Fisiologia del triathlon

Fisiologia della prestazione sportiva

Università degli Studi di Verona
Scienze Motorie
aa 2014-2015

Storia del Triathlon

- Iniziò come allenamento per i runners .
- Primo evento conosciuto con successione nuoto / bici/ corsa si tenne a San Diego nel 1974.
- Il primo “Ironman” si tenne nel 1978 (12 uomini).
- Prima World Championships nel 1989.
- Divenne Sport Olympico nel 2000.

Distanze Triathlon

- Sprint – 1000m nuoto, 10-15 miglia bici, 5Km corsa
- Olympico – 1.5 Km nuoto, 40 Km bici, 10 Km corsa
- Ironman – 4 Km nuoto, 112 Km bici, 42.195 Km corsa

- Kids' Triathlon (età 7-14)
  - 100 to 400 yd. nuoto
  - 1 to 6 mile bici

Table I. Triathlon race distances (km)

Event	Distance	Swim	Bike	Run
Long	Ironman	3.8	180	42
	Middle distance	2.5	80	20
Short	Triathlon[a]	1.5	40	10
	Sprint	0.75	20	5

a. Previously known as Olympic or Classic distance.

Equipaggiamento

Standard

- ✓ Occhiali
- ✓ Bici
- ✓ Casco
- ✓ Scarpe da corsa

Optional

- ✓ Muta
- ✓ Scarpe e pedali a sgancio rapido
- ✓ Aerobars
- ✓ Ruote lenticolari
- ✓ Bustine ermetiche/ lacci elastici

Fattori e performance

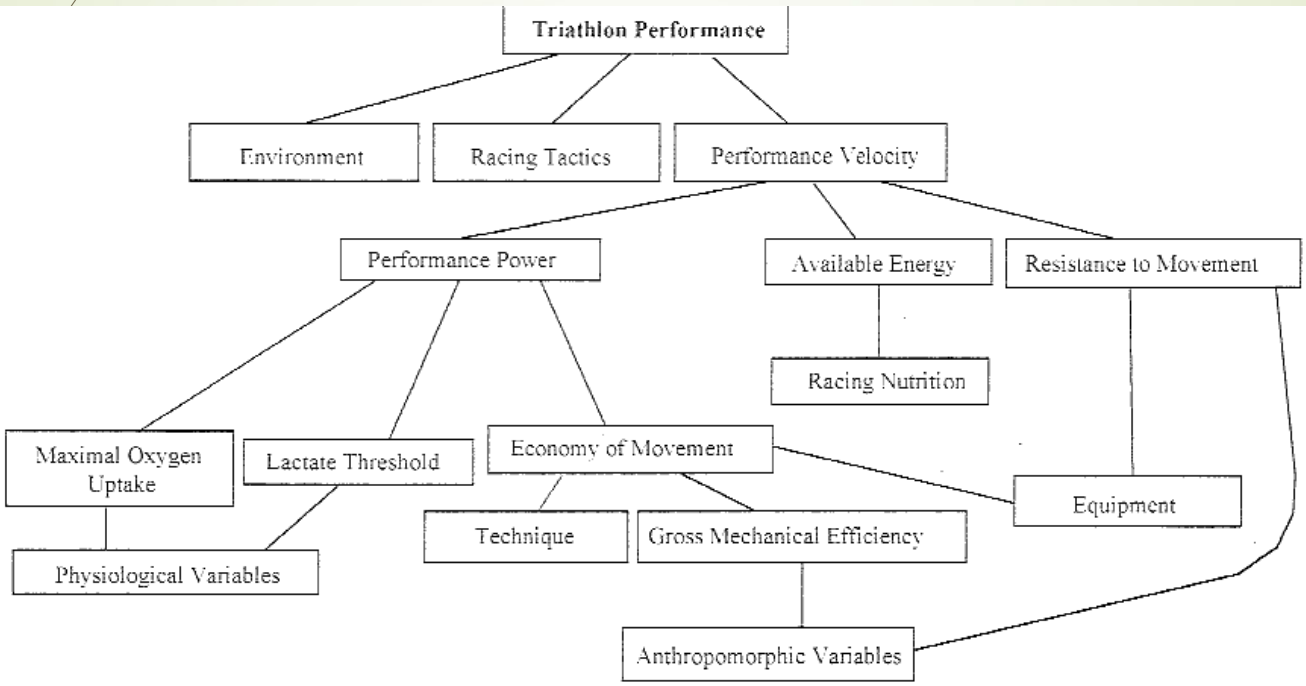


FIG. 59–1. Interrelationship between the major factors determining triathlon performance.

- Nuotata di gruppo ~ 16-23% riduzione del *drag*
- Tempo transizione 1min *sprint;* 1-3min *ironman*

Table II. Average race completion times (h:min:sec) at the 2001 International Triathlon Union World Championships for the top 10 elite and 20- to 24-year-old age-group (AG) male triathletes (data down to 50th finisher not available for all groups) in Ironman and triathlon distance events (draft-legal for elite athletes and non-drafting for AG in standard distance cycle competition)

Distance	Swim		Cycle		Run		Overall	
	elite	AG	elite	AG	elite	AG	elite	AG
Ironman	0:51:10 ± 0:01:40$_x$ [a]	1:01:11 ± 0:05:39$_x$ [b]	4:43:05 ± 0:04:39$_x$ [a]	5:13:09 ± 0:14:11$_x$ [b]	2:53:52 ± 0:04:19$_x$ [a]	3:32:00 ± 0:18:42$_x$ [b]	8:31:09 ± 0:05:06$_x$ [a]	09:52:00 ± 0:31:39$_x$ [b]
Triathlon (senior)	0:18:21 ± 0:00:14$_y$ [a]	0:19:11 ± 0:01:12$_y$ [b]	0:56:53 ± 0:00:17$_y$ [a]	1:00:09 ± 0:01:20$_y$ [b]	0:32:01 ± 0:00:22$_y$ [a]	0:36:52 ± 0:01:17$_y$ [b]	1:48:33 ± 0:00:49$_y$ [a]	2:00:33 ± 0:01:41$_y$ [b]
Triathlon (junior)	0:19:11 ± 0:00:30$_z$ [a]	0:18:47 ± 0:00:50$_y$ [b]	0:58:09 ± 0:00:29$_z$ [a]	1:00:23 ± 0:00:13$_y$ [b]	0:33:52 ± 0:00:40$_z$ [a]	0:37:35 ± 0:01:20$_y$ [b]	1:52:33 ± 0:00:41$_z$ [a]	2:01:23 ± 0:02:32$_y$ [b]

Different superscripts (**a** and **b**) indicate significant ($p < 0.01$) difference (elite *vs* AG) in each discipline (swim, cycle, run) and overall at the 95% confidence level; different subscripts (**x**, **y** and **z**) indicate significant ($p < 0.01$) difference [Ironman *vs* standard (senior) *vs* standard (junior)] in each discipline (swim, cycle, run) and overall at the 95% confidence level.

Table III. Average race completion times (h:min:sec) at the 2001 International Triathlon Union World Championships for the top 10 elite and 20- to 24-year-old age-group (AG) female triathletes (data down to 50th finisher not available for all groups) in Ironman and triathlon distance events (draft-legal for elite athletes and non-drafting for AG in standard distance cycle competition)

Distance	Swim		Cycle		Run		Overall	
	elite	AG	elite	AG	elite	AG	elite	AG
Ironman	0:58:02 ± 0:03:55$_x$ [a]	1:19:07 ± 0:12:24$_x$ [b]	5:25:38 ± 0:09:24$_x$ [a]	6:20:00 ± 0:35:56$_x$ [b]	3:25:35 ± 0:10:19$_x$ [a]	5:03:39 ± 0:44:34$_x$ [b]	9:53:54 ± 0:13:46$_x$ [a]	12:51:12 ± 1:11:51$_x$ [b]
Triathlon (senior)	0:19:21 ± 0:00:19$_y$ [a]	0:21:11 ± 0:01:27$_y$ [b]	1:03:11 ± 0:00:22$_y$ [a]	1:07:09 ± 0:01:36$_y$ [a]	0:36:28 ± 0:00:45$_y$ [a]	0:39:52 ± 0:01:01$_y$ [b]	2:01:15 ± 0:01:54$_y$ [a]	2:11:33 ± 0:02:47$_y$ [b]
Triathlon (junior)	0:20:11 ± 0:00:35$_z$ [a]	0:21:38 ± 0:01:11$_y$ [b]	1:05:09 ± 0:00:36$_z$ [a]	1:11:30 ± 0:02:05$_z$ [b]	0:38:52 ± 0:00:20$_z$ [a]	0:44:46 ± 0:02:30$_z$ [b]	2:05:33 ± 0:00:45$_z$ [a]	2:21:09 ± 0:02:38$_z$ [b]

Different superscripts (**a** and **b**) indicate significant ($p < 0.01$) difference (elite *vs* AG) in each discipline (swim, cycle, run) and overall at the 95% confidence level; different subscripts (**x**, **y** and **z**) indicate significant ($p < 0.01$) difference [Ironman *vs* standard (senior) *vs* standard (junior)] in each discipline (swim, cycle, run) and overall at the 95% confidence level.

Drafting*

TABLE 59–1. *Average splits and percent contribution of swim, cycle, and run sections to total time in elite triathlon*

Event	Swim (min)	Percent contribution	Cycle (min)	Percent contribution	Run (min)	Percent contribution	Total
Short-course draft-illegal, 1990–94							
Men	18.9 (1.0)	16.9	58.1 (2.8)	51.8	33.3 (1.1)	29.7	112.1 (2.1)
Women	21.9 (1.2)	17.4	65.6 (3.1)	52.1	38.1 (1.7)	30.2	126.0 (2.6)
Short-course draft-legal, 1995–97							
Men	20.3 (1.6)	19.0	54.2 (3.7)	50.7	31.3 (1.6)	29.3	106.9 (4.4)
Women	22.5 (2.2)	18.7	60.1 (4.3)	50.0	35.8 (1.7)	29.8	120.2 (5.8)
Long-course, 1995–97							
Men	53.4 (1.9)	10.4	286.1 (9.5)	55.8	172.9 (5.5)	33.7	512.7 (11.0)
Women	58.2 (5.9)	10.0	323.7 (13.7)	55.5	205.6 (11.7)	35.2	583.5 (19.5)

Note: Short-course events are the International Triathlon Union World Championship and long-course events are the Hawaiian Ironman. Times are the average of the top ten finishers, with standard deviations in parentheses. Swim, cycle, and run splits exclude transitions. From refs. 119 and 120.

*Andatura in «scia»

Peso relativo delle varie frazioni di gara

TABLE 59–2. *Pearson correlation of swim, cycle, and run split times with overall time in world championship triathlon*

Event	Swim *r* value	Bike *r* value	Run *r* value
Short-course draft-illegal, 1990–94			
Men	0.62	0.62	0.55
Women	0.33	0.71	0.61
Short-course draft-legal, 1995–97			
Men	0.31	0.17	0.83
Women	−0.11	0.29	0.89
Long-course, 1995–97			
Men	0.33	0.56	0.69
Women	0.46	0.82	0.47

See Table 59–1 for data source. Correlation strength: weak, $r < 0.3$; moderate, $r = 0.3–0.7$; strong, $r > 0.7$.

- Tempo di nuoto non correlato con t performance
- Riduzione dell'importanza della frazione di bici con il drafting
- Aumentata importanza della frazione di corsa

Antropometria dell'atleta di triathlon

TABLE 59–3. *Anthropometric characteristics in elite male and female single-sport athletes: distance swimmers (800–1500 m); cyclist (road, long-distance track and time trial); runners (5,000 m—marathon), and in short- and long-course triathletes*

Population	*N*	Age (years)	Height (cm)	Mass (kg)	Reference	Body fat (%)	Reference
Men							
Single-sport athletes							
Elite swimmers	—	20.5	184.5 (3.4)	78.9 (2.3)	3–5, 28, 41, 95, 121–122	6.8 (1.4)	5, 121
Elite cyclists	—	23.8 (0.9)	181.6 (2.4)	72.3 (2.9)	6, 11, 31, 40, 123, 124	7.3 (1.4)	11, 40, 121
Elite runners	—	26.6 (3.9)	177.0 (1.2)	63.5 (1.1)	3, 39, 125–128	5.8 (1.2)	39, 126
Triathletes							
Recreational	286	33	179.3 (176.4–185.5)	74.6 (66.6–90.9)	12–16, 19–22, 37, 58	11.1 (7.4–12.5)	17, 130
Sub-elite	104	28.5	178.8 (175–182.9)	72.6 (68.9–73.8)	13, 17, 45, 46, 129–131	10.3 (8.6–12.3)	12, 19, 20, 22, 39
Elite short-course	43	25.1	178.9 (176–181.3)	71.1 (69–72.7)	4, 12, 13, 42	7.2 (7.2–7.4)	4, 129
Elite juniors	30	17.8	177.8	67.2		8.2	18
Average all long-course	317	28.9	180.1 (176.5–181.9)	67.2 (69.4–76.6)	3, 4, 8, 9, 12, 43, 52	9.0	4, 9, 12, 43, 63
Eite long-course	50	25.8	178 (176.5–180.1)	71 (69.4–74.1)	4, 12, 43, 63	9.0	4, 43, 63
Women							
Single-sport athletes							
Elite swimmers	—	17.6 (2.4)	169.8 (3.4)	62. (1.6)	3, 121, 132, 135	17.1	132
Elite cyclists	—	26	168.9 (1.7)	60.8 (0.9)	3, 6, 11, 40	13.7 (1.75)	11, 40
Elite runners	—	27.4 (2.4)	163.6 (2.8)	50.2 (3.2)	3, 125, 132	16.1 (0.9)	132, 135
Triathletes							
Recreational	52	29.1 (21–32)	166.5 (162.9–168.9)	58.8 (56.3–63.1)	21, 22, 58, 133	19.8 (19–22.7)	21, 22
Sub-elite	41	31.1 (26.2–35.7)	165 (162.1–169.1)	57.8 (55.2–63.4)	12, 23–25	18.8 (17.7–20)	12, 31
Elite short-course	10	27.1	167	56.4	25	17.3	25
Elite juniors	21	17.5 (17.1–17.8)	168.4 (168–169)	58.2 (57.1–58.8)	18, 134	10.4	18
Average all long-course	—	29.8 (28–35.7)	168.2 (166–171)	59.3 (57.3–61)	1, 8, 9, 12	17.1 (12.6–22.7)	1, 8, 9, 12
Elite long-course	8	30.5 (28–31.3)	169.1 (168.5–171)	60.5 (60.3–61)	8, 12	15.2	8, 12

Note: Values for single-sport athletes are means of reported means, while values for triathletes are sample-size weighted means (see text for explanation). Population variance is shown in parentheses as standard deviations for single-sport athletes and ranges of the reported means for triathletes. *N* = sum of the sample size for each study. Mean values for single-sport athletes were obtained largely from review articles and textbooks in which sample size values were not reported.

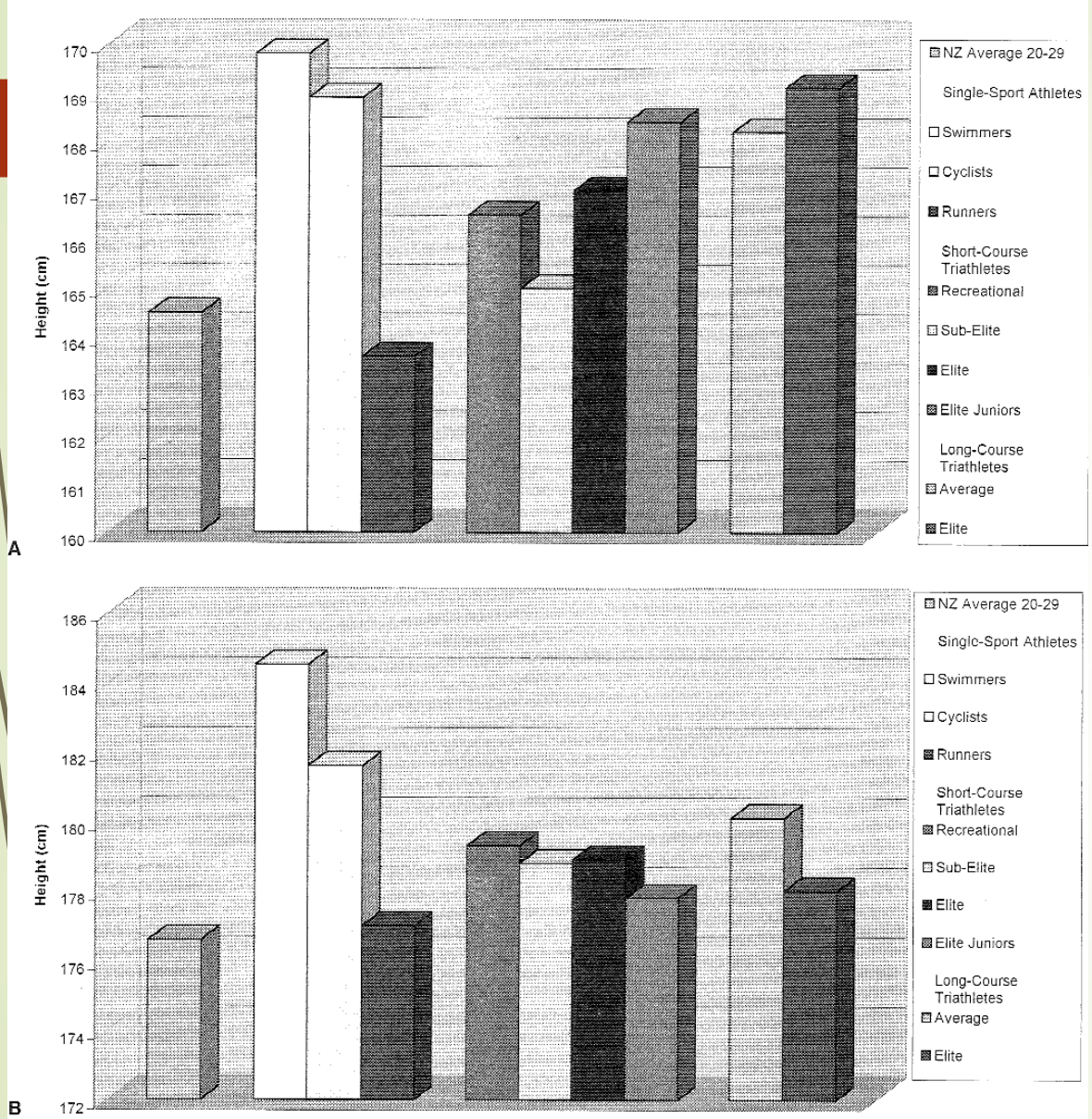


FIG. 59–2. Anthropometric values for the normal population, elite single-sport endurance athletes, and groups of triathletes. Mean body height: females (**A**), males (**B**). (*continued*)

Comparazione dell'altezza dell'atleta per tipo di sport

Massa corporea

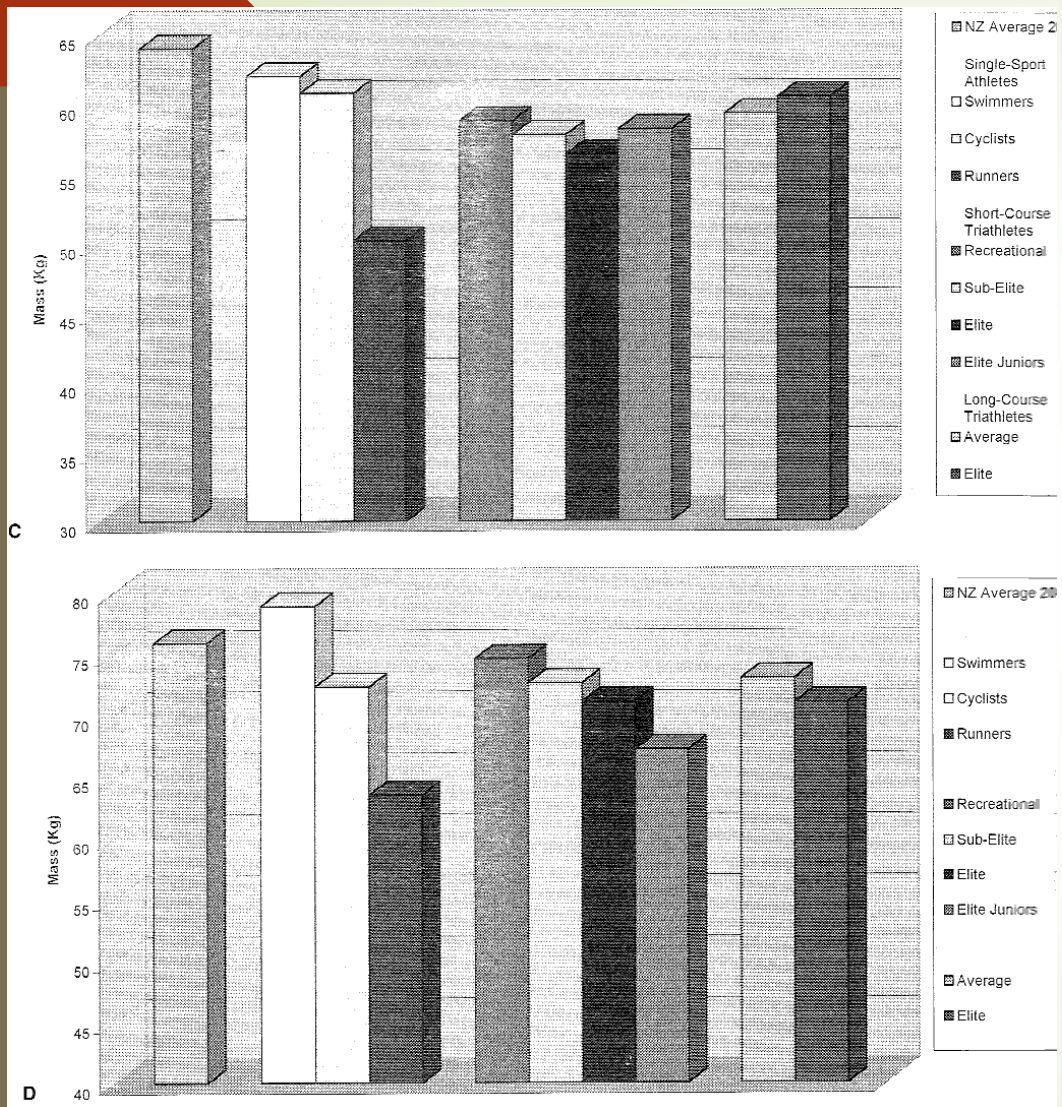


FIG. 59–2. *Continued.* Mean body mass: females (**C**), males (**D**). (Figures prepared from data presented in Table 59–3 a ref. 10.)

I triatleti sono principalmente degli atleti di endurance

La composizione corporea influenza la prestazione

Maschi :6-11% grasso

Femmine: 10-20% grasso

Massa in funzione dell'altezza nella popolazione normale:

Donne: y= 0.6x -39.2

Maschi: y= 0.8x -69.6

Massa corporea attesa(donne):

y= 0.6(169)-39.2 = 62.14

Massa corporea relativa media per atleta del ciclismo donna:

RBM=massa attuale/massa attesa= 60.8/62.14=0.978

Composizione dell'atleta ipotetico

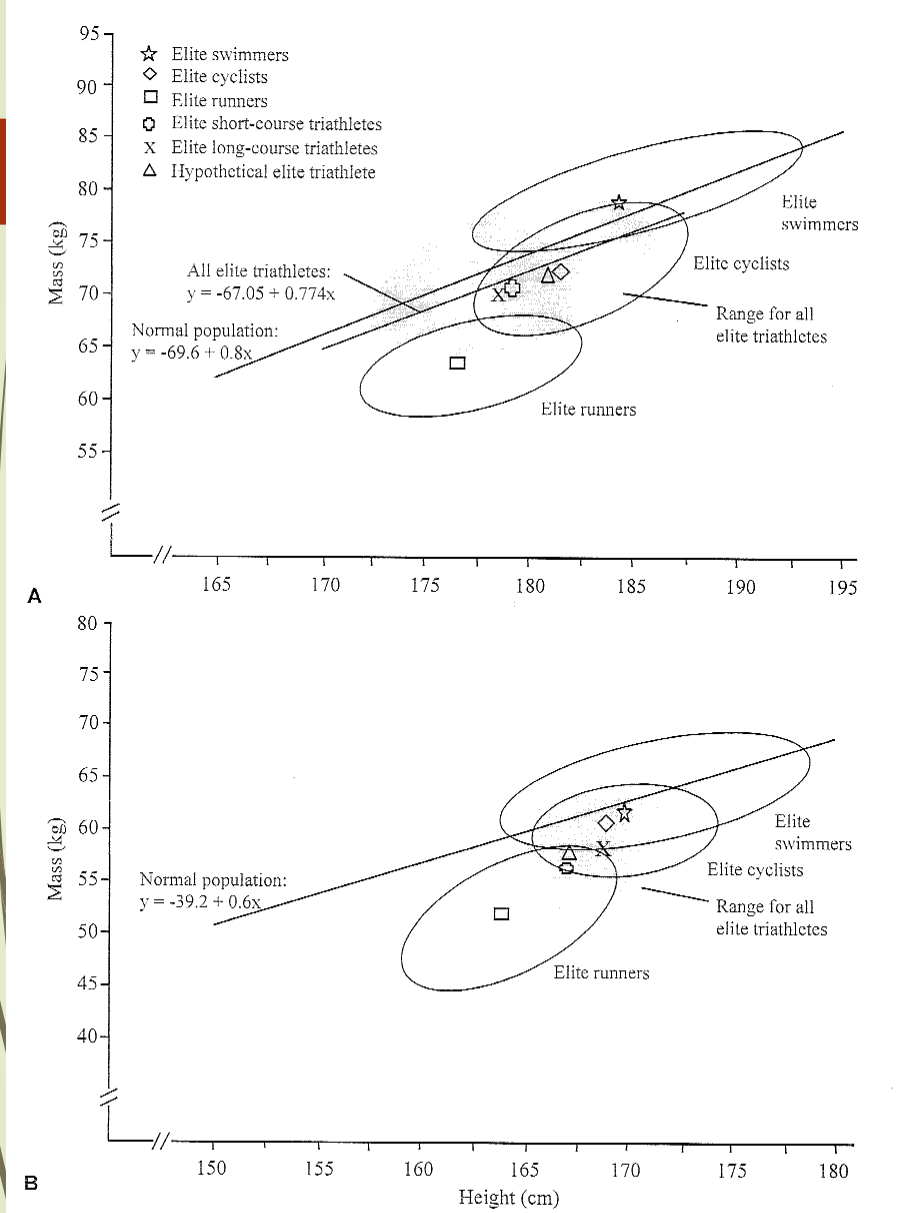


FIG. 59–4. Body height and mass relationships in elite male (**A**) and elite female (**B**) swimmers, cyclists, runners, and triathletes. Regression lines for the correlation of height with weight for all elite triathletes, that is, short- and long-course, and the normal population are shown. *Oblongs* represent the area enclosed by approximately one standard deviation from the range of means for each population reported (Table 59–3). *Large symbols* represent the reported means for single-sport athletes, and the sample-size weighted means for short- and long-course triathletes and the hypothetical elite triathlete.

Mix di caratteristiche, tra nuotatore, ciclista e corridore.

181cm, 71.6kg uomo;
167.4cm, 57.7kg donna;

Caratteristiche fisiologiche

Limite principale alla massima prestazione è determinato dai limiti del sistema aerobico. Cinque fattori incidono sulla prestazione:

1. Massima potenza aerobica
2. Soglia del lattato
3. Economia di movimento
4. Frazione di utilizzazione della massima potenza aerobica
5. Substrati energetici

TABLE 59–4. *Sample size weighted mean maximal oxygen uptake (mL/kg/min) values in elite single-sport athletes and triathletes in tethered swimming (TS), cycle ergometry (CE), and treadmill running (TR)*

	TS	CE	TR	Reference
Men				
Swimmers	67.4 (60–76)		68.6	1, 3, 41, 95, 136, 137
Cyclists		74.8 (73.5–78)		3, 6, 11, 28, 31, 40, 123, 124
Runners			77.6 (71.7–78.8)	4, 5, 8, 28, 34, 35, 39, 41, 95, 125, 138
Triathletes				
Recreational		53 (43.6–60.1)		19, 22, 46, 130, 131
Subelite	54.3 (51–59.4)	63.6 (60.5–64.3)	66.9 (63.7–69.9)	17, 20, 37, 42, 45, 48
Elite			71.7 (71.3–72)	42, 43
Juniors			70.0 (67.9–78.7)	18, 134
Women				
Swimmers	54.9 (48.9–60)		58	1, 28, 41, 95, 136, 137
Cyclists		61 (57.4–65)		3, 6, 11, 40, 95
Runners			70.2 (65–77)	3, 5, 8, 34, 41, 125
Triathletes				
Recreational	38.1	51.1	51.4	46
Subelite		56.9	60.3 (58.7–61)	7, 25, 43
Elite			65 (63.6–65.9)	8, 16, 25, 44, 92, 139
Juniors			58.6 (56.1–62.6)	18, 134

Values in parentheses represent the range of reported means.

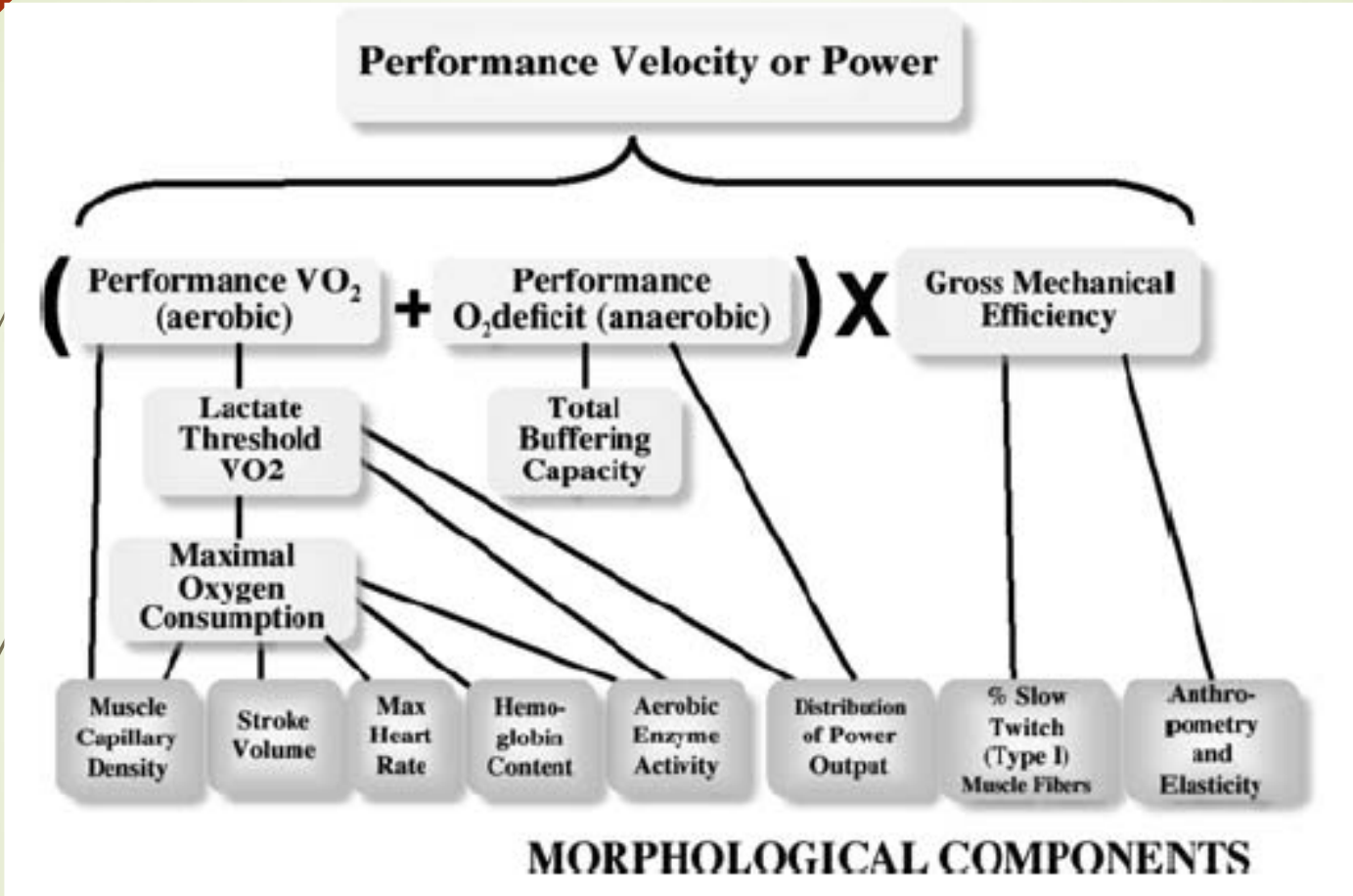


Figure 1. *Overall schematic of the multiple 'traditional' physiological factors that interact as determinants of performance velocity or power output (Coyle, 1995).*

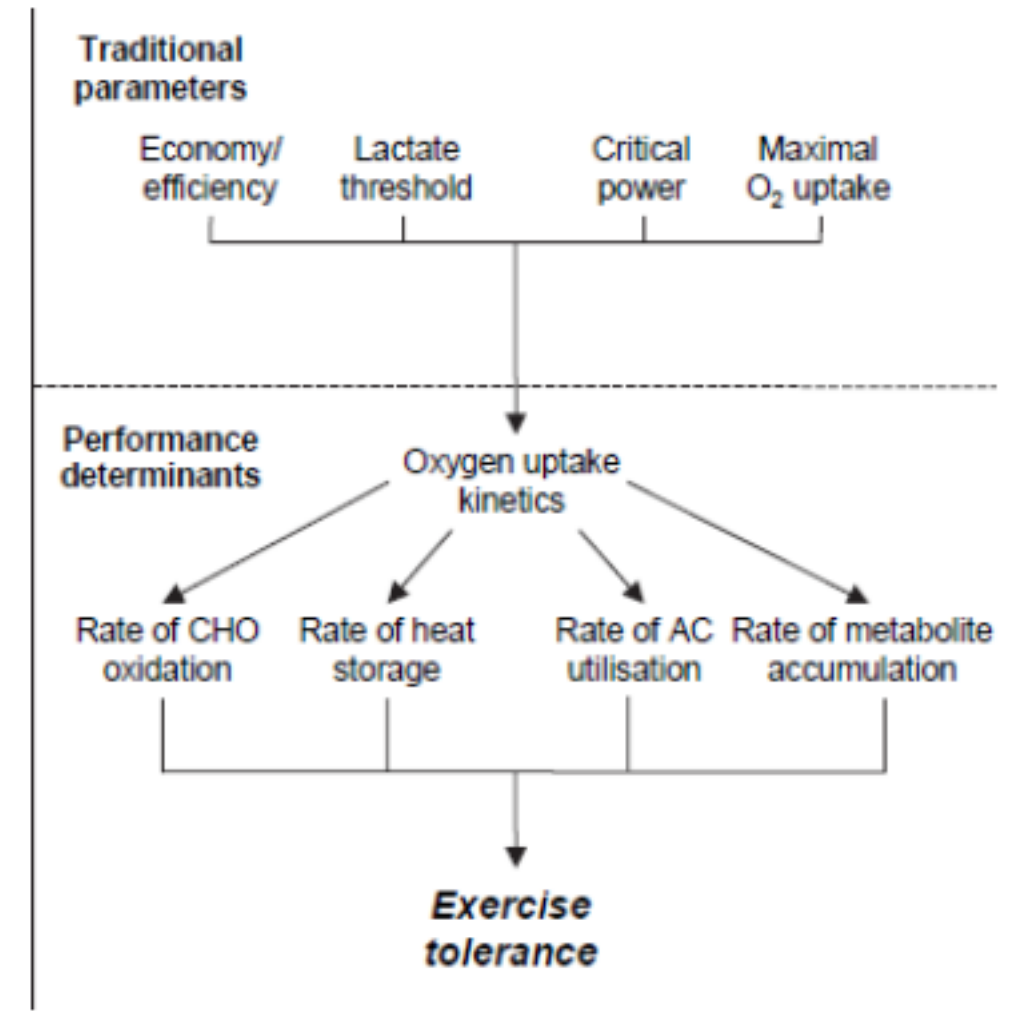


Figure 3. *The role of $\dot{V}O_2$ kinetics in heavy- and severe-intensity exercise tolerance (Burnley & Jones, 2007) (Key: CHO carbohydrate, AC anaerobic capacity).*

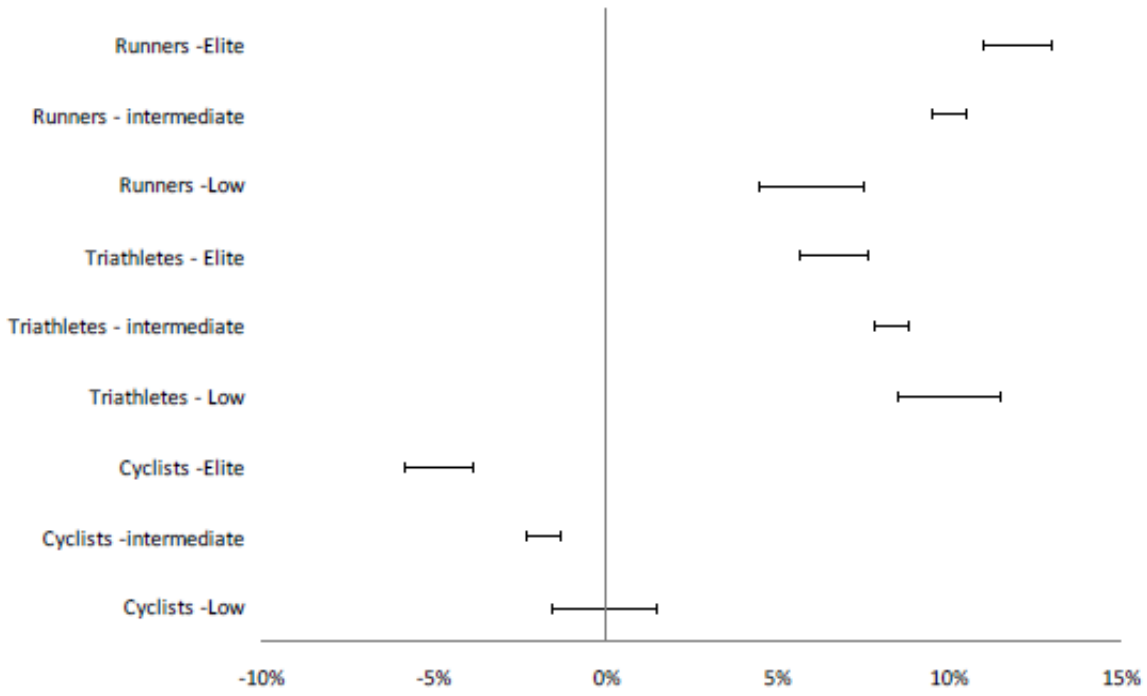


Figure 4. Differences between running and cycling: $\dot{V}O_2max$.

Massima potenza aerobica

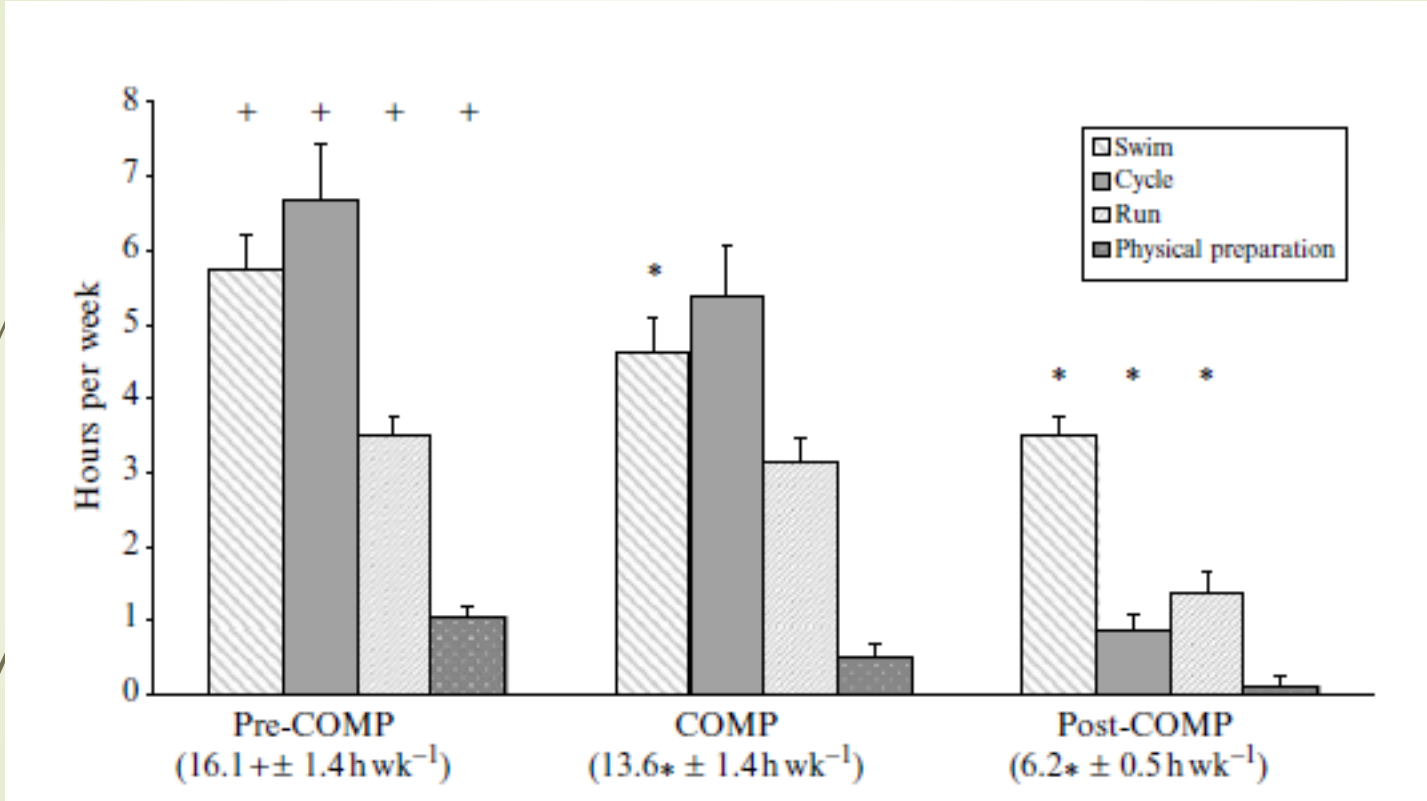
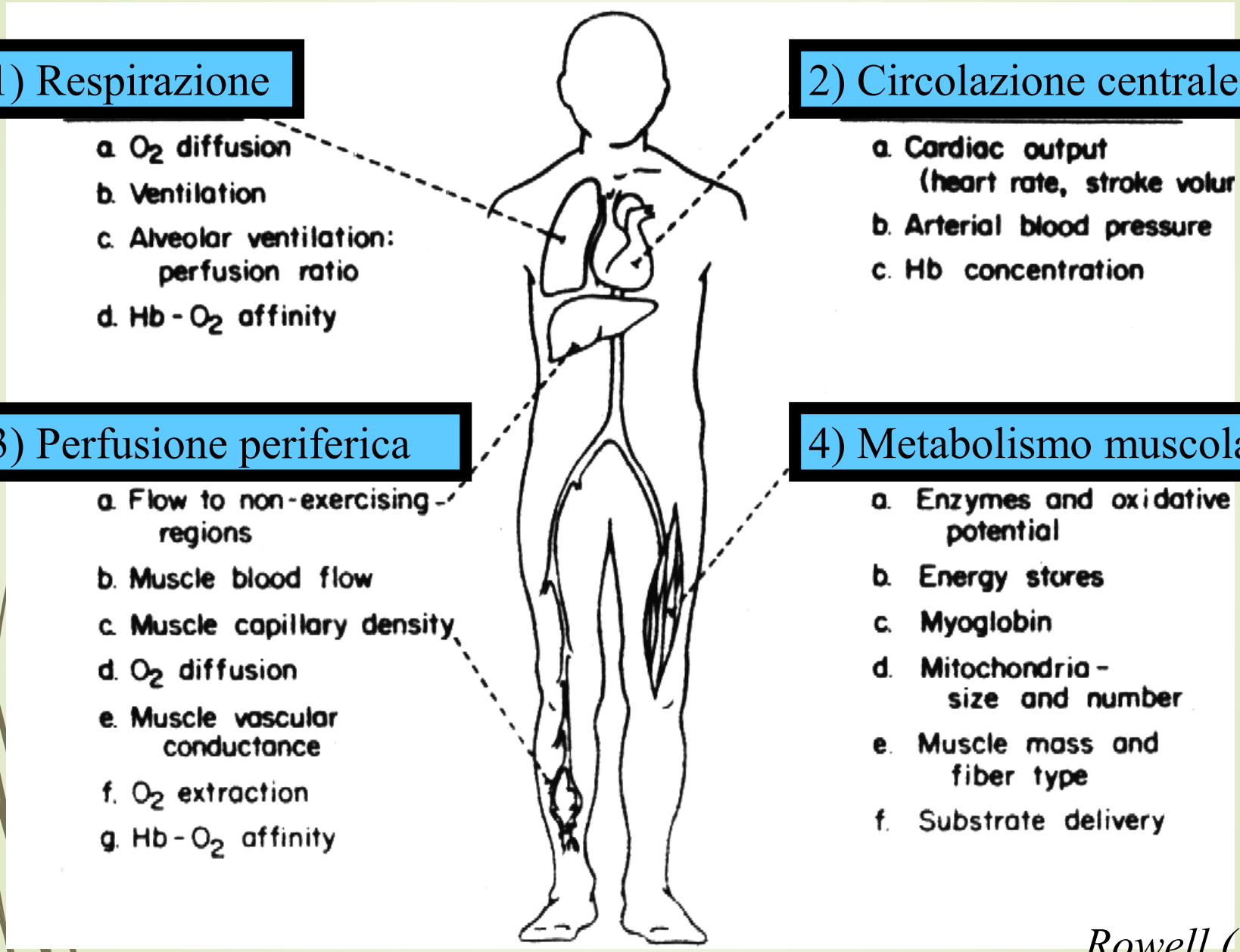


Fig. 1. Training volume per week during Pre-COMP, COMP, and Post-COMP periods. * Significantly different from preceding period. + Significantly higher compared with Post-COMP. Values are means ± SEM, $P < 0.05$.

Potenziali fattori limitanti:



Rowell (1993)

Limiti centrali

Dove agiscono ?

$$\dot{V}O_2 = V_S \text{ x } f_H \text{ x } \Delta O_{2av}$$

Circolazione centrale

Pa_{O_2} dipende dalla respirazione e dalla circolazione centrale

Pv_{O_2} dipende dal metabolismo muscolare e dalla perfusione periferica

Vs Volume di eiezione

f_H Frequenza cardiaca

ΔO_{2av} differenza artero-venosa O_2

Allenamento

TABLE 59–5. *Summary of training techniques for triathlon and presumed benefits*

Training component	Swimming	Cycling	Running	AMI	ML	Purpose	Physiologic responses (7, 9, 72, 117)
Endurance Load	Easy–moderate Small pads; feet tied	Easy–moderate Hills in low gear	Easy–moderate Hill running with normal stride length and rate; soft sand	50–70 50–65	40–60 60–70	Establish fitness base Introduce resistance training, for strength development	See text Recruitment of motor pattern associated with the full range of movement in each discipline; increased motor unit recruitment, altered firing rates and synchronization Conditioning of type II fibers Muscle hypertrophy Increased maximal force generating capacity Endurance training acclimations
High load	Large pads; tethered-swimming; swim bench	Hills and flat in high gear (low cadence)	Bounding or stride-outs on hills	65–75	75–95	Increase strength	Progression from load training
Load speed	Small pads; approx. 3000-m pace	Ironman race-pace in high gear	Exaggerated strides on flat intervals up gradual incline	60–70	65–75	Strength transfer to event-specific speed; develop power	
Low speed	Intervals; approx. 3000-m pace	Long intervals at Ironman race pace	Long intervals at Marathon race pace	75–80	70–75	Ironman race-specific training; preparation for short-course race pace training	Introduced competition specific neuromuscular recruitment patterns Increased mitochondrial material
High speed	4-min intervals; approx. 1500-m pace	5-min intervals; approx. 40-km pace; motor pacing	1-km intervals; approx. 10-km pace	85–95	85–95	Race-specific training for short course	Increase lactate threshold, glycolytic capacity and $\dot{V}O_2max$ Competition-specific neuromuscular recruitment patterns Psychologic conditioning for racing
Sprint	50-m intervals	Sprints: 10–90 sec	100–400 m intervals	85–100	85–100	Anaerobic conditioning for short-course events	Recruitment and hypertrophy of type II fibers Increased activity of glycolytic and glycogenolytic enzyme Increase muscular contraction speed
Over speed	25-m intervals	Motor pacing; downhill spinning sprints	Strideouts down 1–3% hill; leg turnover drills	50–60	50–60	Make high leg turnover more comfortable	Increase muscular contraction speed

Aerobic metabolic intensity (AMI) = % $\dot{V}O_2max$. Muscular load (ML) = % of maximal muscular effort for the exercise task.

Allenamento

TABLE 59–6. *Example of a weekly training schedule for a short-course triathlete*

	Mon	Tue	Wed	Thurs	Fri	Sat	Sun
Swim	3 k		4 k, strength		4-k intervals	2 k	
Bike		50 k, speed		45 k, hills		25 k	80 k, long
Run	17 k, hills		25 k, long	12 k		16 k, speed	

Cycling

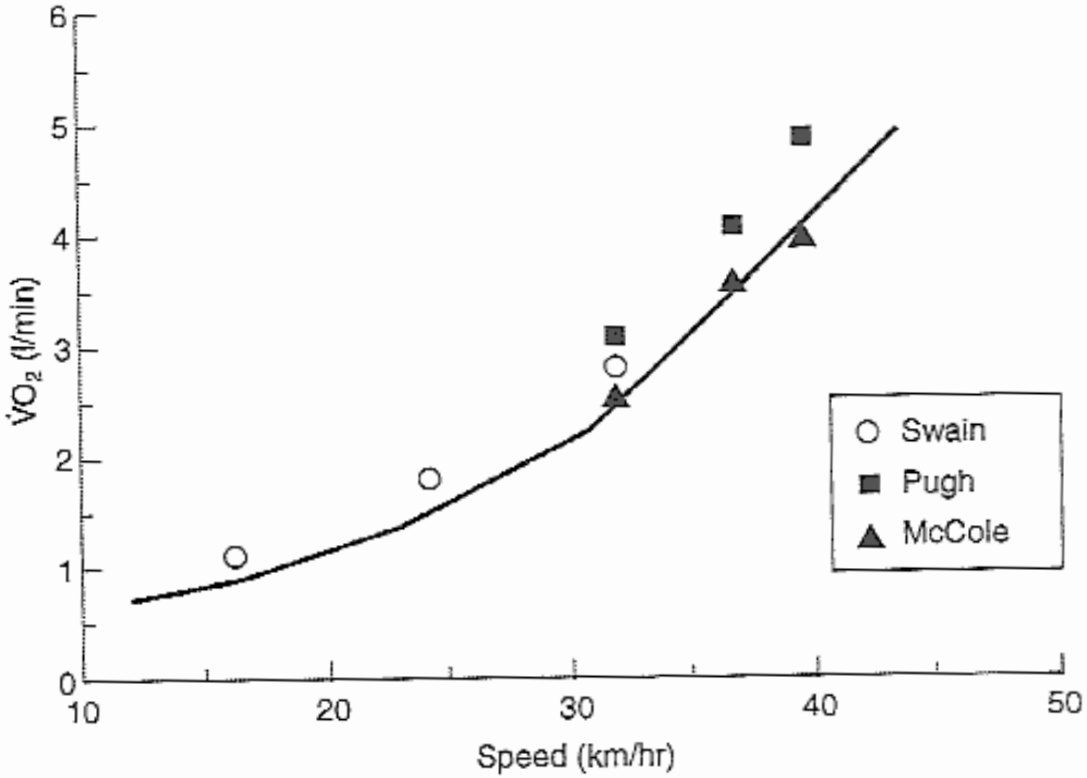


FIG. 48–1. Speed (km/min) versus $\dot{V}O_2$ (L/min) based on the following studies: ref. 1 (*open circles*); ref. 3 (*solid squares*); ref. 2 (*solid triangles*). From ref. 9, with permission.

Costo energetico del ciclismo

$$C = Ca + Cf$$

$$Ca = k \times v^2$$

$$K = \frac{Cx \times Ap \times \rho}{2\eta}$$

Cx coefficiente aerodinamico
Ap area di superficie frontale
ρ densità dell'aria
η rendimento meccanico

Costo energetico del ciclismo

$$v = \frac{\dot{E}a}{Ca}$$

$$\dot{E}a = Ca \times v$$

$$Ca = k \times v^2$$

$$Ea = k \times v^3$$

Il lavoro meccanico per unità di percorso nella locomozione in bicicletta può essere calcolato dall'equazione (di Prampero e Coll., 1979 a):

$$w_{ext} = 3.1 + 0.2v^2$$

dove:
w_{ext} è espresso in $J \cdot m^{-1}$ e v in $m \cdot sec^{-1}$

$$\dot{w}_{int} = 7\ f^3$$

dove f è espressa in sec^{-1}.

$$w_{tot} = 3.1 + 0.21\ v^2$$

Si può rilevare che alla velocità massima (circa 14 $m \cdot sec^{-1}$), w_{int} rende conto soltanto del 6% del lavoro totale. La frequenza di pedalata modifica solo leggermente il rendimento meccanico dell'esercizio (Pugh, 1974; Seabury e Coll., 1977). Presupponendo pertanto un rendimento dello 0.25 è possibile calcolare E in funzione della velocità per mezzo dell'equazione:

$$E = 12.5 + 0.8\ v^2$$

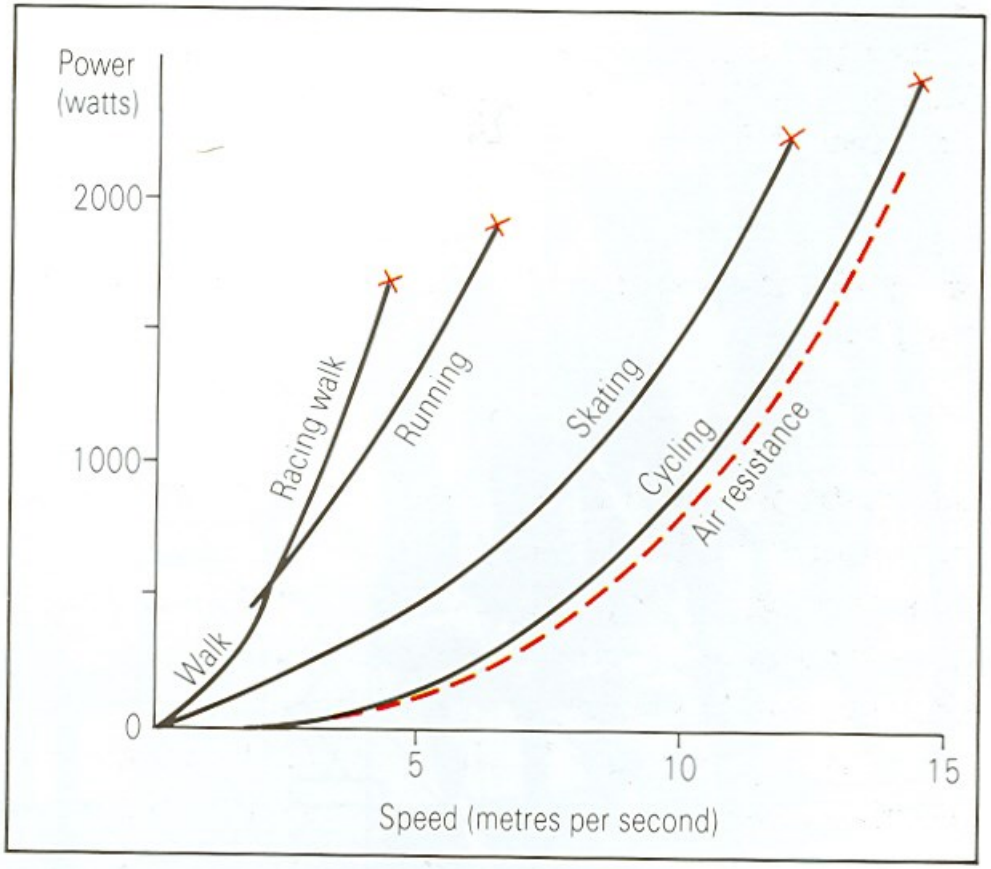


FIG. 8.1 *The metabolic power required for walking, running, skating and cycling, plotted against speed. The graphs have been extrapolated to the world record speeds for 5 kilometre (running) or 10 kilometre races. The broken line represents power required to overcome air resistance. Based on a graph by P.E. di Prampero (1986)* Int. J. Sports Med. **7**, *55–72.*

$$P_{cyc} = P_{dt} + mVA_{cyc} + WV_{sin}(ArctanG) + WVCrr_1\cos(ArctanG) + NCrr_2V^2 + 1/2\,C_dA_pV(V = V_w)^2$$

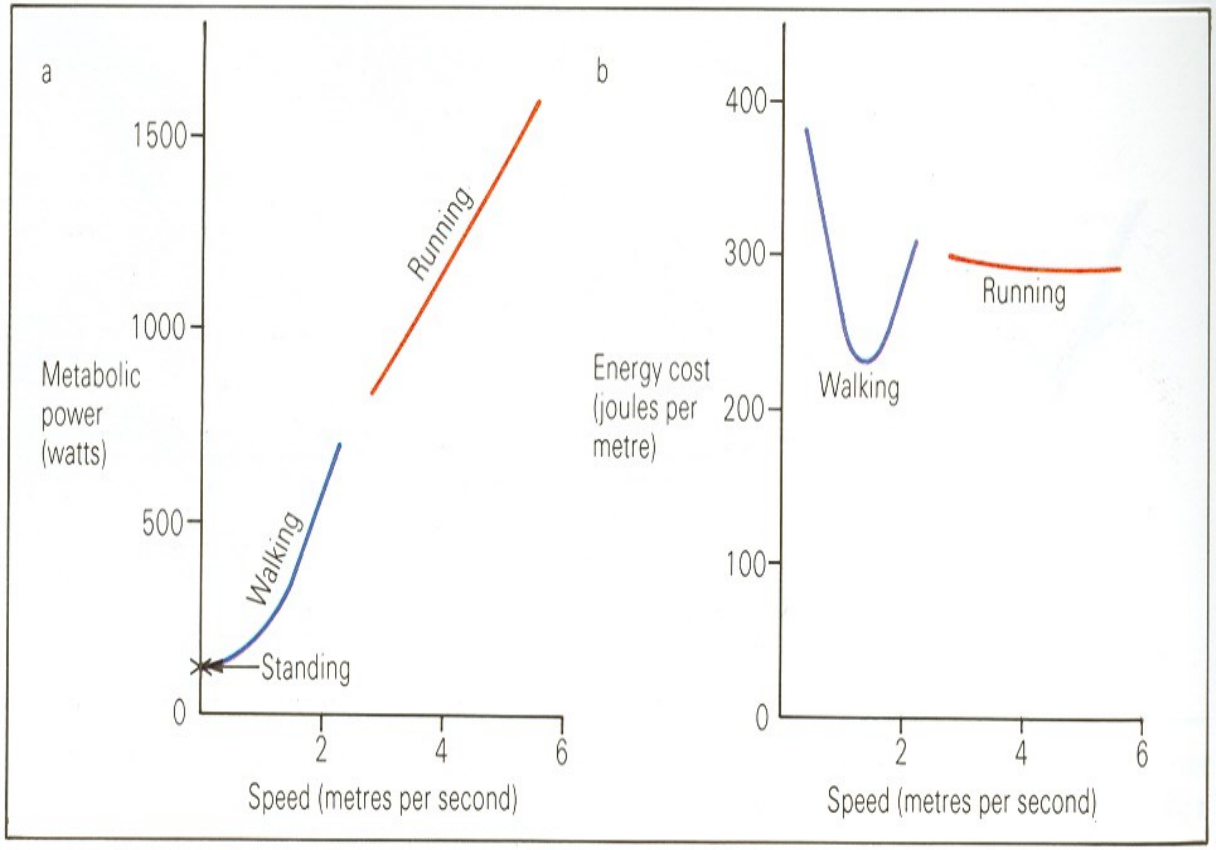
P_{cyc} = the net instantaneous mechanical power produced by the rider
P_{dt} = the power to overcome drive-train friction
m = the mass of the rider and bicycle
V = bicycle velocity
A_{cyc} = instantaneous acceleration or deceleration of the bicycle/rider system
W = the weight of the bicycle and rider

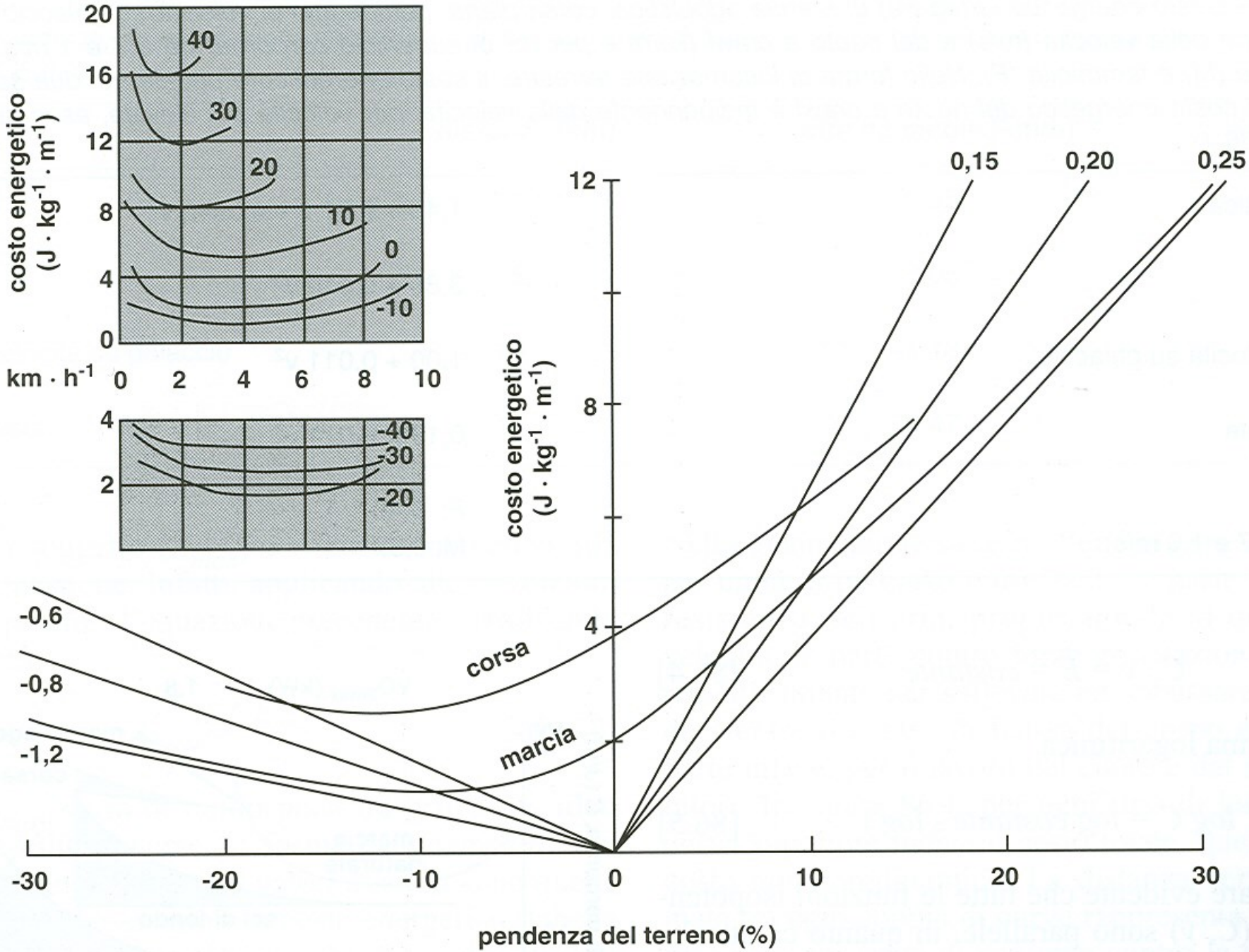
G = the grade
Crr_1 = the coefficient of static rolling resistance
N = the number of wheels (in case a tricycle is analyzed)
Crr_2 = the coefficient of dynamic rolling resistance
C_d = the coefficient of aerodynamic drag
A = the frontal surface area of the rider and bicycle
D = the air density
V_w = the velocity of the headwind or tailwind (positive for headwind)

Running

FIG. 5.9 *This woman is walking on a moving belt while her rate of oxygen consumption is measured. Photograph by Dr N.C. Heglund, Department of Animal Physiology, University of Nairobi.*

FIG. 5.10(a) *Power consumption (calculated from oxygen consumption) against speed for men walking and running, from the data of R. Margaria (1976)* Biomechanics and Energetics of Muscular Exercise. *Clarendon, Oxford.* (b) *Energy used per metre travelled (same data).*




costo energetico
(J · kg-1 · m-1)
20
16
12
8
4
0
40
30
20
10
0
-10
km · h-1
0
2
4
6
8
10
4
2
-40
-30
-20
costo energetico
(J · kg-1 · m-1)
12
8
4
0,15
0,20
0,25
-0,6
-0,8
-1,2
corsa
marcia
-30
-20
-10
0
10
20
30
pendenza del terreno (%)

EXPERIMENTAL MEASUREMENT OF THE MECHANICAL WORK OF LOCOMOTION

Kinetic Energy $\propto$ speed^2

Potential Energy $\propto$ vertical position

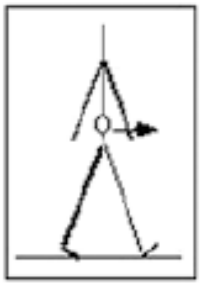
Total Energy: **TE** = **KE** + **PE**

Work = Δ**TE**

CINEMATOGRAPHIC RECORDINGS → **trajectory of body segments**

GROUND REACTION FORCES → **trajectory of body centre of mass**

trajectory of body segments with respect to the body centre of mass



TE = **KE** + **PE** of the body centre of mass

↓

external work

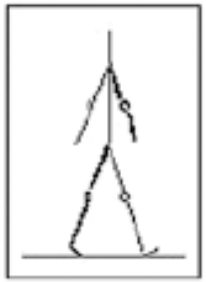
= sum of **TE** increases

KE of body segments

↓

internal work

= sum of **KE** increases



$$W_{tot} = W_{ext} + W_{int}$$

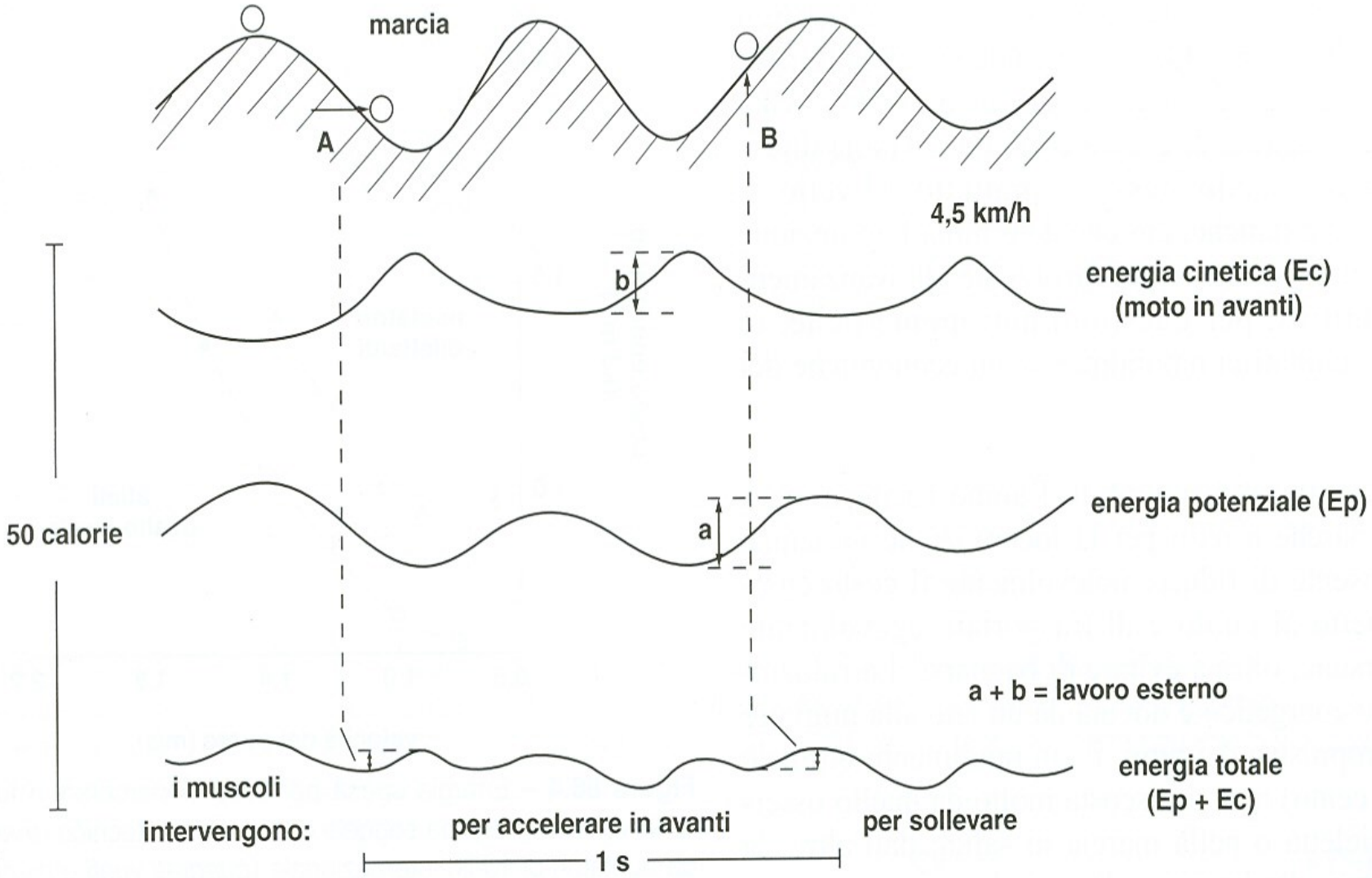
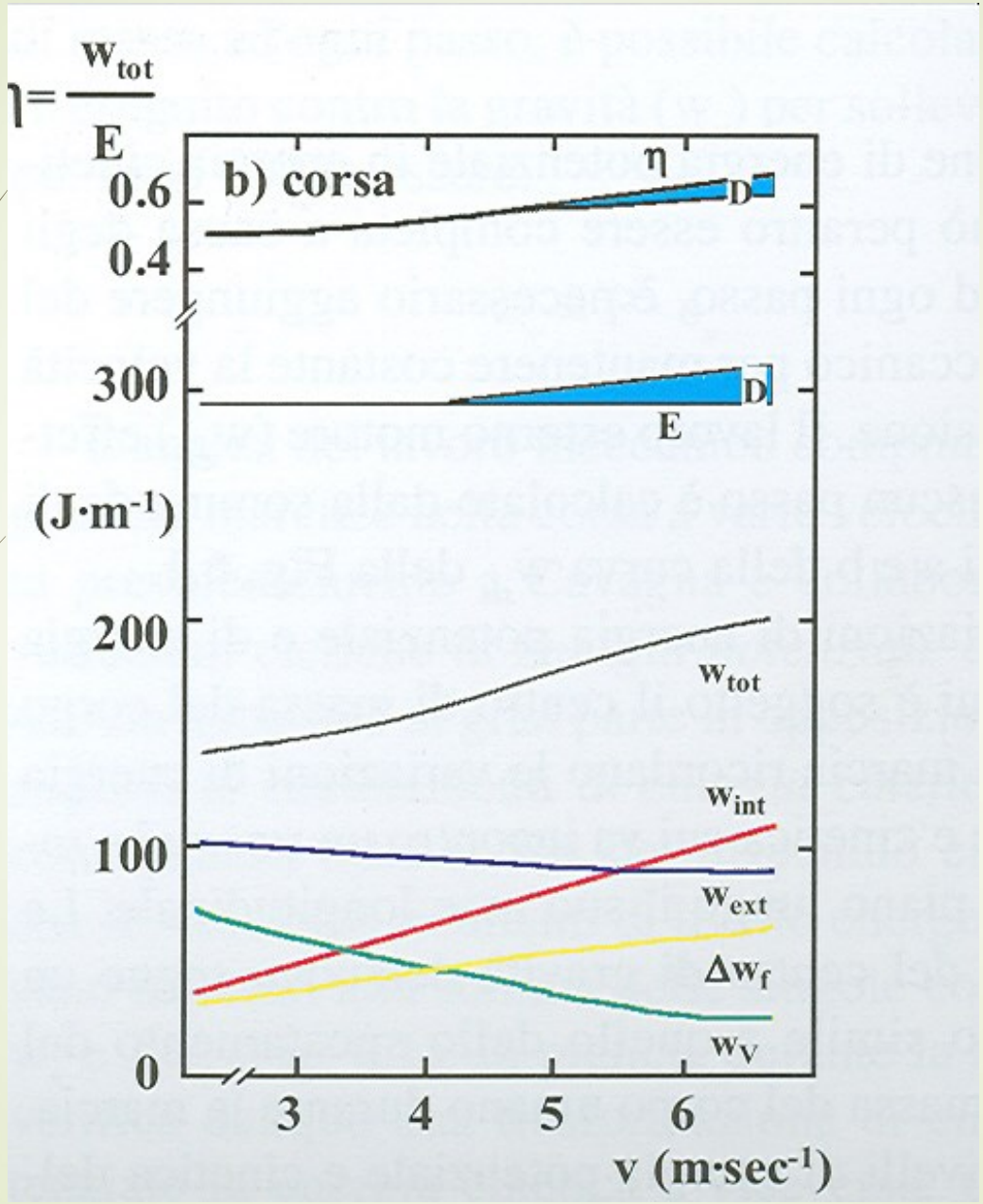


Figura 86.5 – Trasformazioni tra energia potenziale ed energia cinetica durante la marcia.


η = w_tot / E
b) corsa
η
D
0.6
0.4
300
D
E
(J·m⁻¹)
200
w_tot
w_int
100
w_ext
Δw_f
w_V
0
3
4
5
6
v (m·sec⁻¹)

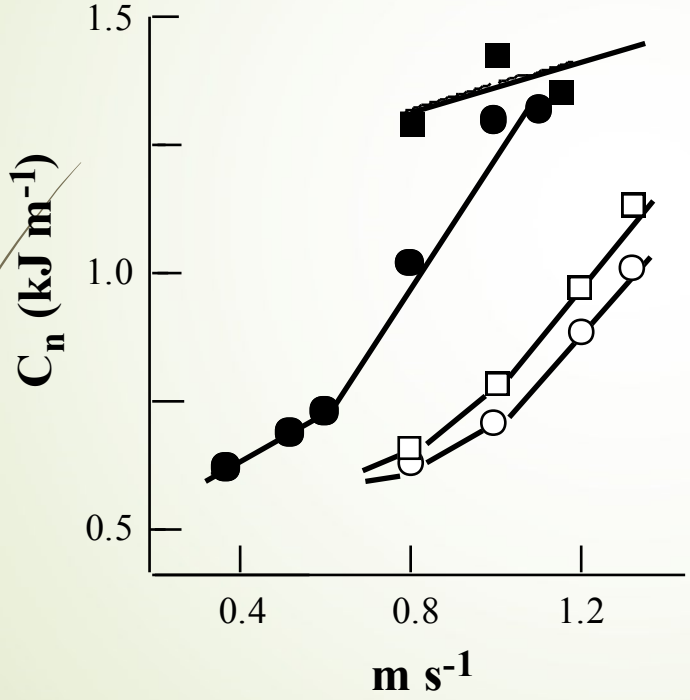
Swimming

- Se H2O temp 16<°C → obbligo di muta; vietata sopra i 20°C → guadagno di portanza e riduzione del drag
- Enegy cost del triatleta 30% > del atleta di nuoto
- propelling efficiency del triatleta 34% < del atleta di nuoto
- Ds (stoke distance) è < nel triatlela

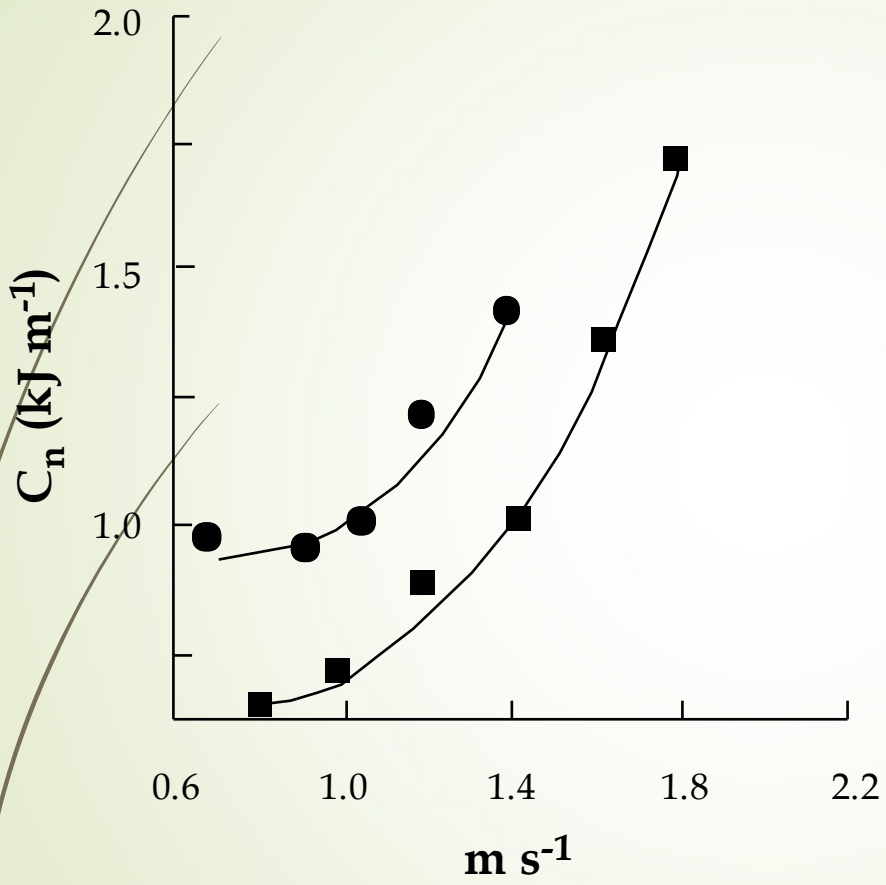
- Drafting durante il nuoto riduce il [la] del 31%, e RPE del 21%

- Effetti del nuoto sulla performance di ciclismo : redistribuzione del sangue (upper body)

Swimming



Cn= costo energetico
Dipende dai vari stili



Dipende dal livello atletico

Dipende dal sesso

Stile	*Sesso*	*n*	*C* (*kJ m-1*)	*C* (*J m-1kg–1*)
Crawl	**M**	**24**	**1.02**	**13.6**
	F	**17**	**0.80**	**13.2**
Rana	**M**	**25**	**1.43**	**18.3**
	F	**24**	**1.12**	**18.6**

Donne più Economiche

(di Prampero et al 1974, Pendergast et al 1977, Costill et al. 1985, Monpetit et al. 1983, Van Handel et al 1988,**Chatard et al, 1991 (16 %))**

Determinanti di C

1 Resistenza Idrodinamica Totale del Nuoto o **Drag (F_d, N)**

$$\mathbf{F_d = K\, v^2}$$

$$\mathbf{F_d = 30\, v^2}$$

$$\mathbf{K = (0.5\, C_d\, \rho\, A)\, v^2}$$

- E' la somma di drag di attrito (F_a), di **pressione (o di forma)** **(F_p)** e di onda (F_o)

- **F_d corrisponde al lavoro speso per unità di distanza per vincere la resistenza idrodinamica**

$$F_d = N = (N\ m)\ m^{-1} = J\ m^{-1}$$

- **La potenza meccanica dissipata per vincere F_d è proporzionale al cubo della velocità**

$$w'_d = F_d\, v = A\, v^3$$

Lavoro totale w_t:

- Vincere il drag
- Contrastare l'affondamento
- Accelerare all'indietro una massa di acqua (Σm_i) ad ogni battuta di durata T imprimendole una variazione di velocità Δv_i

$$\textbf{Forza Propulsiva} = 1/T \sum m_i \Delta v_i$$

La massa di acqua Σm_i spinta all'indietro acquisisce un'energia cinetica E_k

$$\mathbf{E_k = 0.5\ \Sigma\ m_i\ (\Delta v_i)^2}$$

Conclusione: parte di w_t durante la fase di spinta è spesa per muovere nel verso opposto all'avanzamento una massa di acqua Σm_i

Si deriva che lo spostamento in avanti lungo il piano orizzontale del centro di massa del nuotatore nel corso di una bracciata è sempre inferiore alla distanza effettivamente percorsa dal punto di applicazione della forza propulsiva in acqua.

Lavoro Totale $w_t = w_d + w_k^*$

Potenza Totale $w'_t = w_t \; v^*$

* convertita in energia cinetica impressa a Σm_i per unità di distanza

$$\eta = \frac{\dot{w}_d}{\dot{E}} = \frac{Fd \times v}{\dot{E}}$$

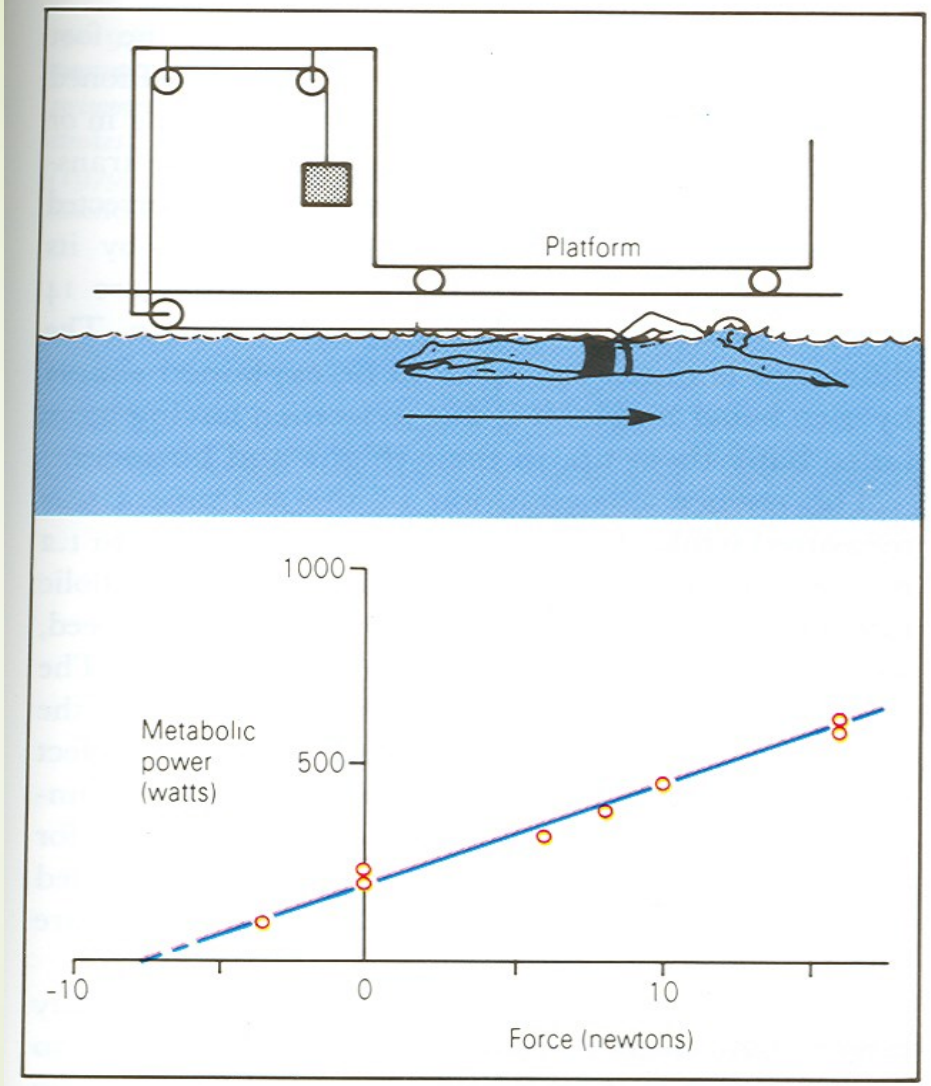


FIG. 9.4 *An experiment to measure the power needed for swimming, and results for a swimming speed of 0.4 metres per second. Metabolic power (above the resting rate) is plotted against the retarding force applied through the rope. After P.E. di Prampero* et al. *(1974)* J. appl. Physiol. **37**, *1–5*.

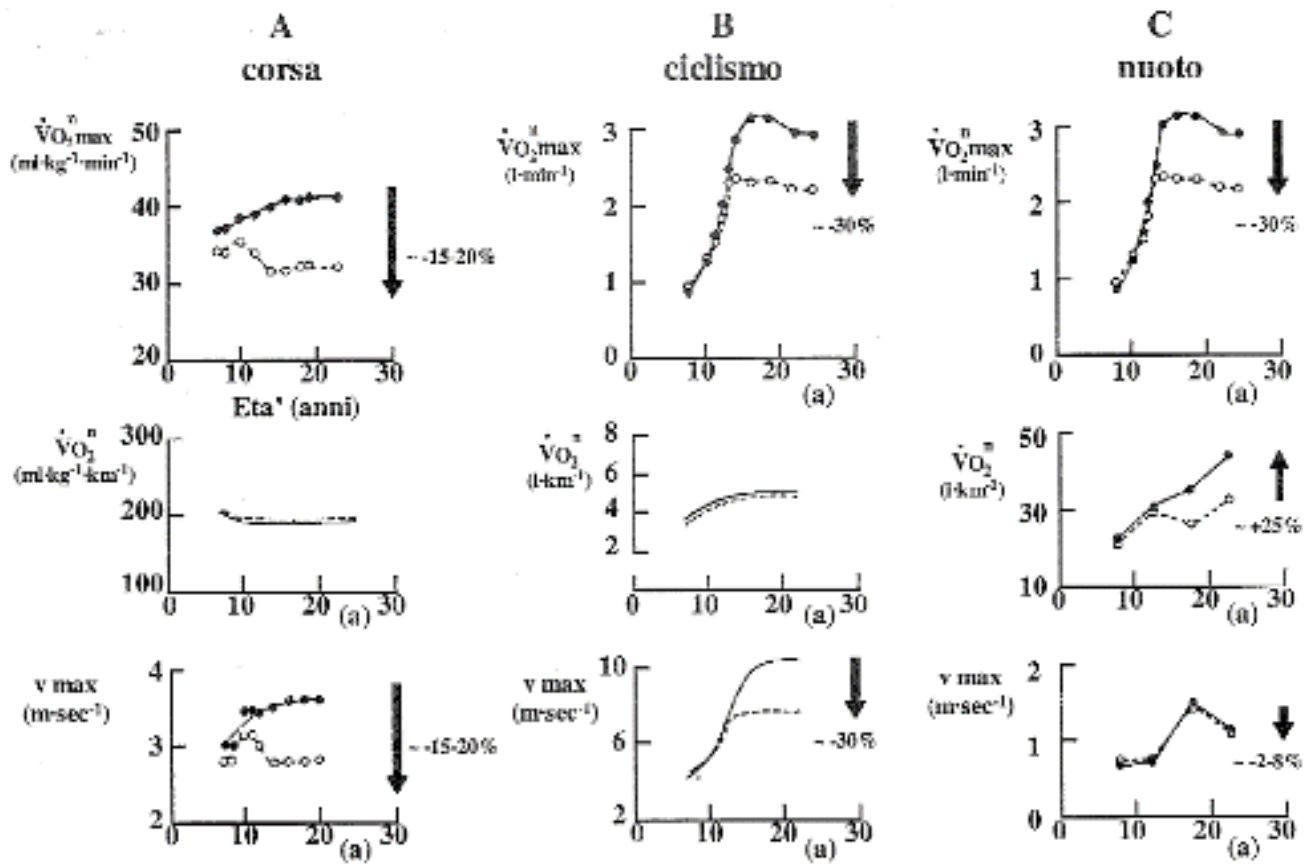


Fig. 6.20 – *Quadranti superiori*. Massimo consumo di O_2 netto ($\dot{V}O_2^n$ max) per kg di peso corporeo (A) ed in valore assoluto (B, C) in funzione dell'età e del sesso (1234 maschi ●, 1085 femmine ○, dati personali). *Quadranti intermedi*. Consumo di O_2 per kg di peso e per km nella corsa a piedi (A), per km in bicicletta (B) e durante nuoto (C) alle massime velocità raggiungibili in condizioni aerobiche, in funzione dell'età (linea tratteggiata = femmine). *Quadranti inferiori*. Massima velocità (m · sec⁻¹) conseguibile in condizioni aerobiche in funzione dell'età e del sesso e nei tre esercizi indicati. I dati (m · sec⁻¹) sono ottenuti dividendo i valori che appaiono nell'omologo quadrante superiore per i dati corrispondenti del quadrante medio (da: Cerretelli e Coll., 1979).

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