Exercise prescription as a novel approach to increase response rates to $\dot{V}O_{2max}$

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ECSS GLASGOW 2024

Key points

1. Increases in maximum oxygen uptake, or $\dot{V}O_{2max}$, (e.g. Δ 1 MET) are associated with reductions in mortality and morbidity, improvements endurance performance, etc.
2. Increases in $\dot{V}O_{2max}$ following training are heterogenous. Some factors affecting response variability may not controlled, but some factors are modifiable – typically around training characteristics.
3. Method of exercise prescription dictates the acute responses to exercise, and thus may also affect response rates.
4. Endurance training prescribed relative to physiological thresholds may create a more consistent stimuli among individuals, which can affect response rates.

1. Maximum Oxygen Uptake – $\dot{V}O_{2max}$

International Journal of Sports Physiology and Performance, 2023, 18, 1362-1365
https://doi.org/10.1123/ijspp.2023-0229

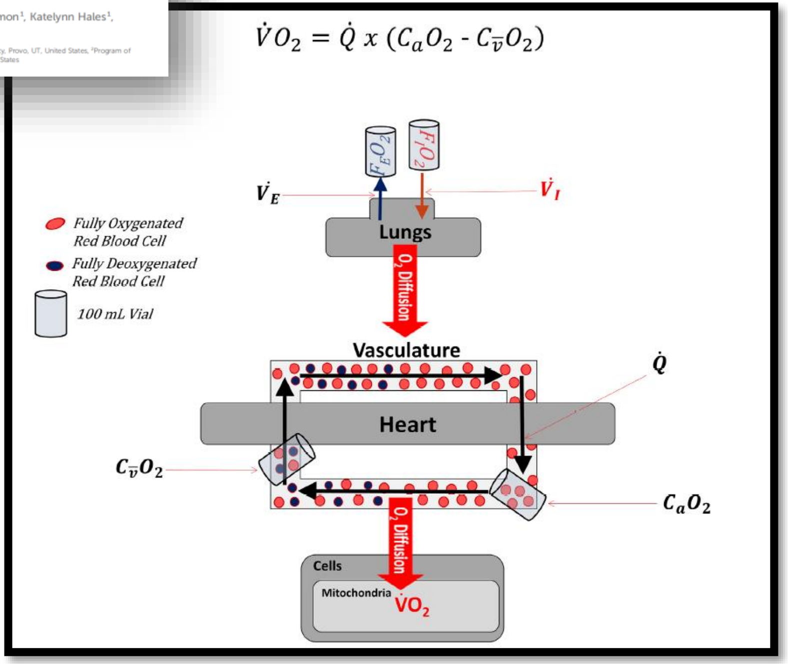
Human Kinetics
INVITED COMMENTARY

The $\dot{V}O_2$max Legacy of Hill and Lupton (1923)—100 Years On

Grégoire P. Millet,[1] Johannes Burtscher,[1] Nicolas Bourdillon,[1] Giorgio Manferdelli,[1] Martin Burtscher,[2] and Øyvind Sandbakk[3]

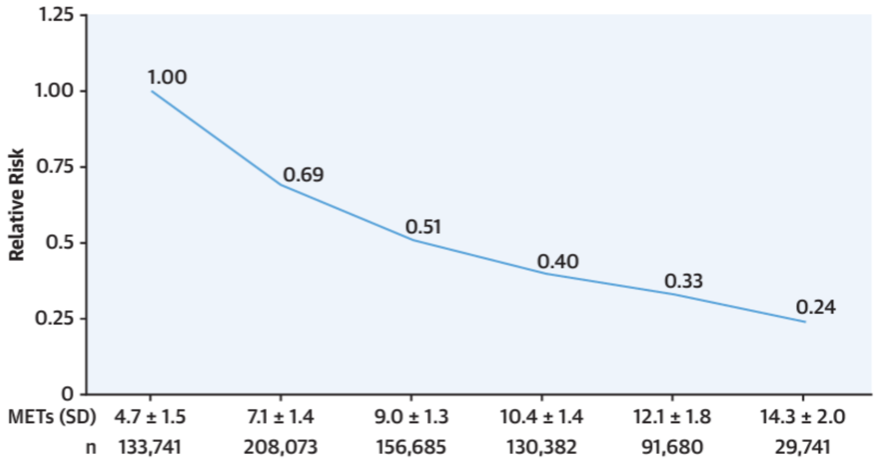
Overdot and overline annotation must be understood to accurately interpret VO_{2MAX} physiology with the Fick formula

Jayson R. Gifford[1,2]*, Christina Blackmon[1], Katelynn Hales[1], Lee J. Hinkle[1] and Shay Richards[1]
[1]Department of Exercise Sciences, Brigham Young University, Provo, UT, United States, [2]Program of Gerontology, Brigham Young University, Provo, UT, United States



Cardiorespiratory Fitness and Mortality Risk Across the Spectra of Age, Race, and Sex

Peter Kokkinos, PhD,[a,b,c] Charles Faselis, MD,[a,c] Immanuel Babu Henry Samuel, PhD,[d,e] Andreas Pittaras, MD,[a,c] Michael Doumas, MD,[a,f] Rayelynn Murphy, MS,[a] Michael S. Heimall, BS,[a] Xuemei Sui, PhD,[g] Jiajia Zhang, PhD,[h] Jonathan Myers, PhD[i,j]



Lower CRF (low $\dot{V}O_{2max}$, expressed as METs) associated with higher risk of mortality.

Endurance training increases $\dot{V}O_{2max}$

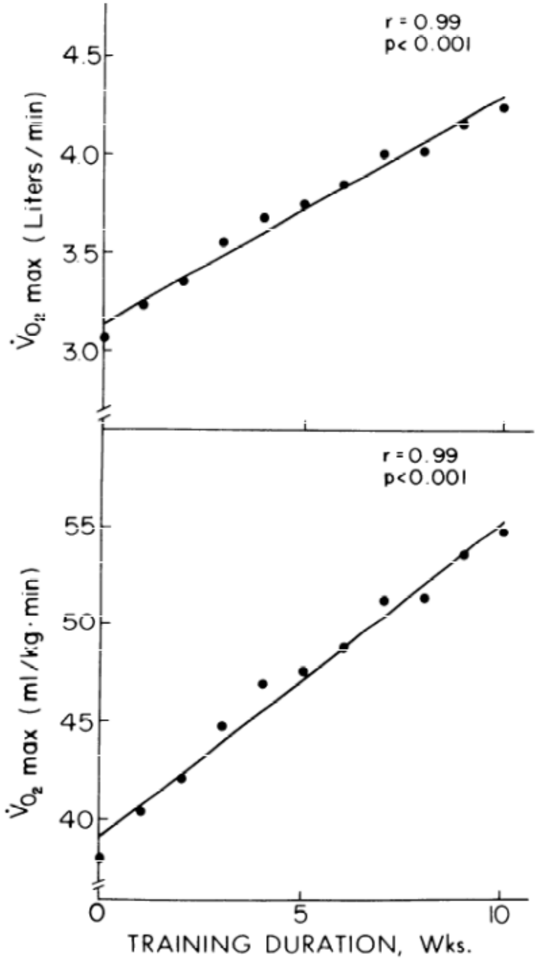
Linear increase in aerobic power induced by a strenuous program of endurance exercise

R. C. HICKSON, H. A. BOMZE, AND J. O. HOLLOSZY
Department of Preventive Medicine, Washington University School of Medicine, St. Louis, Missouri 63110

TABLE 2. *Maximal oxygen uptake of subjects measured weekly during 10-wk training program*

Subj	Duration of Training, wk										
	0	1	2	3	4	5	6	7	8	9	10
	$\dot{V}O_2$, *l/min*										
A	3.35	3.54	3.70	4.21	4.18	4.44	4.63	4.69	4.65	4.74	5.00
B	4.01	4.09	4.21	4.25	4.21	4.45	4.61	4.63	*	4.84	5.05
C	3.43	3.80	3.86	3.98	4.25	4.23	4.40	4.29	4.41	4.61	5.01
D	4.52	4.41	4.75	4.88	5.00	4.94	5.12	5.30	5.31	5.42	5.34
E	3.44	3.44	3.58	3.92	4.09	4.08	4.26	4.87	4.78	4.90	5.01
F	2.62	2.78	2.78	2.99	3.26	3.39	3.30	3.48	3.63	3.92	3.72
G	1.68	2.00	*	2.12	2.25	2.30	2.25	2.51	*	2.61	2.56
H	1.43	1.66	1.83	2.08	2.15	2.12	2.15	2.31	2.23	*	2.26
Mean ± SE	3.06 ±0.38	3.22 ±0.35	3.34 ±0.37	3.55 ±0.37	3.67 ±0.36	3.74 ±0.37	3.84 ±0.40	4.01 ±0.40	4.02 ±0.40	4.16 ±0.41	4.24 ±0.44

* not measured.

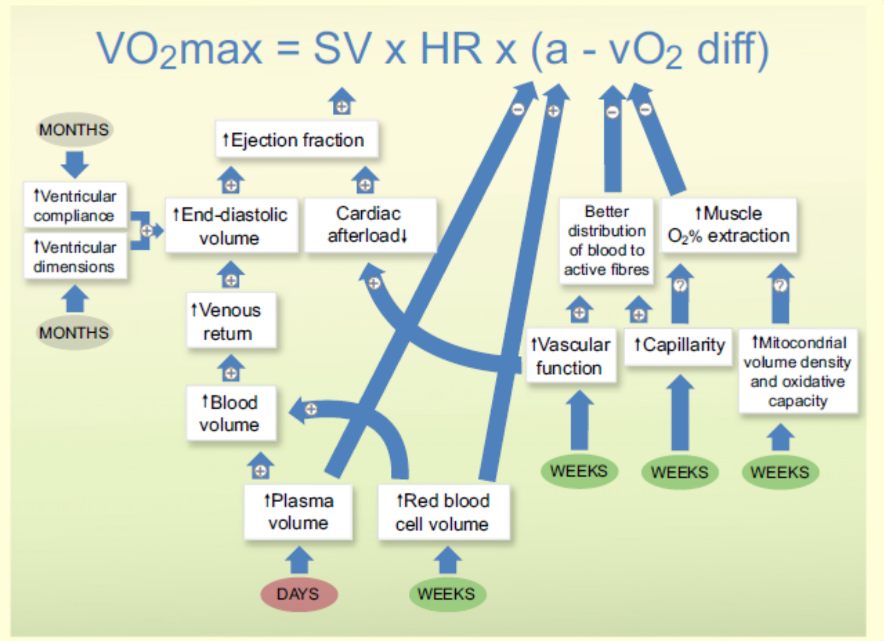


ACTA PHYSIOLOGICA
Acta Physiol 2017, 220, 218–228

REVIEW

Biology of VO_2max: looking under the physiology lamp

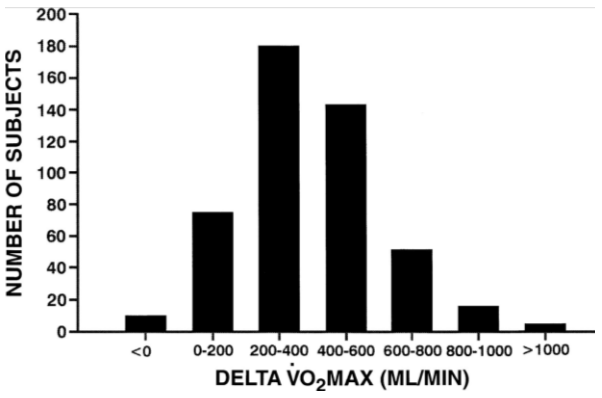
C. Lundby,[1] D. Montero[2] and M. Joyner[3]
1 Zürich Center for Integrative Human Physiology, Institute of Physiology, University of Zürich, Zürich, Switzerland
2 Department of Cardiology, University Hospital Zürich, Zürich, Switzerland
3 Department of Anesthesiology, Mayo Clinic, Rochester, MN, USA

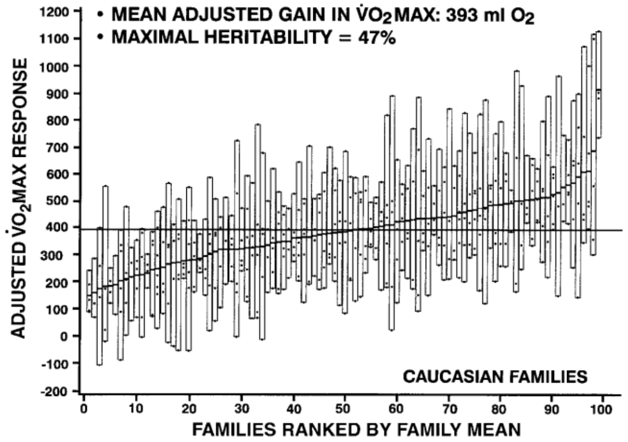


2. Heterogeneous response to endurance training

Familial aggregation of $\dot{V}O_{2max}$ response to exercise training: results from the HERITAGE Family Study

CLAUDE BOUCHARD,[1] PING AN,[2] TREVA RICE,[2] JAMES S. SKINNER,[3] JACK H. WILMORE,[4] JACQUES GAGNON,[1] LOUIS PÉRUSSE,[1] ARTHUR S. LEON,[5] AND D. C. RAO,[2,6]
[1]*Physical Activity Sciences Laboratory, Laval University, Ste-Foy, Québec, Canada G1K 7P4;* [2]*Division of Biostatistics and* [6]*Department of Genetics and Psychiatry, Washington University School of Medicine, St. Louis, Missouri 63110;* [3]*Department of Kinesiology, Indiana University, Bloomington, Indiana 47405;* [4]*Department of Health and Kinesiology, Texas A&M University, College Station, Texas 77843; and* [5]*School of Kinesiology and Leisure Studies, University of Minnesota, Minneapolis, Minnesota 55455*

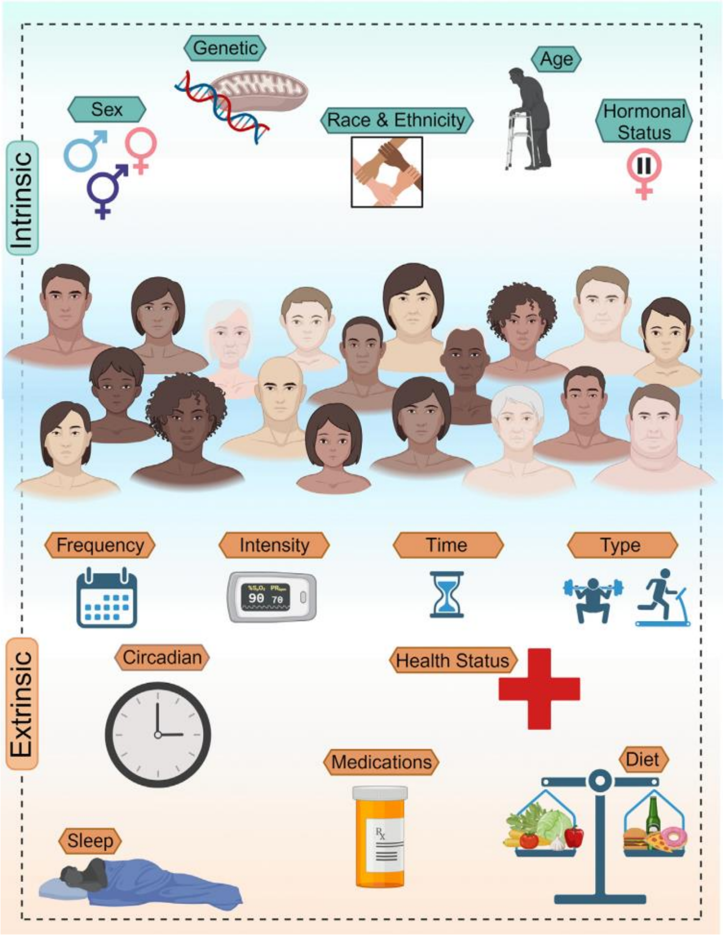




Cell Metabolism
CellPress
Review

Understanding the variation in exercise responses to guide personalized physical activity prescriptions

John Noone,[1,2] Justine M. Mucinski,[1,2] James P. DeLany,[1] Lauren M. Sparks,[1] and Bret H. Goodpaster[1,*]
[1]Translational Research Institute, AdventHealth, Orlando, FL 32804, USA
[2]These authors contributed equally
*Correspondence: bret.goodpaster@adventhealth.com
https://doi.org/10.1016/j.cmet.2023.12.025



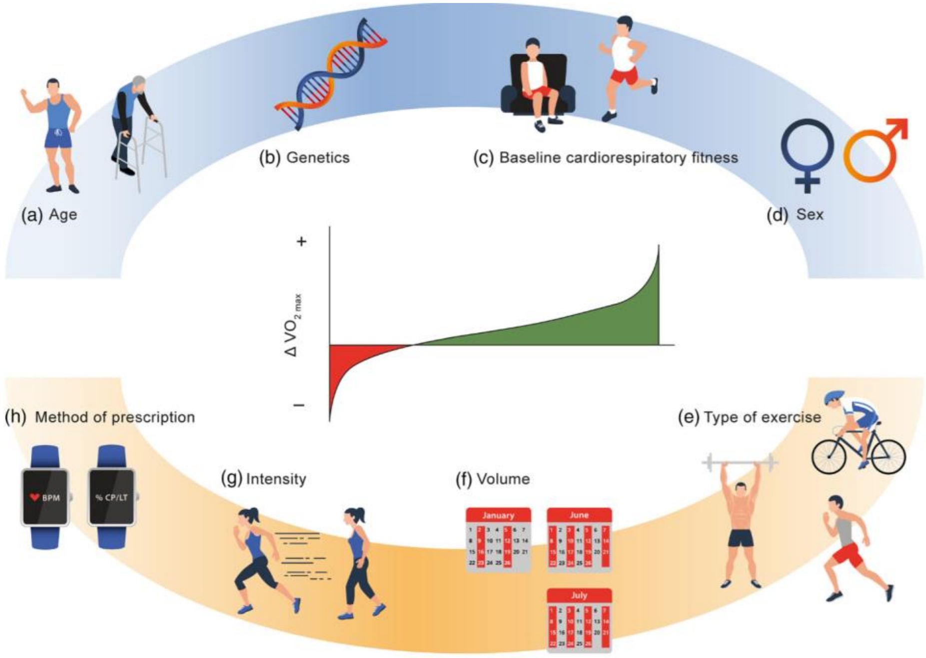
Received: 17 March 2021 | Accepted: 7 May 2021
DOI: 10.1113/EP089565

Experimental Physiology WILEY

REVIEW ARTICLE

Biological and methodological factors affecting $\dot{V}_{O_2\,max}$ response variability to endurance training and the influence of exercise intensity prescription

Samuel Meyler | Lindsay Bottoms | Daniel Muniz-Pumares

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EP Experimental Physiology WILEY

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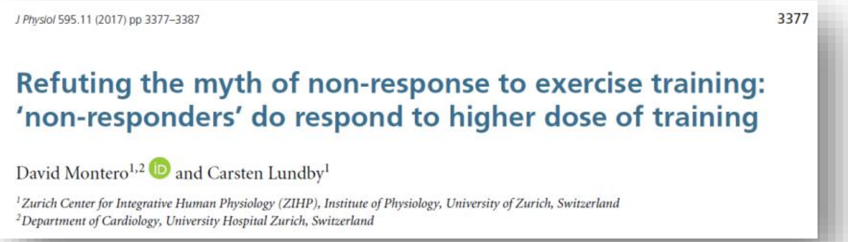
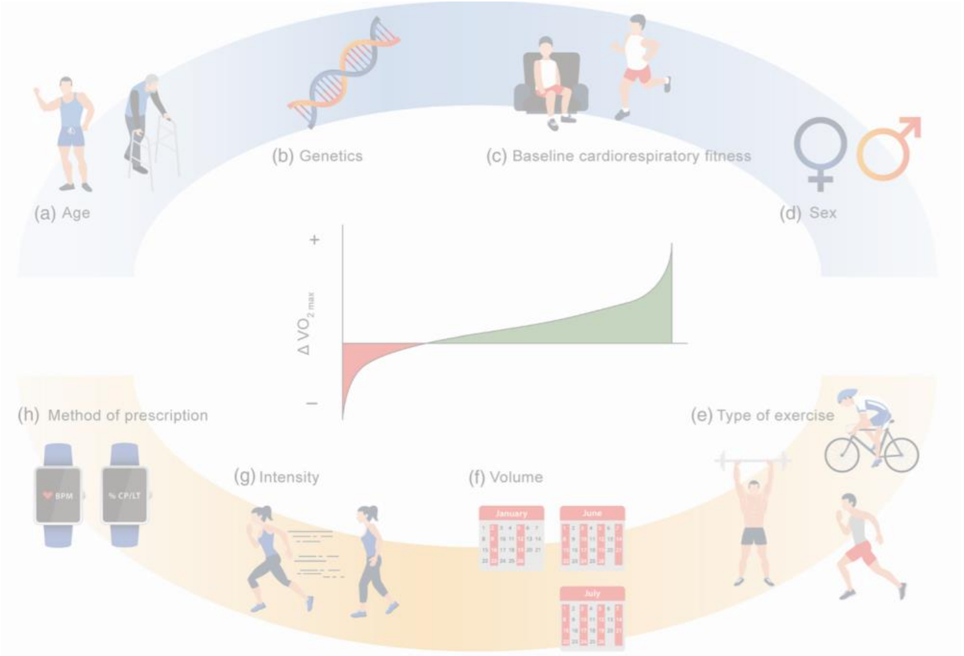
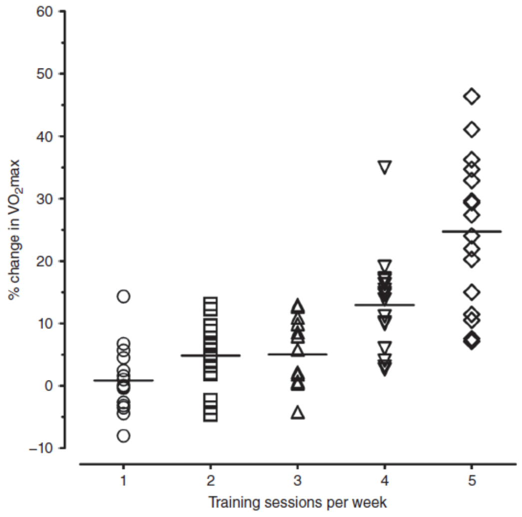

J Physiol 595.11 (2017) pp 3377–3387 3377

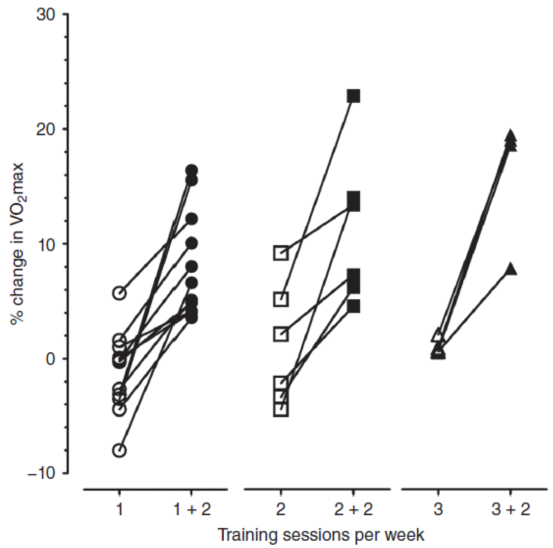
Refuting the myth of non-response to exercise training: ‘non-responders’ do respond to higher dose of training

David Montero[1,2] and Carsten Lundby[1]

[1]Zurich Center for Integrative Human Physiology (ZIHP), Institute of Physiology, University of Zurich, Switzerland
[2]Department of Cardiology, University Hospital Zurich, Switzerland







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EP Experimental Physiology WILEY

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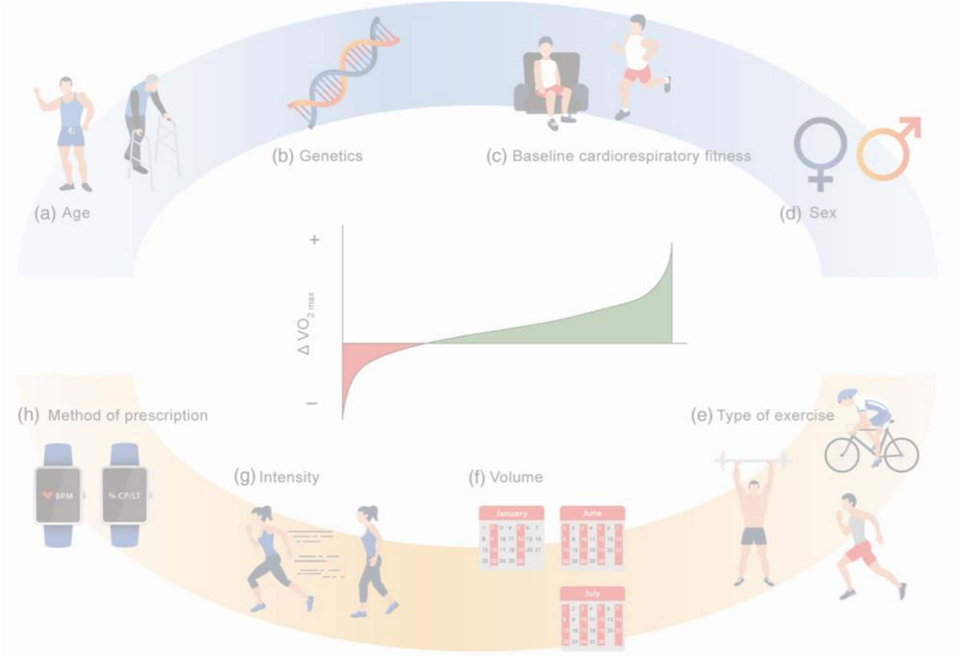
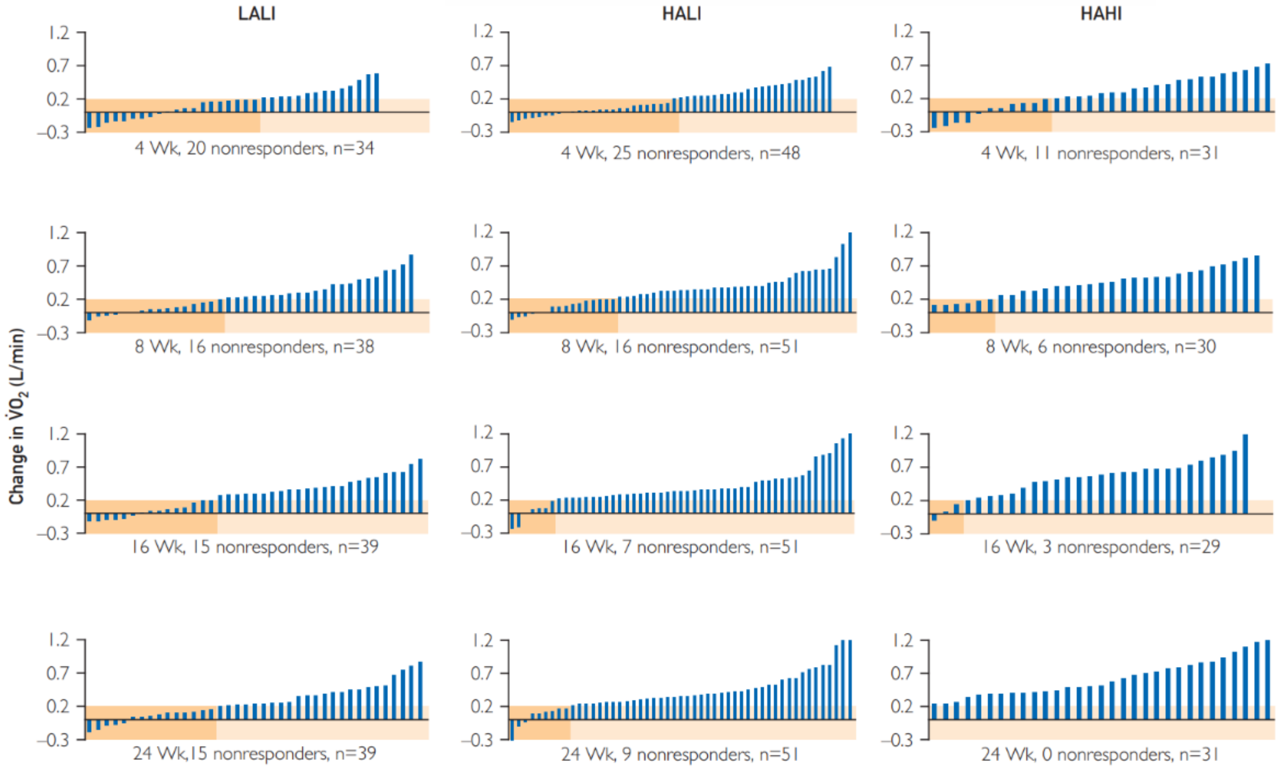
g) Intensity

MAYO CLINIC
ORIGINAL ARTICLE

Separate Effects of Intensity and Amount of Exercise on Interindividual Cardiorespiratory Fitness Response

Robert Ross, PhD; Louise de Lannoy, MSc; and Paula J. Stotz, MSc





‘Amount’ of exercise - Low Amount (LA) vs High Amount (HA)
Intensity of exercise - High Intensity (HI) vs High Intensity (HI)


Received: 17 March 2021 | Accepted: 7 May 2021
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EP Experimental Physiology WILEY

REVIEW ARTICLE

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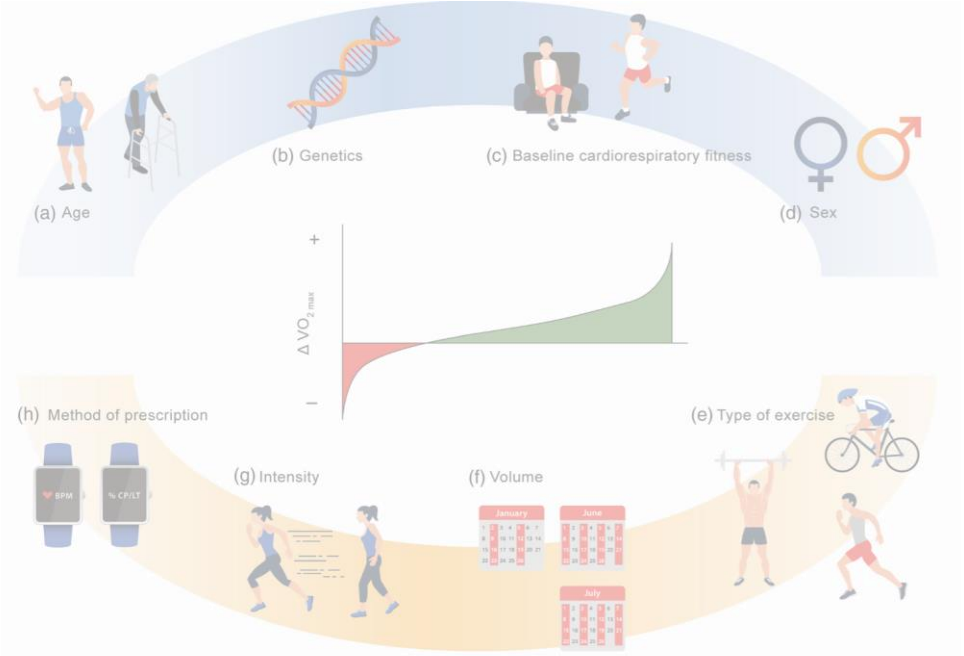
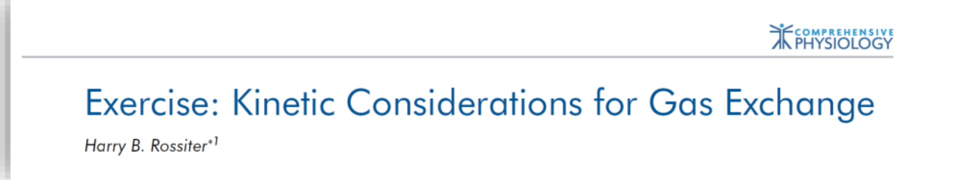
h) Method of prescription

30 min at **85% $\dot{V}O_{2max}$**

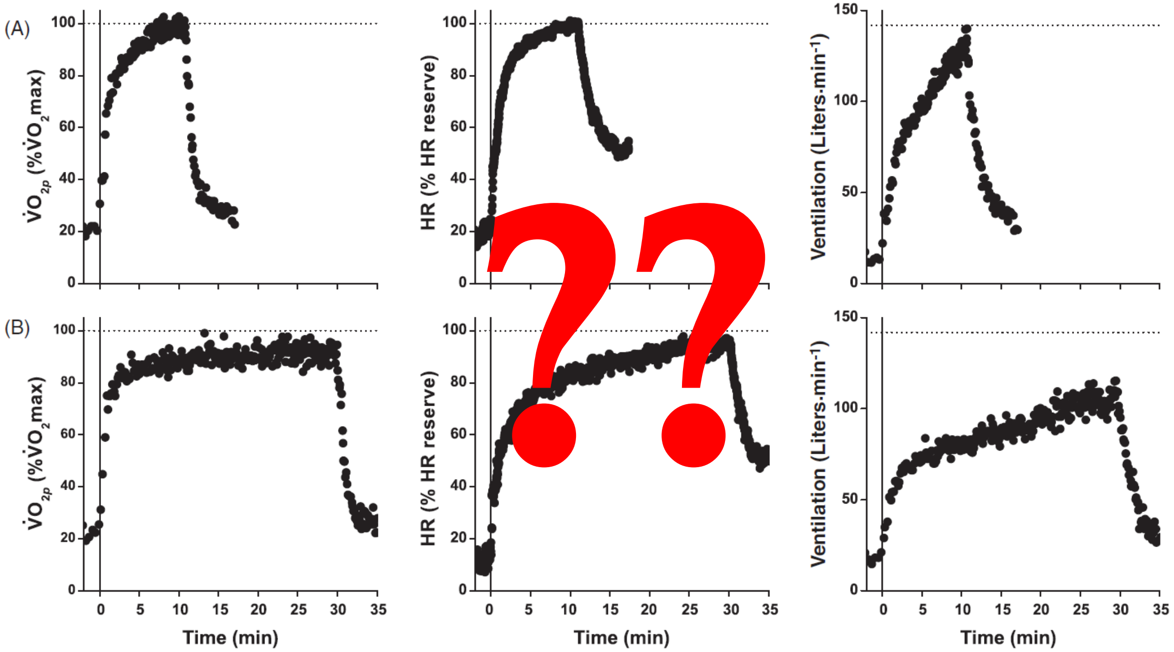
$\dot{V}O_{2max}$ = 2.91 L/min; 215 W




COMPREHENSIVE PHYSIOLOGY

Exercise: Kinetic Considerations for Gas Exchange

Harry B. Rossiter*1



3. Methods to prescribe intensity of exercise

Sports Medicine
https://doi.org/10.1007/s40279-023-01938-6

CURRENT OPINION

A Perspective on High-Intensity Interval Training for Performance and Health

Alexandra M. Coates[1] · Michael J. Joyner[2] · Jonathan P. Little[3] · Andrew M. Jones[4] · Martin J. Gibala[1]

Accepted: 12 September 2023

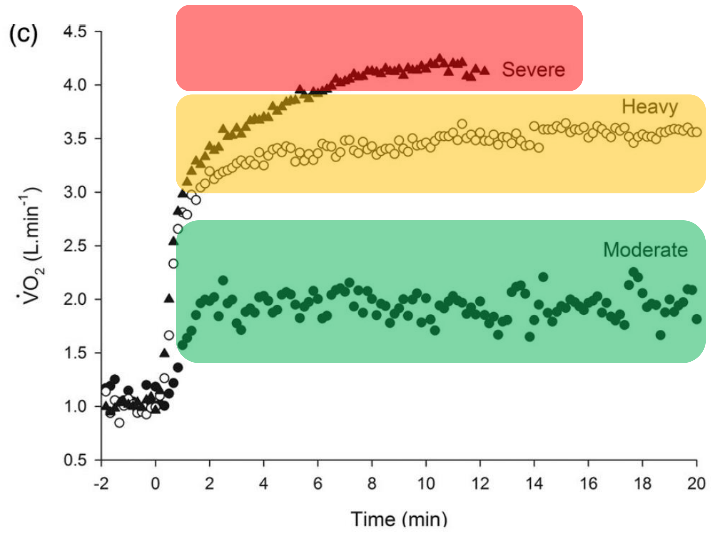
European Journal of Sport Science, 2016
http://dx.doi.org/10.1080/17461391.2016.1249524

ORIGINAL ARTICLE

Power–duration relationship: Physiology, fatigue, and the limits of human performance

MARK BURNLEY[1] & ANDREW M. JONES[2]

Performance		Health	
Hypothetical Example of a 6-Zone Training Model[1]	Common Threshold-Based Exercise Intensity Domains[2]	Common Intensity Classifications For Aerobic Physical Activity[3]	Example of Intensity Classifications for Cardiorespiratory Exercise[4]
Zone 6 - Short Sprint RPE 19-20/20	(Extreme)[6] Severe	Vigorous	Near Maximal to Maximal ≥95% HRmax, ≥90% HRR, ≥91% VO_{2max}, ≥18/20 RPE
Zone 5 - Hard / Interval RPE 17-18/20	CP/CS, LT2, LTP, MLSS	6 METs, 7/10 RPE	Vigorous 77-95% HR_{max}, 60-89% HRR, 64-90% VO_{2max}, 14-17/20 RPE
Zone 4 –Tempo / Threshold RPE 14-16/20	Heavy	Moderate	Moderate 64-76% HR_{max}, 40-59% HRR, 46-63% VO_{2max}, 12-13/20 RPE
Zone 3 – Steady RPE 12-13/20	LT1, GET	3 METs, 5/10 RPE	
Zone 2 – Base / Endurance RPE 10-11/20	Moderate	Light	Light 57-63% HR_{max}, 30-39% HRR, 37%-45 VO_{2max}, 9-11/20 RPE
Zone 1 – Easy RPE ≤9/20		1.5 METs	Very Light <57% HR_{max}, <30% HRR, <37% VO_{2max}, 9/20 RPE



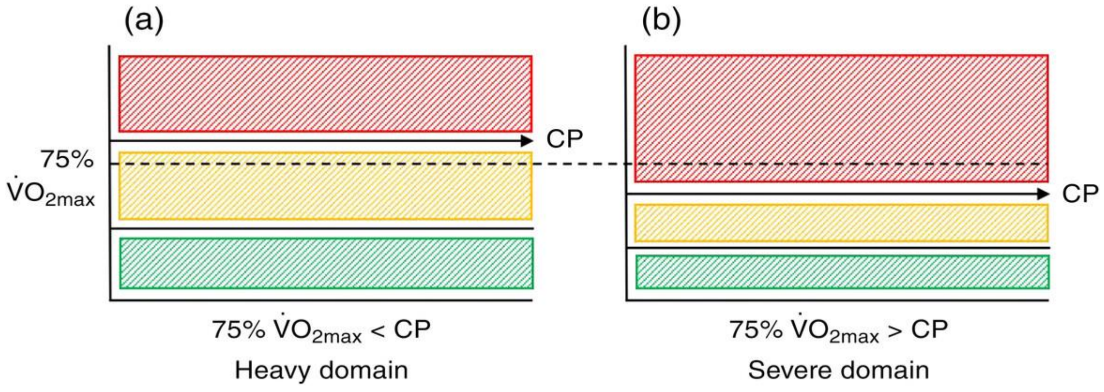
Acute responses to exercise are affected by the method of exercise prescription

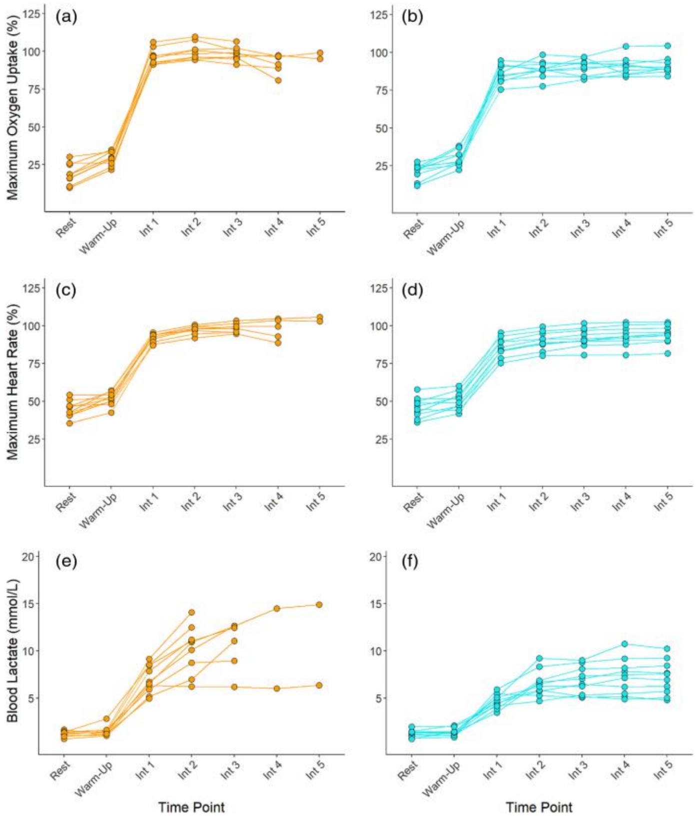
Received: 30 September 2022 | Accepted: 22 December 2022
DOI: 10.1113/EP090878
Experimental Physiology WILEY

RESEARCH ARTICLE

Variability in exercise tolerance and physiological responses to exercise prescribed relative to physiological thresholds and to maximum oxygen uptake

Samuel Meyler | Lindsay Bottoms | David Wellsted | Daniel Muniz-Pumares





Yellow – responses to exercise at % $\dot{V}O_{2max}$

Blue – responses to exercise at % critical power

Highlights

- **What is the central question of this study?**
- Does prescribing exercise intensity using physiological thresholds create a more homogeneous exercise stimulus than using traditional intensity anchors?
- **What is the main finding and its importance?**
- Prescribing exercise using physiological thresholds, notably critical power, reduced the variability in exercise tolerance and acute metabolic responses. At higher intensities, approaching or exceeding the transition from heavy to severe intensity exercise, the imprecision of using fixed $\%\dot{V}_{O_2max}$ as an intensity anchor becomes amplified.

Critical power as a physiological threshold

Metabolic and respiratory profile of the upper limit for prolonged exercise in man

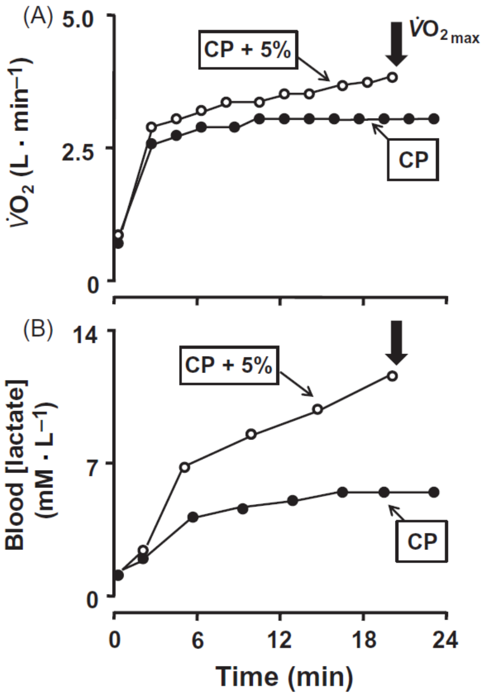
David C. Poole, Susan A. Ward†, Gerald W. Gardner and Brian J. Whipp

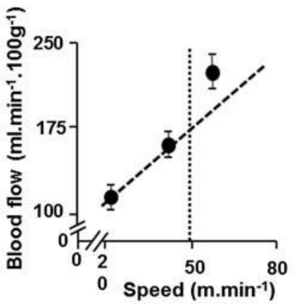
Critical Power: An Important Fatigue Threshold in Exercise Physiology

David C. Poole[1], Mark Burnley[2], Anni Vanhatalo[3], Harry B. Rossiter[4,5], and Andrew M. Jones[3]

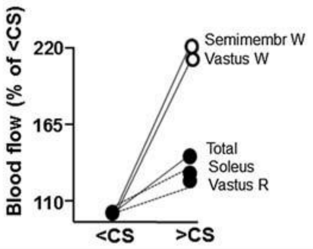
Muscle metabolic responses to exercise above and below the "critical power" assessed using ^{31}P-MRS

Andrew M. Jones,[1] Daryl P. Wilkerson,[1] Fred DiMenna,[1] Jonathan Fulford,[2] and David C. Poole[1,3]



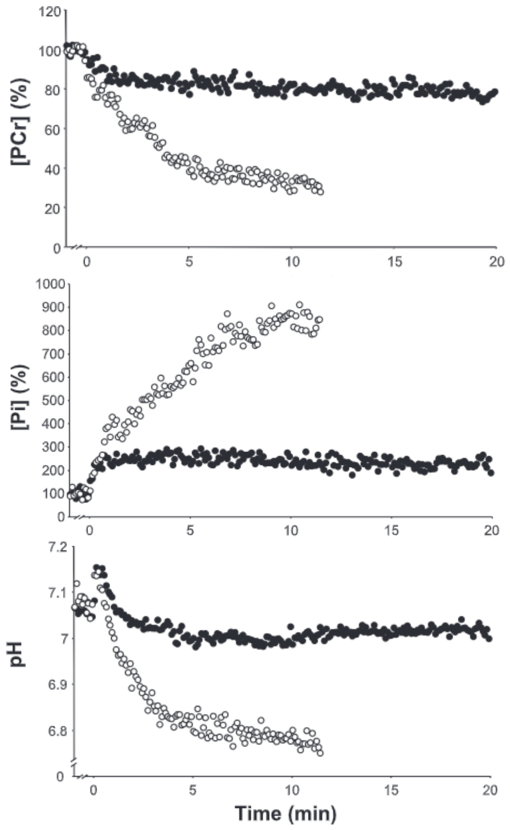


Rat hind limb blood flow is disproportionately high >CS



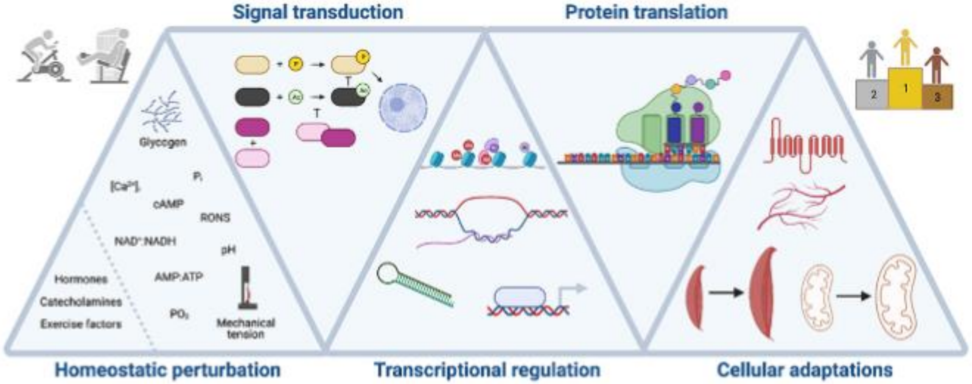
This is due to greater %increases in blood flow to fast twitch low oxidative muscles

Critical power represents a physiological threshold, whereby metabolic, neuromuscular, hemodynamic responses to exercise differ < vs > CP.



From acute responses to long-term adaptations

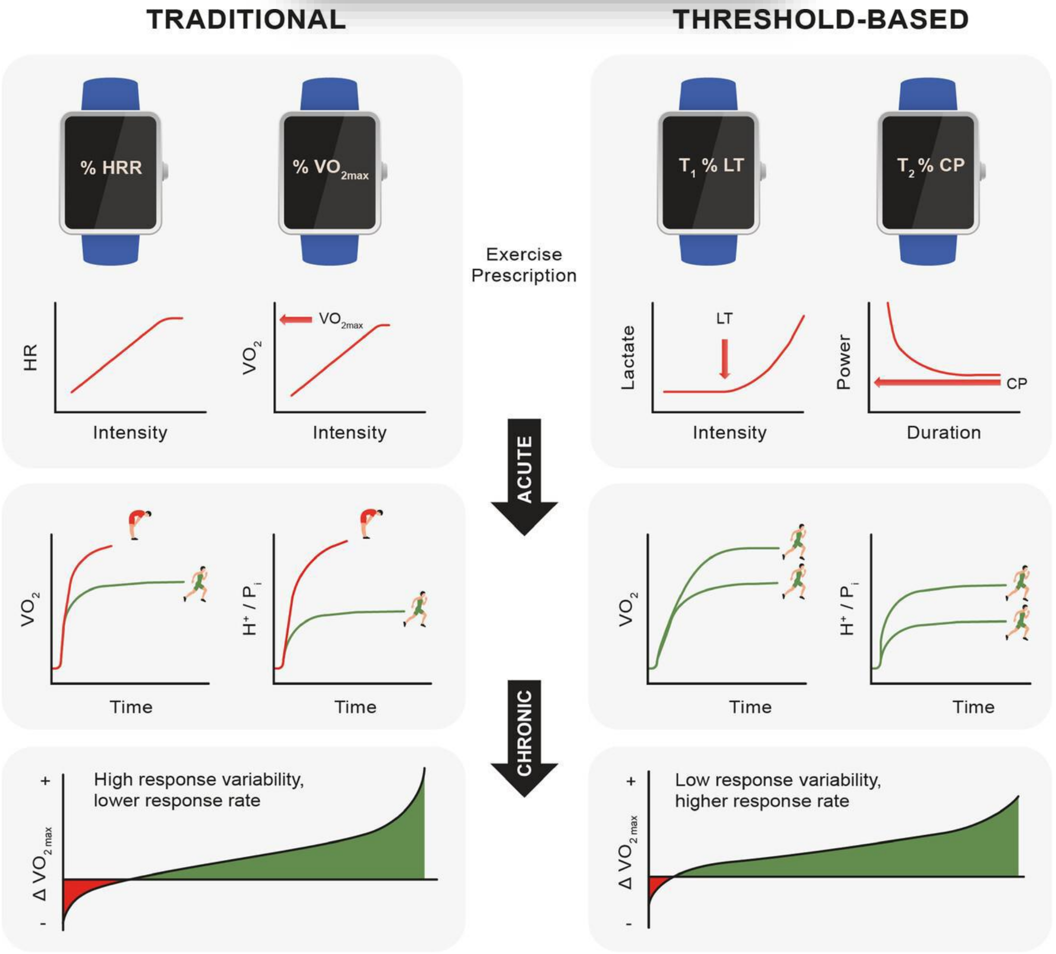

american physiological society
PHYSIOLOGICAL REVIEWS
Physiol Rev 103: 1693–1787, 2023
First published January 5, 2023; doi:10.1152/physrev.00017.2022
REVIEW ARTICLE
THE MOLECULAR ATHLETE: EXERCISE PHYSIOLOGY FROM MECHANISMS TO MEDALS
Regula Furrer,[1] John A. Hawley,[2] and Christoph Handschin[1]
[1]Biozentrum, University of Basel, Basel, Switzerland and [2]Exercise and Nutrition Research Program, Mary MacKillop Institute for Health Research, Australian Catholic University, Melbourne, Victoria, Australia



If training is prescribed using methods which elicit a homogeneous homeostatic perturbation…

…there is potential for more homogeneous chronic adaptations?


Received: 30 September 2022 | Accepted: 22 December 2022
Experimental Physiology WILEY
RESEARCH ARTICLE
Variability in exercise tolerance and physiological responses to exercise prescribed relative to physiological thresholds and to maximum oxygen uptake
Samuel Meyler | Lindsay Bottoms | David Wellsted | Daniel Muniz-Pumares

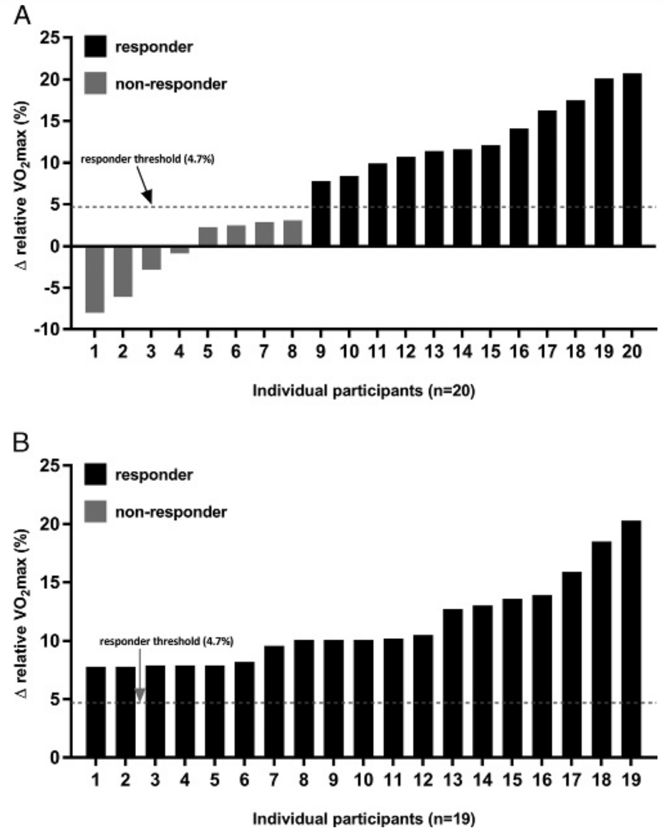


4. ‘Individualised’ exercise prescription

Relatively few studies have compared response rates following TRADITIONAL vs THRESHOLD methods of exercise prescription.

Incidence of $\dot{V}O_2$max Responders to Personalized versus Standardized Exercise Prescription

RYAN M. WEATHERWAX[1,2], NIGEL K. HARRIS[1], ANDREW E. KILDING[3], and LANCE C. DALLECK[2]



European Journal of Applied Physiology
https://doi.org/10.1007/s00421-023-05340-y

ORIGINAL ARTICLE

Modelling inter-individual variability in acute and adaptive responses to interval training: insights into exercise intensity normal

Arthur Henrique Bossi[1,2,3] · Ulrike Naumann[4] · Louis Passfield[5] · James Hopker[1]

European Journal of Applied Physiology (2018) 118:1811–1820
https://doi.org/10.1007/s00421-018-3910-3

ORIGINAL ARTICLE

Change in VO₂ ... and time trial performance in response to high- ... ining prescribed using ventilatory threshold

...vere[1,2] · Theodore Anderson[1,3] · Erin Kellogg[1] · Patrick Holstrom[1] · Sebastian Ring[1] ·

Randomized Controlled Trial > *Med Sci Sports Exerc* (IF: 5.41; Q1). 2024 Jul 1;56(7):1307-1316.
doi: 10.1249/MSS.0000000000003406. Epub 2024 Feb 3.

Heavy-, Severe-, and Extreme-, but Not ... Intensity Exercise Increase $\dot{V}o$ 2max and ... after 6 wk of Training

Erin Calaine Inglis[1], Danilo Iannetta[1], Letizia Rasica[1], Mary Z Mackie[1], Dan...
Martin J Macinnis[1], Juan M Murias

European Journal of Applied Physiology (2021) 121:2039–2059
https://doi.org/10.1007/s00421-021-04676-7

ORIGINAL ARTICLE

Individual cardiovascular responsiveness to work-matched exercise within the moderate- and severe-intensity domains

...Maturana[1,2] · Philipp Schellhorn[1] · Gunnar Erz[1] · Christof Burgstahler[1] · Manuel Widmann[1,2] · ...[2] · Rogerio N. Soares[4] · Juan M. Murias[4] · Ansgar Thiel[2,3] · Andreas M. Nieß[1,2]

RESEARCH ARTICLE Open Access

Is a threshold-based model a superior method to the relative percent concept for establishing individual exercise intensity? a randomized controlled trial

Ali E. Wolpern[1], Dara J. Burgos[1], Jeffrey M. Janot[2] and Lance C. Dalleck[1*]

Meta-analysis of IPD

TITLE

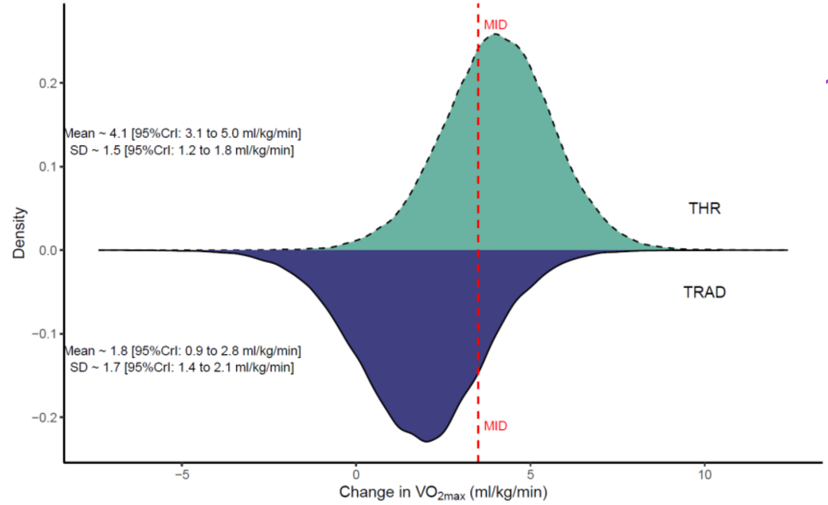
Changes in cardiorespiratory fitness following exercise training prescribed relative to traditional intensity anchors and to physiological thresholds: a systematic review with meta-analysis of individual participant data

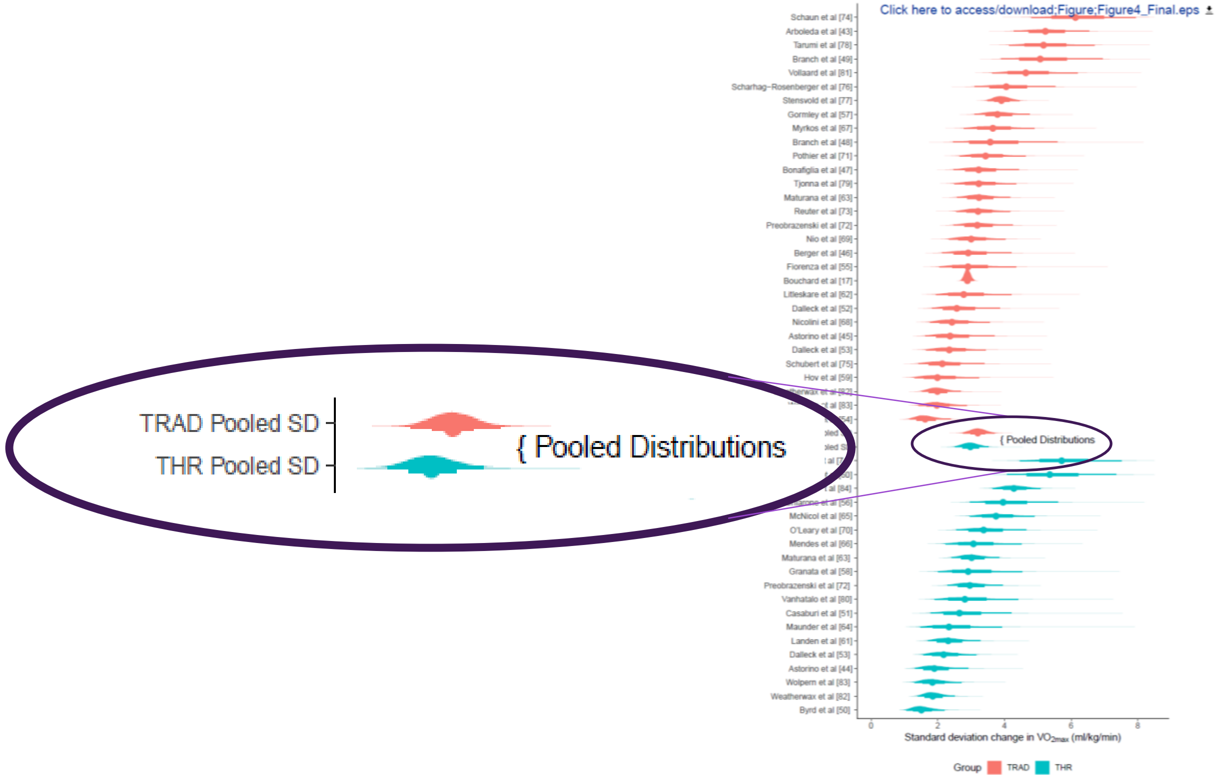
Running heading

Cardiorespiratory Fitness and Exercise Intensity Prescription: Individual Participant Data Meta-analysis

AUTHORS

Samuel J. R. Meyler[1], Paul A. Swinton[2], Lindsay Bottoms[1], Lance C. Dalleck[4], Ben Hunter[5], Mark A. Sarzynski[6], David Wellsted[1], Camilla J. Williams[7], Daniel Muniz-Pumares[1]





Meta-analysis of individual participant data (IPD)

Healthy, non-obese (BMI < 30 kg·m^2) adults undertaking endurance training for > 3 wks, endurance training only (no concurrent training, no additional intervention), direct measurement of $\dot{V}O_{2max}$.

- 4 studies (139 Participants) from studies comparing **TRAD** vs **THR** vs **CON** group.
- 43 studies (1544 participants) from studies reporting TRAD **or** THR.

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AUTHORS

Samuel J. R. Meyler[1], Paul A. Swinton[2], Lindsay Bottoms[1], Lance C. Dalleck[4], Ben Hunter[5], Mark A. Sarzynski[6], David Wellsted[1], Camilla J. Williams[7], Daniel Muniz-Pumares[1]

Sports Medicine (2021) 51:1785–1797
https://doi.org/10.1007/s40279-021-01442-9

ORIGINAL RESEARCH ARTICLE

Exploring Differences in Cardiorespiratory Fitness Response Rates Across Varying Doses of Exercise Training: A Retrospective Analysis of Eight Randomized Controlled Trials

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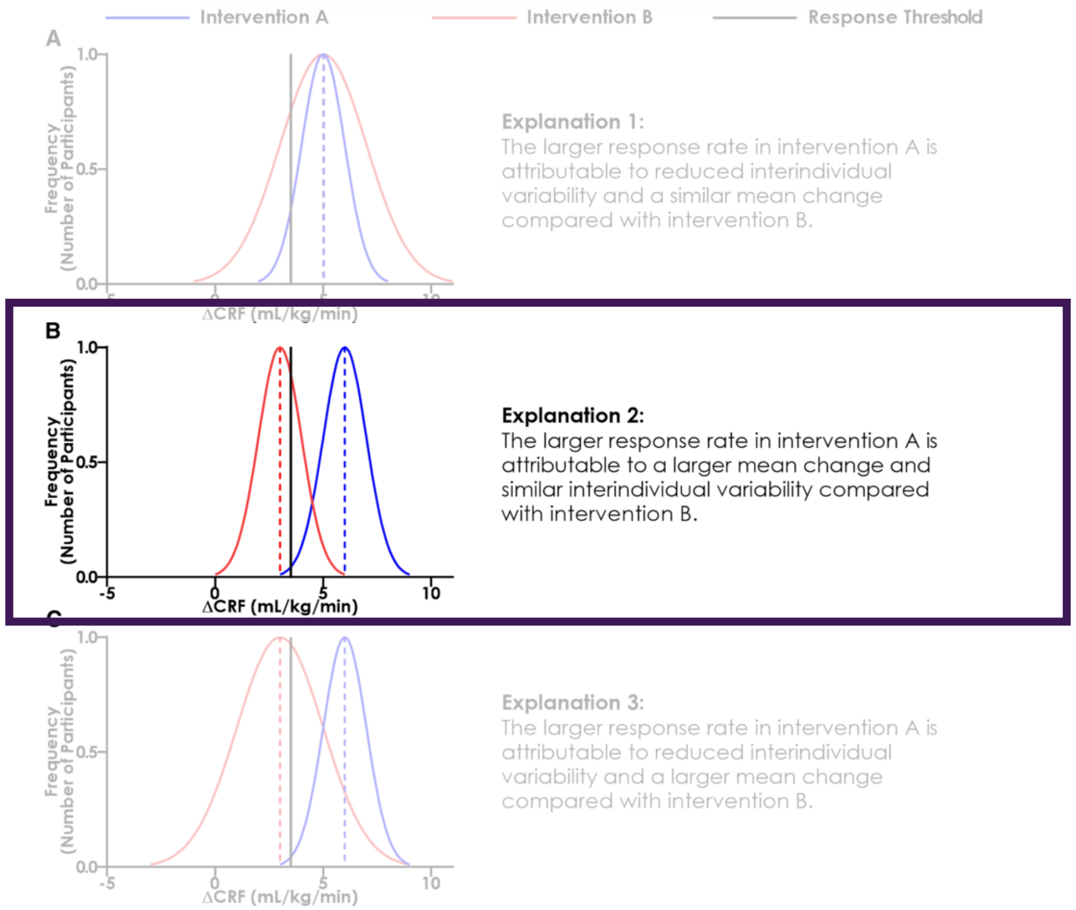

Results from this IPD MA suggest exercise prescribed relative to physiological thresholds increases response rates by increasing the mean response…

whilst having negligible effect on response variability.

Few final considerations

- Studies have different methodologies, and therefore comparation between studies is difficult. Few studies have directly compared THR-based vs TRAD-based approaches.
- Effects on variability may be difficult to detect. Large sample sizes required ($$$).
- Looking for alternatives, e.g. repeating measurements ($).

📅 Today (Friday 5th July) at 1 pm
📌 Room: Forth

Key points

1. Increases in maximum oxygen uptake, or $\dot{V}O_{2max}$, (e.g. Δ 1 MET) are associated with reductions in mortality and morbidity, improvements endurance performance, etc.
2. Increases in $\dot{V}O_{2max}$ following training are heterogenous. Some factors affecting response variability may not controlled, but some factors are modifiable – typically around training characteristics.
3. Method of exercise prescription dictates the acute responses to exercise, and thus may also affect response rates.
4. Endurance training prescribed relative to physiological thresholds may create a more consistent stimuli among individuals, which can affect response rates.

Thank you

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