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Test da Laboratorio, parametri fisiologici e prestazioni nelle discipline dell'off-road running

Alessandro Fornasiero, *PhD*

Seminario Forte di Bard
19/10/2024

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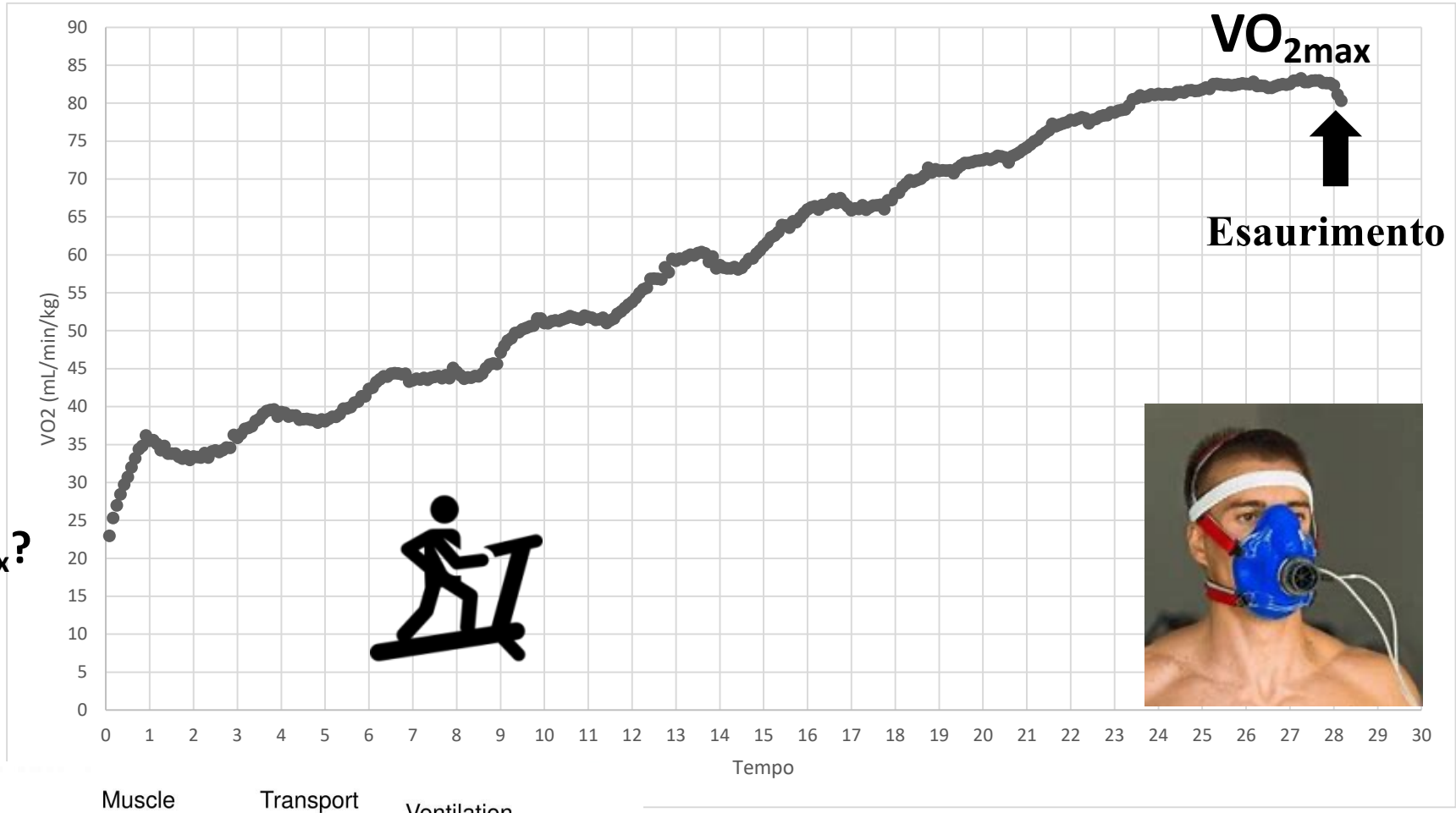
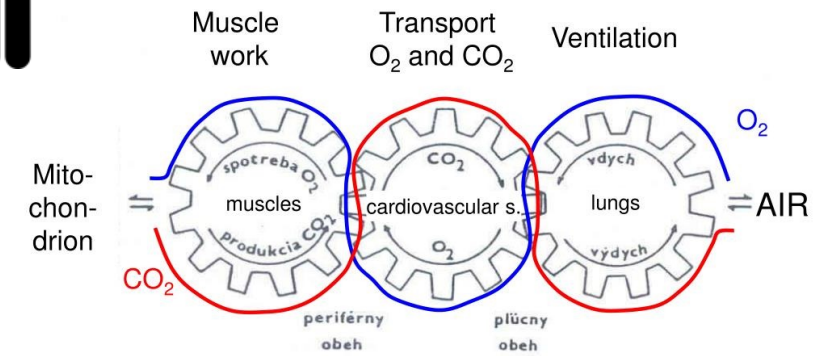
MASSIMO CONSUMO D'OSSIGENO



VO_{2max}?



$$VO_2 = GC \times diff\,(a\text{-}v)O_2$$

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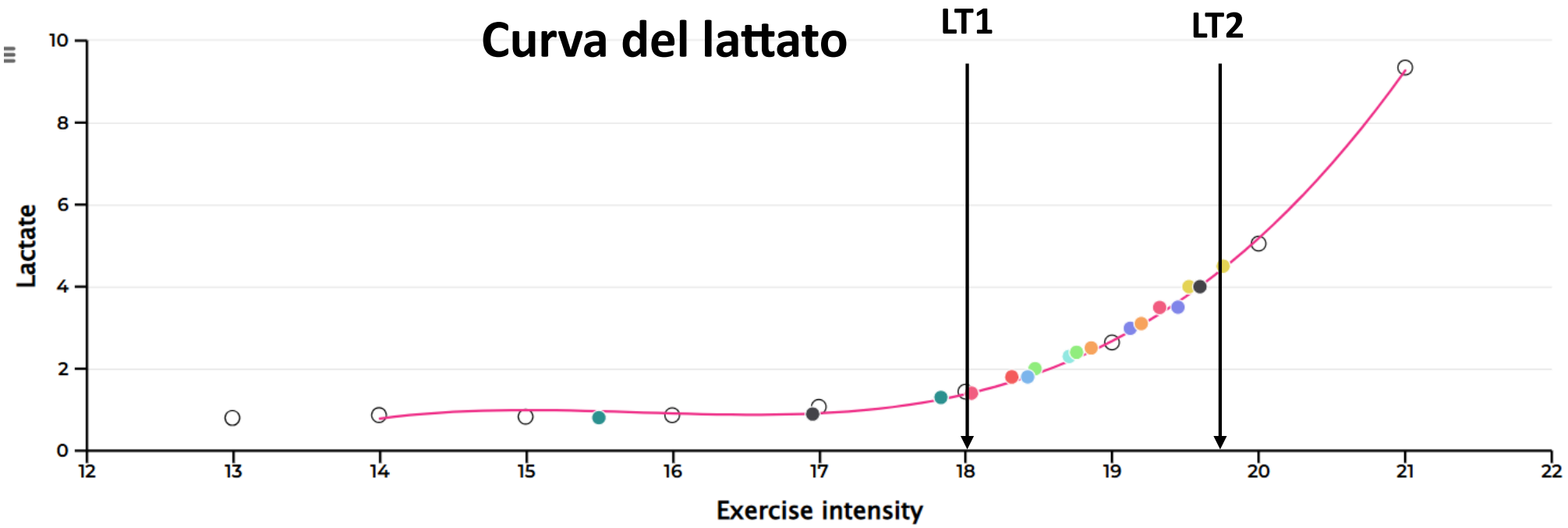
Curva del lattato



Soglie lattacide?

Soglie?

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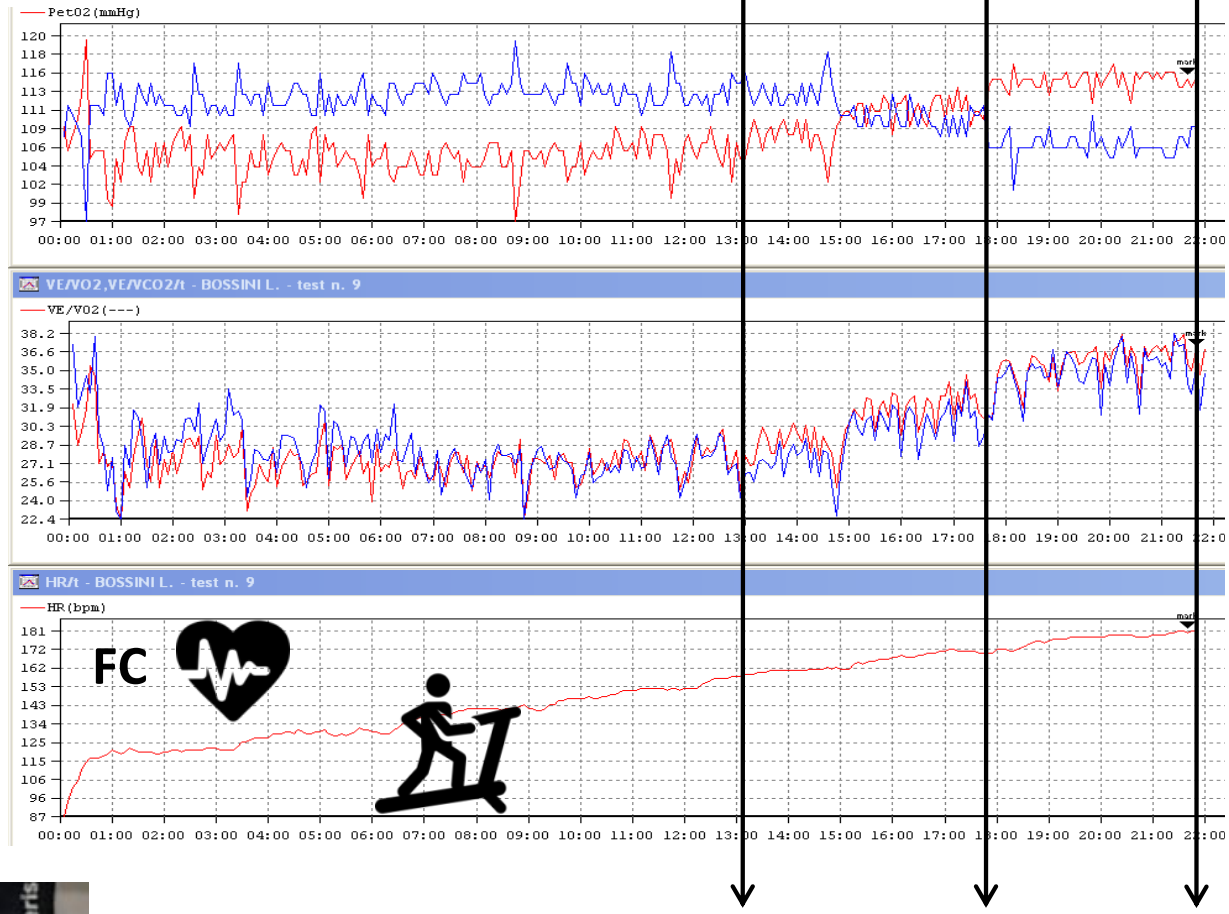
Soglia aerobica **VT1**

Soglia anaerobica **VT2**

MAX



Soglie?

Soglie ventilatorie?

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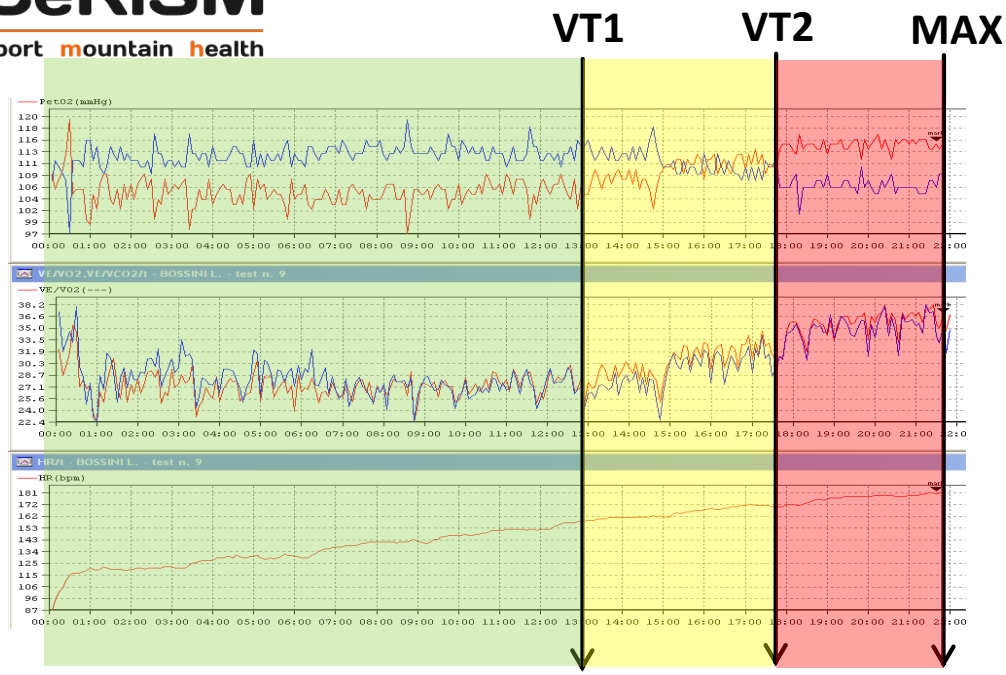
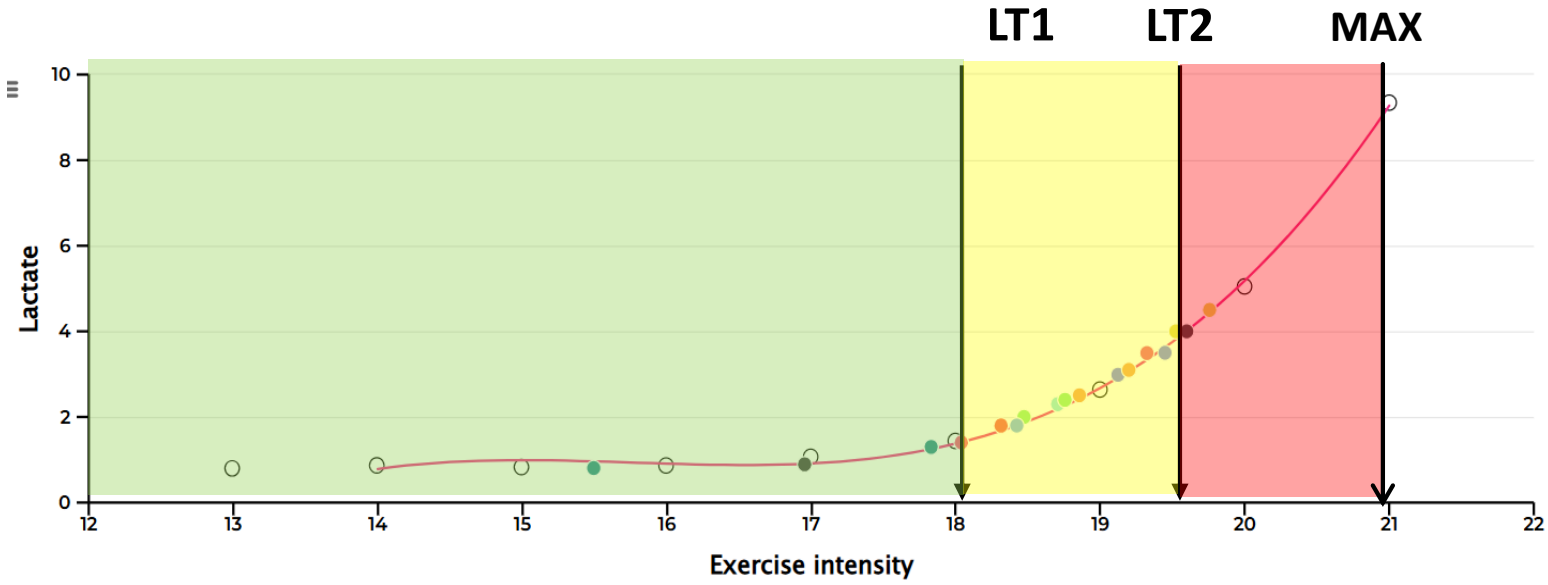


Zone?



3 Distinti domini di intensità a livello metabolico

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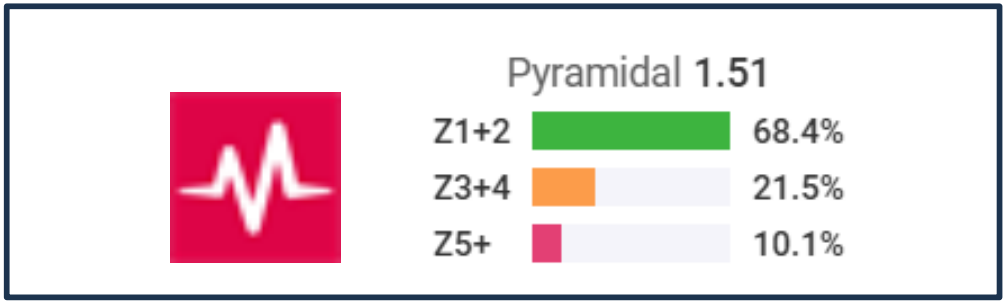
	Valori massimali		
VO_{2max}	Frequenza Cardiaca (FC)	[bpm]	183
	Consumo di ossigeno (VO_2)	[L/min]	3.83
	VO_2/Kg	[ml/kg/min]	63.8
	Ventilazione (VE)	[L/min]	161.3
	Valori soglia anaerobica		
VT2	FC	[bpm]	172
	VO_2	[L/min]	3.30
	VO_2/Kg	[ml/kg/min]	54.9
	%VO_2	[%]	86.1
	Valori soglia aerobica		
VT1	FC	[bpm]	160
	VO_2	[L/min]	2.90
	VO_2/Kg	[ml/kg/min]	48.4
	%VO_2	[%]	75.8

Zone?

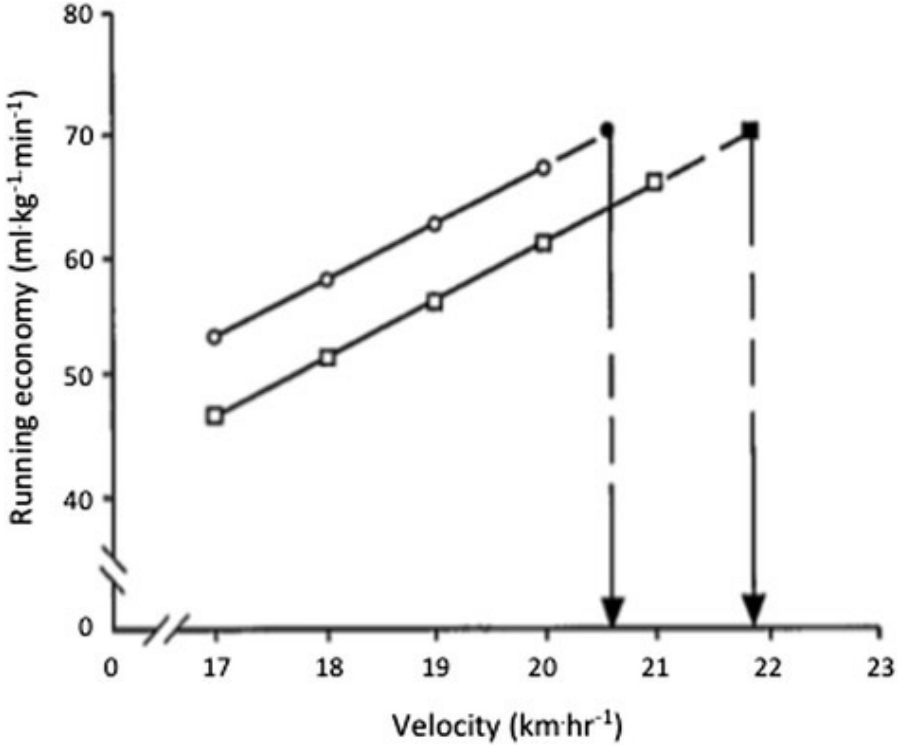
Valori di frequenza cardiaca di riferimento per allenamento

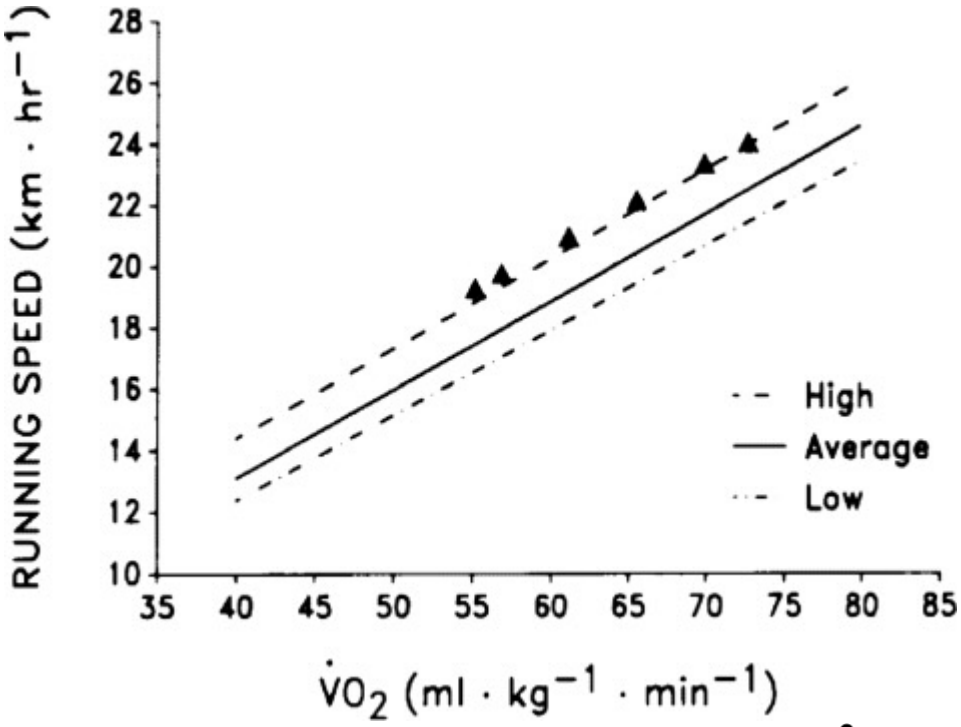
Riscaldamento	< di	137	bpm		
Aerobico moderato	da	138	a	159	bpm
Medio	da	160	a	170	bpm
Soglia anaerobica	da	171	a	173	bpm
Massima potenza aerobica	> di	174			

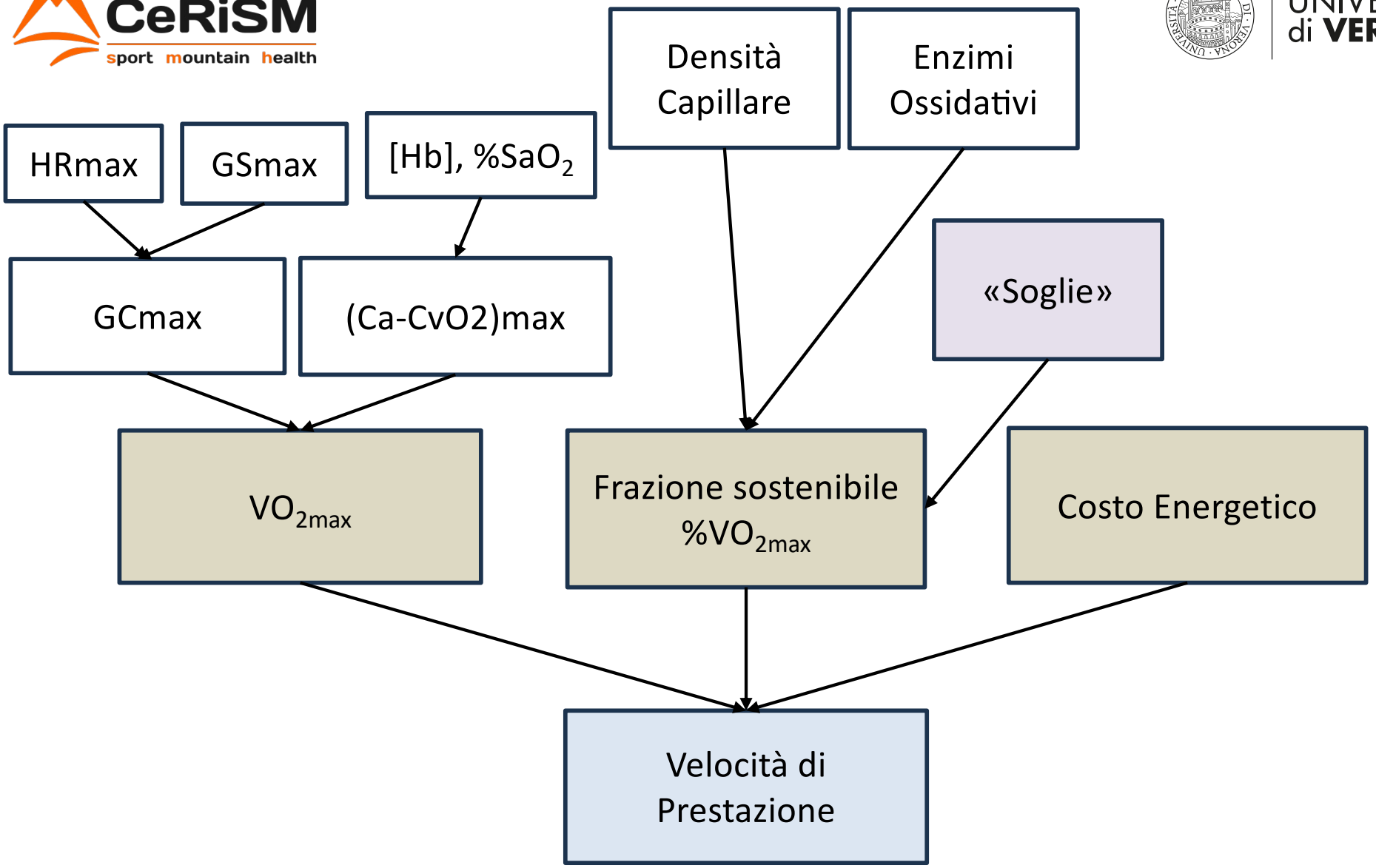


Costo energetico?

Efficienza?

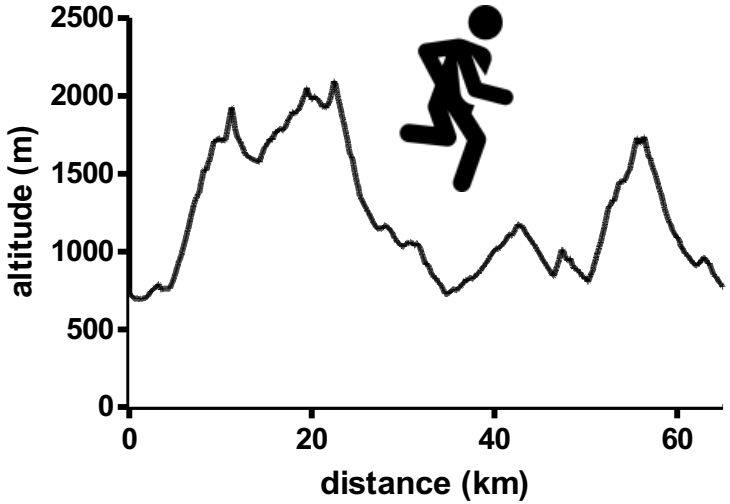





Densità Capillare
Enzimi Ossidativi
HRmax
GSmax
[Hb], %SaO2
«Soglie»
GCmax
(Ca-CvO2)max
VO2max
Frazione sostenibile %VO2max
Costo Energetico
Velocità di Prestazione

Studio 1

Relazione Parametri da Laboratorio e Prestazione in una gara di trail di 65 km



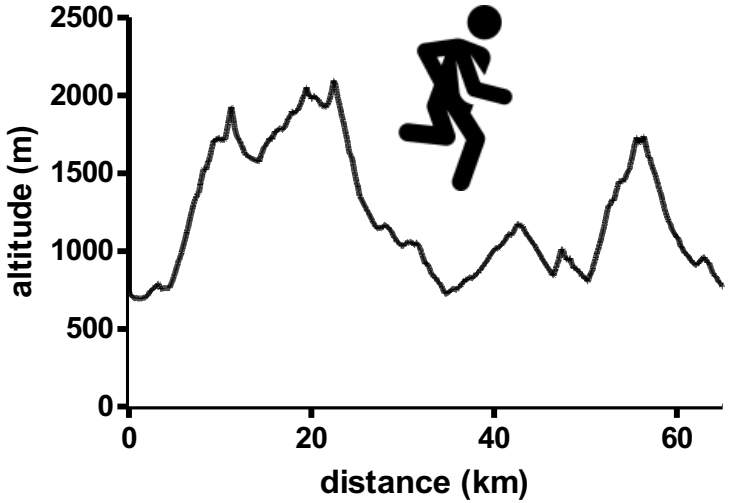
Sports Performance

Physiological intensity profile, exercise load and performance predictors of a 65-km mountain ultra-marathon

Alessandro Fornasiero, Aldo Savoldelli, Damiano Fruet, Gennaro Boccia, Barbara Pellegrini & Federico Schena

Pages 1287-1295 | Accepted 26 Jul 2017, Published online: 04 Sep 2017

Obiettivo



....considering the increasing **popularity** of these events, it seems necessary to quantify...

Ultra-endurance
> 6h

- **Physiological predictors** of performance
- the **sustainable intensity** in this kind of ultra-endurance exercise
- the **physiological loads** imposed on the athletes

Sports Performance

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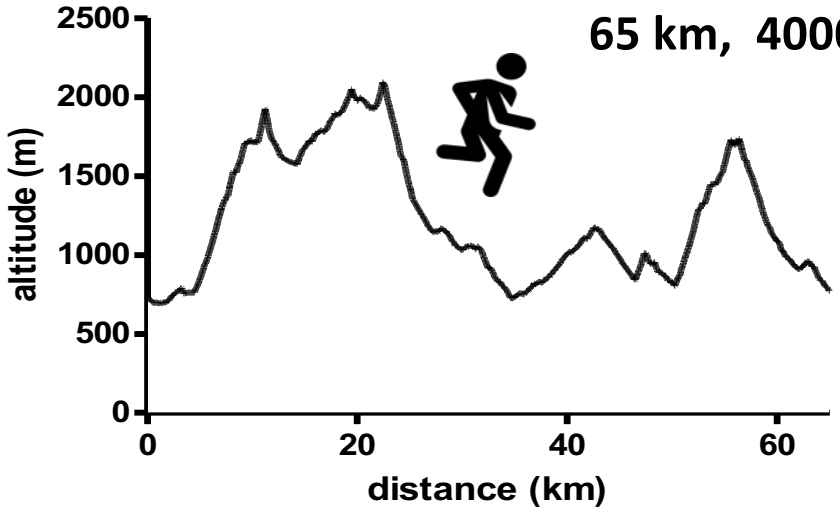

Participants

- **12 trained trail-runners** (4 F)
- 7 ± 3 h/week
- 7 ± 7 running experience (3 ± 3 years trail running experience)

Characteristics of the subjects (N=12)

	mean	±	s.d	range		
Age (years)	38.6	±	6.1	30.4	-	48.9
Anthropometry						
Body mass (kg)	65.8	±	12.1	47.0	-	83.5
Height (cm)	171	±	9	157	-	181
BMI (kg/m^2)	22.2	±	2.7	18.8	-	27.3
Fat-free mass (kg)	55.8	±	10.5	39.6	-	68.8
Fat mass (kg)	10.0	±	4.1	3.9	-	19.4
Body fat (%)	15.1	±	5.0	6.2	-	23.3
Incremental exercise						
VO_2max (ml/min/kg)	58.4	±	6.2	48.0	-	65.1
VO_2 @VT2 (ml/min/kg)	52.9	±	5.0	45.5	-	59.5
VO_2 @VT1 (ml/min/kg)	46.3	±	4.5	36.8	-	52.1
Hrmax (bpm)	182	±	9	164	-	196
HR @VT2 (bpm)	171	±	10	154	-	186
HR @VT1 (bpm)	158	±	11	136	-	175
Pmax (W/kg)	3.1	±	0.6	1.8	-	4.0
P @VT2 (W/kg)	2.4	±	0.4	1.6	-	3.0
P @VT1 (W/kg)	1.7	±	0.3	1.0	-	2.2

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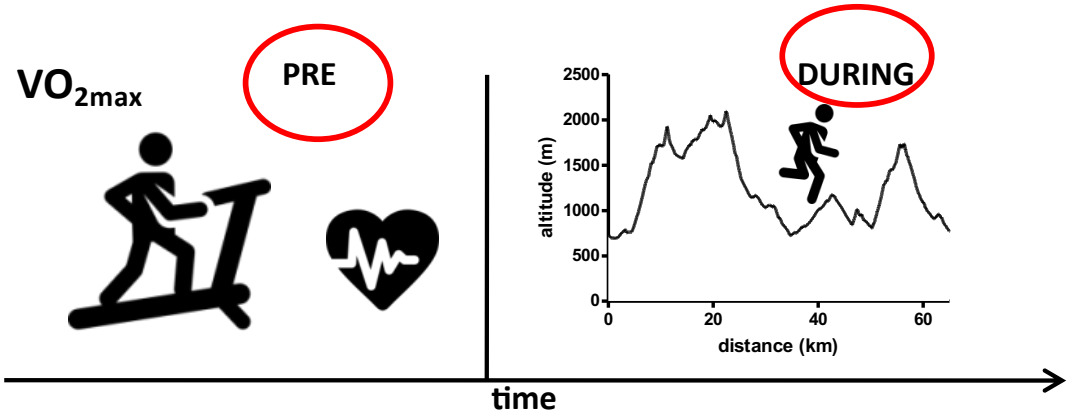
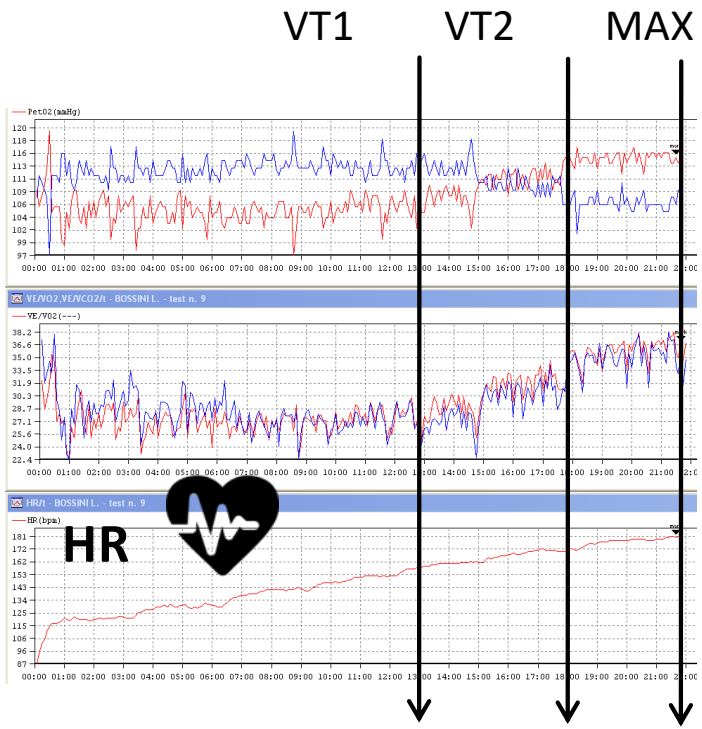
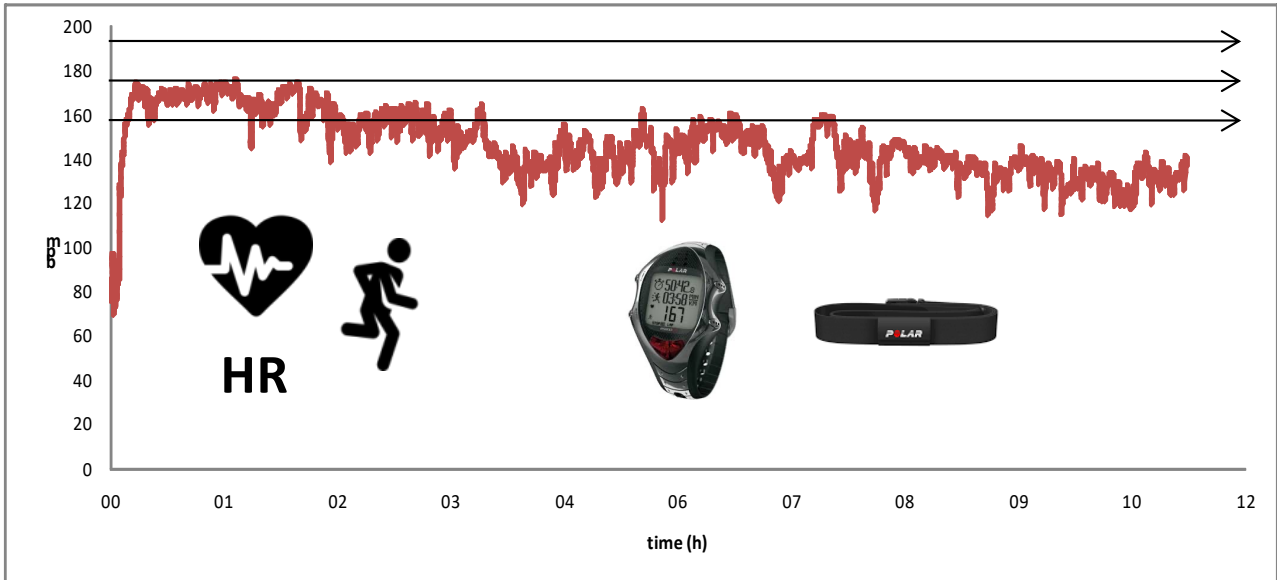




Before the race

- laboratory tests (VO_{2max}, VT1, VT2) and the **heart rate response**



MAX

VT2

VT1

During the race

- **HR** was continuously monitored using portable HR monitors (Polar RS800, Polar Electro, Kempele Finland).

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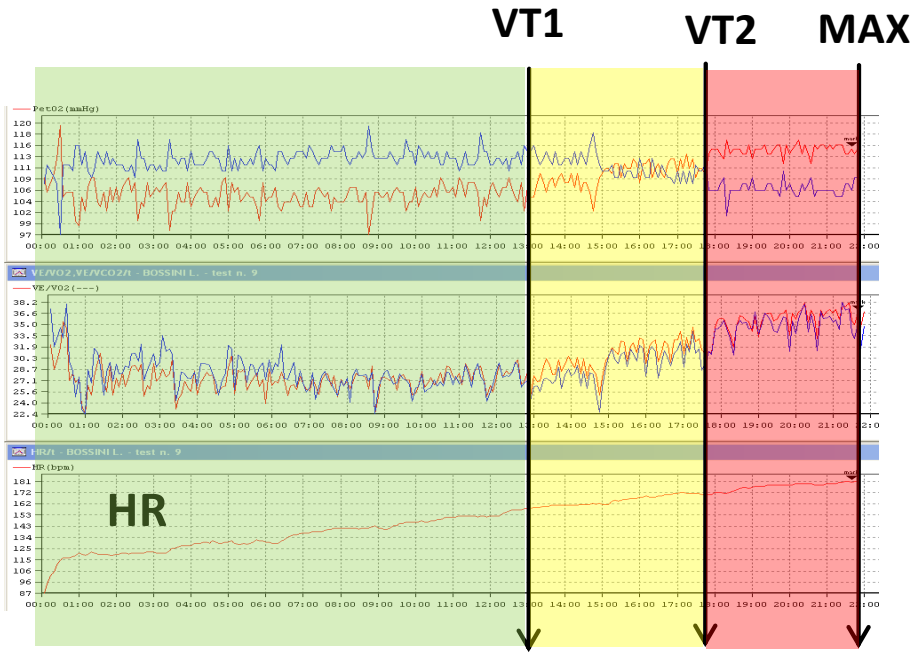
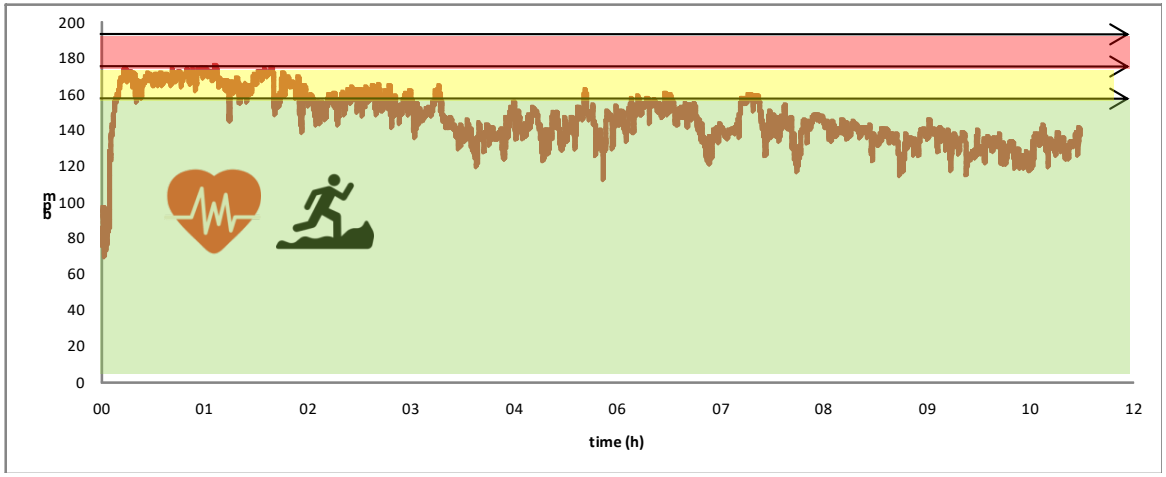


- **Exercise intensity distribution**

  Zone I (<VT1),
  Zone II (VT1-VT2)
  Zone III (>VT2)

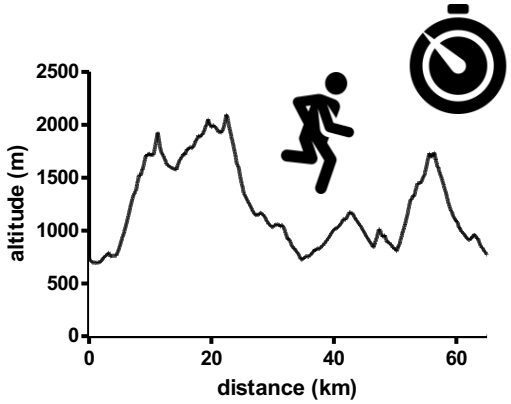
- **Total exercise load** was calculated according to Lucia's training impulse method (Lucia's TRIMP)

1 min in Zone I → 1 TRIMP unit
1 min in Zone II → 2 TRIMP units
1 min in Zone III →3 TRIMP units



MAX
VT2
VT1

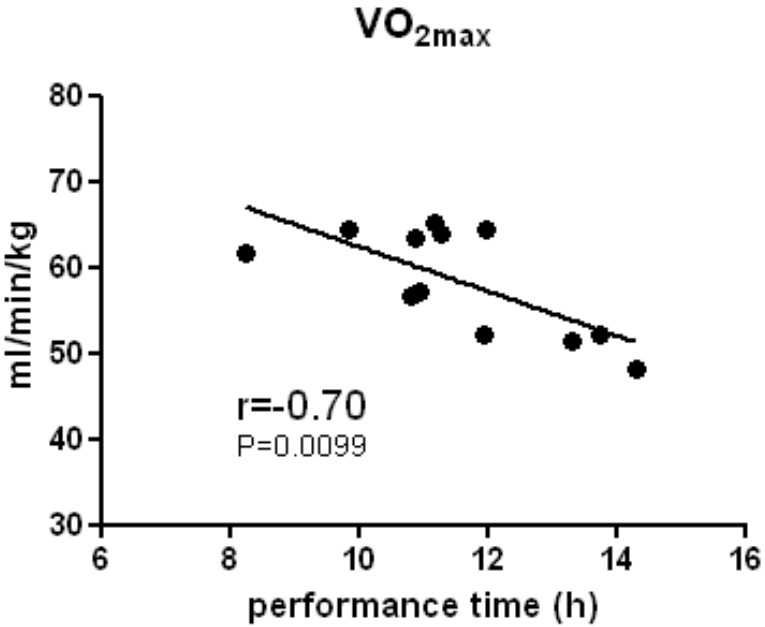
Results

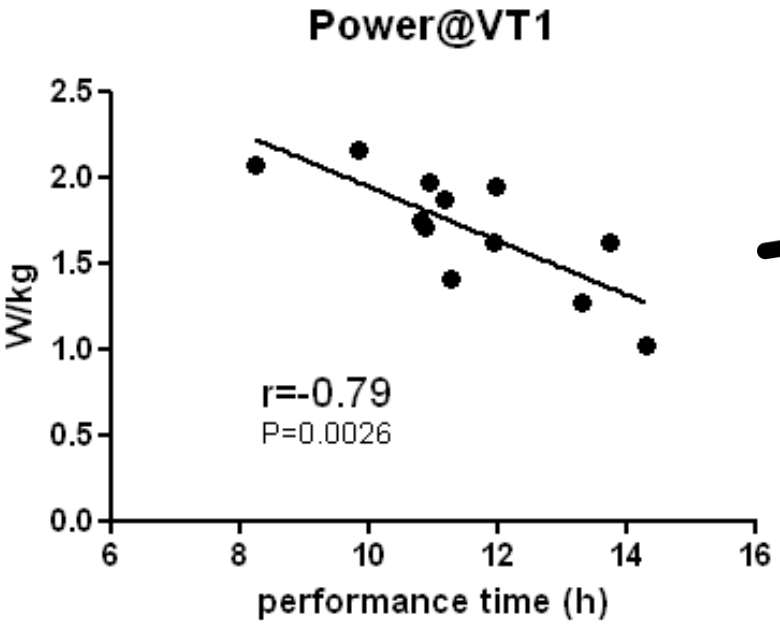


Performance

- Mean performance time for the race was 11.5±1.7 h (range 8.2-14.3h)

- High correlation with **VO_2max**





- The variable that better correlated with the performance was **Power output@VT1** (r=-0.79, P<0.001).

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Results

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Intensity

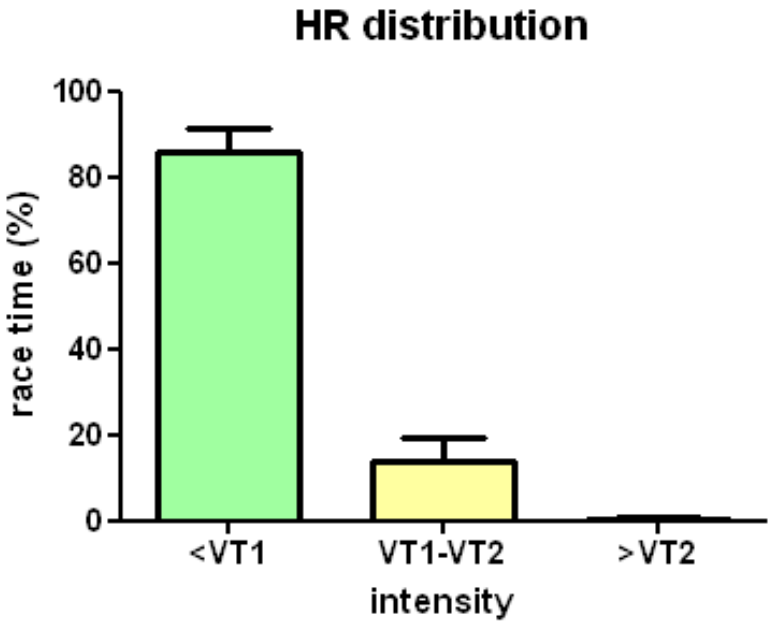
- mean intensity **77 ± 5 % HRmax** (89%±6% HR@VT1)

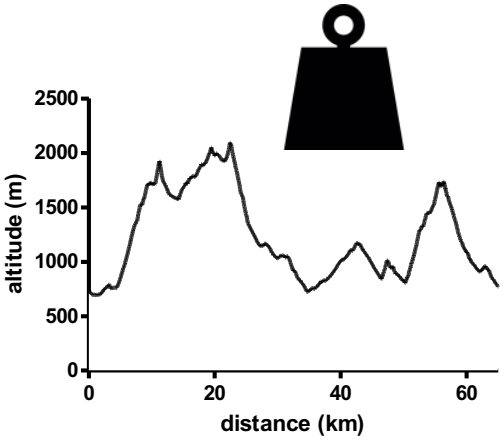
- Exercise intensity distribution was:

✓**86% ± 19% Zone I**

✓14% ± 19% Zone II

✓0% ± 1% Zone III





Training Load

- Total exercise load was **766 ± 110** TRIMP units

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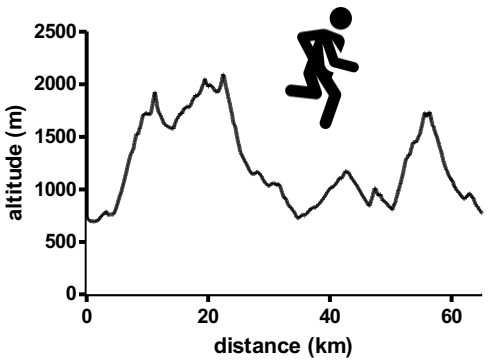
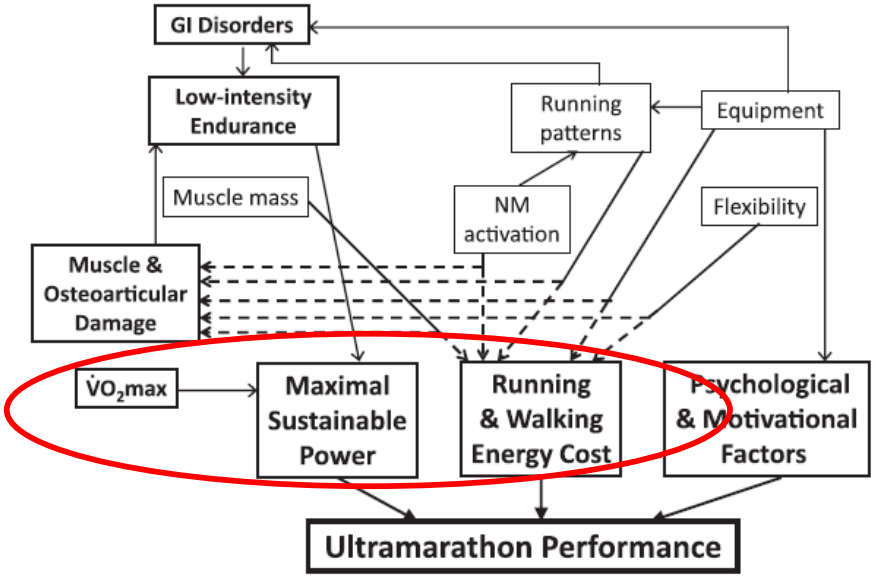
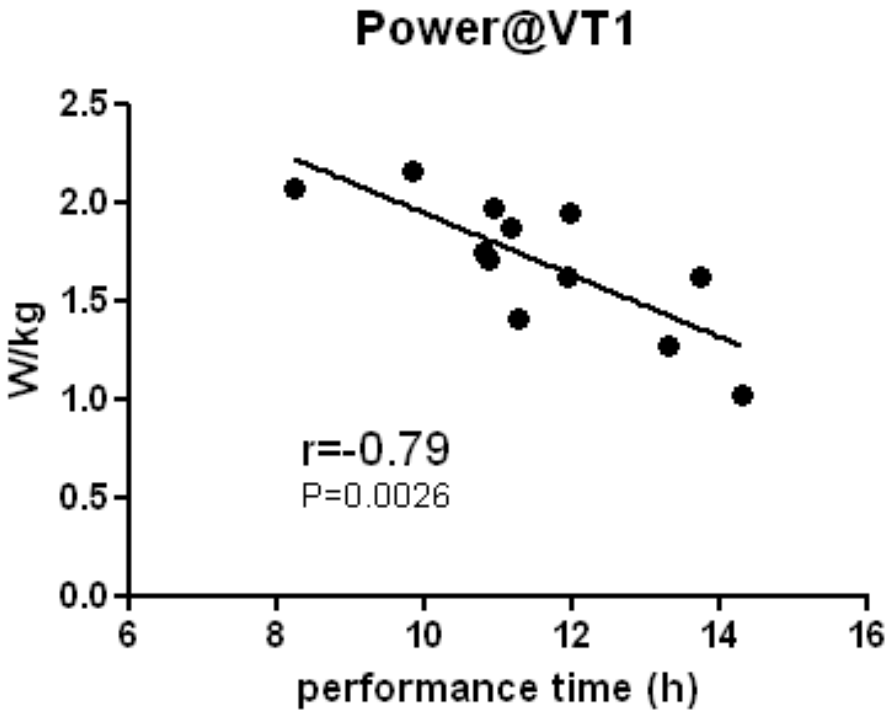






VT1 represents an important threshold in ultra-endurance trail running

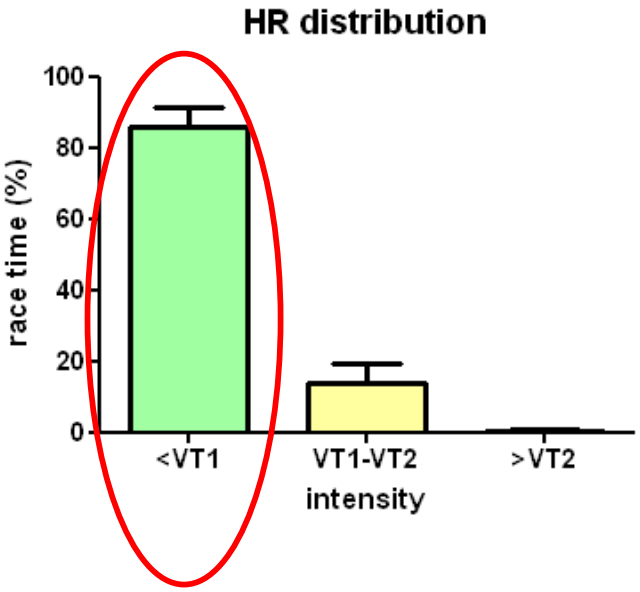
Ultra-endurance
> 6h

- **ultra-endurance threshold** below **VT1** and around **80% HRmax** (O'Toole et al. 1998; Laursen, Knez, et al. 2005)

"…an exercise intensity **marginally below VT1**

89% ± 6% HR@VT1

- higher fat to carbohydrate utilization
- sparing carbohydrate reserves, delaying muscle and liver glycogen depletion



→ **reducing fatigue** …and **improving overall ultra-endurance performance**…"

(Laursen & Rhodes, 2001)

Ultra-endurance
> 6h

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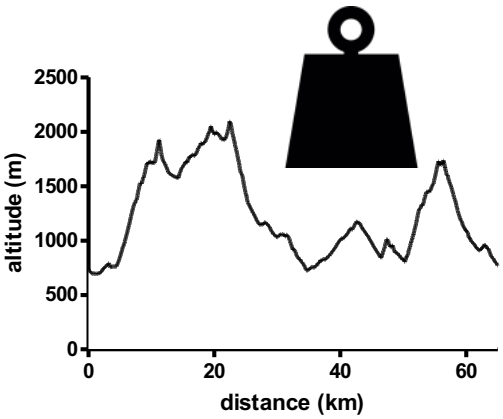
65 km 4000 d+ trail



Physiological load

766 ± 110 TRIMP units

HR-based TRIMP score in literature:

TRAINING:

- ≈ 1000-1500 units/week in professional cycling training (Lucia, Earnest, et al. 2003)
- ≈ 1000 units/week in ultra-endurance triathletes (Muñoz, Cejuela, et al. 2014)
- ≈ 800 units/week elite Kenyan runners (Billat, Lepretre, et al. 2003)
- ≈ 800 units/week in elite junior Nordic skiers (Seiler and Kjerland. 2006)
- ≈ 400 units/week sub-elite runners (Esteve-lanao, san juan, et al 2005)

COMPETITION:

- ≈ 2000 units/week in professional road cycling competition (Lucia, Hoyos, et al. 1999)
- 1061 ± 200 units during an Ironman triathlon (Muñoz, Cejuela, et al. 2014)
- 801 ± 98 units during a 24-h relay cycling race (Bescós, Rodríguez, et al. 2011)

Practical Applications

Ultra-endurance
> 6h

An exercise intensity **slightly below VT1 (~90%)**, could represent a threshold of tolerable intensity for amateur runners in a >10h race, where athletes could manage **their energy reserves and optimize competitive results.**

PHYSIOLOGICAL DEMANDS OF MOUNTAIN RUNNING RACES

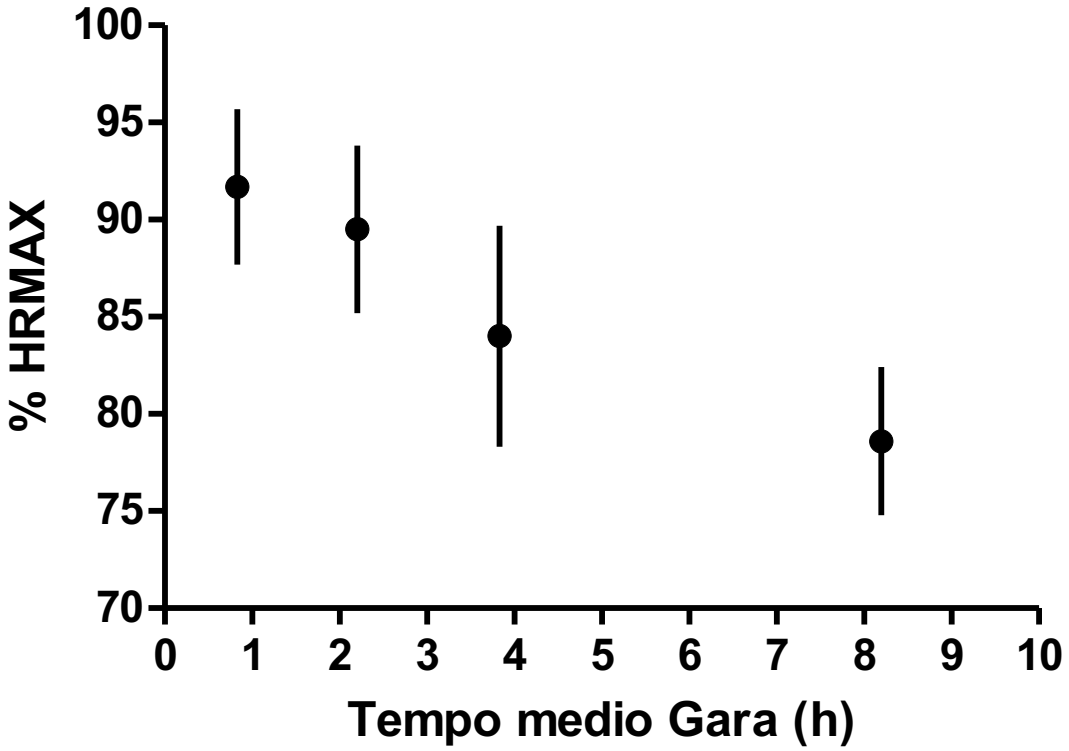
Jose A. Rodríguez-Marroyo[1], Javier González-Lázaro[2,3], Higinio F. Arribas-Cubero[3,4], and José G. Villa[1]

Table 1. Physiological characteristics of subjects

	Mean±*SD*
VO_{2max} (ml·kg^{-1}·min^{-1})	59.3±5.5
HR_{max} (bpm)	186±9
VO_2 RCT (ml·kg^{-1}·min^{-1})	49.3±6.1
% VO_{2max} RCT	83.0±4.5
HR RCT (bpm)	167±9
VO_2 VT (ml·kg^{-1}·min^{-1})	36.4±3.4
% VO_{2max} VT	61.5±3.8
HR VT (bpm)	140±7

Note. VO_{2max}=maximum oxygen consumption, HR_{max}=maximal heart rate, RCT=respiratory compensation threshold, VT=ventilatory threshold, %VO_{2max}=percentage of VO_{2max} at which RCT and VT occur.

- Vertical 91.7±4.0%
- 10-25 km races 89.5±4.3%
- 25-45 km 84.0±5.7%
- >45 km races 78.6±3.8%



Rodríguez-Marroyo1, J.A. et al.: PHYSIOLOGICAL DEMANDS OF MOUNTAIN... Kinesiology 50(2018) Suppl.1:60-66

PHYSIOLOGICAL DEMANDS OF MOUNTAIN RUNNING RACES

Jose A. Rodríguez-Marroyo[1], Javier González-Lázaro[2,3],
Higinio F. Arribas-Cubero[3,4], and José G. Villa[1]

Relazione Parametri da Laboratorio e Prestazione nel Vertical

Studio 2

JOURNAL OF SPORTS SCIENCES
2022, VOL. 40, NO. 22, 2544–2551
https://doi.org/10.1080/02640414.2023.2172801

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SPORTS PERFORMANCE

Eager to set a record in a vertical race? Test your VO_{2max} first!

Alessandro Fornasiero[a,b], Aldo Savoldelli[a,b], Andrea Zignoli[a,c], Alexa Callovini[a,b], Marco Decet[a,b], Lorenzo Bortolan[a,b], Federico Schena[a,b] and Barbara Pellegrini[a,b]

[a]Department of Neurosciences, Biomedicine and Movement Sciences, CeRiSM, Sport Mountain and Health Research Centre, University of Verona, Rovereto, Italy; [b]Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Verona, Italy; [c]Department of Industrial Engineering, University of Trento, Trento, Italy

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Relationship between VO_{2max} and performance in vertical races

- **270** performances, from **26 VRs**

- **CPET data** of **64 highly-trained mountain runners**

53 M: VO_{2max}: 75.7±5.8 mL/min/kg VT2 ~90% VO_{2max}

11 F: 65.7±3.4 mL/min/kg VT2 ~89% VO_{2max}

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SPORTS PERFORMANCE

Check for updates

Eager to set a record in a vertical race? Test your VO_{2max} first!

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[a]Department of Neurosciences, Biomedicine and Movement Sciences, CeRiSM, Sport Mountain and Health Research Centre, University of Verona, Rovereto, Italy; [b]Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Verona, Italy; [c]Department of Industrial Engineering, University of Trento, Trento, Italy

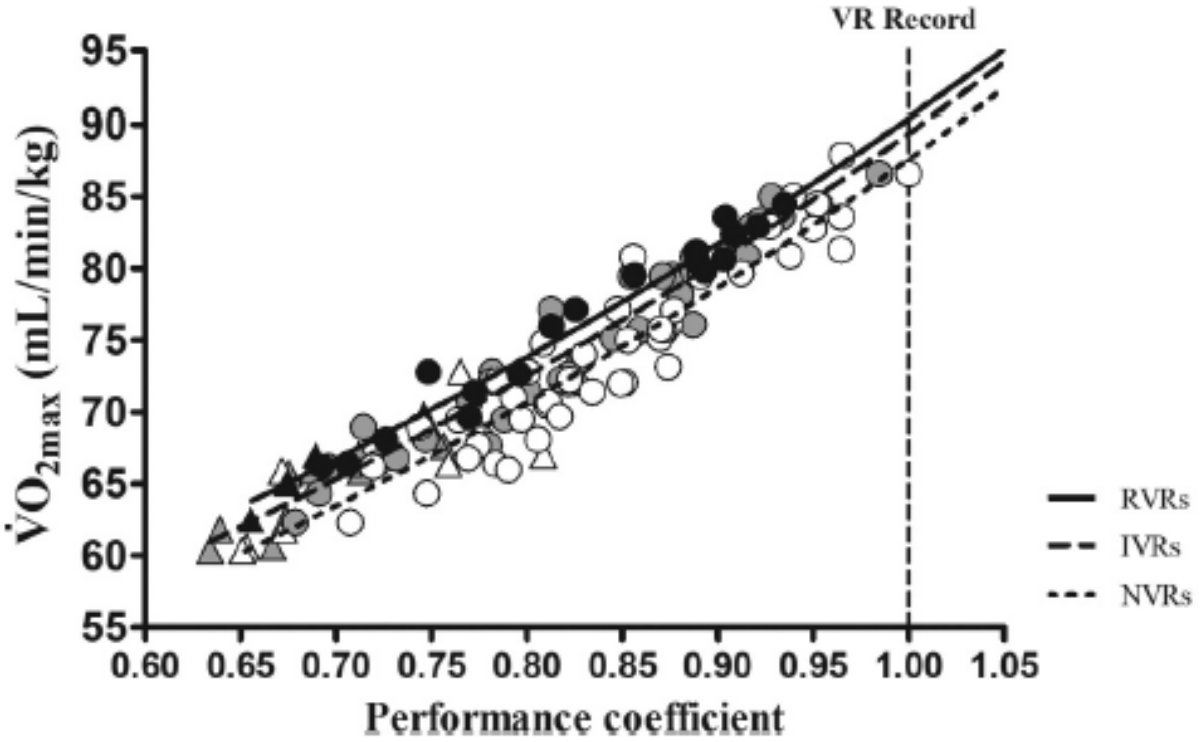


Figure 2. Performance coefficient-VO_{2max} relationships in vertical races (VRs) according to their level of prestige: national Vertical Races (NVRs), international VRs (IVRs) and VRs of current pole-assisted and pole-unassisted vertical kilometre records (RVRs). Performance Coefficient is calculated as the ratio between the observed performance time and the current record time for the specific races considered. Black, grey and white circles represent observations for male athletes in RVRs, IVRs and NVRs, respectively. Black, grey and white triangles represent observations for female athletes in RVRs, IVRs and NVRs, respectively. No statistical differences in Performance coefficient-VO_{2max} relationships between male and female athletes were noted.

International Races:

Average VO_{2max} best performance (RECORD):

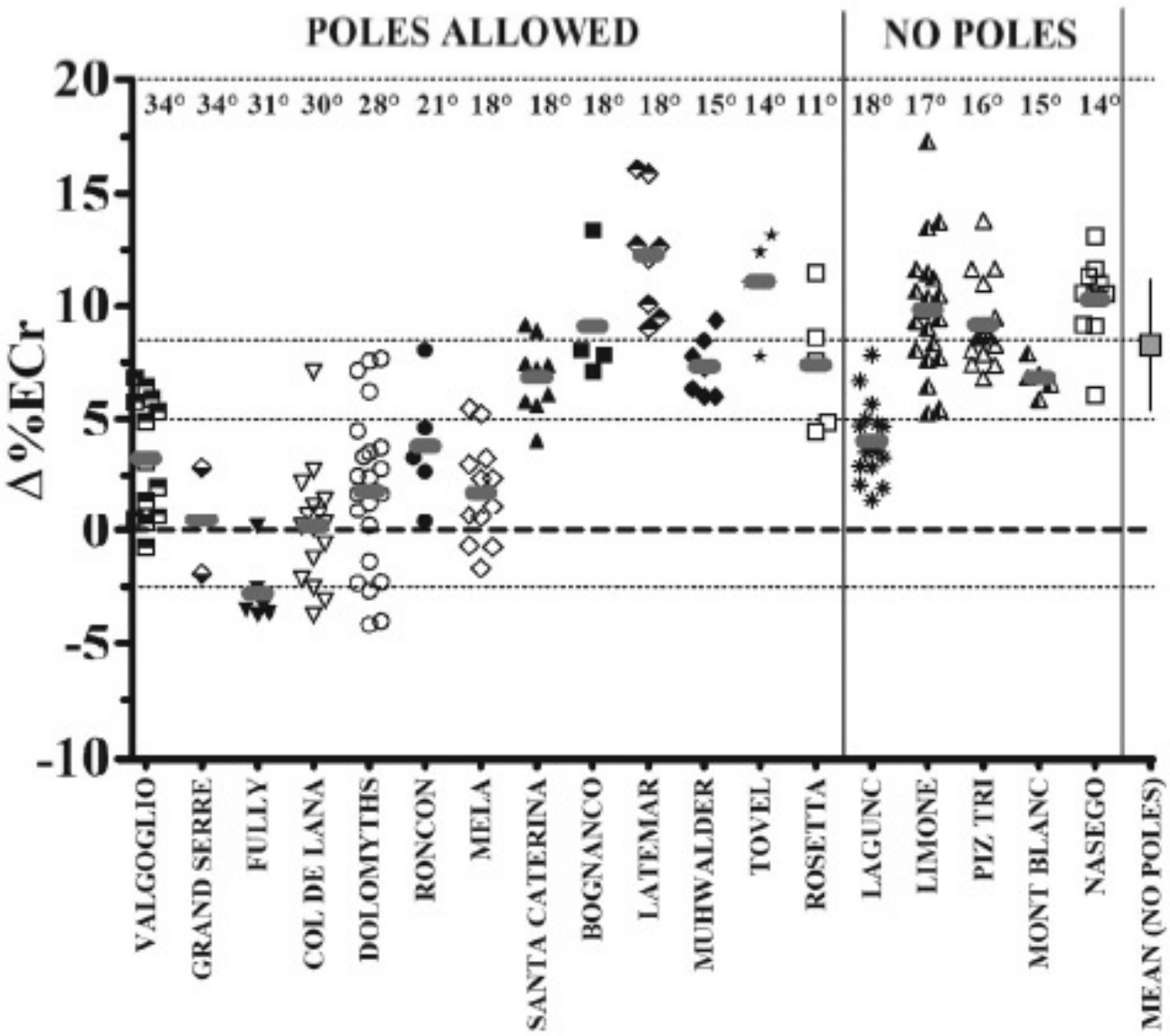
- 89.4 (88.2–90.5) M
- 76.8 (76.4–77.3) F

Average VO_{2max} (mL/min/kg) to WIN:

- 86.2 (85.3–87.1) M
- 74.0 (73.6–74.4) F

VK record

- 90.4(89.0–91.8) M
- 77.1(77.6–77.7) F



non-uniform variation in the metabolic demand of off-road running, likely attributable to the different features of the VRs (e.g., terrain, technical level, use of poles).

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Studio 3
(work in progress)

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Dataset Gare Vertical Record Maschili e femminili

N	Race	Prestige	POLES	d+ (m)	distance (m)	slope (°)	quota arrivo (a.s.l)	Record Time
1	DARFO VERTICAL	NAT		1081	7100	8.8	1301	41.2
2	AURONZO VERTICAL	NAT	✓	780	5000	9.0	1539	31.3
3	TRANSVULCANIA	INT		1203	7600	9.1	1160	47.4
4	SOSTILA	NAT	✓	1000	6200	9.3	1301	40.4
5	PIRENEU KV	INT	✓	860	5000	9.9	2520	36.7
6	CIGNANA	NAT		969	5500	10.1	2286	37.8
7	ROSETTA VERTICAL	NAT	✓	1279	6900	10.7	2742	50.8
8	FENIS VERTICAL	INT	✓	1000	5300	10.9	1567	38.7
9	BROKEN ARROW VK	NAT	✓	954	5000	11.0	2708	41.1
10	FLAGSTAFF	NAT		1000	5000	11.5	2850	42.8
11	BECCA DI VIOU	NAT	✓	1000	5000	11.5	2855	42.2
12	CARA AMON	INT	✓	980	4800	11.8	2053	39.4
13	SALOMON MAMORES VK	INT	✓	1037	5000	12.0	1055	39.3
14	ARLES	NAT	✓	1000	4800	12.0	1284	37.1
15	DOMOBIANCA	NAT	✓	774	3500	12.8	1853	28.6
16	VERTICAL LUCO	NAT	✓	1080	4800	13.0	2430	40.8
17	VAL RESIA VK	NAT	✓	1070	4700	13.2	1650	39.5
18	LONE PEAK VK	INT		1107	4800	13.3	3403	46.0
19	VALGEROLA	NAT	✓	1269	5500	13.3	2150	48.8
20	VERTICAL VIOZ	NAT	✓	1000	4300	13.4	3200	38.9
21	NASEGO VERTICAL	INT		1000	4200	13.8	1430	33.8
22	PLAN DAS STRIES	NAT	✓	1000	4100	14.1	1580	33.9
23	COSTOLINA	NAT	✓	700	2800	14.5	1700	25.3
24	CERVINO VERTICAL K	INT	✓	1014	4002	14.7	3020	39.9
25	VK MERIDIANO	NAT	✓	1002	3950	14.7	1237	34.5
26	VALMALENCO VERTICAL	NAT	✓	1020	4000	14.8	1900	38.9
27	MONVISO VERTICAL	NAT		1000	3900	14.9	2330	36.3
28	MORISSOLO VERTICAL	NAT	✓	1000	3900	14.9	1311	37.0
29	VERTICAL TOVEL	NAT	✓	1105	4300	14.9	2075	38.7
30	MONT BLANC VK	INT		1000	3800	15.3	2000	34.1
31	GRAN SASSO VK	NAT	✓	1044	3800	15.9	2136	35.8
32	PUIG CAMPANA	INT	✓	1028	3650	16.4	1408	35.8
33	LA RAMPIGADA	INT	✓	1063	3750	16.5	2483	36.9
34	PIZ TRI VERTIKAL	INT		1000	3524	16.5	1822	32.1
35	KV DE MANIGOD	NAT	✓	1046	3600	16.9	2219	36.3
36	PRESOLANA VERTICAL	NAT		1000	3400	17.1	2250	34.2
37	GRÈSTE DE LA MUGHÉRA VK	INT		1094	3700	17.2	1160	36.0
38	LATEMAR VK	INT	✓	1000	3300	17.6	1670	35.7

DATASET CON 62 GARE VERTICAL, RELATIVE CARATTERISTICHE E RECORD TIME

Modello prestazione: predittori:

- Dislivello
- pendenza media
- quota d'arrivo
- uso bastoni

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3. Model Information

Sample	Dependent Variable	Predictors	R	R^2	Adj R^2	SE	R^2 change	F change	p Change
n = 62	Performance (min)	D+	0.72	0.51	0.50	3.57	0.51	62.6	**0.000**
		D+, Slope	0.92	0.85	0.84	2.03	0.34	63.8	**0.000**
		D+, Slope, Altitude	0.96	0.92	0.91	1.49	0.07	51.1	**0.000**
		D+, Slope, Altitude, Poles	0.96	0.93	0.92	1.41	0.01	0.8	0.385

~93% varianza totale spiegata

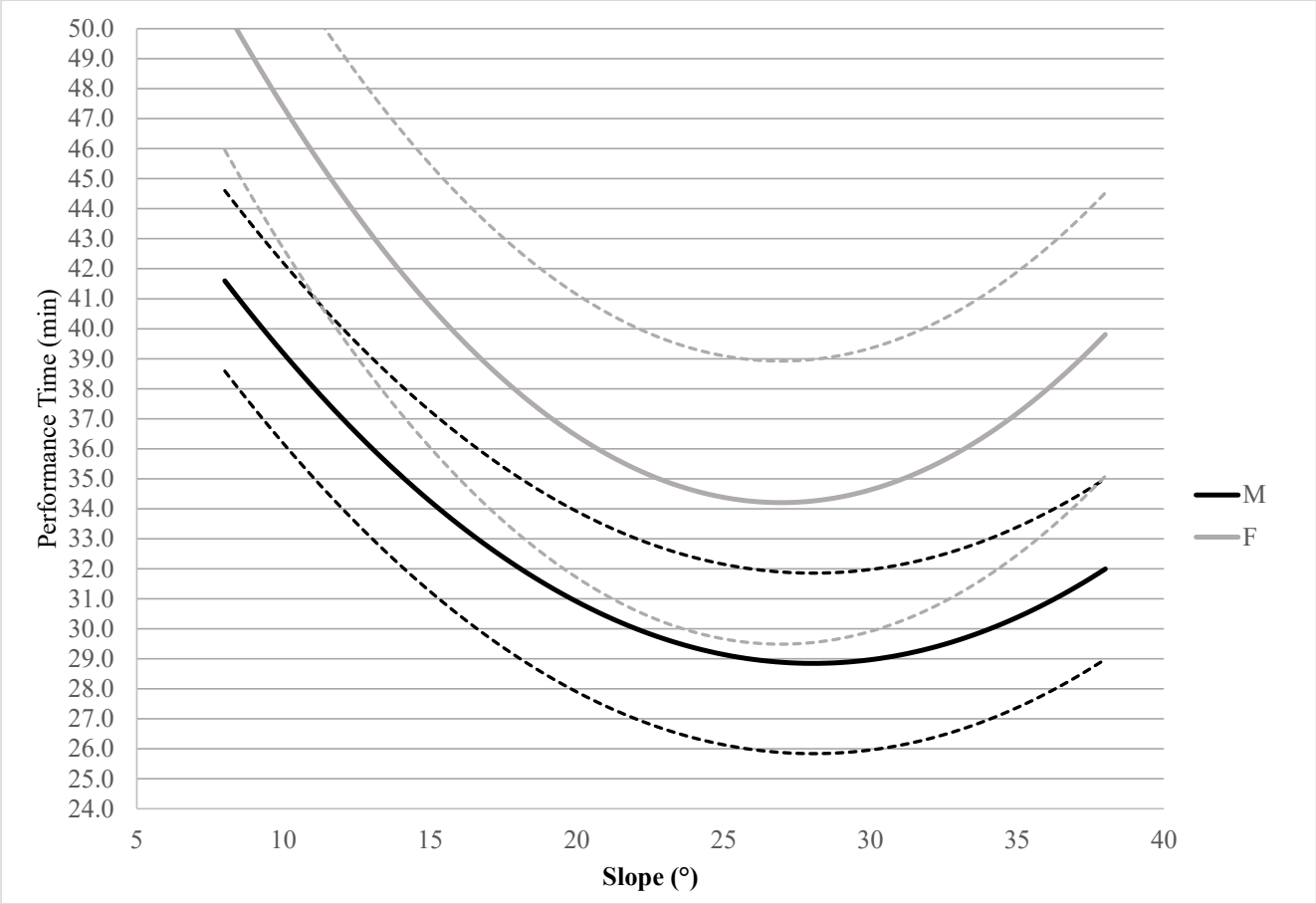
Effetto dislivello

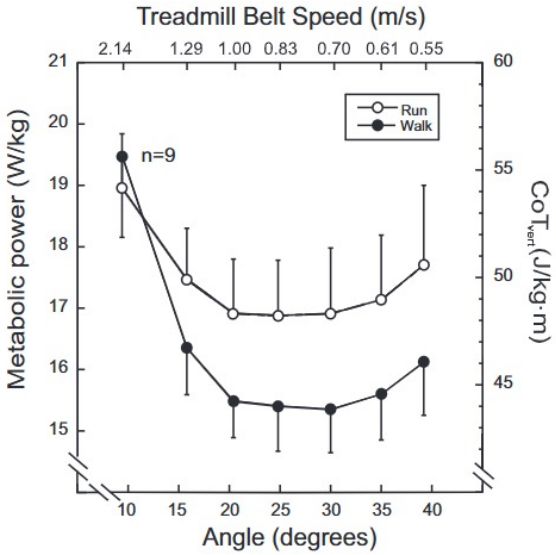
Effetto pendenza

Effetto quota

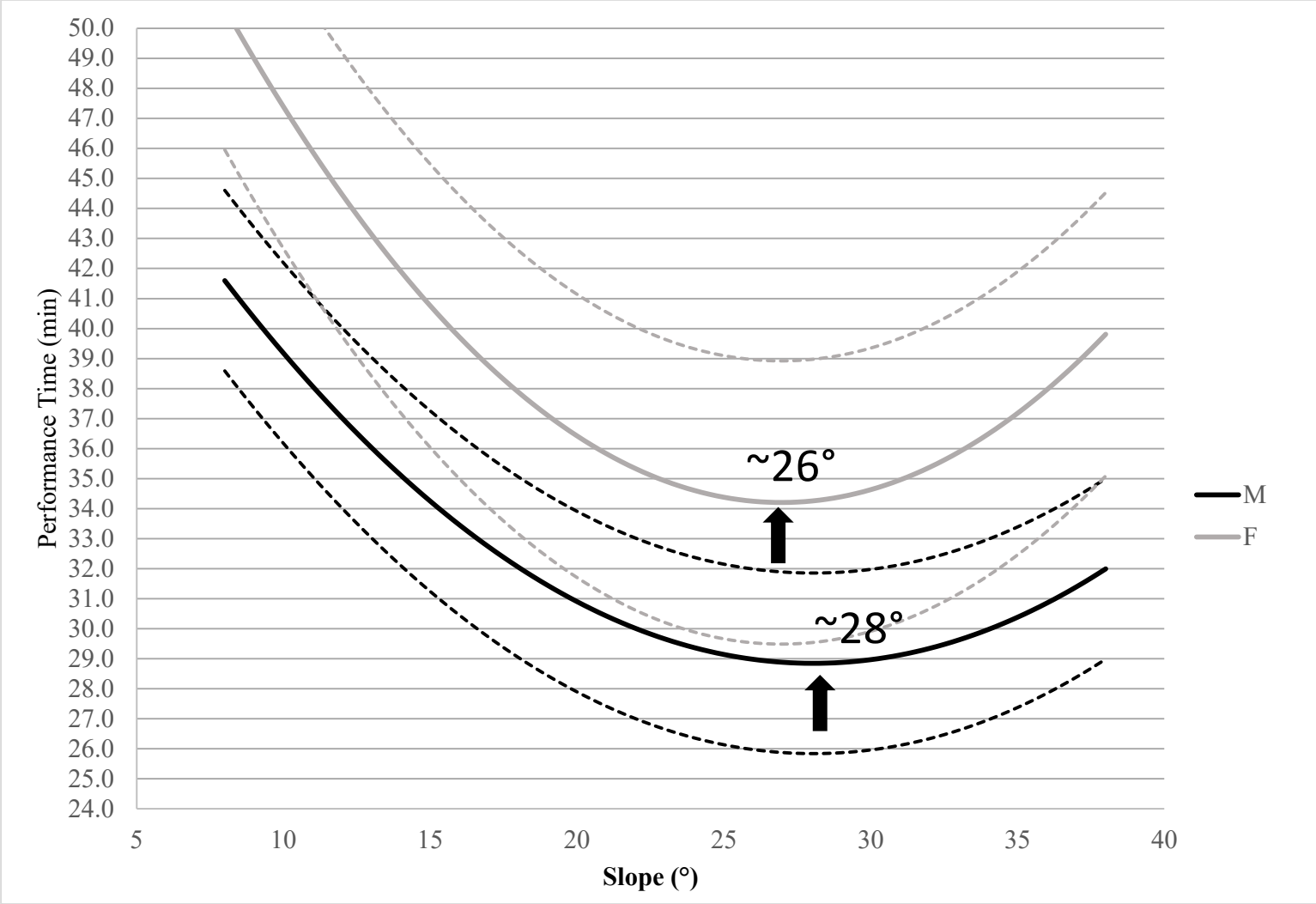
No effetto bastoni

Pendenza

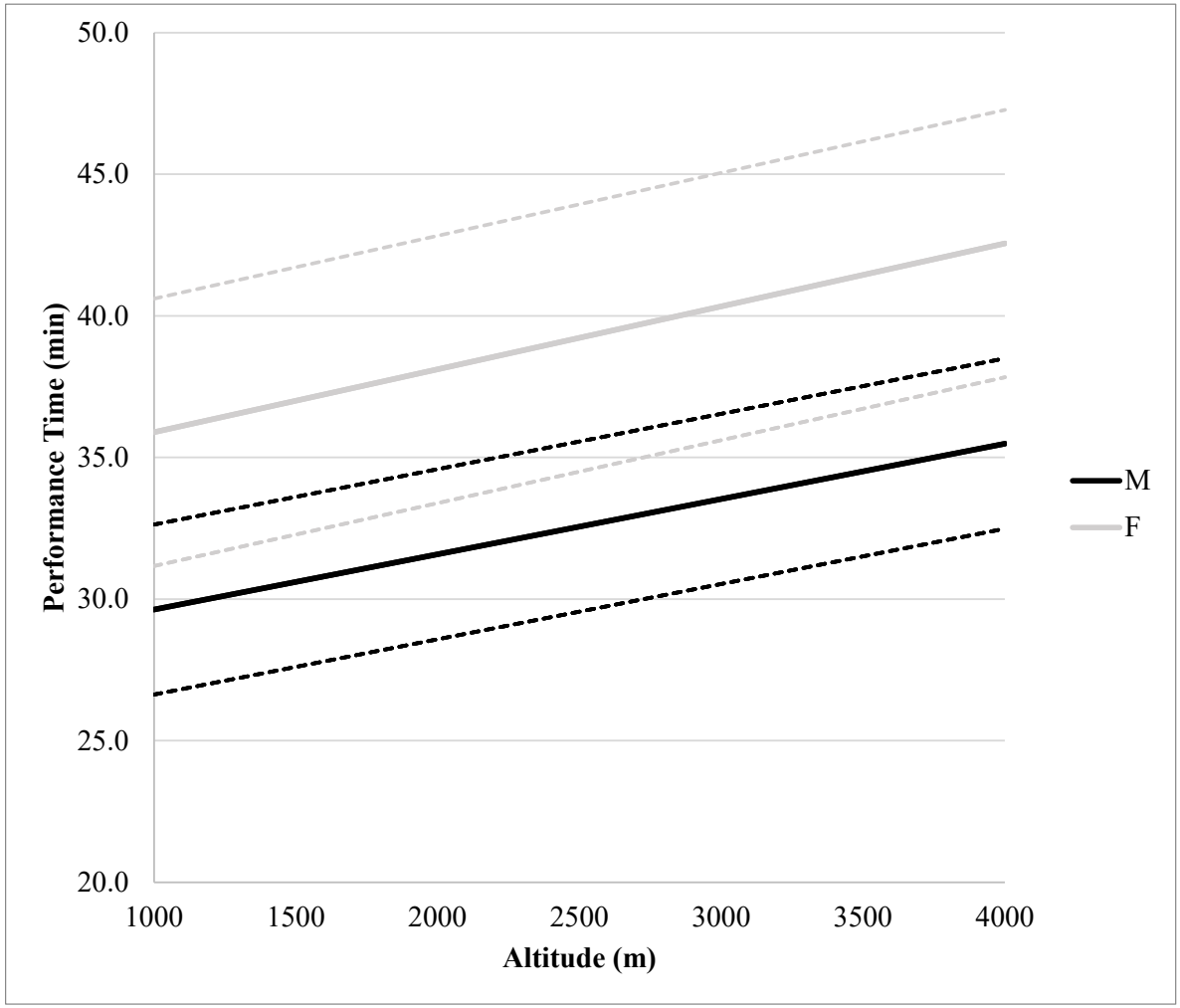

Performance Time (min)
50.0
49.0
48.0
47.0
46.0
45.0
44.0
43.0
42.0
41.0
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
30.0
29.0
28.0
27.0
26.0
25.0
24.0
5
10
15
20
25
30
35
40
Slope (°)
M
F


Treadmill Belt Speed (m/s)
2.14
1.29
1.00
0.83
0.70
0.61
0.55
Run
Walk
n=9
Metabolic power (W/kg)
21
20
19
18
17
16
15
60
55
50
45
10
15
20
25
30
35
40
Angle (degrees)

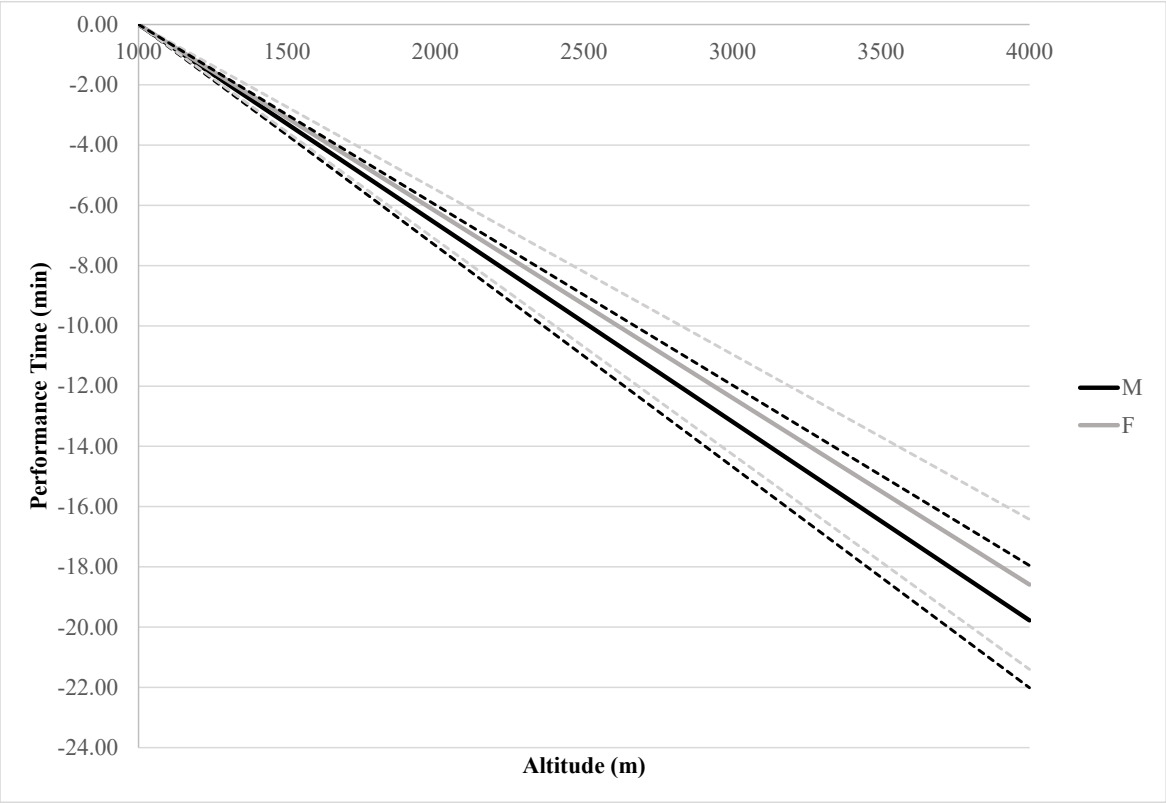
Pendenza

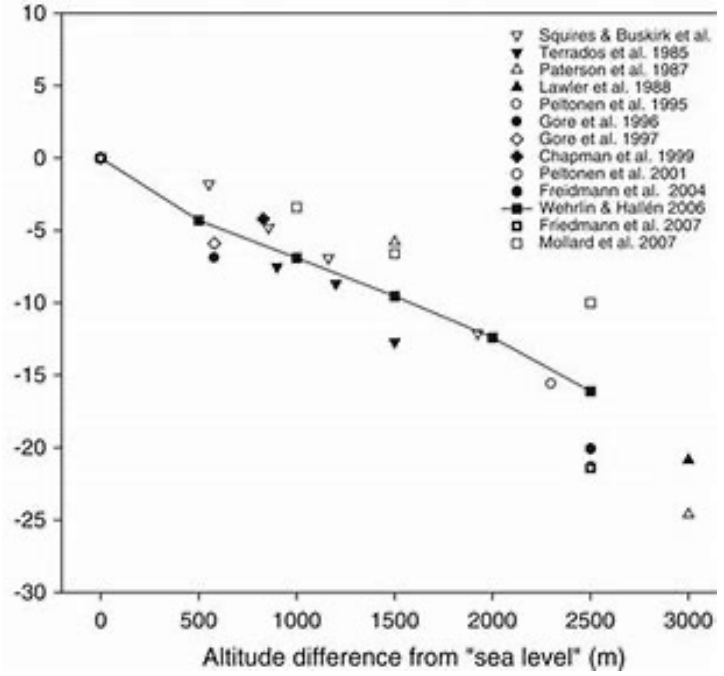

50.0
49.0
48.0
47.0
46.0
45.0
44.0
43.0
42.0
41.0
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
32.0
31.0
30.0
29.0
28.0
27.0
26.0
25.0
24.0
Performance Time (min)
5
10
15
20
25
30
35
40
Slope (°)
~26°
~28°
M
F

Quota


50.0
45.0
40.0
35.0
30.0
25.0
20.0
Performance Time (min)
1000
1500
2000
2500
3000
3500
4000
Altitude (m)
M
F

Decremento in funzione quota d'arrivo





- -6.5%/1000m M
- -6.2%/1000m F

TENTATIVO DI RECORD VERTICALE?

ATLETA MASCHIO con ~91mL/min/kg
ATLETA FEMMINA con ~ 78mL/min/kg

Gara da 0 a 1000 m per limitare il più possibile l'influenza della quota

Pendenza media 28° per gli UOMINI
Pendenza media 26° per le DONNE

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Grazie per l'attenzione!