



UNIVERSITÀ DEGLI STUDI DI MILANO

Department of Biomedical Sciences for Health

# FATIGUE-INDUCED CHANGES ON UPHILL LOCOMOTION AFTER AN EXTREME MOUNTAIN ULTRA MARATHON

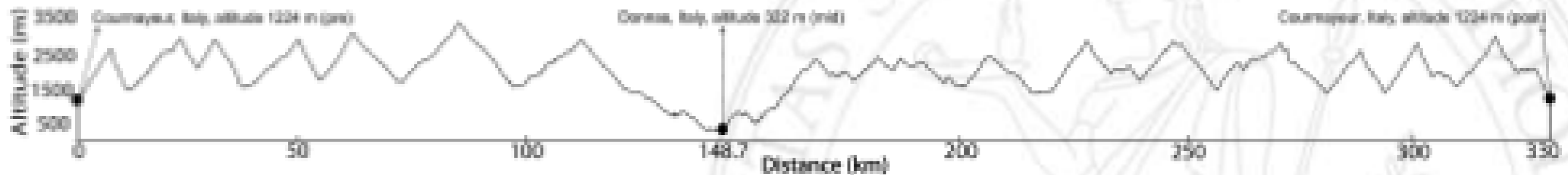
**VERNILLO G.\*, SAVOLDELLI A., SKAFIDAS S., ZIGNOLI A., LA TORRE A.,  
PELLEGRINI B., GIARDINI G., TRABUCCHI P., MILLET G.P., SCHENA F.**

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# Mountain ultramarathon (MUM)

Running/walking an (extreme) distance over rough terrain with a large positive/negative elevation change along their course

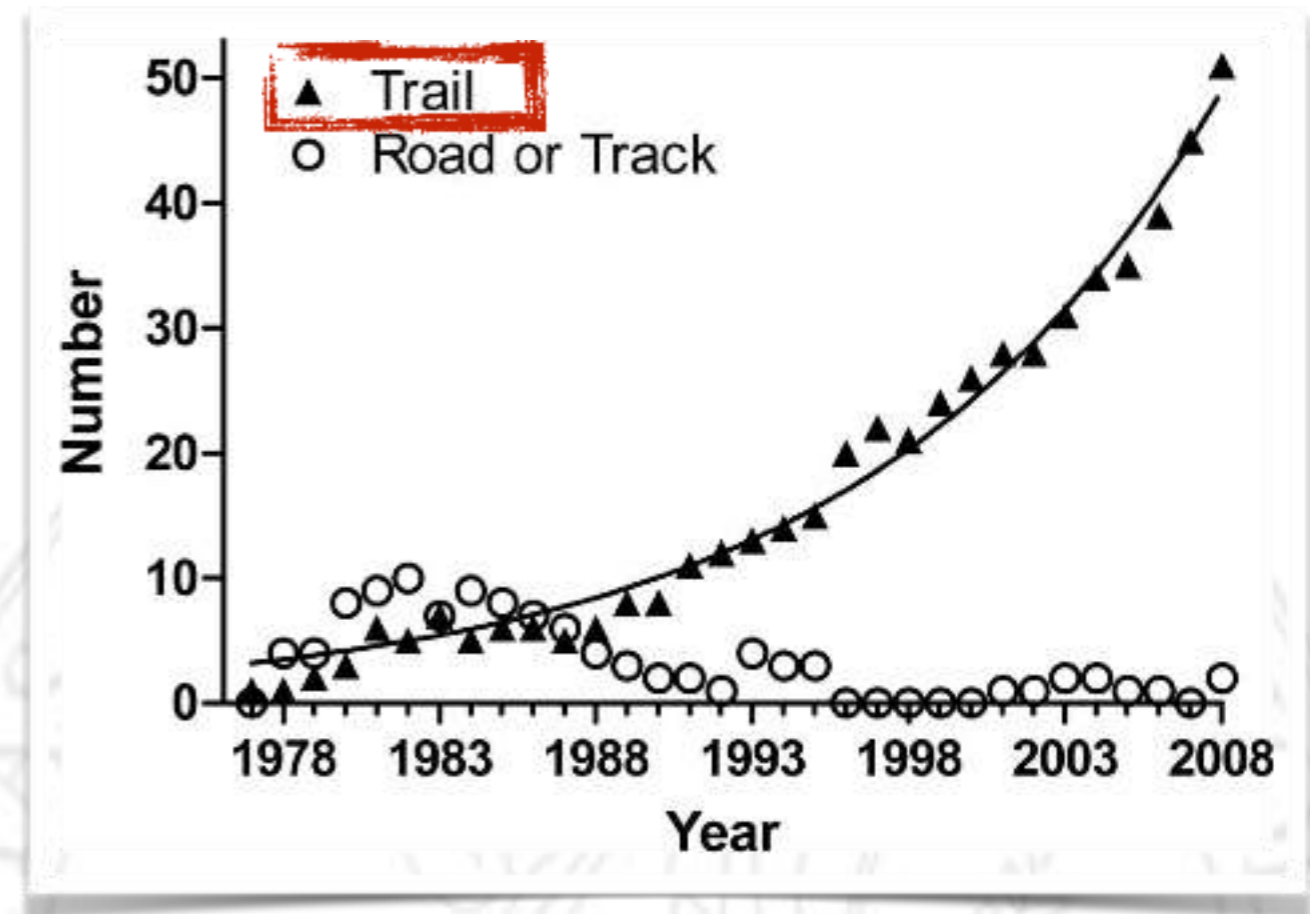


Vernillo et al., *Eur J Appl Physiol*, 2014; *J Sports Sci*, 2015; *Scand J Med Sci Sports*, 2015



# POPULARITY

Exponential growth in the last 40-yr



Hoffman et al., *Int J History Sport*, 2010



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Vernillo et al.  
Energy Cost  
Mountain Ultramarathon

# POPULARITY

Outstanding model for the study of  
adaptive responses to extreme load and stress

Millet & Millet, *BMC Med*, 2012



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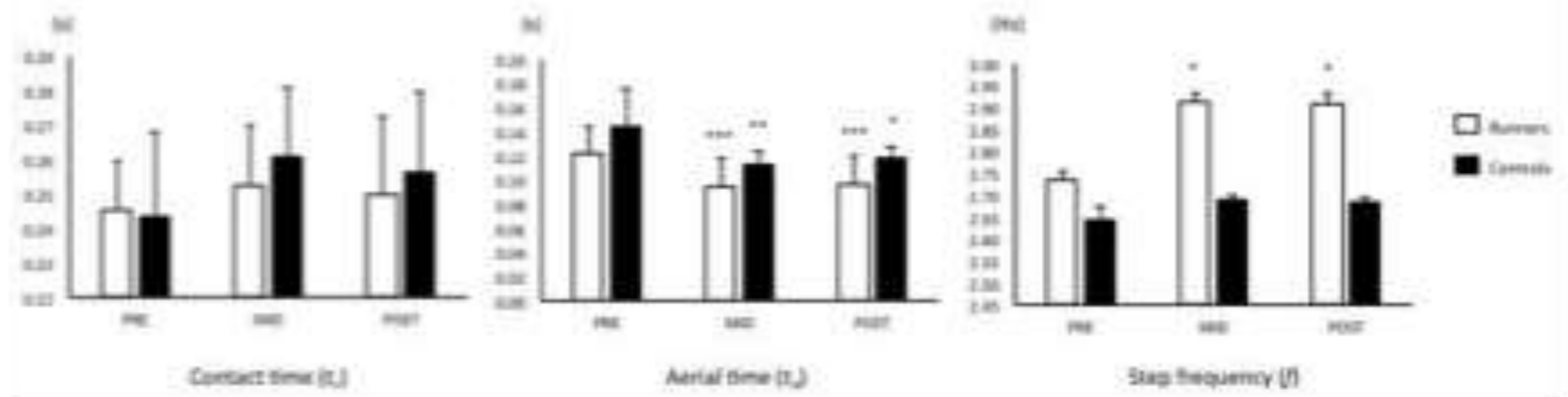
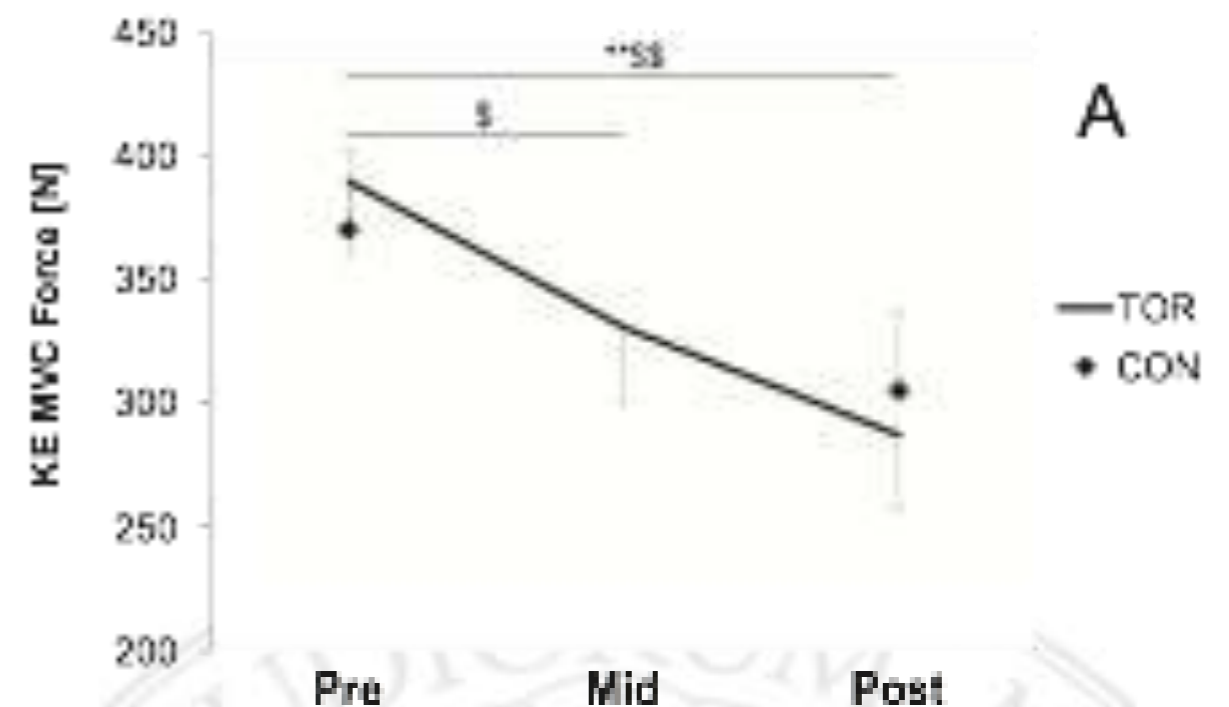
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Vernillo et al.  
Energy Cost  
Mountain Ultramarathon

# POPULARITY

Energy demand at the extremes of human tolerance

MUM can induce an extreme fatigue state that can influence both physiological and biomechanical characteristics of human locomotion

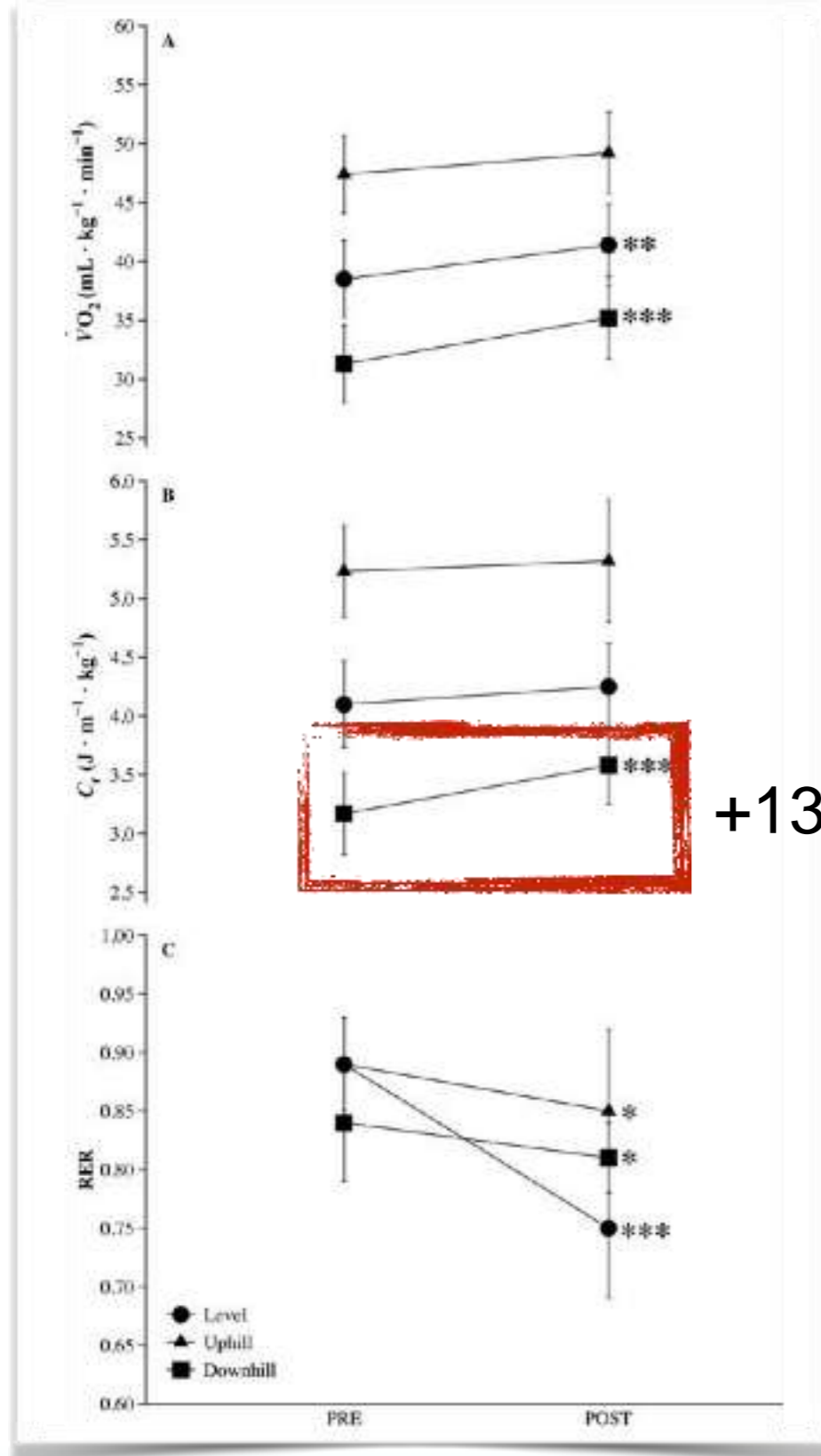


Millet et al., *PLoS ONE*, 2011; Morin et al., *J Biomech*, 2011; Saugy et al., *PLoS ONE*, 2013; Degache et al., *Int J Sport Physiol Perf*, 2015





# BACKGROUND



+13.1%

65-km MUM-induced fatigue varied between the level, uphill and downhill running conditions

Significant (worsening) only in the downhill energy cost increment

Vernillo et al., *J Sports Sci*, 2015



# BACKGROUND

**Table 6** Changes in the kinematics data measured during running at 6 km h<sup>-1</sup> at an inclination of +15 % (9°) before (pre-) and after (post-) the MUM (n = 10)

Variable	Pre-			Post-			% Change	ES	±90 % CI
	Mean	SD	Range	Mean	SD	Range			
t <sub>c</sub> (s)	0.387	0.043	0.329–0.480	0.428*	0.075	0.373–0.635	+10.3	+0.61 (moderate)	0.39
DF (%)	52.1	3.5	46.9–56.6	56.2*	3.8	49.3–63.4	+8.1	+1.03 (moderate)	0.37
t <sub>c</sub> <sup>-1</sup> (s <sup>-1</sup> )	2.61	0.28	2.08–3.04	2.39*	0.31	1.58–2.68	-8.4	-0.70 (moderate)	0.34
t <sub>s</sub> (s)	0.357	0.03	0.307–0.397	0.334*	0.032	0.293–0.401	-6.4	-0.68 (moderate)	0.36
CT (s)	0.742	0.053	0.681–0.848	0.759	0.096	0.647–1	+2.2	+0.21 (small)	0.38
FQ (Hz)	1.35	0.09	1.18–1.47	1.33	0.13	1–1.47	-1.8	-0.18 (trivial)	0.32
SL (m)	1.24	0.09	1.13–1.41	1.27	0.16	1.08–1.67	+2.2	+0.21 (small)	0.38

**Table 4** Changes in the metabolic variables measured during running at 6 km h<sup>-1</sup> at an inclination of +15 % (9°) before (pre-) and after (post-) the MUM (n = 10)

Variable	Pre-			Post-			% Change	ES	±90 % CI
	Mean	SD	Range	Mean	SD	Range			
E <sub>t</sub> (J m <sup>-1</sup> kg <sup>-1</sup> )	4.6	0.5	3.8–5.7	3.9*	0.6	3.1–4.8	-13.8	-1.0 (moderate)	0.48
W <sub>ven</sub> (W kg <sup>-1</sup> )	0.21	0.01	0.19–0.23	0.21	0.02	0.16–0.23	+0.1	+0.01 (trivial)	0.19
VE (L min <sup>-1</sup> )	93.6	14.6	80.0–130.4	109.6*	16.2	89.7–137.6	+17.9	+0.94 (moderate)	0.45
VO <sub>2</sub> (L min <sup>-1</sup> )	3.1	0.3	2.5–3.7	2.8	0.3	2.4–3.2	-7.5	-0.70 (moderate)	0.45
VCO <sub>2</sub> (L min <sup>-1</sup> )	3.1	0.4	2.5–4.1	2.9	0.4	2.3–3.4	-7.3	-0.51 (small)	0.40
VE/VO <sub>2</sub>	30.6	3.2	25.5–35.1	37.3*	8.5	23.3–50.6	+21.6	+0.94 (large)	0.62
VE/VCO <sub>2</sub>	30.4	3.0	25.1–33.8	39.2*	5.8	28.0–46.3	+29.2	+1.75 (large)	0.52
RER	1.00	0.05	0.94–1.10	1.00	0.09	0.88–1.10	-0.9	-0.10 (trivial)	0.32

Vernillo et al., *Eur J Appl Physiol*, 2014



# BACKGROUND

- **Energy cost increase** during or after **extended running** exercises  
(e.g., Brückner et al., *Eur J Appl Physiol*, 1991)
- **Level running protocol** previously used during MUM studies **are not ecological**
- **MUM** are mainly (almost totally) **characterized by up and downhill sections**
- During the **uphill sections leg muscles** produce **more concentric contractions** and likely ensuing in **higher metabolic fatigue**  
(Minetti et al., *J Exp Biol*, 1994; Minetti et al., *J Appl Physiol*, 2002)









# AIM

**Changes on uphill locomotion after Tor des Geants<sup>®</sup>**  
the world's most challenging mountain ultramarathon  
**(330-km and 24,000 D+)**



# PROTOCOL



Rest	5 km/h +20%	6 km/h +15%	8 km/h +10%
			
5 min	5 min	5 min	5 min



Oxygen Uptake ( $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ )

Heart Rate ( $\text{beats}\cdot\text{min}^{-1}$ )

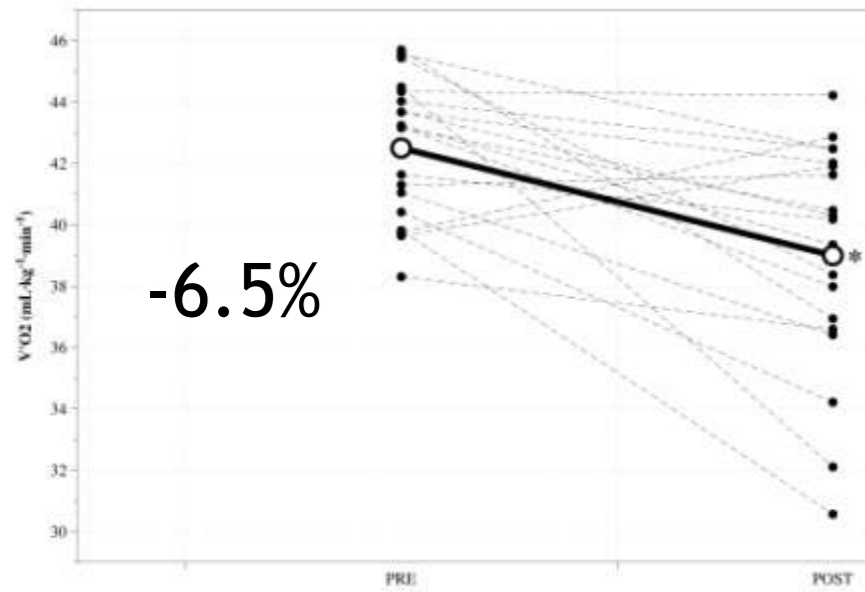
Gross Energy Cost ( $\text{J}\cdot\text{kg}^{-1}\cdot\text{m}^{-1}$ )

Net Energy Cost ( $\text{J}\cdot\text{kg}^{-1}\cdot\text{m}^{-1}$ )

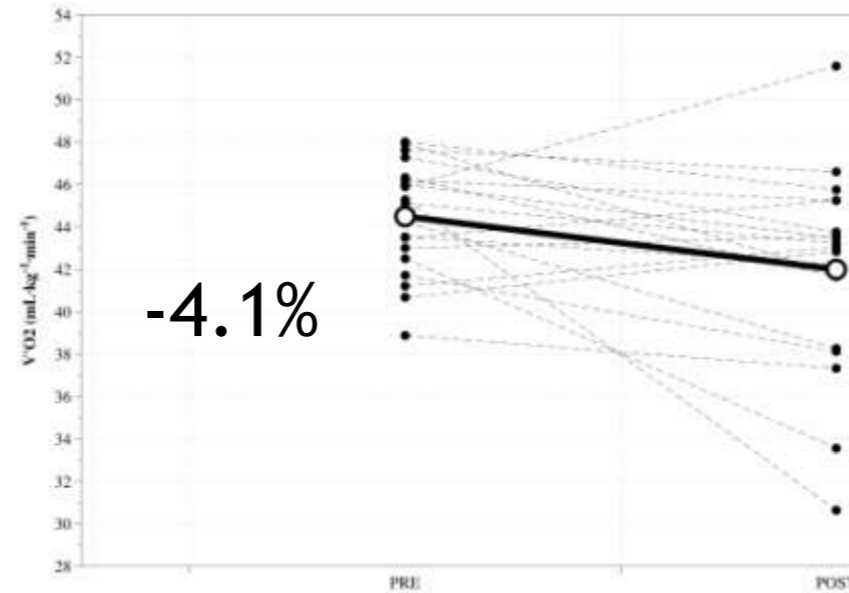


# RESULTS ➤ EXERCISE INTENSITY

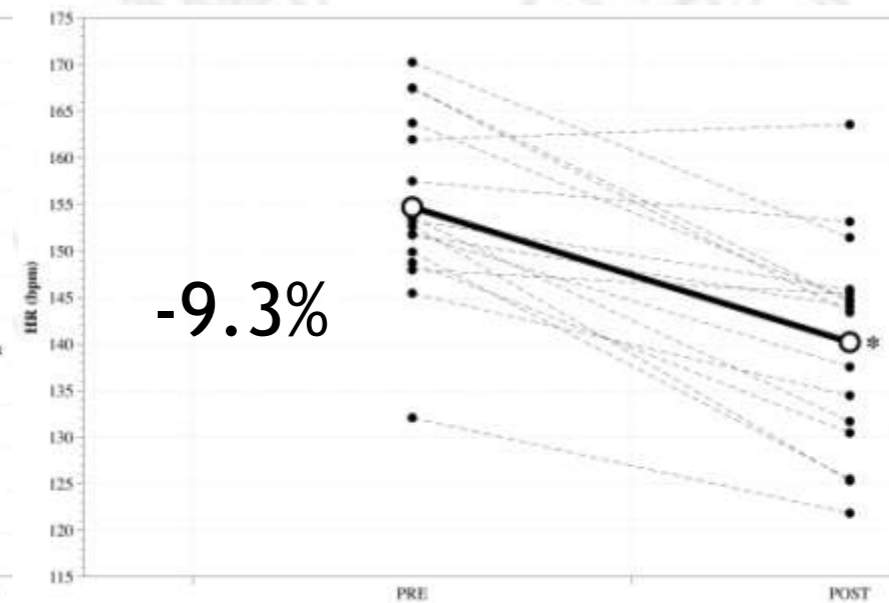
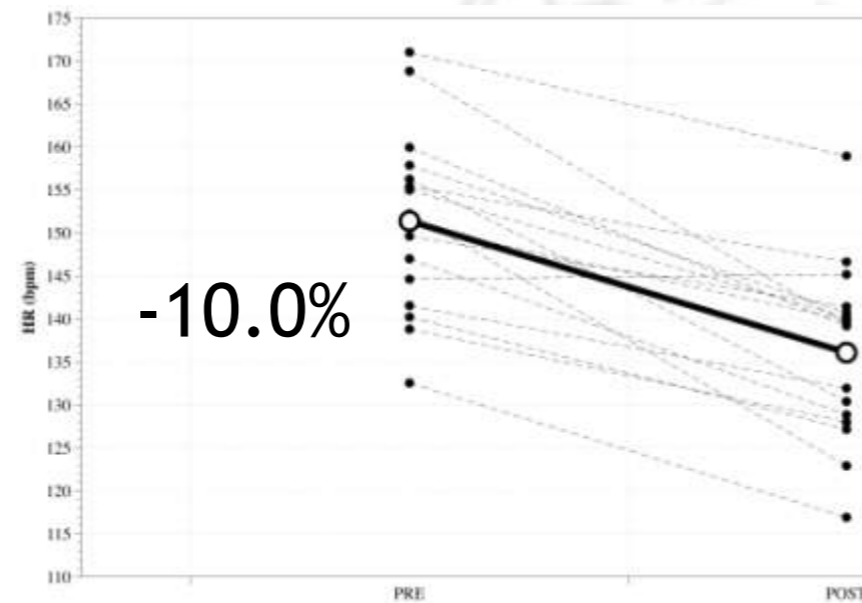
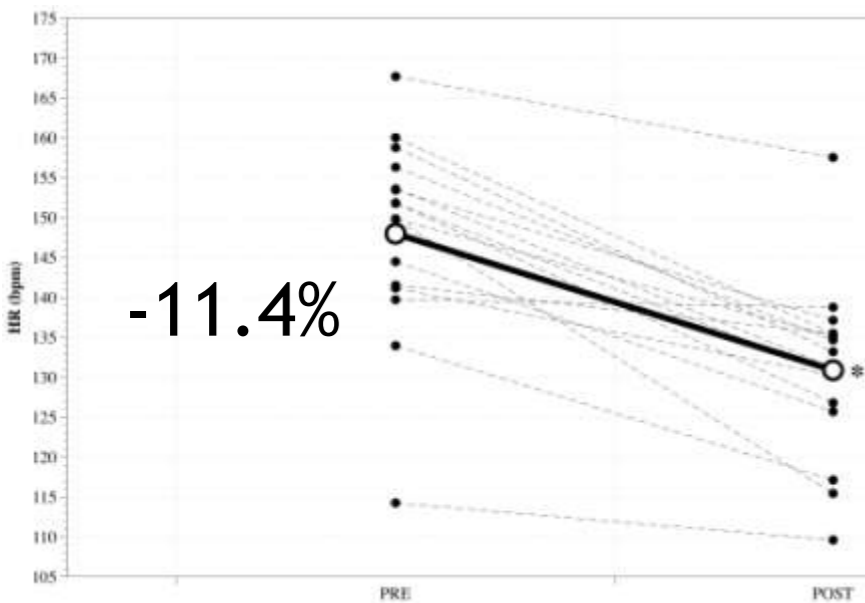
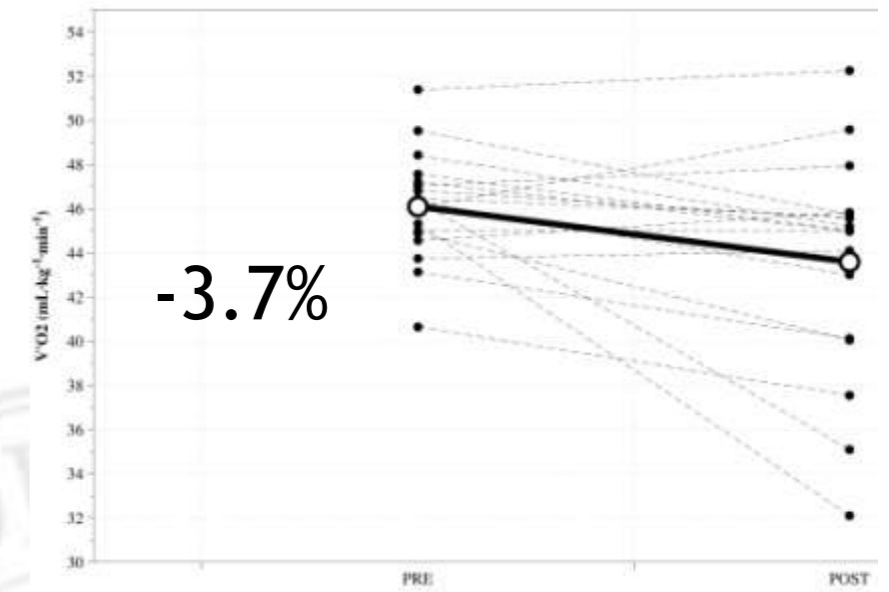
Walking  
5 km/h 20%



Running1  
6 km/h 15%



Running2  
8 km/h 10%



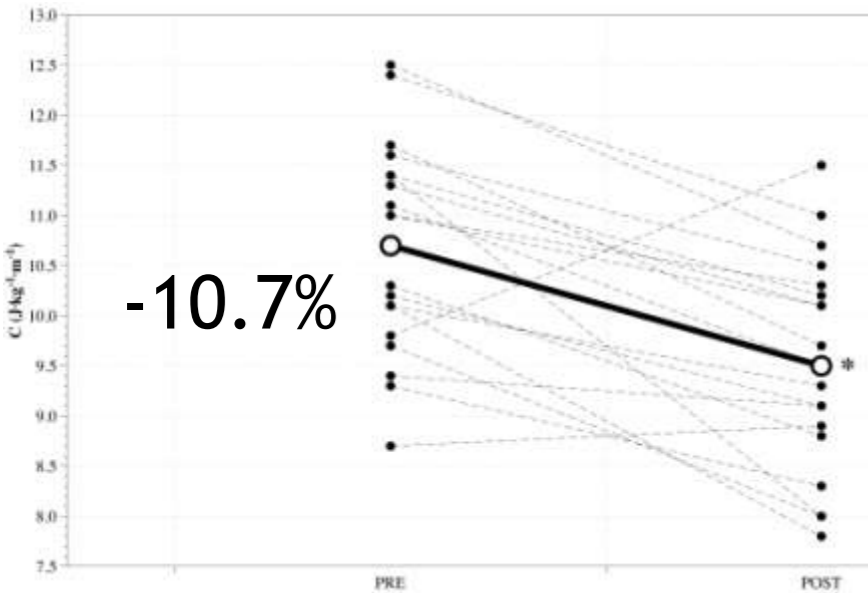
\* Repeated measures ANCOVA,  $P < 0.05$



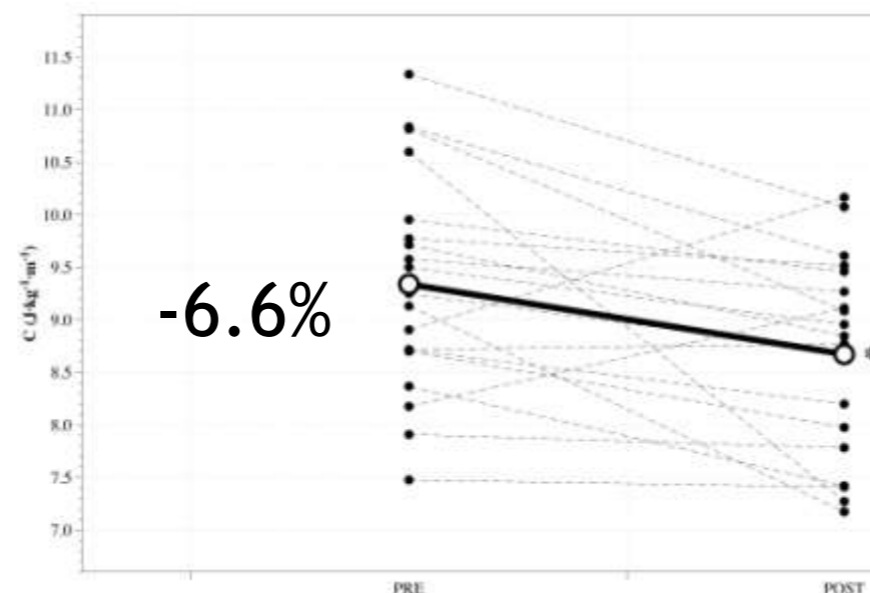


# RESULTS ➤ ENERGY COST

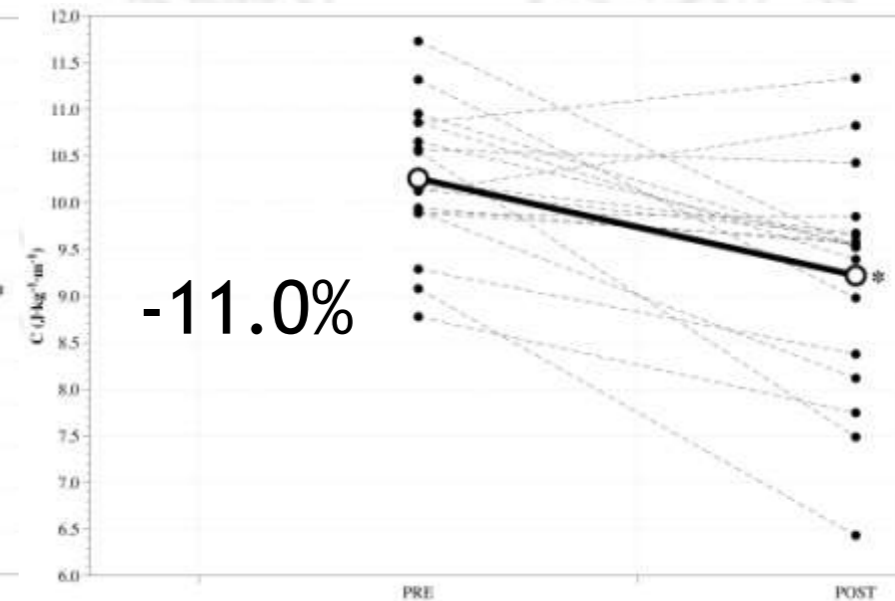
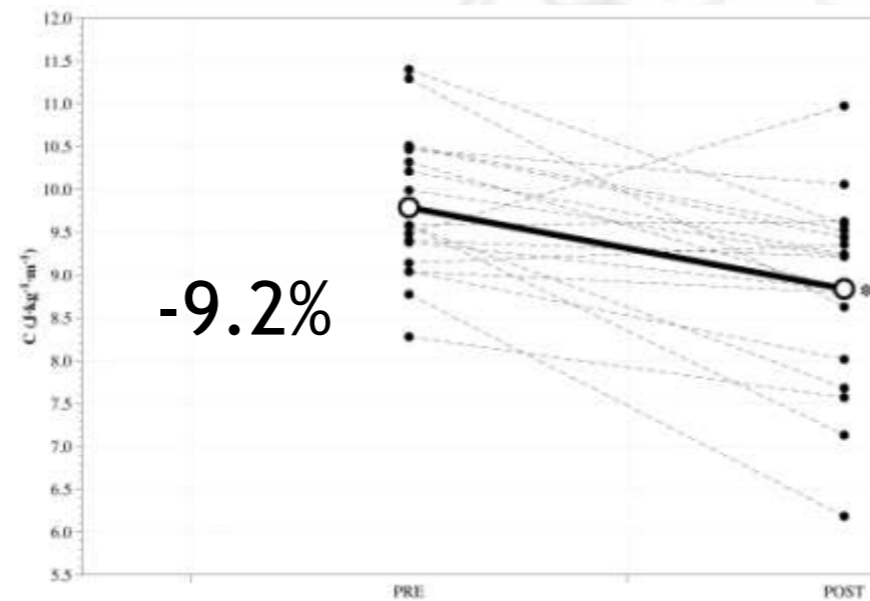
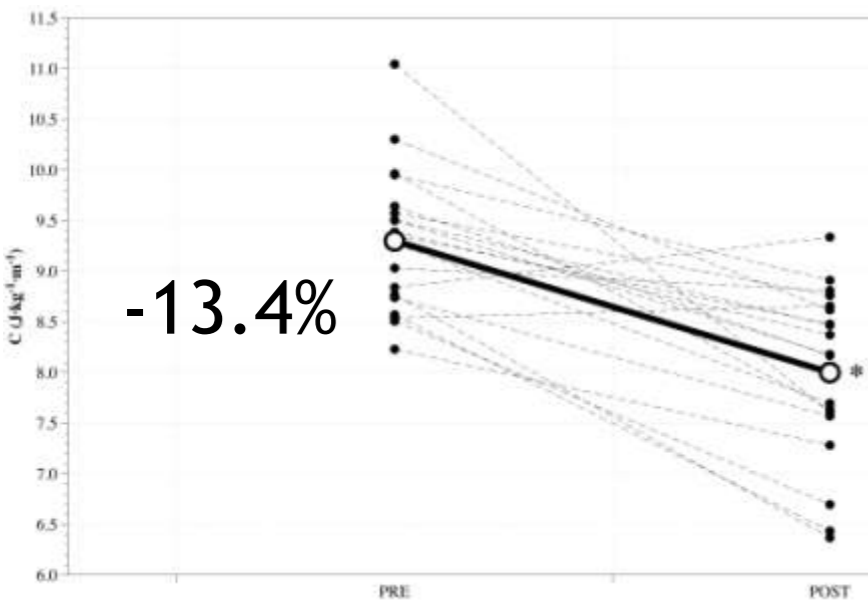
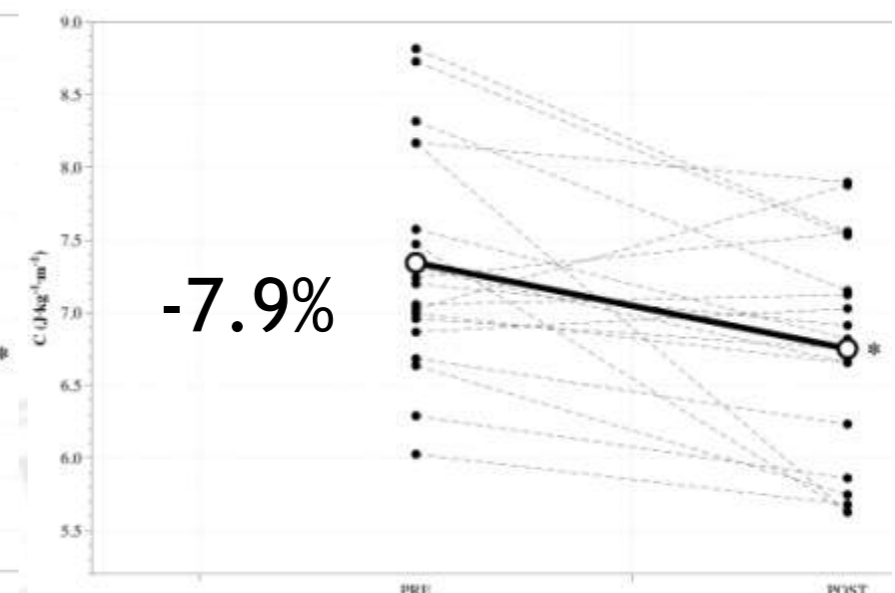
## Walking 5 km/h 20%



## Running1 6 km/h 15%



## Running2 8 km/h 10%



\* Repeated measures ANCOVA, P < 0.05



# CONCLUSIONS

- Decrease (improvement) in the energy cost of different uphill locomotions after 330-km and 24000 D+
- Lower relative exercise intensity (both in terms of oxygen uptake and heart rate)
- Positive MUM-induced adaptation





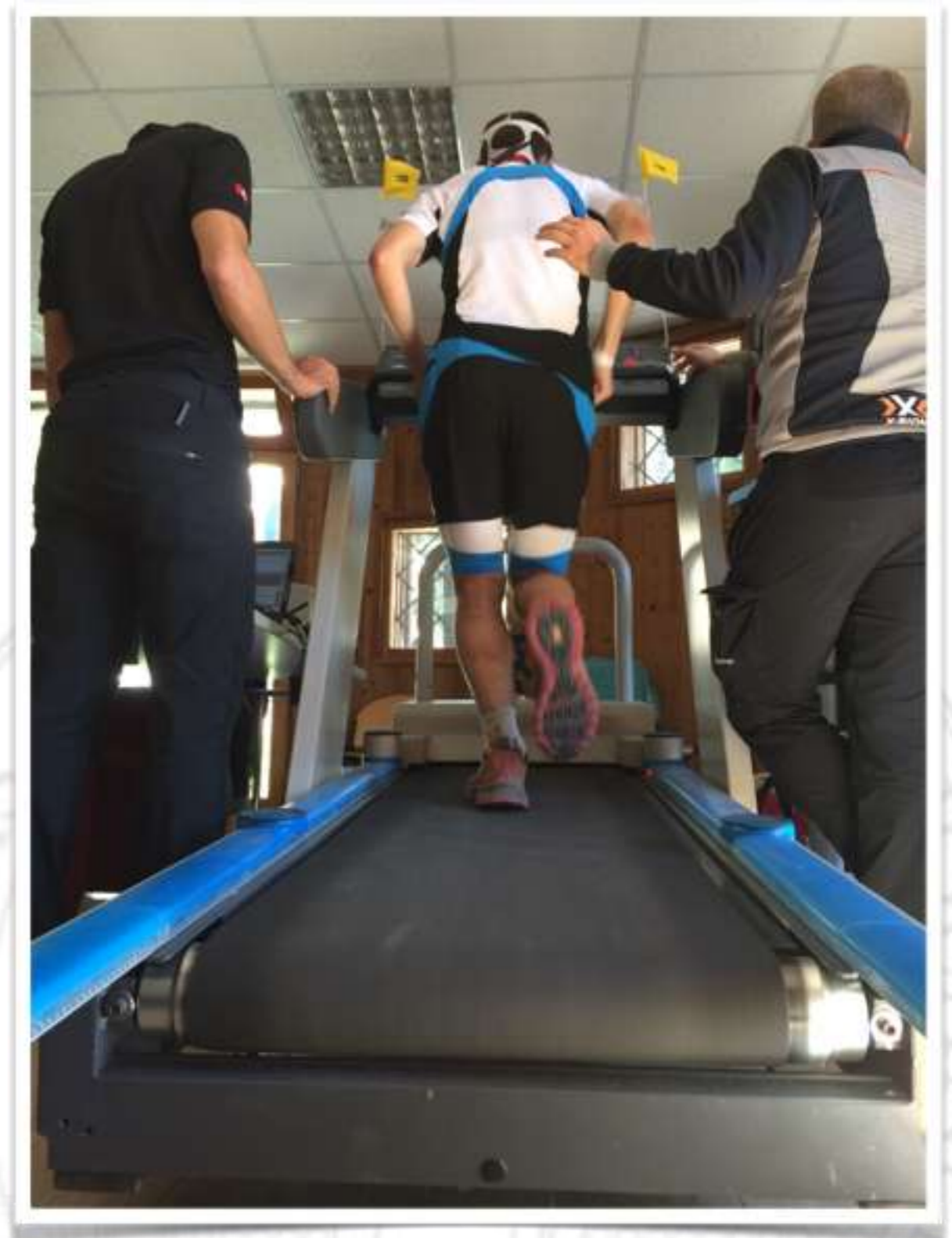
# REASONS?

- **Instruments?** *Possibly but unlikely*
  - Calibration and verification done (Winter, *J Sports Sci*, 2012; Garcia-Tabar et al., *Front Physiol*, 2015)
- **Uphill locomotion mechanics?** *Possibly but unlikely*
  - the runners were still able to replicate it at POST
- Generic **improvement in the efficiency of locomotion** induced by **prolonged, repetitive walking/running?** *Likely*
  - Tor des Geants® 2012 (Vernillo et al., *Eur J Appl Physiol*, 2014)
  - trekking expedition (Tam et al., *Eur J Appl Physiol*, 2015)
  - 50 yr-old ultratrailer on Tor des Geants® 2013 (Savoldelli et al., in preparation)



# PRACTICAL APPLICATION

- Incorporating long-lasting uphill locomotion training
- Predisposition to sustain such loading





# ACKNOWLEDGMENTS



Savoldelli A.



Spyros S.



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La Torre A.



Pellegrini B.



Giardini G.



Trabucchi P.



Millet G.P.



Schena F.





# ACKNOWLEDGMENTS



Walking with a friend in the dark is better than walking alone in the light.

H. Keller







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**THANK YOU FOR YOUR ATTENTION**

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