Laurea specialistica in Scienze e tecniche dello sport

Biomeccanica del movimento e dello sport ARDIGO' 16
(2010/2011)

La locomozione e le 'interferenze' ambientali

Martedì 29 Marzo h. 15:30÷17 Biomeccanica del movimento e dello sport ARDIGO' 16

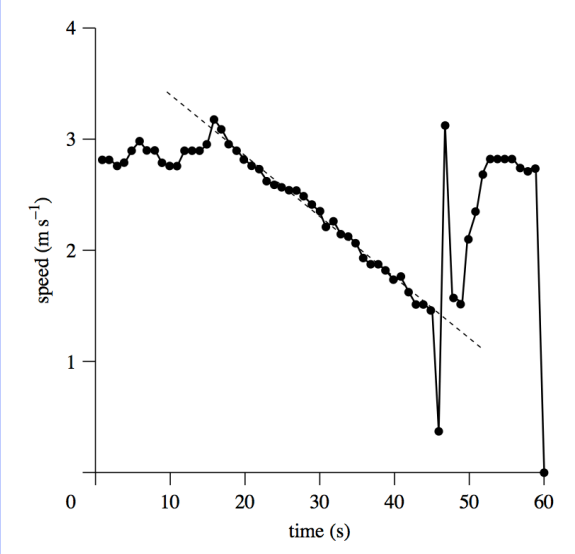
Luca P. Ardigò

C_r (1) (coasting down)

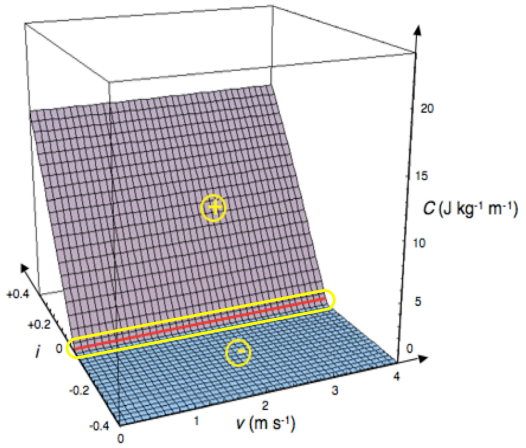
$$R_r = C_r M g$$

$$F = -R_r$$

$$v = v_0 - C_r g t$$



C_r (2)
(pendenza neutra)



M g (pendenza) = C_r M g

Fonti:

Human locomotion on ice: the evolution of ice-skating energetics through history. Formenti F, Minetti AE J Exp Biol. 2007 May;210(Pt 10):1825-33.

Human locomotion on snow: determinants of economy and speed of skiing across the ages. Formenti F, Ardigò LP, Minetti AE Proc Biol Sci. 2005 Aug 7;272(1572):1561-9.

Biomechanics and energetics of basketball wheelchairs evolution. Ardigò LP, Goosey-Tolfrey VL, Minetti AE Int J Sports Med. 2005 Jun;26(5):388-96.

From bipedalism to bicyclism: evolution in energetics and biomechanics of historic bicycles. Minetti AE, Pinkerton J, Zamparo P Proc Biol Sci. 2001 Jul 7;268(1474):1351-60. Erratum in: Proc R Soc Lond B Biol Sci 2001 Dec 22;268(1485):2616.

Esercitazione 2a (Giovedì 7 Aprile h. 10:30÷12 Biomeccanica del movimento e dello sport ES. ARDIGO' 12?)

Spazio	pista
Velocità	10 km h^{-1} (< 20 km^{-1})
Variabili	C_r
n°	2

Esercitazione 2b

Spazio	treadmill
Velocità	10 km h^{-1}
Variabili	pendenza = C_r
n°	2

Superficie
(erba vs. asfalto)

distribuzione di pressione
(corsa, area di contatto, tempo di contatto e pressione picco)

Table 1
Mean and standard deviation of contact area (cm^2), contact time (ms) and peak pressure (kPa) for each foot region in grass and asphalt running.

		Contact area (cm^2)	Contact time (ms)	Peak pressure (kPa)
Medial rearfoot	Grass	12.1 (2.1)	154.0 (30.5)	304.8 (63.5)
	Asphalt	12.0 (2.4)	146.2 (27.8)	315.5 (83.6)
Central rearfoot	Grass	22.4 (6.5)[a]	179.0 (44.9)[a]	303.8 (66.7)[a]
	Asphalt	19.6 (2.3)[a]	157.3 (35.2)[a]	342.2 (76.3)[a]
Lateral rearfoot	Grass	11.2 (2.7)	170.5 (53.0)	312.7 (75.8)[a]
	Asphalt	11.1 (2.9)	171.5 (57.7)	350.9 (98.3)[a]
Midfoot	Grass	42.4 (5.0)	214.0 (35.6)	124.2 (29.8)
	Asphalt	41.6 (6.2)	209.8 (43.0)	124.7 (33.7)
Medial forefoot	Grass	36.5 (2.6)	228.5 (21.1)	353.9 (90.5)
	Asphalt	36.0 (3.9)	220.4 (29.0)	362.0 (98.6)
Lateral forefoot	Grass	37.2 (3.0)	236.8 (21.5)	221.4 (42.9)[a]
	Asphalt	36.6 (4.3)	232.4 (31.2)	245.3 (55.5)[a]

[a] Statistically significant difference between the surfaces in the respective regions ($p < 0.001$).

-> rischio d'infortunio

Fonte: In-shoe plantar pressure distribution during running on natural grass and asphalt in recreational runners. Tessutti V, Trombini-Souza F, Ribeiro AP, Nunes AL, Sacco Ide C J Sci Med Sport. 2010 Jan;13(1):151-5.

1 kPa ≈ 100 kg m^{-2}

Velocità

corsa

Superficie

treadmill

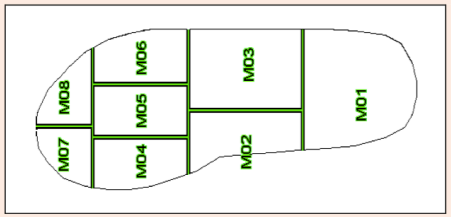


Figure 1. Eight anatomical regions of the foot defined to be used for plantar pressure distribution analysis. M01: Heel, M02: Medial midfoot, M03: Lateral midfoot, M04: Medial forefoot, M05: Central forefoot, M06: Lateral forefoot, M07: Hallux, M08: Toes.

Table 1. The peak pressure at same slope 0% with different speeds. Data are means (±SD).

Mask	Speed 1.5	Speed 2.0	Speed 2.5	F Value	Post Hoc
He(M01)	143.6 (73.6)	170.7 (85.7)	191.3 (71.8)	4.54*	S2.5>S2.0>S1.5
MM(M02)	154.1 (79.2)	172.9 (83.9)	178.2 (92.2)	7.23*	S2.5,2.0>S1.5
LM(M03)	130.3 (44.8)	149.5 (41.9)	162.3 (46.4)	19.17*	S2.5>S2.0>S1.5
MF(M04)	339.8 (108.1)	360.7 (114.2)	377.8 (101.2)	2.42	S2.5>S1.5
CF(M05)	223.8 (48.6)	244.5 (53.1)	266.5 (64.6)	10.74*	S2.5>S2.0>S1.5
LF(M06)	172.7 (51.3)	189.0 (49.9)	203.9 (54.4)	11.76*	S2.5>S2.0>S1.5
Ha(M07)	309.3 (123.9)	323.6 (123.1)	333.1 (103.4)	0.94	
To(M08)	126.3 (47.4)	139.0 (49.3)	147.8 (50.7)	5.13*	S2.5>S1.5

He(M01): Heel, MM(M02): Medial midfoot, LM (M03): Lateral midfoot, MF(M04): Medial forefoot, CF(M05): Central forefoot, LF(M06): Lateral forefoot, Ha(M07): Hallux, To(M08): Toes. * $p < 0.05$

1 kPa ≈ 100 kg m^{-2}

Pendenza

corsa

Superficie

treadmill

1 kPa ≈ 100 kg m^{-2}

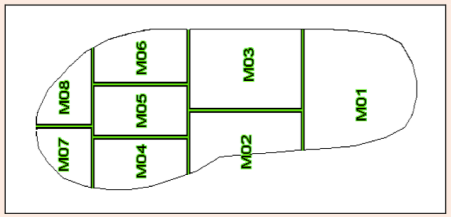


Figure 1. Eight anatomical regions of the foot defined to be used for plantar pressure distribution analysis. M01: Heel, M02: Medial midfoot, M03: Lateral midfoot, M04: Medial forefoot, M05: Central forefoot, M06: Lateral forefoot, M07: Hallux, M08: Toes.

Table 3. The peak pressure at same speed 2.0m·s^{-1} with different slopes. Data are means (±SD).

Mask	SL0	SL5	SL10	SL15	F Value	Post Hoc
He(M01)	170.7 (85.7)	161.4 (56.6)	142.6 (40.3)	124.1 (41.6)	4.36*	SL0,5>SL10,15; SL10>SL15
MM(M02)	172.9 (83.9)	155.1 (77.5)	164.8 (82.3)	159.3 (83.2)	1.17	
LM(M03)	149.5 (41.9)	155.2 (33.9)	161.1 (44.4)	161.7 (46.6)	2.32	
MF(M04)	360.7 (114.2)	322.1 (90.1)	318.5 (78.0)	306.8 (105.5)	3.98*	SL0>SL5,10,15
CF(M05)	244.5 (53.1)	290.8 (290.3)	249.1 (51.6)	240.7 (54.4)	1.14	
LF(M06)	189.0 (49.9)	192.9 (48.3)	196.3 (51.4)	194.1 (55.0)	1.00	
Ha(M07)	323.6 (123.1)	277.5 (90.7)	258.5 (82.2)	238.9 (71.9)	9.26*	SL0>SL5,10,15; SL5>SL15
To(M08)	139.0 (49.3)	120.4 (36.3)	116.0 (30.7)	113.0 (30.2)	9.92*	SL0>SL5,10,15

He(M01): Heel, MM(M02): Medial midfoot, LM (M03): Lateral midfoot, MF(M04): Medial forefoot, CF(M05): Central forefoot, LF(M06): Lateral forefoot, Ha(M07): Hallux, To(M08): Toes. * $p < 0.05$

Velocità corsa Superficie treadmill

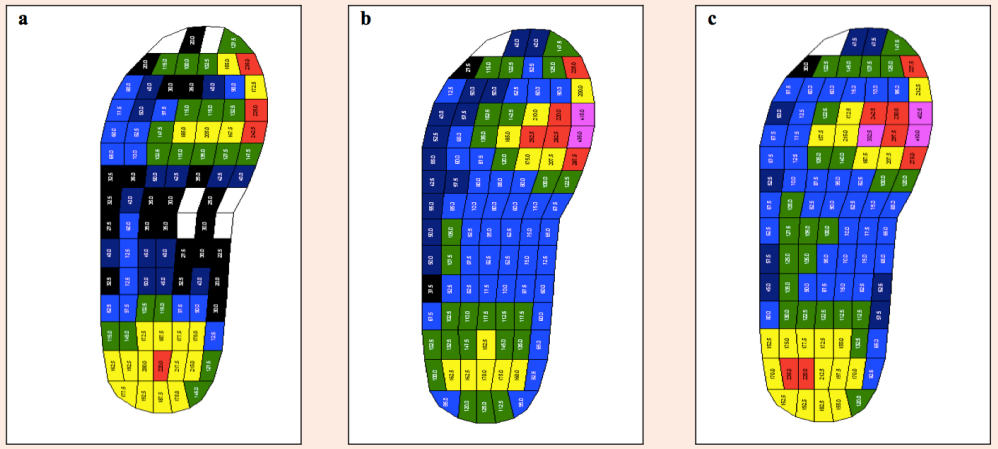


Figure 2. **The peak pressure at same slope 0% with different speeds (a) 1.5 m·s^{-1} (b) 2.0 m·s^{-1} (c) 2.5 m·s^{-1} with the increasing speed, the value of the peak pressure would become larger.**

Pendenza corsa Superficie treadmill

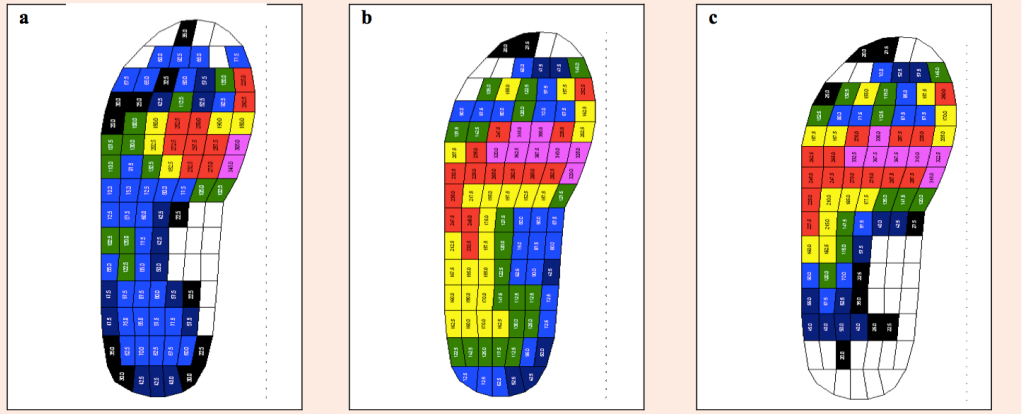


Figure 3. **The peak pressure at same speed 2m·s^{-1} with different slope (a) 5% (b) 10% (c) 15% the increased pressure in the lateral metatarsal could be the consequence of the inverted foot while slope jogging.**

Key points

- The study aimed to compare the plantar pressure distribution of the foot between different incline and speed during treadmill jogging by using plantar insole measurement system.
- With the increase of speed, apart from the hallux and medical forefoot, the peak pressure of all regions was raised significantly.
- As the slope increased, there was reduced peak pressure of the heel, medial forefoot, and hallux and toes.

Fonte: Comparison of plantar pressure distribution between different speed and incline during treadmill jogging. I-Ju Ho, Yi-You Hou, Chich-Haung Yang, Wen-Lan Wu, Sheng-Kai Chen, Lan-Yuen Guo Journal of Sports Science and Medicine (2010) 9, 154-160.

Superficie
(peggioramento?)

pista vs. treadmill
(marcia e corsa)

VARIABLE	TREADMILL LOCOMOTION	OVER-GROUND LOCOMOTION
Stance phase	<	>
Cadence	+ 7% in adults + 10% in children 6 - 7 years	<
Length stride cycle	<	>
Propulsion phase	>	<
Hip and knee flexion	>	<
Pelvic oscillation	<	>

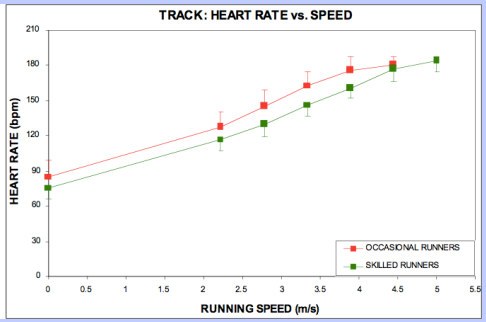
Superficie
(peggioramento?)

pista vs. treadmill
(corsa)

SPEED (m/s)	HR (bpm) on TREADMILL		HR (bpm) on TRACK	
	OCCASIONAL RUNNERS	SKILLED RUNNERS	OCCASIONAL RUNNERS	SKILLED RUNNERS
Rest	87.49 ± 11.58	72.66 ± 11.34	84.67 ± 14.18	75.02 ± 8.45
2.22	134.57 ± 7.32	124.41 ± 11.64	127.62 ± 12.94	116.59 ± 8.96
2.78	150.53 ± 7.63	138.99 ± 11.23	145.46 ± 13.60	130.22 ± 11.46
3.33	166.67 ± 9.12	152.75 ± 11.68	162.16 ± 11.96	145.71 ± 8.63
3.89	179.01 ± 11.07	166.93 ± 11.41	175.72 ± 11.24	160.56 ± 8.83
4.44	186.31 ± 7.59	178.16 ± 7.56	180.32 ± 6.75	177.21 ± 10.64
5.00	result not available	183.57 ± 10.50	result not available	184.32 ± 10.16

Superficie
(peggioramento?)

pista vs. treadmill
(corsa)



differenza sempre significativa

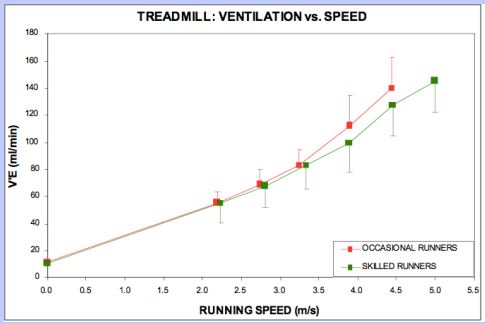
Superficie
(peggioramento?)

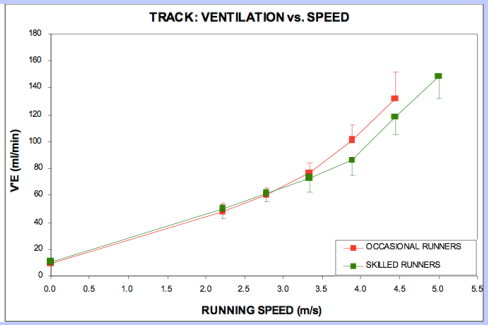
pista vs. treadmill
(corsa)

SPEED (m/s)	V'E (ml/min) on TREADMILL		V'E (ml/min) on TRACK	
	OCCASIONAL RUNNERS	SKILLED RUNNERS	OCCASIONAL RUNNERS	SKILLED RUNNERS
Rest	11.40 ± 2.09	10.30 ± 1.62	10.08 ± 1.46	10.88 ± 1.47
2.22	55.34 ± 8.24	55.03 ± 14.65	48.10 ± 6.20	10.88 ± 1.47
2.78	68.49 ± 11.46	67.67 ± 15.37	60.28 ± 5.81	50.35 ± 7.85
3.33	82.82 ± 11.23	82.95 ± 17.40	76.87 ± 6.92	61.77 ± 6.67
3.89	112.19 ± 22.84	99.06 ± 21.12	101.41 ± 11.13	73.37 ± 10.69
4.44	139.47 ± 23.59	127.06 ± 22.22	131.99 ± 19.91	86.27 ± 10.82
5.00	result not available	145.13 ± 22.29	result not available	118.37 ± 13.04

Superficie
(peggioramento?)

pista vs. treadmill
(corsa)





differenza sempre significativa

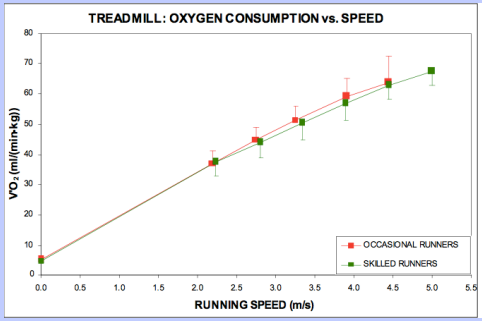
Superficie
(peggioramento?)

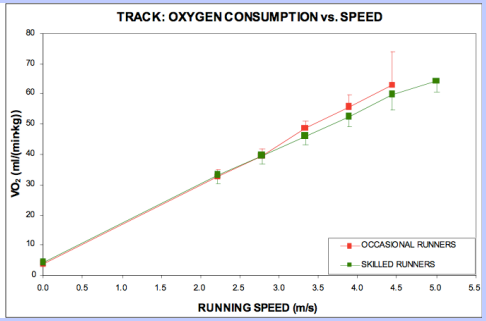
pista vs. treadmill
(corsa)

SPEED (m/s)	$V'O_2$ (ml/kg·min) on TREADMILL		$V'O_2$ (ml/kg·min) on TRACK	
	OCCASIONAL RUNNERS	SKILLED RUNNERS	OCCASIONAL RUNNERS	SKILLED RUNNERS
Rest	5.23 ± 0.93	4.64 ± 0.60	3.80 ± 0.73	4.26 ± 1.08
2.22	36.83 ± 4.21	37.53 ± 4.89	32.47 ± 3.28	33.13 ± 2.59
2.78	44.74 ± 4.37	43.99 ± 5.10	39.44 ± 2.30	39.57 ± 2.73
3.33	51.09 ± 4.61	50.53 ± 5.68	48.52 ± 2.42	45.98 ± 2.56
3.89	59.29 ± 5.97	57.02 ± 5.50	55.73 ± 4.01	52.57 ± 3.37
4.44	63.84 ± 8.48	62.84 ± 4.58	62.81 ± 11.12	59.79 ± 4.89
5.00	result not available	63.53 ± 4.72	result not available	64.26 ± 3.41

Superficie
(peggioramento?)

pista vs. treadmill
(corsa)

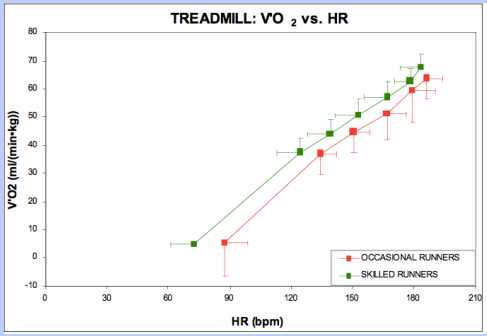


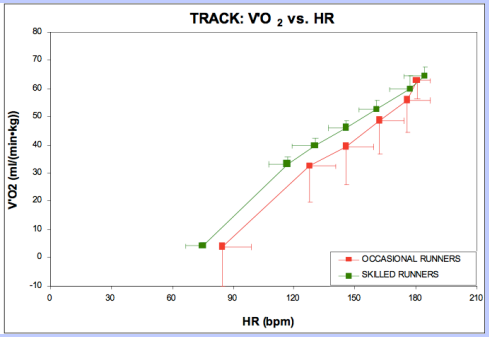


differenza sempre significativa

Superficie
(peggioramento?)

pista vs. treadmill
(corsa)





differenza sempre significativa

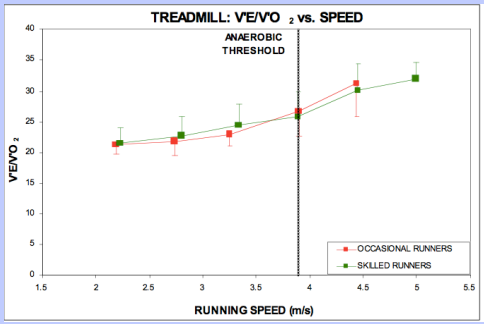
Superficie
(peggioramento?)

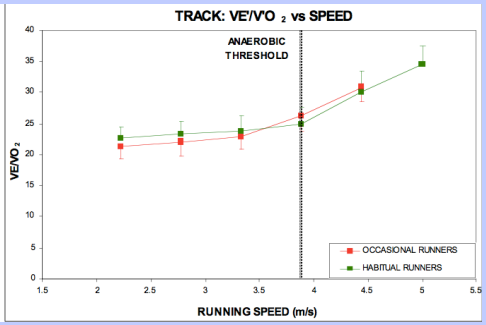
pista vs. treadmill
(corsa)

SPEED (m/s)	V'E/V'O2 on TREADMILL		V'E/V'O2 on TRACK	
	OCCASIONAL RUNNERS	SKILLED RUNNERS	OCCASIONAL RUNNERS	SKILLED RUNNERS
2.22	21.29 ± 1.54	21.52 ± 2.41	21.26 ± 2.07	22.55 ± 187
2.78	21.76 ± 2.23	22.74 ± 3.07	21.98 ± 2.17	23.28 ± 2.05
3.33	22.92 ± 1.87	24.36 ± 3.53	22.77 ± 1.95	23.73 ± 2.54
3.89	26.67 ± 3.91	25.76 ± 4.07	26.14 ± 2.34	24.79 ± 2.88
4.44	31.16 ± 5.43	30.09 ± 4.22	30.81 ± 2.41	29.95 ± 3.40
5.00	result not available	31.93 ± 2.66	result not available	34.44 ± 3.00

Superficie
(peggioramento?)

pista vs. treadmill
(corsa)





differenza sempre significativa (non soglia)

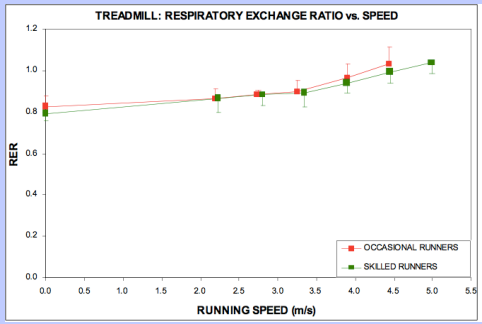
Superficie
(peggioramento?)

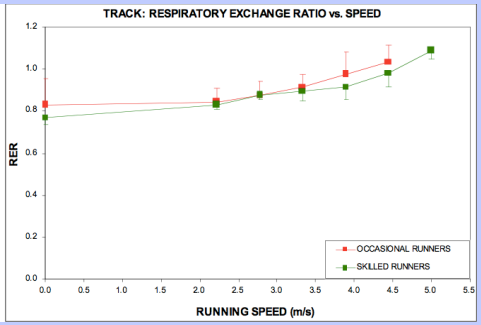
pista vs. treadmill
(corsa)

SPEED (m/s)	RQ on TREADMILL		RQ on TRACK	
	OCCASIONAL RUNNERS	SKILLED RUNNERS	OCCASIONAL RUNNERS	SKILLED RUNNERS
Rest	0.82 ± 0.05	0.79 ± 0.04	0.83 ± 0.12	0.77 ± 0.03
2.22	0.86 ± 0.05	0.87 ± 0.07	0.85 ± 0.06	0.83 ± 0.02
2.78	0.88 ± 0.02	0.88 ± 0.05	0.88 ± 0.07	0.88 ± 0.02
3.33	0.89 ± 0.05	0.89 ± 0.07	0.91 ± 0.07	0.90 ± 0.05
3.89	0.96 ± 0.07	0.94 ± 0.05	0.98 ± 0.10	0.91 ± 0.06
4.44	1.03 ± 0.08	0.99 ± 0.06	1.03 ± 0.08	0.98 ± 0.07
5.00	result not available	1.04 ± 0.05	result not available	1.09 ± 0.04

Superficie
(peggioramento?)

pista vs. treadmill
(corsa)





differenza sempre significativa

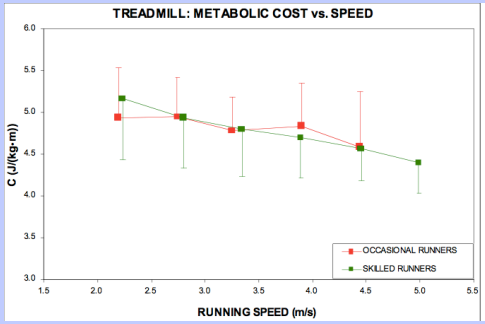
Superficie
(peggioramento?)

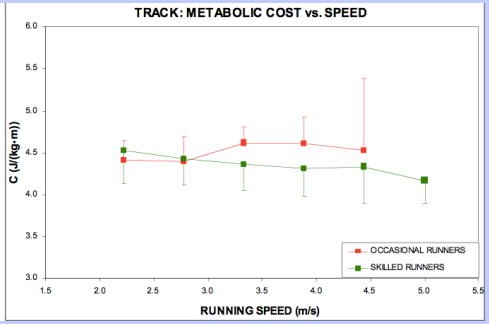
pista vs. treadmill
(corsa)

SUBJECTS	SPEED (m/s)	TREADMILL	TRACK
		C (J/(kg·m))	C (J/(kg·m))
OCCASIONAL RUNNERS	**2.22**	4.93 ± 0.60	4.41 ± 0.24
	2.78	4.94 ± 0.47	4.40 ± 0.29
	3.33	4.78 ± 0.41	4.62 ± 0.20
	3.89	4.83 ± 0.52	4.60 ± 0.33
	4.44	4.58 ± 0.67	4.52 ± 0.87
	5.00	result not available	
SKILLED RUNNERS	**2.22**	5.16 ± 0.73	4.53 ± 0.39
	2.78	4.93 ± 0.60	4.43 ±0.31
	3.33	4.80 ± 0.57	4.36 ±0.32
	3.89	4.69 ± 0.48	4.31 ± 0.33
	4.44	4.56 ± 0.38	4.33 ± 0.43
	5.00	4.39 ± 0.36	4.17 ± 0.28

Superficie
(peggioramento?)

pista vs. treadmill
(corsa)





differenza sempre significativa

Fonte: Dati Nardello, Ardigò

Superficie
(peggioramento?)

pista vs. treadmill
(corsa)

QUESITO INSOLUTO

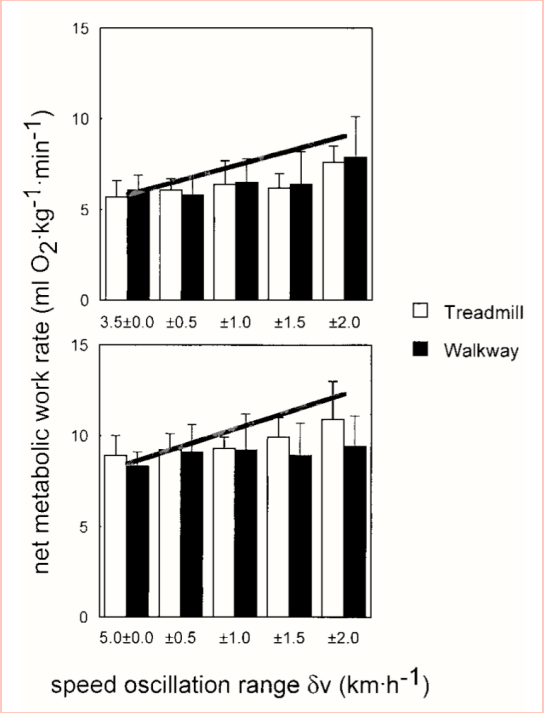
(indubbiamente, la possibilità di far misure su treadmill aumenta quantitativamente e qualitativamente il grado d'indagine (stato stazionario, motion capture..))

-> Domanda Supplementare: c'è un 'costo dello stato stazionario'?

Background
(marcia)

Fonte:

Minetti A. E., Ardigò L. P., Capodaglio E. M., Saibene F. (2001) Energetics and mechanics of human walking at oscillating speeds. Am. Zool. 41: 205-210



Esercitazione 3 (Lunedì 11 Aprile h. 10:30÷13 Biomeccanica del movimento e dello sport ES. ARDIGO' 14?)

Pista	partenza 1° rettilineo: 1 giro di lancio+2 giri di riferimento
Velocità	preferita (media)
Variabili	velocità istantanea con GPS
n°	5

Esercitazione 3b

Pista	partenza 1° rettilineo: 1 giro di lancio+2 giri di riferimento
Velocità	(a partire da 2° rettilineo) 10 km h^{-1} dietro bici con GPS, curve a velocità libera con raccomandazione di mantenere 'ritmo costante' ma senza controllo velocità
Variabili	velocità media e $\dot{V}_{O2}$ (post riposo)..
n°	5

Esercitazione 3c

Treadmill	4'+2' di riferimento
Velocità	v_{pista}
Variabili	$\dot{V}_{O2}$ (post riposo)..
n°	5

Superficie
(peggioramento?)

pista vs. treadmill
(marcia)

ABSTRACT

The energy consumption of walking relates to the intensity of physical effort and can be affected by the alterations in walking speed. Therefore, walking speed can be accepted as a crucial, determinant of energy consumption measurement for a walking test. We aimed to investigate the differences in preferred walking speed (PWS) determined both on overground and on a treadmill and, to measure walking energy expenditure and spatio-temporal parameters of gait on a treadmill at both, speeds. Participants ($n = 26$) walked on a treadmill at two pre-determined speeds for 7 min while, indirect calorimetry measurements were being performed. Spatio-temporal parameters were collected, by video-taping during each walking session on a treadmill. The average overground preferred walking speed (O-PWS) was 85.96 ± 12.82 m/min and the average treadmill preferred walking speed (T-PWS), was 71.15 ± 13.85 m/min. Although T-PWS was lower, oxygen cost was statistically higher when, treadmill walking at T-PWS (0.158 ± 0.02 ml/kg/m) than when the treadmill walking at O-PWS, (0.1480 ± 0.02 ml/kg/m). Cadence (127 ± 9.13 steps/min), stride (134.02 ± 14.09 cm) and step length (67.02 ± 6.90 cm) on the treadmill walking at O-PWS were significantly higher than cadence (119 ± 10 steps/min), stride (117.96 ± 14.38 cm) and step length (59.13 ± 7.02 cm) on the treadmill walking at TPWS. In conclusion, walking on treadmill using O-PWS is more efficient than walking on treadmill using TPWS, in walking tests. Since using T-PWS for treadmill walking tests overestimates the oxygen cost of walking, O-PWS should be used for oxygen consumption measurement during treadmill walking tests.

1.43 ± .21
1.19 ± .23
3.30 ± .42

3.09 ± .42

Superficie
(peggioramento?)

pista vs. treadmill
(marcia e corsa)

VARIABLE	TREADMILL LOCOMOTION	OVER-GROUND LOCOMOTION
Stance phase	<	>
Cadence	+ 7% in adults + 10% in children 6 - 7 years	<
Length stride cycle	<	>
Propulsion phase	>	<
Hip and knee flexion	>	<
Pelvic oscillation	<	>

Disponibili tirocini, tesi triennale e specialistica (1: 5)

- Recupero corsa in avanti vs. corsa all'indietro;
- bioenergetica della corsa prolungata in pista e su treadmill;
- bioenergetica & biomeccanica della corsa prolungata (MF);
- bioenergetica & biomeccanica dell'in-line skating (MpF);
- bioenergetica & biomeccanica dell'handbiking (PhD p);

Disponibili tirocini, tesi triennale e magistrale (2: 6)

- bioenergetica & biomeccanica dell'handbiking dopo RMET (PhD p);
- bioenergetica & biomeccanica dell'handbiking dopo HIT (PhD p);
- bioenergetica & biomeccanica dopo long bed rest (MF);
- bioenergetica & biomeccanica del nordic running;
- bioenergetica & biomeccanica di vari trekking (MF);
- costo metabolico marcia, corsa, ciclismo e sci di fondo stessi soggetti;

Disponibili tirocini, tesi triennale e magistrale (3: 5)

- costo EMG della marcia (MF);

- frequenza di skipping e costo metabolico della corsa (MpF);

- review dei sistemi di misura portatili dell'attività fisica e del dispendio metabolico (C);

- salto in lungo da fermo con masse aggiunte ed allenamento;

- bioenergetica e biomeccanica della regata velica.