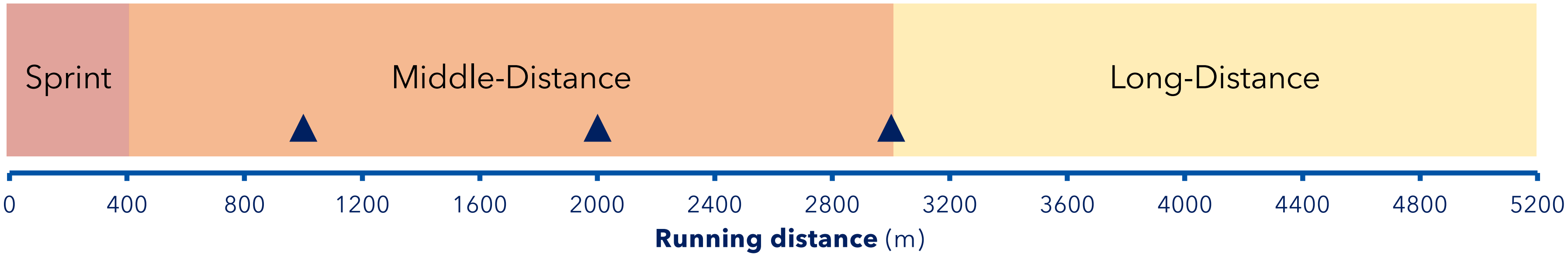
RELATIONSHIP BETWEEN PHYSIOLOGICAL PARAMETERS AND TIME-TRIAL PERFORMANCE OVER 1, 2 AND 3 KM IN WELL-TRAINED RUNNERS

SCHWARZ YM, NOLTE S, FUCHS M, GEHLERT G, SLOWIG Y, SCHIFFER A, FOITSCHIK T, ABEL T, QUITTMANN OJ

Deutsche Sporthochschule Köln
German Sport University Cologne
Institute of Movement and Neurosciences



Physical Fitness and Performance

Determinants of 800-m and 1500-m Running Performance Using Allometric Models

STEPHEN A. INGHAM[1], GREGORY P. WHYTE[2], CHARLES PEDLAR[3], DAVID M. BAILEY[1], NATALIE DUNMAN[3], and ALAN M. NEVILL[4]

[1]*English Institute of Sport, Loughborough University, Loughborough, Leicestershire, UNITED KINGDOM;* [2]*Research Institute for Sport and Exercise Science, Liverpool John Moores University, Henry Cotton Campus, Truman Road, Liverpool, UNITED KINGDOM;* [3]*English Institute of Sport, St. Mary's College, Twickenham, UNITED KINGDOM; and* [4]*Department of Sports Studies, University of Wolverhampton, Walsall Campus, Walsall, UNITED KINGDOM*

Ingham et al. (2008) *Phys Fit Perf*

REVIEW ARTICLE

Sports Med. 19 (4): 268-277, 1995
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Physiological Factors Associated with Middle Distance Running Performance

L. Jerome Brandon

Georgia State University, Atlanta, Georgia, USA

Brandon (1995) *Sports Med*

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Differential modeling of anaerobic and aerobic metabolism in the 800-m and 1,500-m run

Véronique Billat,[1] Laurence Hamard,[1] Jean Pierre Koralsztein,[2] and R. Hugh Morton[3]

[1]*Faculty of Sport Sciences, University of Evry-Val d'Essonne, Evry, France;* [2]*Sport Medicine Center CCAS, Paris, France; and* [3]*Institute of Food, Nutrition, and Human Health, Massey University, Palmerston North, New Zealand*

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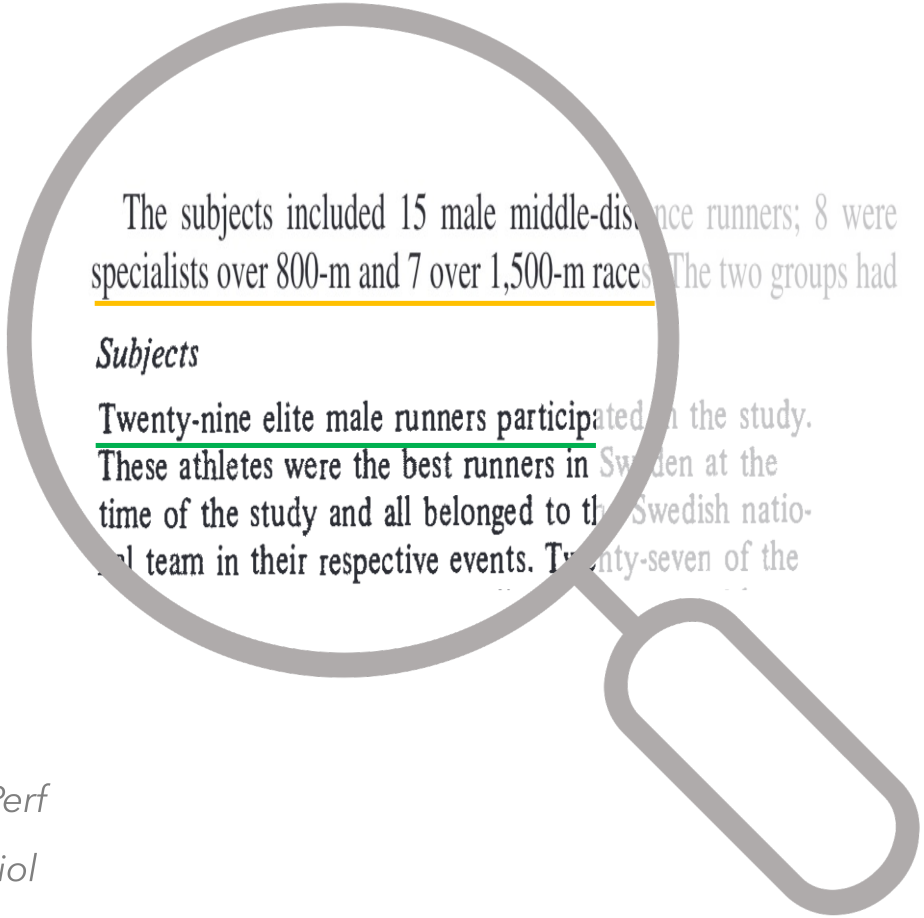
Billat et al. (2006) *J Appl Physiol*

Previous studies often investigated physiological traits of **elite athletes** and athletes **specialized in middle-distance running**



Ingham et al. (2008) *Phys Fit Perf*

Billat et al. (2006) *J Appl Physiol*

"Using **samples restricted** (truncated) **to contain only elite athletes** or highly trained individuals **may result in biased results**."

Borgen (2018) *Sports Med*

Participants

Sprinters (n = 6)

Middle-/ long-distance runners (n = 16)

(Ultra-)marathon runners (n = 3)

Mean Characteristics

Age: 25.5 ± 4.7 years
Body mass: 69.2 ± 6.4 kg
Body fat (%): 11.3 ± 2.2 %

$\dot{V}O_2max$: 66.0 ± 5.71 $mL \cdot min^{-1} \cdot kg^{-1}$
RE: 222.0 ± 11.1 $mL \cdot kg^{-1} \cdot km^{-1}$

Investigated Parameters

Physiology

1. Maximal oxygen uptake ($\dot{V}O_2max$)
2. Maximal fat oxidation (MFO)
3. Running economy (RE)
4. Fractional utilization of at $\dot{V}O_2max$ MLSS (%$\dot{V}O_2max$)
5. Maximal lactate accumulation rate ($\dot{V}La_{max}$)
6. Difference between resting and maximal post 100-m sprint lactate concentration (ΔLa_{100})

Performance

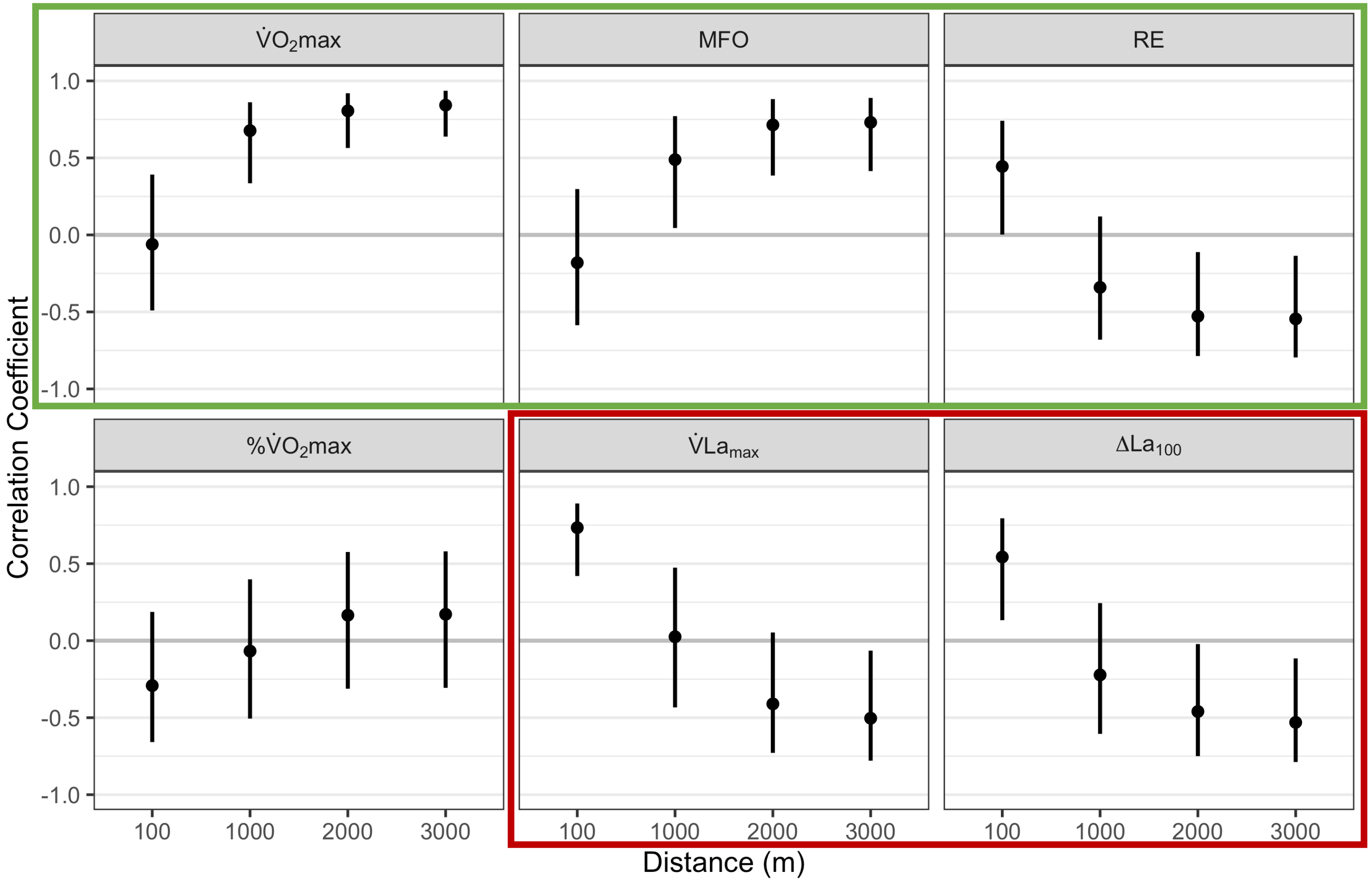
7. Velocity associated with $\dot{V}O_2max$ (v$\dot{V}O_2max$)
8. Maximal lactate steady-state (MLSS)
9. Critical Velocity (CV)
10. Velocity associated with MFO (Fat_{max})
11. Finite amount of energy that can be expended above CV (D′)
12. Anaerobic speed reserve (ASR)
13. Speed reserve ratio (SRR)

Experimental design

Week 1		medical check-up incremental step test		100 m sprint test ramp test	
Week 2	1st constant load test		2nd constant load test		3rd constant load test
Week 3	1st time trial		2nd time trial		3rd time trial

Legend

- = recovery
- = incremental, sprint & ramp test
- = constant load tests
- = time trials if 2 or 3 constant load tests were necessary



Aerobic parameters ($\dot{V}O_2max$, MFO, RE) have increasingly **positive influence**

Anaerobic parameters ($\dot{V}La_{max}$, ΔLa_{100}) had increasingly **negative influence**

No influence was found for **%$\dot{V}O_2max$**

Figure 1 Correlation coefficients of physiological parameters and 100 m sprint and 1, 2, and 3 km TTs are displayed as solid dots and bars indicating respective confidence intervals.

Intersection of confidence intervals with zero corresponds to p-values exceeding 0.05.

Time-trial	Model	R^2	ΔR^2	Resid. Std. Error	p	AIC
100 m	$\dot{V}La_{max}$	0.60		0.31	< 0.0001	-45.22
	$\dot{V}La_{max} + \Delta La_{100}$	0.97	0.12	0.08	< 0.0001	-96.96
1000 m	$\dot{V}O_{2max}$	0.46		0.26	0.001	-52.56
	$\dot{V}O_{2max} + \dot{V}La_{max}$	0.53	0.07	0.25	0.003	-53.39
	$\dot{V}O_{2max} + \dot{V}La_{max}$ + MFO	0.58	0.05	0.24	0.004	-53.52
	$\dot{V}O_{2max} + \dot{V}La_{max}$ + MFO + RE_{MLSS}	0.62	0.05	0.23	0.004	-53.88
2000 m	$\dot{V}O_{2max}$	0.65		0.20	< 0.0001	-61.86
	$\dot{V}O_{2max}$ + MFO	0.78	0.13	0.16	< 0.0001	-69.55
	$\dot{V}O_{2max}$ + MFO + RE_{MLSS}	0.83	0.05	0.15	< 0.0001	-72.36
	$\dot{V}O_{2max}$ + MFO + RE_{MLSS} + $\dot{V}La_{max}$	0.85	0.02	0.14	< 0.0001	-73.28
3000 m	$\dot{V}O_{2max}$	0.71		0.21	< 0.0001	-61.32
	$\dot{V}O_{2max}$ + MFO	0.83	0.12	0.16	< 0.0001	-70.53
	$\dot{V}O_{2max}$ + MFO + RE_{MLSS}	0.88	0.05	0.14	< 0.0001	-75.33
	$\dot{V}O_{2max}$ + MFO + RE_{MLSS} + $\%\dot{V}O_{2max}$	0.93	0.05	0.11	< 0.0001	-83.00

Figure 2 Forward stepwise regression models of physiological parameters for sprint and TT velocity are displayed including coefficient of determination (R^2), change of R^2 and relation to inferior model (ΔR2), residual standard error (m·s-1), probability of alpha error (p). Akaike's Information Criterion (AIC) was used for successive selection of added variables.

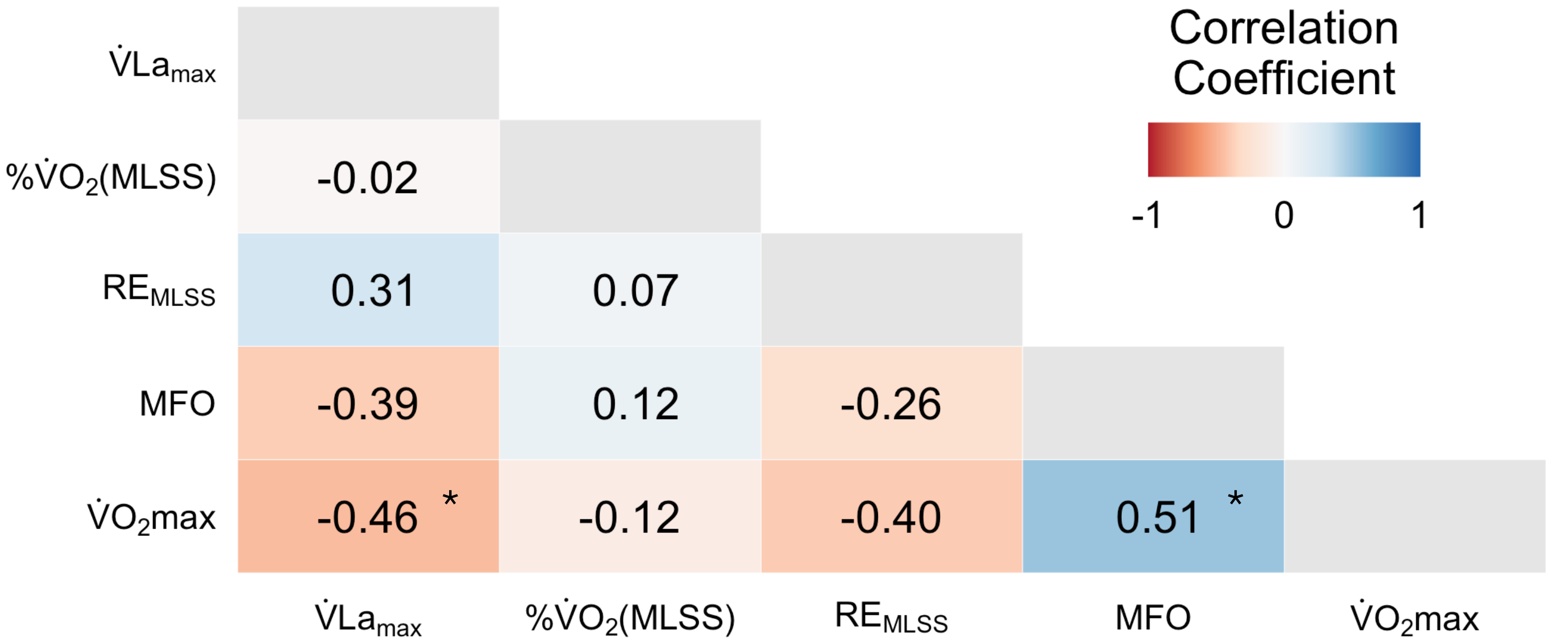


Figure 3 Correlation matrix displaying correlation coefficients for all physiological parameters. * indicates probability of alpha error below 0.05

- **High relevance of $\dot{V}O_2max$ for middle-distance running** is congruent with previous research
  (Brandon, 1995; Ingham et al., 2008; Billat et al., 2006)
- Evidence exists, that **%$\dot{V}O_2max$ might not play** such **a decisive role** as previously assumed **in endurance running**
  (Joyner & Coyle, 2008; Støa et al., 2010, Gordon et al., 2017)
- It could be assumed that **MFO indicates general status of endurance performance** rather than directly influencing middle-distance running (Maunder)
  (Maunder et al., 2018)
- **Few studies have investigated influence of anaerobic variables** directly
  (Schnabel & Kindermann, 1983 ; Sandford et al., 2019a, Sandford et al., 2019b, Bellinger et al., 2021)

Influence of anaerobic metabolism on sprint and time-trial performance

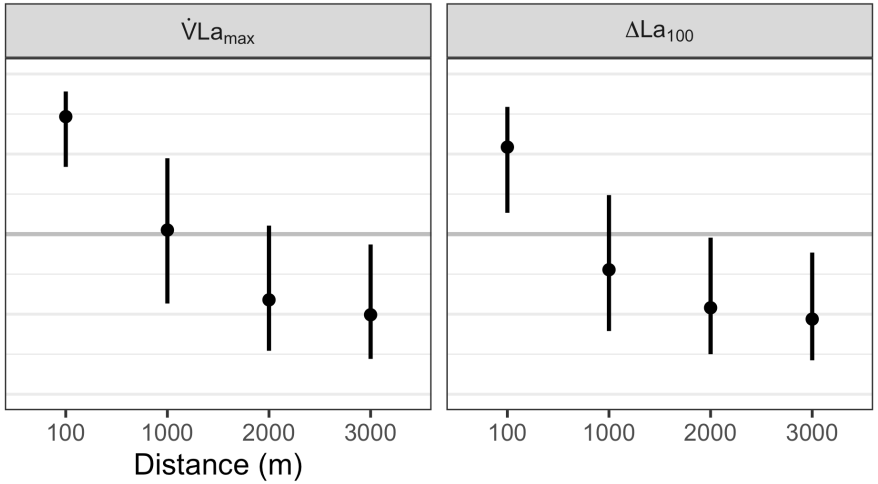
- Anaerobic metabolism enables **higher total rates of energy release**

  (Robergs et al., 2004, Hanon et al., 2019)

- **Muscular acidosis** as a result of anaerobic energy release **is detrimental for endurance performance**

- **Fast-twitch fibers** involved in high-intensity running **are more prone to fatigue**

  (Lievens et al., 2020)



Limitations

- **Applicability** of results **for more homogenous cohorts** remains unknown
- Difficulties in valid assessment of anaerobic power and capacities (Noordhof et al., 2018, Buchheit & Laursen, 2013)
- Investigated **"anaerobic" parameters might not solely reflect influence of anaerobic metabolism** but other characteristics such as muscle typology etc. (Lievens et al., 2020)

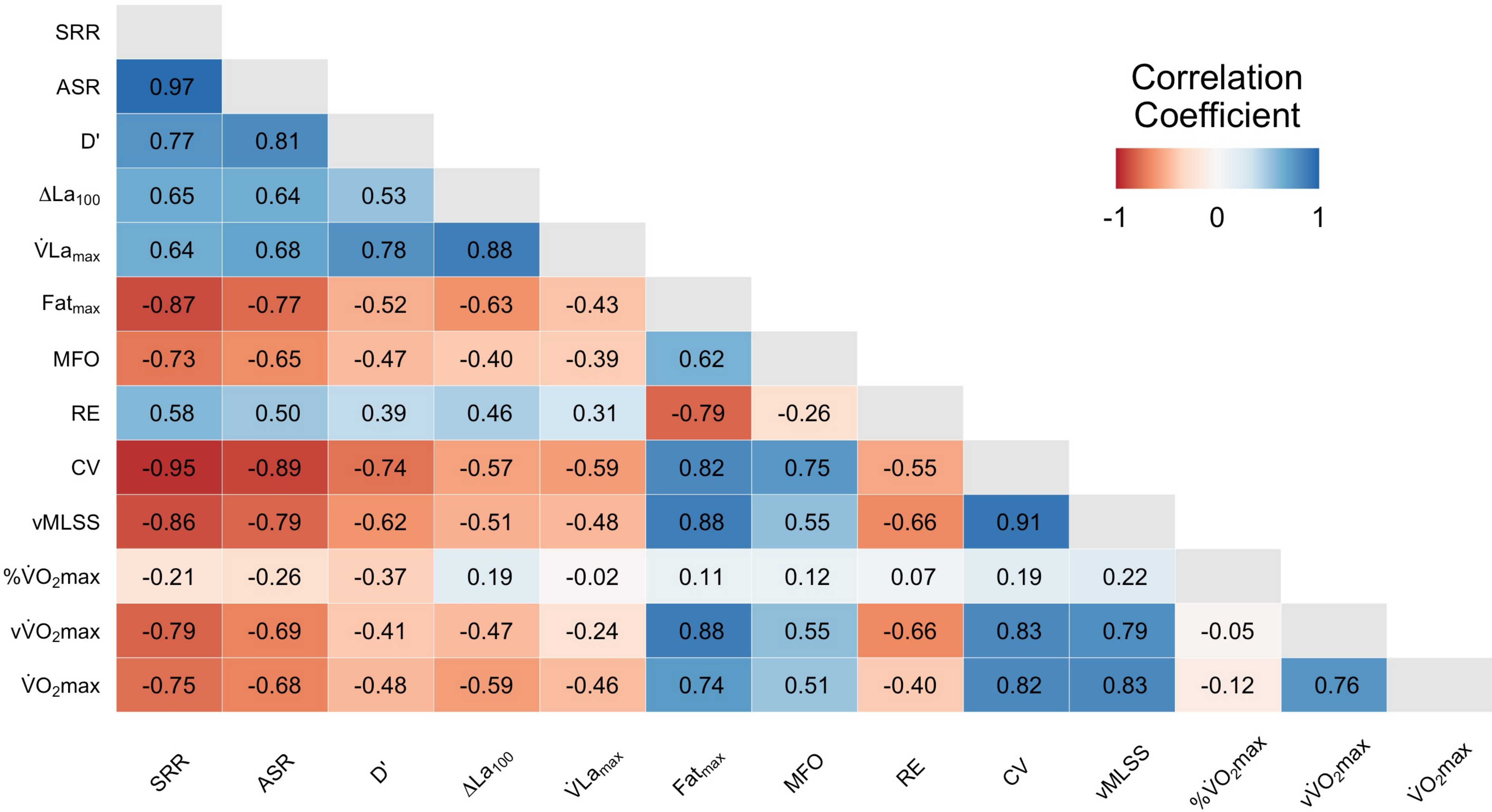
Future Directions

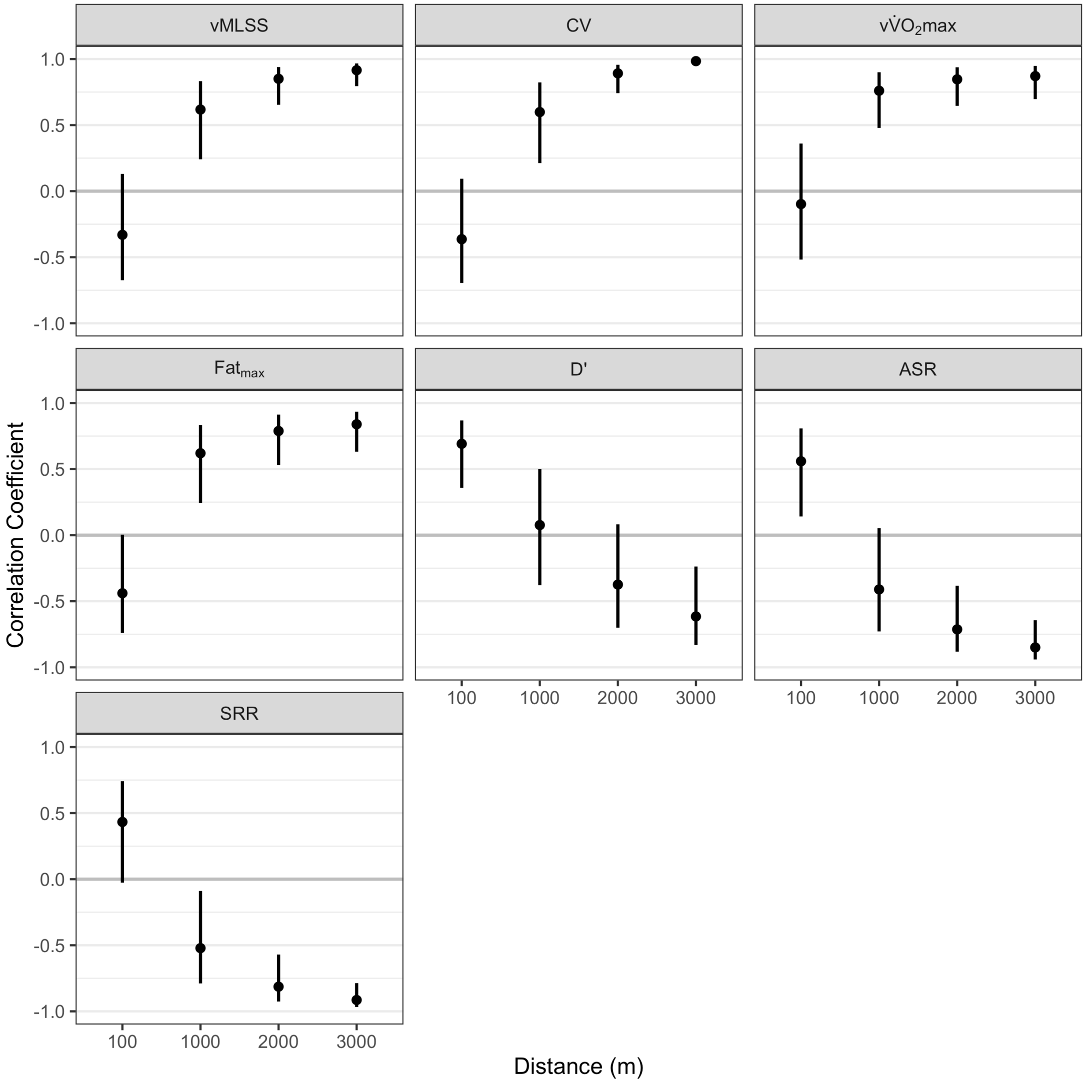
- **Training intervention studies** are needed to further understand modulation of anaerobic parameters and endurance performance through exercise prescription
- Studies **investigating underlying mechanisms of detrimental effects of anaerobic metabolism** on endurance performance

Conclusions

- **Aerobic variables** ($\dot{V}O_2max$, MFO, RE) **have an increasingly positive influence** on time trial performance
- **Anaerobic variables** ($\dot{V}La_{max}$, ΔLa_{100}) **have an increasingly negative influence** on time trial performance
- **Beneficial and detrimental effects of anaerobic metabolism** might be in balance in maximal running lasting approximately three minutes
- **Regular monitoring of anaerobic parameters** might be of special interest for middle-distance runners and coaches

Supplementary Data


Correlation Coefficient
-1
0
1
SRR
ASR 0.97
D' 0.77 0.81
ΔLa100 0.65 0.64 0.53
V̇Lamax 0.64 0.68 0.78 0.88
Fatmax -0.87 -0.77 -0.52 -0.63 -0.43
MFO -0.73 -0.65 -0.47 -0.40 -0.39 0.62
RE 0.58 0.50 0.39 0.46 0.31 -0.79 -0.26
CV -0.95 -0.89 -0.74 -0.57 -0.59 0.82 0.75 -0.55
vMLSS -0.86 -0.79 -0.62 -0.51 -0.48 0.88 0.55 -0.66 0.91
%V̇O2max -0.21 -0.26 -0.37 0.19 -0.02 0.11 0.12 0.07 0.19 0.22
vV̇O2max -0.79 -0.69 -0.41 -0.47 -0.24 0.88 0.55 -0.66 0.83 0.79 -0.05
V̇O2max -0.75 -0.68 -0.48 -0.59 -0.46 0.74 0.51 -0.40 0.82 0.83 -0.12 0.76
SRR
ASR
D'
ΔLa100
V̇Lamax
Fatmax
MFO
RE
CV
vMLSS
%V̇O2max
vV̇O2max
V̇O2max



vMLSS
CV
vV̇O2max
Fatmax
D'
ASR
SRR
Correlation Coefficient
1.0
0.5
0.0
-0.5
-1.0
100
1000
2000
3000
Distance (m)

Time-trial	Model	R_2	ΔR_{2adj}	Resid. Std. Error	p	AIC
100 m	D'	0.48		0.35	< 0.001	-39.85
	D' + CV	0.53	0.05	0.34	0.002	-39.88
1000 m	$v\dot{V}O_2max$	0.58		0.23	0,0001	-57.53
	$v\dot{V}O_2max$ + D'	0.76	0.18	0.18	< 0.0001	-66.86
	$v\dot{V}O_2max$ + D' + CV	0.97	0.21	0.06	< 0.0001	-106.84
2000 m	CV	0.80		0.16	< 0.0001	-72.60
	CV + D'	0.98	0.18	0.05	< 0.0001	-118.70
3000 m	CV	0.97		0.06	< 0.0001	-105.55
	CV + D'	1.00	0.03	0.02	< 0.0001	-165.15

Participant characteristics

		vMLSS [m·s^{-1}]	CV * [m·s^{-1}]	Fat_{max} [m·s^{-1}]	D‘ * [m]
SP (n = 6 / 4*)	mean	3.53	4.15	2.43	285.84
	SD	0.27	0.15	0.34	46.14
MD-LD (n = 16 / 15*)	mean	4.33	4.78	3.23	186.68
	SD	0.41	0.37	0.28	52.47
M-UM (n = 3 / 1*)	mean	4.37	4.95	3.24	167.08
	SD	0.21	0.21	0.23	19.52
Total (n = 25 / 20)	mean	4.14	4.67	3.04	203.70
	SD	0.50	0.41	0.45	62.98

		$v\dot{V}O_2max$ [m·s^{-1}]	v100 [m·s^{-1}]	ASR [m·s^{-1}]	SRR
SP (n = 6)	mean	5.10	8.54	3.44	1.68
	SD	0.29	0.33	0.45	0.12
MD-LD (n = 16)	mean	5.65	7.62	1.97	1.35
	SD	0.36	0.36	0.37	0.08
M-UM (n = 3)	mean	5.45	7.17	1.72	1.32
	SD	0.53	0.20	0.55	0.13
Total (n = 25)	mean	5.49	7.78	2.29	1.43
	SD	0.42	0.56	0.77	0.17

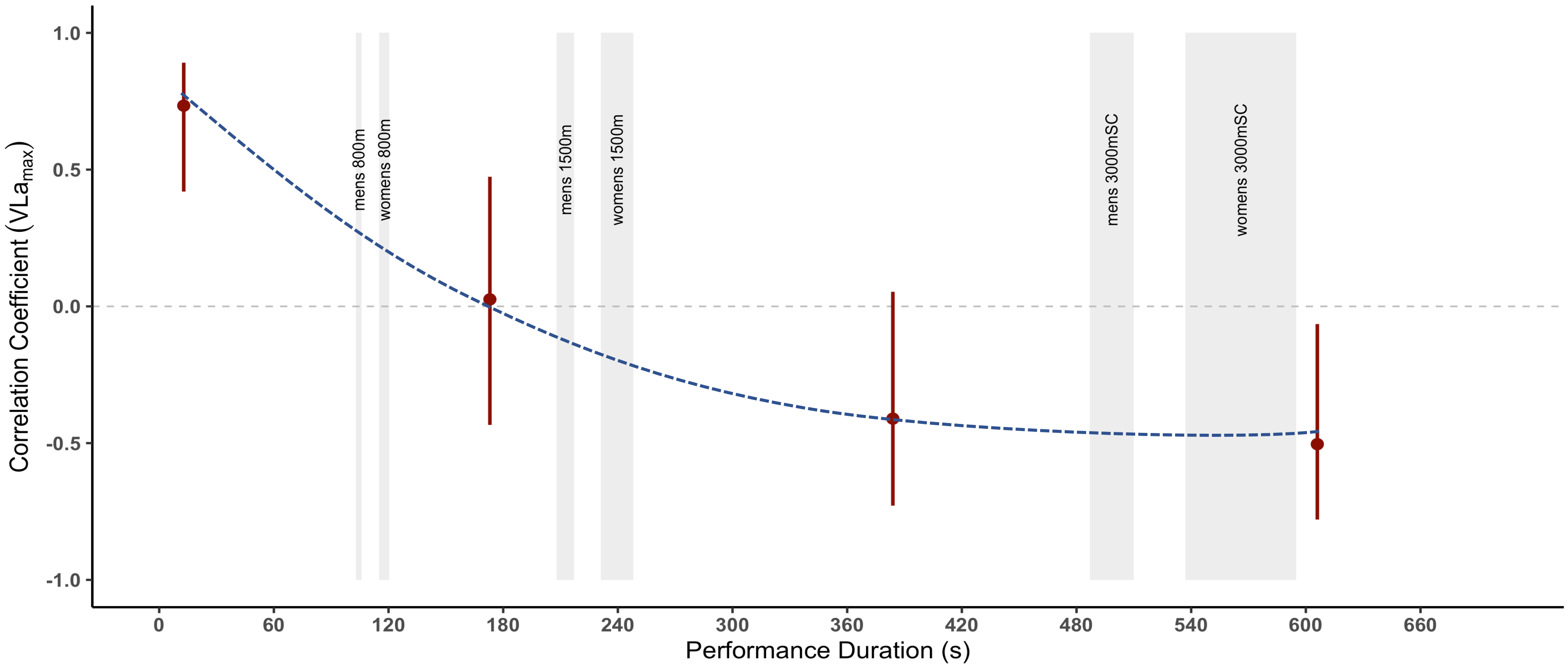


Figure 4 Conceptual data displaying correlation coefficients and confidence intervals of respective mean time-trial. Grey areas indicate time range of TOP50 (World Athletics, 2022) male and female performances in the 800 m, 1500 m and 3000 m SC running events.

Calculation of maximal lactate accumulation rate

$$\frac{\text{maximal post- sprint lactate concentration} - \text{resting lactate concentration}}{\text{100-m sprint time} - \text{alactic time}}$$

Non-normally distributed parameters

%$\dot{V}O_2max$
MFO
$\dot{V}La_{max}$

ASR
SRR