

Advances in Biomechanics Applied to Sports

Marcos Duarte

Biomechanics and Motor Control Laboratory

Federal University of ABC

<http://demotu.org/>

marcos.duarte@ufabc.edu.br

FAPESP support in numbers* to *"biomecânica" or "controle motor"*

36	<u>Ongoing research grants</u>
363	<u>Completed research grants</u>
61	<u>Ongoing scholarships in Brazil</u>
542	<u>Completed scholarships in Brazil</u>
10	<u>Ongoing scholarships abroad</u>
35	<u>Completed scholarships abroad</u>
1047	<u>All Research Grants and Scholarships</u>

Current projects/interests of the Biomechanics and Motor Control Laboratory

- Balance control in humans (older individuals)
- Biomechanics of long distance running and injury mechanisms (non-athletes)
- Modeling and simulation of human movement (open software)
- Improvement of biomechanical analysis of human movement (clinical use)
- Public data sets of biosignals related to human movement (BIG data, worldwide)
- Services for clinical gait analysis and wheelchair propulsion analysis (free @ BMClab)
- Dissemination of science and mathematics to society using sports

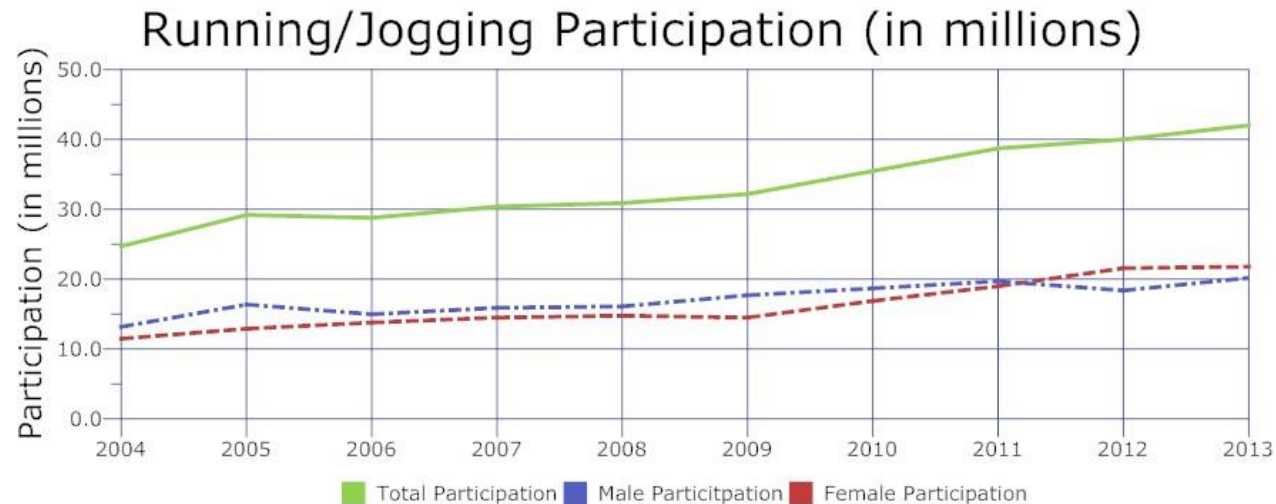
Biomechanics of long distance running

Biomechanics and Motor Control Laboratory

- Balance control in humans (older individuals)
- **Biomechanics of long distance running and injury mechanisms (non-athletes)**
- **Modeling and simulation of human movement (open software)**
- **Improvement of biomechanical analysis of human movement (clinical use)**
- **Public data sets of biosignals related to human movement (BIG data, worldwide)**
- Services for clinical gait analysis and wheelchair propulsion analysis (free @ BMClab)
- Dissemination of science and mathematics to society using

Background

- Increased running participation
 - Brazil: ~4.5 million runners (anecdotal evidence)
 - USA: ~30 million¹
 - Increased older runners' participation² (healthy aging)



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total Participation	24.7	29.2	28.8	30.4	30.9	32.2	35.5	38.7	40.0	42.0
Male Participation	13.2	16.4	15.0	15.9	16.1	17.7	18.7	19.7	18.4	20.2
Female Participation	11.5	12.9	13.8	14.5	14.8	14.5	16.9	19.0	21.6	21.8

¹<http://www.runningusa.org/>

²Jokl et al. (2004) BJSM.

Background

- **Running injury frequency between 15-85%¹**
- **Economic burden of a running injury²**
 - Direct cost €57.97
 - Indirect costs €115.75
- **Older age has been associated with higher incidence³**

¹Nigg et al. (2015) BJSM; ²Hespanhol et al. (2015) SJMSS; ³Nielsen et al. (2013) OJSM.

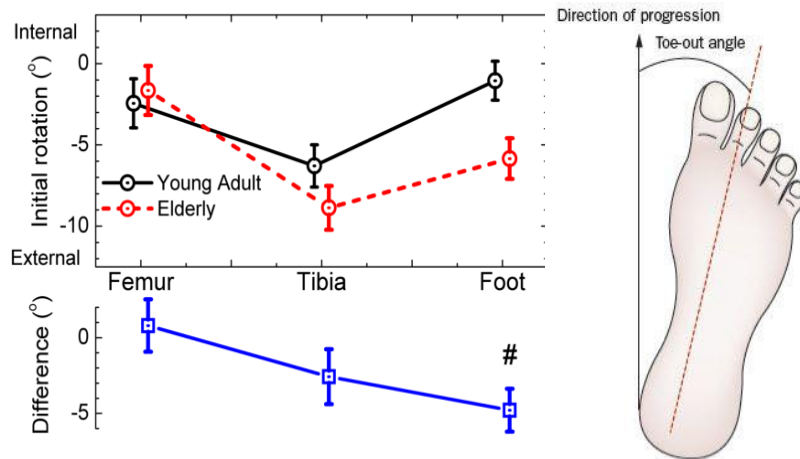
Background

- **Running injury etiology is likely multifactorial¹**
 - Epidemiological data
 - Biomechanical studies
 - Clinical research
 - Behavioral research
- **Atypical running patterns have been associated with injuries²**
- **Age-related changes in running biomechanics have been consistently observed^{3,4}**

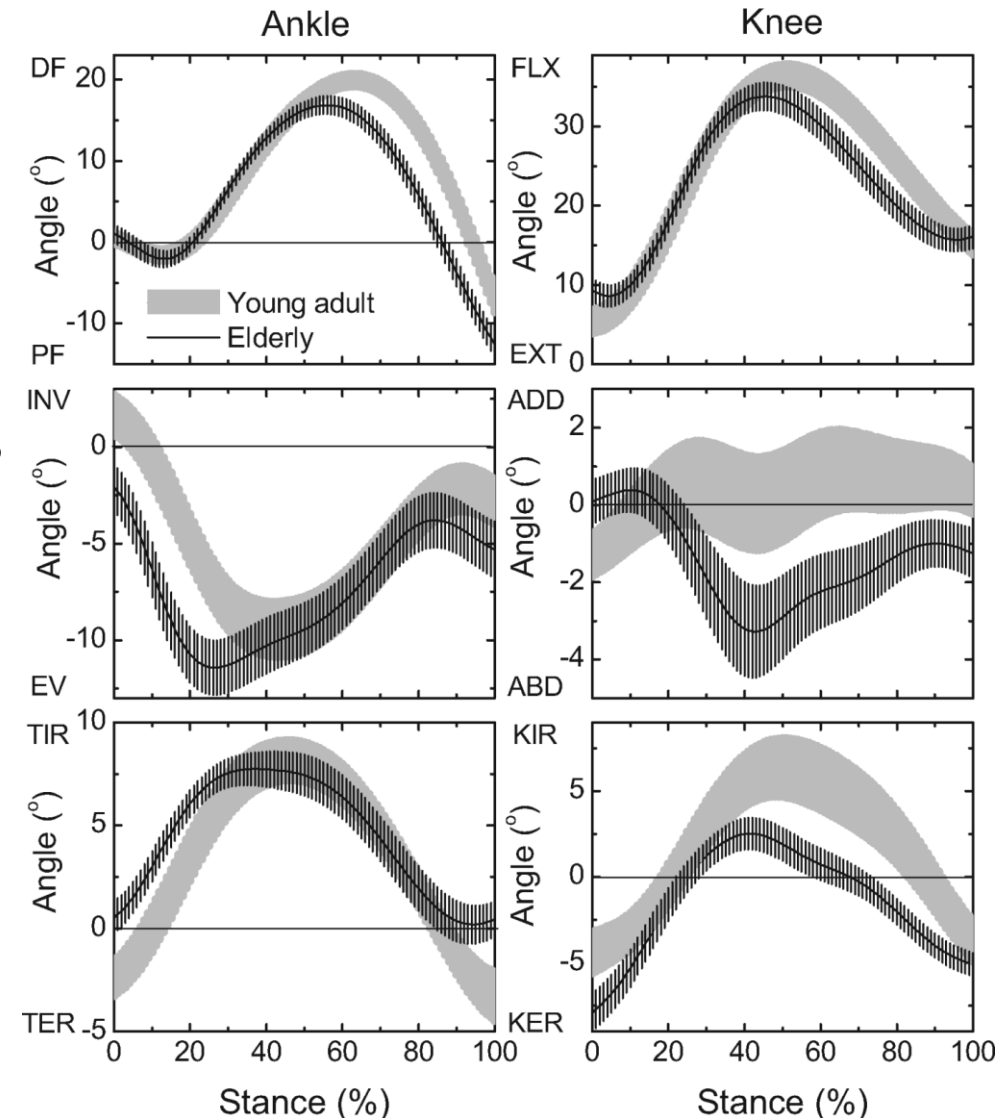
¹Hulme and Finch (2016) JSHS; ²Hreljac (2004) MSSE; ³Fukuchi and Duarte (2008) JSS; ⁴Fukuchi et al. (2014) CB.

Aging & biomechanics of long distance running

- ↓ stride length
- ↑ stride frequency
- Altered joint kinematics

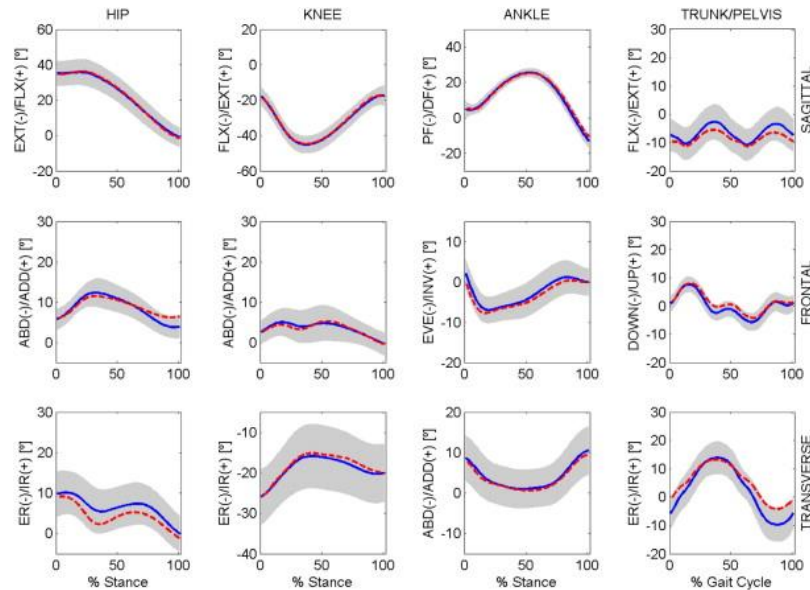


Fukuchi & Duarte (2008)

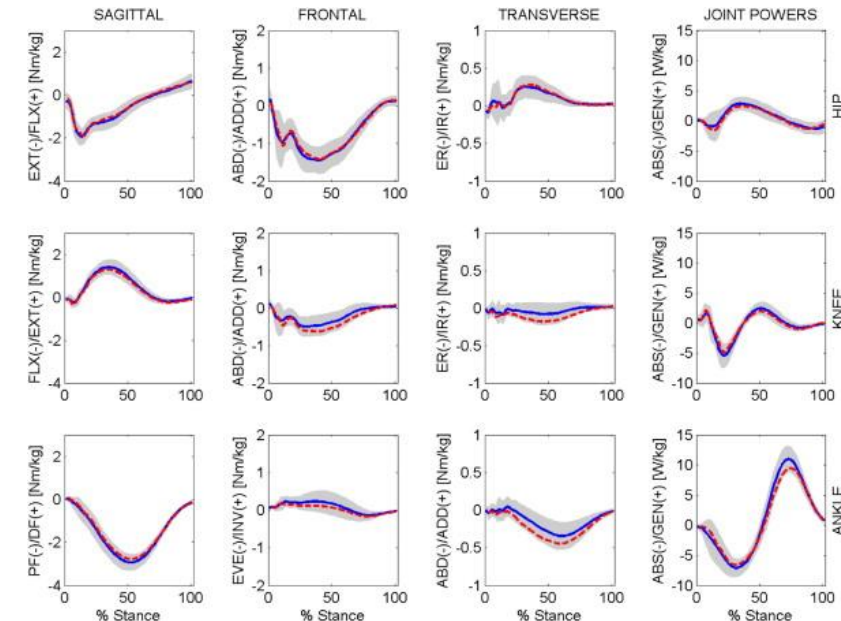


Aging & biomechanics of long distance running

- **↓ flexibility and ↓ muscle strength in older**
- **Atypical gait in older runners**



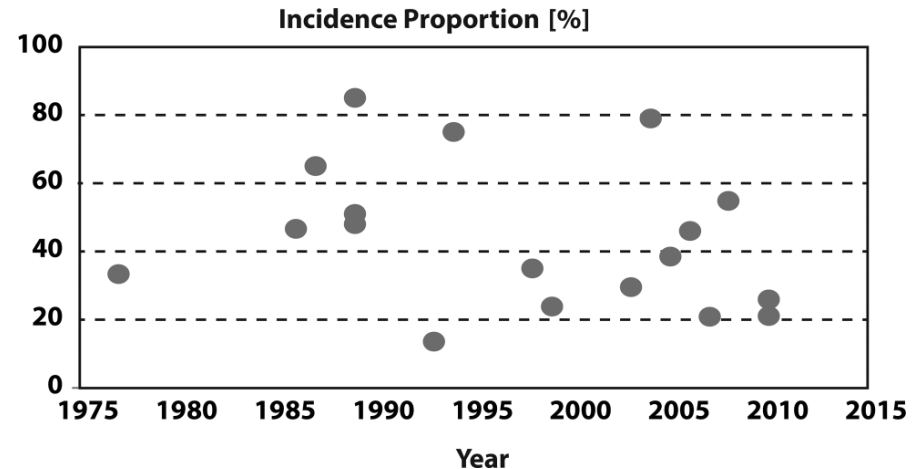
Kinematics



Kinetics

The Problem

- Despite intense research the injury rates have not declined¹

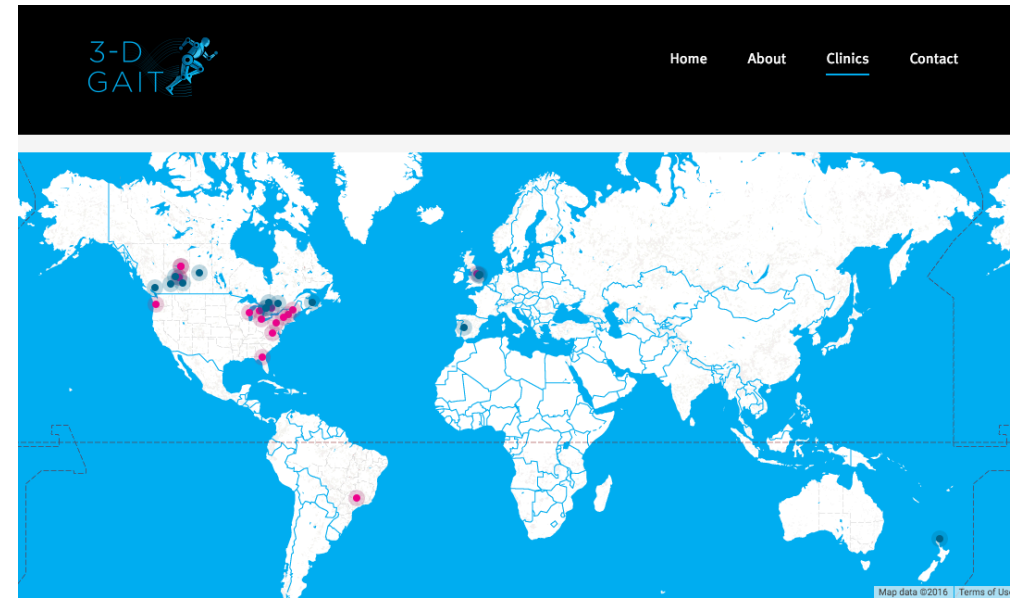


- Complex nature of running biomechanics data has been examined by simplistic approaches²
- What is the typical and atypical (injured) running pattern?

¹Nigg et al.(2015) BJSM; ²Chau (2001) GP; ³Mullineaux et al. (2001) JSS.

Possible approach for a solution

- A public database of running ranging from demographics, biomechanical, musculoskeletal function and epidemiological data with a large population of runners.



<http://3dgaitanalysis.com/>

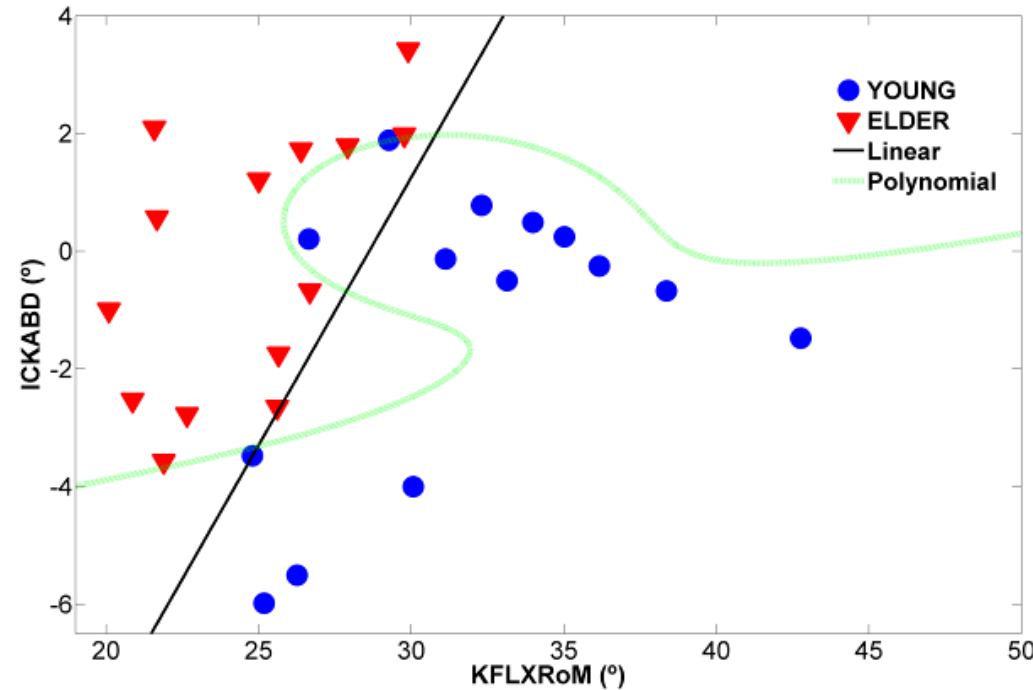
Public running database

- To provide good quality data to the scientific community
- Development and testing of novel and robust data analysis approaches to address the complex, multivariate nature of running injuries etiology



<http://mobilize.stanford.edu>

Aging & biomechanics of long distance running



- **85% overall classification accuracy rate**
 - **100% classification accuracy rate was achieved**
- when only six kinematic features were combined**

Fukuchi et al. (2011)

Biomechanics of long distance running

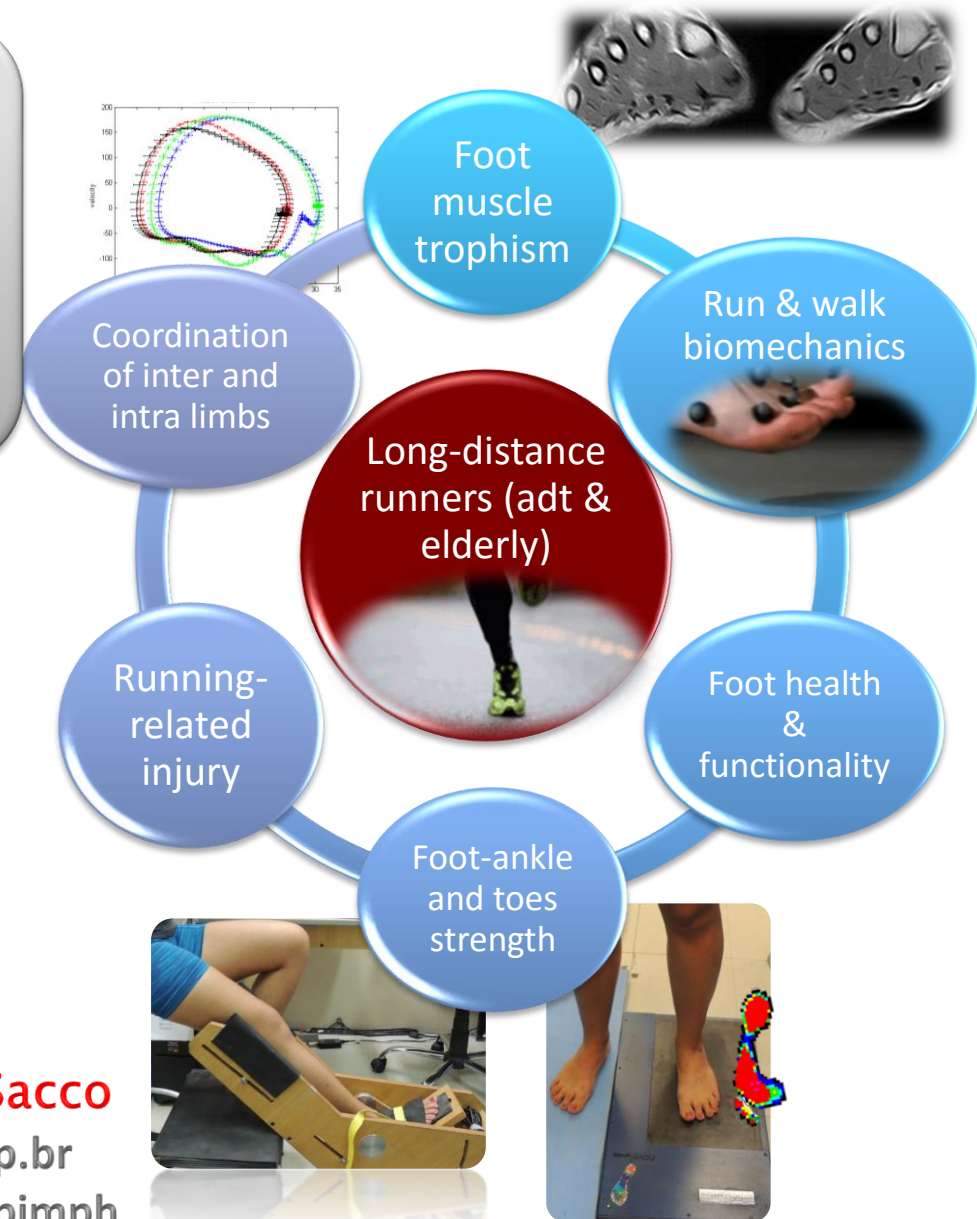
Biomechanics and Motor Control Laboratory

- But there are still too many unsolved problems with the biomechanics of long distance running and injury mechanisms ...

Aim - Investigate the effects of :
 (1)a "ground-up" therapeutic approach and
 (2)aging on...
 ... running and gait biomechanics, on lower limbs
 coordination, on strength and functionality of the
 muscles of the lower limbs and on the prevention
 of running-related injuries.



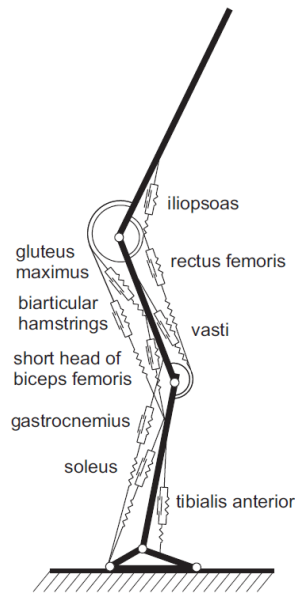
Isabel C. N. Sacco
 icsacco@usp.br
 www.usp.br/labimph



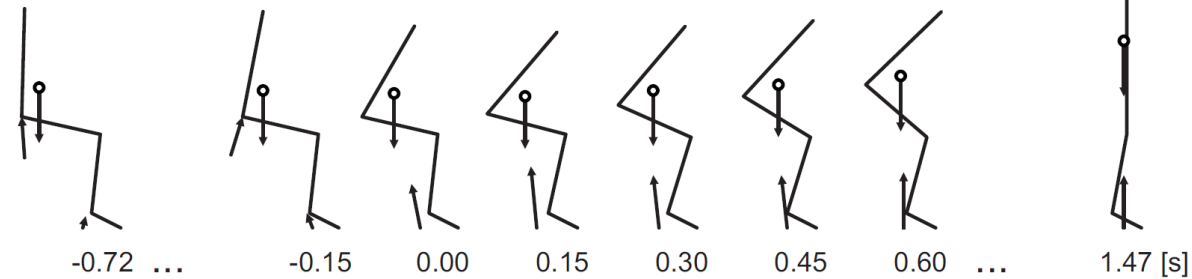
(some) Collaborators in São Paulo State

Optimal Control of Human Movement

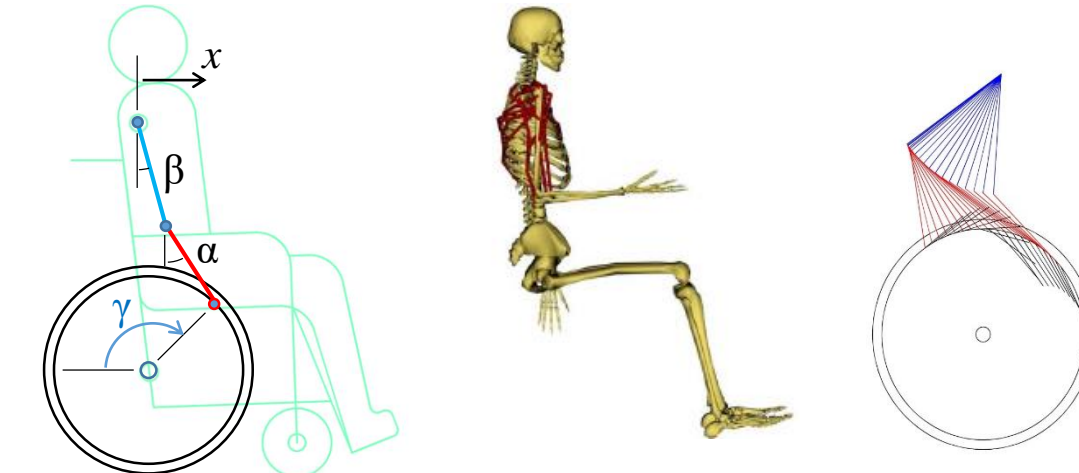
- **Marko Ackermann** – *FEI University, São Bernardo do Campo, Brazil*
- **Maarten F. Bobbert** – *VU University Amsterdam, The Netherlands*



Sit-to-stand task (CNPq Project: 402831/2012-8, Marco Vaz, PA)



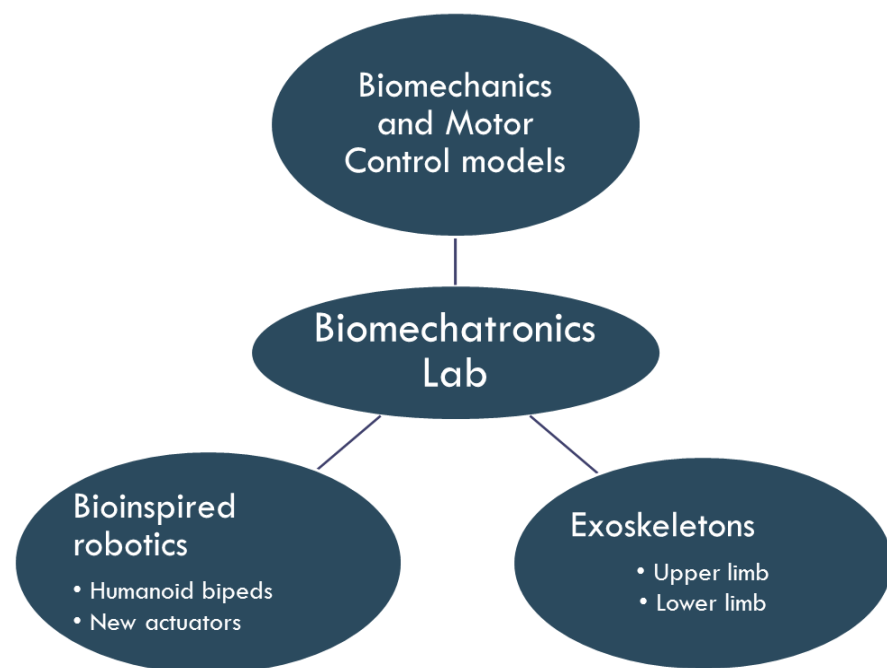
Wheelchair propulsion



BIOMECHATRONICS LAB. MECHATRONICS DEPARTMENT ESCOLA POLITÉCNICA. UNIVERSITY OF SÃO PAULO

Biomechatronics = Biomechanics + Motor Control (Natuurlijk! –F.C.T. vd Helm–)

Models of the human motor control system from a control engineering perspective



• Faculty:
Arturo Forner-Cordero
Rafael T. Moura

• Post-docs
Fabianne Furtado

• PhD
Luis Filipe Rossi
Carlos Noriega
Milton Cortez Junior
Guilherme Umemura

• Visiting Professors (NL):
Jacques Duysens (CNPq)
Bouwien Smits-Engelsman
Noel Keijsers

• MSc students
Camila Souit
Mayra B. Villalpando
Rafael S. Souza
Eduardo Garcia
Leonardo F. Sommer
Michele Sakata

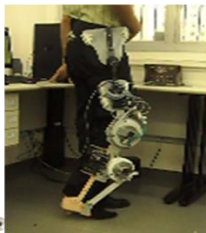
<http://sites.poli.usp.br/pmr/biomecatronica/>

BIOMECHATRONICS LAB. (A. FORNER-CORDERO)



Exoskeleton

Miranda et al, 2012



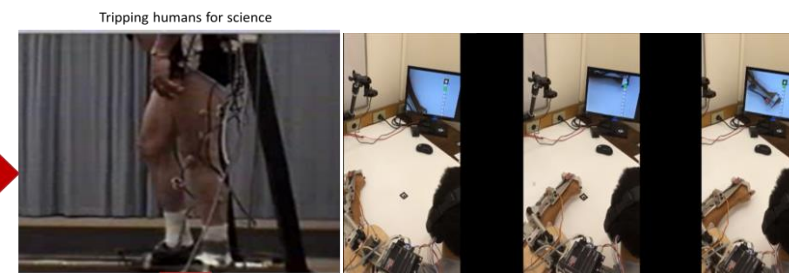
Assist

Human



Da Vinci L, 1490

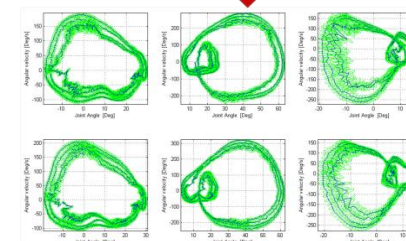
Measure



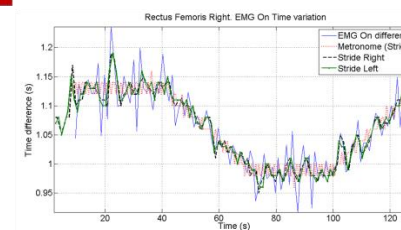
Tripping humans for science

Forner-Cordero et al,
Gait&Posture, 2003
J. Biomech., 2006

Analyze



Experimental Limit Cycles of human gait used to define stability limits

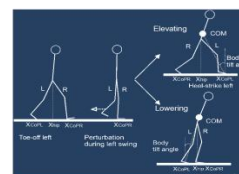


Forner-Cordero et al, 2014

Models

Gallego et al, 2012

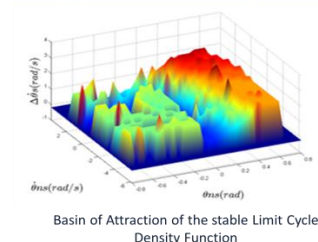
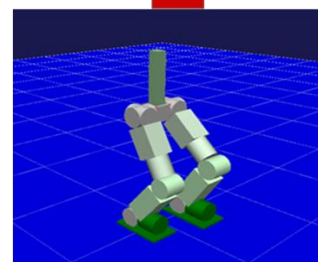
Forner Cordero et al, 2004



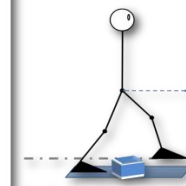
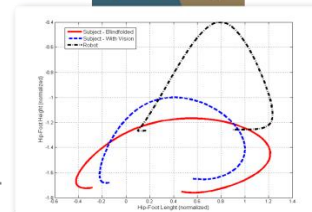
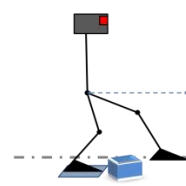
Rossi et al, 2014

Design

Rossi et al, 2014



Basin of Attraction of the stable Limit Cycle Density Function



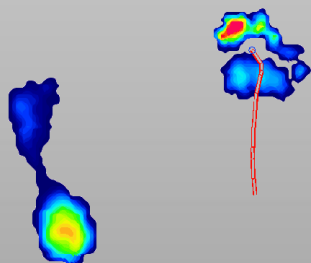
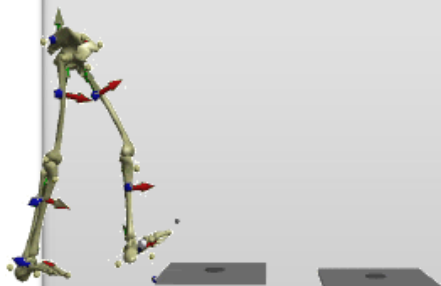
Forner-Cordero A; Rodrigues ST; Duysens J.
Obstacle crossing differences between blind and blindfolded subjects after haptic exploration. J Motor Behavior (in press)

Forner-Cordero A; Itiki C; Souza R;
Lourenco JCMC; Krebs HI (2014).
Experimental assessment of gait with rhythmic auditory perturbations. BioRob2014

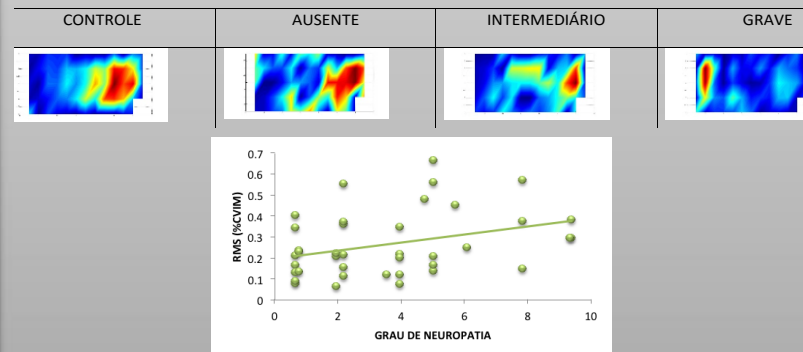
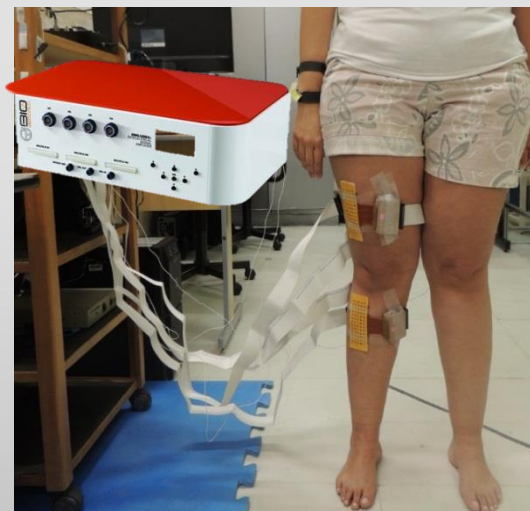


Diabetic Neuropathy

Kinematics, Kinetics,
Plantar pressure



sEMG multichannel



RCT Effect foot exercises in PP
& gait speed



Obrigado

Marcos Duarte

Biomechanics and Motor Control Laboratory

Federal University of ABC

<http://demotu.org/>

marcos.duarte@ufabc.edu.br