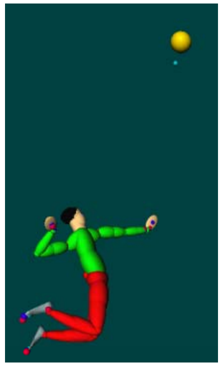
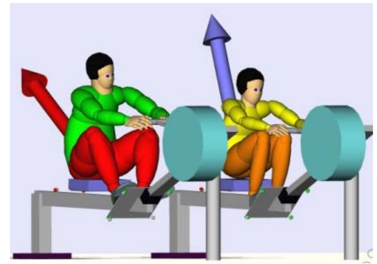
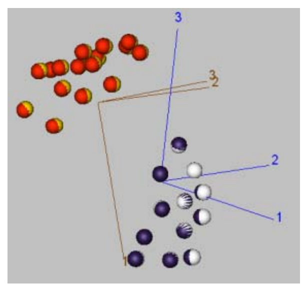




Biomechanical Modelling Applied to Human Movement Analysis



Karen Roemer PhD
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General Idea…

- **Parameter identification**
  - Kinematics
  - Kinetics

- **Motion Analysis**
  - Field tests
  - Lab tests

- **Biomechanical Modelling**
  - Inverse problem
  - Interaction athlete - equipment

Application…

Volleyball, Leg press, Rowing

Volleyball Spikes

- **Biomechanical Modeling**
  - Shoulder kinematics

- **3D Motion Analysis**
  - Field test

Application

Investigation of shoulder angles in volleyball spikes

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Volleyball Spikes

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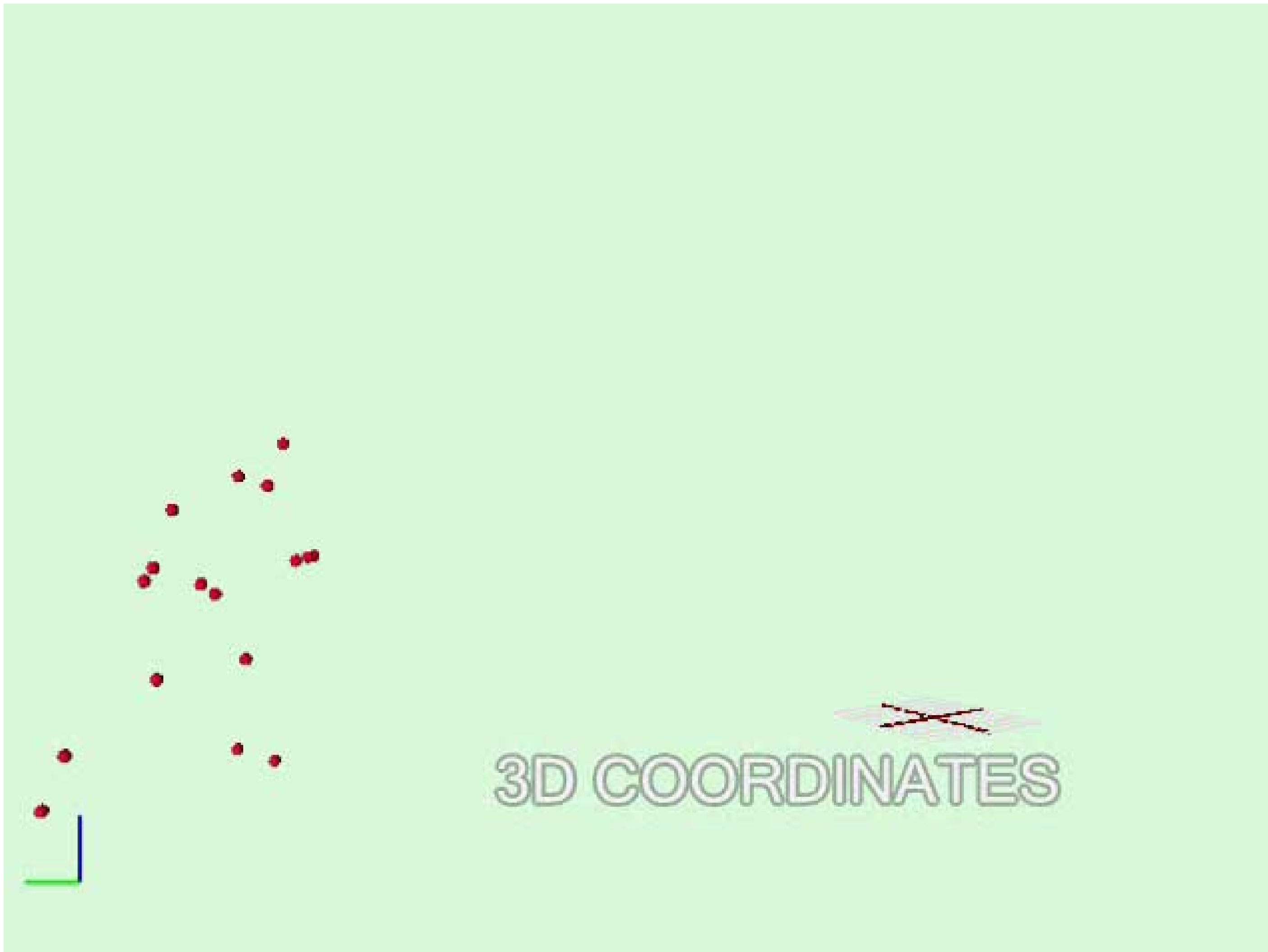
Volleyball Spikes



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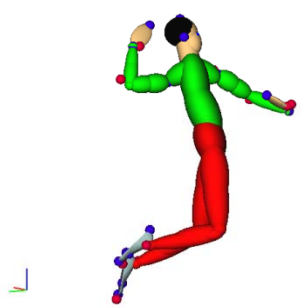
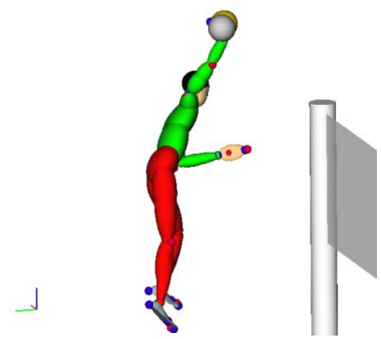
Volleyball Spikes

- Analysis of shoulder kinematics for volleyball spikes
- Definition of parameters for the investigation of shoulder kinematics in volleyball spikes
- Definition of parameters and graphs to present the results to coaches
- Focus on the phase between strike out position and ball impact





- Pilot study with 2 subjects and 4 spikes
- Follow up study with 10 subjects and 16 spikes

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Volleyball Spikes

Data Acquisition:

- European top level outside hitters of the national teams of Croatia, Estonia, Germany, and Netherlands
- European League
- Pilot study: four high speed Basler cameras (100Hz) and the software Simi Motion
- Follow-up study: eight high speed Basler cameras (200Hz), two Vosskuehler (200-1000Hz) and the software Simi Motion
- Manual digitizing
- Reproduction of movements with high accuracy (control points: ± 9 mm) using the man model DYNAMICUS (Roemer et al. 2007).

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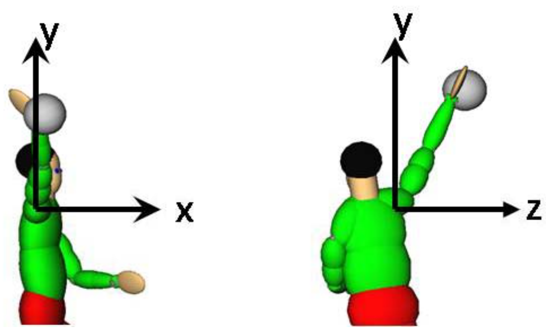
Volleyball Spikes

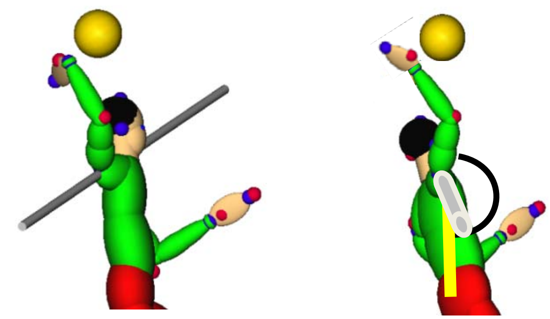
Data Processing:

- time normalization with respect to take-off and ball-impact

position and orientation of the coordinate systems fixed to thorax and humerus were defined using the ISB recommendations



Based on the unit quaternion, the axis angle representation of this rotational movement was determined *(Liu & Prakash 2003)*



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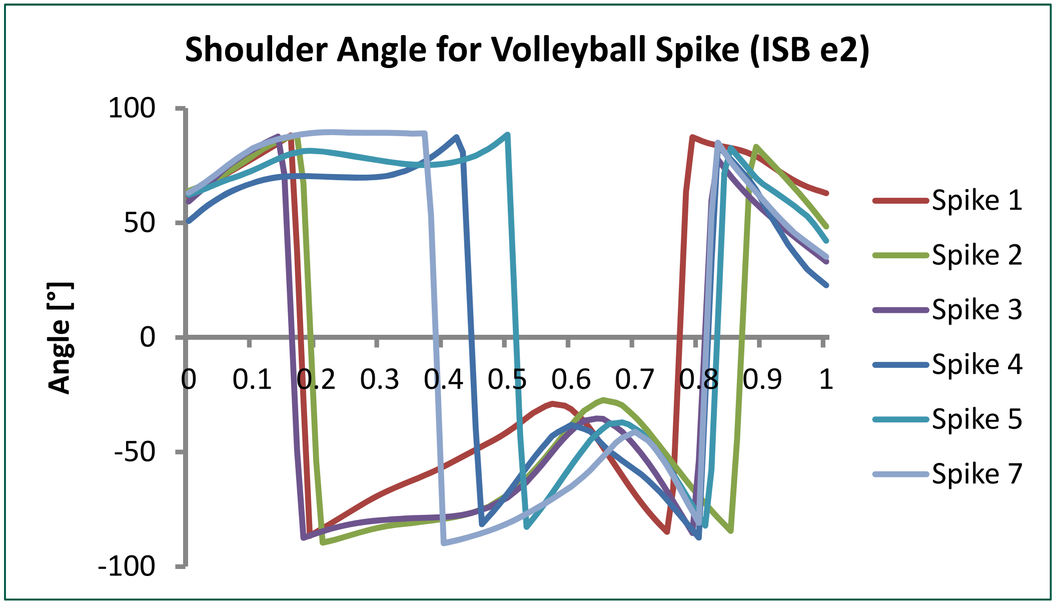
Volleyball Spikes

Euler angles lead to discontinuities in time histories of results ➔ gimbal lock (GL)

- ISB shoulder group proposed standardization for describing shoulder kinematics (Wu et al. 2005)



- Depending on the observed range of motion other rotation sequences can be found in the literature to avoid the GL (Levasseur et al. 2007, Senk & Cheze 2006)
- altering the rotational sequence influences results significantly (Karduna et al. 2000)

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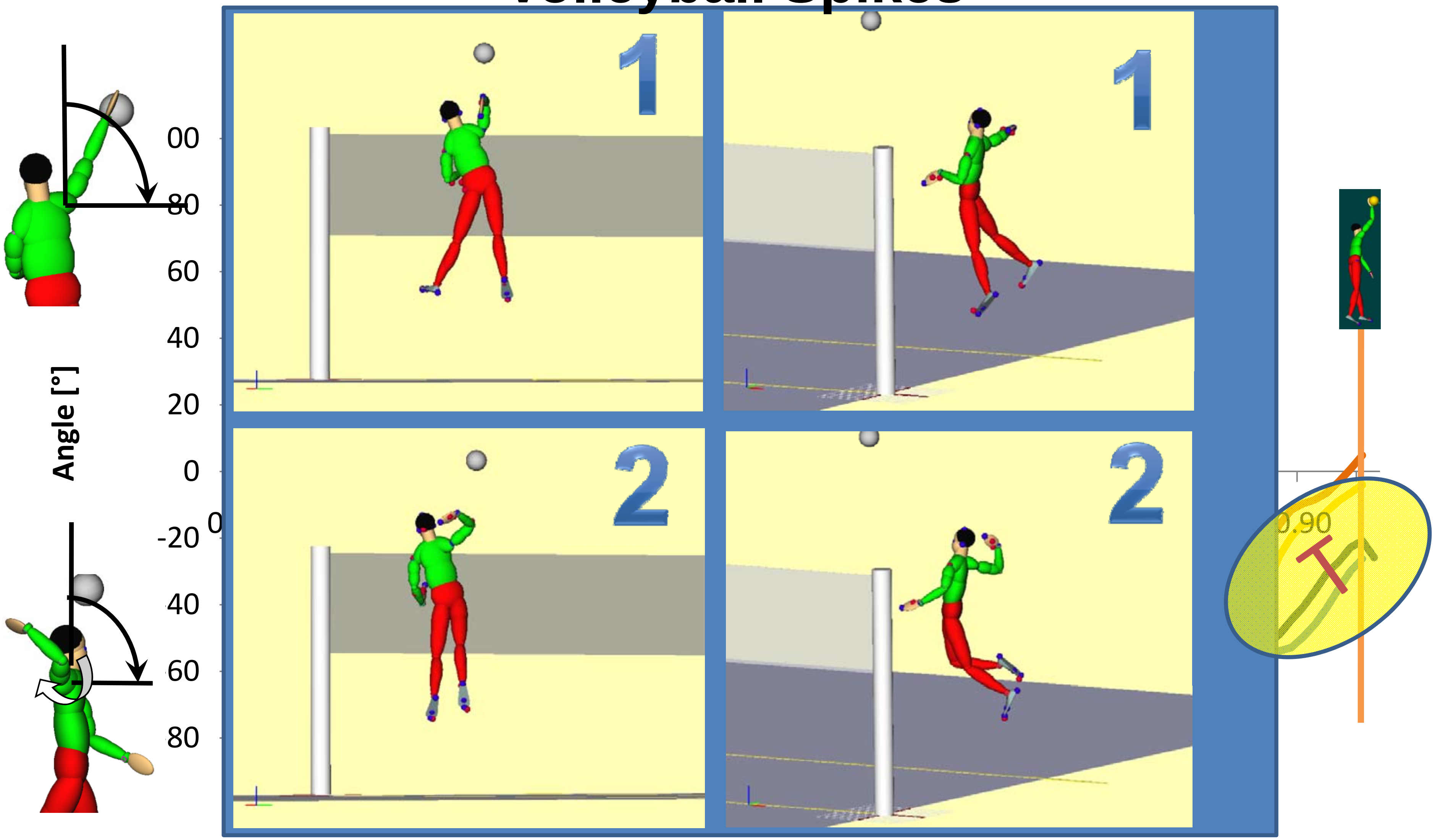
Volleyball Spikes



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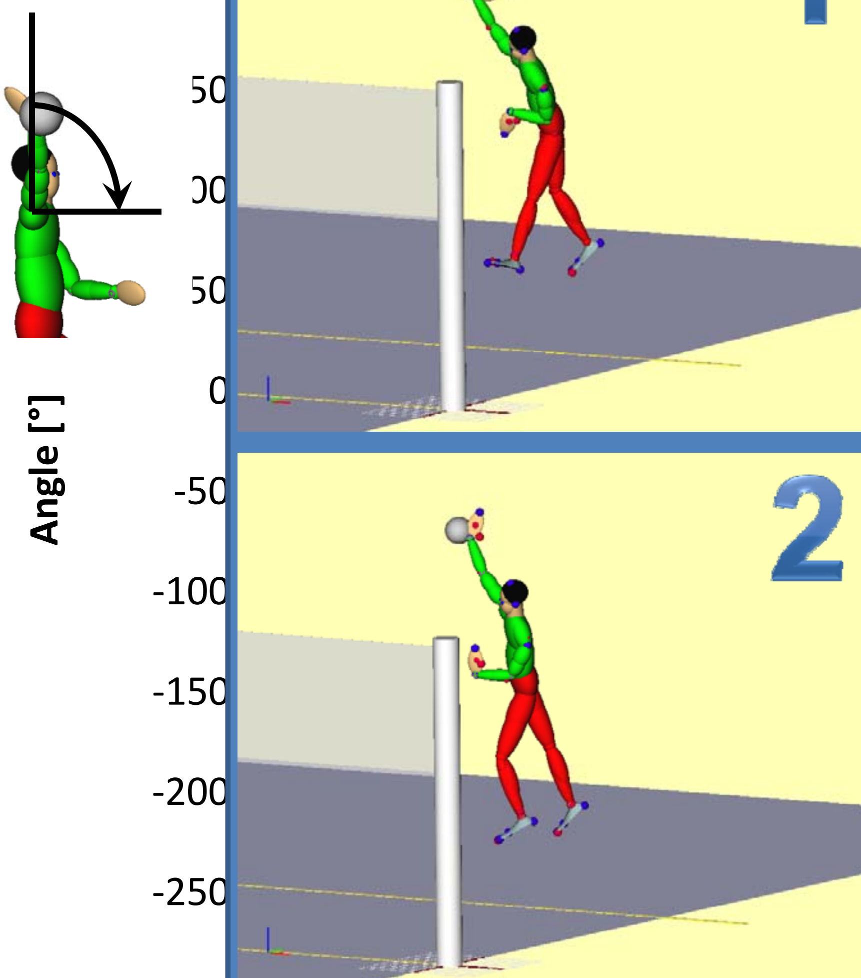
Volleyball Spikes



- indentical anthropometrics
- european top level outside hitters
- same COM-Height at Impact
- But: 8-10 cm difference in impact height was found

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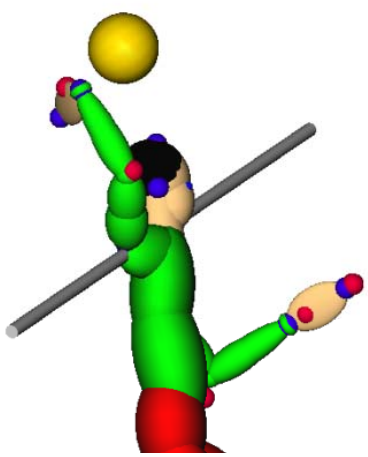
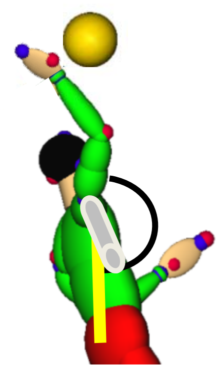
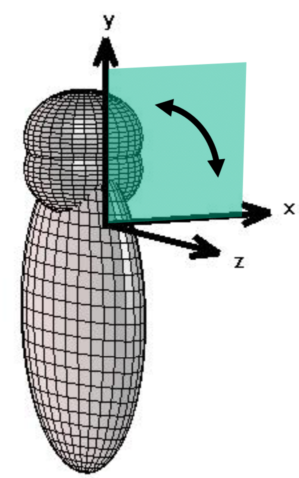
Volleyball Spikes

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Trial 11	Trial 12	Trial 13	Trial 14	Trial 15	Trial 16
ellb x-coord./ axis z-coord.	-0.94	-0.98	-0.99	-0.95	-0.80	-0.79	-0.81	-0.78	-0.70	-0.98	-0.85	-0.97	-0.84	-0.99	-0.95	-0.94
ellb y-coord./ axis z-coord.	-0.98	-0.97	-0.94	-0.91	-0.78	-0.82	-0.84	-0.92	-0.97	-0.95	-0.64	-0.93	-0.62	-0.95	-0.97	-0.98



➔ movements in the sagittal plane influence the orientation of RA concerning z-coordinate significantly ($p<0.01$)





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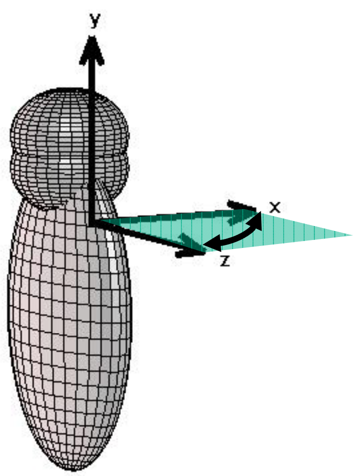
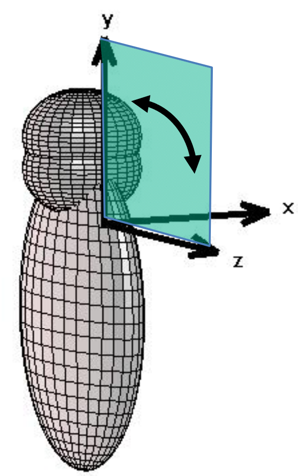
Volleyball Spikes

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Trial 11	Trial 12	Trial 13	Trial 14	Trial 15	Trial 16
ellb z-coord./ axis x-coord.	-0.91	-0.62	*-0.09*	0.80	-0.53	*-0.20*	*-0.33*	0.59	*0.26*	*-0.43*	*0.06*	*0.25*	-0.83	0.74	0.88	*-0.26*
ellb z-coord./ axis y-coord.	0.85	0.93	*0.48*	-0.75	0.69	*0.37*	*0.55*	-0.70	*-0.57*	0.76	*-0.21*	*0.10*	0.94	-0.67	-0.76	*0.45*



- ➔ eight trials out of 16 show no significant correlation
- ➔ four trials indicate significant positive correlation
- ➔ four trials indicate significant negative correlation for the same coordinate

?



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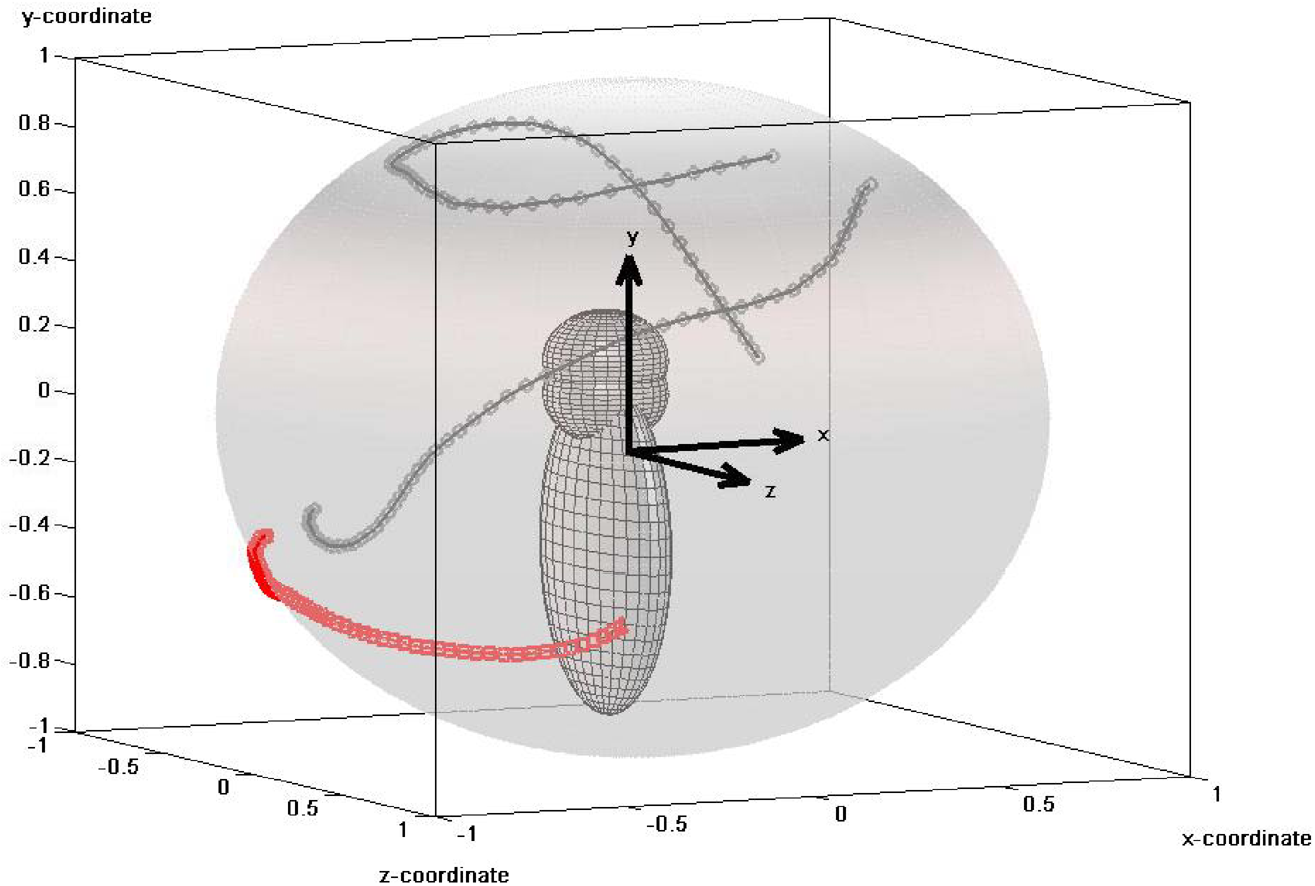
Volleyball Spikes



Ellbow

Hand

RA

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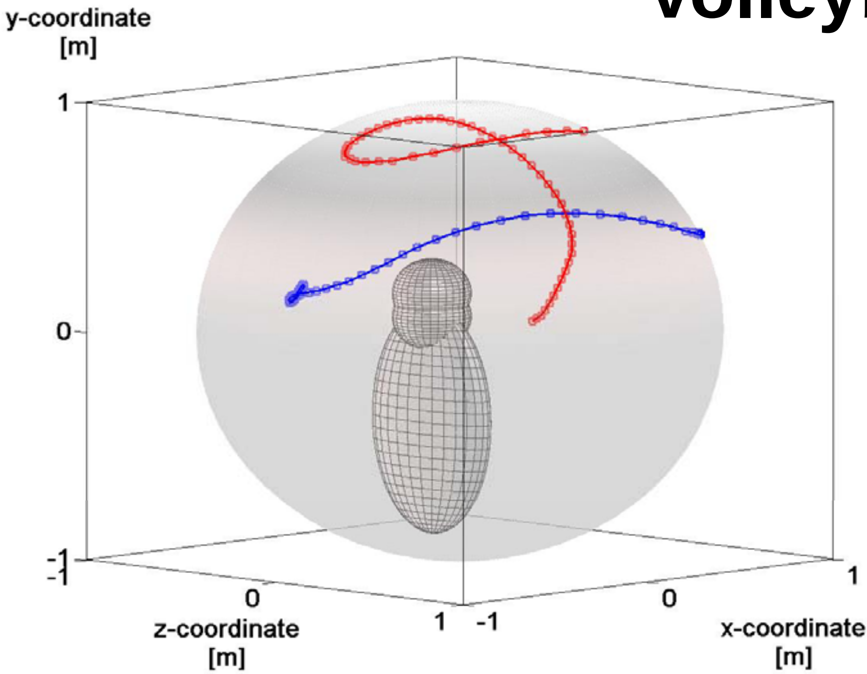
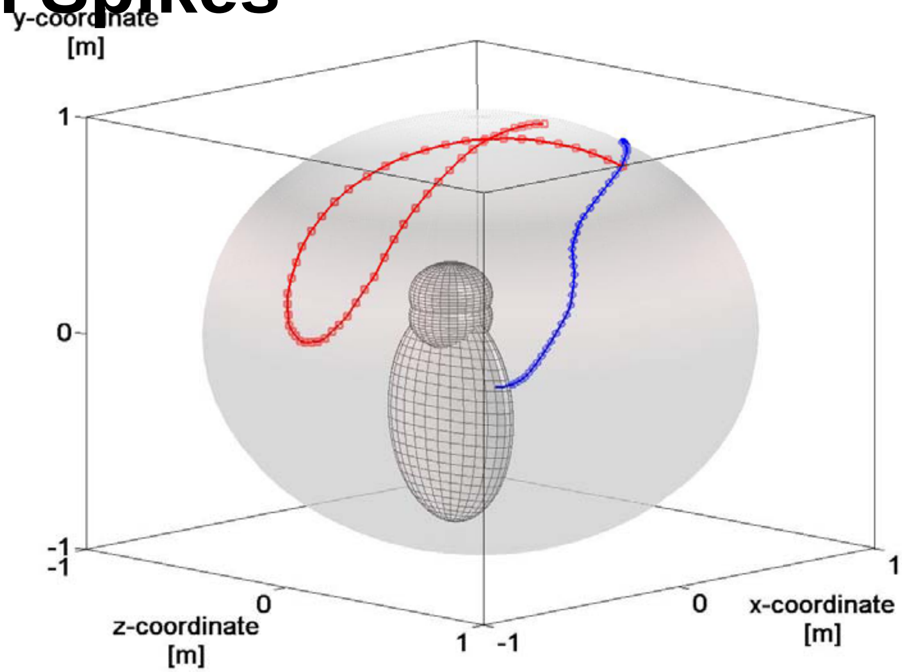
Volleyball Spikes





ROM : 90° to 142 °
Start : ***min.*** 60° of internal rotation

- ➔ Changes in the elbow z-coordinate do correlate with rotational angles in the shoulder joint
- ➔ Negative correlation of elbow z-coordinate with RA x coordinate

ROM : 53° to 116°
Start : ***max.*** 50° of internal rotation

- ➔ Changes in the elbow z-coordinate do not correlate with rotational angles in the shoulder joint
- ➔ Positive correlation of elbow z-coordinate with RA x coordinate

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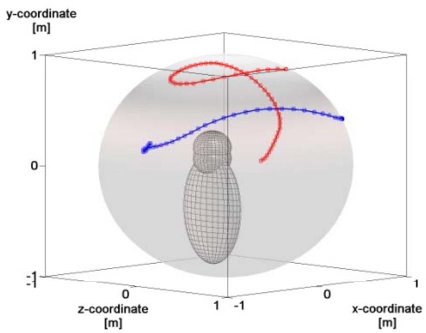
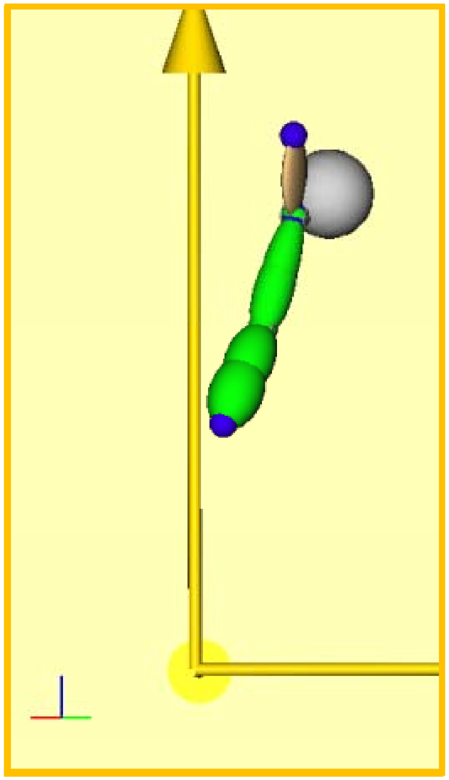
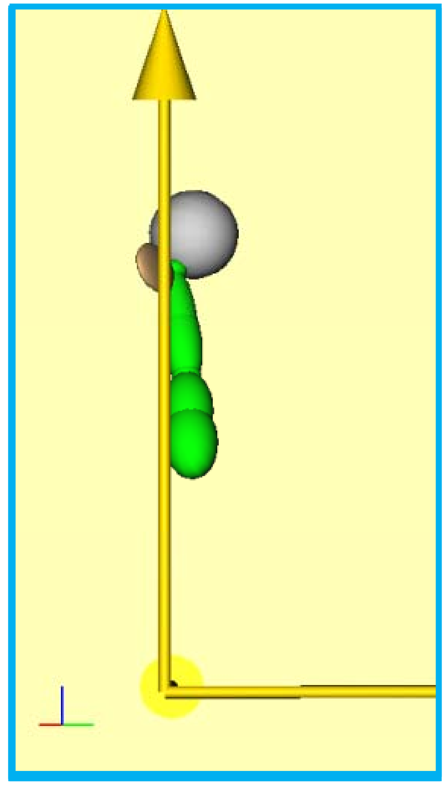
Volleyball Spikes

Impact-Indicator

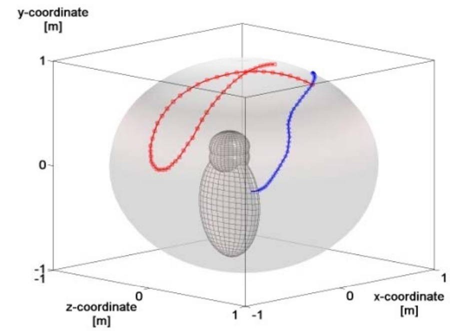




Technique 1



Technique 2



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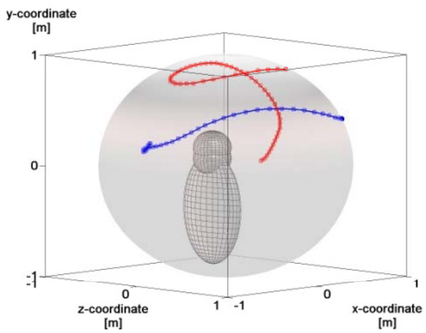
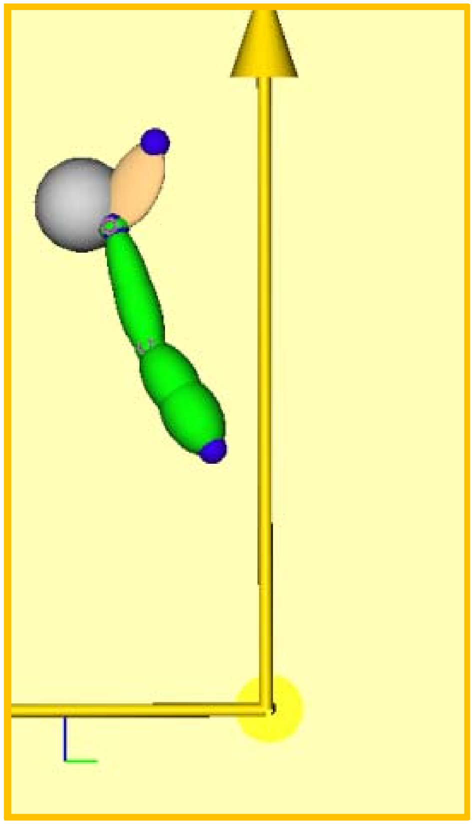
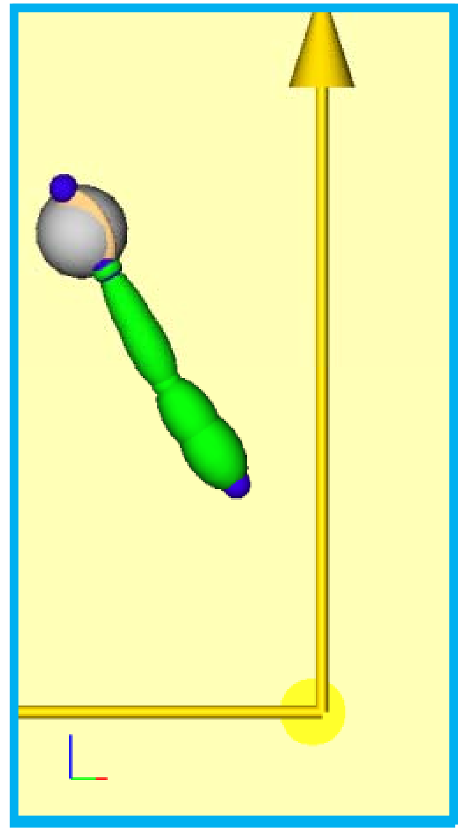
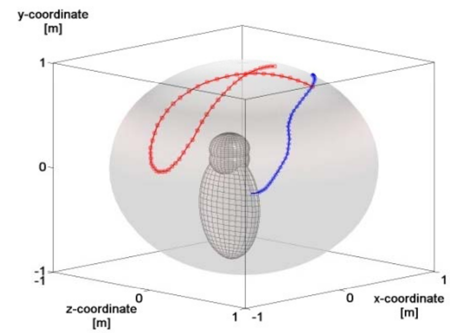
Volleyball Spikes

Ball-Indicator









Technique 1

Technique 2

➔ Graphic representation of results to transfer the knowledge to athletes and coaches

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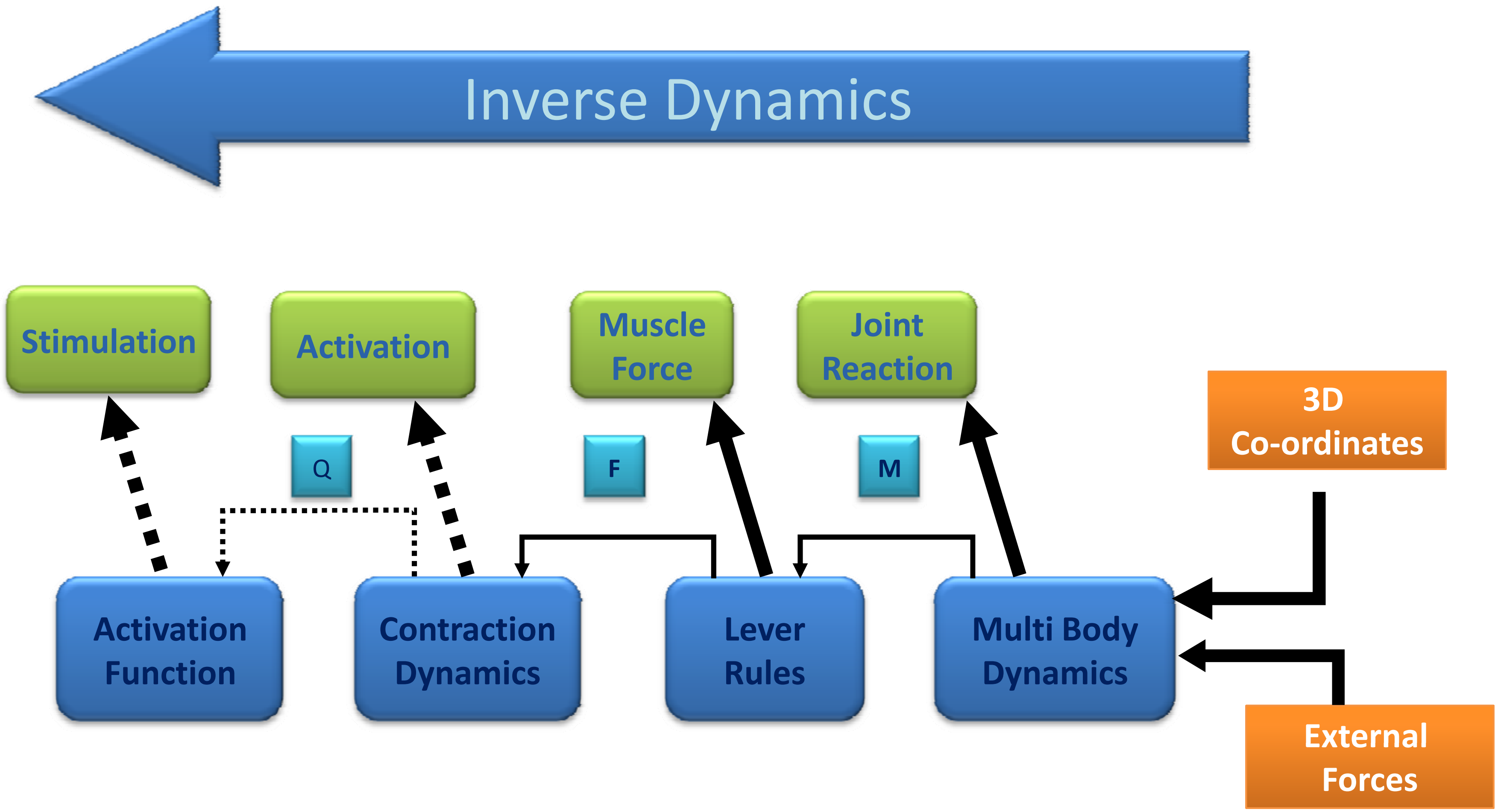
Analysis of Leg Extension Movements



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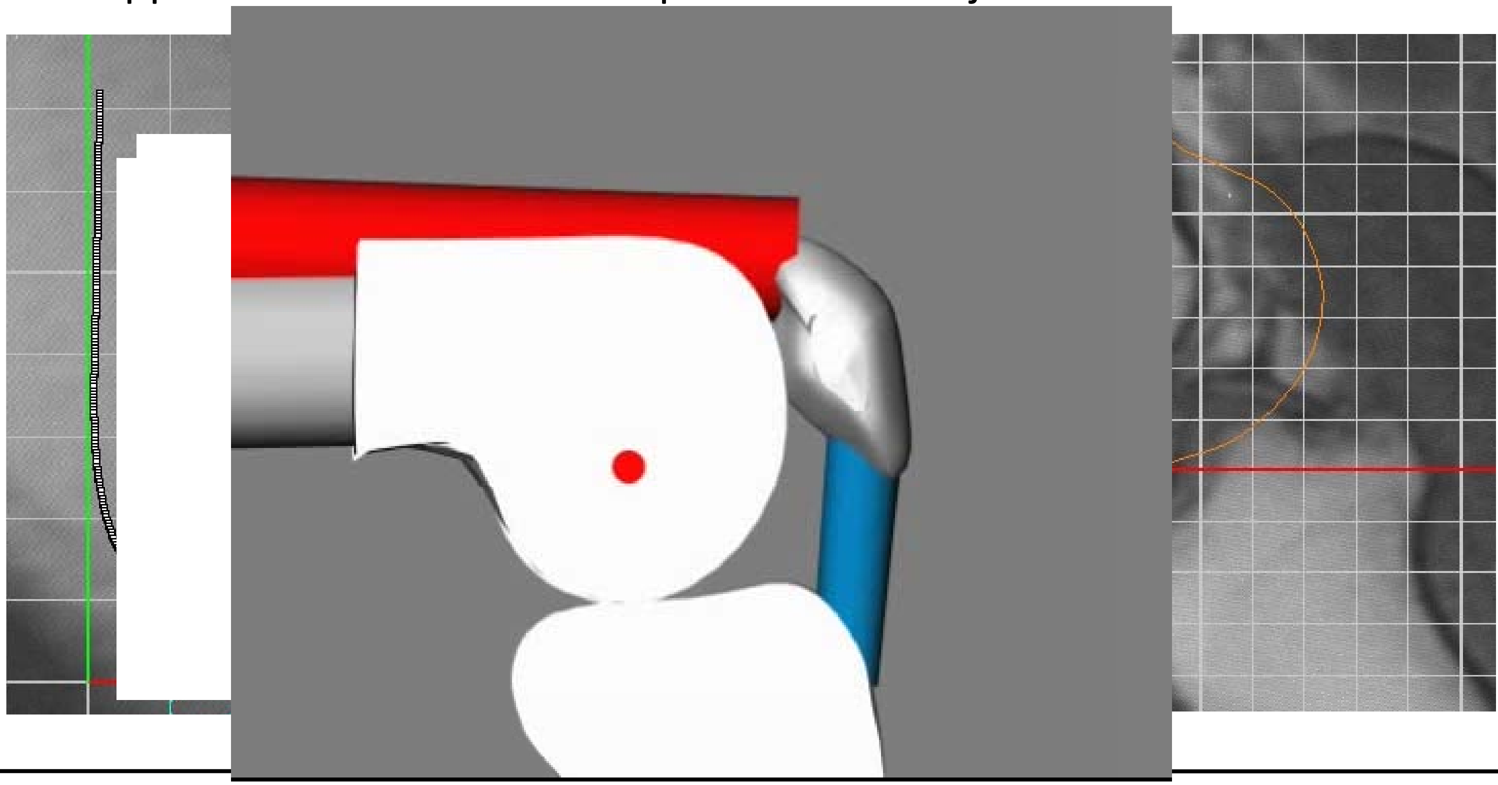
Analysis of Leg Extension Movements

- Geometric approach
  - MRI based model, coordinates of joint axis depend on the outline of the condylus femoris
  - and the linear displacement of the tibia *(see WANK 2000)*
  - applied to tibio-femoral and patello-femoral joint



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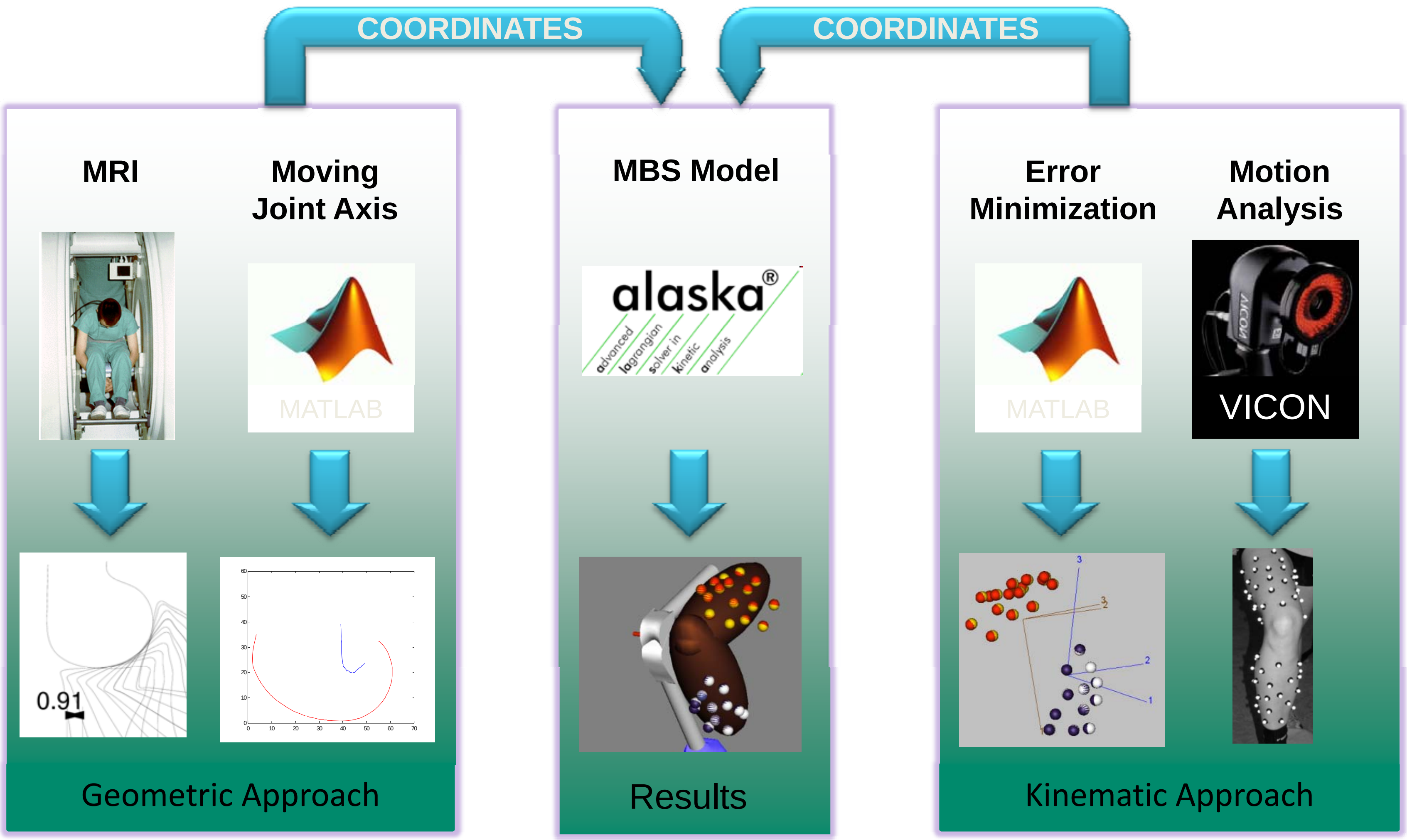
Analysis of Leg Extension Movements



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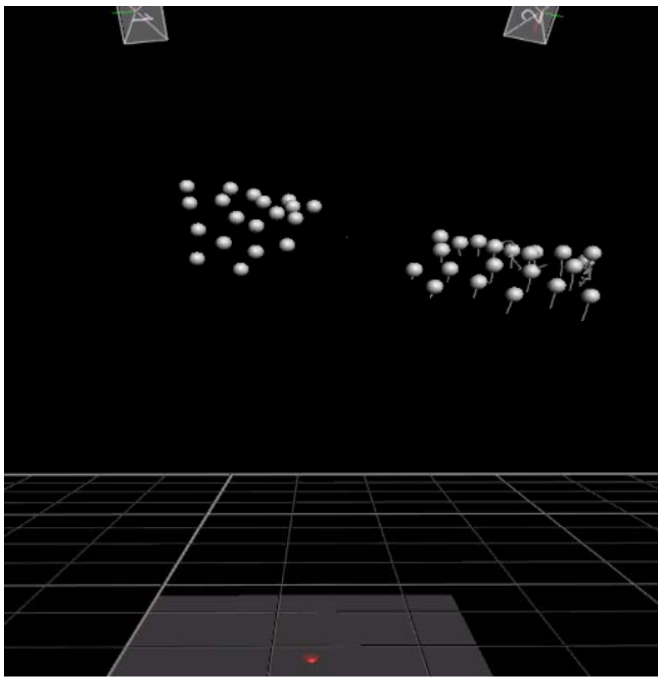
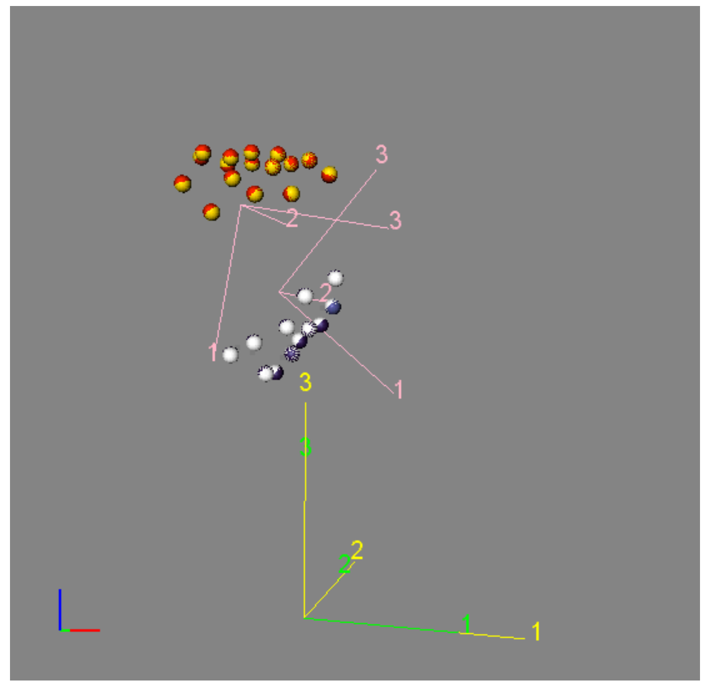
Analysis of Leg Extension Movements

Kinematic Theory Approach (Motion Analysis)





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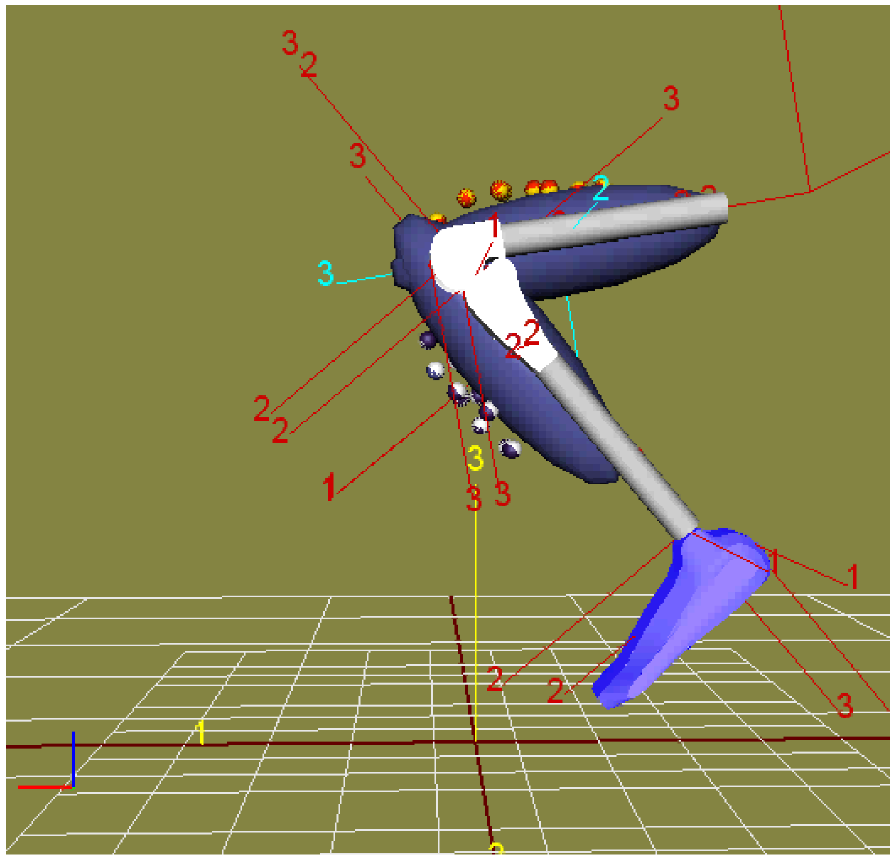
Analysis of Leg Extension Movements

MBS Model



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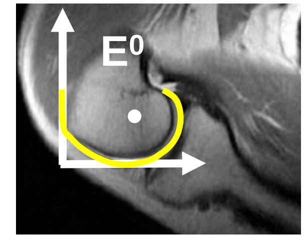
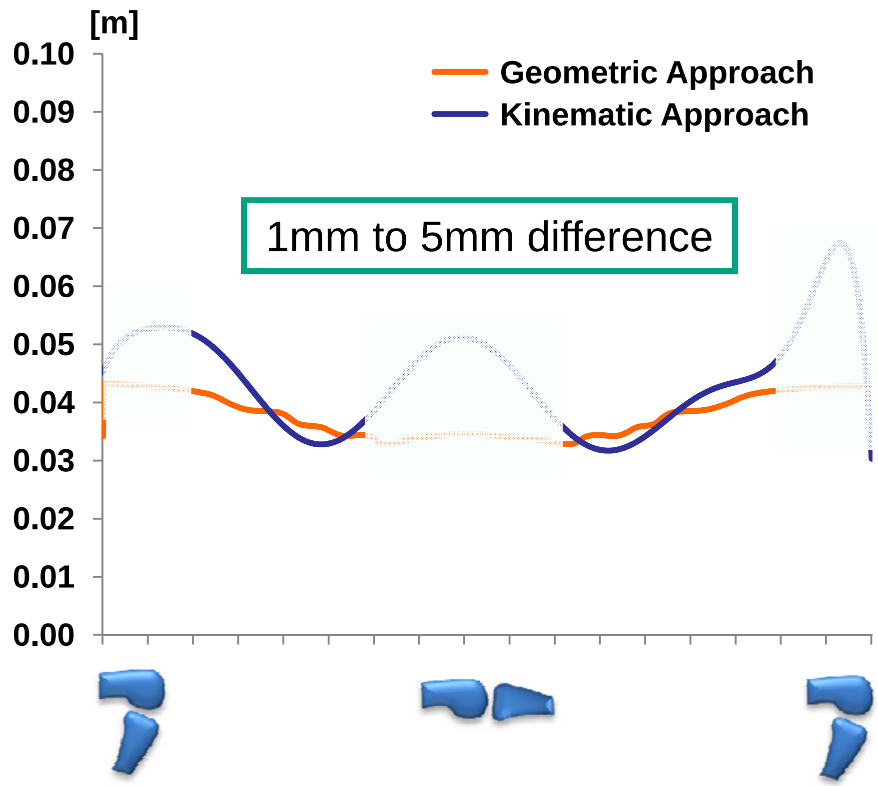
Analysis of Leg Extension Movements



Femur related results

X-Direction



$$\xi(t) = \frac{1}{\dot{\varphi}(t)} \cdot (\dot{x}(t) \cdot \sin(\varphi(t)) + \dot{y}(t) \cdot \cos(\varphi(t)))$$

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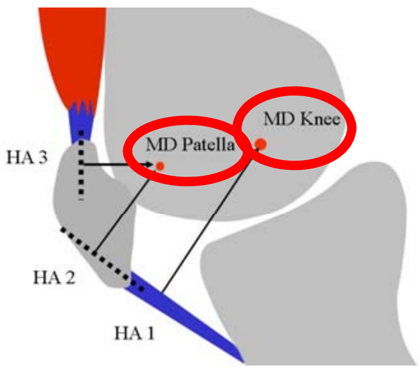
Analysis of Leg Extension Movements

Influence of different model types on calculated muscle forces



- Individually parameterized models for:
  - tibiofemoral joint with moving joint axis
  - patellofemoral joint with moving joint axis

➔ Tibiofemoral joint as hinge joint

➔ Individually parameterized with a moving joint axis

➔ Patellofemoral joint moving on a circular path

➔ Individually parameterized path for the patella with a moving joint axis

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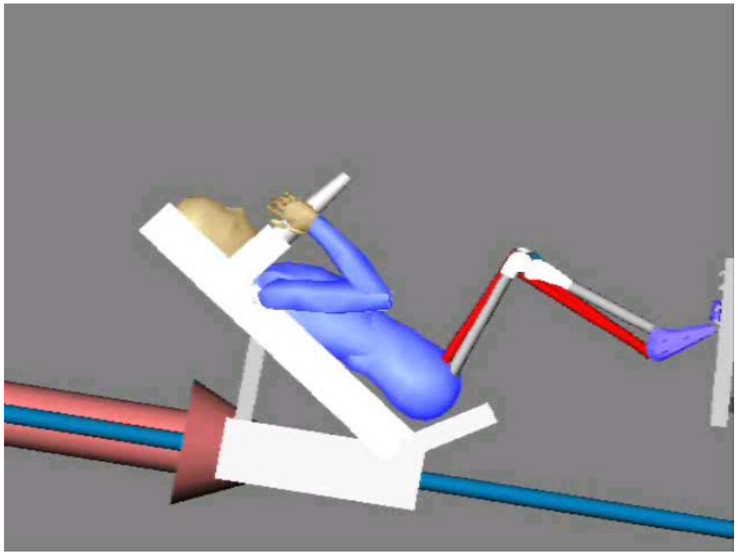
Analysis of Leg Extension Movements

- Reconstruction of the movement

  - Integration of the Lagrangian equations of motion using *alaska*
  - Calculation of time histories for the spatial coordinates of the man model *DYNAMICUS*



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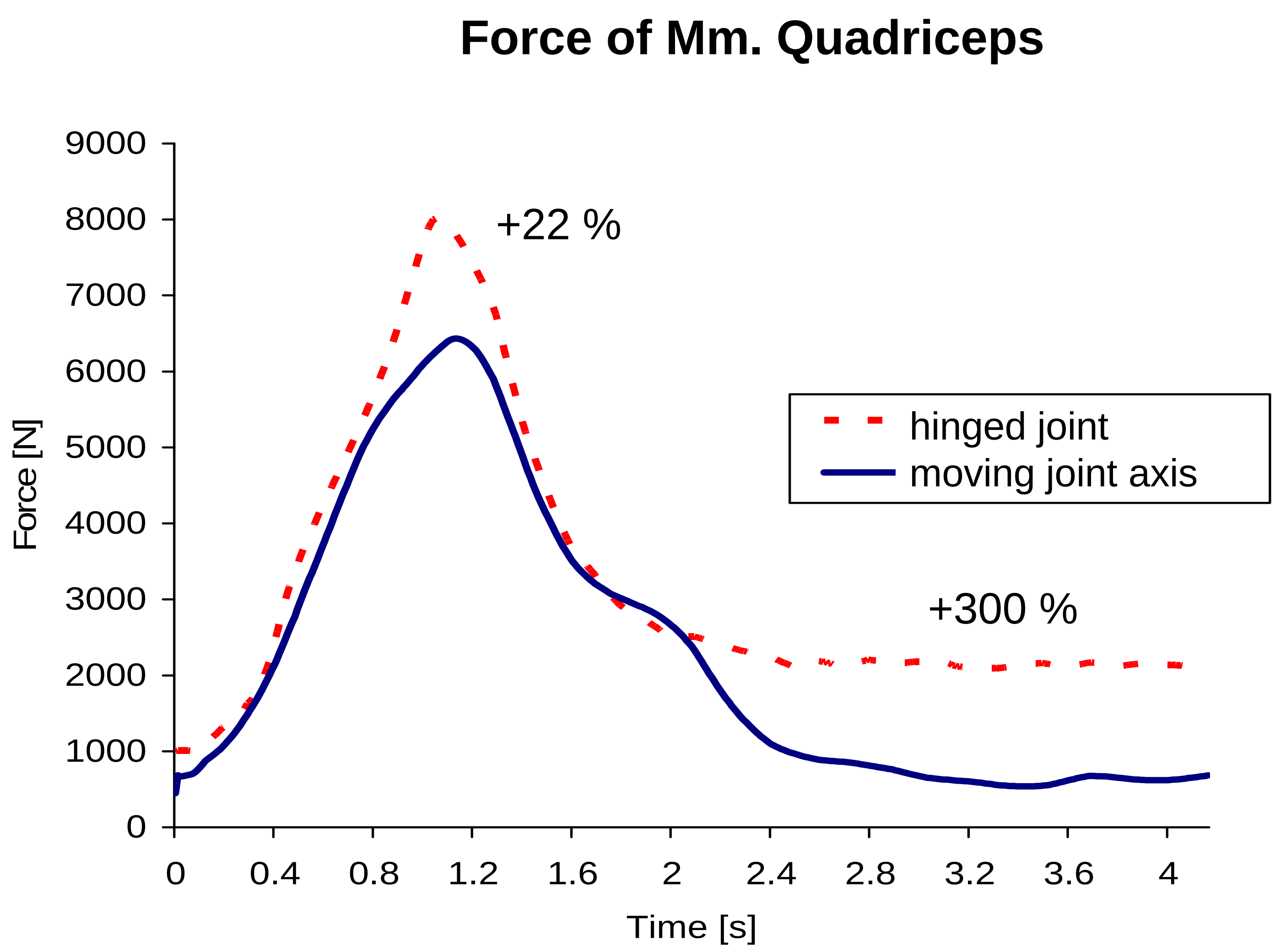
Analysis of Leg Extension Movements



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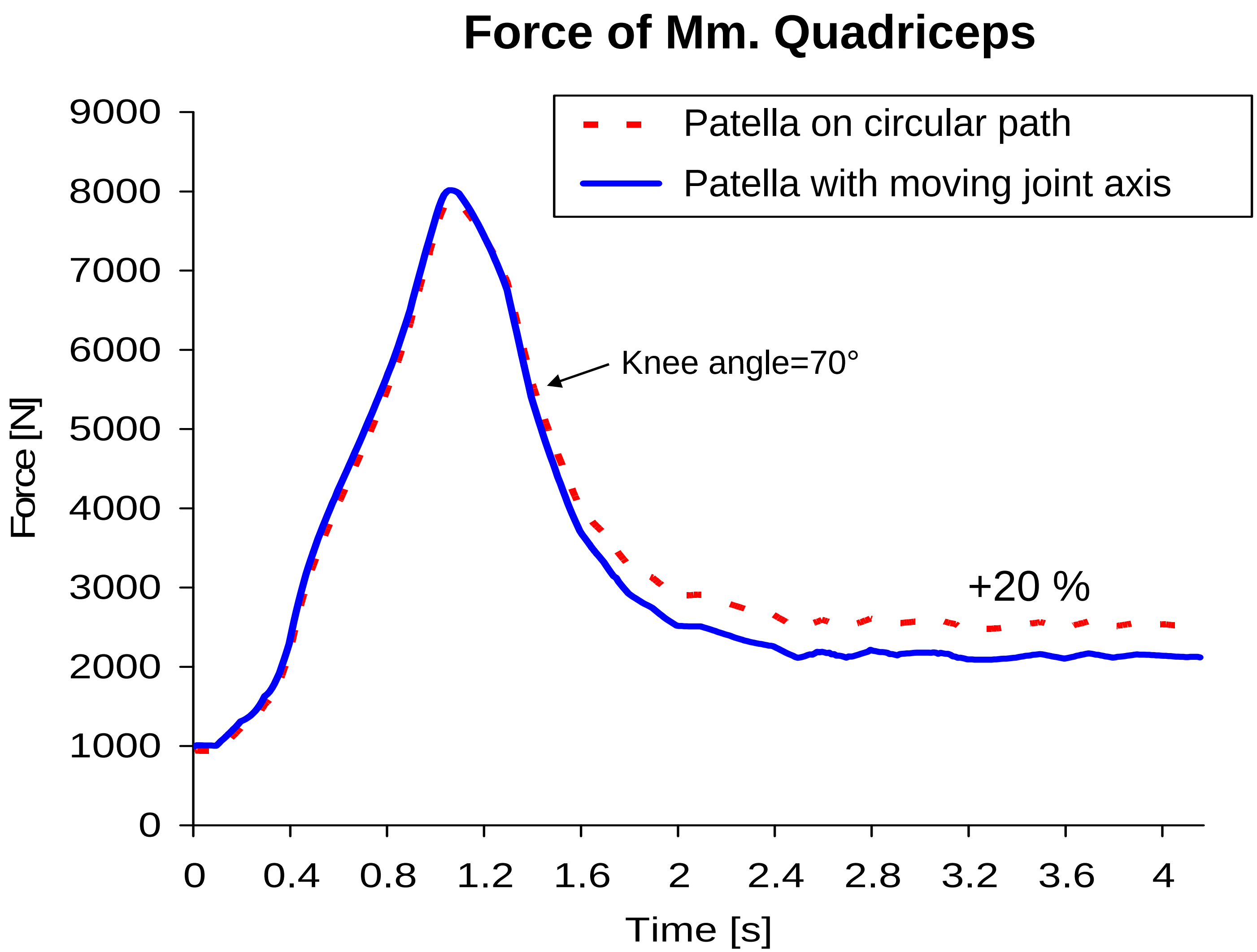
Analysis of Leg Extension Movements



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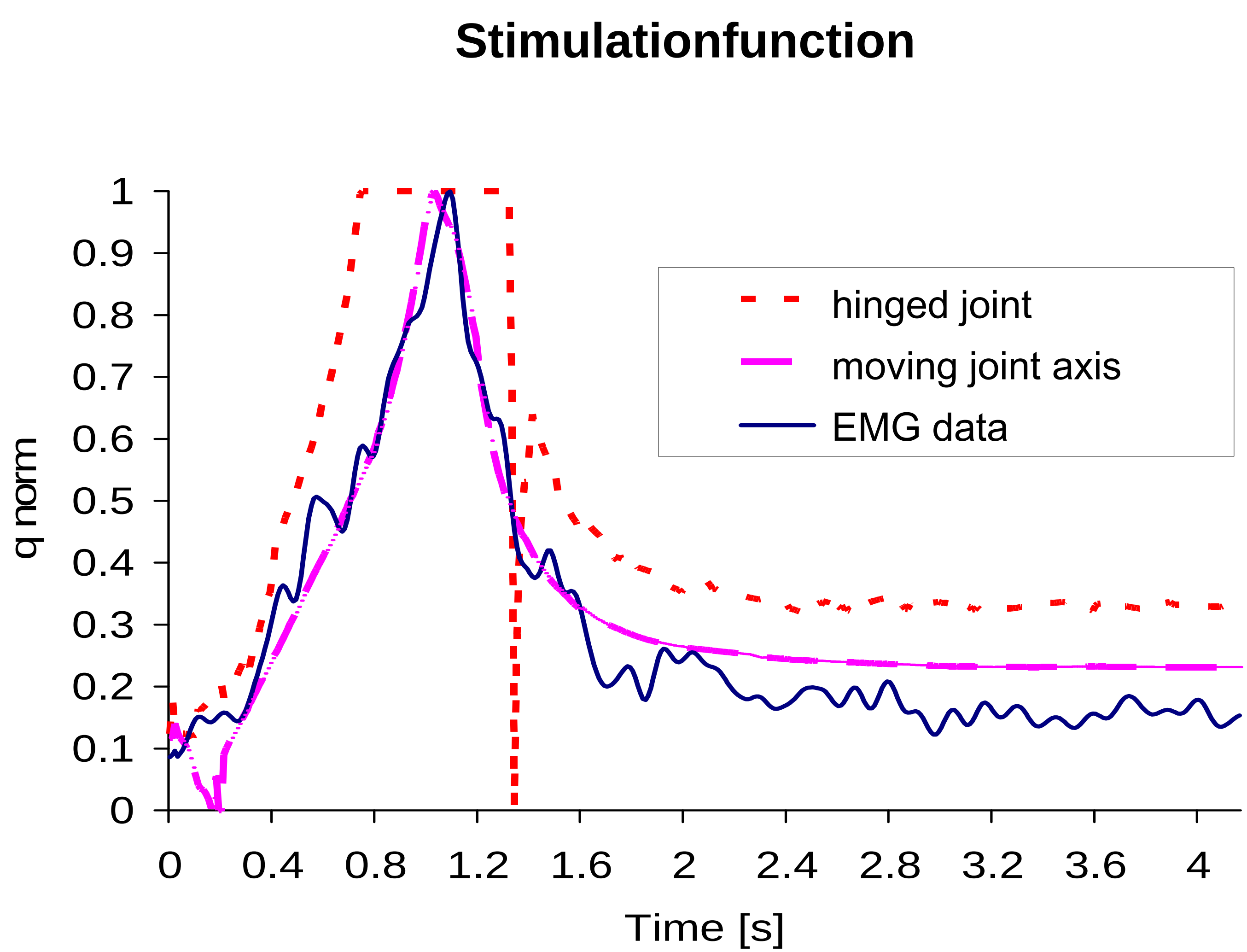
Analysis of Leg Extension Movements



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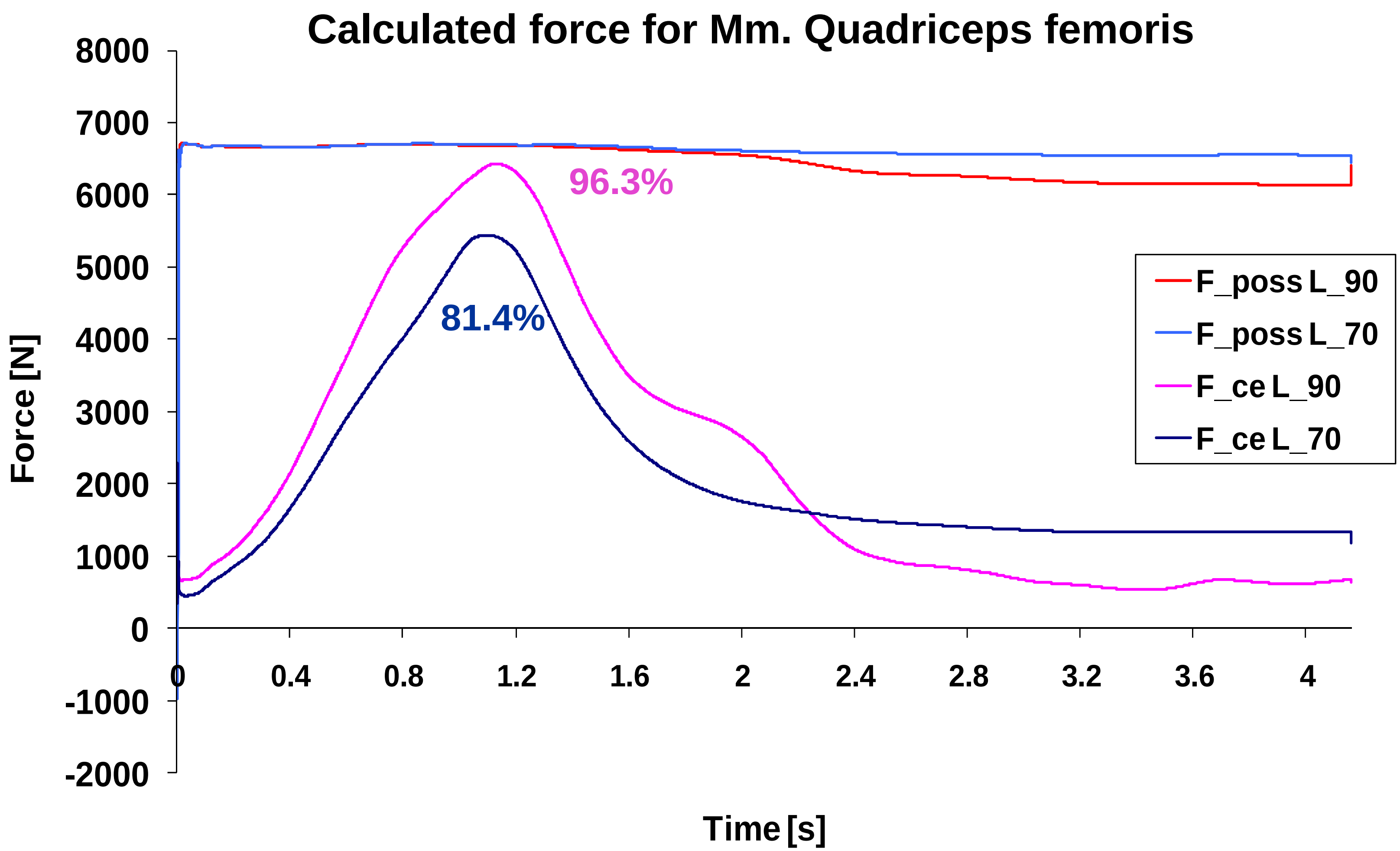
Analysis of Leg Extension Movements

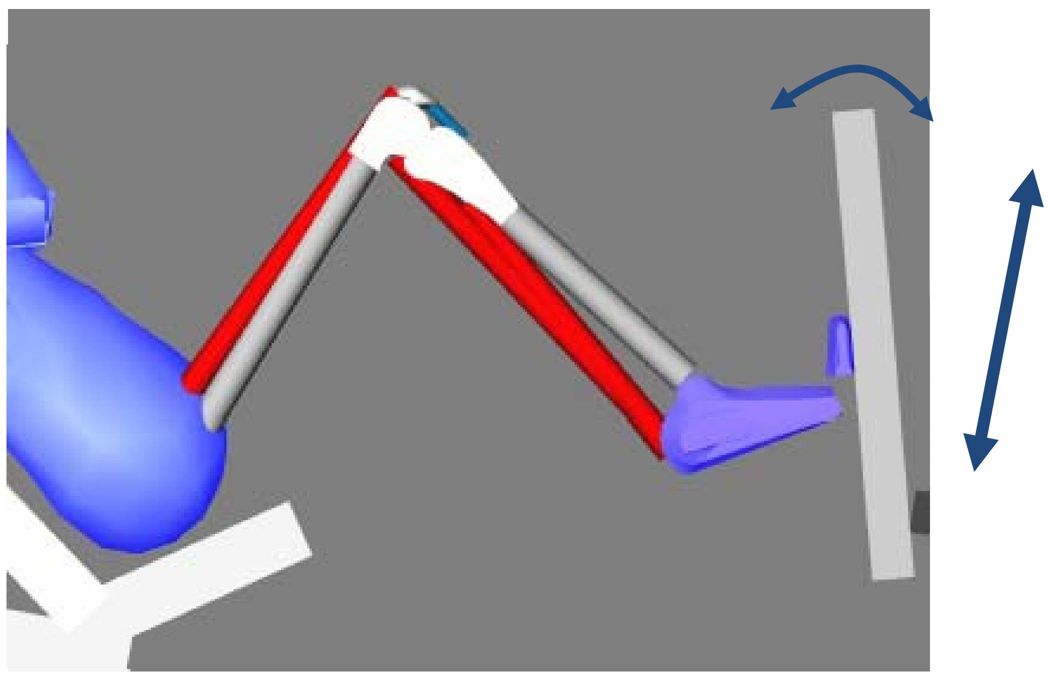


➔ **How can we match the internal load with the external load?**

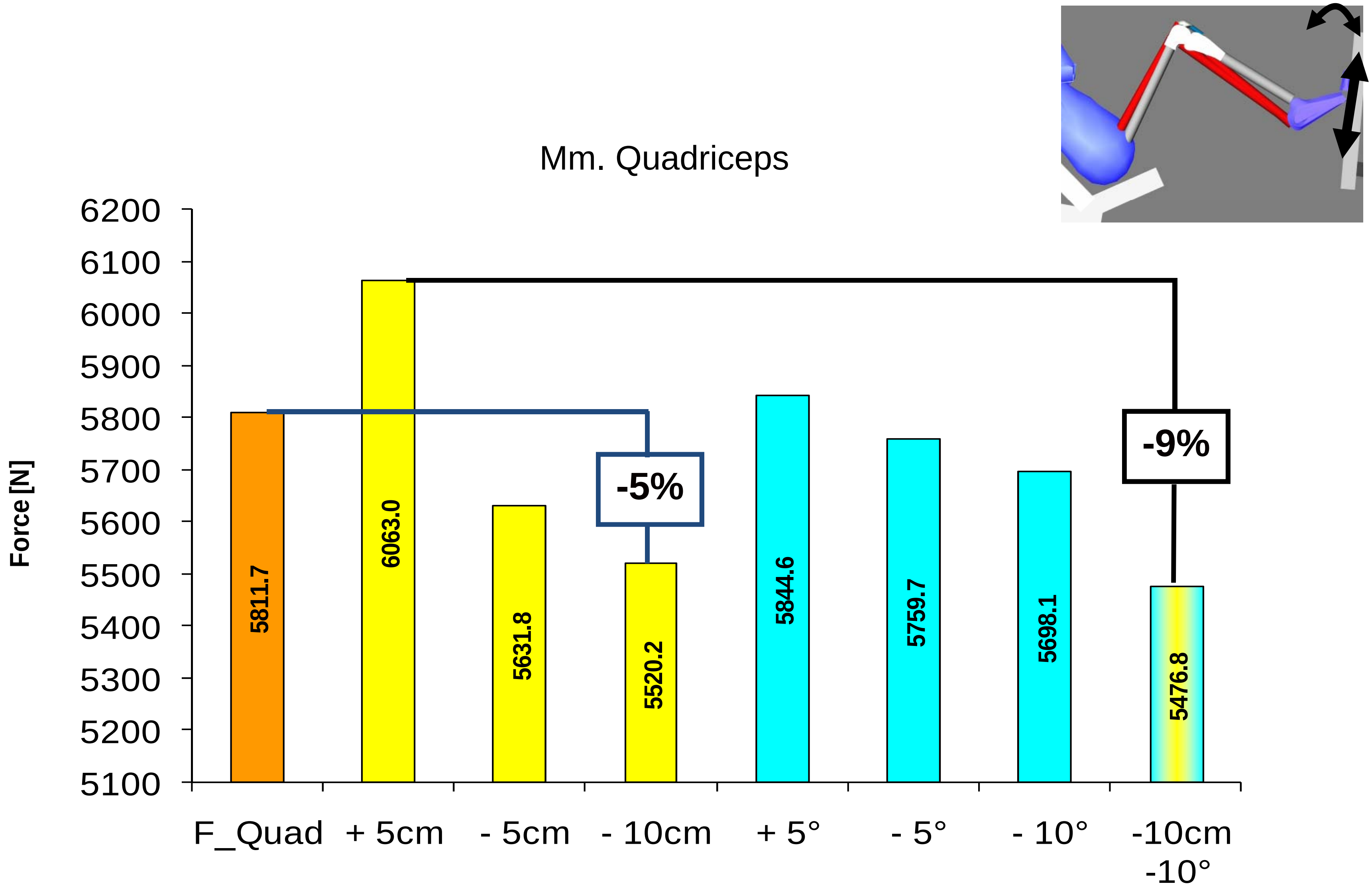
Analysis of Leg Extension Movements

The following boundary conditions were varied:

- Contact position on the foot pad: +5 cm, -5 cm, –10 cm
- Angle of the foot pad: +5 °, -5 °, -10 °.



Analysis of Leg Extension Movements



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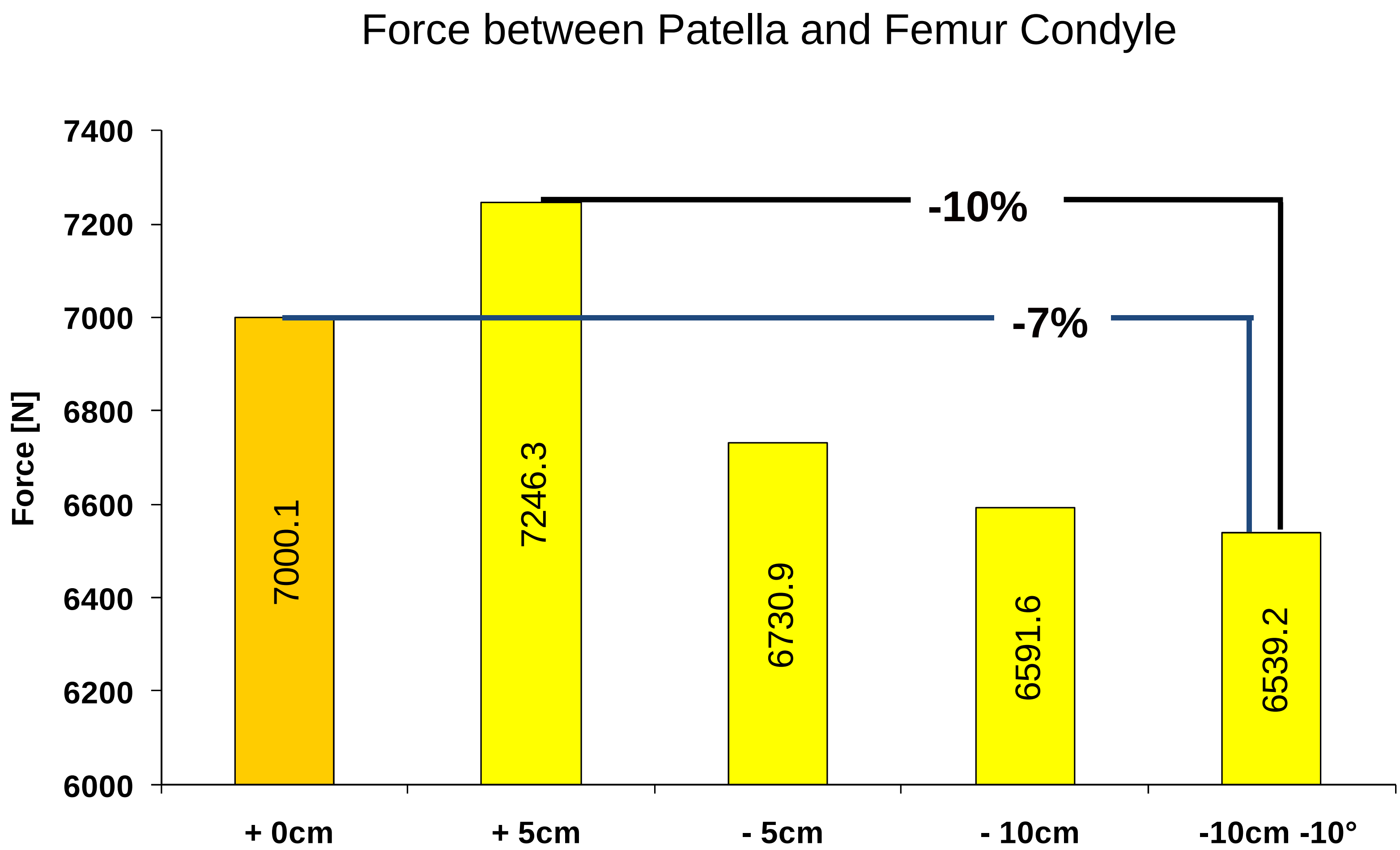
Analysis of Leg Extension Movements



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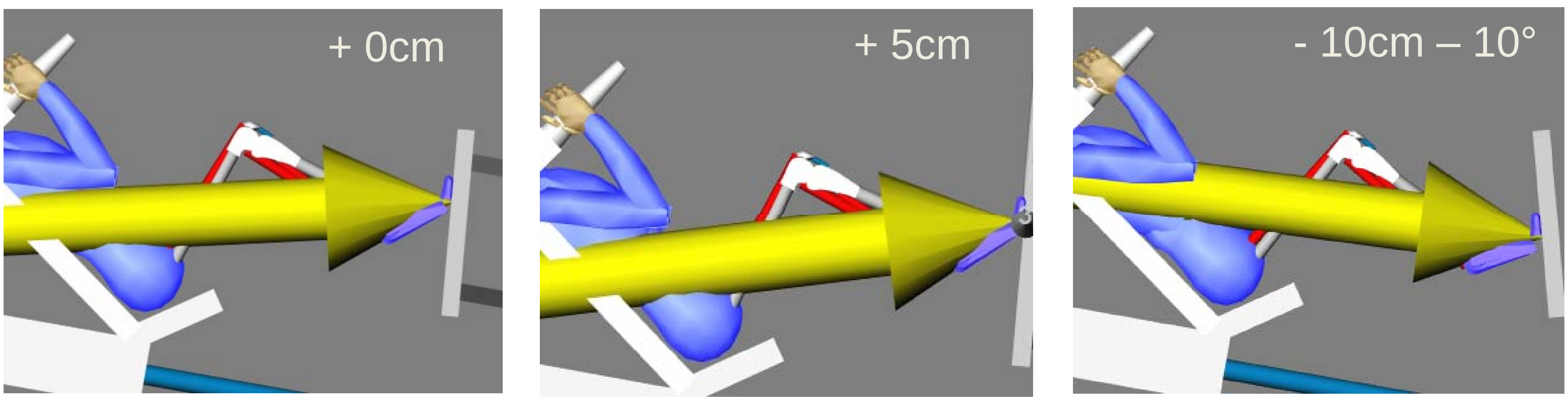
Analysis of Leg Extension Movements

Reason: Orientation of the GRF



➔ Graphic representation of results to transfer the knowledge to athletes, coaches, and PT

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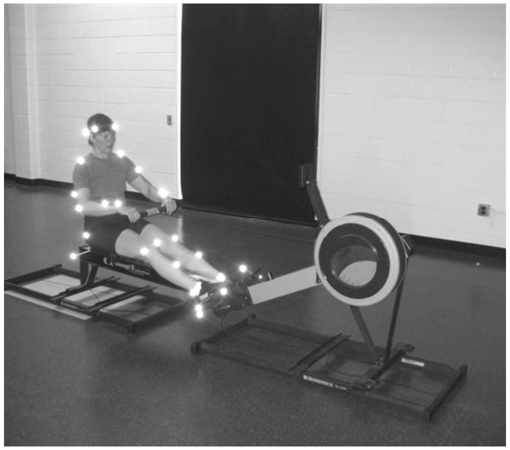
Influence of BMI on Movement Kinematics

- 40 subjects
  - ➔10 NW skilled
  - ➔10 NW
  - ➔10 overweight
  - ➔10 obese

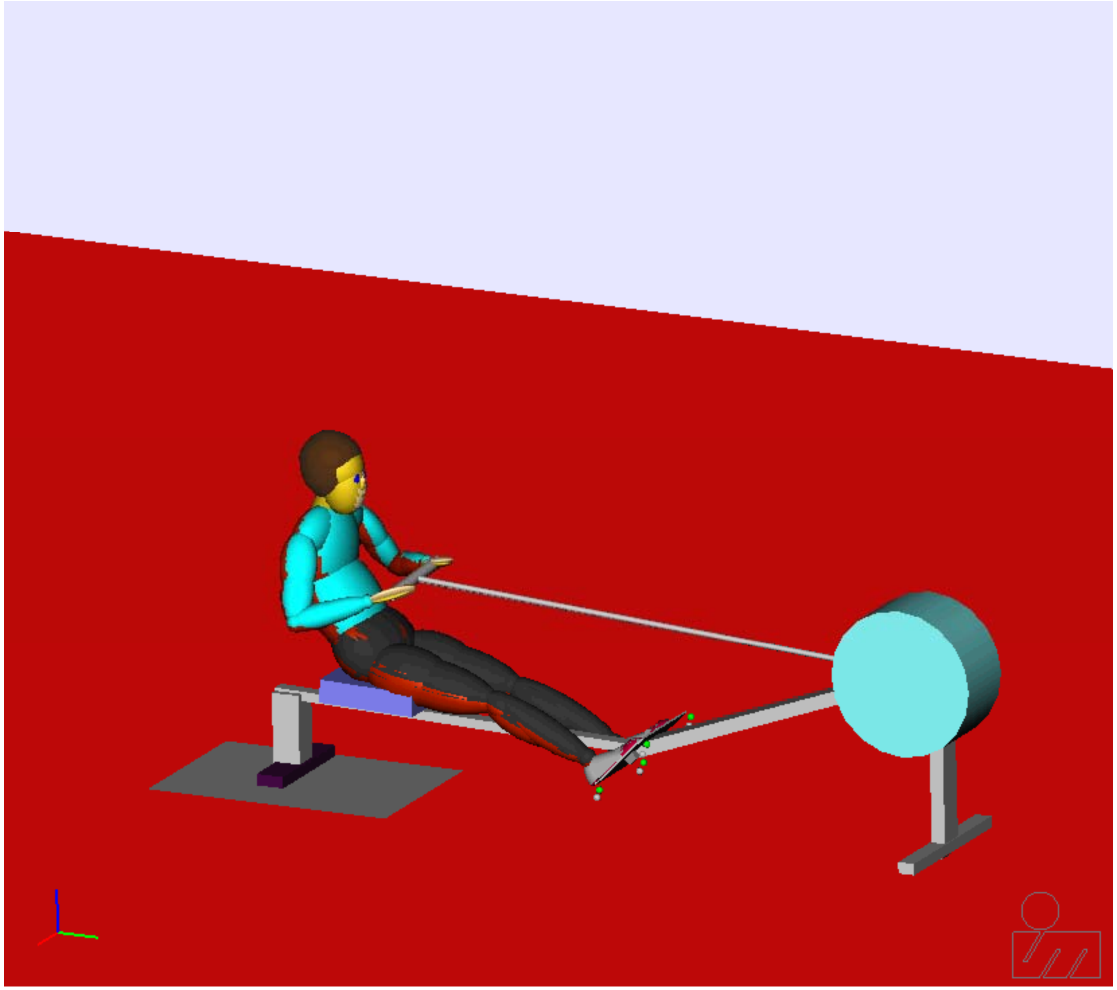
Height [cm]	Age [y]	BMI [kg/m^2]
179±9	23±4	21.9±1.2
174±8	27±7	21.8±1.6
171±9	24±6	26.7±1.3
170±9	26±3	35.5±4.7

- rowing at three different resistance levels for 2 min each ➔ 2min rest



Funded by: Research Excellence Fund, Michigan Technological University, USA

Influence of BMI on Movement Kinematics



Within subject variability: ±0.9° for 10 strokes

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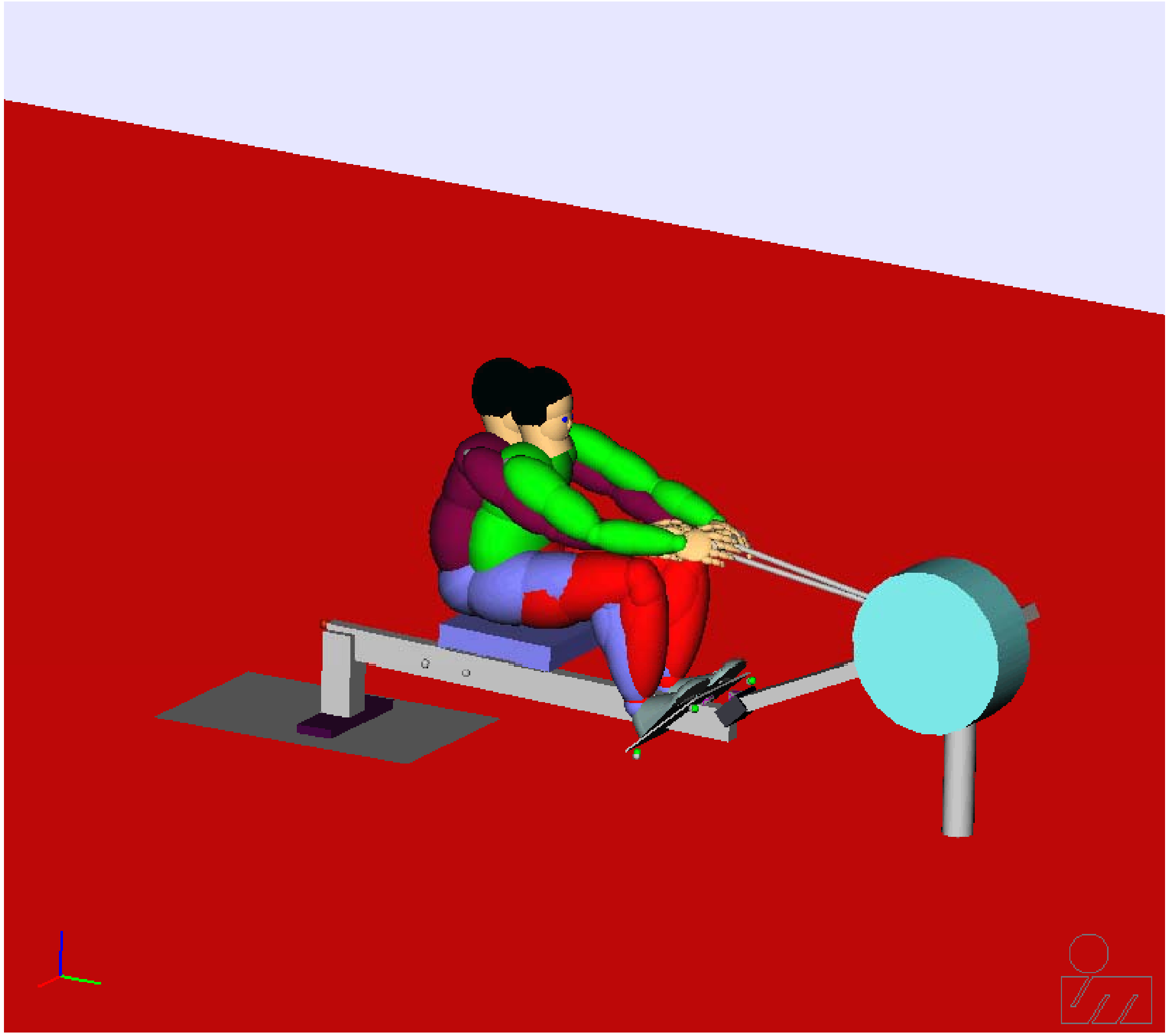
Influence of BMI on Movement Kinematics



Within subject variability: ±0.9° for 10 strokes

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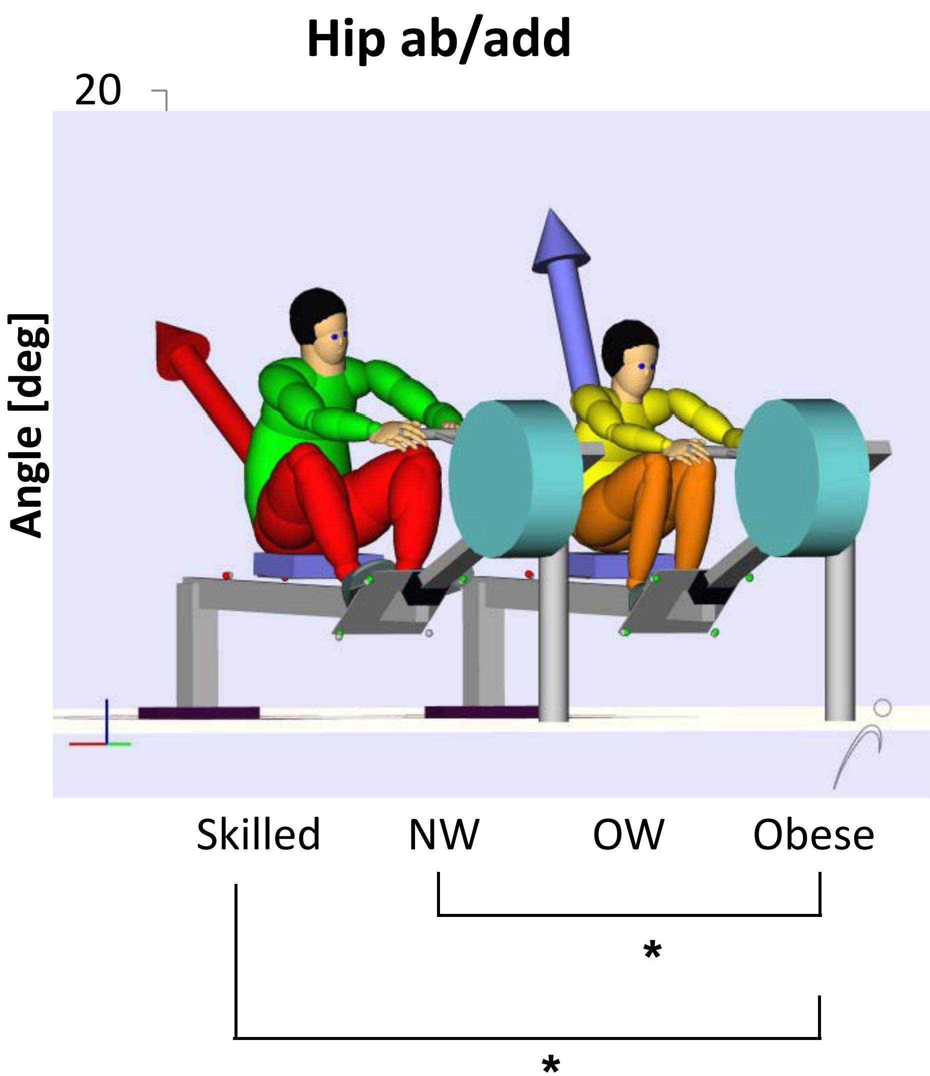
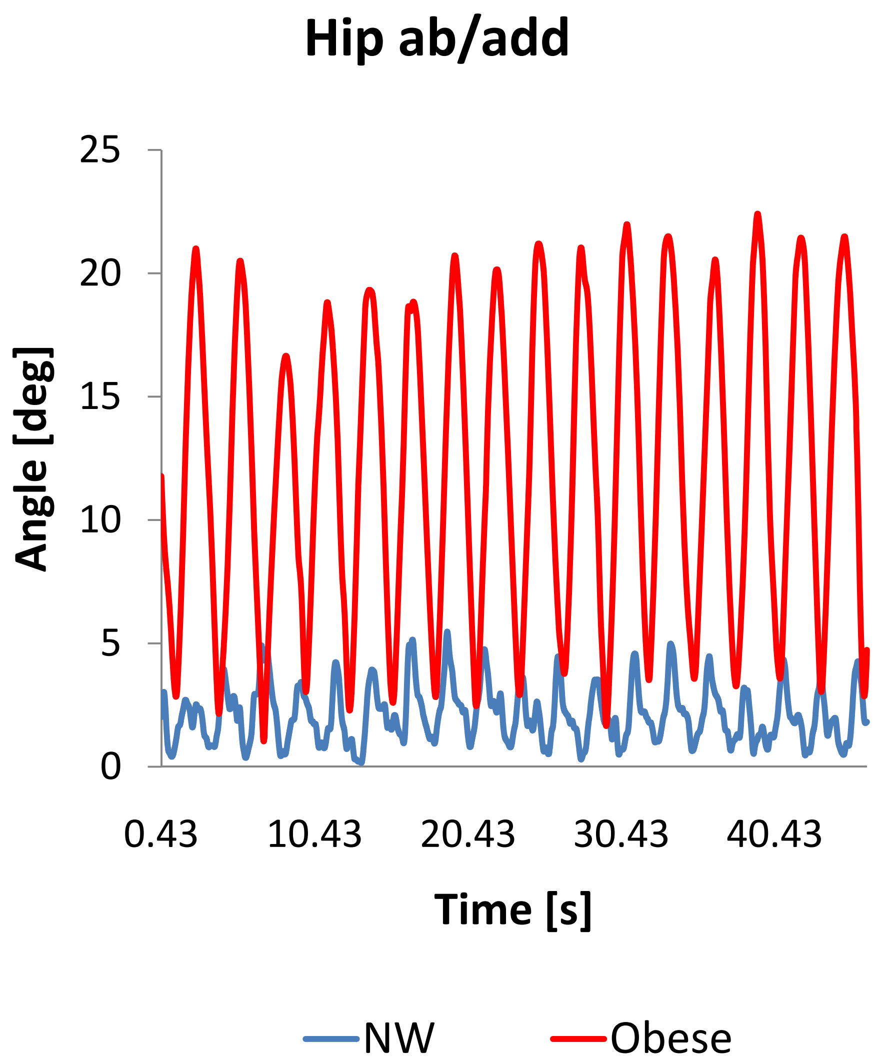
Influence of BMI on Movement Kinematics





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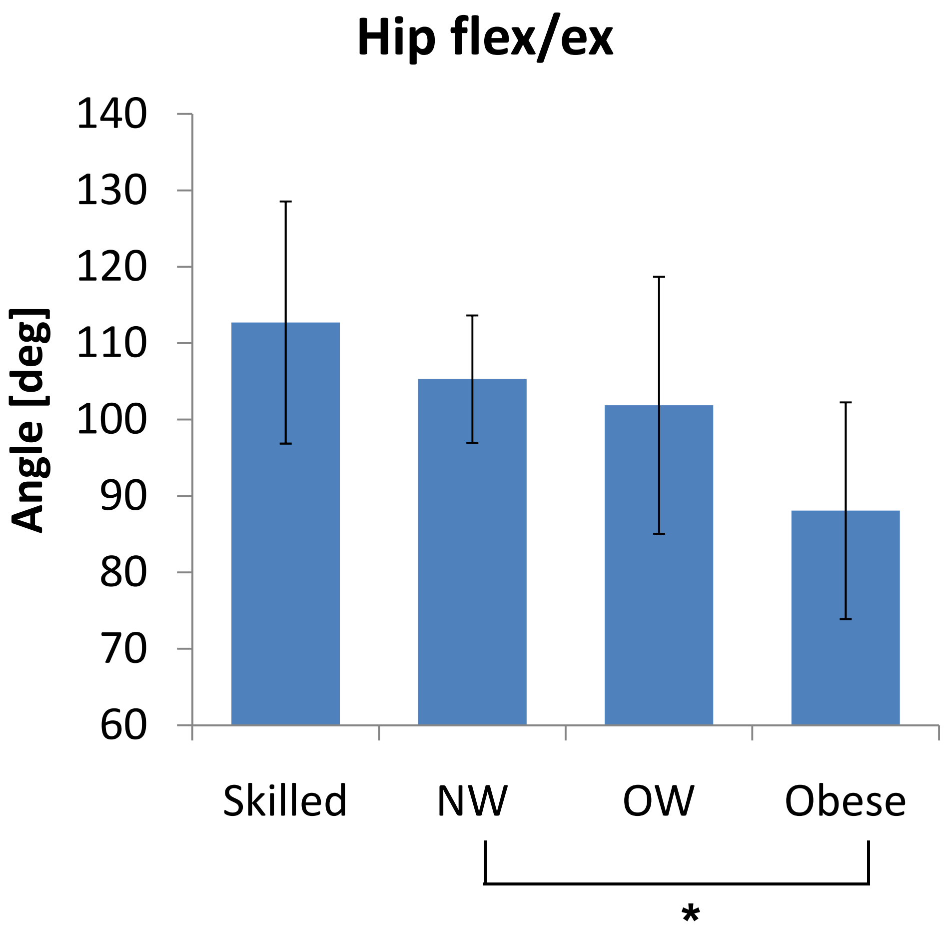
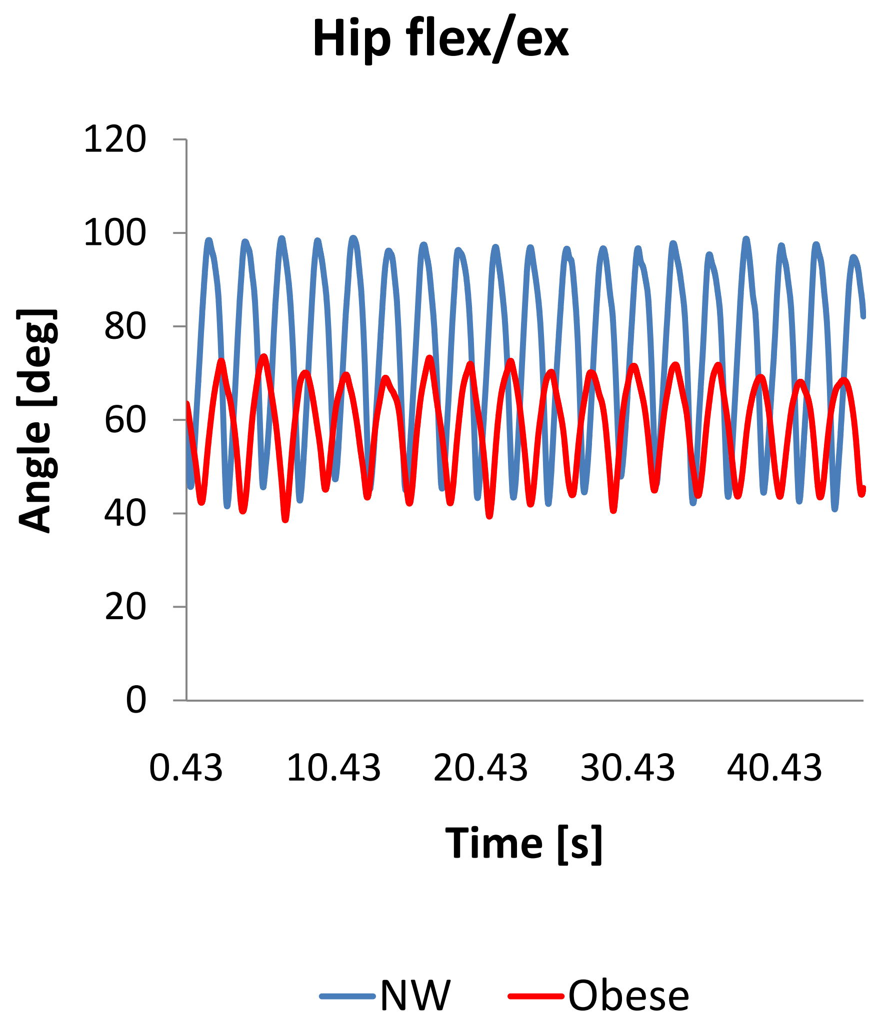
Influence of BMI on Movement Kinematics



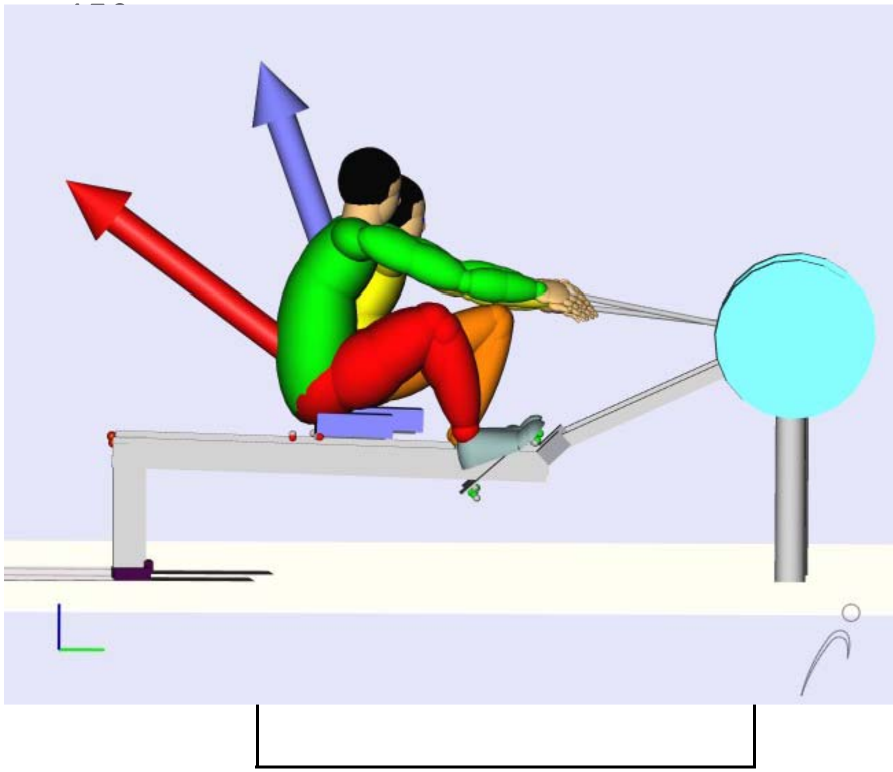


Funded by: Research Excellence Fund, Michigan Technological University, USA

Michigan Tech
Create the Future

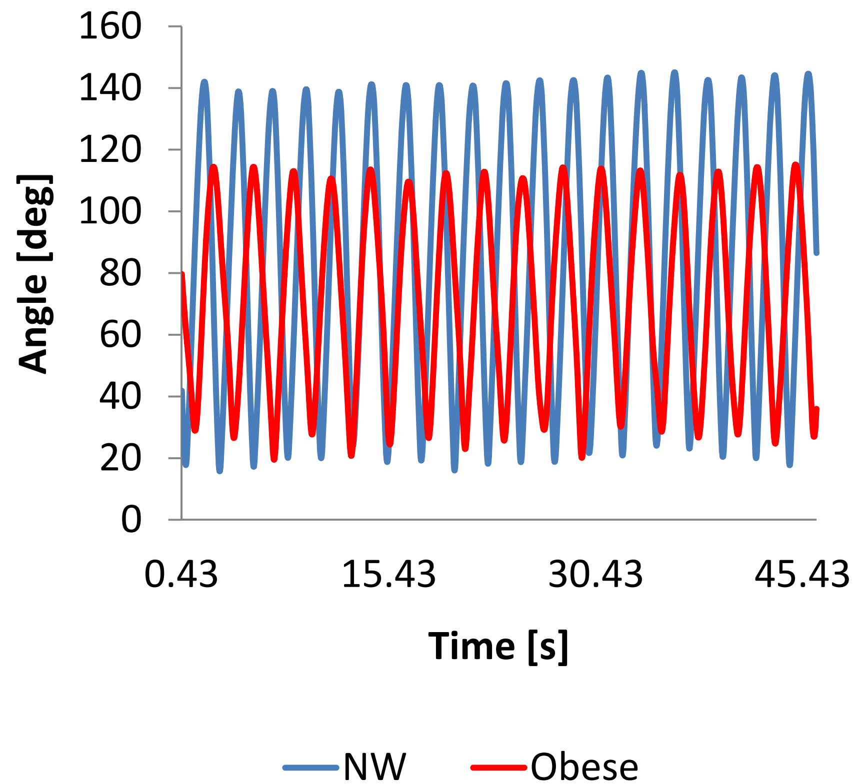
Influence of BMI on Movement Kinematics

Knee flex/ex



*

Knee flex/ex



➔ Graphic representation of results to transfer the knowledge to athletes, coaches, and PT

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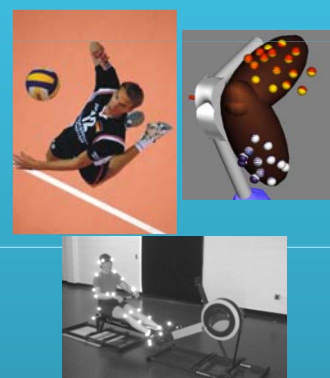
General Idea…

- **Parameter identification**
  - Kinematics
  - Kinetics

- **Motion Analysis**
  - Field tests
  - Lab tests



- **Biomechanical Modelling**
  - Inverse problem
  - Interaction athlete - equipment

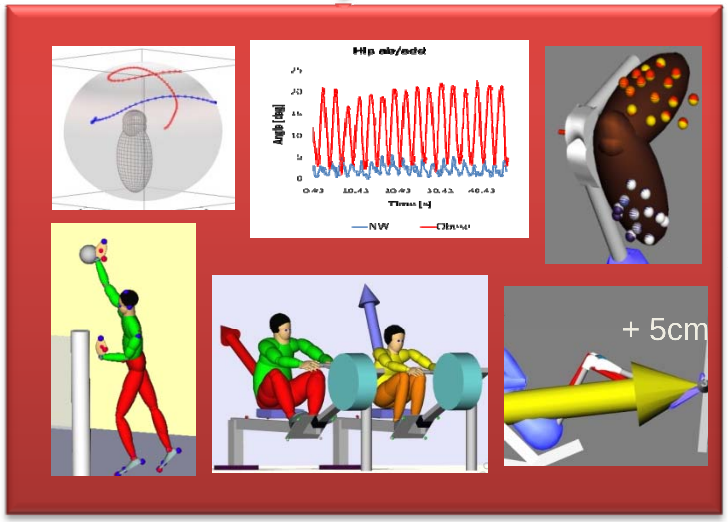
Application…

Volleyball, Leg press, Rowing

Application …

- **Parameter identification**
  - Kinematics
  - Kinetics

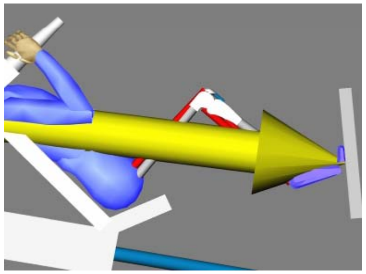
- **Motion Analysis**
  - Field tests
  - Lab tests

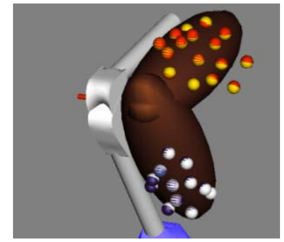


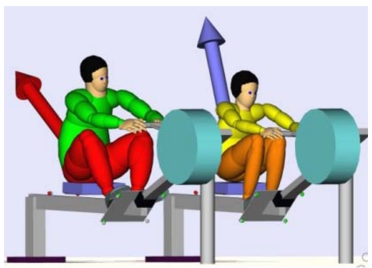
- **Biomechanical Modelling**
  - Inverse problem
  - Interaction athlete - equipment

Transfer

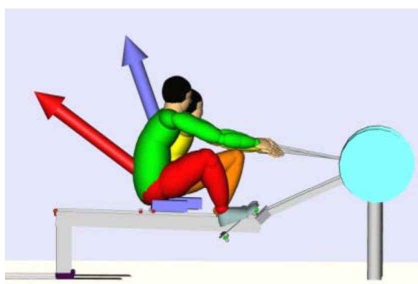
Coaches, Athletes, Students ….

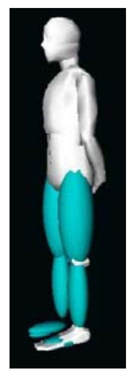


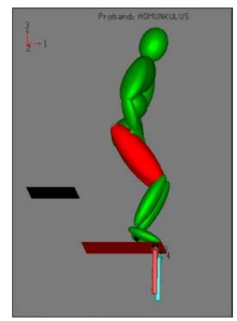




Thank you for your attention







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