Double amputee sprinting

– biomechanical challenge, mechanical advantage or just a different kind of locomotion

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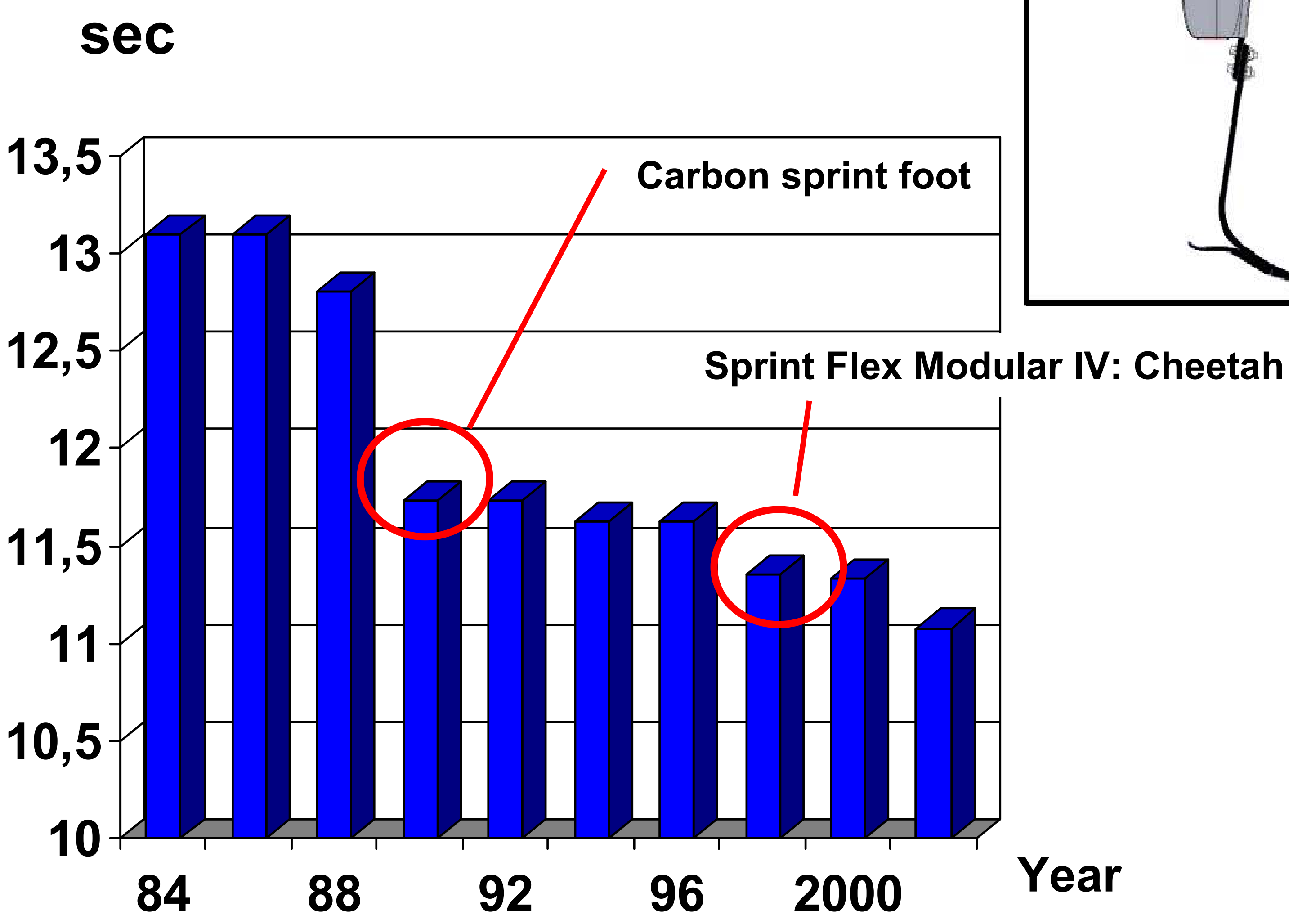
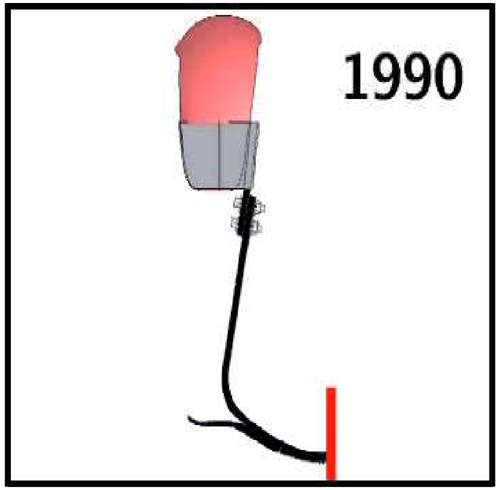
Sprinting and jumping with prostheses - 2008

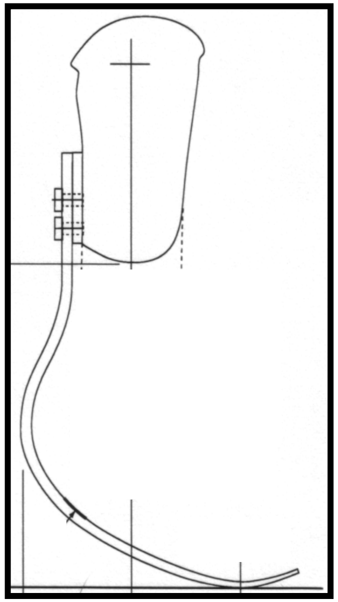
Sprint (100m): < 11 s

Long jump: > 6.00 m (6.50 m)

World record 100m TT44 Transtibial male



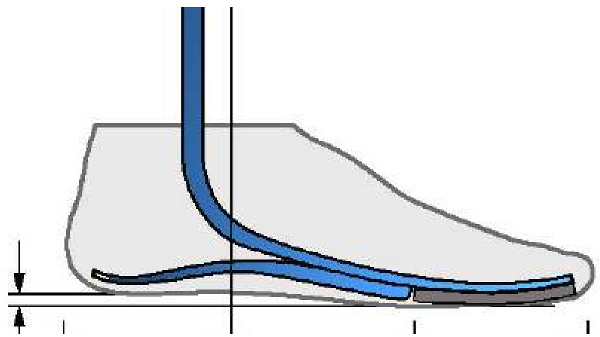




• **SACH (1950)**

• **Seattle (1970-1980)**

• **Flex-Foot (1984)**

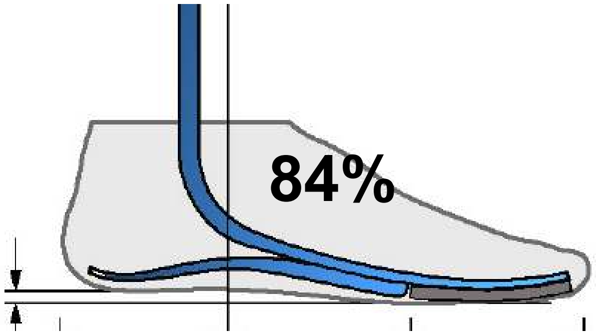


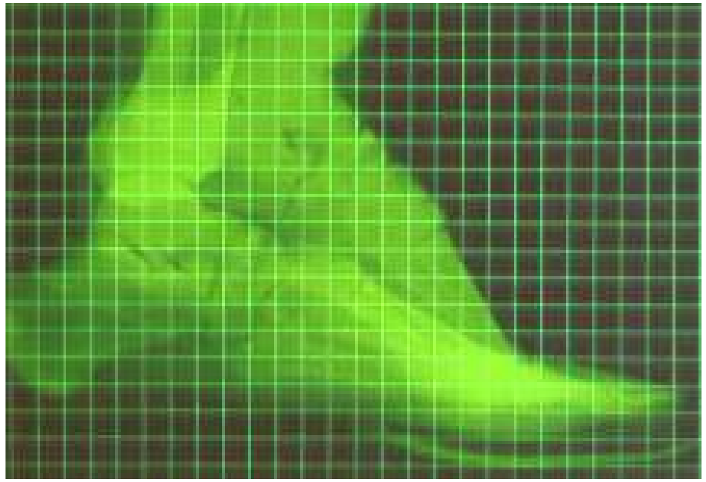
Energy return

SACH
FOOT

SEATTLE
FOOT

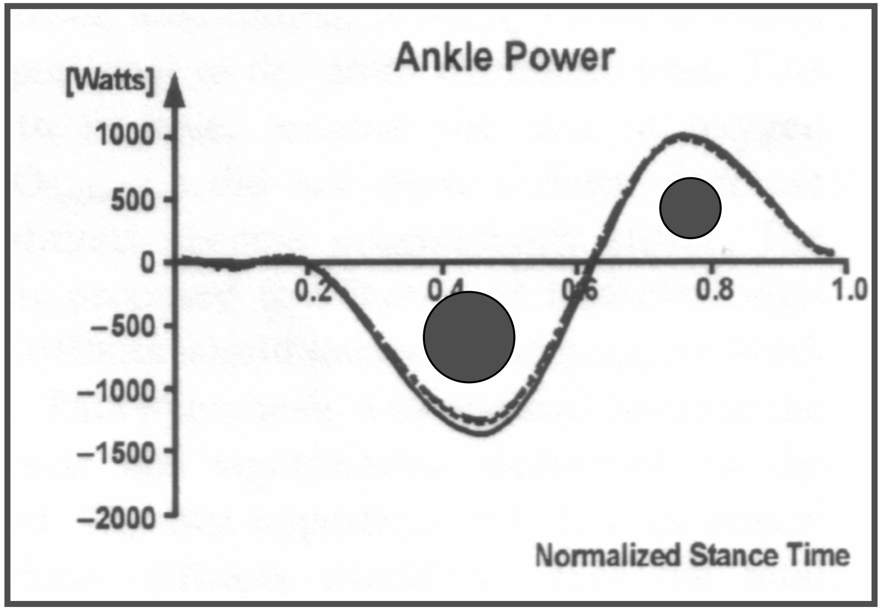
FLEX
FOOT

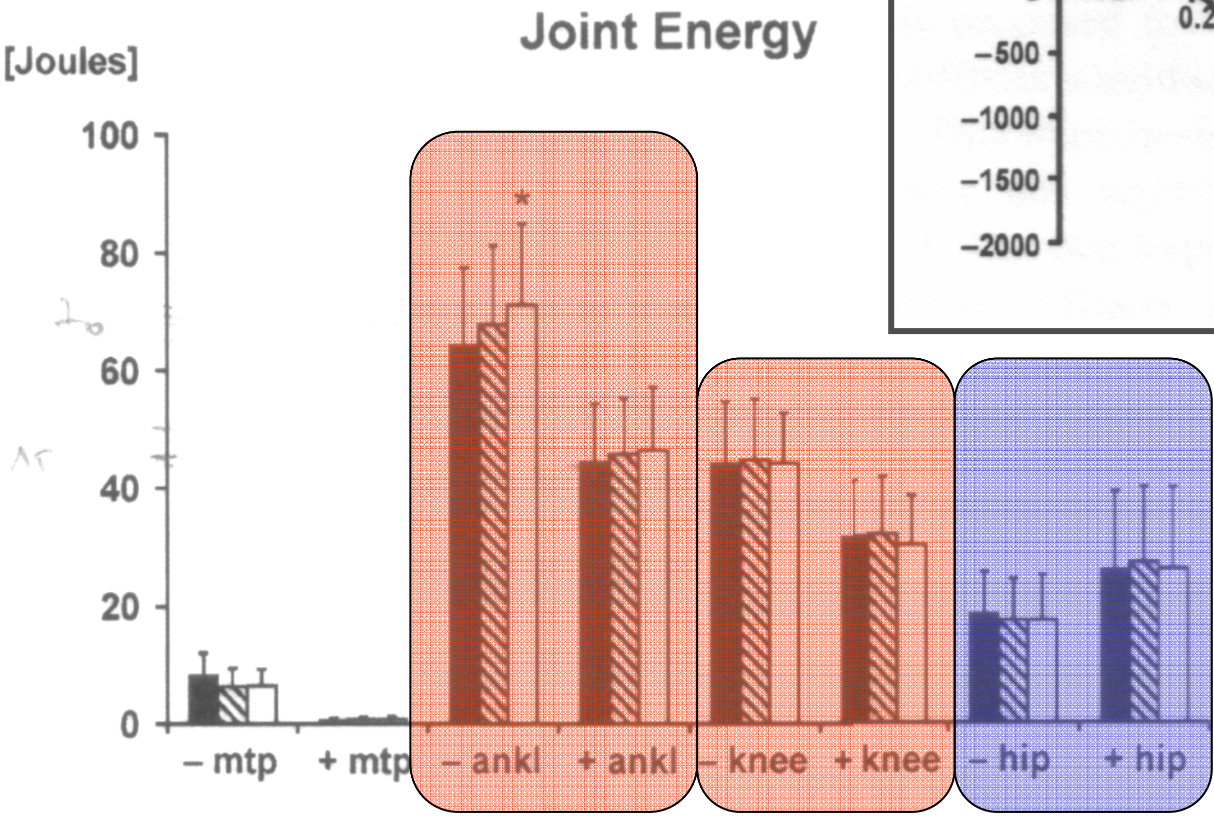




Ankle joint in WALKING: 240 %

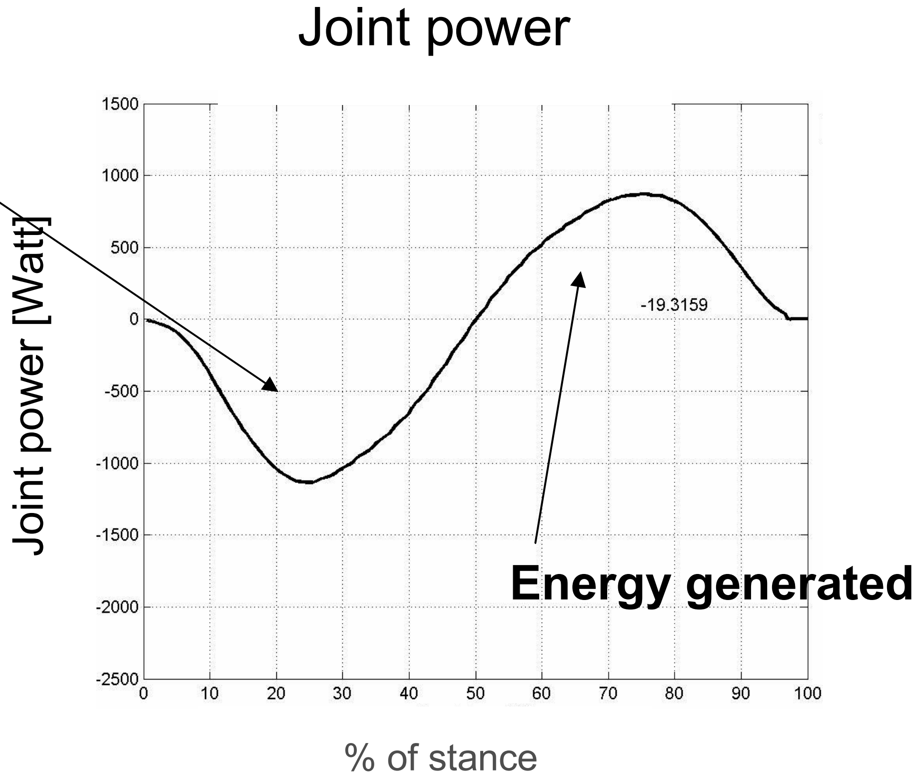
Energy return: running





Roy et al. 2006

At a running speed of 7,5 ms^{-1} (knee disarticulation sprinter)



Energy loss: 19,3%

Run-up speed: 7.04 m/s

Oscar Pistorius, * November 22nd, 1986

without fibulae, calcanei and lateral foot rays

amputated at 11 months

walking on prostheses

various sports activities in adolescence

since 2004 sprinting on blades

Olympic Finals *(2004 Summer Paralympics)***:**
100 m, Bronze
200 m, Gold

World Finals *(2006 Paralympic World Cup)***:**
200 m, Gold
400 m, Gold

Olympic Finals *(2008 Summer Paralympics)***:**
100 m, Gold
200 m, Gold
400 m, Gold

Competing with able bodied athletes

Rome 2007: 2^{nd} in Golden League Meeting Race

Plan to start in Bejing Olympics 2008

> IAAF rule 144.2:
> “...any technical device that incorporates springs, wheels or any other element that provides a user with an advantage over another athlete not using such a device"

Comparison of sprinting biomechanics of Pistorius and able bodied athletes (same level)

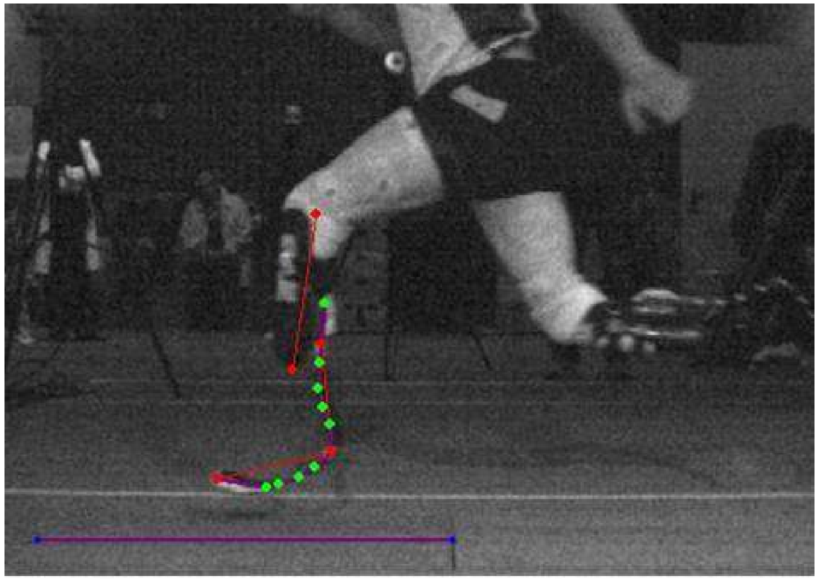
… in the phase of maximal constant running speed

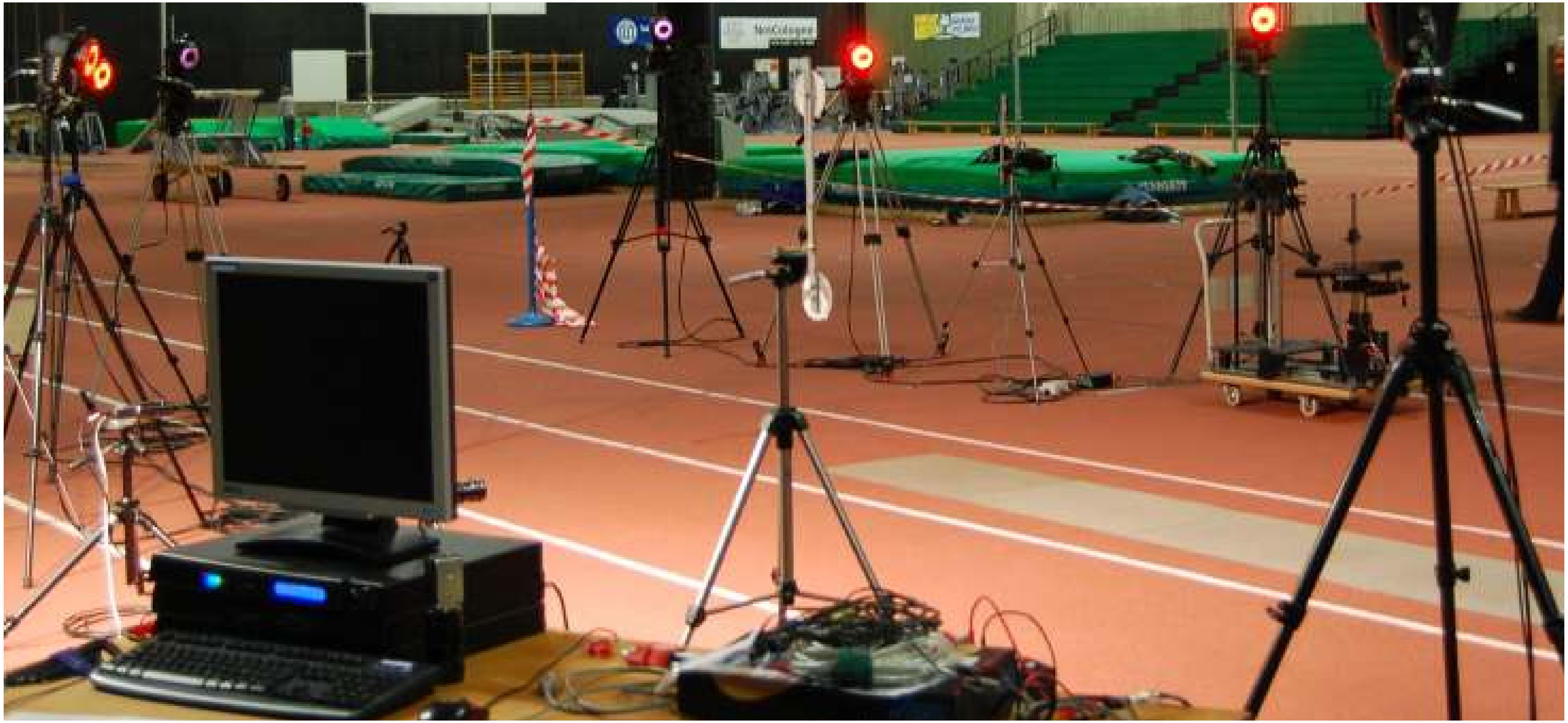
Methods - Subjects

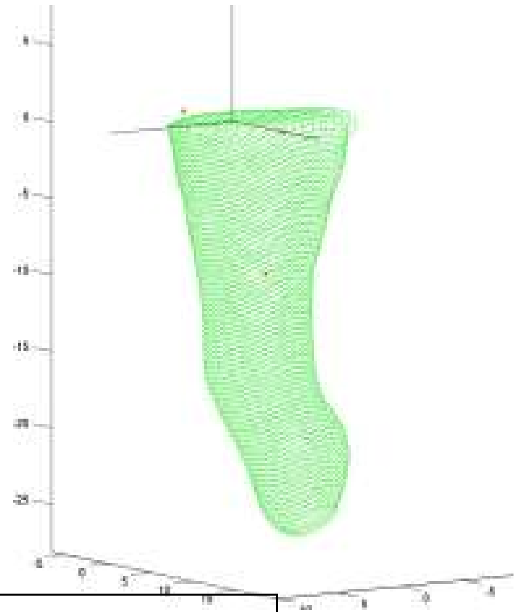
Oscar Pistorius	5 able bodied sprinters
1.85 m	1.88 m
83.3 kg	78.6 kg
400 m: 46.56 sec	400 m: 46.5 – 49.26 sec
Cheetah (Össur)	spikes

Model

- Marker placement on the artificial limb according to anatomical positions
- blade modelled as a torsion spring





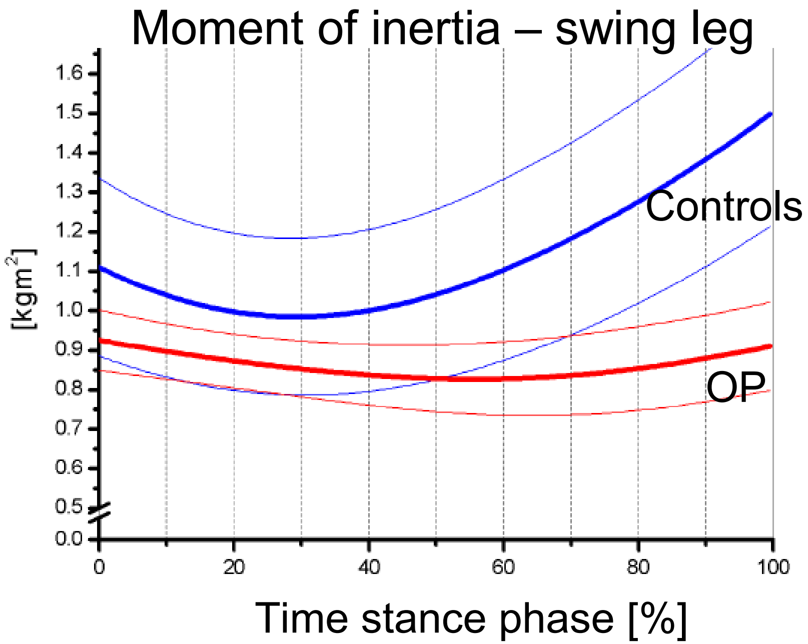


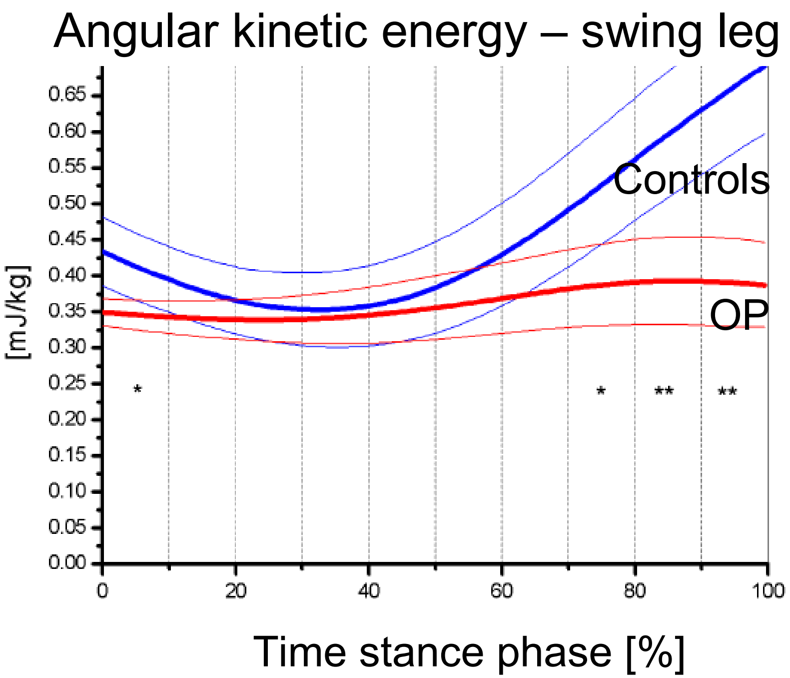
Mass

Stump, socket, blade:	**3,0 kg**
Shank, foot, shoe:	**5,8 kg**

Moment of inertia (resp. knee)

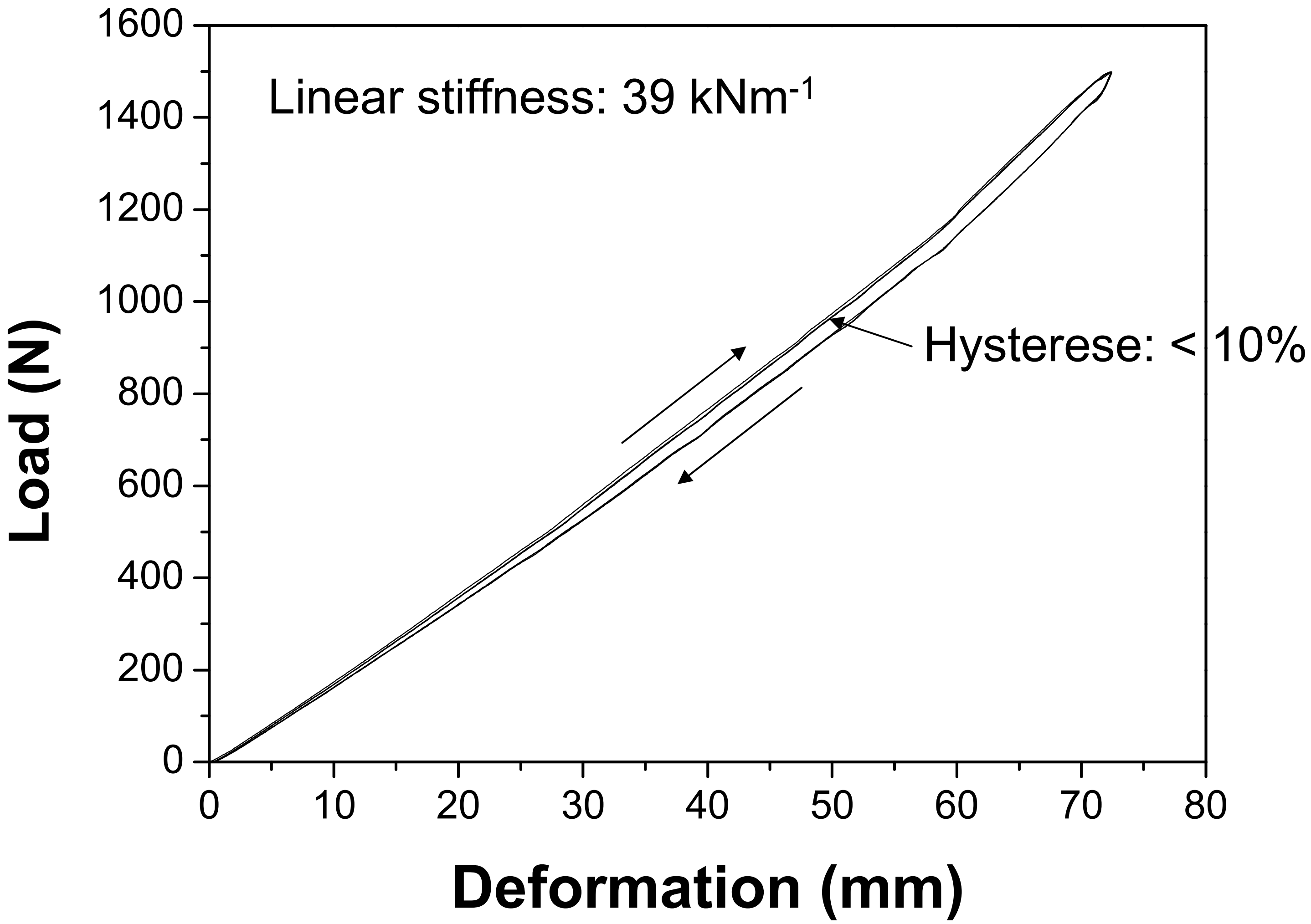
Stump, socket, blade:	**0,24 kgm^2**
Shank, foot, shoe:	**0,51 kgm^2**



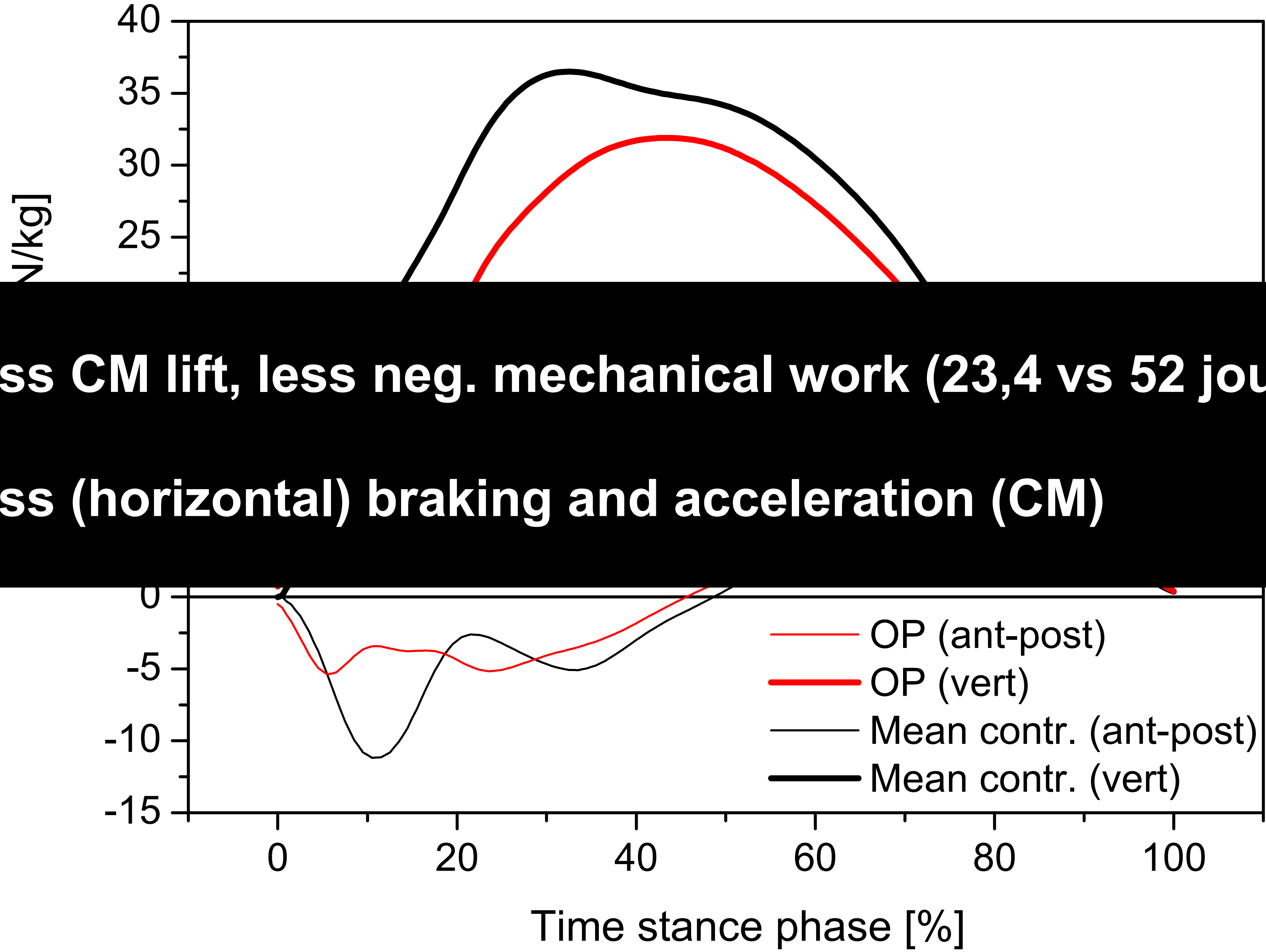


The lower moment of inertia of the swing leg of OP,

- **the smaller amount of mechanical (muscular) work in the swing,**
- **the less energy for the swing.**


Linear stiffness: 39 kNm-1
Hysterese: < 10%
Load (N)
Deformation (mm)
0
200
400
600
800
1000
1200
1400
1600
0
10
20
30
40
50
60
70
80

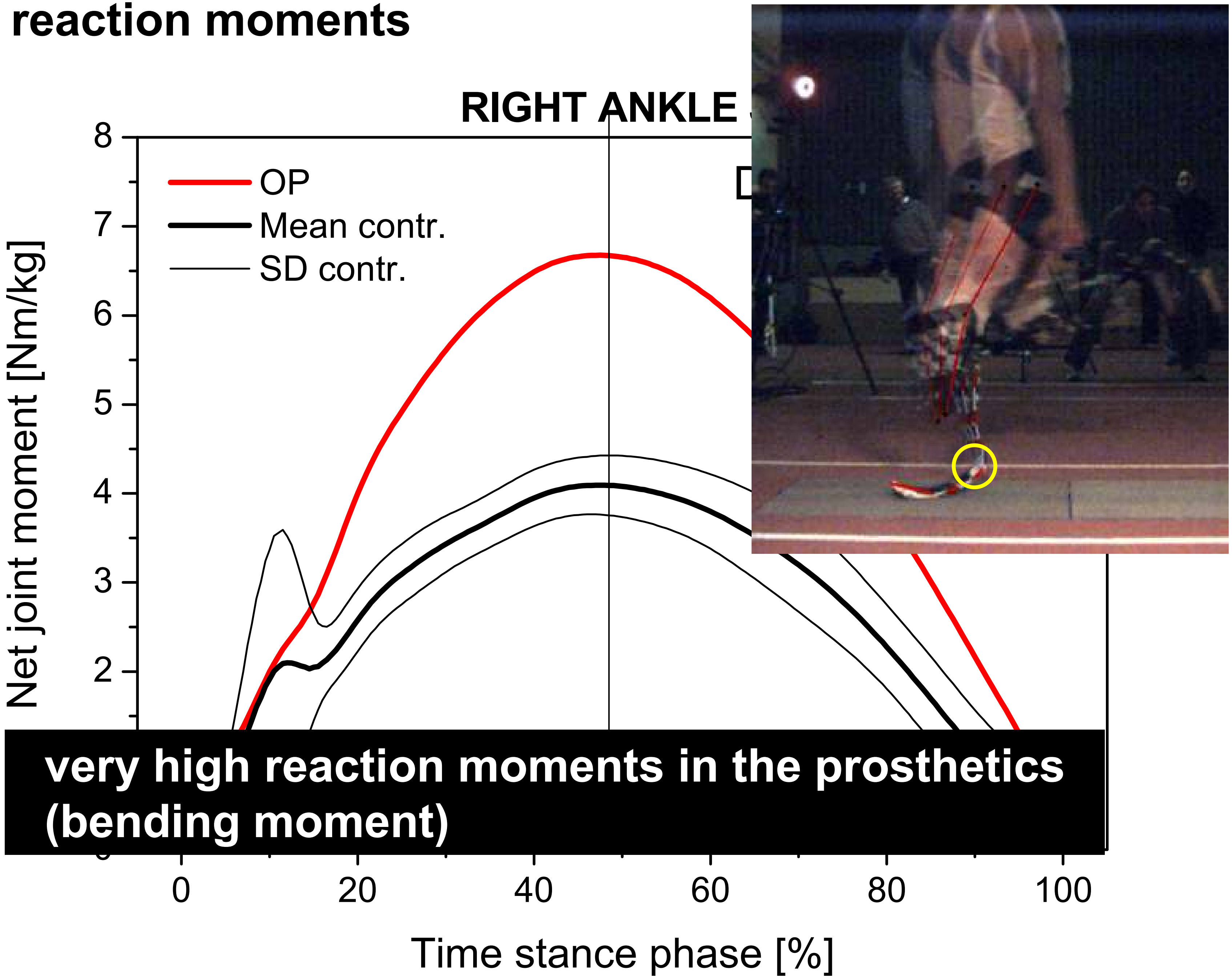
Ground reaction forces (speed > 9 ms^{-1})



less CM lift, less neg. mechanical work (23,4 vs 52 joules)

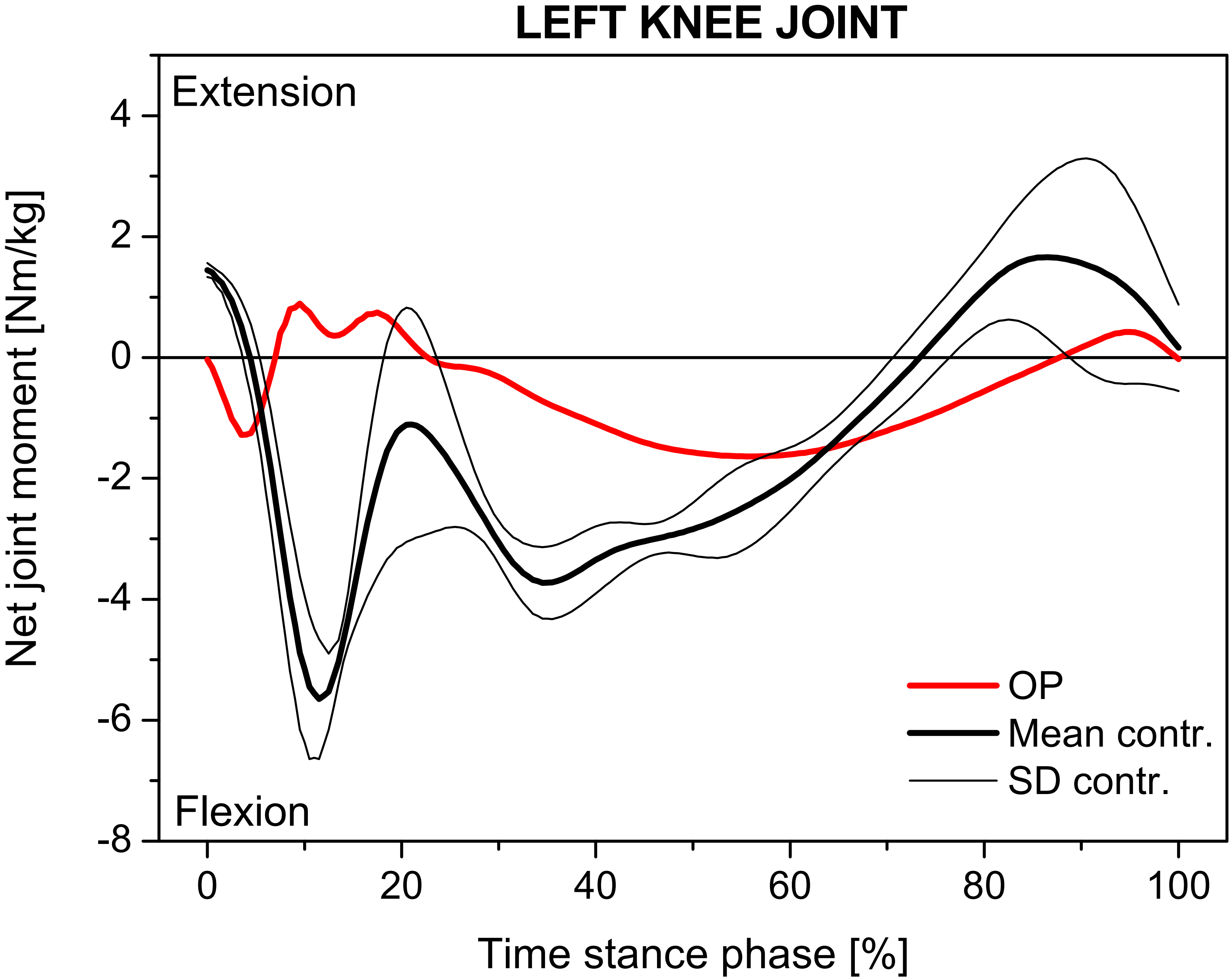
less (horizontal) braking and acceleration (CM)

Joint reaction moments

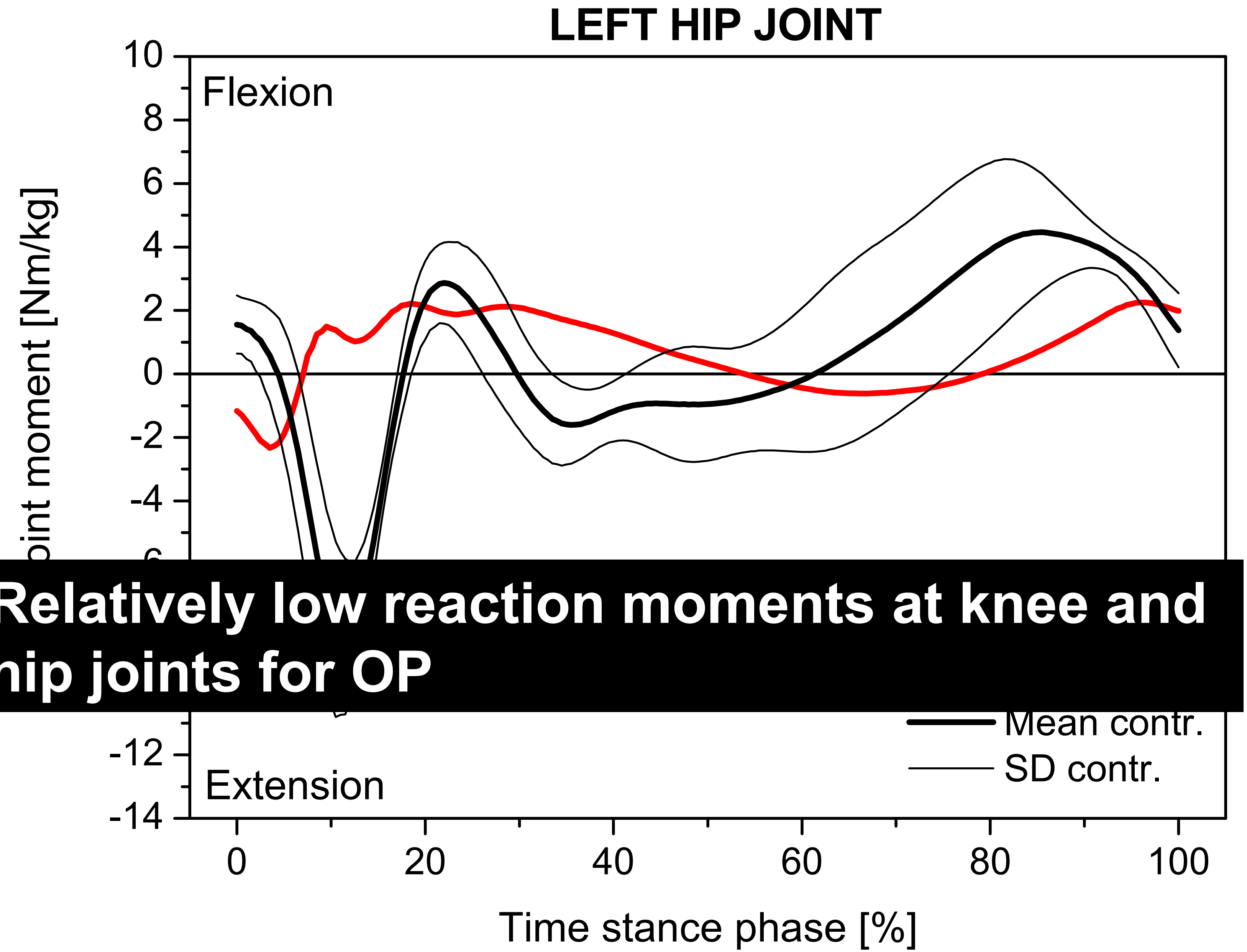


very high reaction moments in the prosthetics (bending moment)

Joint reaction moments

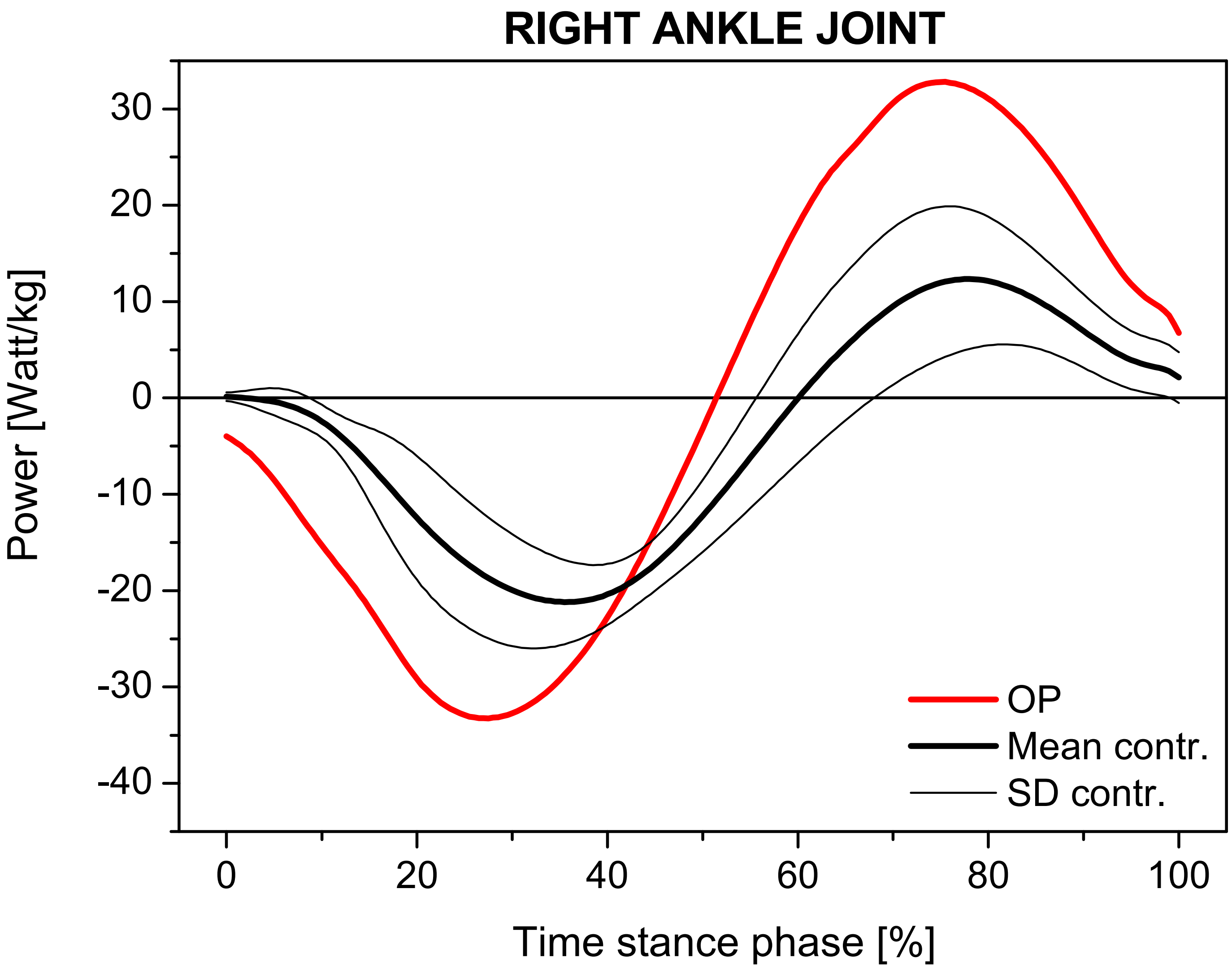


Joint reaction moments

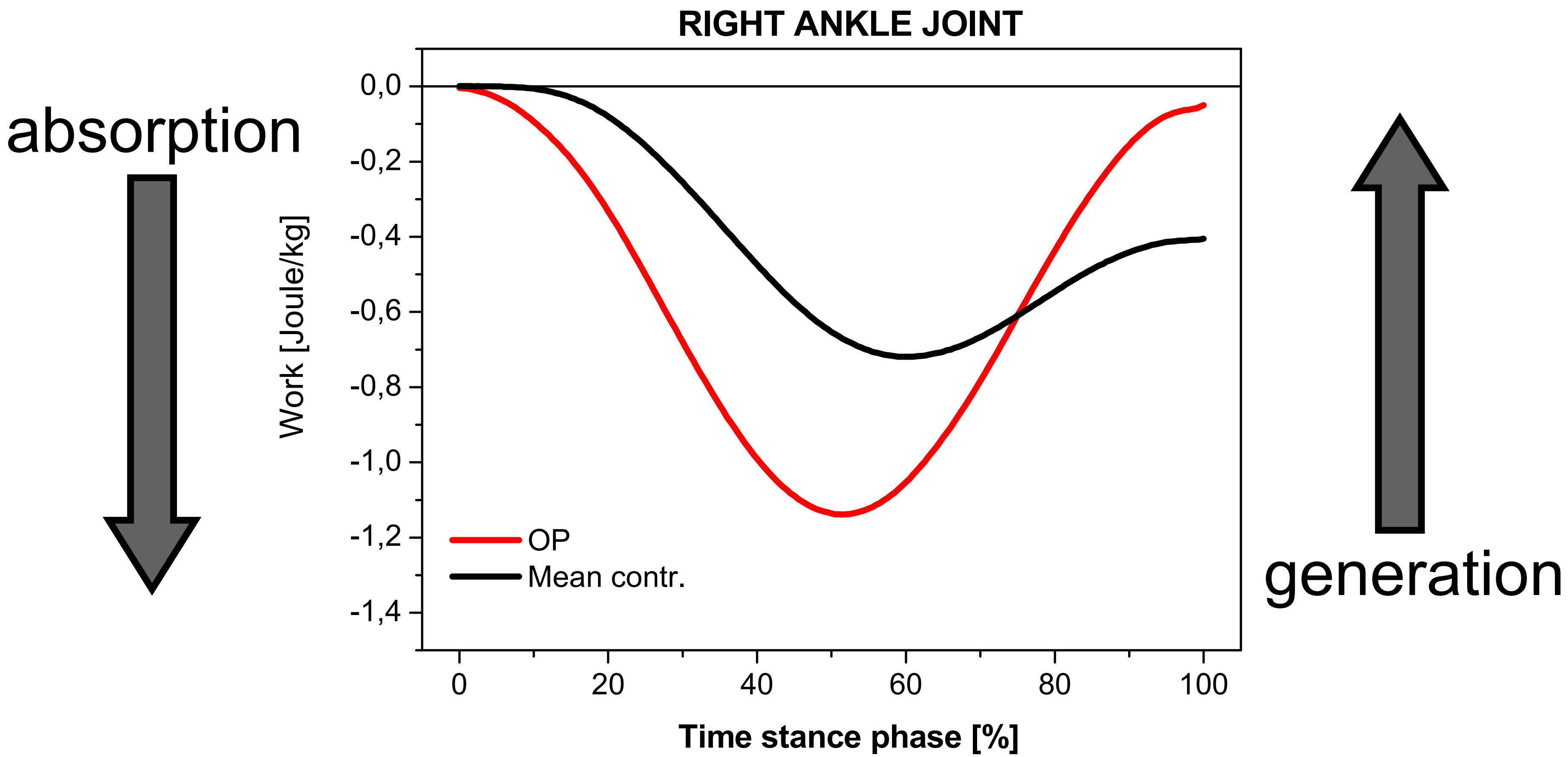


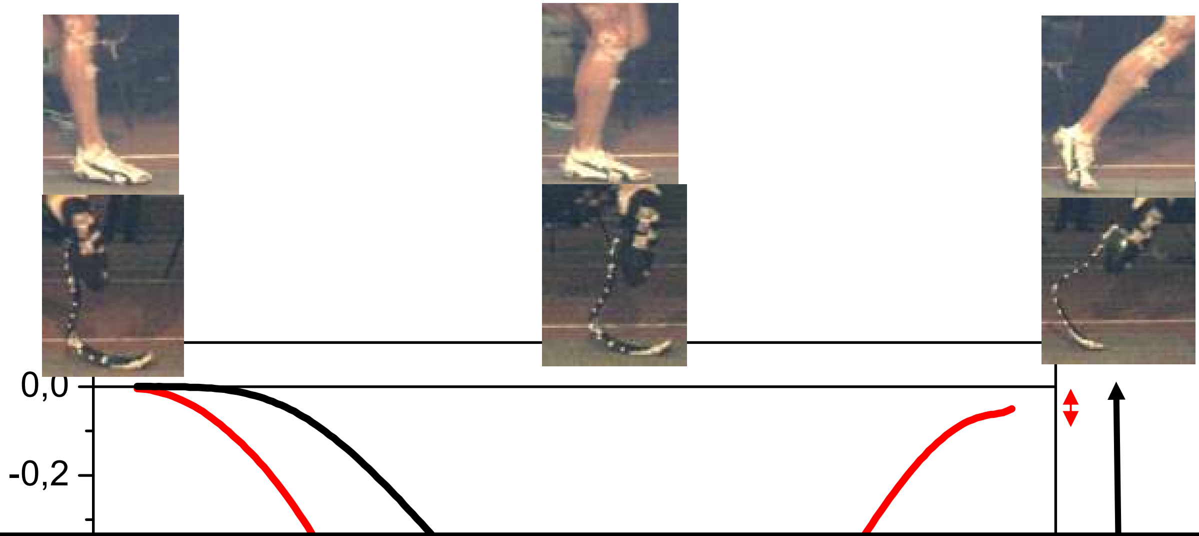
Relatively low reaction moments at knee and hip joints for OP

Mechanical power, ankle joint



Mechanical work, ankle joint





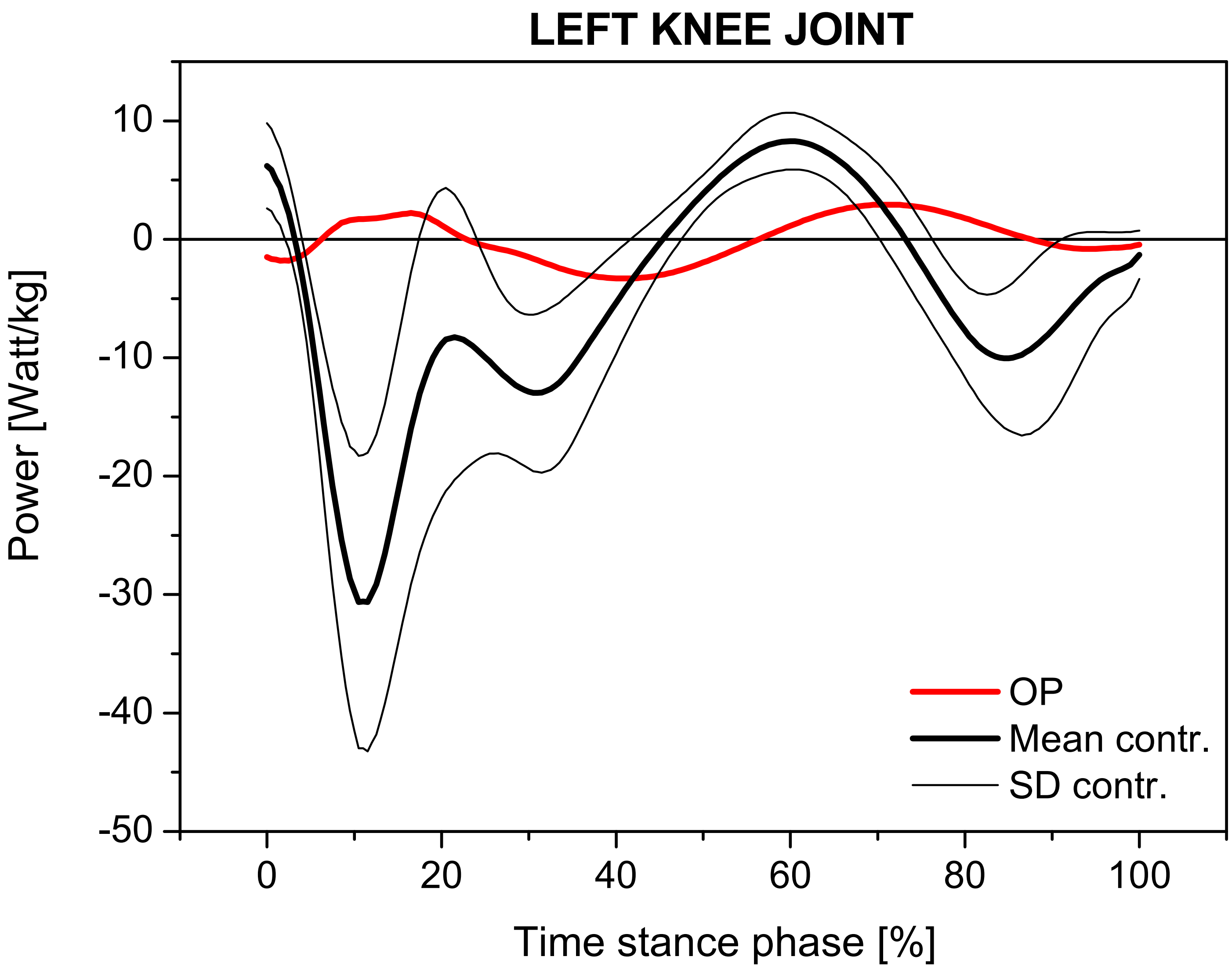
~ 100% more work done in the prosthesis than in healthy lower leg

Energy dissipation (loss)

O. Pistorius: 8%

Healthy controls: 40%

Mechanical power, knee joint



Summary

- Lower GRFs when sprinting with Cheetah prostheses.

- Much higher load (moment) in the blade
  compared to ankle joint.

- Hip and knee are much less loaded when sprinting
  with Cheetah prostheses.

Summary

- Majority of work done in blade (without muscular work).
- Blade returns elastic energy up to 92% (< 10% dissipated).
- … ankle joint about 60% (~ 40% dissipated).
- Different kind of locomotion.

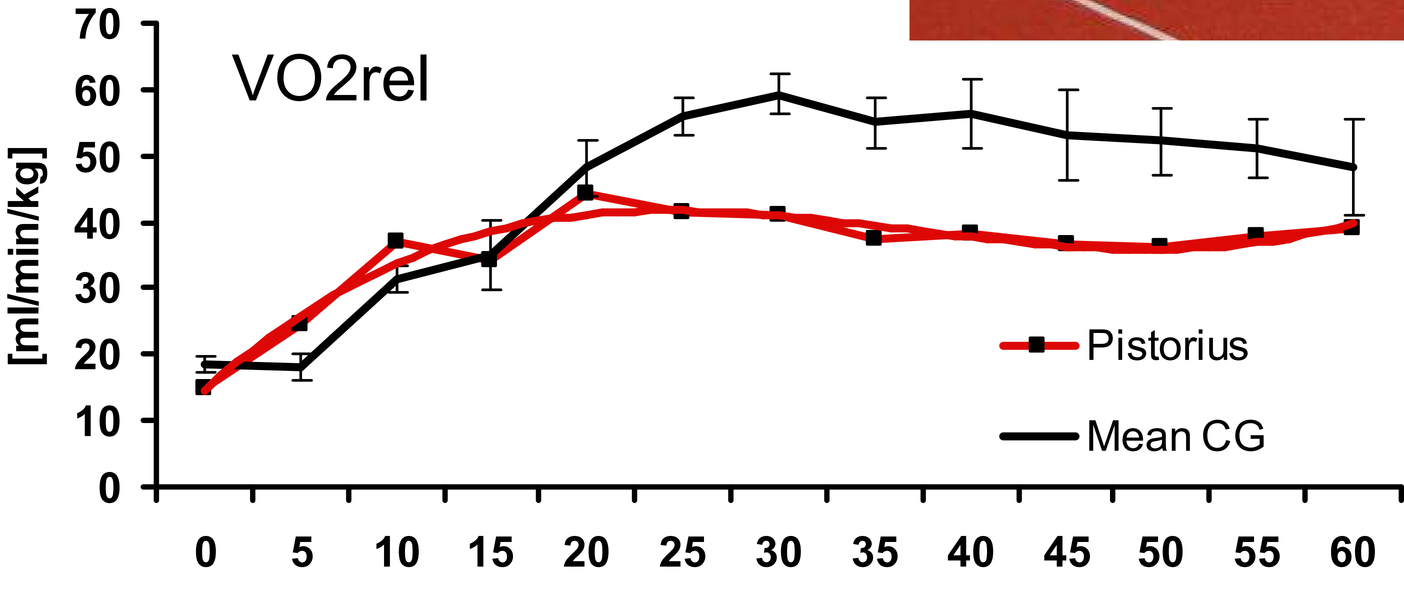
(with less muscular work and lower metabolic costs (?))

Metabolic capacity

- submaximal 400m race, VO2 consumption

400m race simulation
- VO2 uptake

O. Pistoriuis: 51.3s
Controls: 52.18s (50.5 – 55.4s)



lower oxygen uptake, about the same speed

- **Running of a double transtibial amputee using dedicated prostheses is biomechanically different from sprinting of able bodied athletes.**

- **Majority of work done in blade (without muscular work and fatigue) driven by the total body kinetic energy.**

- **Blade returns elastic energy up to 92%.**
  … sound ankle joint about 60% (in sprinting).

- **Less muscular work is required at knee and hip joint.**

- **Different kind of locomotion at lower metabolic cost.**

Double amputee sprinting

• is a biomechanical challenge

“People have always thought the human body is the ideal. It's not."

Hugh Herr, MIT Boston
double transtibial amputee
expert witness for Pistorius

“ I would like to challenge the biomechanics community to develop prostheses that will produce world records in many track and field disciplines. It should not be too difficult.“

Benno M. Nigg
University of Calgary
Human Performance Lab


K4