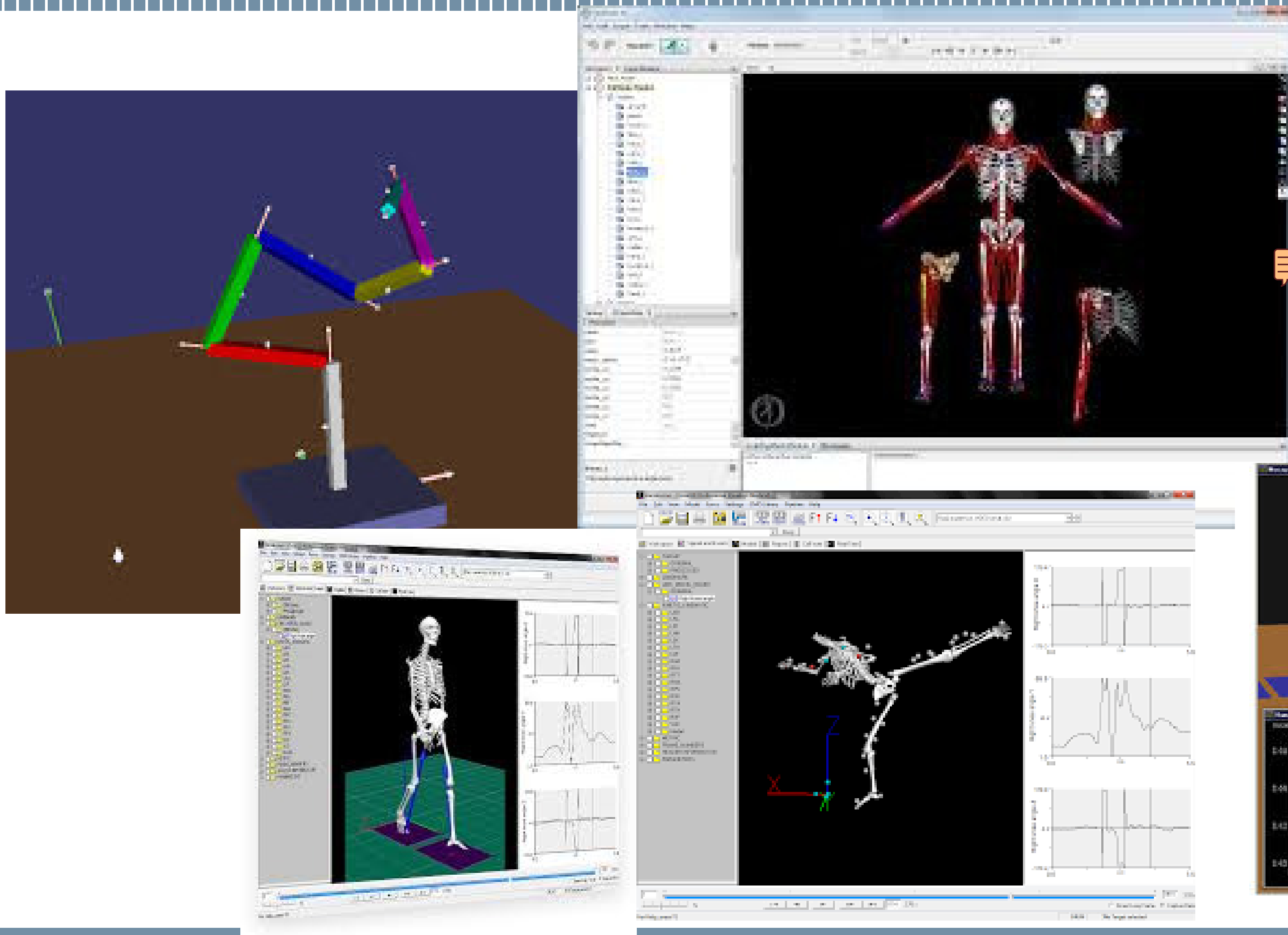



Muscle forces

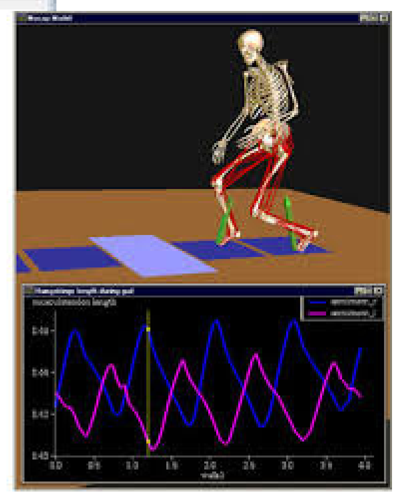



Joint torques

# A computational tool is needed: simulation software



muscles forces, joints foces



# Software for human motion virtualization: requirements

?

# Software for human motion virtualization: requirements

1. Editable human model (skeletal, muscle)
2. Loading of data: kinematics, EMG, force platform
3. Editable joint kinematics
4. Editable muscle length-force database
5. Visualization of main biomechanical parameters (joint angles,…, muscle length, moment arm, ….)
6. Forward/ Inverse kinematics tool
7. Forward / Inverse dynamics tool
8. Simulation of muscle displacement
9. ….