Parliamo di "Economia di Corsa"

G. Pavei

Il problema dei "sinonimi"

RE

Cost of Transport

Metabolic Cost

COT

ECOT

Cr

C

Running Economy

Energy Cost

net

J/(kg m)

W/kg

mlO_2/(kg km)

mlO_2/(kg min)

Kcal/(kg km)

Kcal/(kg min)

Definizione

Costo

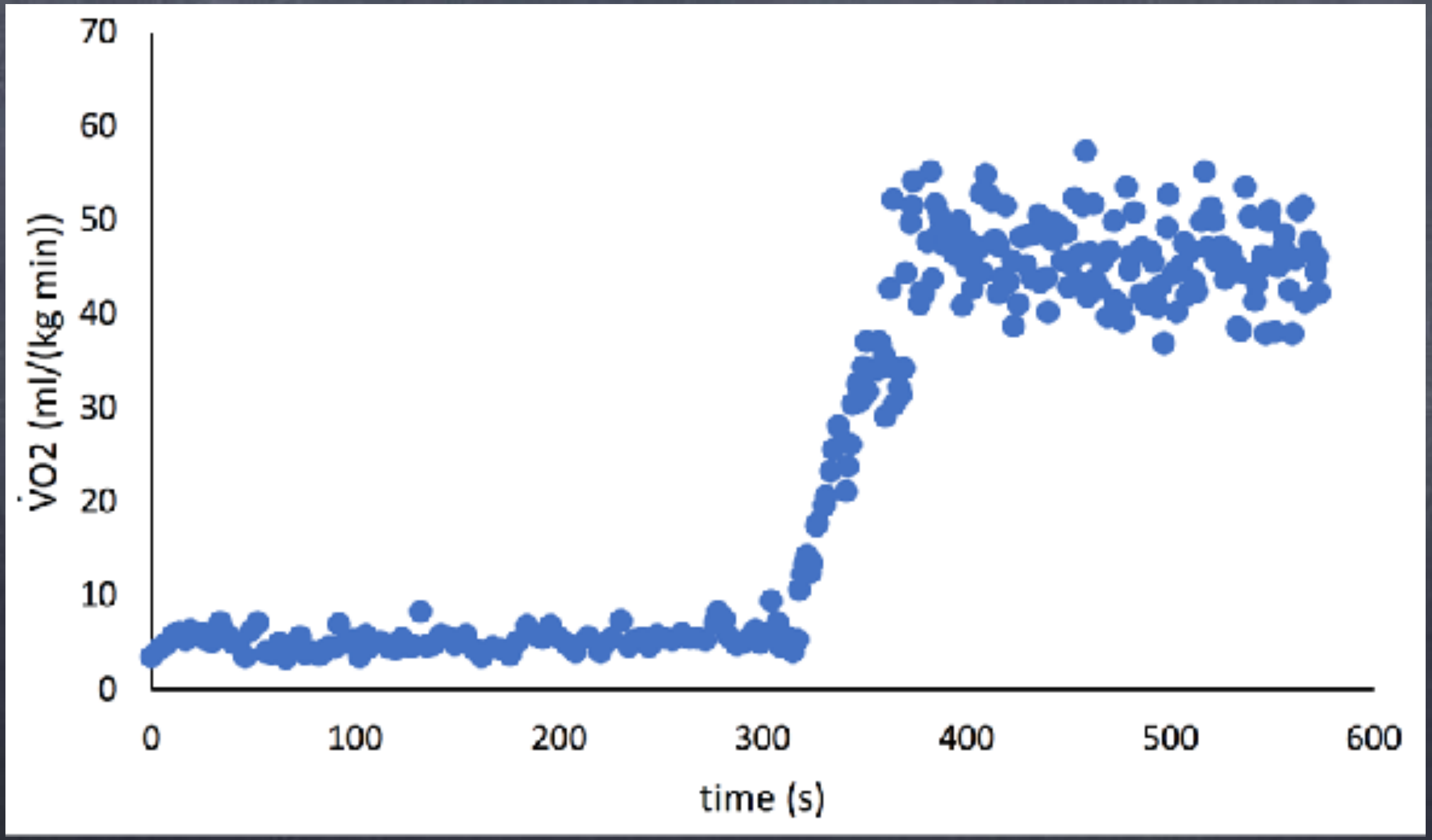
- Energia (metabolica) necessaria per muovere un chilogrammo di massa per un metro (J/(kg m))

Margaria 1938

Come si Misura

Come si Misura

$$C = \frac{(\dot{V}O_{2ss} - \dot{V}O_{2basale}) * EqQR}{v} \quad (J/(kg\ m))$$



Margaria 1938
Schmidt-Nielsen 1972

Come si Misura

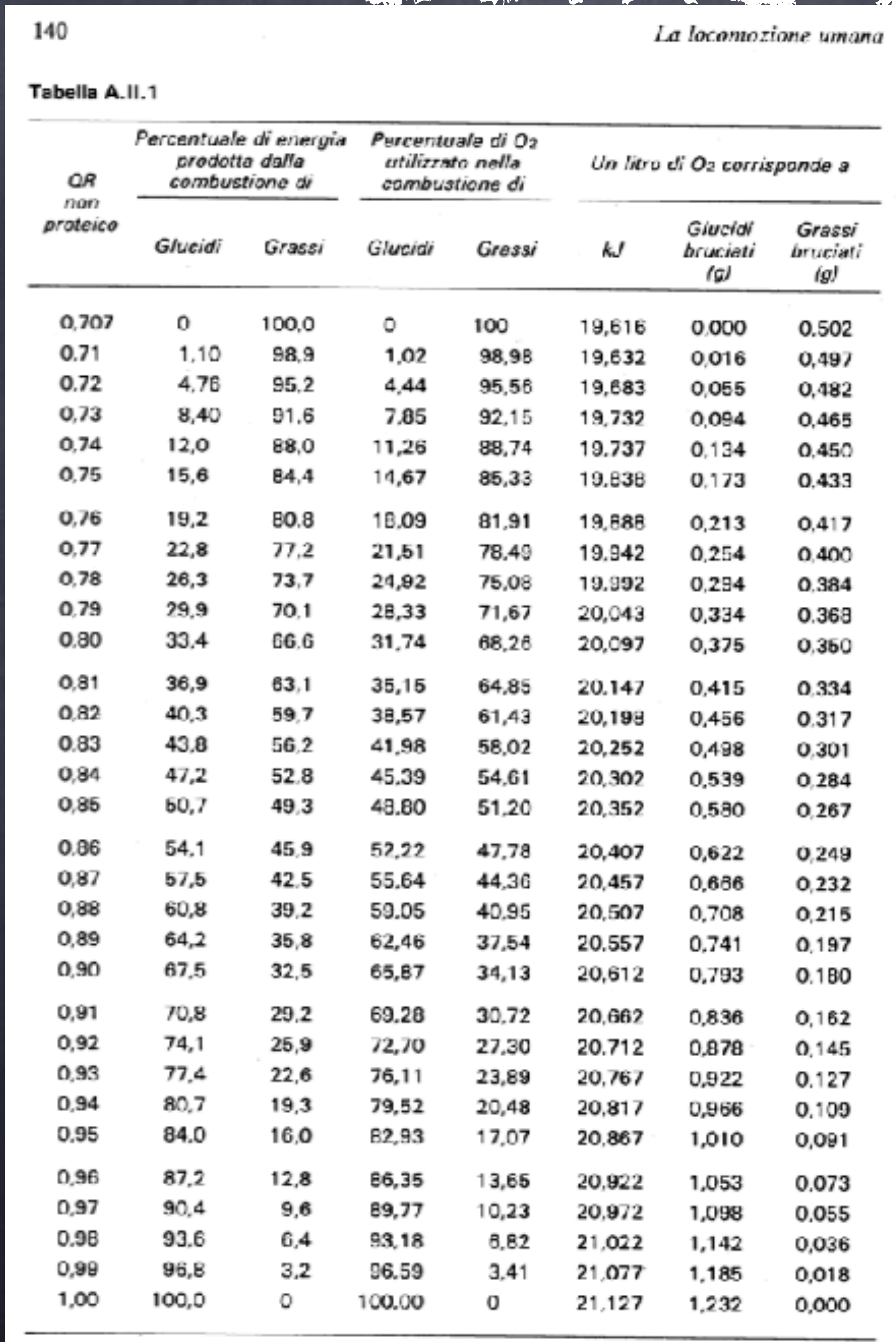
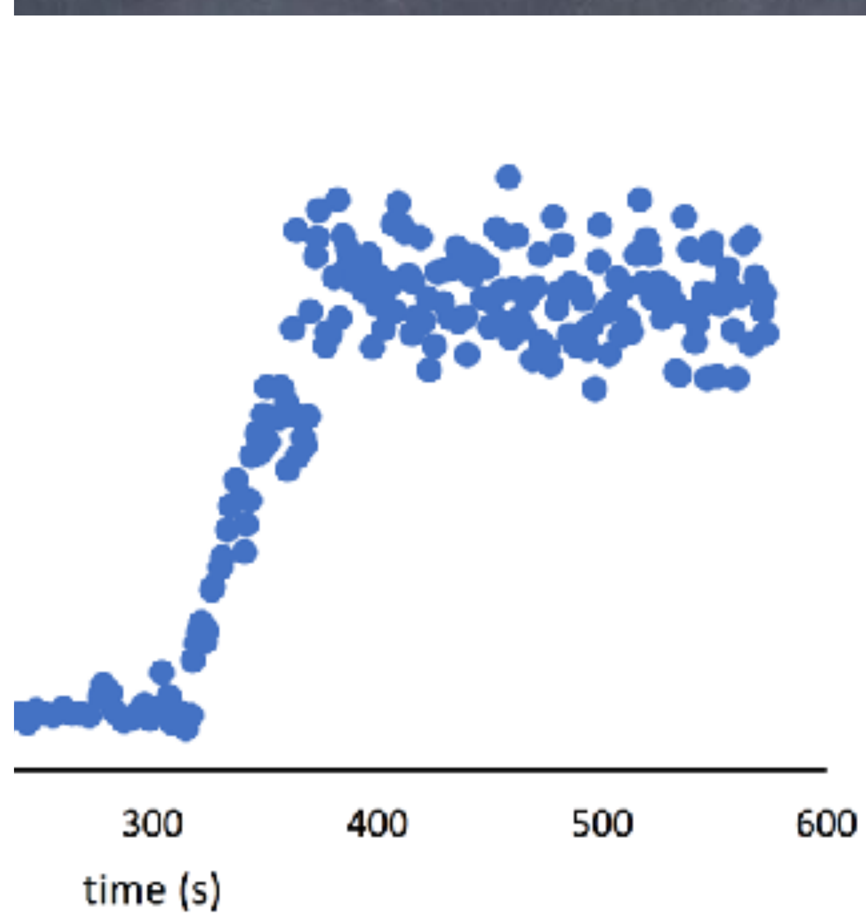


Tabella A.II.1

QR non proteico	Percentuale di energia prodotta dalla combustione di		Percentuale di O_2 utilizzato nella combustione di		Un litro di O_2 corrisponde a		
	Glucidi	Grassi	Glucidi	Grassi	kJ	Glucidi bruciati (g)	Grassi bruciati (g)
0,707	0	100,0	0	100	19,616	0.000	0.502
0.71	1,10	98.9	1,02	98,98	19,632	0,016	0,497
0.72	4,76	95,2	4,44	95,56	19,683	0,055	0,482
0,73	8,40	91,6	7,85	92,15	19,732	0,094	0,465
0,74	12,0	88,0	11,26	88,74	19.737	0,134	0,450
0,75	15,6	84,4	14,67	85,33	19.838	0,173	0,433
0,76	19,2	80.8	18,09	81,91	19,888	0,213	0,417
0,77	22,8	77,2	21,51	78,49	19.942	0,254	0,400
0,78	26,3	73,7	24,92	75,08	19.992	0,294	0,384
0,79	29,9	70,1	28,33	71,67	20,043	0,334	0,368
0.80	33,4	66,6	31,74	68,26	20,097	0,375	0,360
0,81	36,9	63,1	35,15	64,85	20.147	0,415	0,334
0,82	40,3	59,7	38,57	61,43	20,198	0,456	0,317
0,83	43,8	56,2	41,98	58,02	20,252	0,498	0,301
0,84	47,2	52,8	45,39	54,61	20,302	0,539	0,284
0,85	50,7	49,3	48,80	51,20	20,352	0,580	0,267
0,86	54,1	45,9	52,22	47,78	20,407	0,622	0,249
0,87	57,5	42,5	55,64	44,36	20,457	0,666	0,232
0,88	60,8	39,2	59,05	40,95	20,507	0,708	0,215
0,89	64,2	35,8	62,46	37,54	20.557	0,741	0,197
0,90	67,5	32,5	65,87	34,13	20,612	0,793	0.180
0,91	70,8	29,2	69,28	30,72	20,662	0,836	0,162
0,92	74,1	25,9	72,70	27,30	20.712	0,878	0,145
0,93	77,4	22,6	76,11	23,89	20,767	0,922	0,127
0,94	80,7	19,3	79,52	20,48	20,817	0,966	0,109
0,95	84,0	16,0	82,93	17,07	20,867	1,010	0,091
0,96	87,2	12,8	86,35	13,65	20,922	1,053	0,073
0,97	90,4	9,6	89,77	10,23	20,972	1,098	0,055
0,98	93,6	6,4	93,18	6,82	21,022	1,142	0,036
0,99	96,8	3,2	96,59	3,41	21,077	1,185	0,018
1,00	100,0	0	100,00	0	21,127	1,232	0,000

...le) * EqQR

(J/(kg m))



Margaria 1938

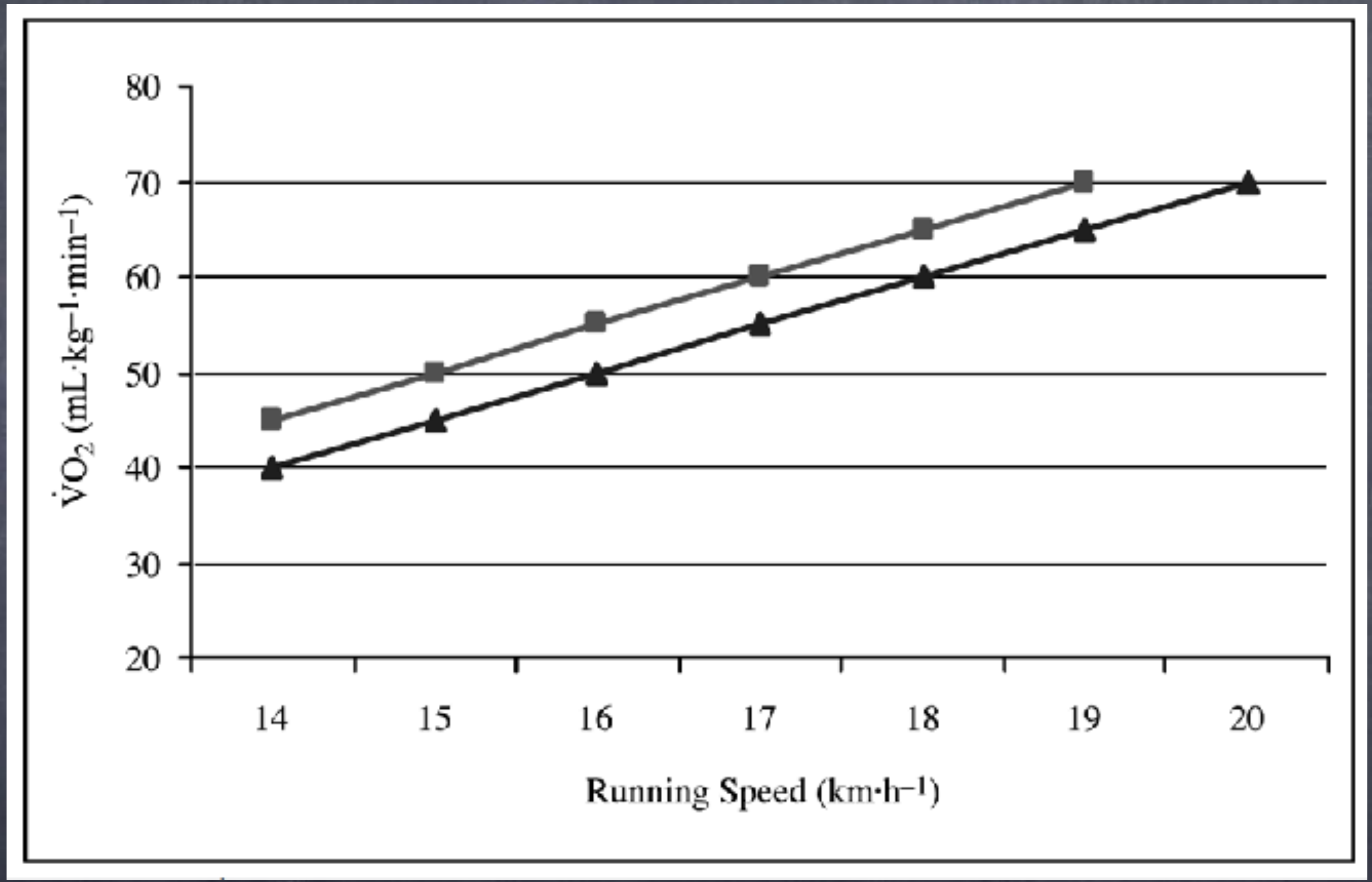
Schmidt-Nielsen 1972

Perchè ci interessa?

- $v_{max} = \frac{\dot{V}O_{2max}}{C}$
- $v = \frac{f\dot{V}O_{2max}}{C}$

di Prampero 1986

Perchè ci interessa?



Jones 2006

Costo e Allenamento

MARGARIA ET AL.

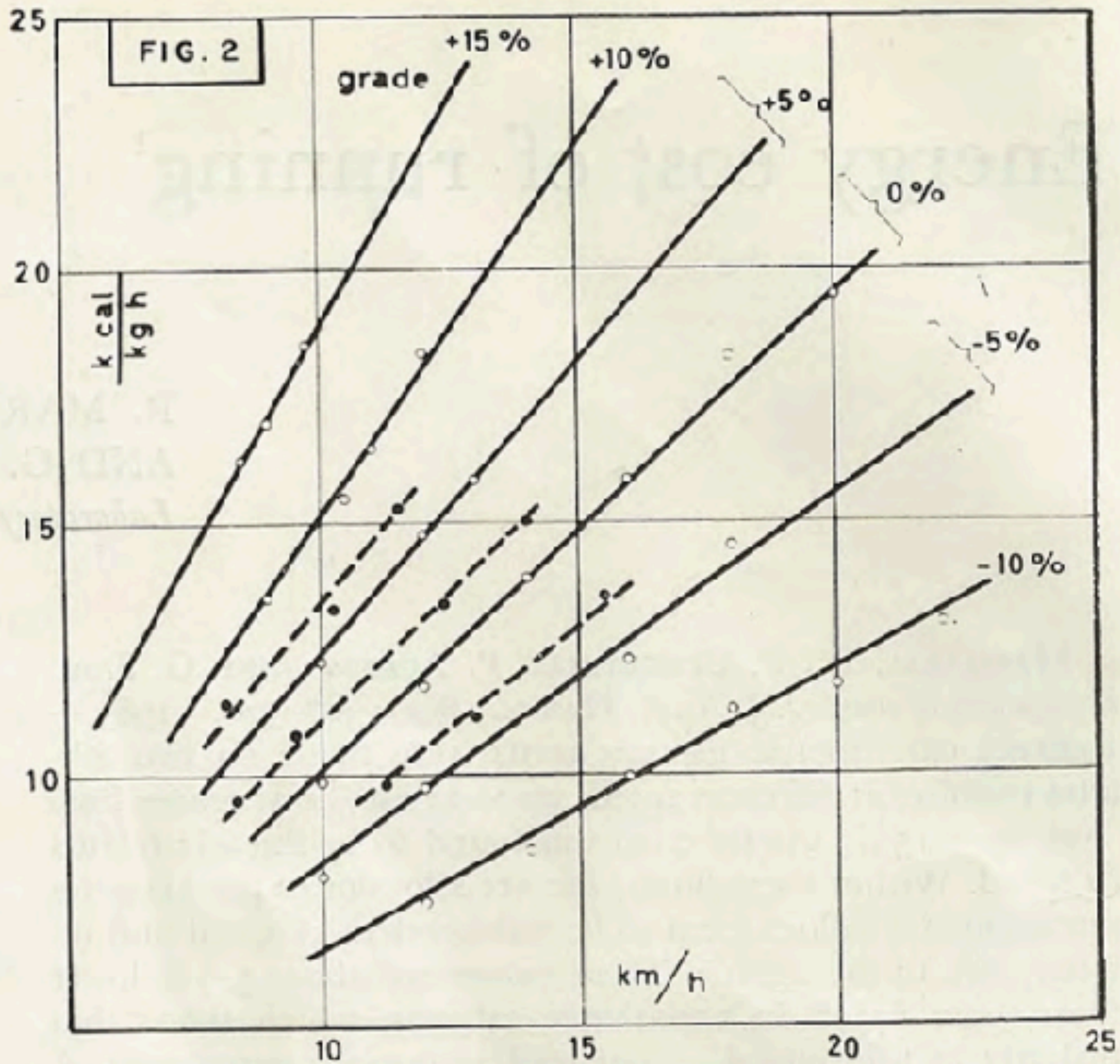
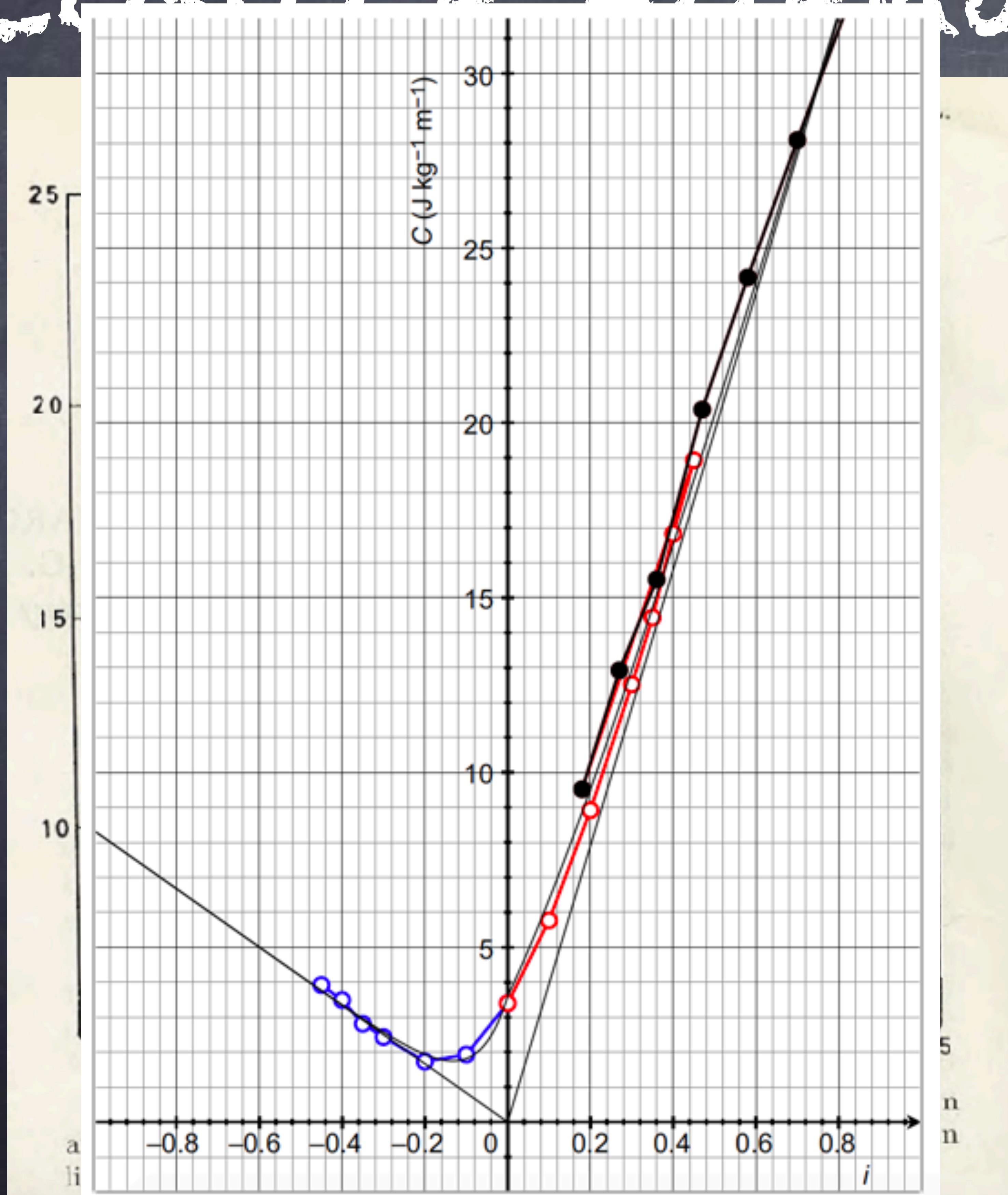


FIG. 2. Energy expenditure in running as a function of speed in athletes (solid lines); data on nonathletes (1) are also given (broken lines).

Margaria et al. 1963

Costo e Allenamento



In Minetti & Pavei 2018

Costo e Allenamento

A CMIT
I) 64.5 min @70%GET
II) 58.5 min @80%GET — 34.1±3.1 km
III) 54 min @90%GET

B DHIT
I) 18x1min @120%GET, rec 2min @65%GET
II) 18x1min @130%GET, rec 2min @65%GET
III) 18x1min @140%GET, rec 2min @65%GET

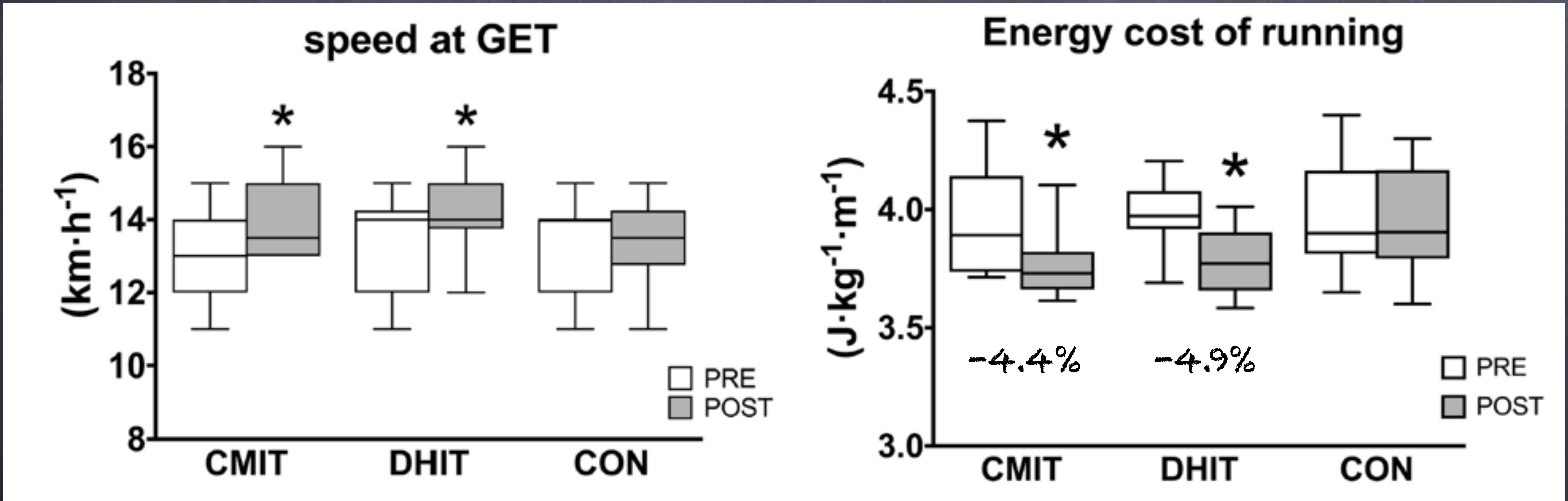
33.3±2.8 km

C CON — Quello che fate di solito — 51.8±13.4 km

Pugliese et al. 2018

Costo e Allenamento

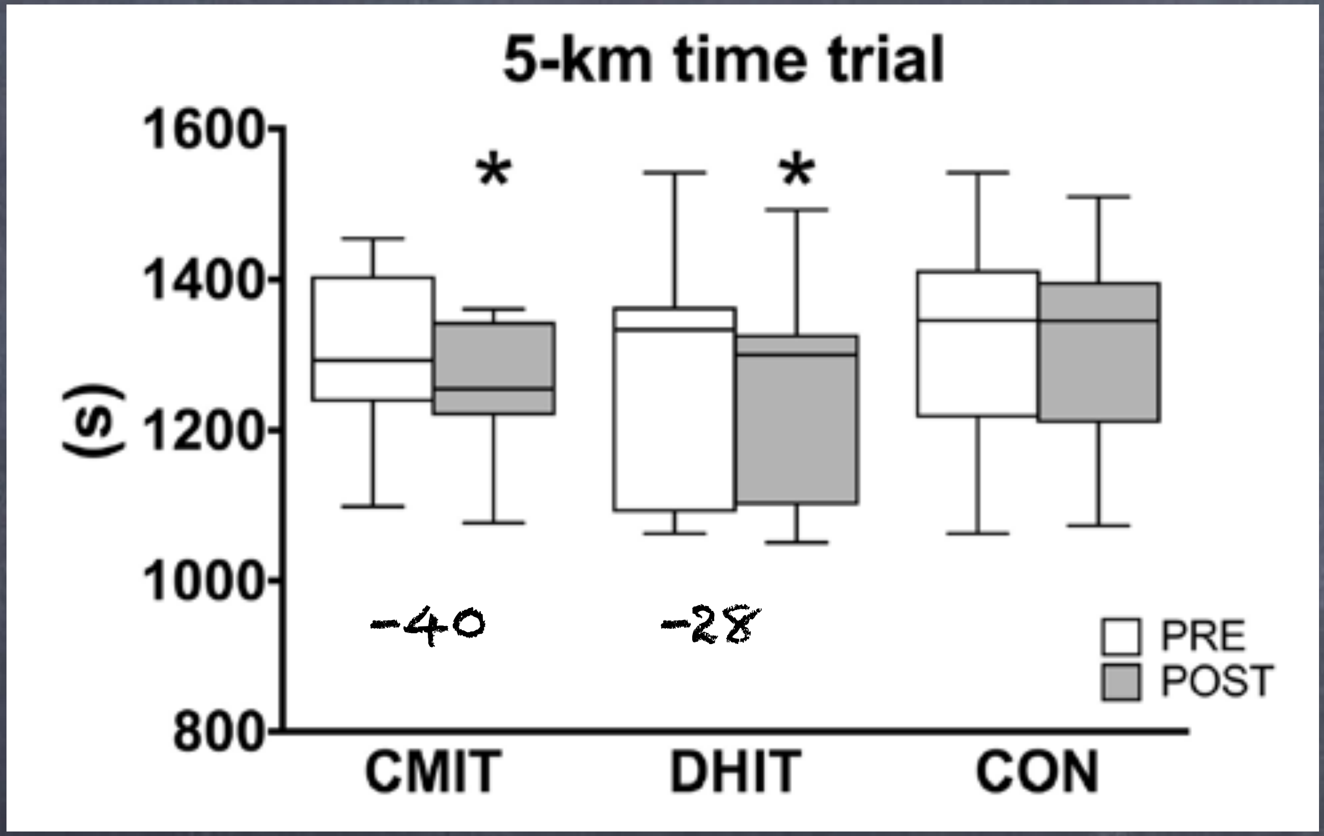
- $\dot{V}O_{2max}$, GET nessuna variazione



Pugliese et al. 2018

Costo e Allenamento

- $\dot{V}O_{2max}$, GET nessuna variazione



- Miglioramento neuromuscolare sia come stiffness, sia come reclutamento/sincronizzazione

Pugliese et al. 2018

Costo e Allenamento

- Forza -

- Qualsiasi tipo di Allenamento di Forza può portare miglioramenti al costo fino al 10%
- L'allenamento con Alti carichi/Basse Ripetizioni (Forza massima) sembra leggermente superiore al Pliometrico o altre espressioni di Forza (e.g. resistenza alla)
- l'allenamento dovrebbe essere protratto per almeno 8/10 settimane con almeno 2 sedute/settimana

Barnes & Kilding 2015

Costo e Allenamento

- Forza -

- Aumento della forza per sé
- Miglior reclutamento e sincronizzazione
- Coordinazione e minori co-attivazioni
- Aumento della Stiffness muscolo-tendina

Barnes & Kilding 2015

Costo e Allenamento

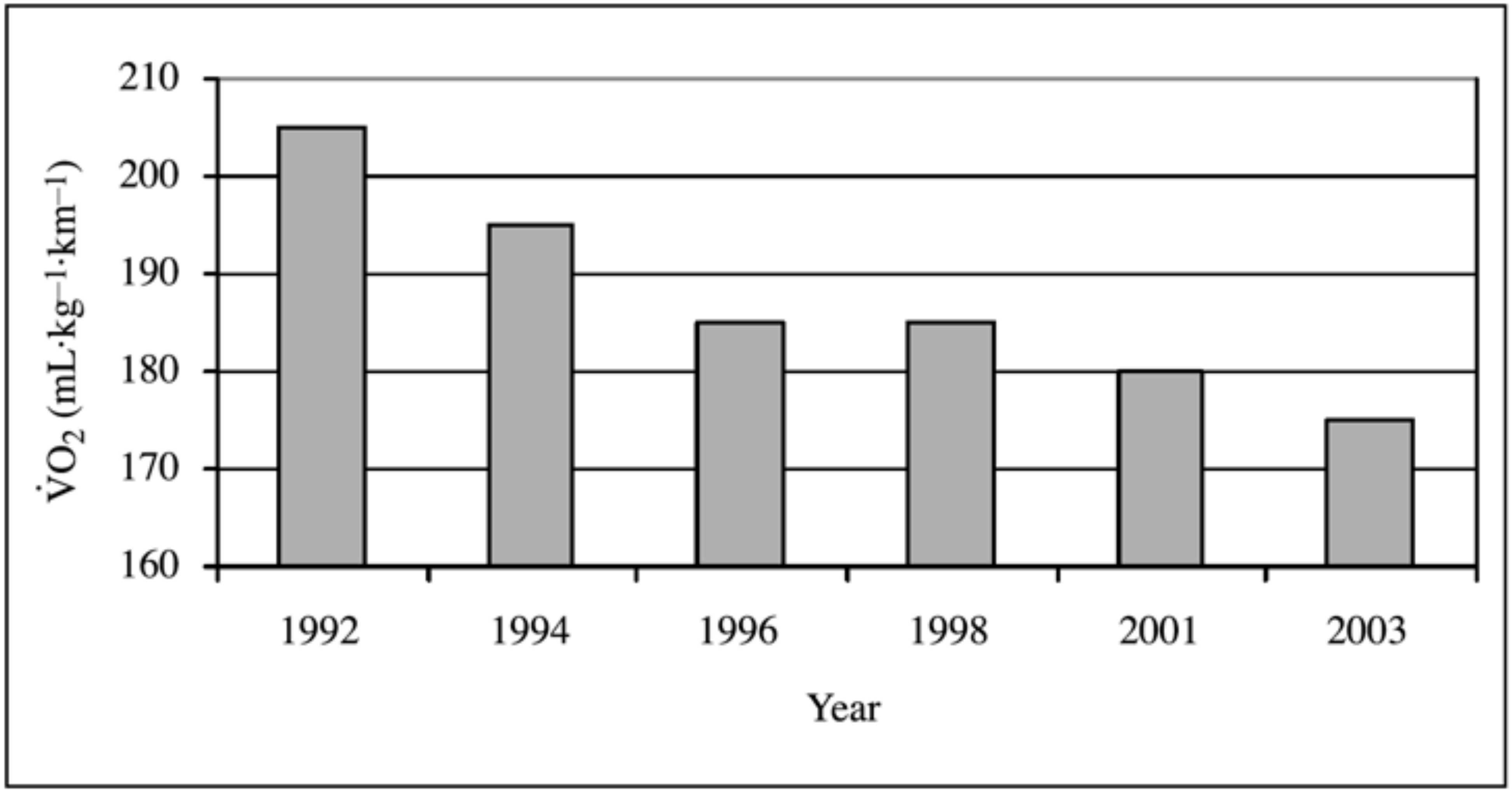


Figure 4. PR's $\dot{V}O_2$ While Running at 16.0 km·h^{-1}, 1992-2003

Jones 2006

Costo e Allenamento

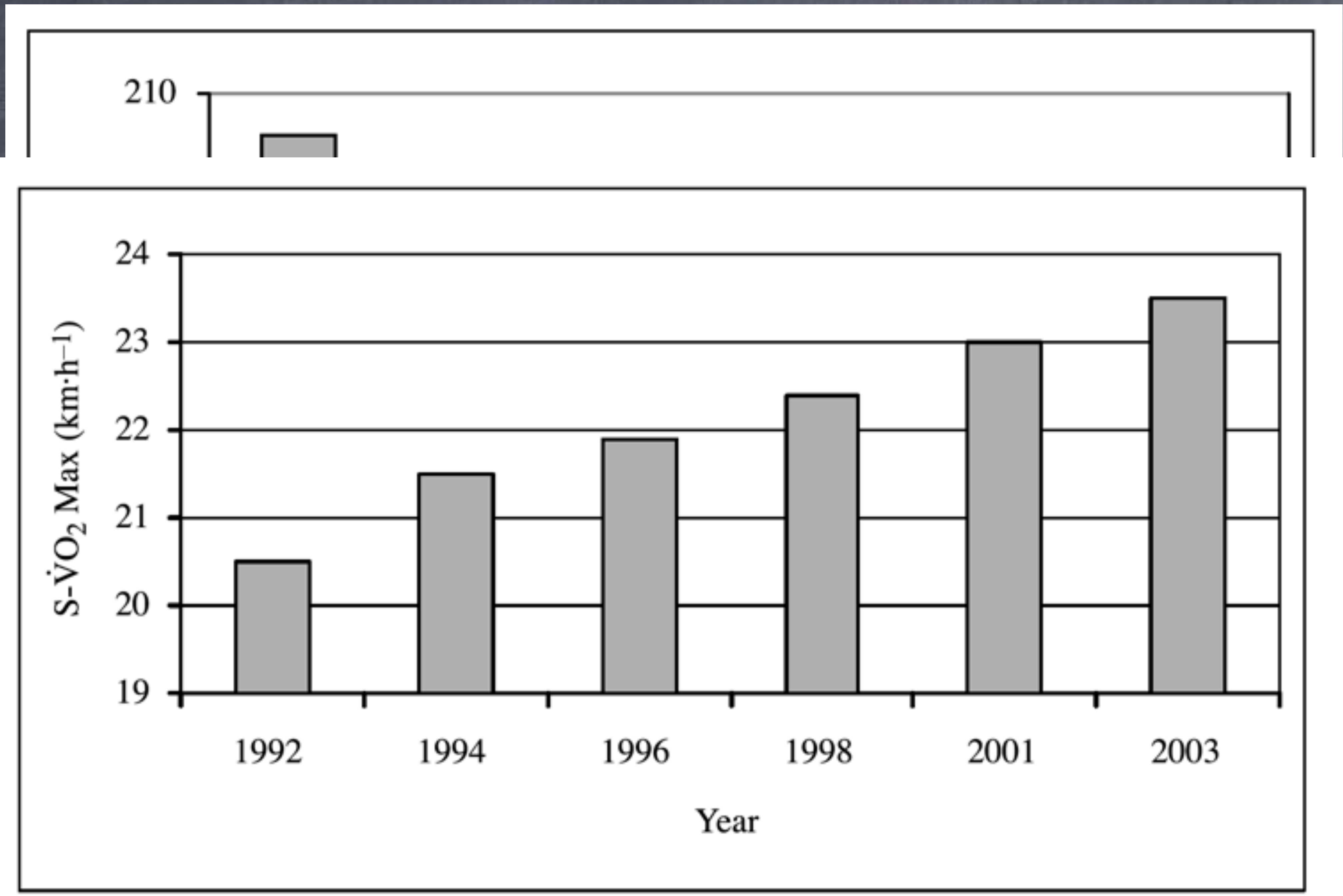


Figure 5. PR's Running Speed at $\dot{V}O_2$ max, 1992-2003

Jones 2006

Costo e Allenamento

Table 1 Basic characteristics of the subjects and their performances on the marathon and the half-marathon

Subjects	Age (yy)	Height (cm)	Body mass (kg)	Resting $\dot{V}O_2$ (ml min^{-1} kg^{-1})	Resting fh (min^{-1})	Marathon time (s)	Half-marathon time (s)
KA							
Mean	29	172	59.4	5.7	59	7,637	3,640
SD	4	7	5.8	1.4	4	87	31
EC							
Mean	33	175	61.1	6.7	65	7,704[a]	3,717
SD	4	5	4.5	2.3	11	75	47

Concerning performances, as expressed in IAAF official timing rules, the average marathon times corresponded to 2 h 7 min and 17 s (SD 1 min 27 s) in KA, and 2 h 8 min 24 s (SD 1 min 15 s) in EC, whereas the average half-marathon times corresponded to 60 min and 40 s (SD 31 s) in KA and 61 min and 57 s (SD 47 s) in EC

$\dot{V}O_2$ oxygen consumption, *fh* heart rate, *KA* top-level Kalenjins ($n = 10$), *EC* European controls ($n = 9$)

Tam et al. 2012

Costo e Allenamento

Table 1 Basic characteris

Subjects	Age (yy)	…	…ion …)	Half-marathon time (s)
KA				
Mean	29			3,640
SD	4			31
EC				
Mean	33			3,717
SD	4			47

Concerning performances, a … 7 min and 17 s (SD 1 min 27 s) in KA, and 2 h 8 min … min and 40 s (SD 31 s) in KA and 61 min and 57 s (…

$\dot{V}O_2$ oxygen consumption, …

Table 3 Energy cost of running (C_r) (mean and standard deviations) at the various investigated speeds (v)

V (km h^{-1})	C_r (J kg^{-1} m^{-1})		C_r (ml kg^{-1} km^{-1})		p
	KA	EC	KA	EC	
12					
Mean	3.48	3.44	167	165	0.766
SD	0.26	0.28	13	14	
14					
Mean	3.56	3.53	170	169	0.853
SD	0.30	0.29	15	14	
16					
Mean	3.67	3.61	176	173	0.748
SD	0.38	0.41	18	20	
18					
Mean	3.72	3.71	178	178	0.943
SD	0.34	0.34	16	16	

Tam et al. 2012

Costo e distanza

C (ml02/(kg km))

N	7	8	9	10	11	12
D (km)	0	15	0	32	0	42
VIG	165.9	167.3	161.7	168.4	158.6	170.5
CEN	194.1	183.5	180.1	193.4	181.1	188.9
RAT	185.7	181.5	175.1	183.6	176.4	182.9
COU	170.9	166.8	161.2	175.1	156.9	179.6
LAC	185.0	190.7	187.3	181.4	180.6	192.7
BER	159.9	155.3	171.1	167.0	160.3	162.2
BUR	182.2	177.3	179.9	180.8	171.6	179.3
PEB	160.3	168.7	162.0	178.0	155.5	171.7
MAU	161.9	162.9	153.0	167.1	144.5	162.5
MON	191.3	197.2	177.2	212.3	183.4	196.3
Mean	175.7		170.9		166.9	
SD	13.4		10.9		13.4	
Mean		175.1		180.7		178.7
SD		13.2		13.9		11.9
P				<0.05		<0.001

340 m indoor

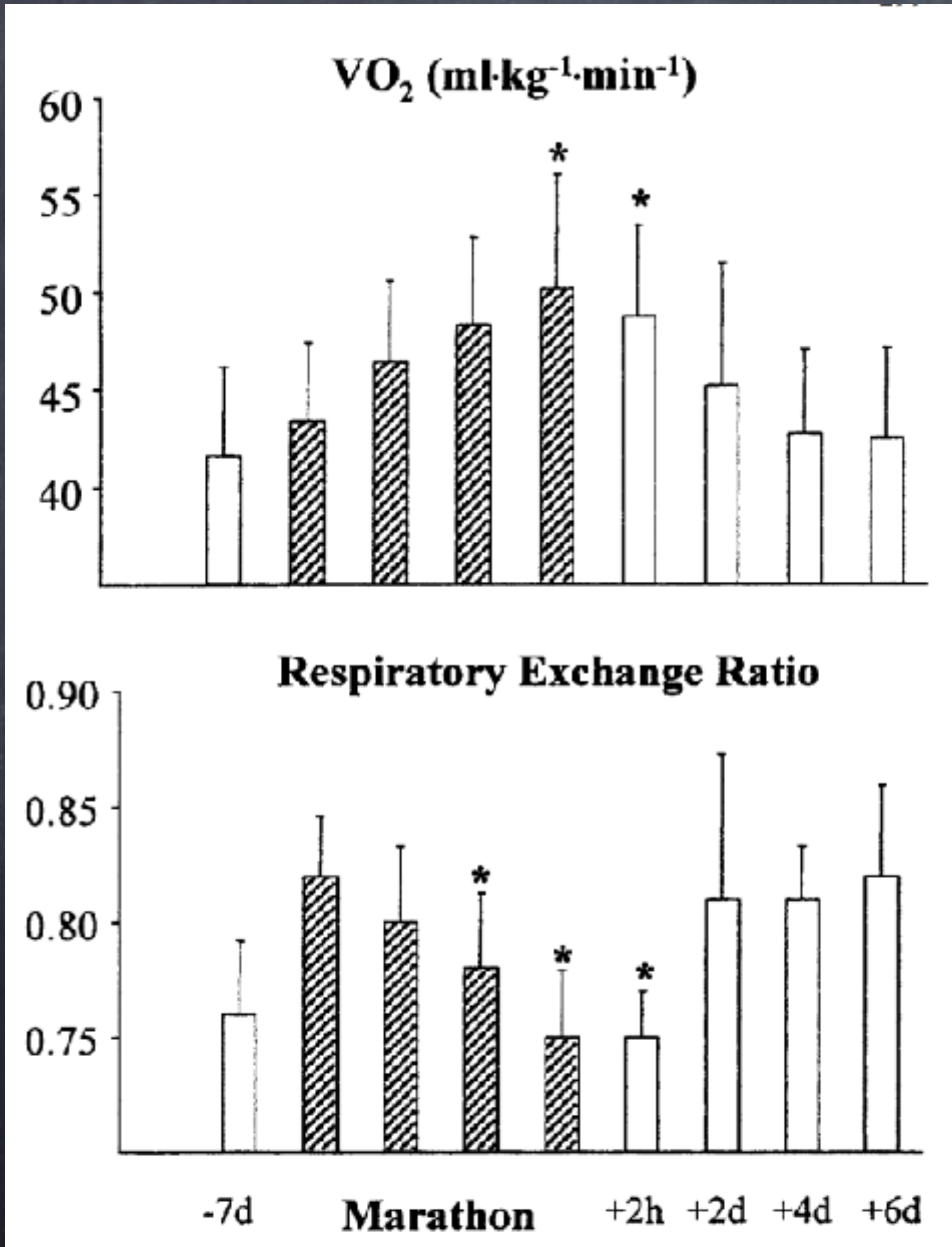
15-30gg .. 2x

+0.12% Km

C +5%

Bruekner et al. 1991

Costo e distanza

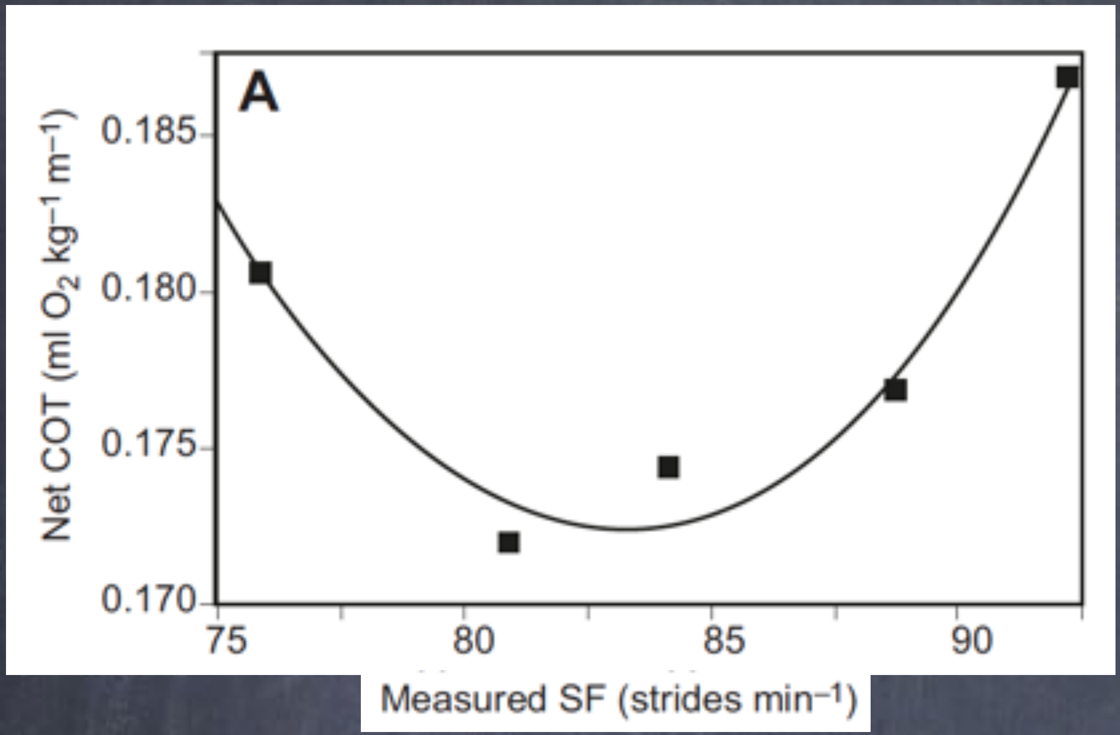


0; 13; 26; 42 Km

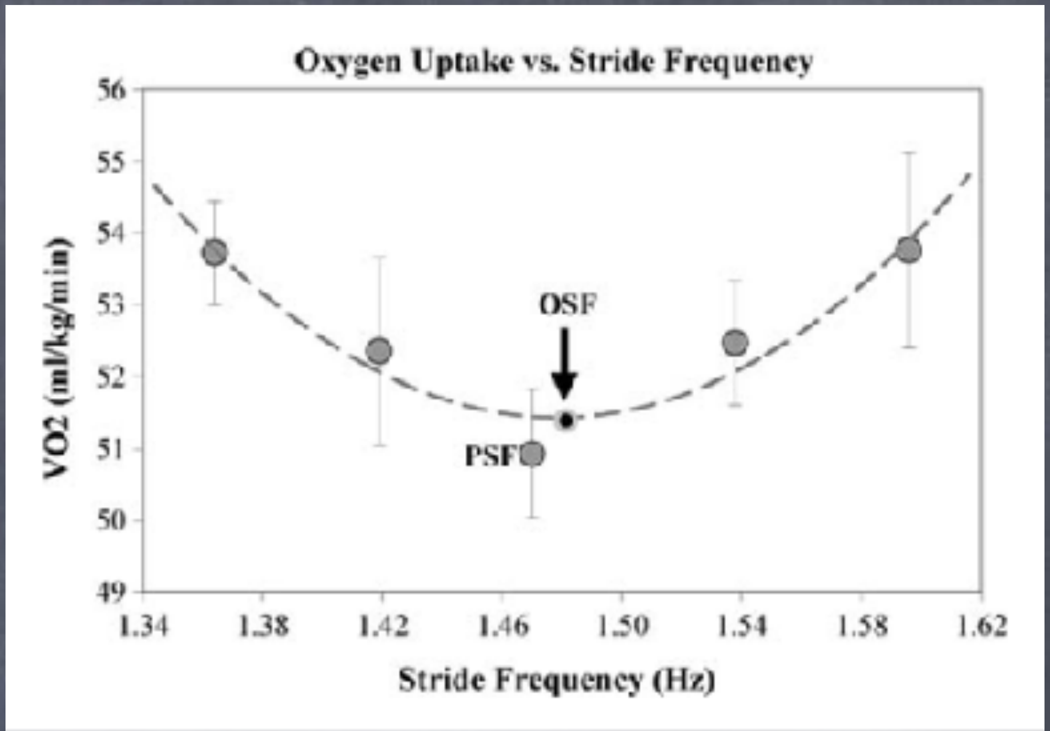
- No cambiamenti in cinematica o meccanica
- Diverso combustible
- Temperatura corporea
- Possibile danno muscolare

Kyröläinen et al. 2000

Costo e cinematica



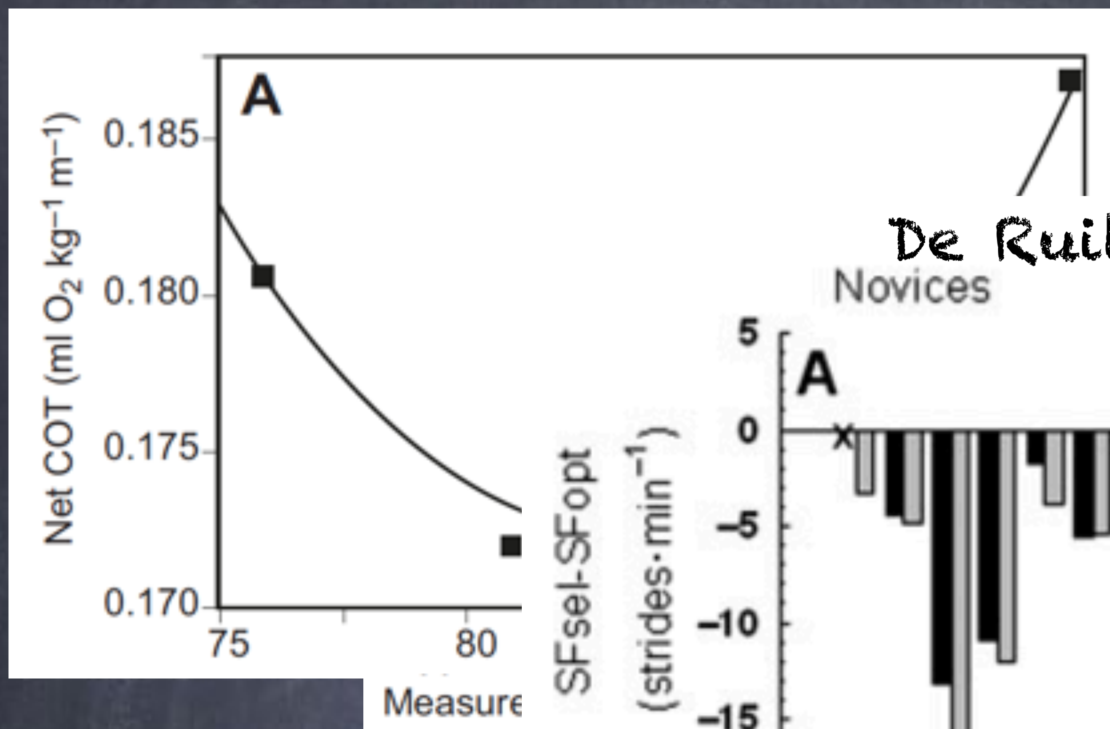
Lieberman et al. 2015

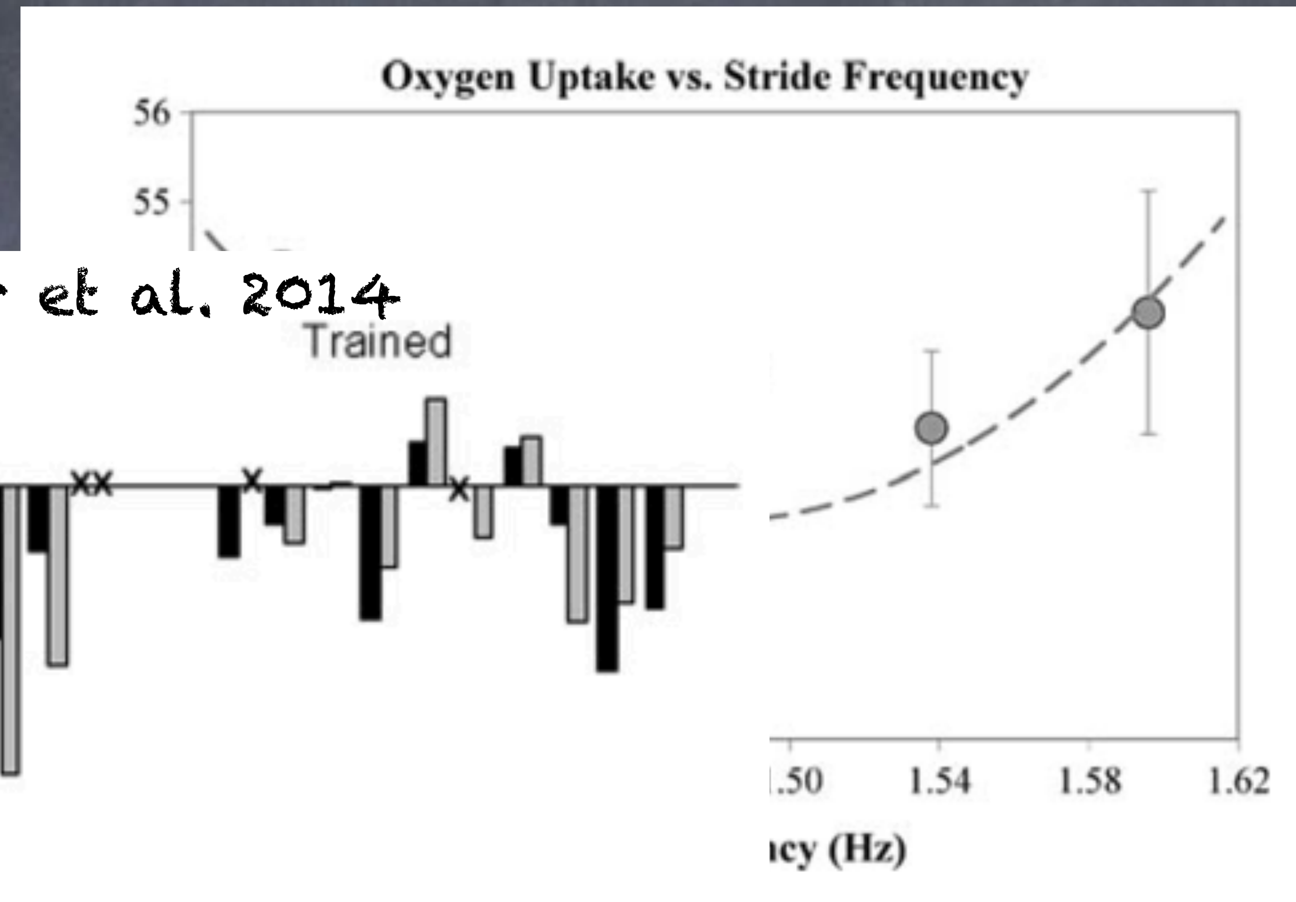


Hunter & Smith 2007

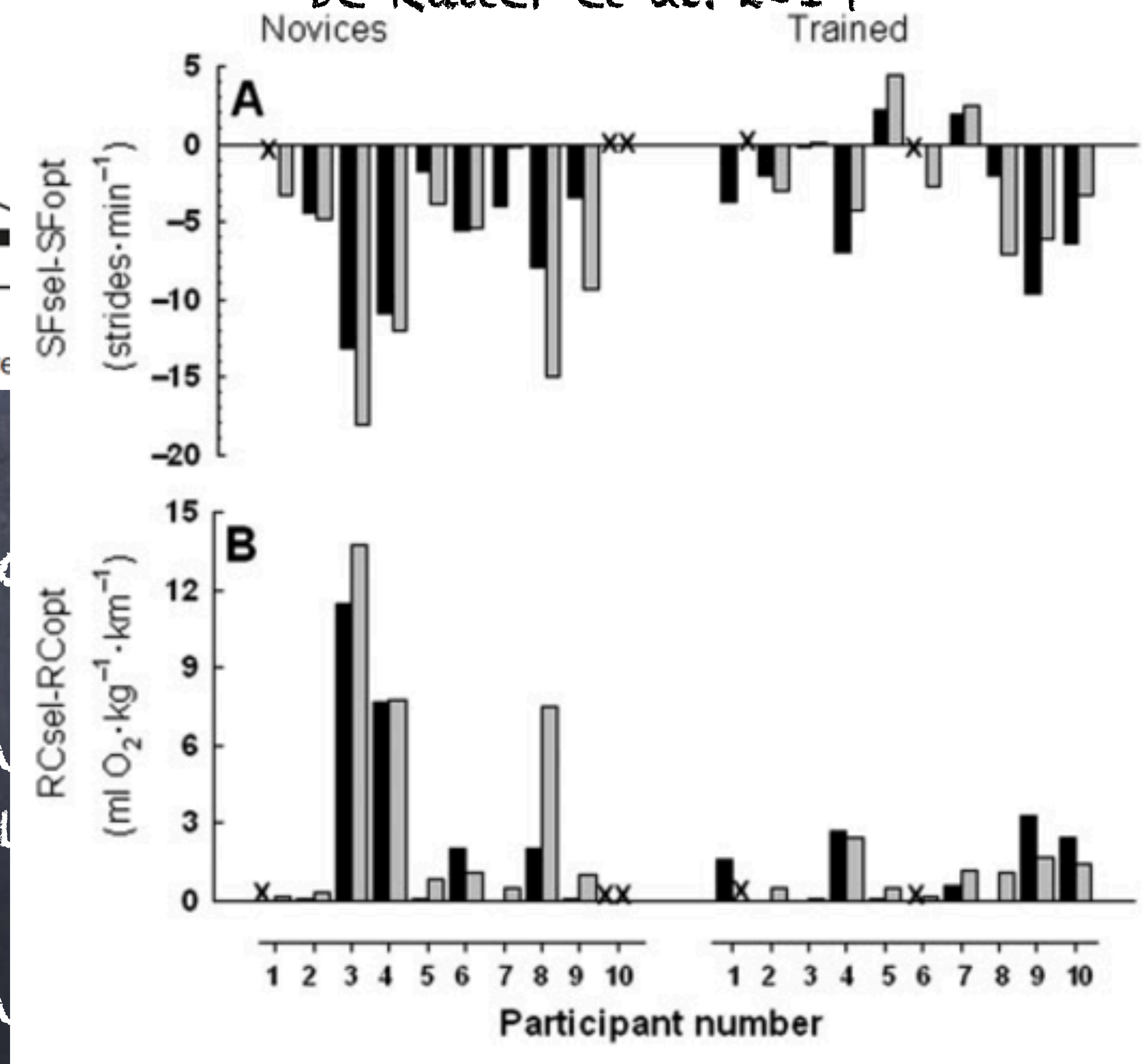
- Minimizzare lavoro meccanico (Cavagna et al. 1988)
- Ottimizzare l'apporto dell'Energia Elastica (eg. Cavagna et al. 1997)
- Ottimizzare lo spring-mass model e derivati (eg. Farley et al. 1991; Daley & Usherwood 2010)

Costo e cinematica





De Ruiter et al. 2014



- Minimizza ... et al. 1988)
- Ottimizza ... stica (eg. Cavagna et al
- Ottimizza ... erivati (eg. Farley et al. 1991; Daley & Usherwood 2010) ...nter & Smith 2007 Lieberman et al. 2015

Costo e cinematica

- Tempo di Contatto (4 a 4, ma in 2 migliora con contatto più lungo, in 2 più corto) (Moore 2016)
- Meno varia la velocità nell'appoggio (quindi le forze antero-posteriori), meglio è (eg. Moore 2016)
- angoli discordanti, manca un trend e nel complesso non spiegano differenze (Kyröläinen et al. 2000, 2001; Lacour & Bourdin 2015)
- forefoot vs. rearfoot strikers non c'è evidenza di differenza (Moore 2016)

Prendiamo o Perdiamo Quota?

C Migliora	C Non Migliora
9	11
1 LHTH 8 LHTL (6 simulata)	6 LHTH 4 LHTL (5 simulata)

- Adattamenti CardioRespiratori?
- Mitocondriali?

Barnes & Kilding 2015

Costo/Economia

NON è Sinonimo

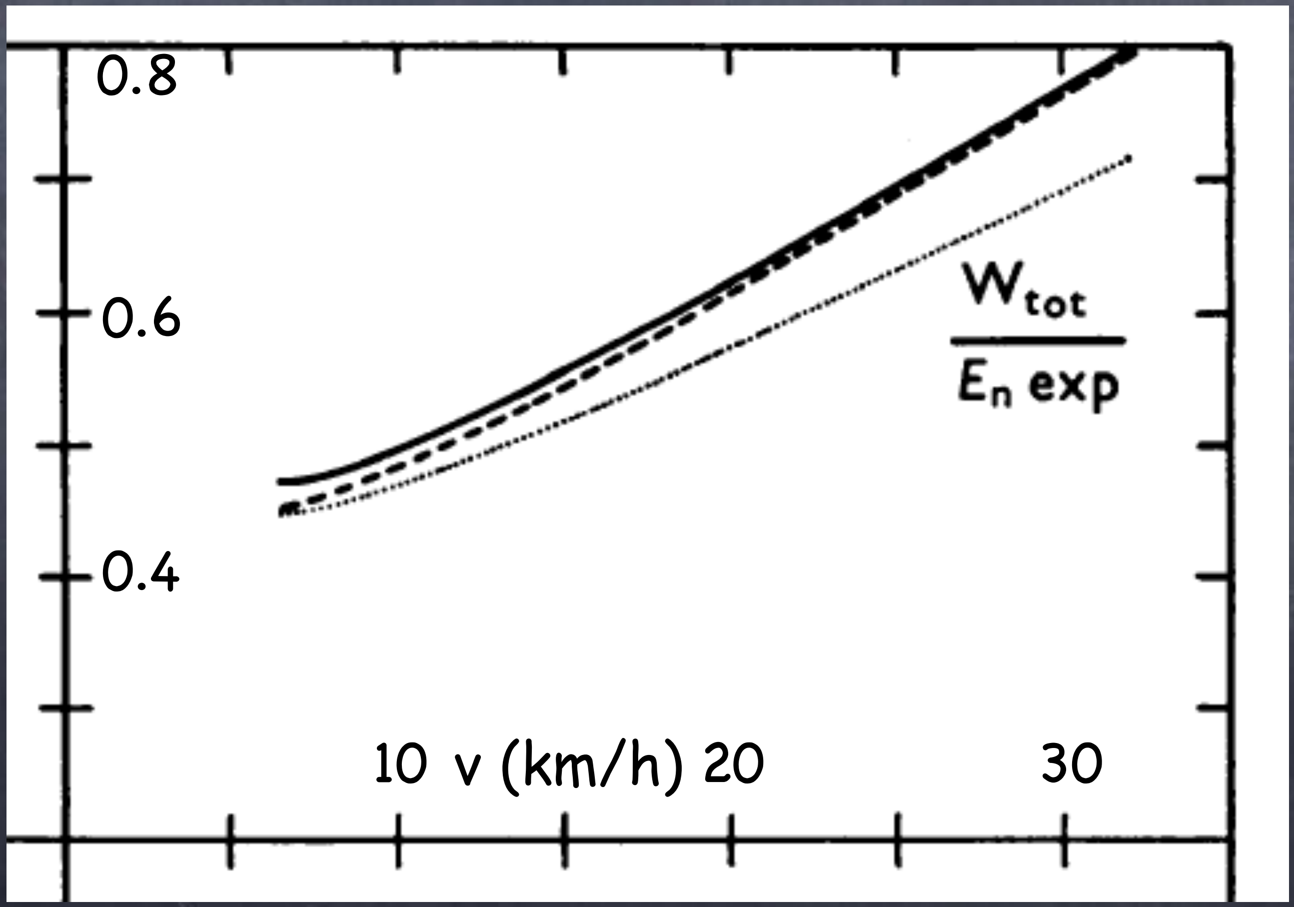
di Efficienza

Efficienza (o Rendimento)

$$\text{Efficienza} = \frac{\text{Output Meccanico}}{\text{Input Chimico}}$$

Efficienza (o Rendimento)

$$\text{Efficienza} = \frac{\text{Lavoro Meccanico} \quad J/(kg\ m)}{\text{Costo} \quad J/(kg\ m)}$$



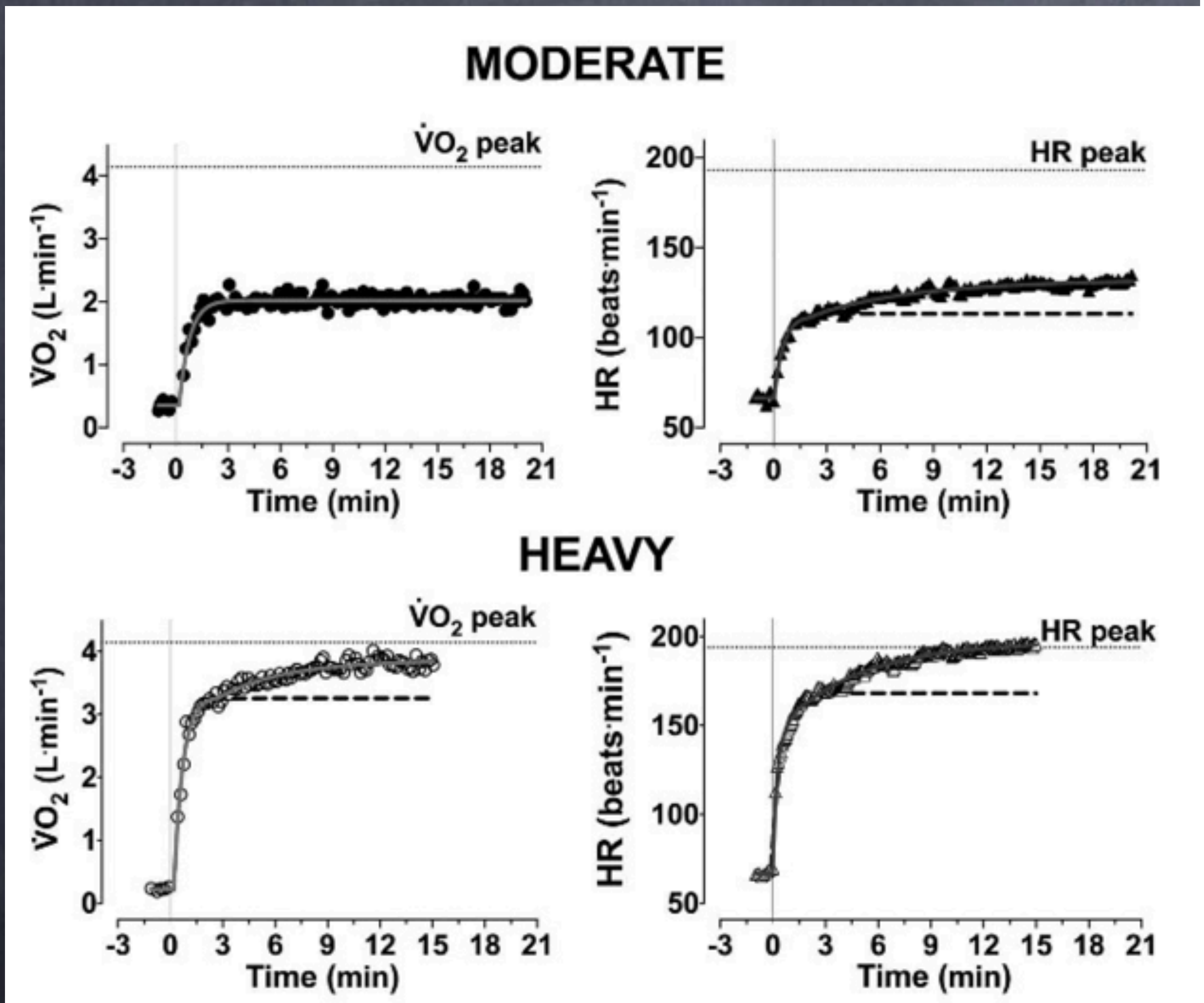
Cavagna & Kaneko 1977

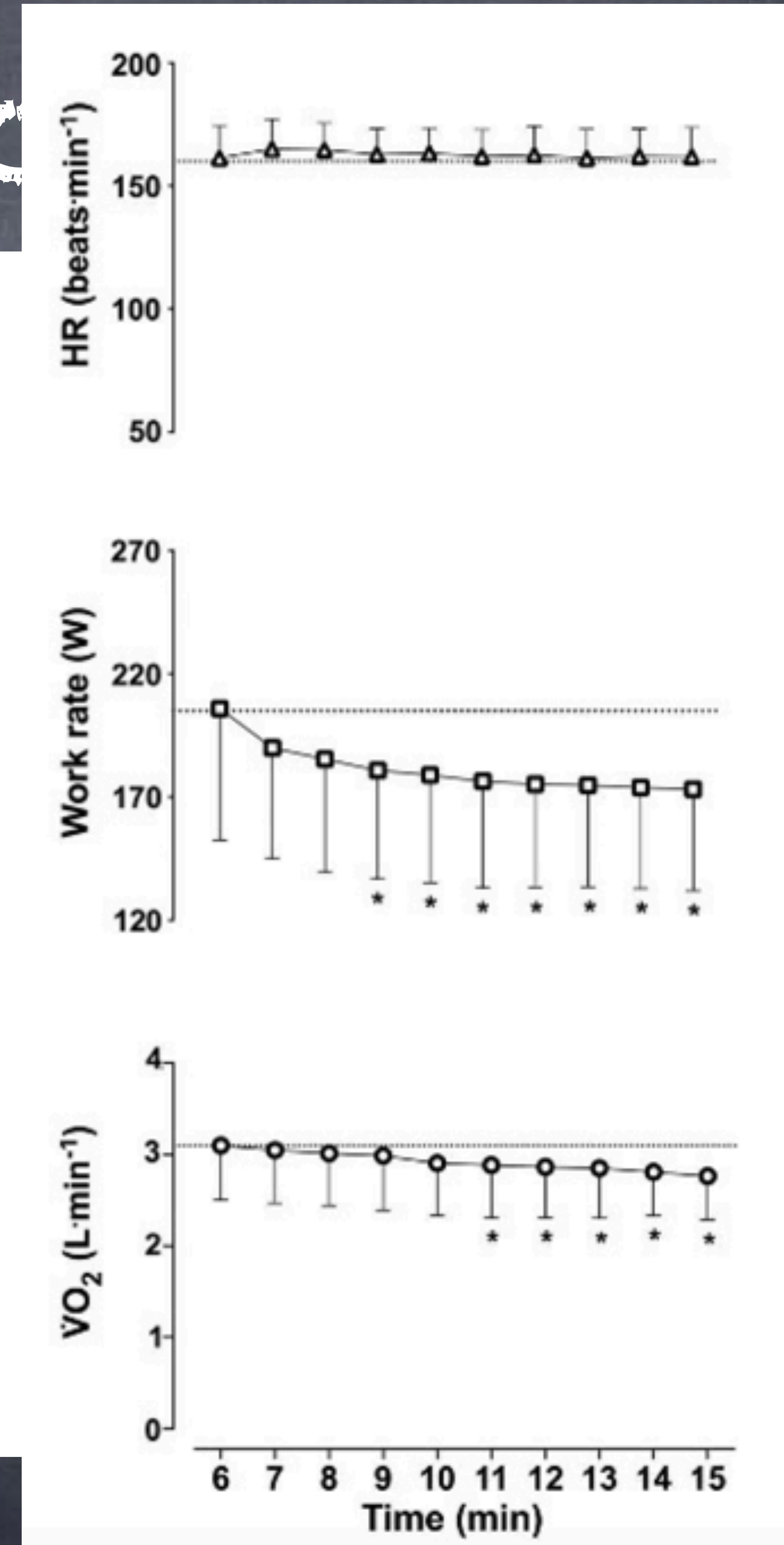
Strumenti Surrogati?

Frequenza Cardiaca?

- Fick
- Linearità..

Strumenti Surro





Zuccarelli et al. 2018

Strumenti Surrogati?

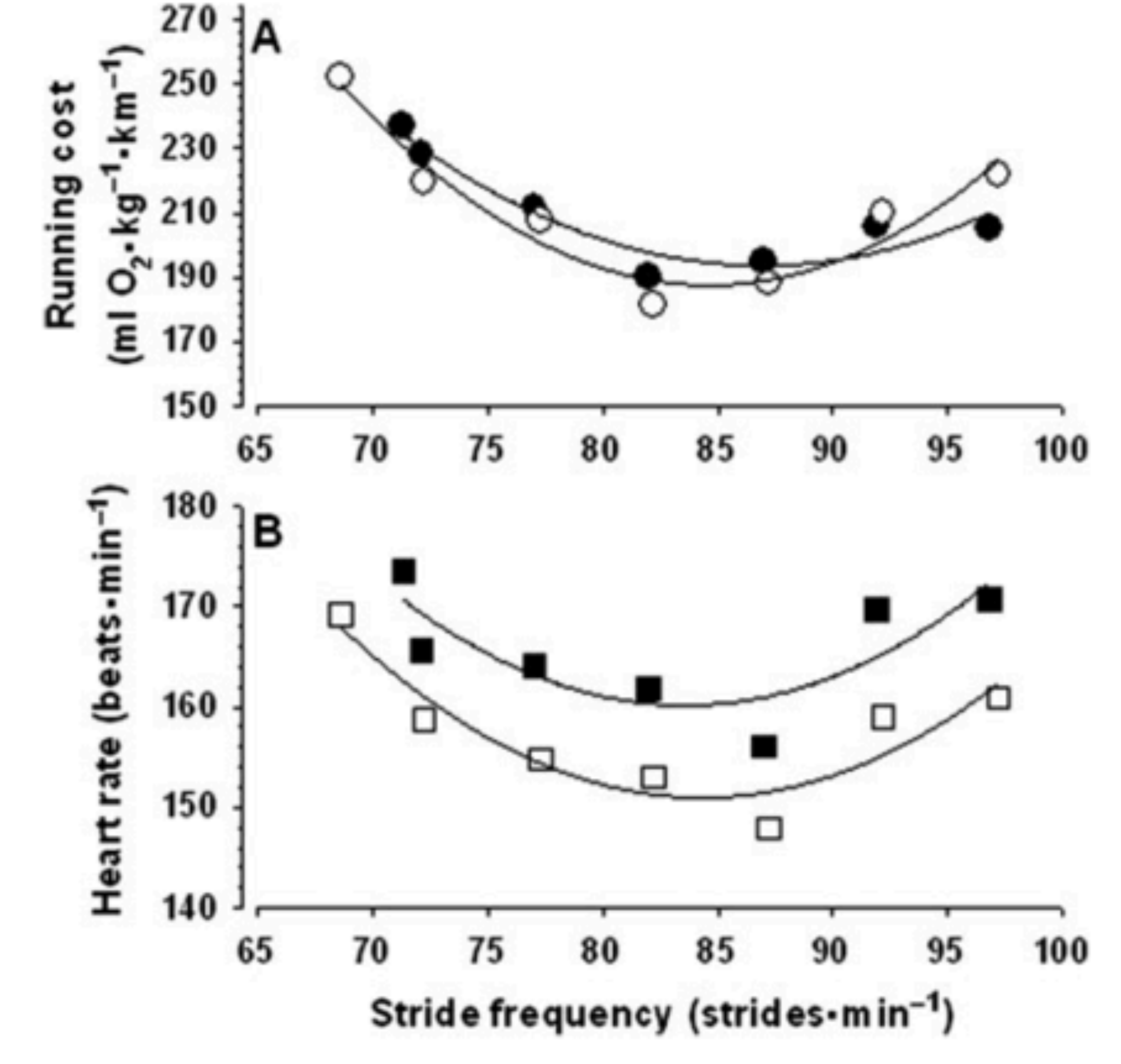


Figure 3. Running cost (A) and heart rate (B) as a function of stride frequency, obtained on two different days (black and white) in a trained runner (no. 10). Irrespective of the relationship used, optimal stride frequency was near 85 strides·min^{-1}.

De Ruiter et al. 2014

Per queste ragioni:
Non userei
la frequenza Cardiaca
per valutare/calcolare
il Costo

Costo e scarpe

- è solo 1 esempio, attuale -

Hoogkamer et al. 2018

- è solo

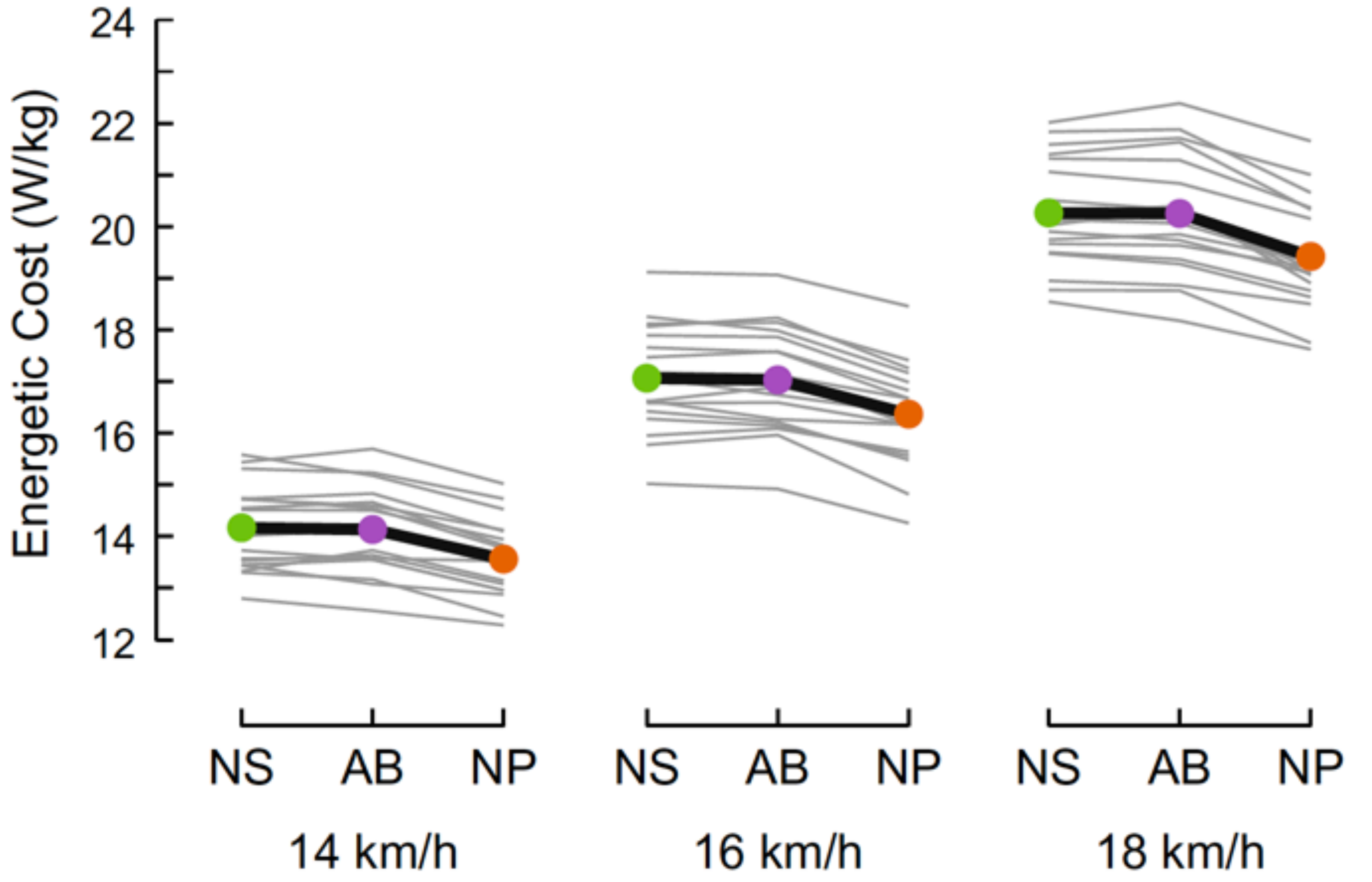


Fig. 4 Over the three velocities tested, runners in the NP shoes used an average of 4.16% less metabolic energy than the NS shoes and 4.01% less than in the AB shoes (both $p < 0.001$). The AB and NS shoes were similar ($p = 0.34$). Values are the gross energetic cost of running. *NS* Nike Zoom Streak 6, *AB* adidas adizero Adios BOOST 2, *NP* Nike prototype

Hoogkamer et al. 2018

Costo e scarpe

- è solo 1 esempio, attuale -

Barnes & Kilding 2019

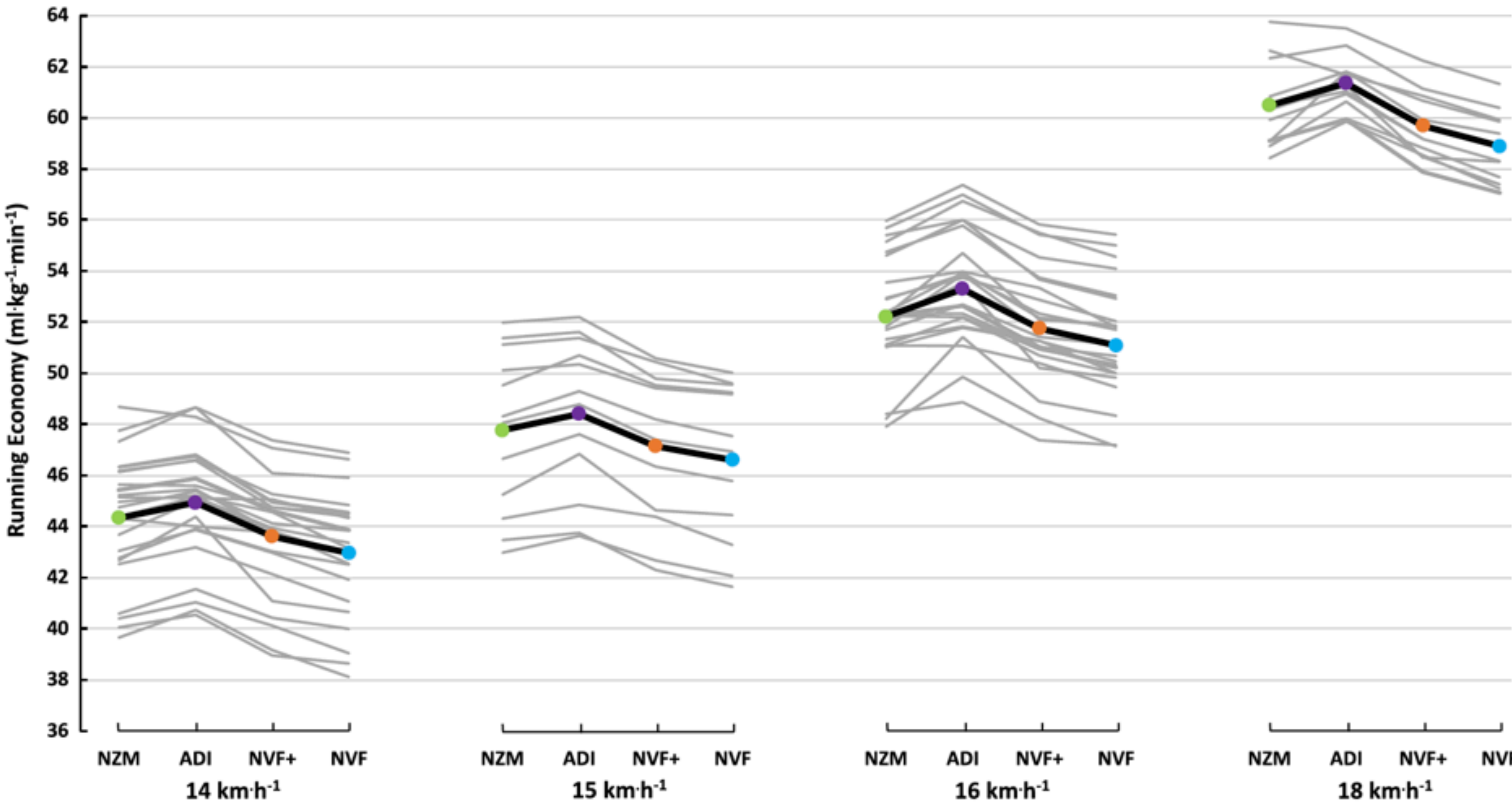


Fig. 2 Rates of VO_2 at 14, 15, 16, and 18 km·h^{-1} in each of the four shoe conditions: Nike Zoom Matumbo 3 (NZM), Adidas Adios BOOST 3 (ADI), Nike Zoom Vaporfly 4% (NVF), and NVF plus weight to match the mass of ADI shoe condition (NVF+). Over the four testing velocities, runners in the NVF shoes had 4.2% better running economy (lower VO_2) compared with ADI and 2.6% compared with NZM (both $p < 0.008$). When weighted to match the mass of ADI, the NVF+ was 2.9% more efficient than ADI across all running speeds ($p < 0.001$). *VO_2* oxygen uptake, *NZM* Nike Zoom Matumbo 3, *ADI* Adidas Adios BOOST 3, *NVF* Nike Zoom Vaporfly 4%, *NVF+* NVF plus weight to match the mass of the ADI shoe condition

Barnes & Kilding 2019


BASTA!