Combining effects in human walking: load, speed and gradient

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Mountain, Sport and Health Congress 2015

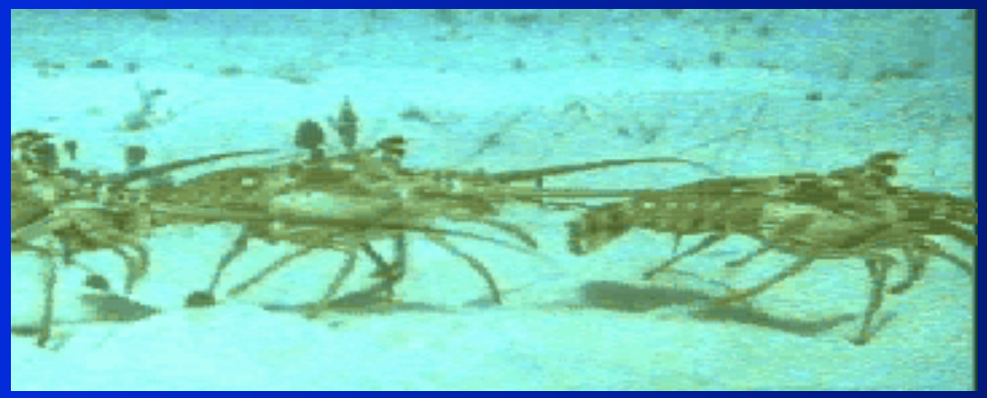
Locomotion - Mechanics and Energetics of Terrestrial Locomotion

Study of mechanisms minimizing the energy expenditure during walking and running, so-called pendular and elastic mechanisms, respectively.

In Elite sports, we are carrying out evaluations and experiments in volleyball players, sprinters, and long distance runners.

Porto Alegre: Capital of gaúchos

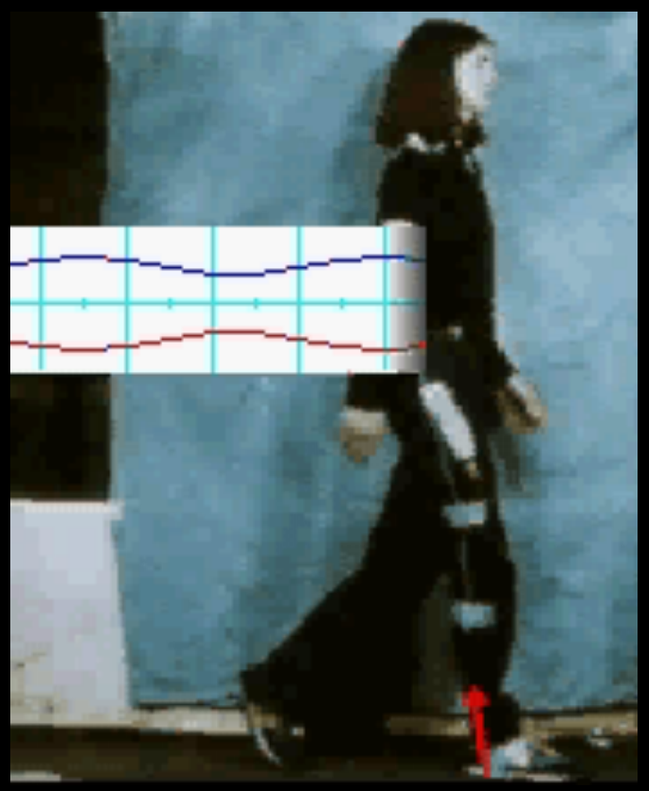
Exercise Research Laboratory

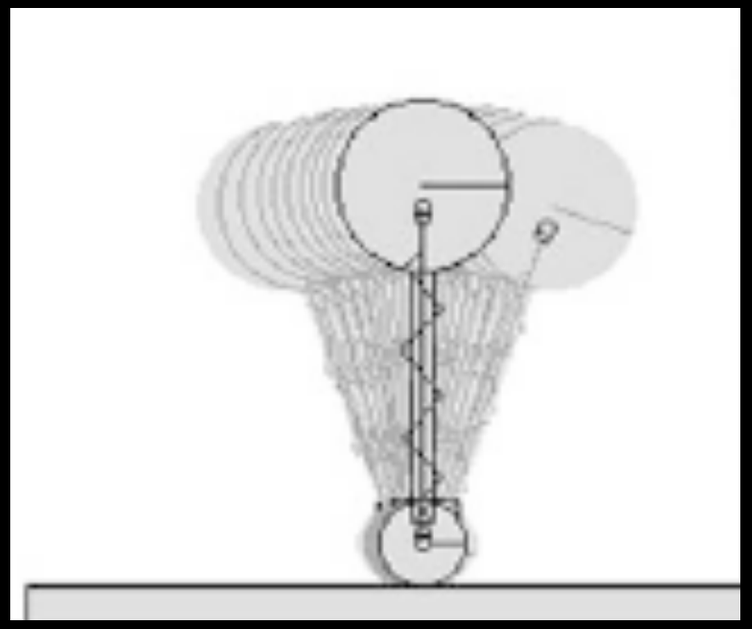


Mechanic Paradigms:

walking: inverted pendulum

Reconversion between kinetic and potential energy and vice-versa of the COM.





Cavagna et al., J Appl Physiol,1963, 1976.

but

Constraints

- The two basic and fundamental constraints to the paradigms are:
  - LOAD
  - INCLINE

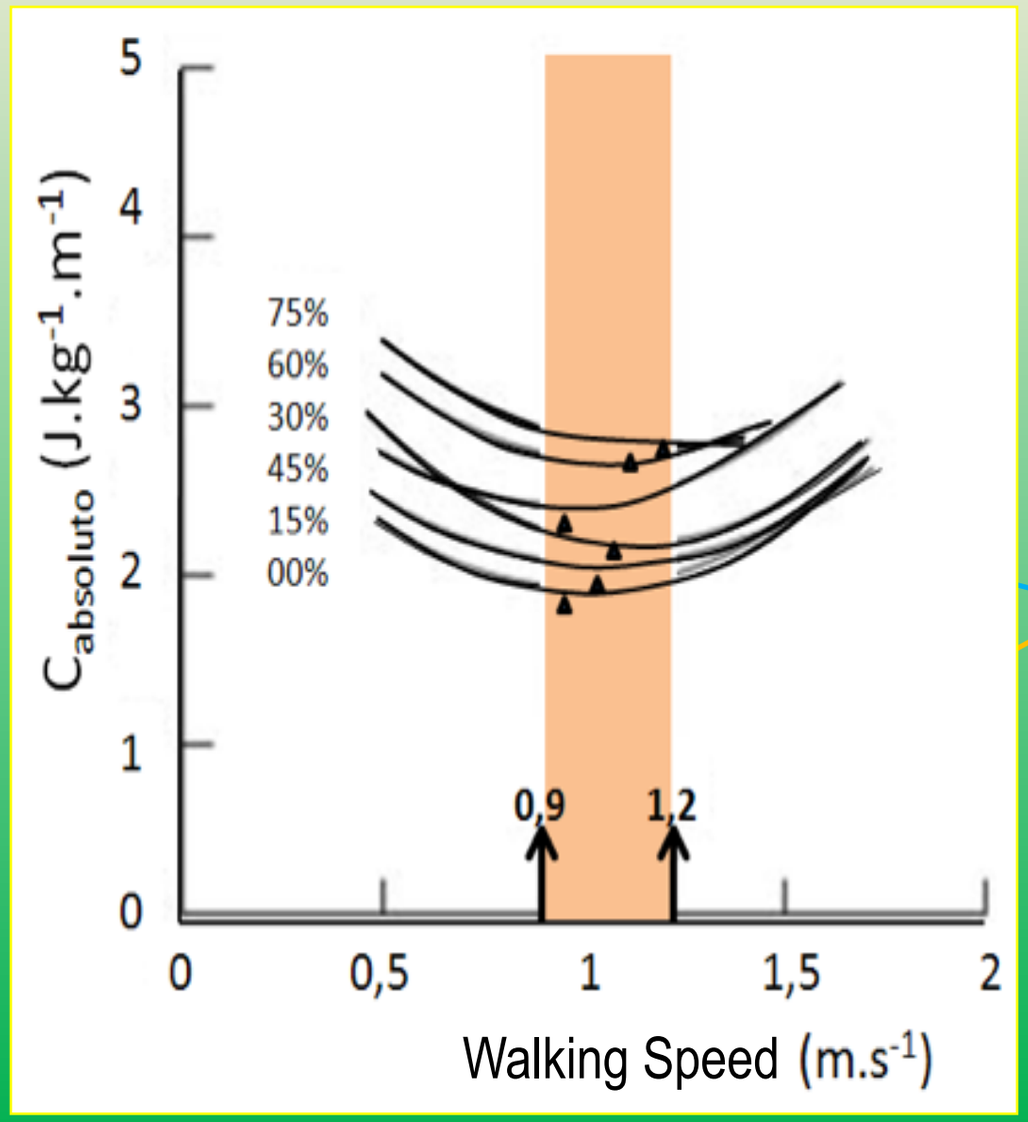
Applied point-of-view

- Understand these restrictions is important because:
  - fitness programs out- and indoor.
  - to test hypothesis of human evolution.

Amazon Mountains (~3.400m)

Load effects on C and $V_{optimum}$

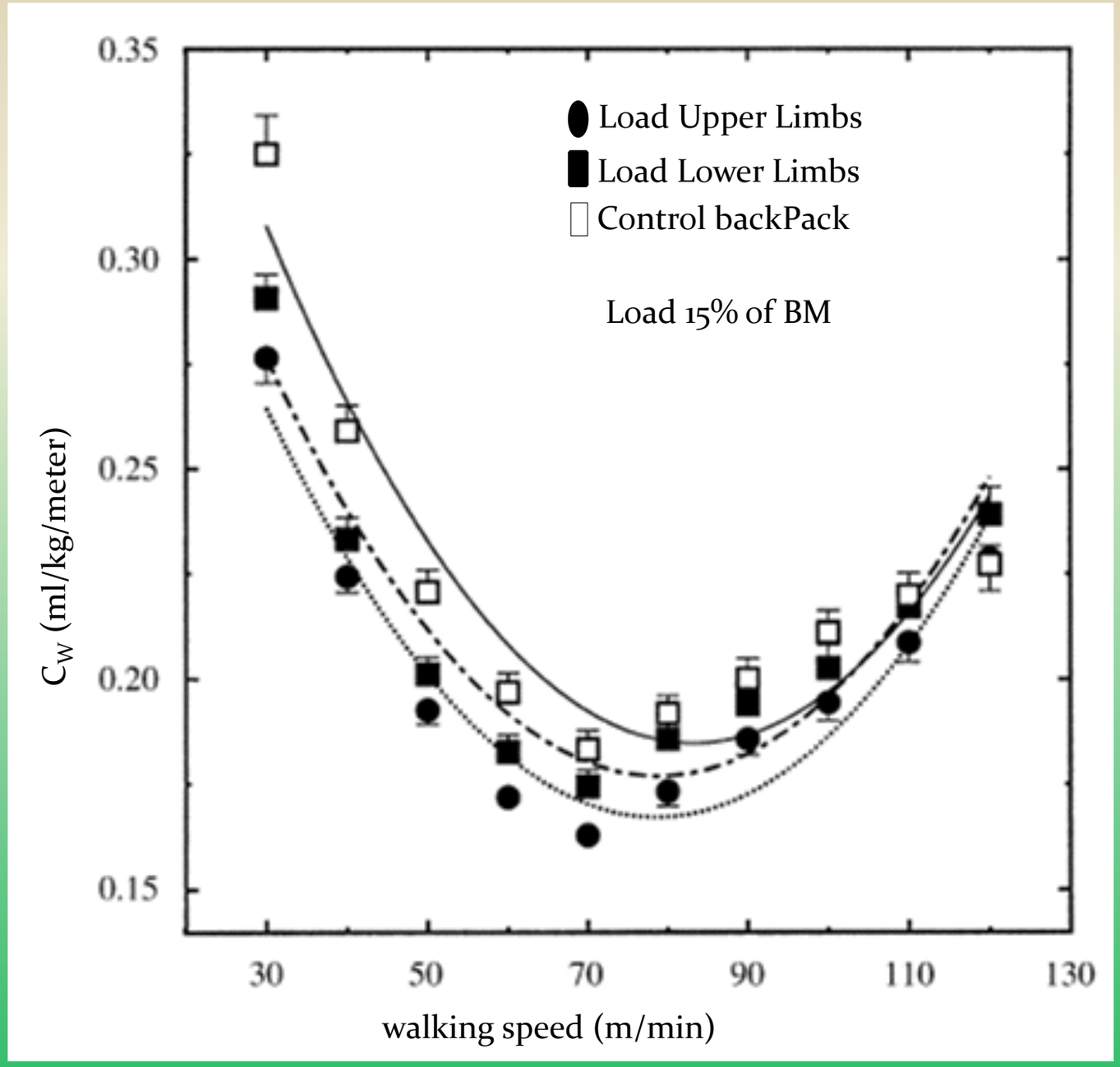
- The classical determinant of $V_{optimum}$ in level walking is the *Recovery*, yielding max value ≈ 60% at ≈ 4.5 km.h^{-1} (1.3 m.s^{-1}).



At level, the $V_{optimum}$ is maintained with loads up to 75% of body mass.

Bastien *et al.*, Eur J Appl Physiol, 2005.

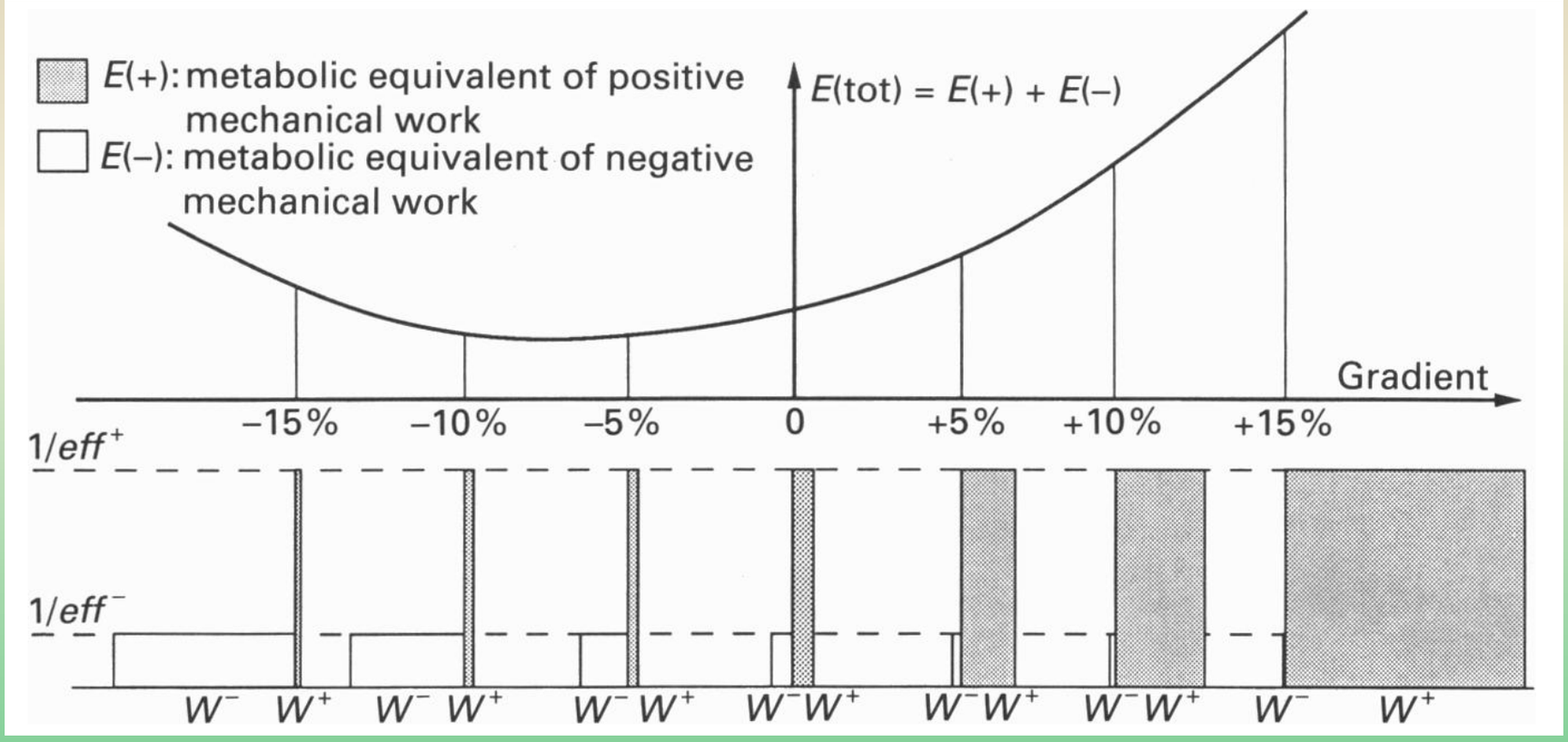
Load position effects



At level, the $V_{optimum}$ is maintained with different load position.

Abe *et al*., Appl Ergon, 2008.

Walking in gradients



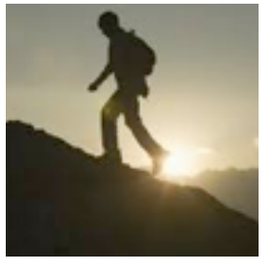
The minimum cost at gradient -10%, is determined by the positive and negative mechanical work and their different efficiencies.

Minetti *et al*., J Physiol, 1993.

Although load and incline effects on metabolic cost are determined, their combined effects are unknown.

load

incline



load + incline

The purpose of this study was:

- to analyze the combined effects of

speed, **load** and **gradients** on

Metabolic cost

Mechanical work

Pendular mechanism

Material and Methods

- we asked to 10 health subjects to walk on treadmill at:
  - 5 constant speeds: 1-5 km/h (at level 2-6 km/h)
  - 3 slopes: 0, 7, 15%
  - unload and loaded 25% bm

data acquisition

- O2 consumption and
- kinematics 3D

data analysis

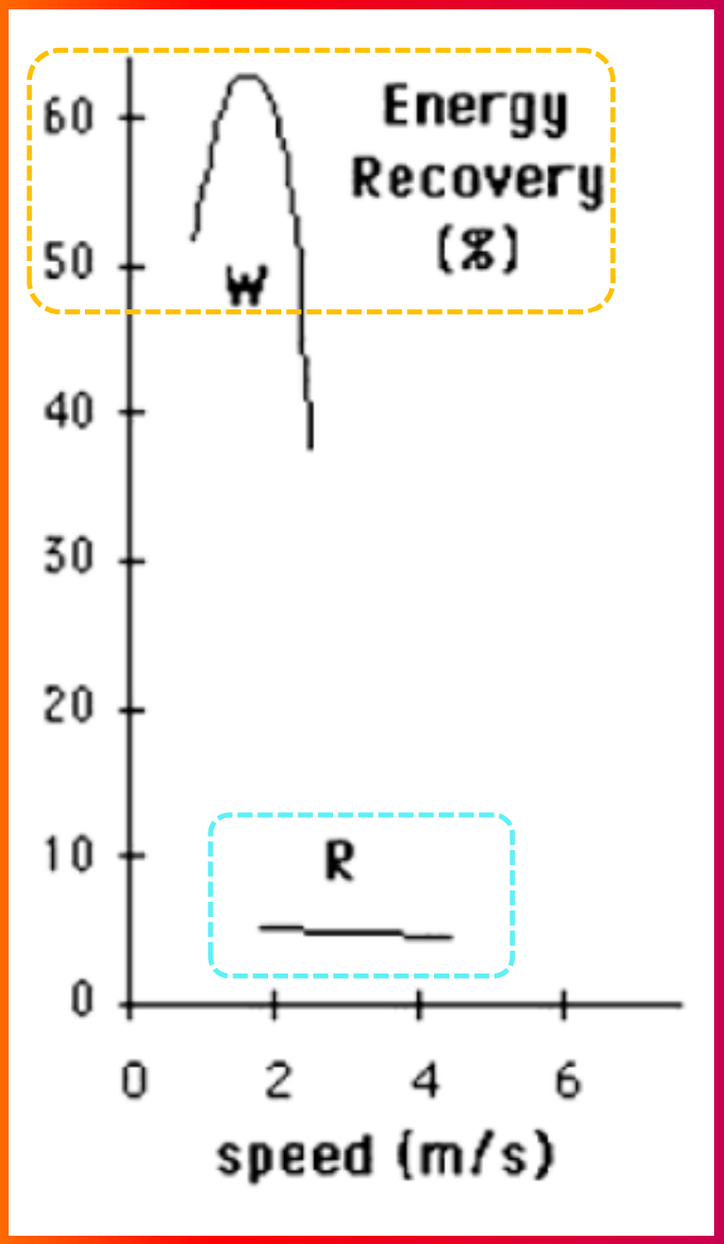
- the fluctuations of mechanical energies of body and segmental CoM were calculated.

Cavagna, 1975

- The metabolic cost was determined taking into account the combustion enthalpy of different substrates and the difference from exercise to stand metab power.

Saibene and Minetti, 2003

Recovery



R : is the transfer percentage between Kinetic and Potential energies of BCoM during a whole stride.

$$R(\%) = \frac{W_{ext,f} + W_{ext,v} - W_{ext}}{W_{ext,f} + W_{ext,v}} 100$$

In humans

Walking: high (up to 60% on $V_{optimum}$) (KE and KE are opposed).

Run: low

(KE and KE are in phase).

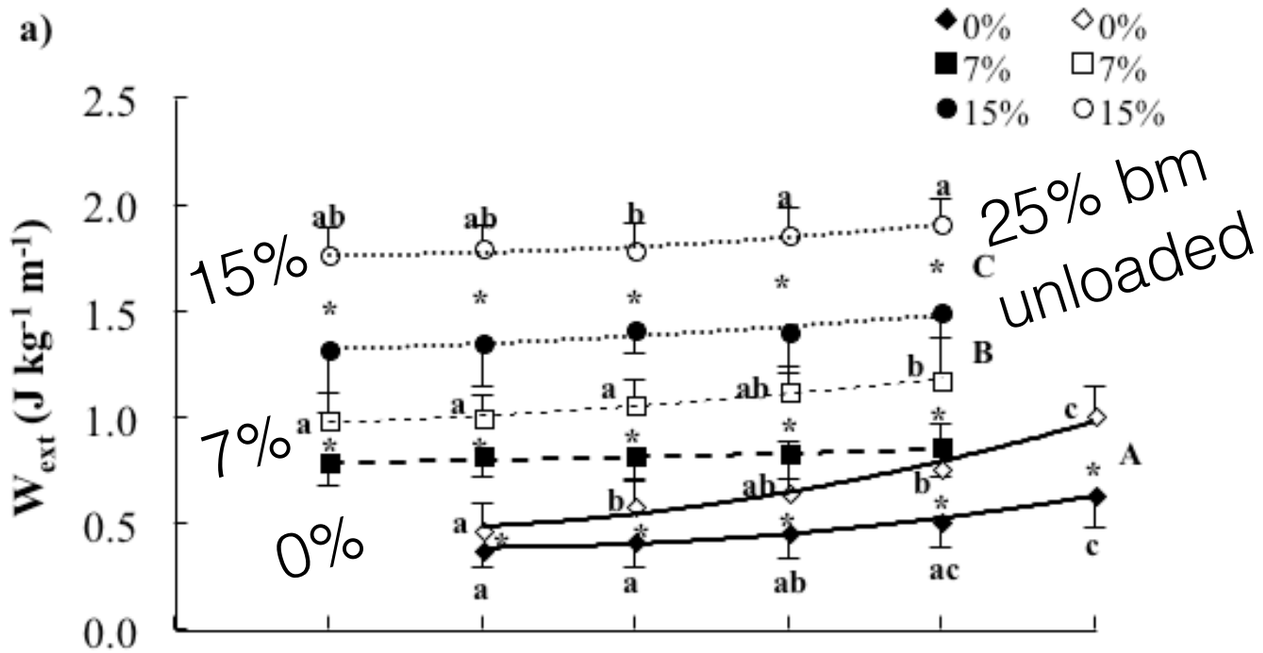
Cavagna, 1976.
Saibene & Minetti, 2003.

statistical procedures

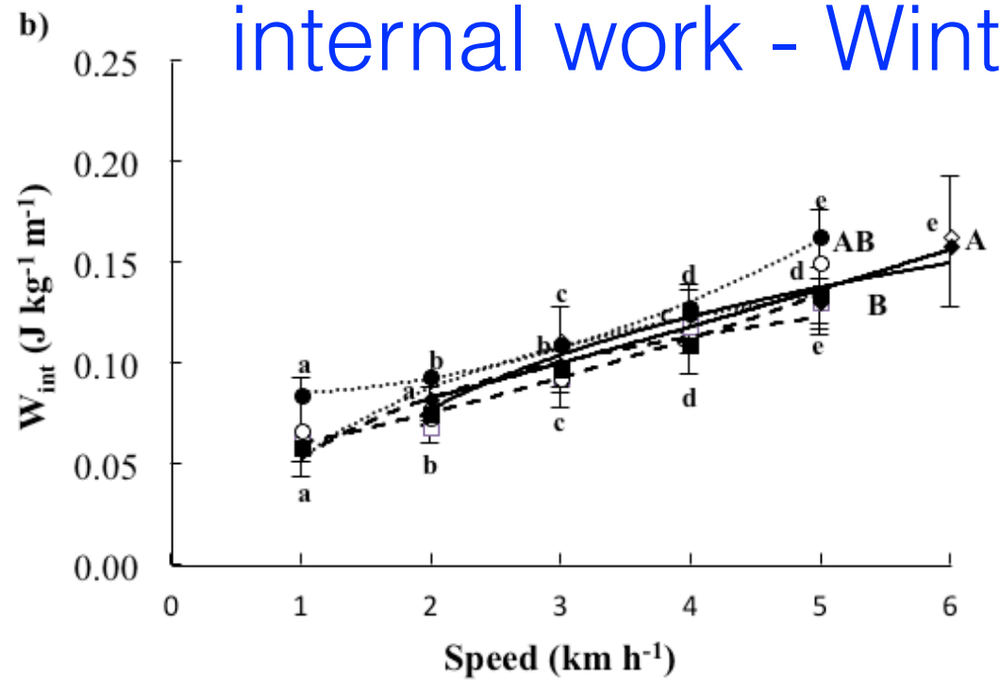
- Anova with measures-repeated
- bonferroni's correction
- alfa = 0.05 at SPSS vs. 18.

Results

external work - Wext



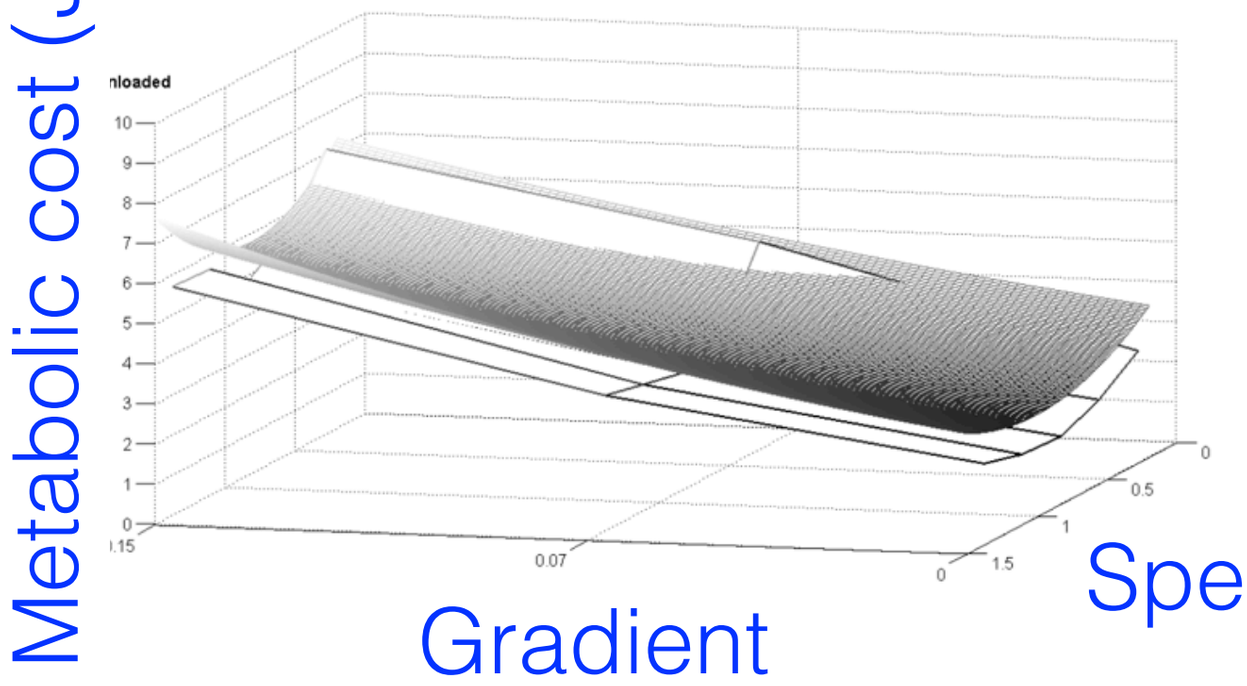
internal work - Wint



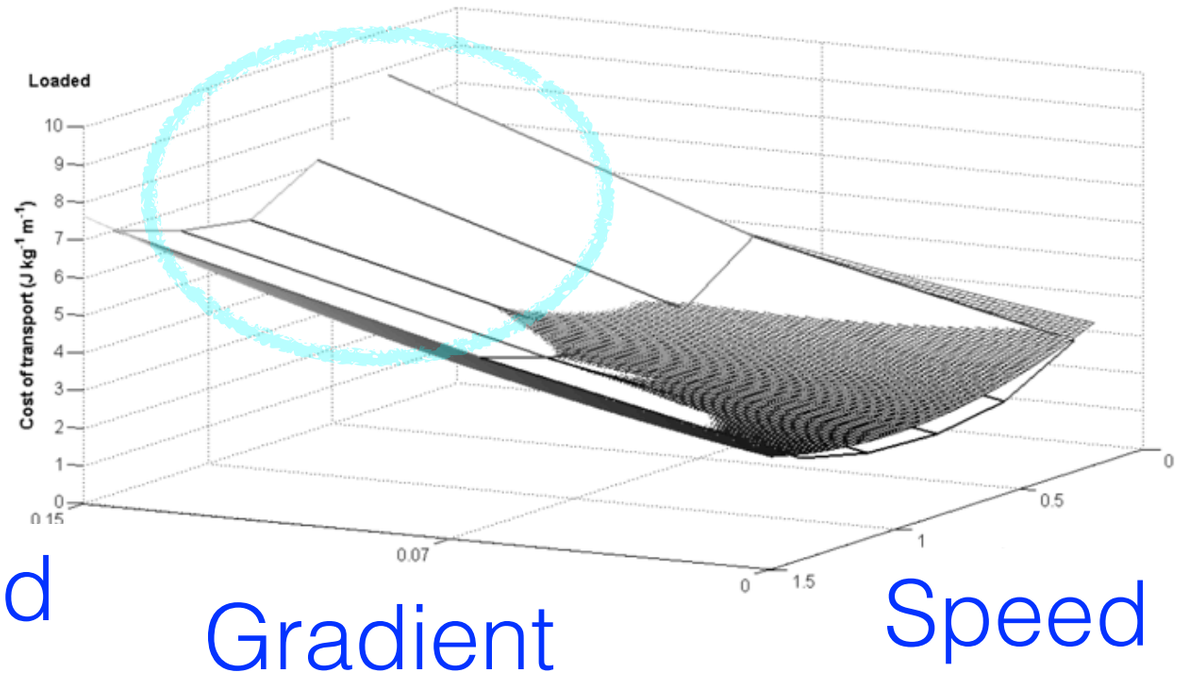
- Wint very low and not affected by load and gradient
- Wext is dependent of load and gradient

Results

Unloaded

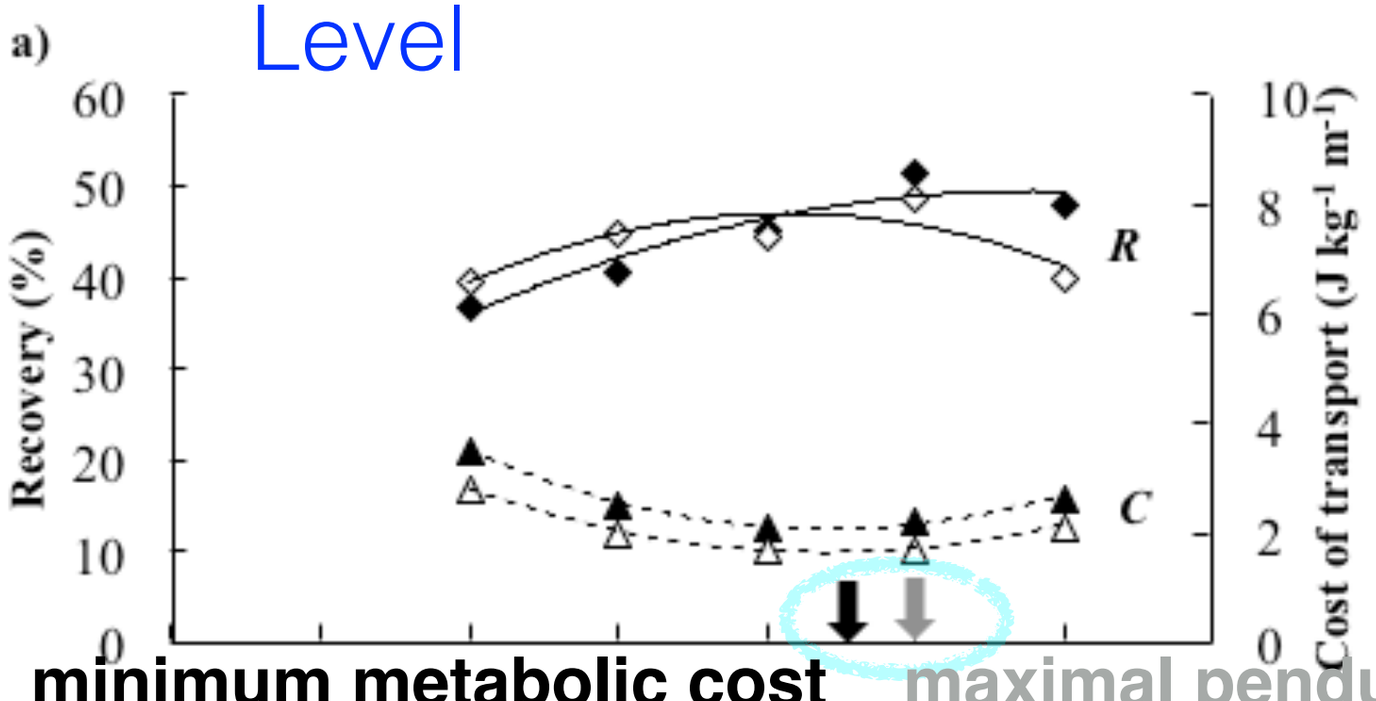


Loaded 25% bm

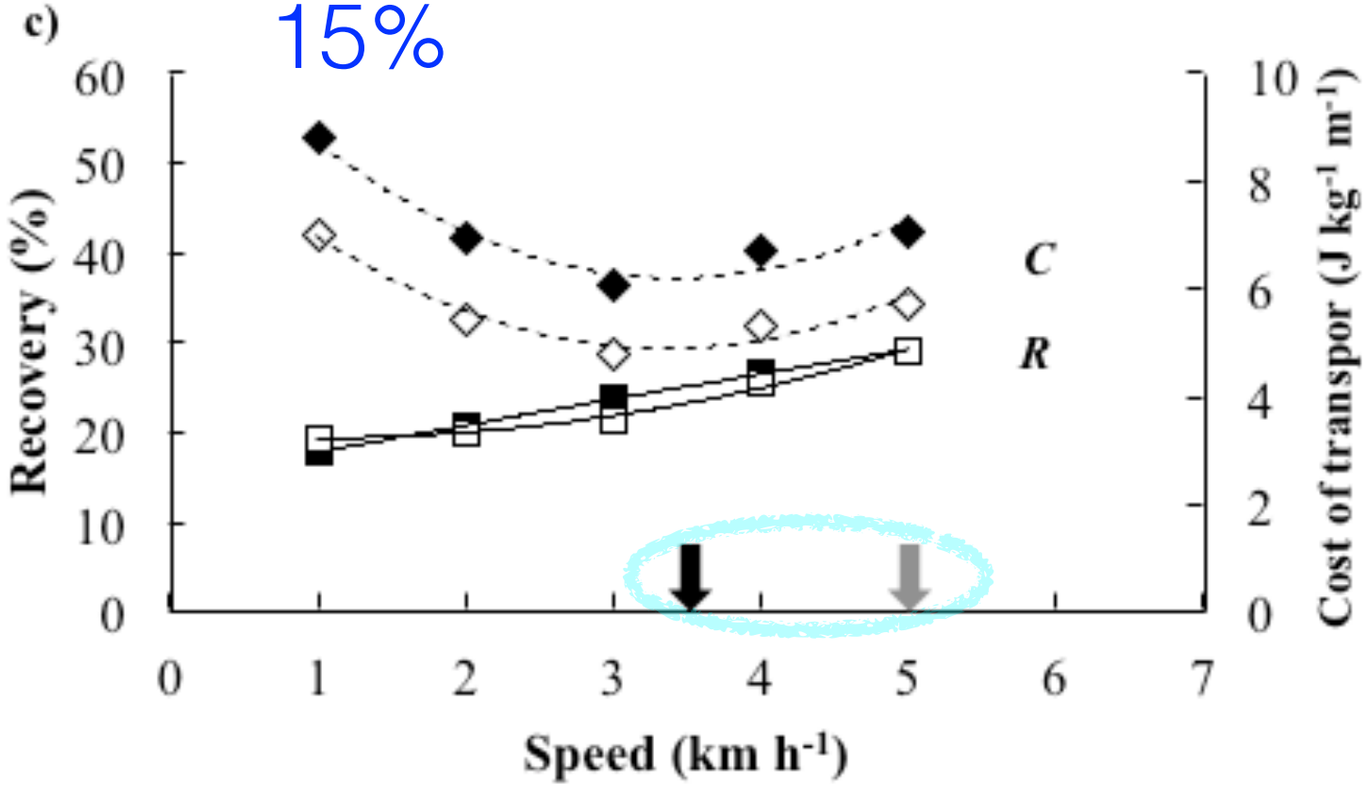


- the metab cost to carry 1kg is major at extreme gradients

Results



AT LEVEL - The max pend Rec coincides to min metal cost



AT 7/15% - The max pend Rec yields to max speed and; the min metab cost attains ~3.4 km/h

Is the treadmill ecological enough?

VS

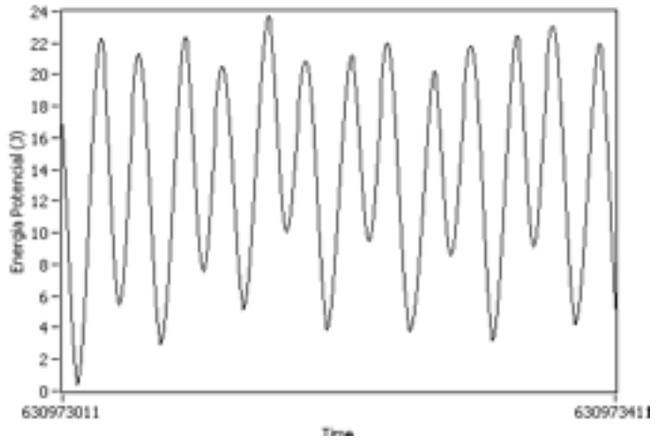
Probably not…
the stability could include
other sources to metab cost

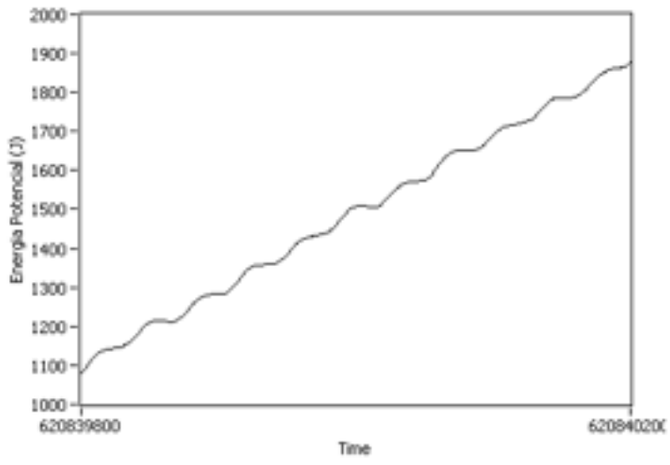
last minute findings…

4km/h plano Sem carga

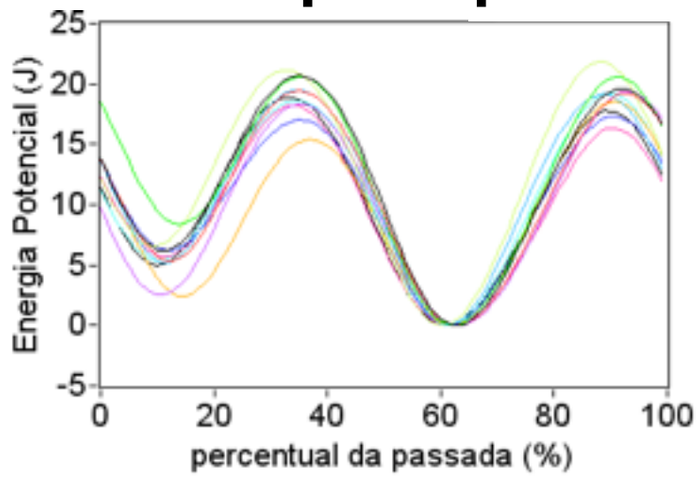
3km/h +15% Sem carga

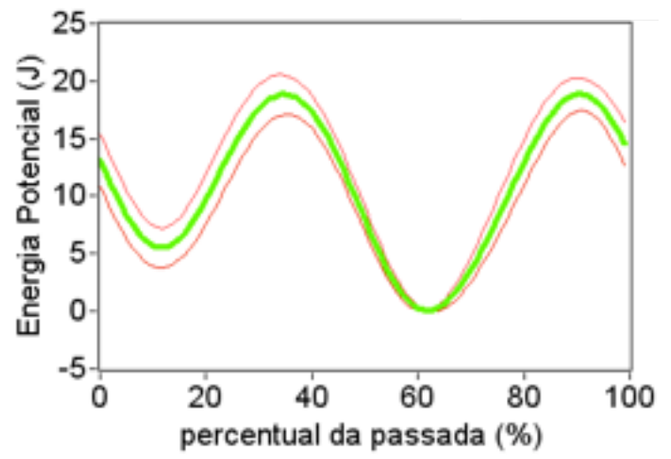
Suaviza

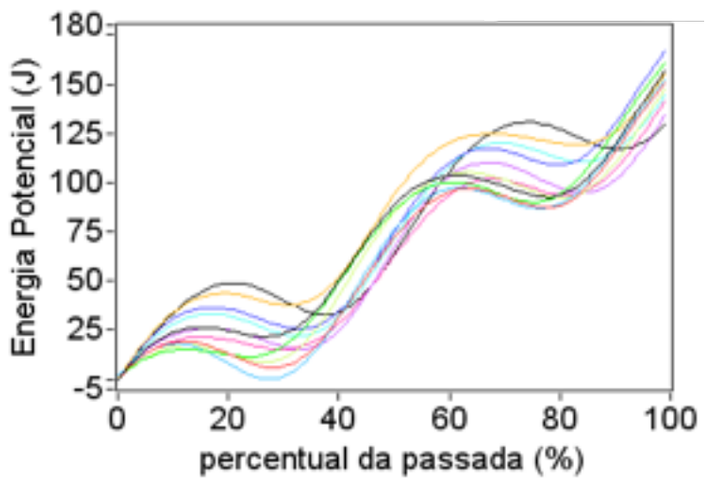


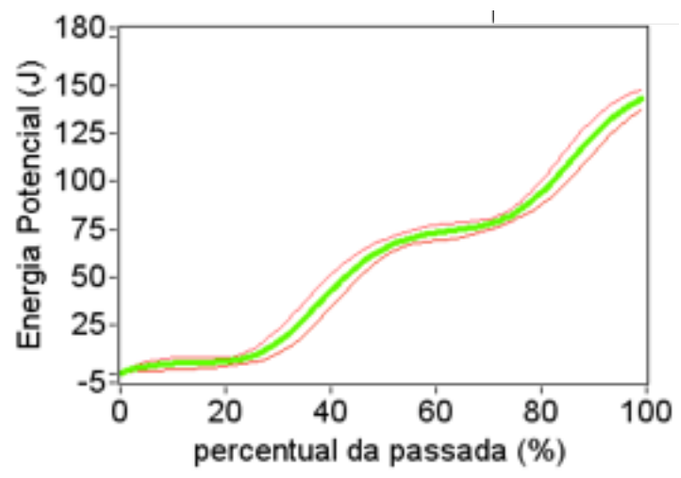


Recorta por passada Média e +- dp









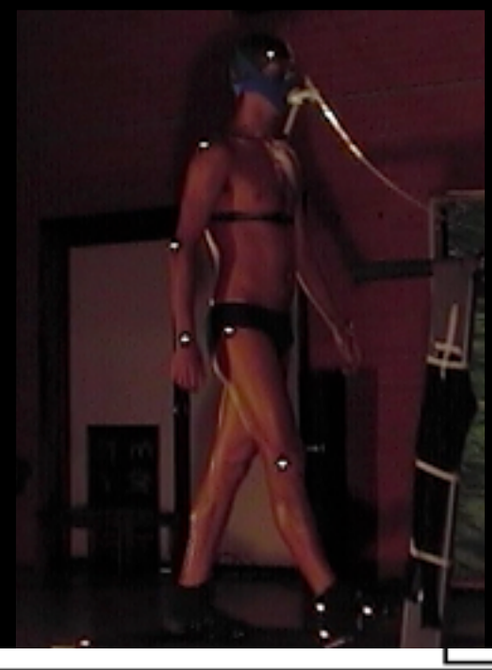
with load

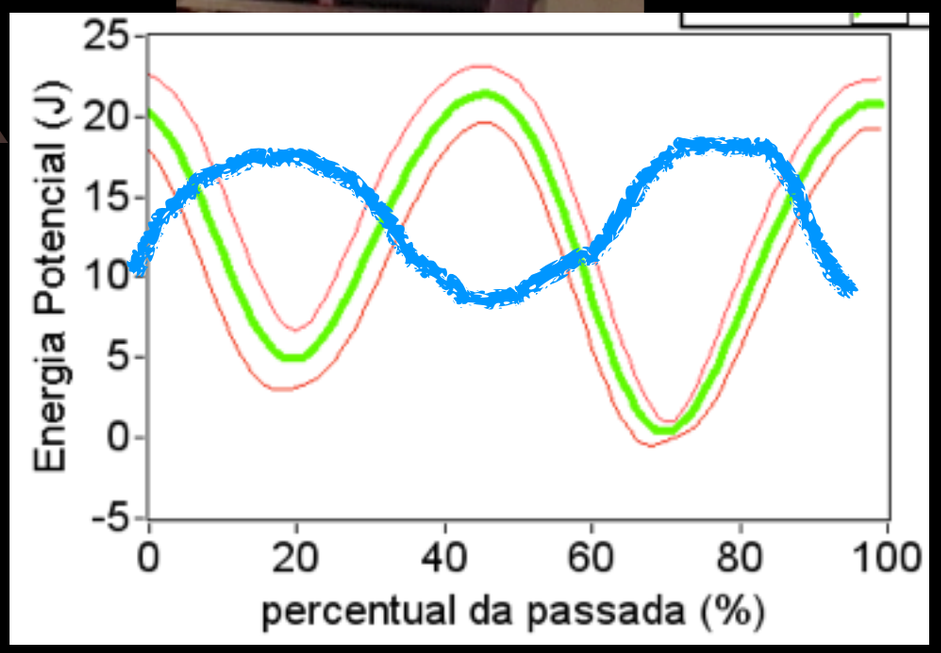
4km/h, level

Greater variation with load

Further energy expenditure

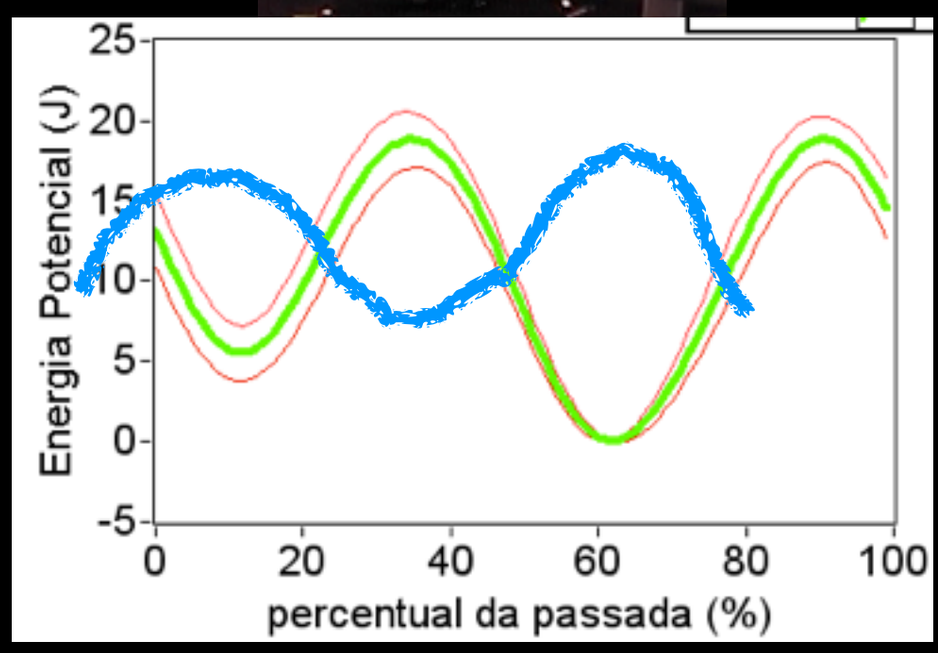
unloaded





Kinetic En

Potential En



loaded

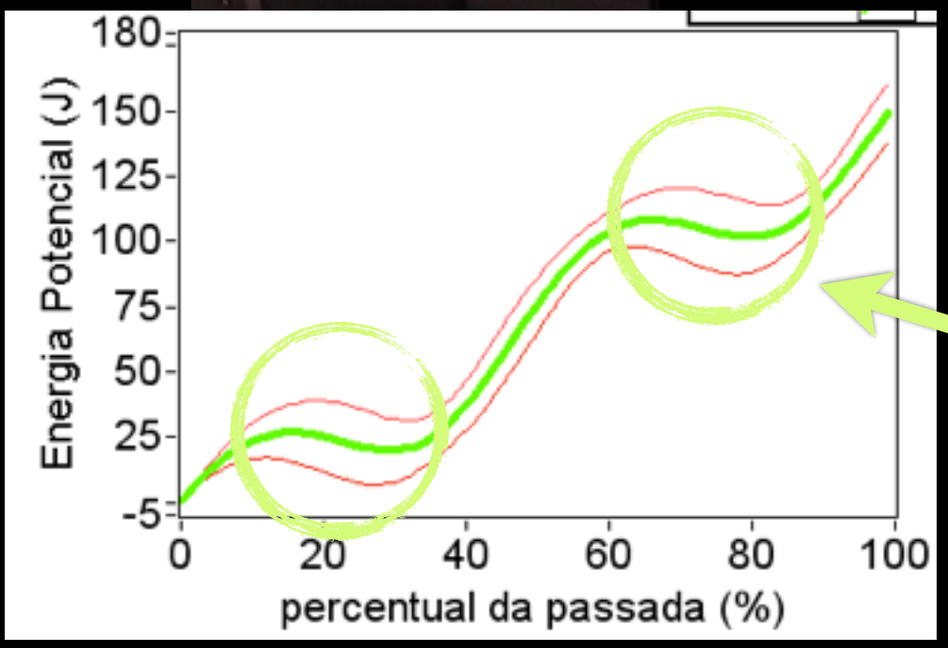
3km/h, +15%

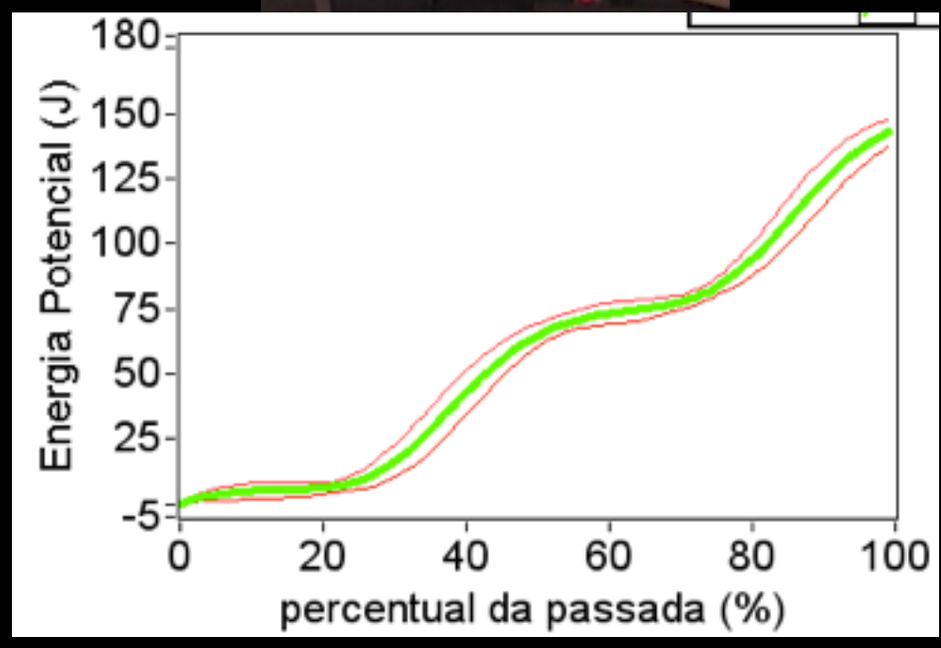
unloaded

negative work

Strategy
non-stabilized

huge variation





Dynamical stability (CoV of Pot En, %)

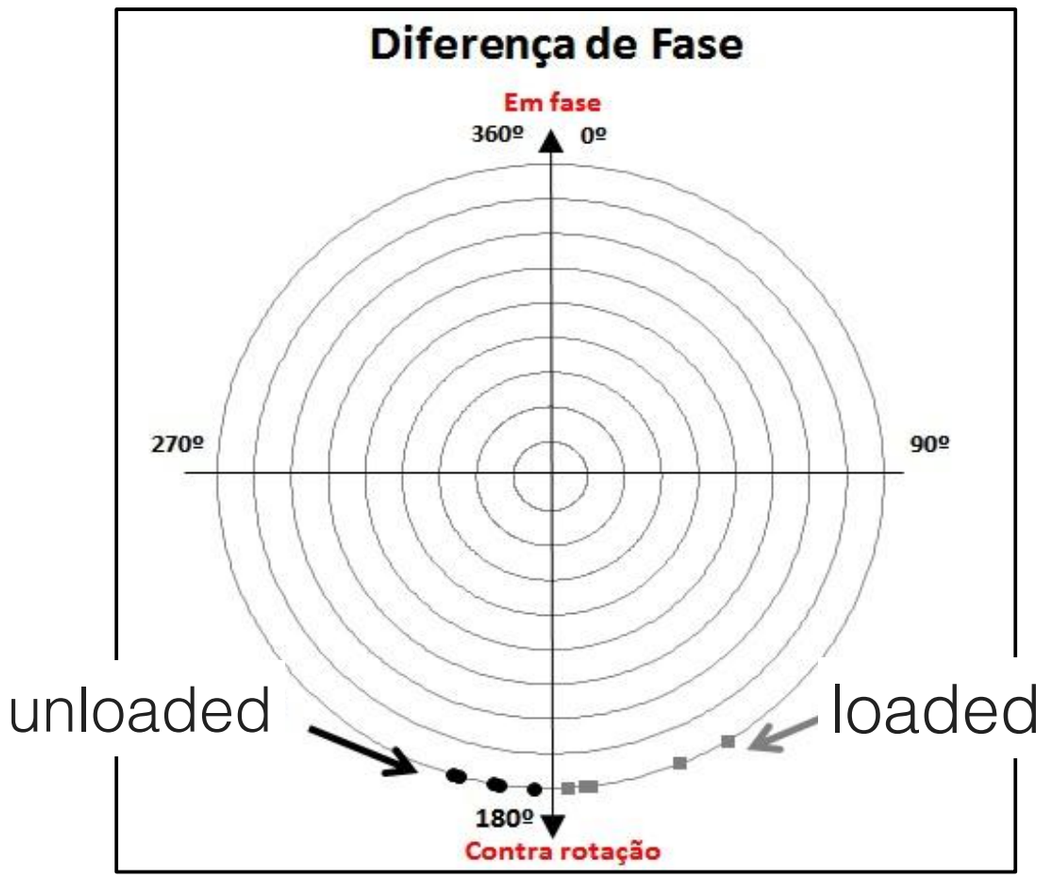
gradient effect
increasing the stability

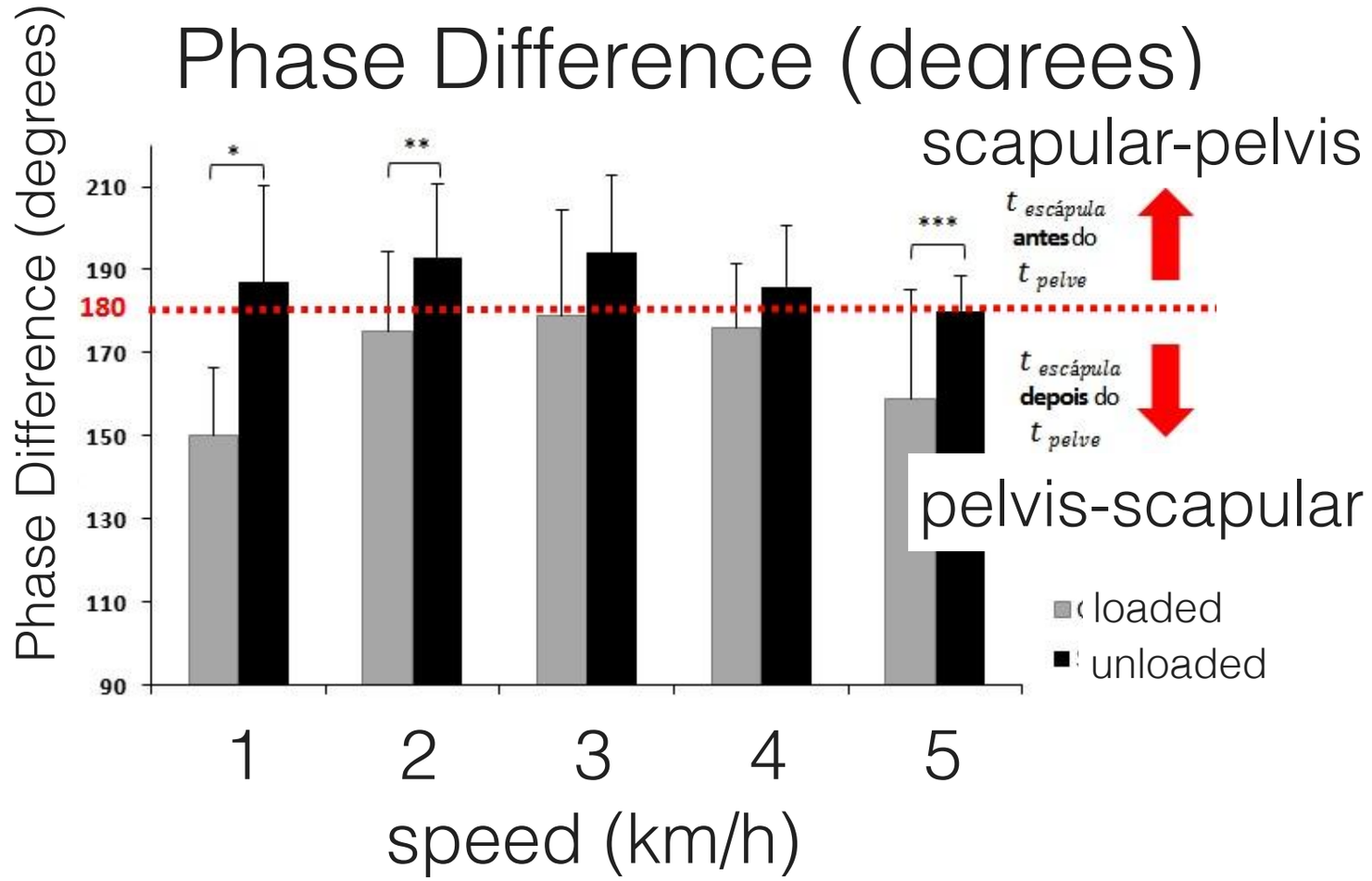
load effect
decreasing
the stability

	LEVEL	+15%
UNLOADED	14	9
LOADED 25% BM	19	14

Effects of load on pelvic-trunk coordination 15% incline

Qualitatively different on coord pattern with load. with timing delay (phase diff) between scapular and pelvic girdles completely different.





Young Investigator Award, Rodrigo Rosa, 2012

Final messages

The energy expenditure of carrying loading in gradients is reduced throughout pendular mechanism (~30% at Voptimum),

Although metabolically more expensive, the loading does not change the Rec nor the Vopt at positive gradients.

The dynamical stability seems to be affected on contrary way by loading and incline effects (loading reducing and incline increasing the dynamical stability).

But, more ecological studies with more variability are needed to confirmate these findings.

Locomotion
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LAPEX - UFRGS

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Muito Obrigado!!!

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