Uomini e Donne nel Trail Running

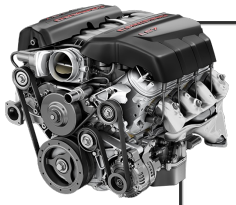
I predittori della performance a confronto

CeRiSM sport montagna salute

UNIVERSITÀ di VERONA

UNIVERSITÀ DI TRENTO

LA PERFORMANCE DI ENDURANCE



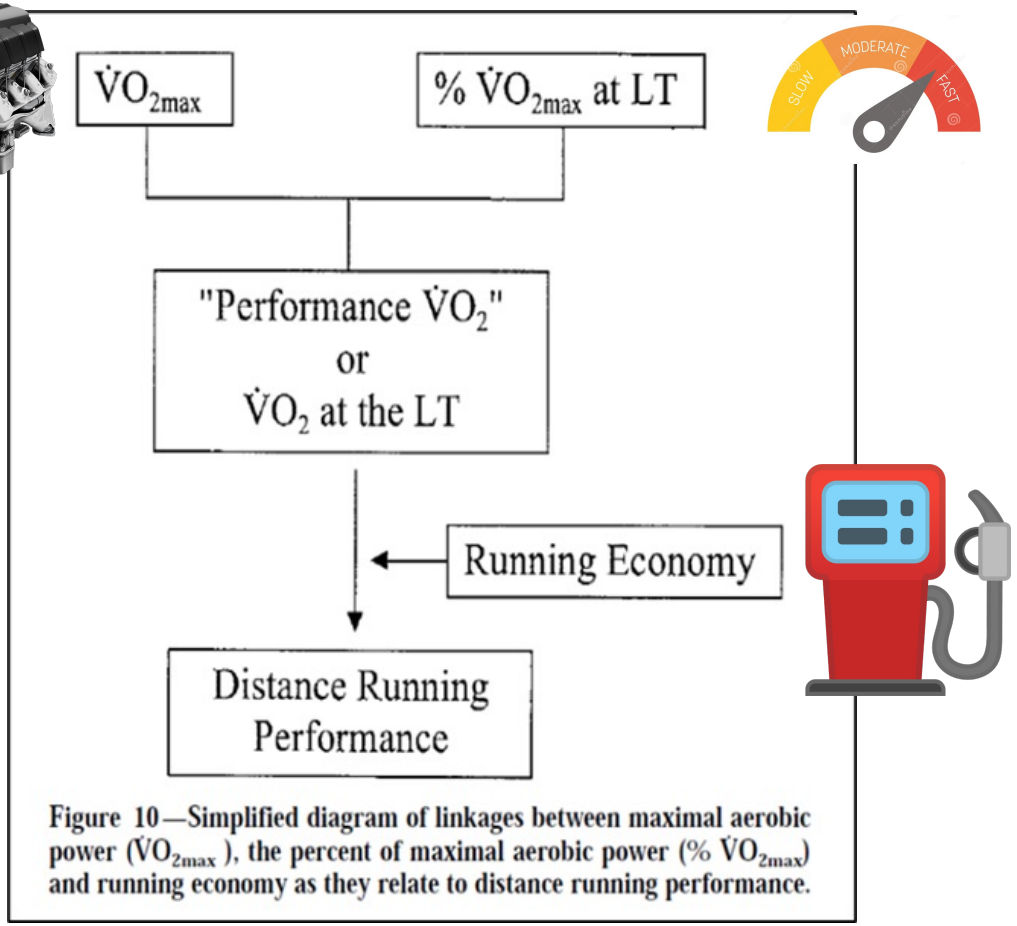
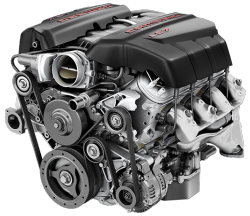


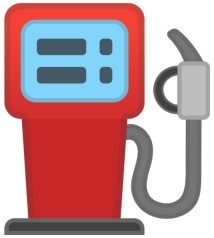
Figure 10—Simplified diagram of linkages between maximal aerobic power ($\dot{V}O_{2max}$), the percent of maximal aerobic power (% $\dot{V}O_{2max}$) and running economy as they relate to distance running performance.

LA PERFORMANCE DI ENDURANCE



VO2max

%VO2 at LT

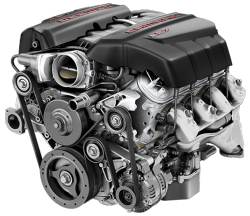


Running Economy

90-95% of road-performance prediction:

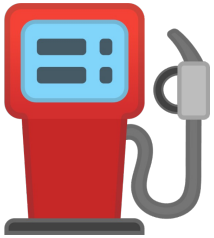
- From **800 m** to **marathon races**
- From **amateur** to **national and international runners** (60 vs 75 ml/kg/min)
  (Di Prampero et al., McLaughlin et al., Ingham et al.)

LA PERFORMANCE DI TRAIL



VO2max

%VO2 at LT

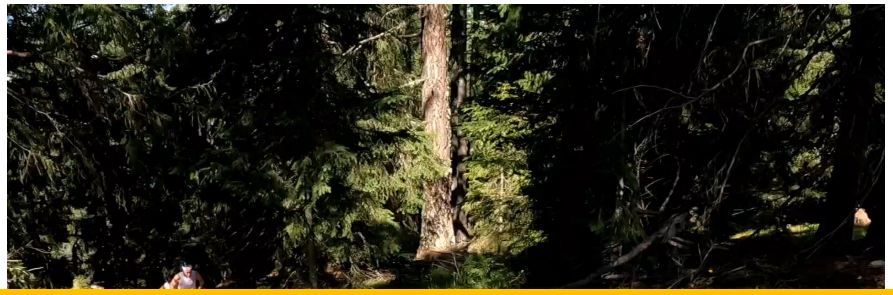


Running Economy

Trail- performance prediction:

- 48% of a short trail- 27 km, 1400m D+ (Ehrstrom et al.)
- 62% of a long trail- 166 km, 9500m D+ (Pastor et al.)

LA PERFORMANCE DI TRAIL



A foot race in a natural environment including mountains, deserts, forests, coastal areas, jungles/rainforests, grassy or arid plains over a variety of different terrains (e. g. **dirt road, forest trail, single track, beach sand, etc**.) with minimal paved or asphalt roads, not exceeding 20–25 % of the total race course

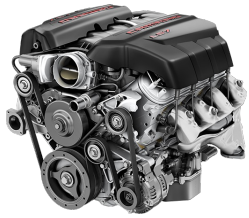
Trail- performance prediction:

- 48% of a short trail- 27 km, 1400m D+ (Ehrstrom et al.)
- 62% of a long trail- 166 km, 9500m D+ (Pastor et al.)

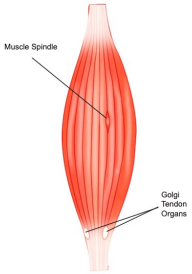
LA PERFORMANCE DI TRAIL

.27 km, 1400m D+, highly trained runners (VO2max:67 ml/kg/min) (Ehrstrom et al. 2021)

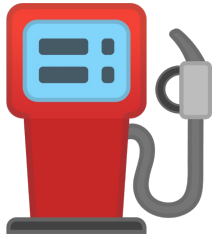
Performance correlation to VO2max: 0.76



VO2max

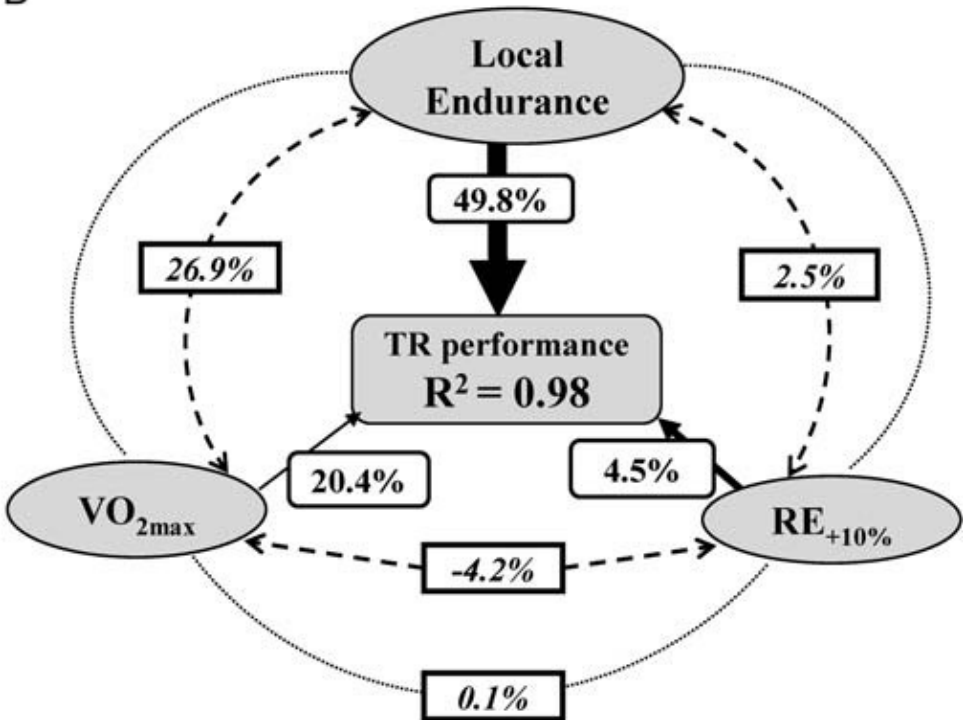


Local Endurance



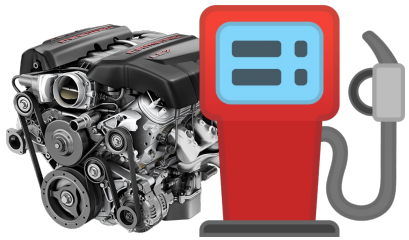
Running Economy Uphill

B

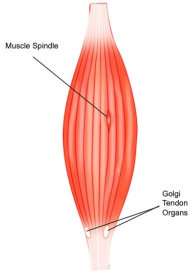


LA PERFORMANCE DI TRAIL

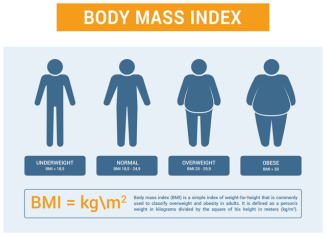
- 5 km **UPHILL** **predictors, highly trained runners** **(VO2max:70.4 ml/kg/min)** (Lemire et al., 2021)



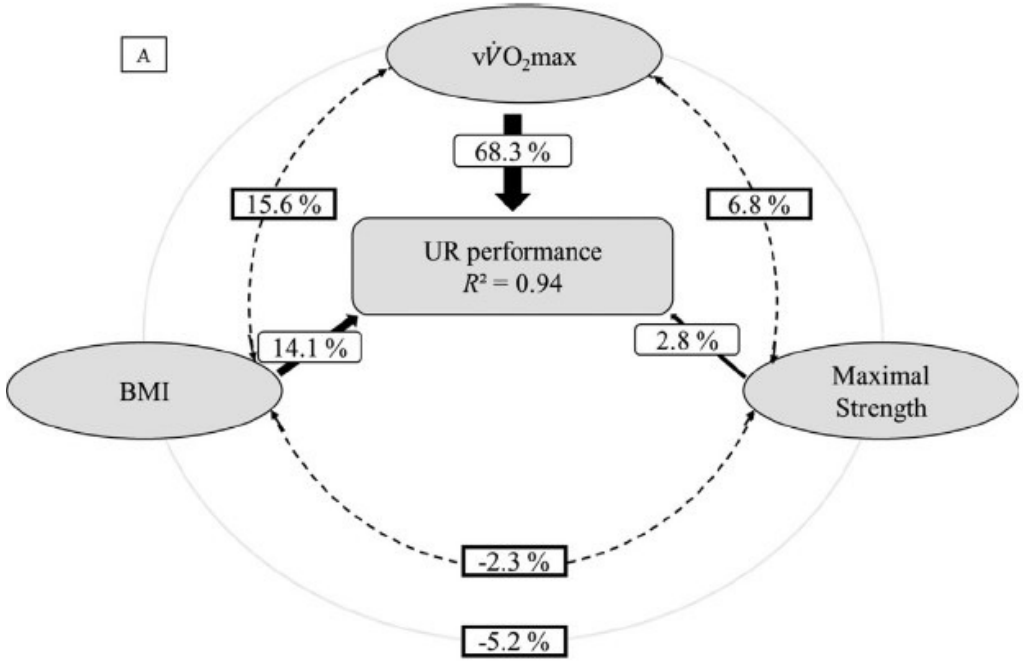
vVO2max



Maximal Strength



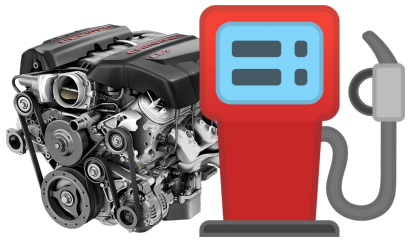
BMI



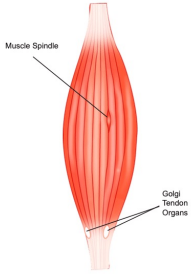
LA PERFORMANCE DI TRAIL

- 5 km **DOWNHILL**

predictors, highly trained runners
(VO2max:70.4 ml/kg/min) (Lemire et al., 2021)

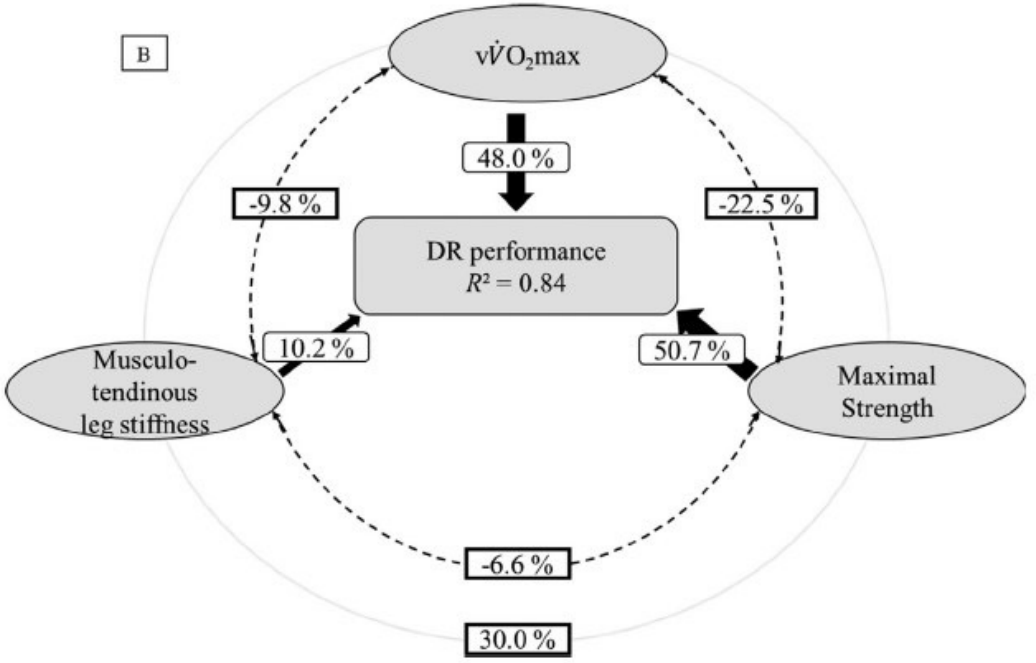


vVO2max



Maximal Strength

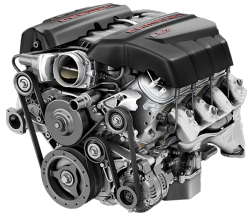
Musculo tendinous leg stiffness



LA PERFORMANCE DI TRAIL

- **47.5 km, 2900**

recreational runners
(VO2max: 57.6 ml/kg/min)

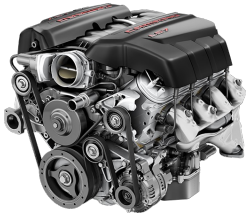


VO2max

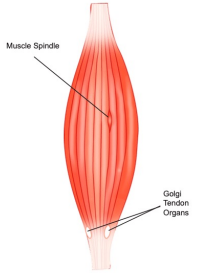
% Fatmax

- **101 km, 6100 –**

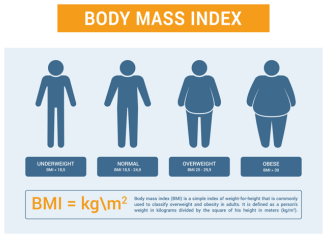
recreational runners
(VO2max: 58.3 ml/kg/min)



VO2max



Max voluntary contraction



Body Fat%

LA PERFORMANCE DI TRAIL

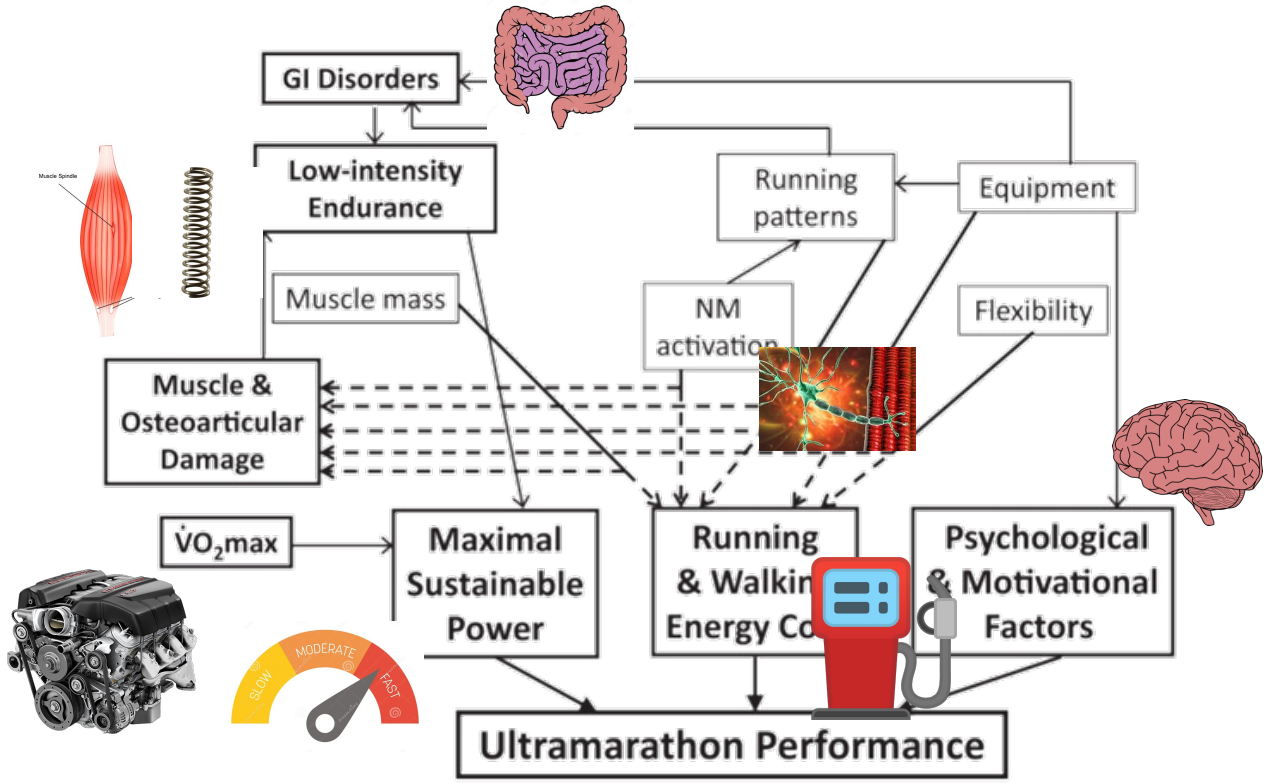
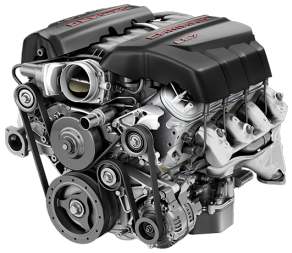


Fig. 1. Determinants of performance in ultramarathons that may be subjected to a compromise between energy cost and lower limb tissue injury (dashed lines). GI, gastrointestinal; NM, neuromuscular. Most important factors for ultramarathon performance are in bold.

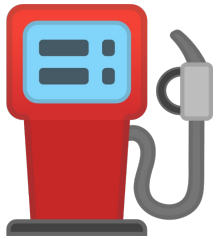
LA PERFORMANCE DI TRAIL

From 5 km to >100 km

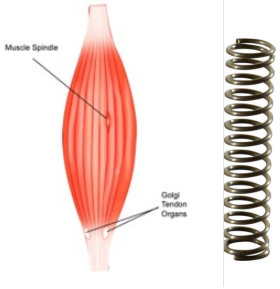


VO2max

Local Endurance



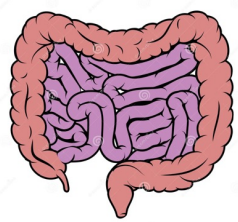
Running Economy Uphill

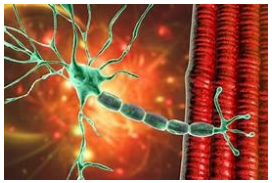


Musculo tendinous aspects

Substrate use (Fatmax)

Body composition





PASTOR 2022, Elite Road vs. Trail Runners: Comparing Economy,Biomechanics, Strength, and Power

Practical Applications

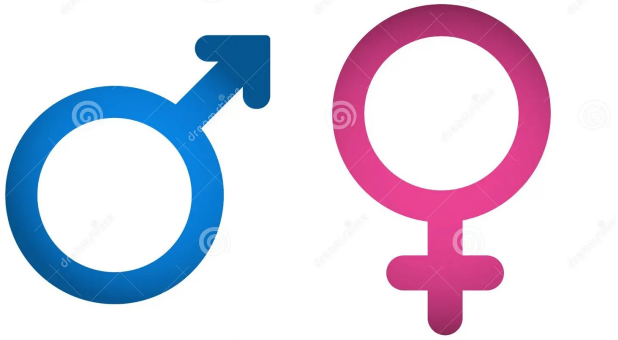
No previous study has compared the differences between road and trail elite runners. Our results are of interest for athletes, coaches, and practitioners working with trail runners as well as road runners, as they highlight some of the differences between elite road and trail runners, which can help design specific preparation strategies for each discipline. Trail runners should pay special attention to neuromuscular factors (i.e., developing strength and power). This may be especially relevant to road runners who wish to change disciplines to compete in trail running. In terms of training, we show that there is a gap in the amount of time dedicated to training when comparing elite road and trail runners, with trail runners training much less, on average. This suggests that it takes less training to become a world class athlete in trail running compared with road running (i.e., that the "maturity" of the 2 disciplines differ). Increasing training volume of trail runners may present an opportunity to increase their level of performance.

Figure 3. Monthly training hours of elite TRAIL and ROAD runners. Difference between road and trail runners: $^{*}p < 0.05$; $^{***}p < 0.001$.

.... E IL RUOLO DEL SESSO?

SEX

Biological attributes of an individual, the physical and physiological features determined by genetics and hormone function, which are generally classified as female or male



GENDER

Social construct that relates to the roles, behaviors, and identities that an individual fulfils in society

LEMAT 2023, Running Endurance in Women Compared to Men: Retrospective Analysis of Matched Real-World Big Data

The difference in performance between sexes remains around 10–12% for running events from sprint to marathon.

Sex differences seem to decrease with increasing race distance.

BUT- Sex difference in performance appears constant with increasing distance when considering the first males and the first females.

TILLER 2021, Do Sex Differences in Physiology Confer a Female Advantage in Ultra-Endurance Sport?

50km: men are 15% faster than females

100 km: men are 5% faster than females

From 100 to 200 km: men are 12.4% faster than females

Females were 0.6% faster than males in races > 195 miles

Histoire du Trail #7 - Corinne Favre remporte la première CCC

121: Pam Reed – La leggenda dell'ultramaratona nel deserto (Badwater 2002)

> Hiroko Okiyama is the first woman to win the Deutschlandlauf.

Spine Race: Jasmin Paris becomes first female winner of 268-mile ultra marathon

How Courtney Dauwalter Won the Moab 240 Outright

LEMAT 2023, Running Endurance in Women Compared to Men: Retrospective Analysis of Matched Real-World Big Data

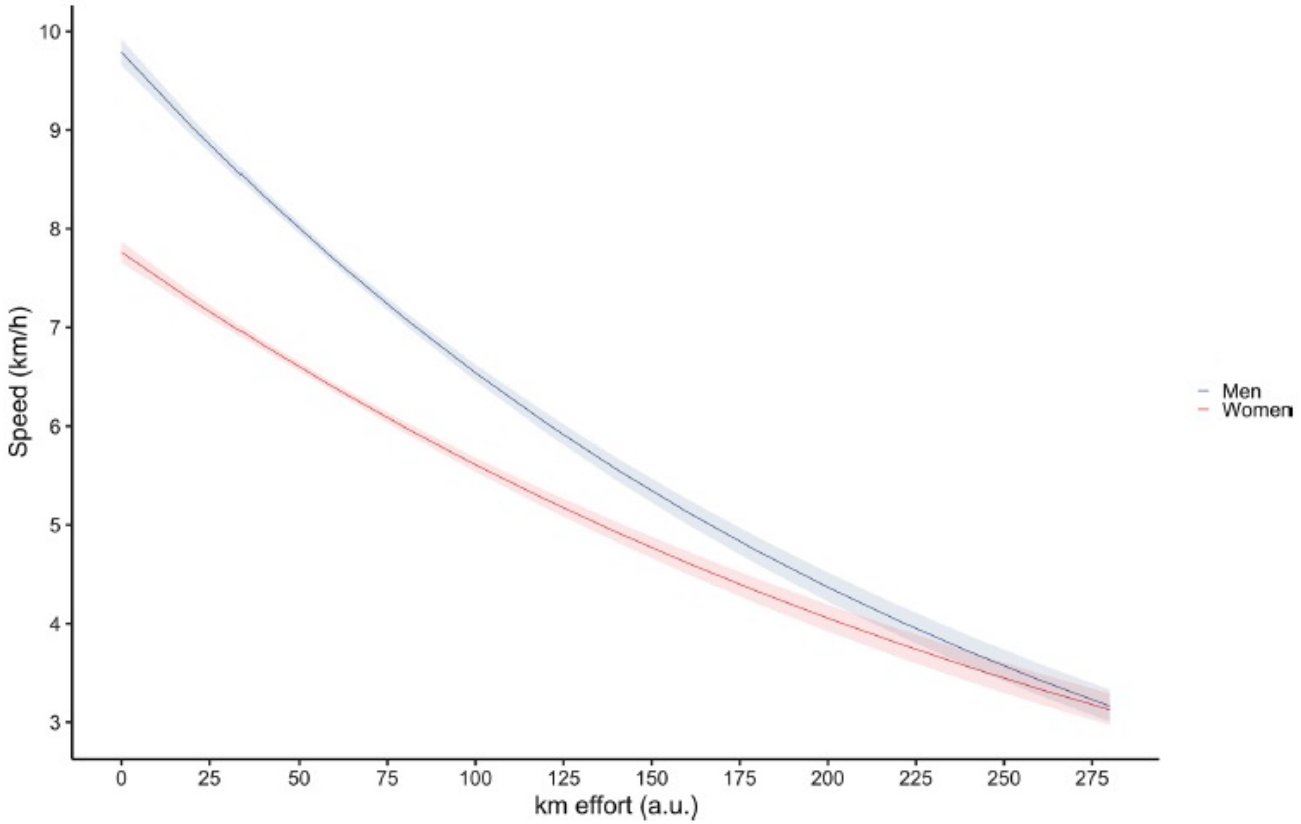


Fig. 2 Sex effect on the speed evolution in function of the km-effort distance. The lines are the marginal effect of each sex (red: women, blue: men) estimated on the selected best gamma model. Shaded areas are the 95% confidence interval calculated using the likelihood profiles for each estimate coefficient

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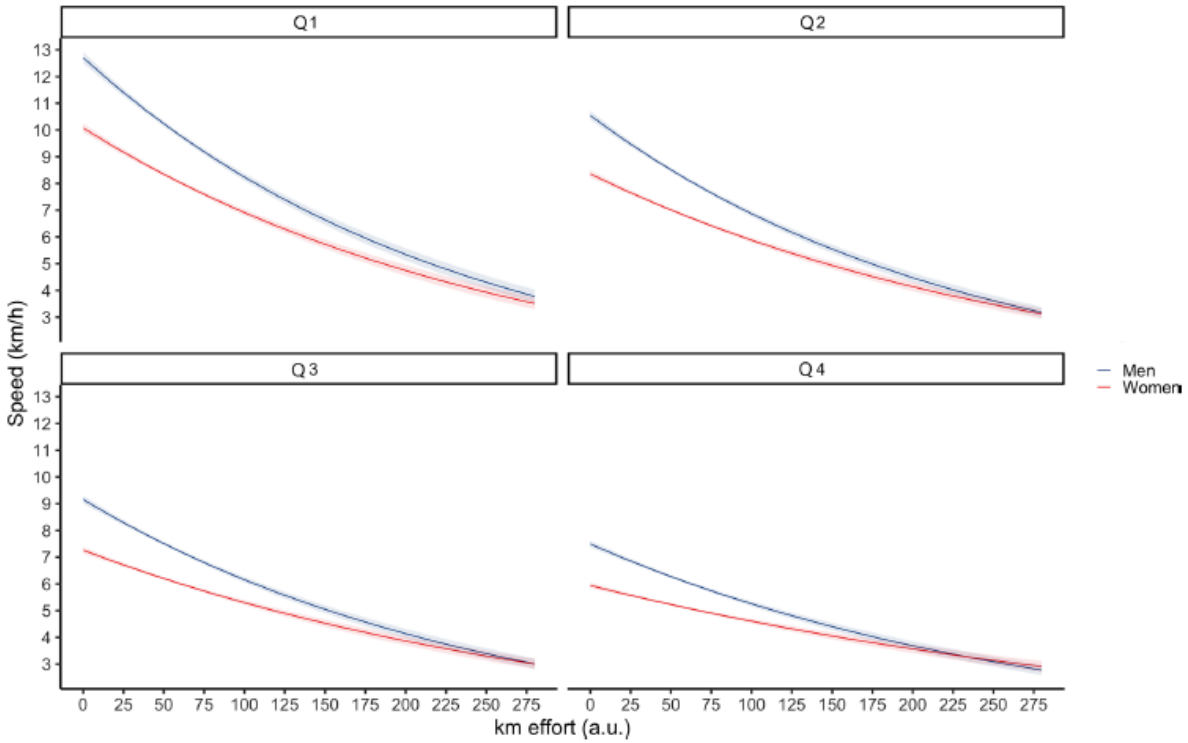


Fig. 3 Sex effect on the speed evolution in function of the km-effort distance and the performance level. The lines are the marginal effect of each sex (red: women, blue: men) for each performance level (quartile 1 [Q1], quartile 2 [Q2], quartile 3 [Q3] and quartile 4 [Q4]) estimated on the selected best gamma model. Shaded areas are the 95% confidence interval calculated using the likelihood profiles for each estimate coefficient

NAVALTA 2018 Sex and Age Differences in Trail Half Marathon Running

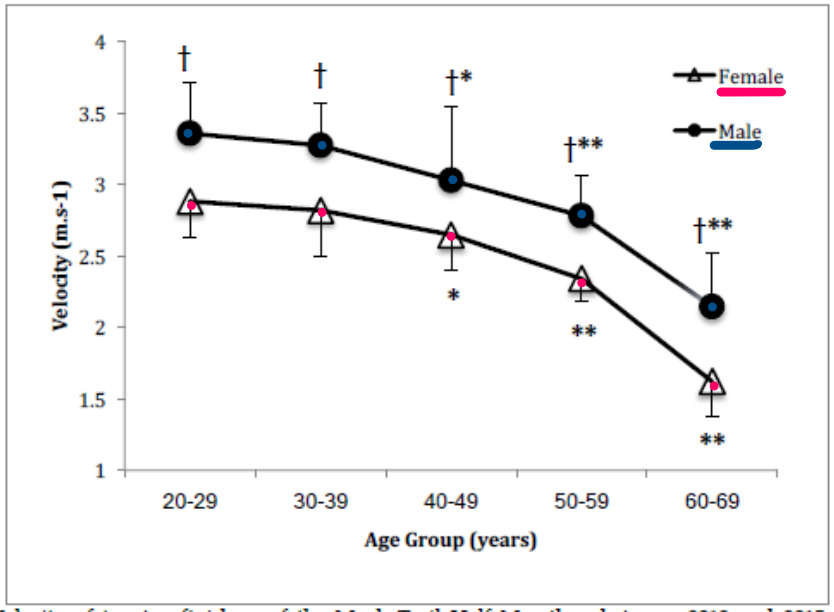
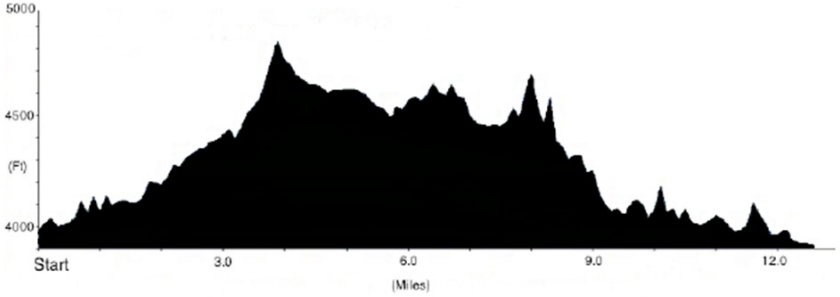


Figure 2. Velocity of top ten finishers of the Moab Trail Half Marathon between 2012 and 2015. † indicates significant differences between males and females (P <0.0001). * indicates significantly different from the 20 - 29 year age group for each sex ($P < 0.001$), ** indicates significantly different from all other age groups for each sex ($P < 0.001$).

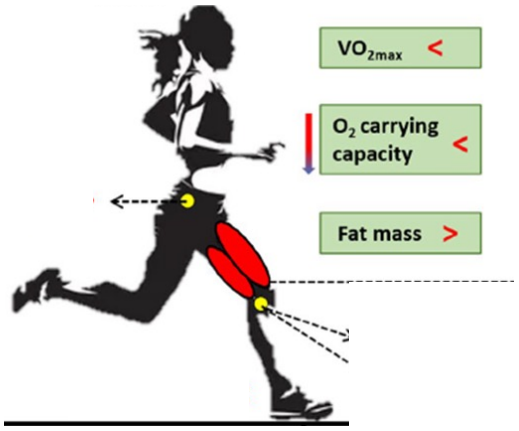
Table 2. Mean finishing time and pace across age category.

		20-29 years	30-39 years	40-49 years	50-59 years	60+ years
Top Finish Time (hr:min:sec)	Female	1:48:19	1:51:22	1:50:35	2:15:45	2:47:06
	Male	1:30:48	1:35:18	1:47:45	1:49:47	2:06:18
10th Place Finish Time (hr:min:sec)	Female	2:07:39	2:11:33	2:21:25	2:38:07	4:25:20
	Male	1:51:42	1:56:11	2:08:28	2:13:26	3:16:16
Top Finisher Pace (min:mile)	Female	8:34	8:27	8:53	10:14	14:13
	Male	7:04	7:20	8:09	8:20	9:41
10th Place Finisher Pace (min:mile)	Female	9:56	10:09	10:53	12:26	18:43
	Male	8:43	8:52	9:45	10:43	15:57

Moab Trail Half Marathon, 21 km 560m D+



…. BESSON 2022, Sex differences in endurance running



The difference in performance between sexes remains around 10–12% for running events from sprint to marathon.

…. BESSON 2022, Sex differences in endurance running

- Higher **gluteus maximus** activation at all speed and inclines
- Larger **vastus lateralis** activity as incline increases
- Higher **quadriceps** and lower hamstring activation
- Higher **medial hamstring** preactivation in downihill
- Higher activation of **peroneal muscle**

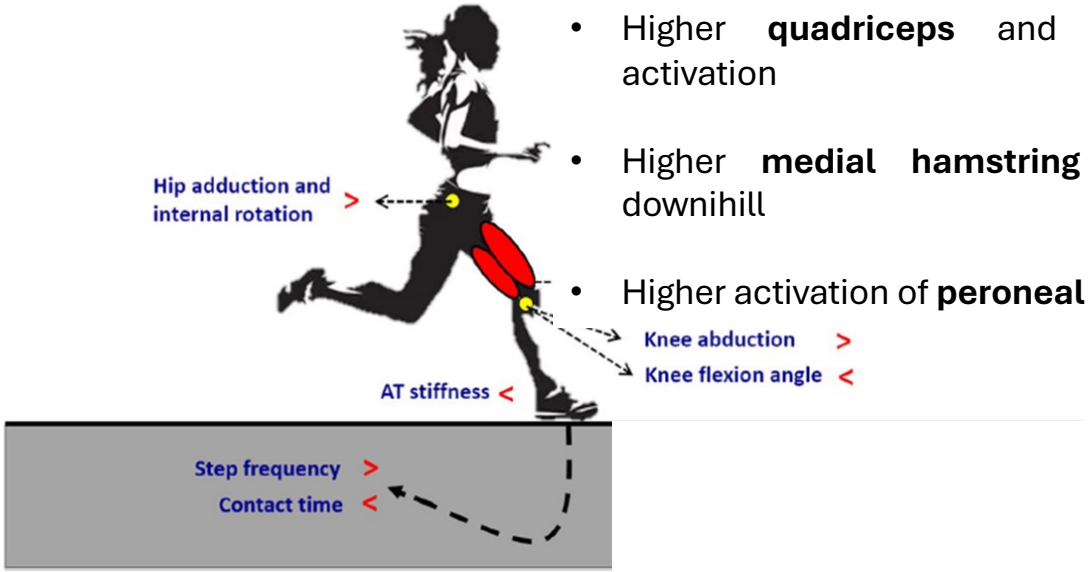


Fig. 1 This schematic representation of a female runner is an overview of the main psychological, physiological, neuromuscular and biomechanical sex differences in endurance running. Parameters that could give an advantage to males and to females in endurance running performance are boxed in green and orange, respectively. >: superior in females, <: inferior in females, =: no sex difference, *AT* Achilles tendon, O_2 oxygen, $\dot{V}O_{2max}$ maximal oxygen uptake

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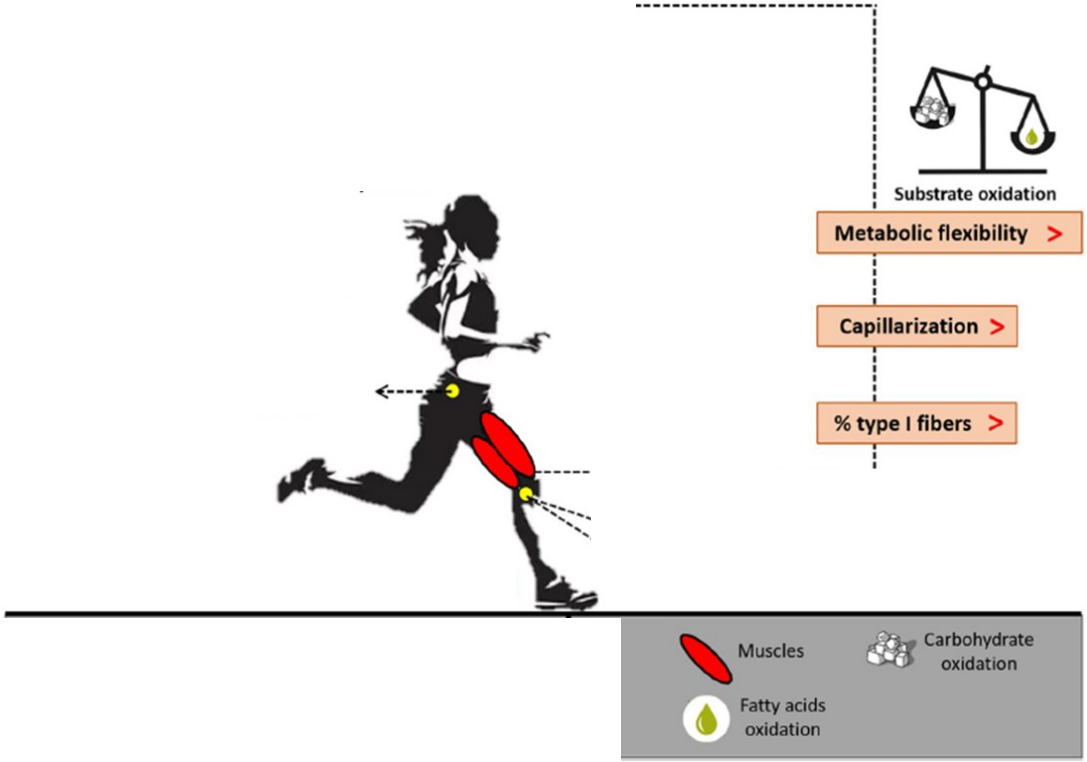

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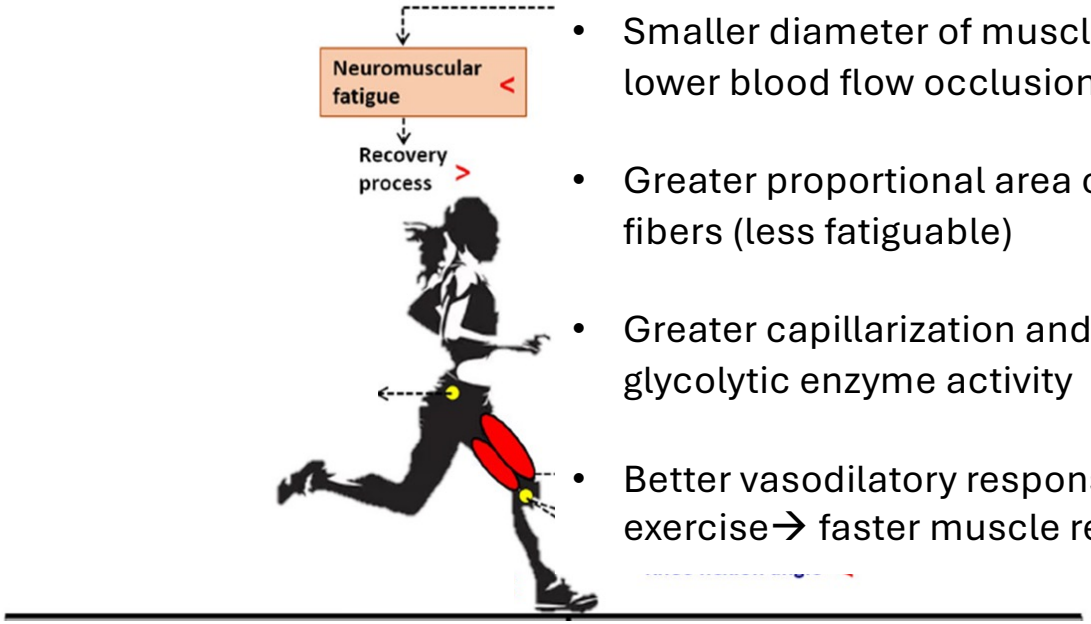

- Smaller diameter of muscle fibers→ lower blood flow occlusion
- Greater proportional area of type I fibers (less fatiguable)
- Greater capillarization and lower glycolytic enzyme activity
- Better vasodilatory response to exercise→ faster muscle recovery

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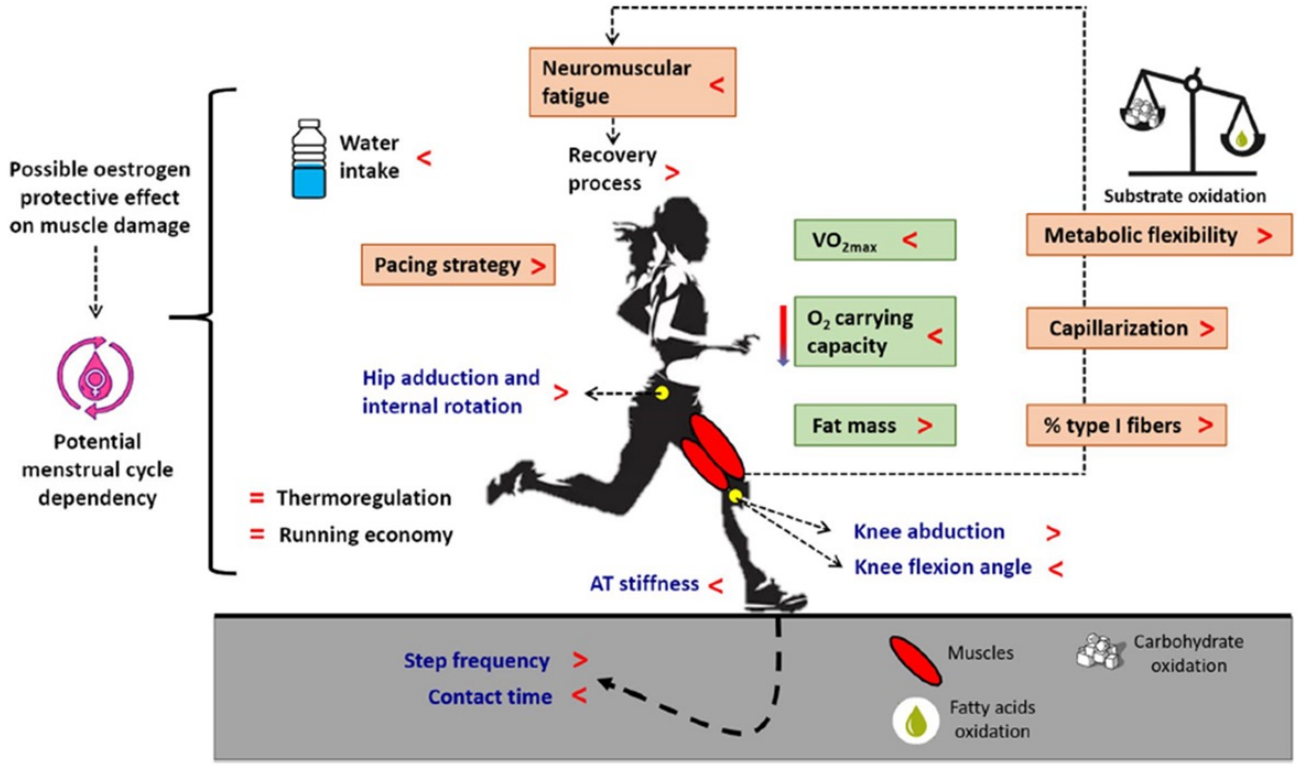

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KELLY 2023, Is there Evidence for the Development of Sex-Specific Guidelines for Ultramarathon Coaches and Athletes?

Table 1 Predictors of performance

Study	Participants	Measures	Design	Evidence quality	Major findings
Martinez-Navarro et al.[28]	32 athletes who completed a 107 km mountain ultramarathon (13 females and 19 males)	Squat jump height, ankle rebound test (Leg QIndex), half squat IMVC, FVC, FEV1, PEF, MIP, 107 km race time	Cohort study	Low	MIP correlated with performance in males ($r = 0.576$, $p = 0.010$) Leg QIndex correlated with performance in females ($r = -0.607$, $p = 0.028$)
Martinez-Navarro et al.[16]	Same cohort as above study	VO_2max, VT1 and VT2, Vpeak, MFO, body composition, 107 km race time	Cohort study	Low	Correlation with race time: peak oxygen uptake (males: $r = -0.63$, $p = 0.004$; females: $r = -0.85$, $p < 0.001$), peak speed (males: $r = -0.74$, $p < 0.001$; females: $r = -0.69$, $p = 0.009$), speed at first (males: $r = -0.49$, $p = 0.035$; females: $r = -0.76$, $p = 0.003$) and second (males: $r = -0.73$, $p < 0.001$; females: $r = -0.76$, $p = 0.003$) ventilatory threshold, and maximal fat oxidation (males: $r = -0.53$, $p = 0.019$; females: $r = -0.59$, $p = 0.033$) Percentage of fat mass (males: $r = 0.58$, $p = 0.010$; females: $r = 0.62$, $p = 0.024$) and lean body mass (males: $r = -0.61$, $p = 0.006$; females: $r = -0.61$, $p = 0.026$) In males: Vpeak and MFO together predicted 66% of variation in race time In females: VO_2max predicted 69% of variation in race time
Hoffman et al.[26]	72 athletes (17 females and 55 males) who completed a 161 km ultramarathon with qualifying criteria	BMI, BF%, 161 km race time	Cross-sectional	Low	BF% related to running speed in males ($R^2 = 0.23$; $p = 0.0025$), but not females
Citarella et al.[27]	10 athletes (4 females and 6 males) from the Italian ultramarathon team	BMI, body composition, dietary adequacy score, training volume, record 100 km time	Cross-sectional	Low	Strong association between training volume and 100 km record time with no sex differences ($p = 0.891$, $p = 0.009$) Females had higher dietary adequacy scores than males (39.94 ± 6.33 vs. 57.50 ± 10.78; $p = 0.038$)
O'Loughlin et al.[15]	83 athletes (26 females and 57 males) who completed a 62 km trail ultramarathon	BMI, training history, pre-race experience, race time	Cross-sectional	Low	Measures associated with running performance in females: training volume ($R^2 = 0.116$, $p = 0.049$), half marathon ($R^2 = 0.509$, $p = 0.0001$), 10 km ($R^2 = 0.373$, $p = 0.021$), and 5 km PB ($R^2 = 0.432$, $p = 0.002$). In males: Age ($R^2 = 0.061$, $p = 0.035$), BMI $R^2 = 0.085$, $p = 0.016$), average training speed ($R^2 = 0.183$, $p = 0.0001$), number of training years ($R^2 = 0.079$, $p = 0.023$), marathon ($R^2 = 0.233$, $p = 0.002$) and 5 km PB ($R^2 = 0.225$, $p = 0.003$)
Coates et al.[29]	31 athletes (20 females and 11 males) competing in a 50 km trail race	Training and racing history, anthropometrics, BP, HR, HRV, haematocrit, CPET	Cross-sectional	Low	BMI and MAP related to performance in males (BMI: $r = 0.75$, $p < 0.05$; MAP: $r = 0.87$, $p < 0.001$), but not in females (BMI: $r = 0.02$ ns, MAP: r = -0.31 ns) Age, resting HR, HRV, VO_2max and Vpeak related to 50 km performance in both sexes

IMVC, isometric maximal voluntary contraction; FVC, forced vital capacity; FEV1, forced expiratory volume over 1 s; PEF, peak expiratory flow; MIP, mean inspiratory pressure; VO_2max, maximal oxygen uptake; and VT1, first ventilatory threshold; VT2, second ventilatory threshold; Vpeak, peak speed reached during cardiopulmonary exercise testing; MFO, maximal rate of fat oxidation; BMI, body mass index; BF%, body fat percentage; MAP, mean arterial pressure; PB, personal best; BP, blood pressure; HR, heart rate; HRV, heart rate variability; CPET, cardiopulmonary exercise test; and ns, not statistically significant

KELLY 2023, Is there Evidence for the Development of Sex-Specific Guidelines for Ultramarathon Coaches and Athletes?

Table 2 Immune function and oxidative stress

Study	Participants	Measure/s	Design	Evidence quality	Major findings
Nieman et al.[30]	31 athletes (9 females and 22 males) who finished a 160 km ultramarathon	SIgA secretion rate, Incidence of post-race URTI	Cohort study	Low	Female athletes had lower sIgA secretion rates than males both pre (358 ± 52 µg/min compared to 560 ± 38 µg/min, respectively, $p = 0.011$)- and post-race (163 ± 23 µg/min compared to 293 ± 39 µg/min, respectively, $p = 0.008$). No sex difference in post-race URTI incidence
Mastaloudis et al.[31]	22 athletes (11 females and 11 males) who completed a 50 km ultramarathon. Age 39 ± 2.5 years	Percentage of cells with DNA damage (comet assay)	RCT – double blinded	High	Females had higher levels of DNA damage post-race (gender x treatment x time interaction ($p < 0.01$) Females taking AO had 62% fewer cells with DNA damage 24 h post-race compared with placebo ($p < 0.0008$). No significant effect on males
Mastaloudis et al.[32]	Same subjects as study above	Plasma LDH and CK, Hamstrings and quadriceps MVC	RCT – double blinded	High	LDH and CK increased after the race – there was no effect of sex or AO use after correction for lean body mass. No sex differences or effect of AO on relative loss of muscle strength post-race
Mastaloudis et al.[33]	Same subjects as study above	Plasma F2-IsoPs (marker of lipid peroxidation), Plasma CRP, TNF-α, IL-6	RCT – double blinded	High	Plasma F2-IsoPs increased only in placebo group (28 ± 2 to 41 ± 3 pg/ml, $p < .0001$) In placebo group, females' F2IsoP levels returned to normal within 2 h, whereas males' remained elevated for 6 days post-race (gender x treatment interaction, $p < 0.03$). Inflammatory markers increased, regardless of sex or treatment group
Miyata et al.[34]	95 athletes (16 females and 79 males)	Urinary 8-hydroxydeoxyguanosine, plasma AST, CPK, myoglobin	Cohort study	Low	No sex differences in markers of oxidative stress, or antioxidant repair systems
Guerrero et al.[35]	32 athletes (13 females and 19 males)	CG (marker of protein peroxidation), MDA (marker of lipid peroxidation), GR and GPx (AO enzymes)	Cohort study	Low	48 h post-race: MDA levels were significantly higher in males ($p < 0.05$), whereas CG levels were significantly higher in females ($p < 0.05$). No sex difference in GR or GPx

sIgA, salivary immunoglobulin A secretion; URTI, upper respiratory tract infection; AO, antioxidant; DNA, deoxyribonucleic acid; RCT, randomised controlled trial; LDH, lactate dehydrogenase; CK, creatine kinase; MVC, maximal voluntary contraction; F2IsoP, F2 isoprostanes; CRP, C-reactive protein; TNF-α, tumour necrosis factor alpha; IL-6, interleukin 6; AST, aspartate transaminase; CPK, creatine phosphokinase; CG, carbonyl groups; MDA, malondialdehyde; GR, glutathione reductase; and GPx, glutathione peroxidase

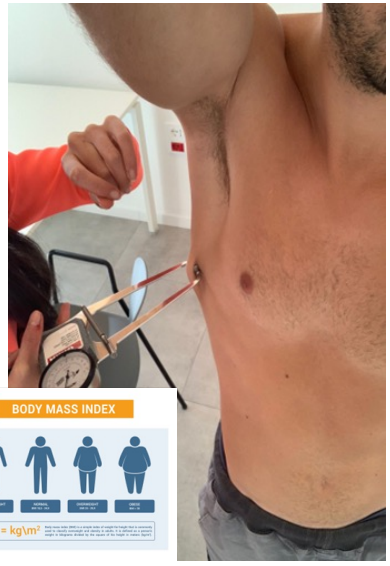
KELLY 2023, Is there Evidence for the Development of Sex-Specific Guidelines for Ultramarathon Coaches and Athletes?

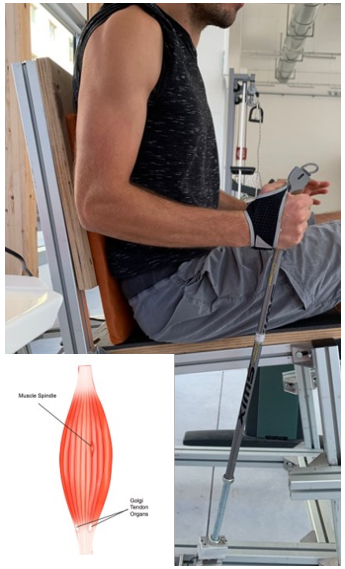
Areas where evidence of sex-differences exists
Performance predictors for longer (>100km) ultramarathons: women's performance predicted by ankle reactive strength and VO_2MAX; men's performance predicted by mean inspiratory pressure, Vpeak and maximal fat oxidation rates.
Fatigue: peripheral fatigue of plantar-flexors (greater in men); cardiac fatigue in races <100km (greater in men).
Pacing strategies: more even pacing in women for relatively flat races; more even pacing in men for mountain races.
Risk of long-term health issues: bone stress injuries, eating disorders, athlete triad (greater in females).
Risk of race-related medical illness (greater in females).
Incidence of heat-related issues (greater in men).
Oxidative stress and antioxidant (AO) supplementation: protein peroxidation, DNA damage, and effect of AO supplementation on these measures (greater in females).

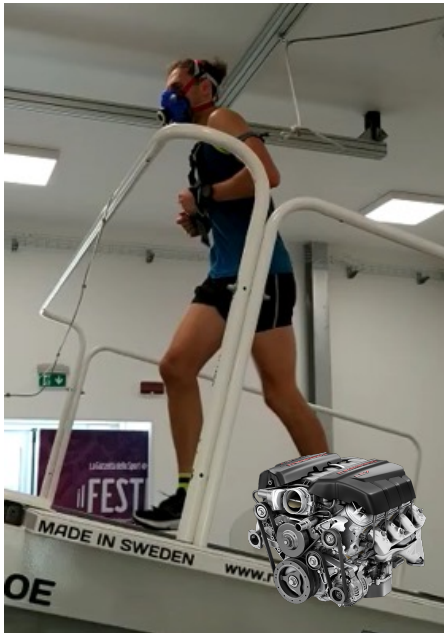
Fig. 2 Areas where evidence of sex differences exists

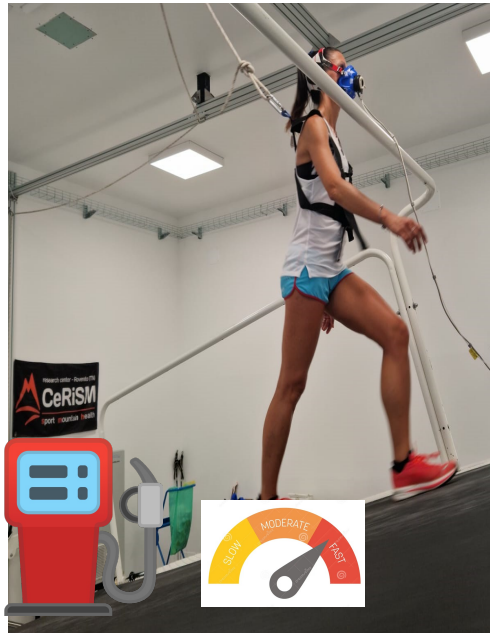
CALLOVINI 2025?

- Races with km-effort between 25 and 74 (ITRA 1 or 2, XS and S)
- From 2h to 4.30h
- 10 men and 10 women, same absolute performance
- Do performance predictors change?









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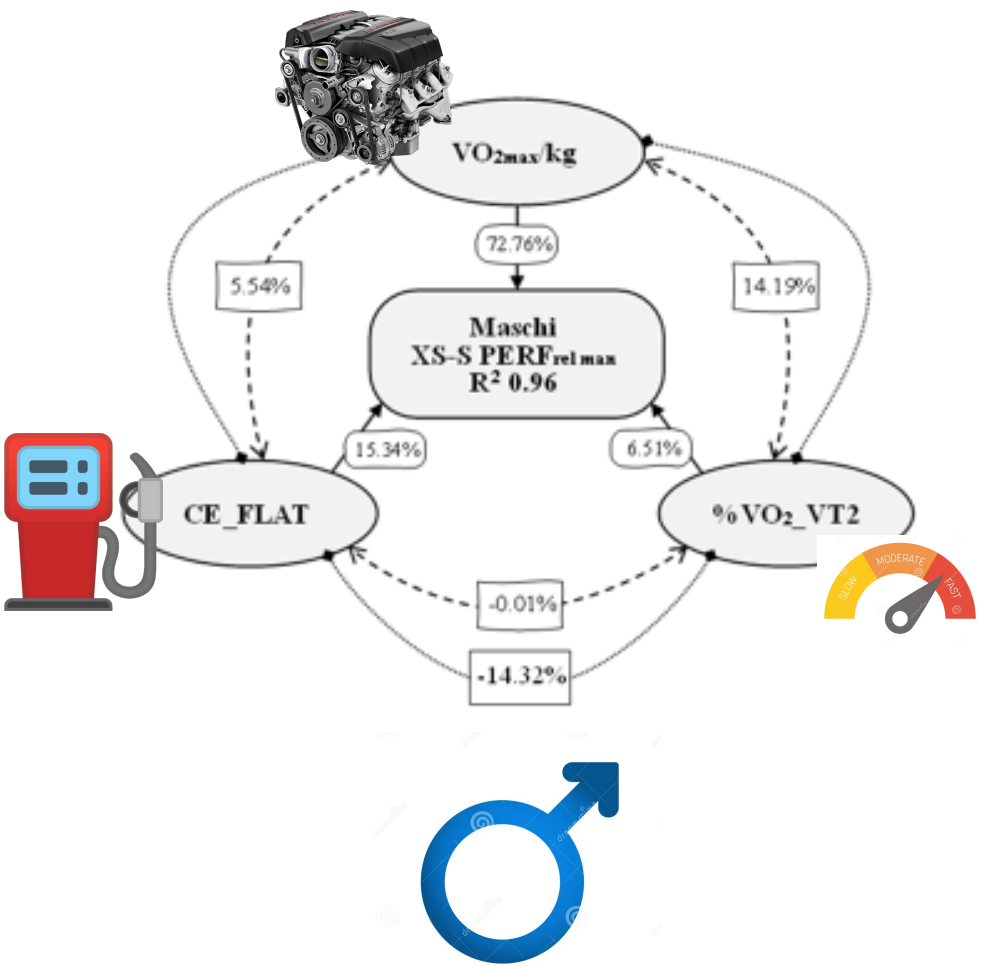

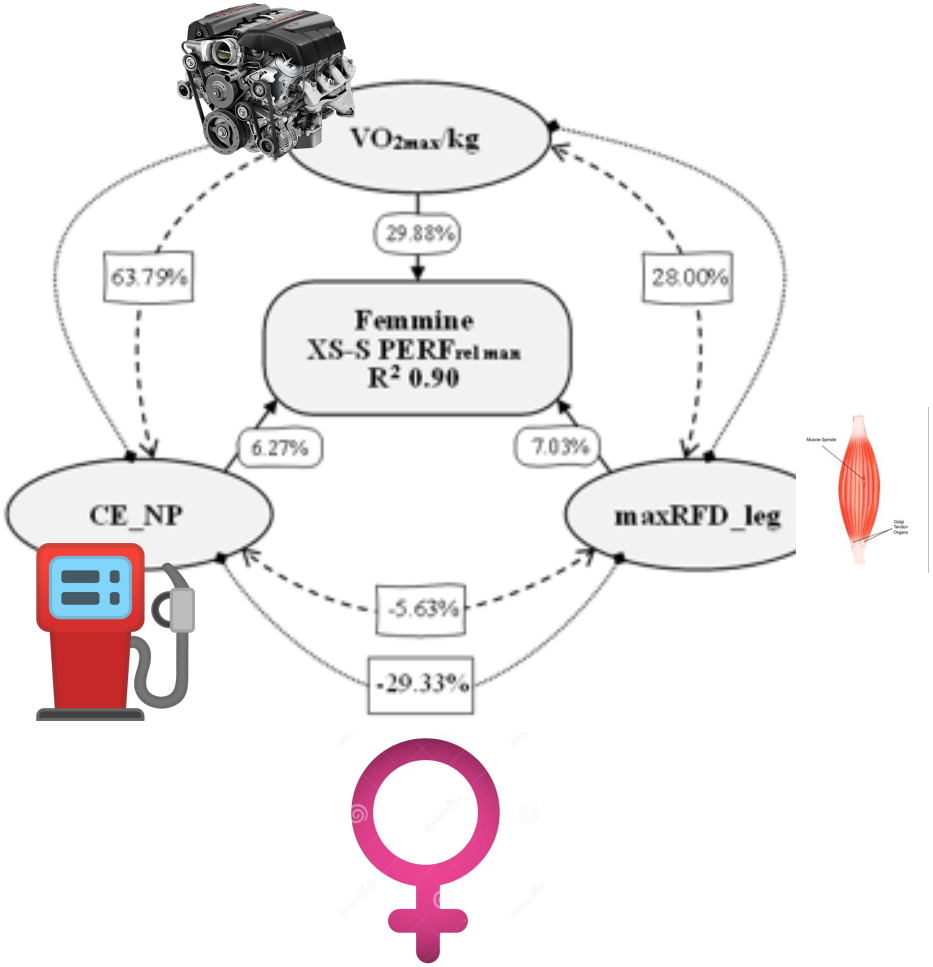

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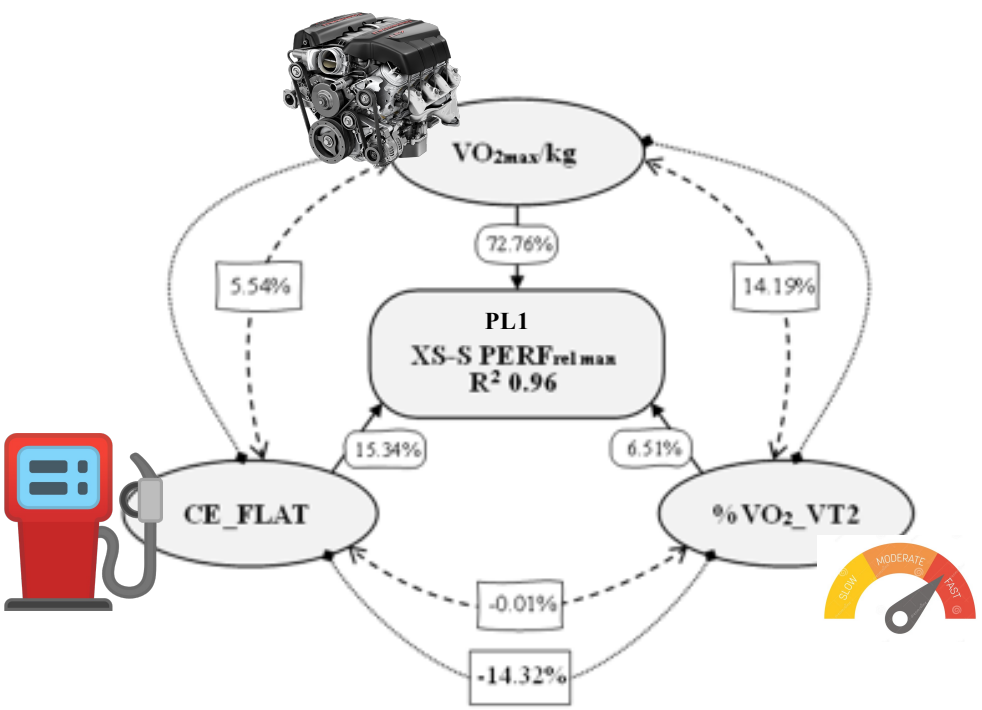
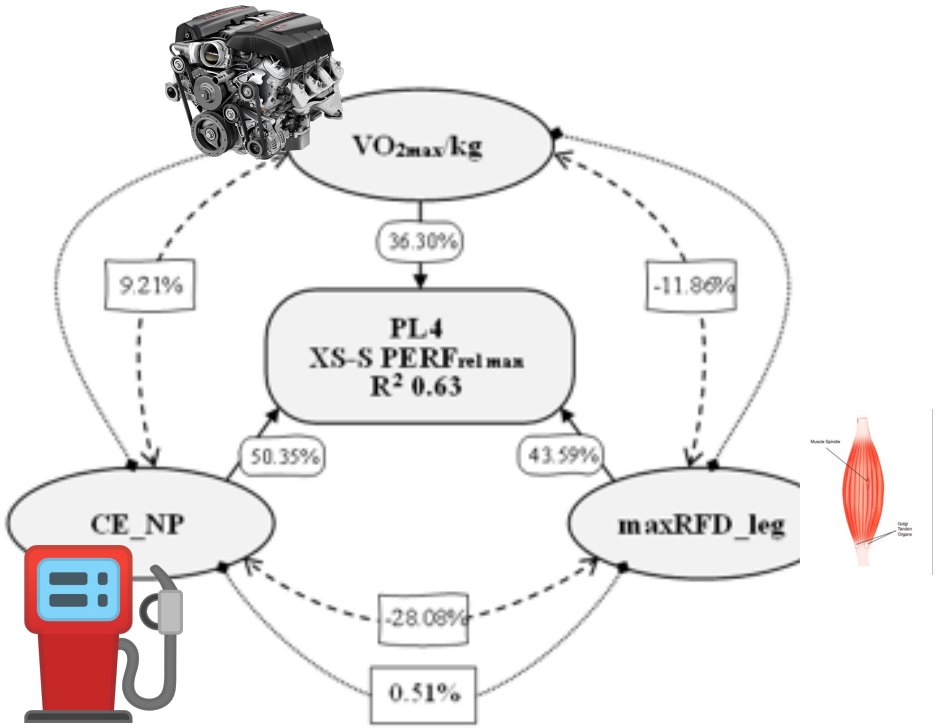


PL1

48 ml/kg/min



PL4

68 ml/kg/min

AND.... THE MENSTRUAL CYCLE?

1st Author (Year)	Study Design	Participants	Phases Studied	Main Findings
Burrows (2005) [86]	Randomised, counter-balanced based on MCP of first testing session	Highly trained 1500 m to marathon distance runners (n = 10)	EF, LF, EL and LL	↔ Treadmill velocity at VO2max ↔ Peak treadmill velocity
Cook (2018) [27]	Two group, longitudinal	National level (n = 6) and club/recreational (n = 16) figure shaping, soccer, netball or triathlon athletes	LF, OVU and ML	↑ Peak power (3 × 6 s cycle ergometer sprints) in OVU compared to LF and ML ↑ Improvement in peak power following post-activation potentiation stimulus in OVU compared to LF and ML
De Souza (1990) [87]	Two group, longitudinal	Well trained runners (n = 8)	EF and ML	↔ Relative VO2max (incremental, maximal treadmill test) ↔ TTE (incremental, maximal
Goldsmith (2020) [90]	Longitudinal	Well trained runners (n = 10)	EF, LF and ML	↓ Running economy in ML compared to EF ↔ Relative VO2max and TTE (incremental, maximal treadmill test) ↔ Running speed at lactate threshold and 4 mmol/L blood lactate
Lara (2019a) [96]	Double-blind, placebo-controlled, cross-over (randomly assigned MCP of first testing session)	Female triathletes (n = 13)	EF, OVU and ML	↔ Peak power, mean power and fatigue index (15 s modified Wingate test) ↔ Lactate accumulation ↔ Magnitude of ergogenic effect of caffeine
Lara (2019b) [97]	Double-blind, placebo-controlled, cross-over, randomised (randomly assigned MCP of first testing session)	Female triathletes (n = 13)	EF, OVU and ML	↔ Peak power (incremental, maximal cycle ergometer test) ↔ Magnitude of ergogenic effect of caffeine

ACTUAL ENDURANCE PERFORMANCE SEEMS NOT TO BE AFFECTED BY THE MENSTRUAL CYCLE PHASE

Carmichael 2021

AND.... THE MENSTRUAL CYCLE?

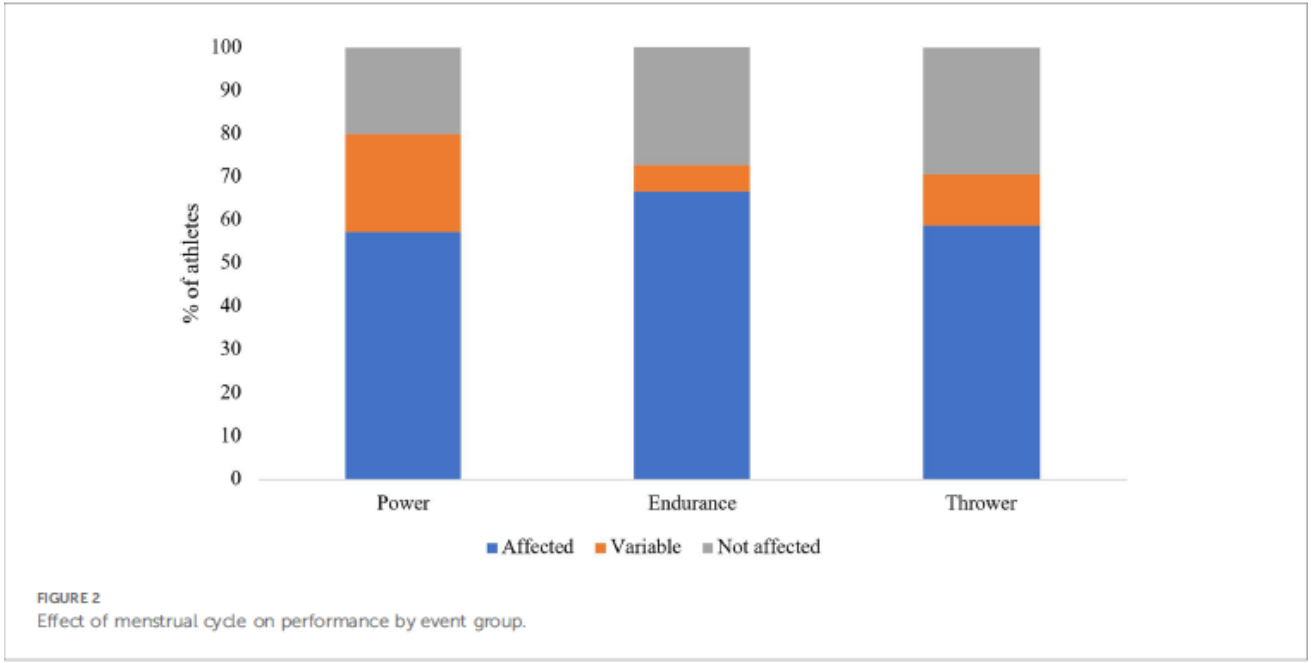


FIGURE 2
Effect of menstrual cycle on performance by event group.

PERCEIVED PERFORMANCE IS AFFECTED BY THE MENSTRUAL CYCLE PHASE

Jones 2024

TAKE HOME MESSAGES

ENDURANCE PERFORMANCE IS DIFFERENTLY PREDICTED IN ROAD AND TRAIL RACES, AND THIS SHOULD BE TAKEN INTO ACCOUNT FOR TARINING PRESCRIPTION.

WOMEN HAVE A 10% LOWER PERFORMANCE THAN MEN, BUT THE GAP COULD BE REDUCED FOR VERY LONG RACES.

THE PERFORMANCE PREDICTORS FOR VERY LONG (>100) BUT NOT SHORT TRAIL RACES COULD BE DIFFERENT IN WOMEN IF COMPARED TO MEN.

MUSCULAR ACTIVATION AND RECOVERY IS DIFFERENT BETWEEN SEXES, AND THIS SHOULD BE CONSIDERED FOR INJURIES PREVENTION AND TRAINING PRESCRIPTION.

MORE FEMALE ATHLETES' KNOWLEDGE OF THE MENSTRUAL CYCLE'S IMPACT ON PERFORMANCE IS NECESSARY.

GRAZIE PER L'ATTENZIONE

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