# Exercise intensity prescription: How close (or how far) are we from getting it right?

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# Responders and non-responders to aerobic exercise

**Participants:** 481 individuals from 98 two-generation families of Caucasian descent (236 men, 245 women)

**Training:** HR associated with 55% of their initial $VO_{2max}$ for 30 min/day and gradually progressed to the HR associated with 75% of their initial $VO_{2max}$ for 50 min/day at the end of 14 wk.

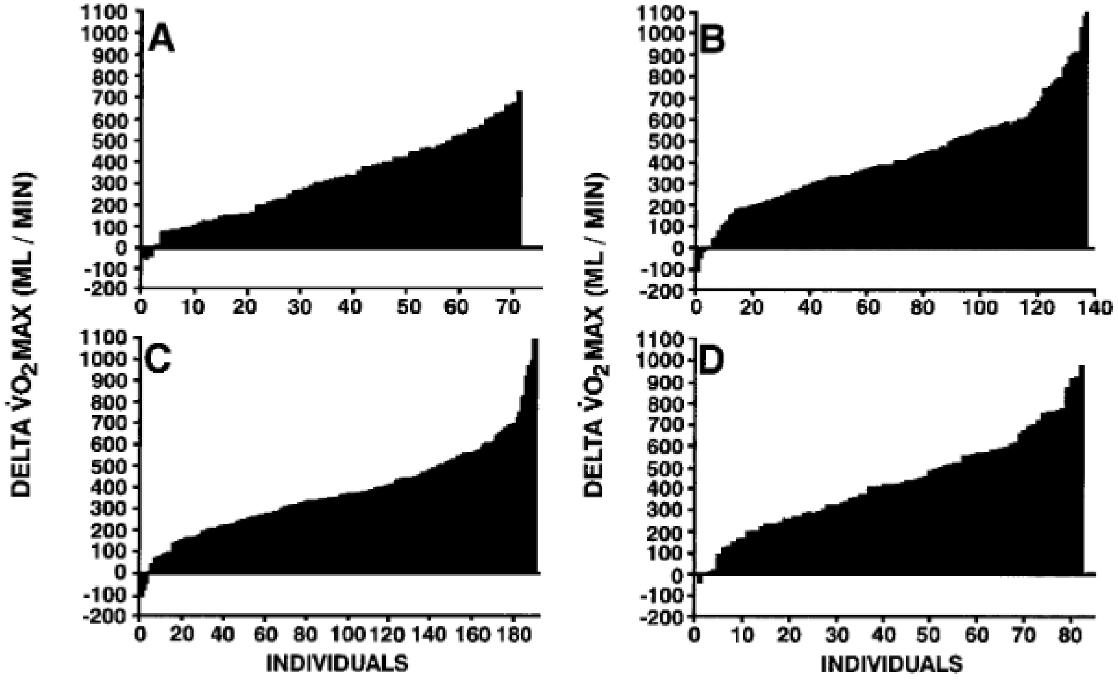



Fig. 1. Individual differences (delta) in increase in maximal $O_2$ uptake ($\dot{V}o_{2max}$) with training for 481 individuals of the study distributed across the four Clinical Centers: Indiana (*A*), Minnesota (*B*), Quebec (*C*), and Texas (*D*).

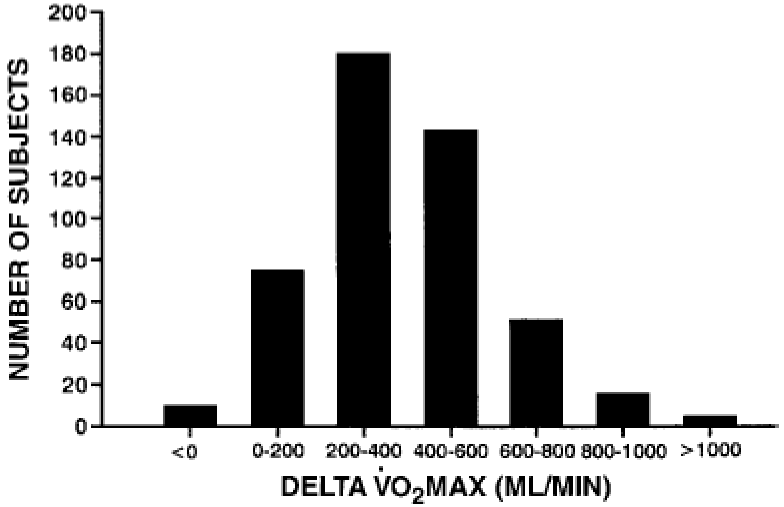



Fig. 2. Distribution of the 481 subjects by classes of increase (delta) in $\dot{V}o_{2max}$ from baseline levels.

"What is the main cause of the heterogeneity in the response to training? We believe that it has to do with as yet undetermined genetic characteristics."

Bouchard et al., J Appl Physiol 87(3): 1003–8, 1999

# Responders and non-responders to aerobic exercise

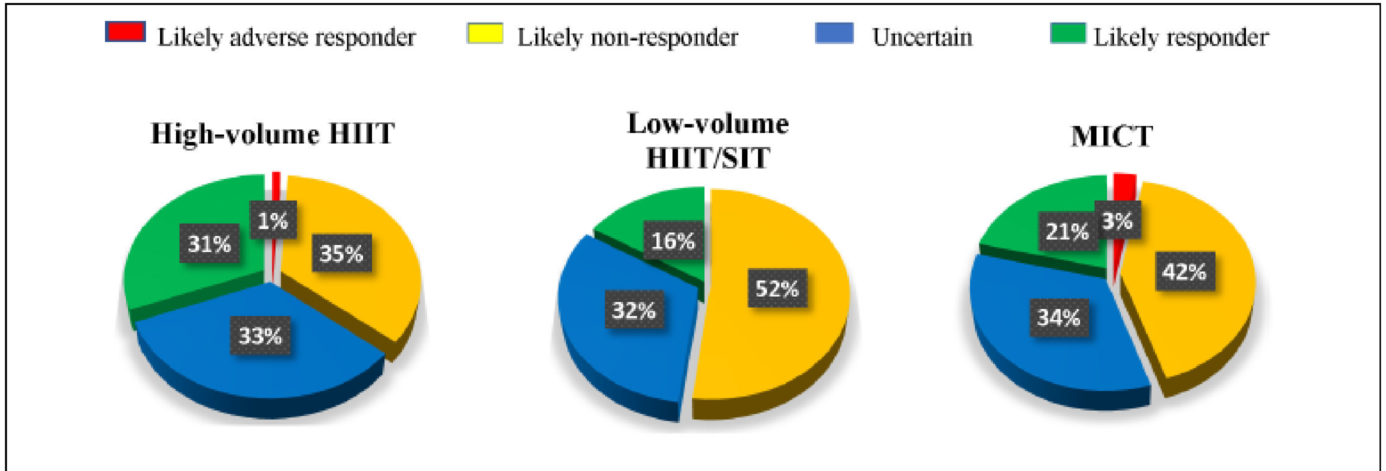



**FIGURE 2** | Percentage of likely responders to changes in relative $\dot{V}O_{2peak}$ in each training intervention.

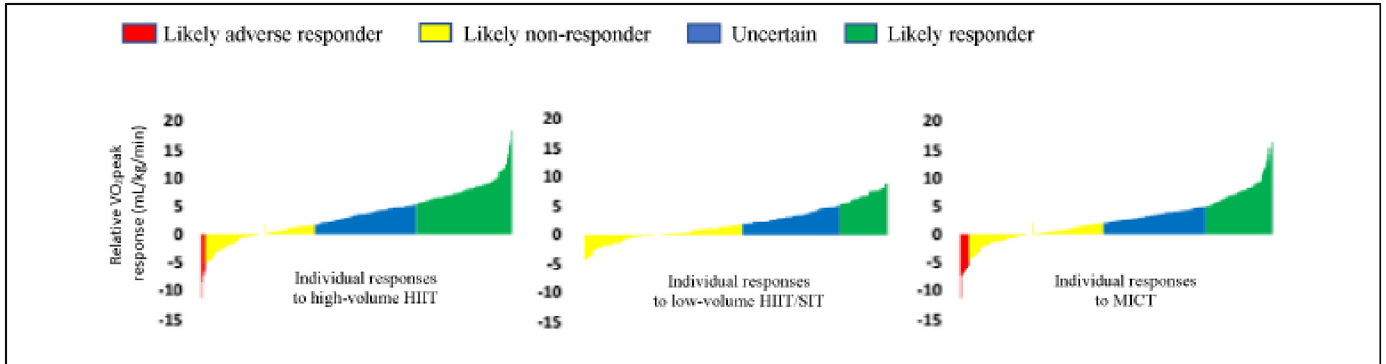



**FIGURE 3** | Waterfall plots of the relative $\dot{V}O_{2peak}$ (mL/kg/min) response rates for each intervention (raw data).

The age (18–81 years), volume of work (60 min to 4 min and 50% peak HR to 170% peak WR) and duration (3 to 104 weeks) varied considerably for the individual studies included in the current analysis.

"…**a higher training load may be more effective in** those…considered a **'low responder'** to training because participants are working at a threshold high enough **to activate certain genes and molecular pathways** required to induce a clinically meaningful exercise training"

"It would be **interesting to see if** those who were deemed a **'likely non-responder'** from our analysis would **'respond' with an increase in training duration, frequency or intensity.**"

Williams et al., Front Physiol (5)10: 19, 2019

# Responders and non-responders to aerobic exercise

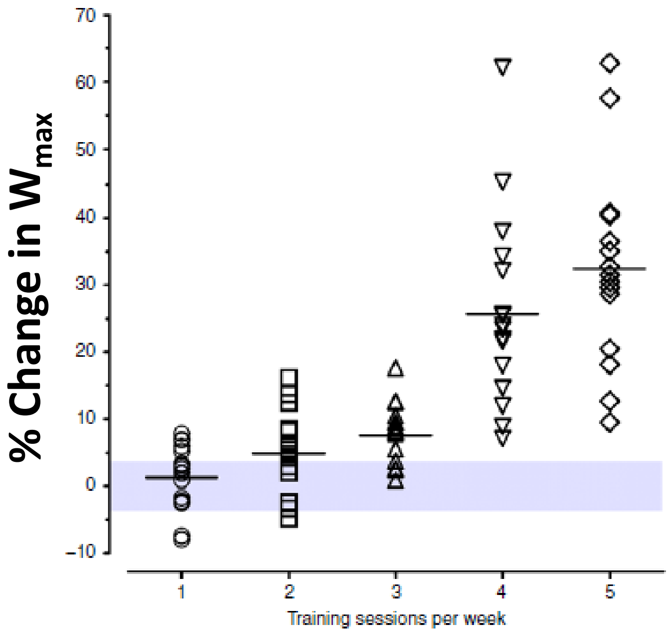



**Figure 1. Individual percentage changes in maximal power output ($W_{max}$) after the first exercise training period in each group**
The typical error of measurement (%TE) for $W_{max}$ measurement is illustrated by the shaded area. Values within this area represent non-response. Non-response was 69% (11 of 16), 40% (6 of 15), 29% (4 of 14), 0% (0 out of 17) and 0% (0 out of 16) for groups 1, 2, 3, 4 and 5, respectively. [Colour figure can be viewed at wileyonlinelibrary.com]

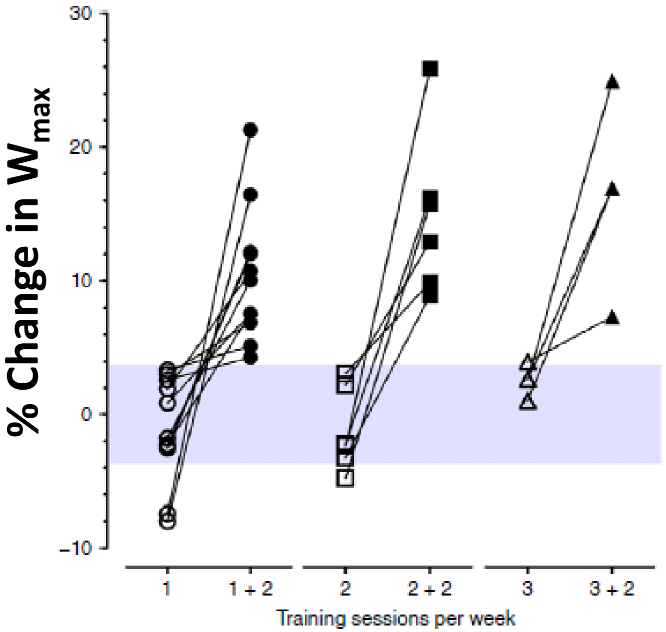



**Figure 2. Individual percentage changes in maximal power output ($W_{max}$) after the second exercise training period for non-responders in each group**
The typical error of measurement (%TE) for $W_{max}$ measurement is illustrated by the shaded area. Values within this area represent non-response. Non-response was abolished after the second exercise training period in all individuals. [Colour figure can be viewed at wileyonlinelibrary.com]

"The prevalence of cardiorespiratory fitness (CRF) **non-response gradually declines in healthy individuals exercising 60, 120, 180, 240 or 300 min per week** for 6 weeks."

"Following a successive identical 6-week training period but comprising **120 min of additional exercise per week, CRF non-response is universally abolished**.."

Montero and Lundby, J Physiol 595(11): 3377-87, 2017

6 weeks of training. Four different intensity profiles, comprising moderate continuous exercise and high-intensity intervals. **Each profile had an average exercise intensity of 65% of peak WR for 60 min**.

# Responders and non-responders to aerobic exercise

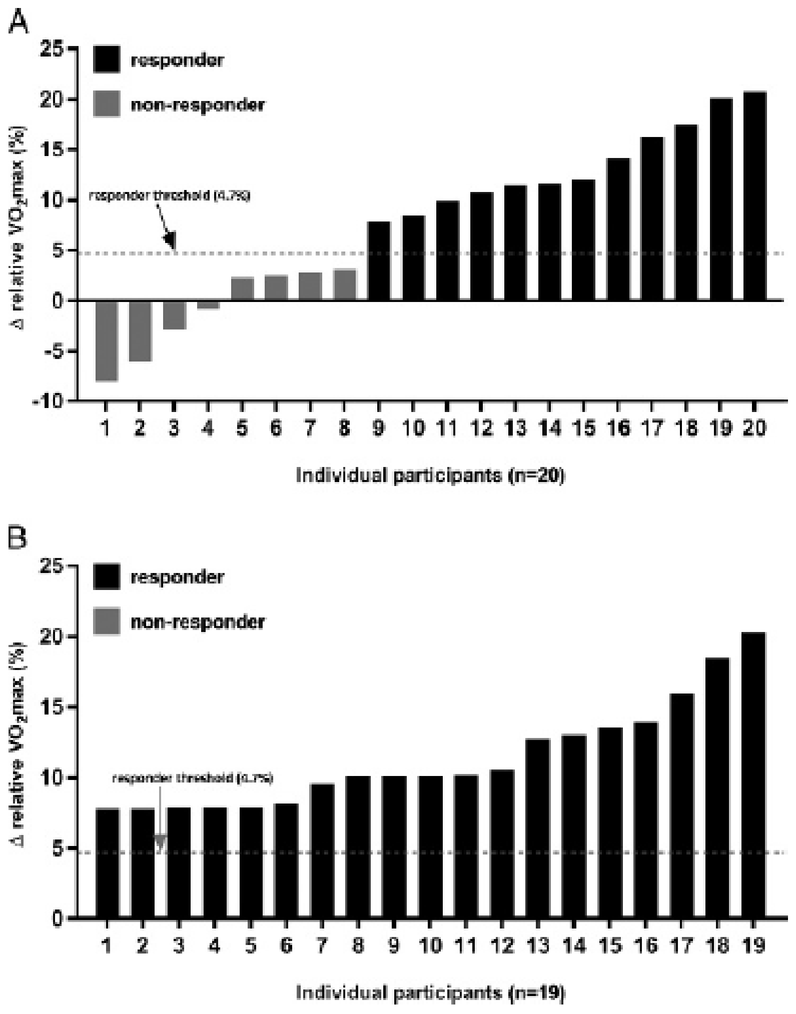



FIGURE 2—Variability in relative $\dot{V}O_2max$ responsiveness (% change) to 12 wk of standardized (A) and individualized (B) exercise training. The dashed line indicates the minimum change ($\Delta > 4.7\%$) required to be considered a meaningful adaptation in $\dot{V}O_2max$ ($mL \cdot kg^{-1} \cdot min^{-1}$).

For the **standardized group**, exercise intensity was based on percentages of HRR (from **40% progressing to 65% HRR**).

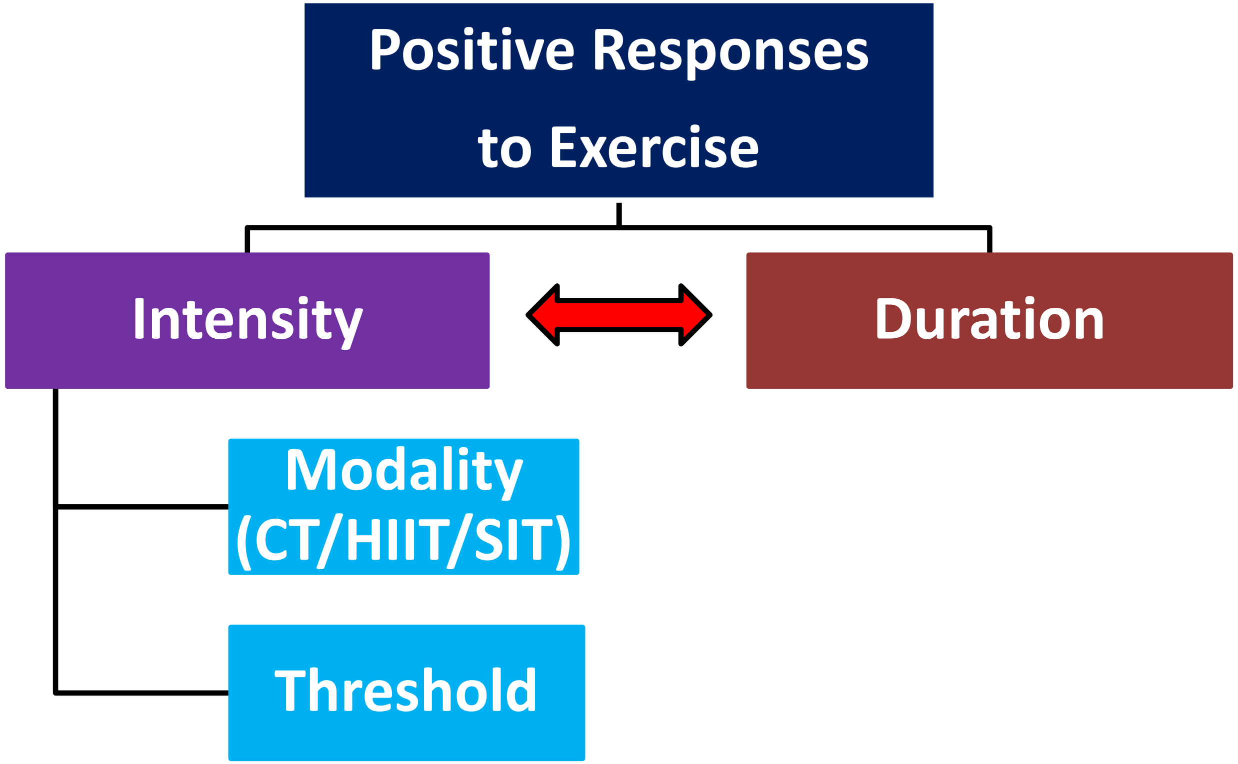
The **individualized group** had an intensity that was established **based on VT1 and VT2**:

- **Target HR < VT1** = HR range of 10 bpm below VT1 to the HR at VT1
- **Target HR > VT1 to < VT2** = HR range of 15 bpm directly between VT1 and VT2
- **Target HR > VT2** = HR range of 10 bpm above VT2

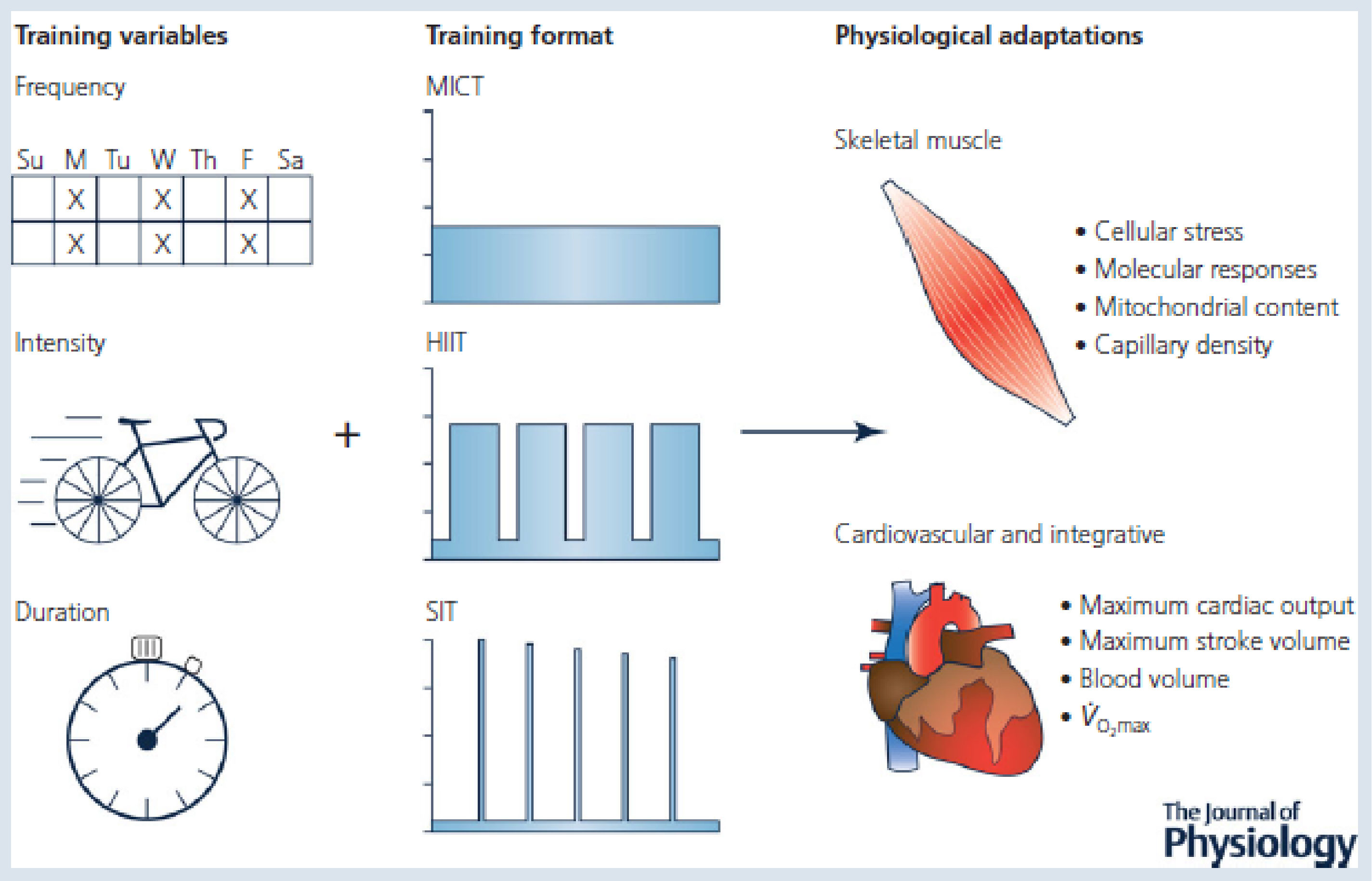
Weatherwax et al., Med Sci Sports Exerc 51(4): 681–91, 2019

# Responders and non-responders to aerobic exercise

**Although some of the research shows responders and no-responders to exercise, some argue that everyone should respond to exercise training provided that the right stimulus is presented** (Joyner and Lundby, Exerc Sport Sci Rev 46(3): 138–43, 2018)



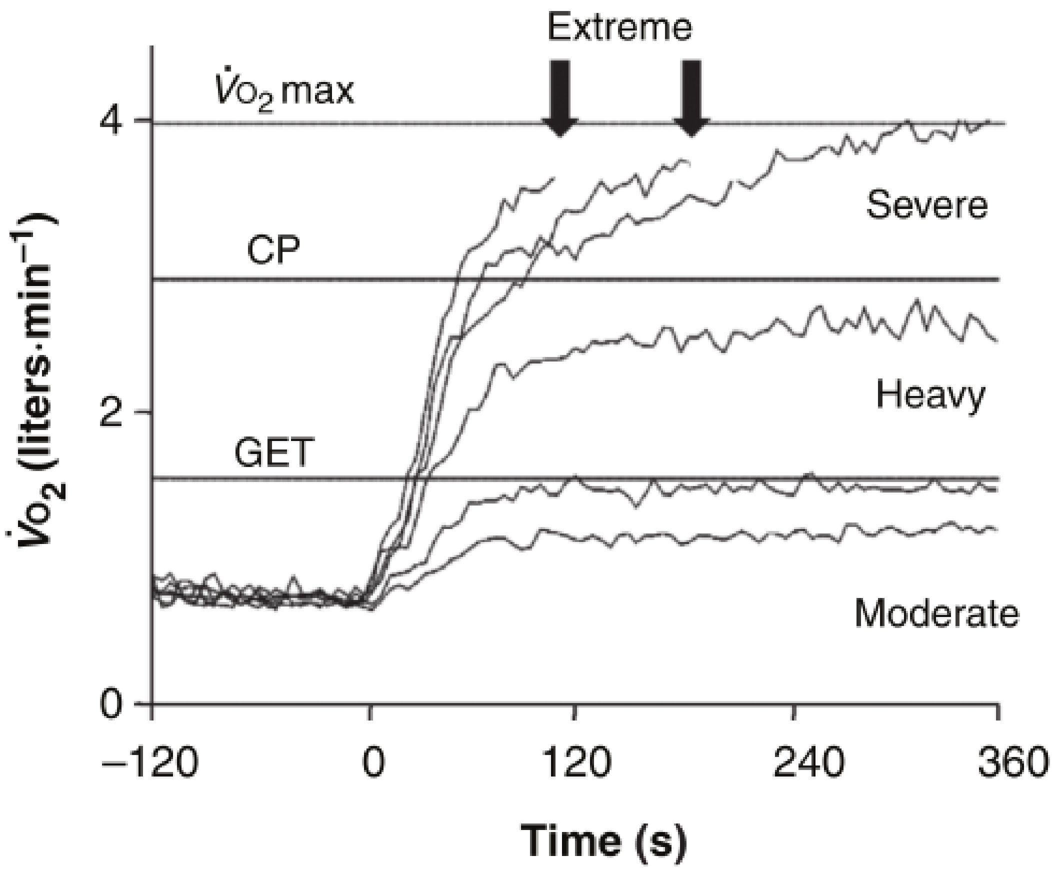
# The role of exercise intensity




- "With respect to skeletal muscle adaptations, **cellular stress and the resultant metabolic signals** for mitochondrial biogenesis **depend largely on exercise intensity**."
- "At the whole-body level, **$VO_{2max}$ is generally increased more by HIIT than MICT** for a given training volume, whereas **SIT and MICT similarly improve $VO_{2max}$** despite differences in training volume."

MacInnis and Gibala., J Physiol 595(9): 2915–2930, 2017

# Exercise intensity domains



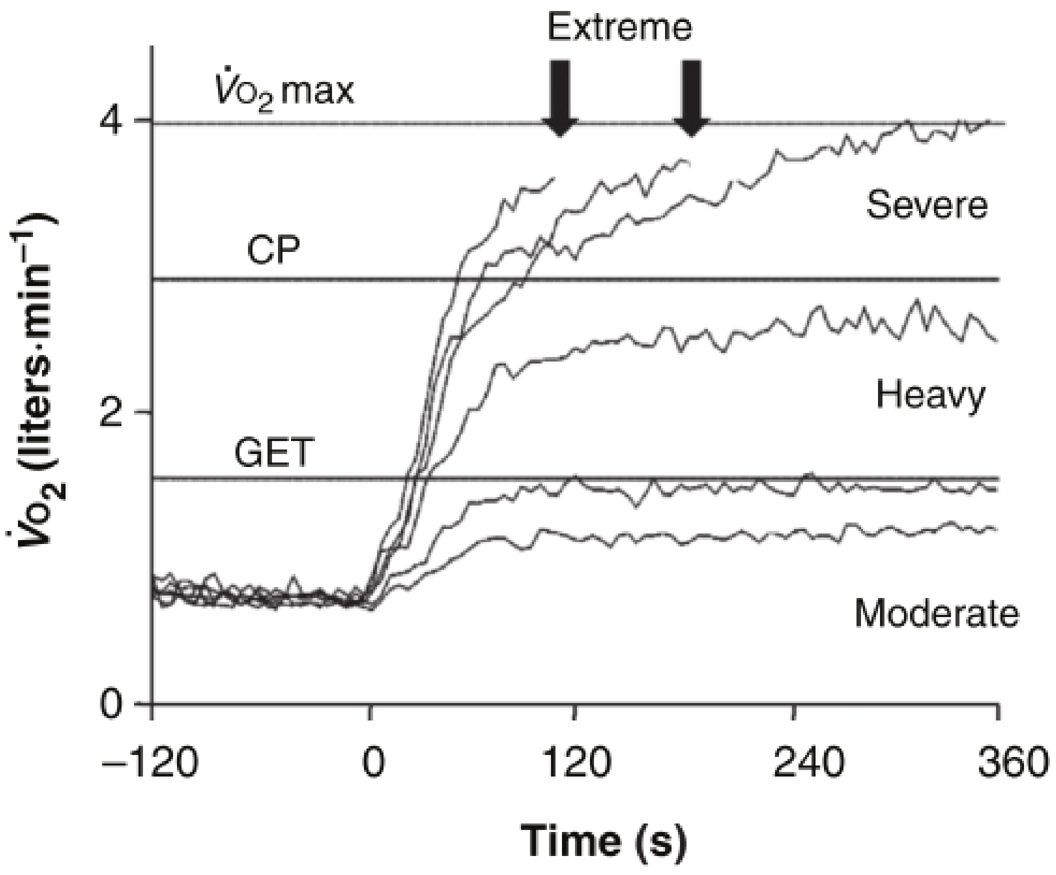

**Severe: [La] and $VO_2$ are unstable and project to maximal values (*ABOVE CP/MLSS*)**

**Heavy: increased but stable [La] and $VO_2$. Development of $VO_{2SC}$ (*ABOVE GET BUT BELOW CP/MLSS*)**

**Moderate: no increase in [La] and stable $VO_2$ (*BELOW GET*)**

Poole and Jones, Comp Physiol, 2(2): 933-96, 2012

# Exercise intensity domains




Severe: > 12 mL·min$^{-1}$ per W

Heavy: ~11-12 mL·min$^{-1}$ per W

Moderate: ~10 mL·min$^{-1}$ per W

Poole and Jones, Comp Physiol, 2(2): 933-96, 2012

# Exercise intensity domains

- **Lactate threshold (LT) or gas exchange threshold (GET)**
  - Separates **Moderate** from **Heavy** intensity exercise

- **Maximal lactate steady-state (MLSS) or critical power (CP)**
  - Separates **Heavy** from **Very-Heavy/Severe** intensity exercise

# Exercise intensity domains: Can we get it right?

## CSEP classification of aerobic exercise relative intensity based on $\dot{V}O_{2max}$ test

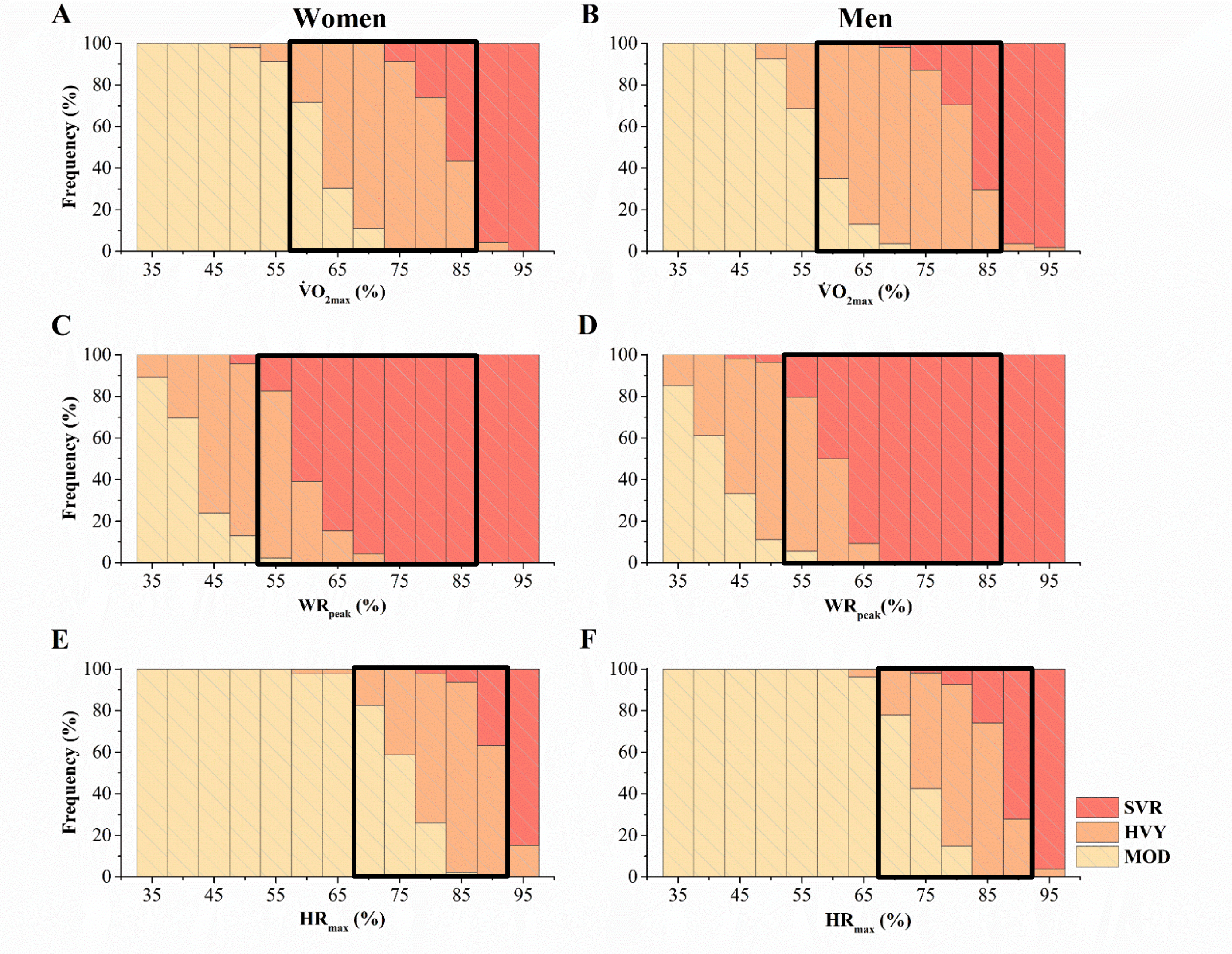
| | $\%\dot{V}O_{2R}$ or $\%HR_R$ | $\%\dot{V}O_{2peak}$ | $\%HR_{peak}$ |
|---|---|---|---|
| **Very Light** | < 20 | < 25 | < 35 |
| **Light** | 20-39 | 25-44 | 35-54 |
| **Moderate** | 40-59 | 45-59 | 55-69 |
| **Heavy** | 60-84 | 60-84 | 70-89 |
| **Very Heavy** | ≥ 85 | ≥ 85 | ≥ 90 |
| **Maximal** | 100 | 100 | 100 |

Modified from CSEP guidelines

CSEP | SCPE

# Exercise intensity domains: Can we get it right?

| | $\%\dot{V}O_{2R}$ or $\%HR_R$ | $\%\dot{V}O_{2peak}$ | $\%HR_{peak}$ | |
|---|---|---|---|---|
| **Heavy** | 60-84 | 60-84 | 70-89 | **HEAVY** |



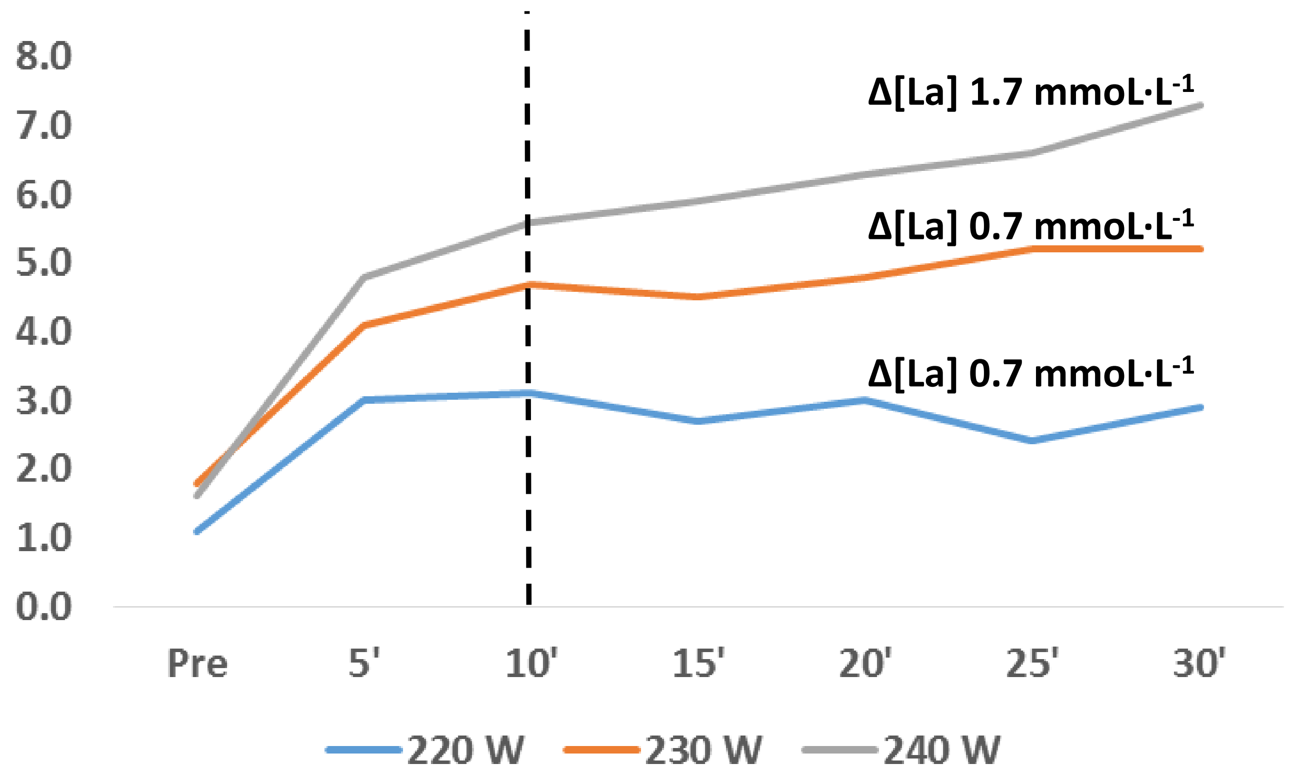

- The most **commonly used percent values** for exercise prescription are likely to **fall within at least two** different **domains**.
- The **dissociation** between **constant-load vs. ramp/step** exercise VO2 and work rate is mostly **ignored**.

Iannetta et al., Med Sci Sports Exerc (under review)

**We need to find ways of identifying constant-load work rates associated with the exercise intensity domains model**

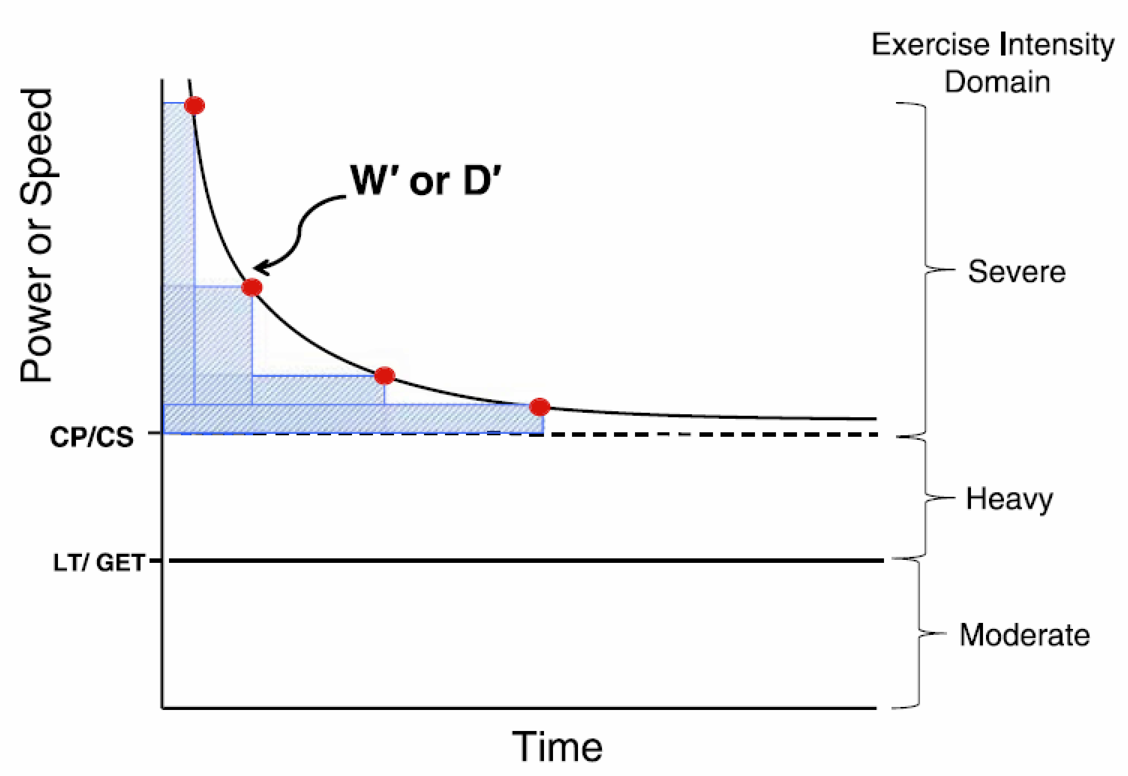
**Maximal lactate steady-state and Critical Power**

# Maximal Lactate Steady-State (MLSS)




- Highest PO at which [La] (and $VO_2$) remain stable
- Measures at 5 min intervals
- Stable = < 1 $mmol \cdot L^{-1}$ ↑ from min 10 to min 30
- Typically requires 2-4 30 min tests

# Critical Power: The upper limit of sustainable exercise (?)




- **CP:** the asymptote for power. The highest power sustainable without drawing continuously on W'.
- **W':** Predicts the tolerable duration of exercise when exercising above CP.

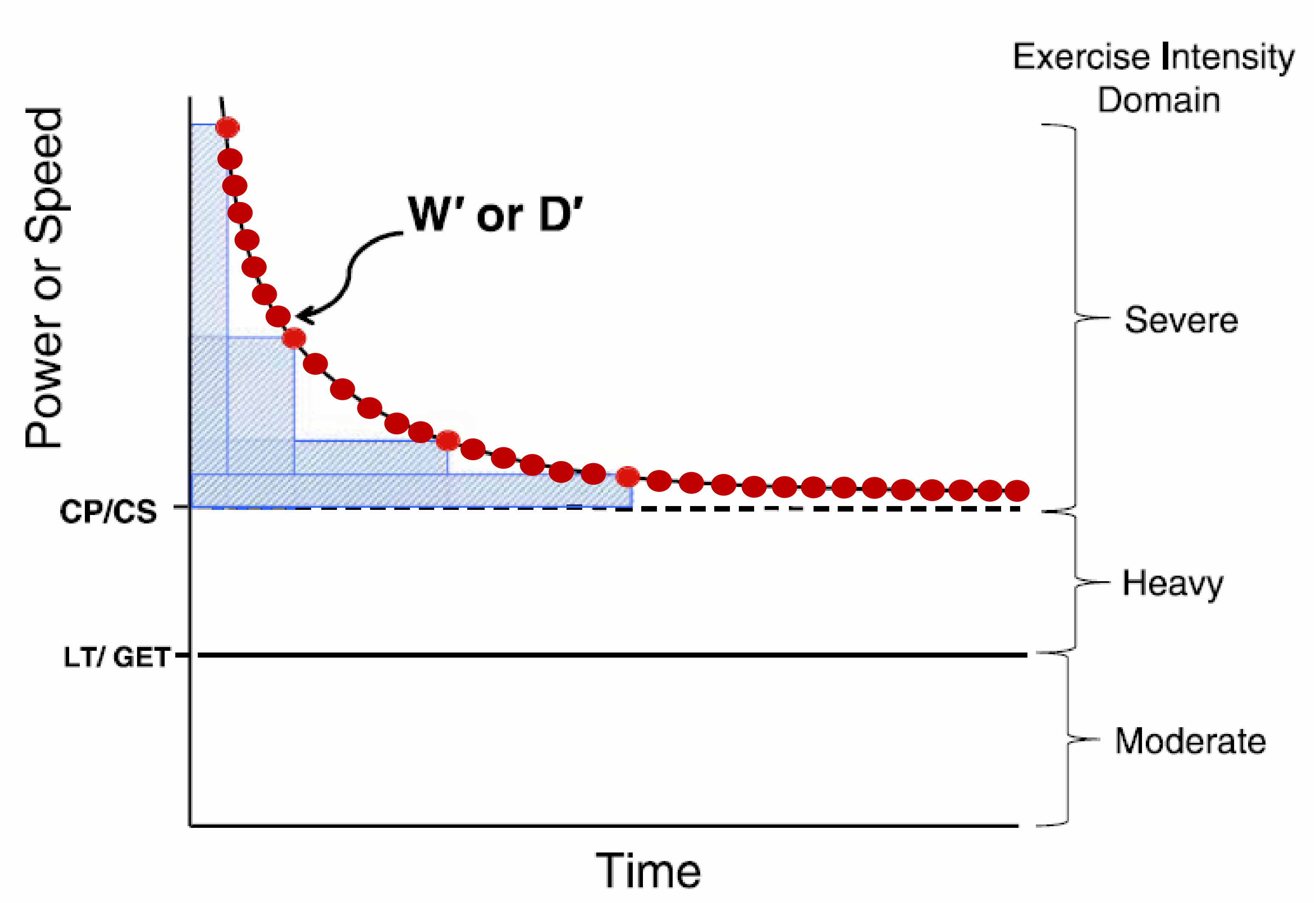
Poole et al., Med Sci Sports Exerc, 48(11): 2320–34, 2016

# Critical Power: The upper limit of sustainable exercise (!)

- "In contrast to historical definitions, **CP is now considered to represent the greatest metabolic rate that results in wholly oxidative energy provision**."
- "Although it is possible to estimate CP to the nearest watt (e.g., 200 W), given a **typical error of ~5%,** the 'actual' CP might lie between approximately **190 and 210 W in a given individual**."

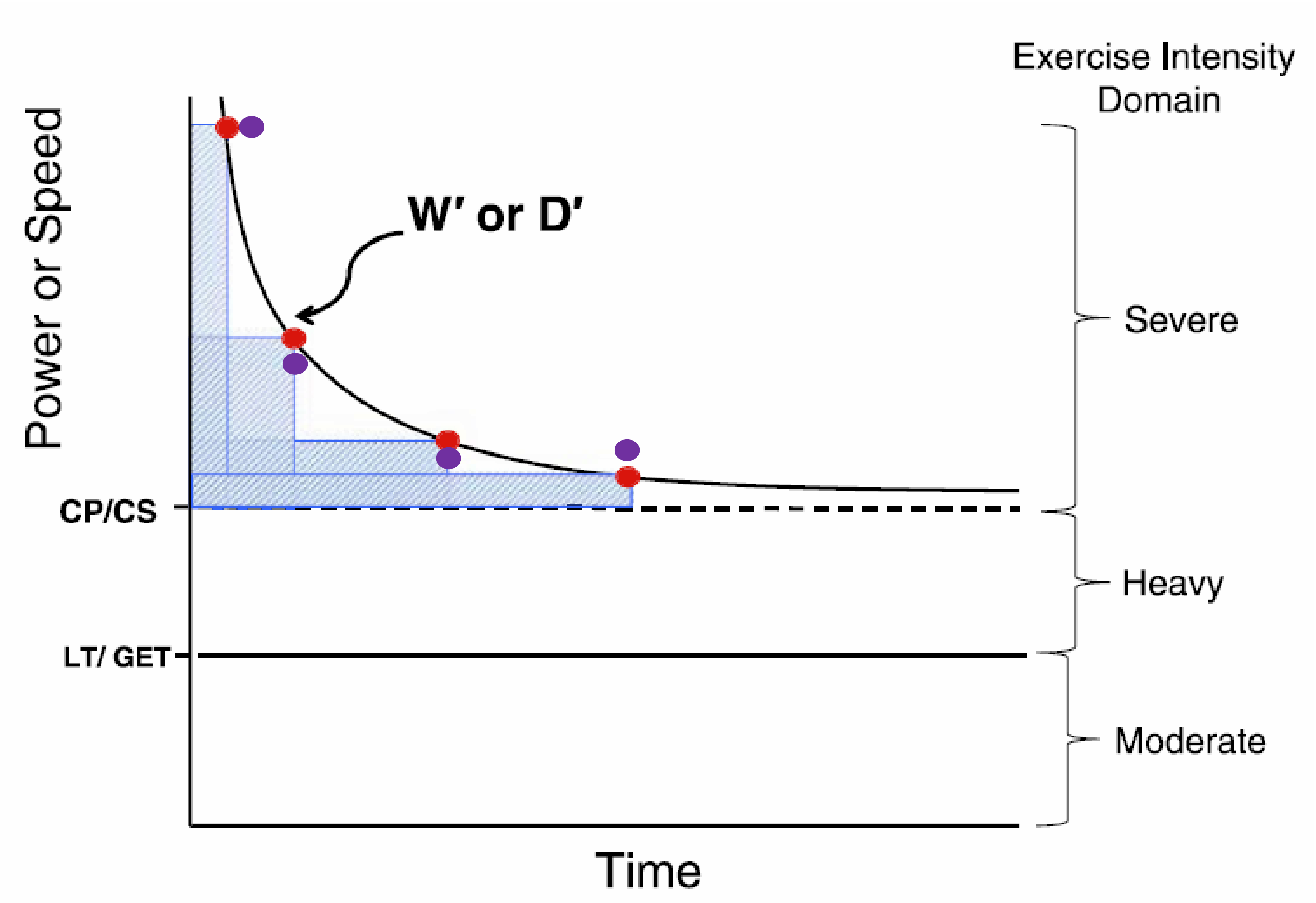
Poole et al., Med Sci Sports Exerc, 48 (11): 2320–34, 2016

# Critical Power: The upper limit of sustainable exercise (?)




Poole et al., Med Sci Sports Exerc, 48 (11): 2320–34, 2016

# Critical Power: The upper limit of sustainable exercise (?)

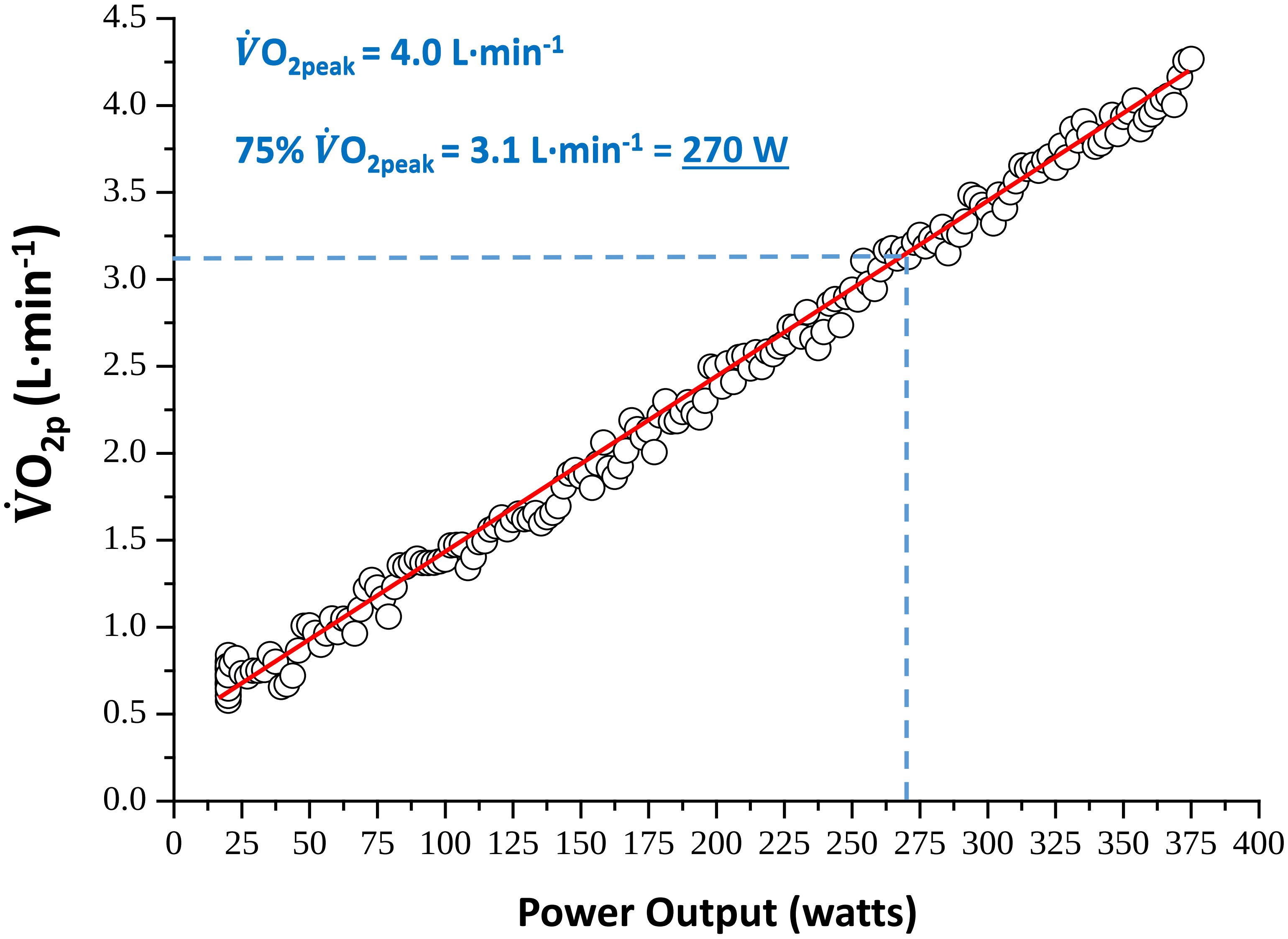



Poole et al., Med Sci Sports Exerc, 48 (11): 2320–34, 2016

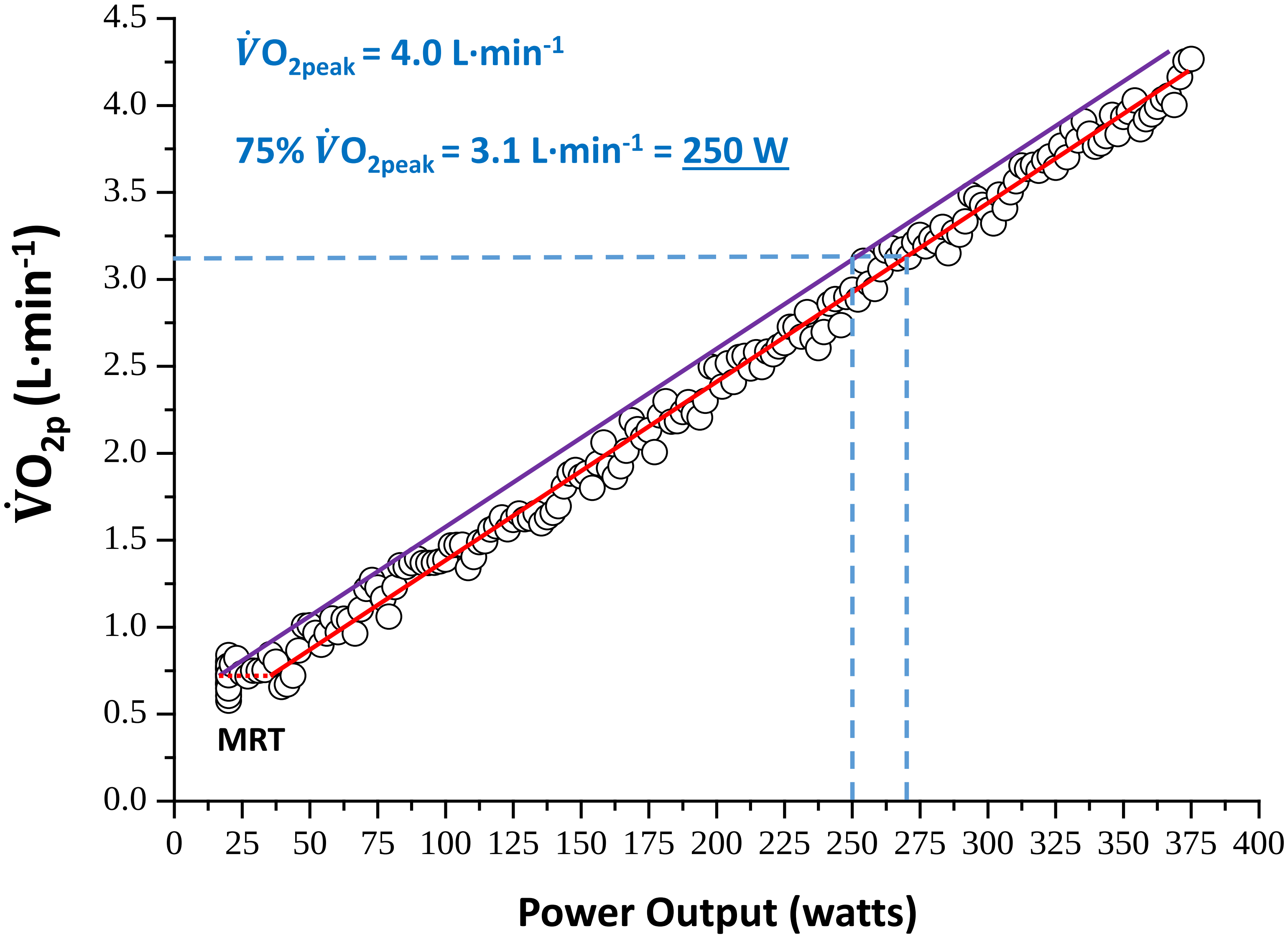
## We need to find ways of identifying constant-load work rates associated with the exercise intensity domains model

## Using data from ramp incremental tests

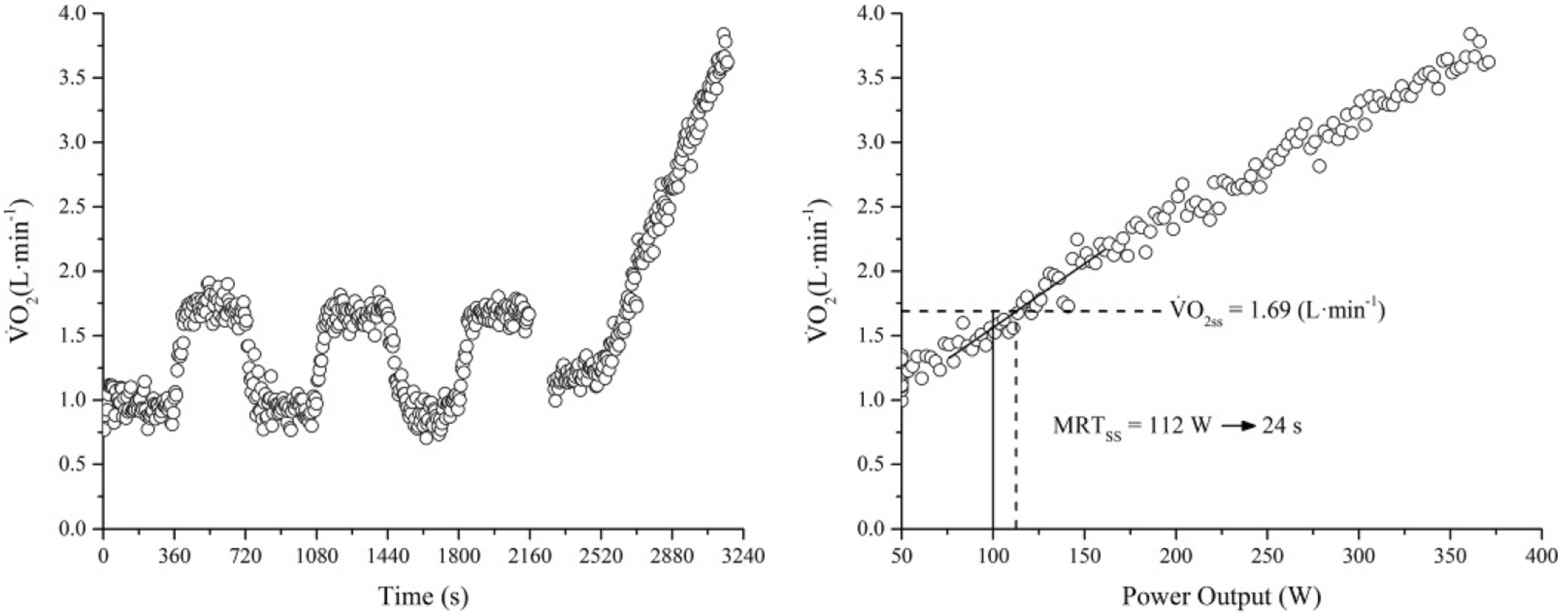
# Constant PO from ramp Incremental exercise - Limitations



# Constant PO from ramp Incremental exercise - Limitations



# Constant PO from ramp Incremental exercise - Limitations



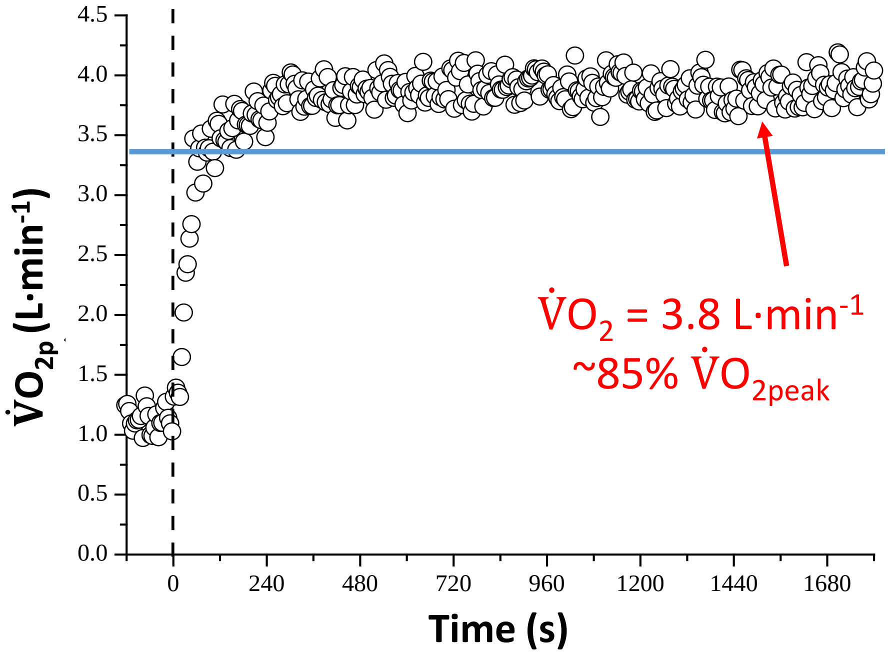

Iannetta et al., Med Sci Sports Exerc, 51 (5): 1080-1086, 2019

# Constant PO from ramp Incremental exercise - Limitations

- Two individuals asked to cycle for 30 min @ 75%$\dot{V}O_{2peak}$

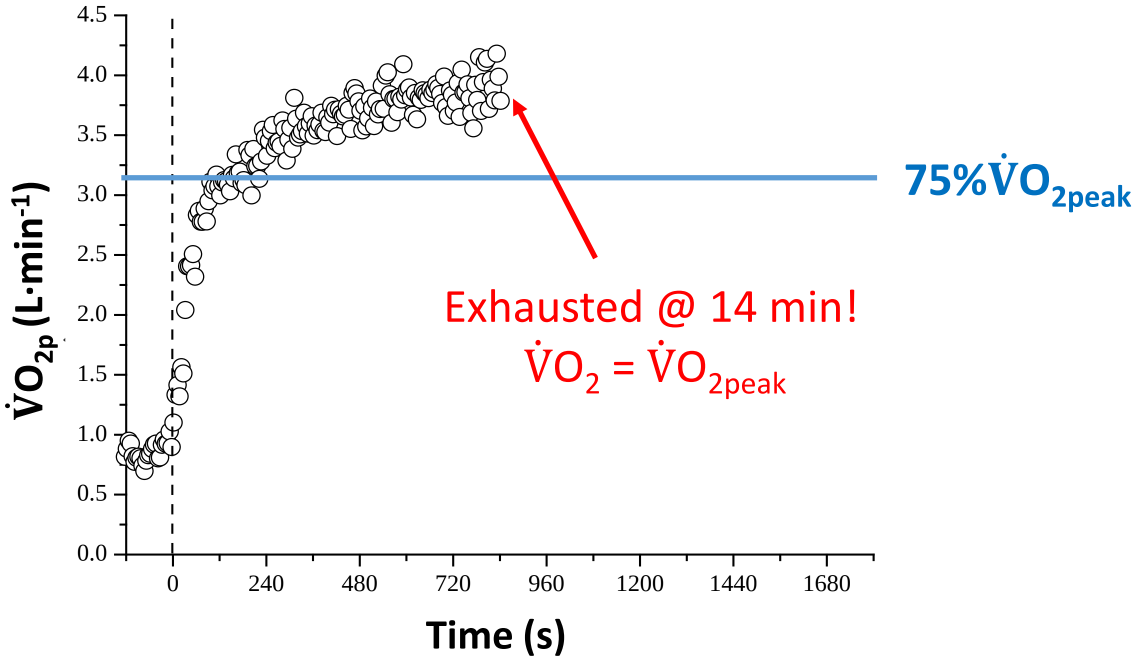
**Subject 1**

$\dot{V}O_{2peak}$ = 4.5 L·min$^{-1}$ (50 mL·kg$^{-1}$·min$^{-1}$)
75%$\dot{V}O_{2peak}$ = 3.4 L·min$^{-1}$ (PO = 280 W)

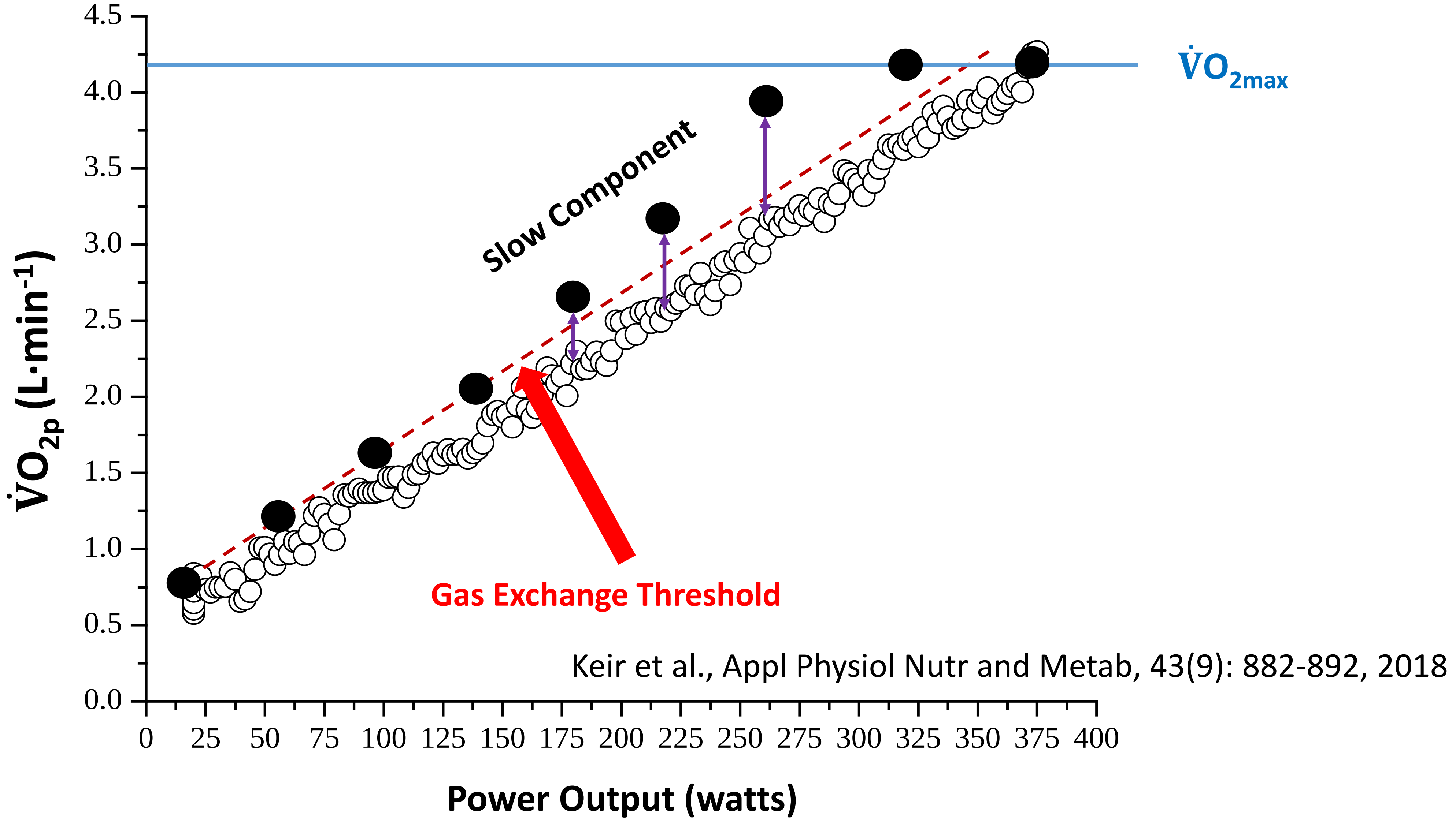



**Subject 2**

$\dot{V}O_{2peak}$ = 4.0 L·min$^{-1}$ (50 mL·kg$^{-1}$·min$^{-1}$)
75%$\dot{V}O_{2peak}$ = 3.1 L·min$^{-1}$ (PO = 250 W)

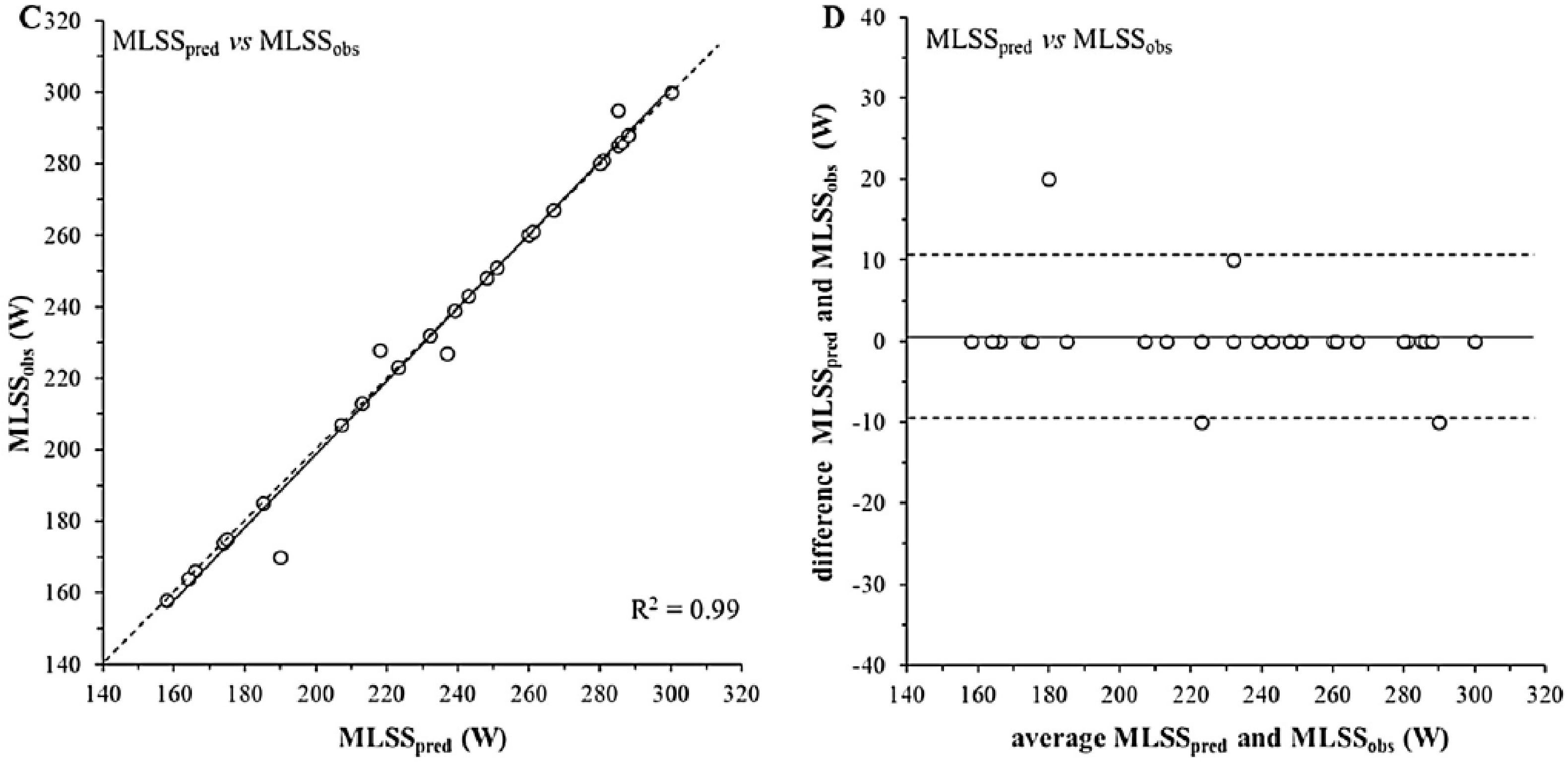


# Constant PO from ramp Incremental exercise - Limitations



# Constant PO from ramp Incremental exercise

## Solution #1: Using a prediction equation




- A prediction equation was developed from **60 participants** from which the **ramp incremental and MLSS test** had been performed.
- **The ability** of the equation **to predict** the PO associated with **MLSS** from a ramp incremental test was **evaluated in 29 participants**.

Iannetta et al., J Sci Med Sport; 21 (12): 1274-1280, 2018

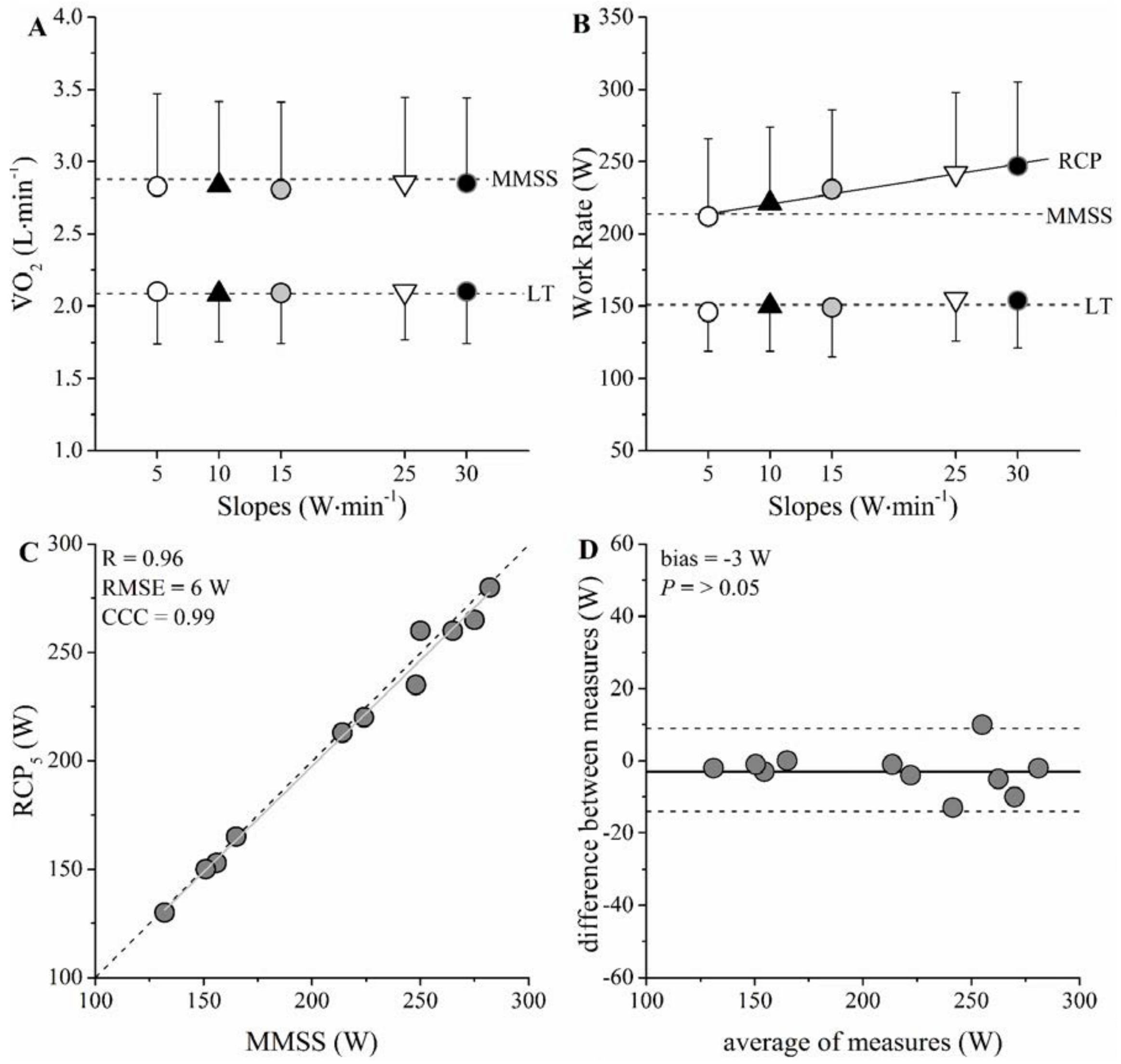
# Constant PO from ramp Incremental exercise
# Solution #2: Using slow ramps

| Ramp-slope (W·min-1) | 5 | 10 | 15 | 25 | 30 |
|---|---|---|---|---|---|
| Peak Work Rate (W) | 262±55 | 291±59* | 310±63*† | 340±66*†‡ | 353±69*†‡§ |
| $VO_{2max}$ ($L \cdot min^{-1}$) | 3.35±0.68 | 3.44±0.67 | 3.44±0.69 | 3.44±0.74 | 3.44±0.72 |
| LT ($L \cdot min^{-1}$) | 2.10±0.36 | 2.08±0.33 | 2.09±0.35 | 2.10±0.33 | 2.10±0.36 |
| LT (W) | 146±27 | 150±31 | 149±34 | 155±29 | 152±33 |
| RCP ($L \cdot min^{-1}$) | 2.83±0.65 | 2.84±0.59 | 2.82±0.61 | 2.86±0.60 | 2.86±0.61 |
| RCP (W) | 212±54 | 221±53* | 231±55*† | 242±56*†‡ | 247±58*†‡§ |

Iannetta et al., Med Sci Sports Exerc (under review)

# Constant PO from ramp Incremental exercise

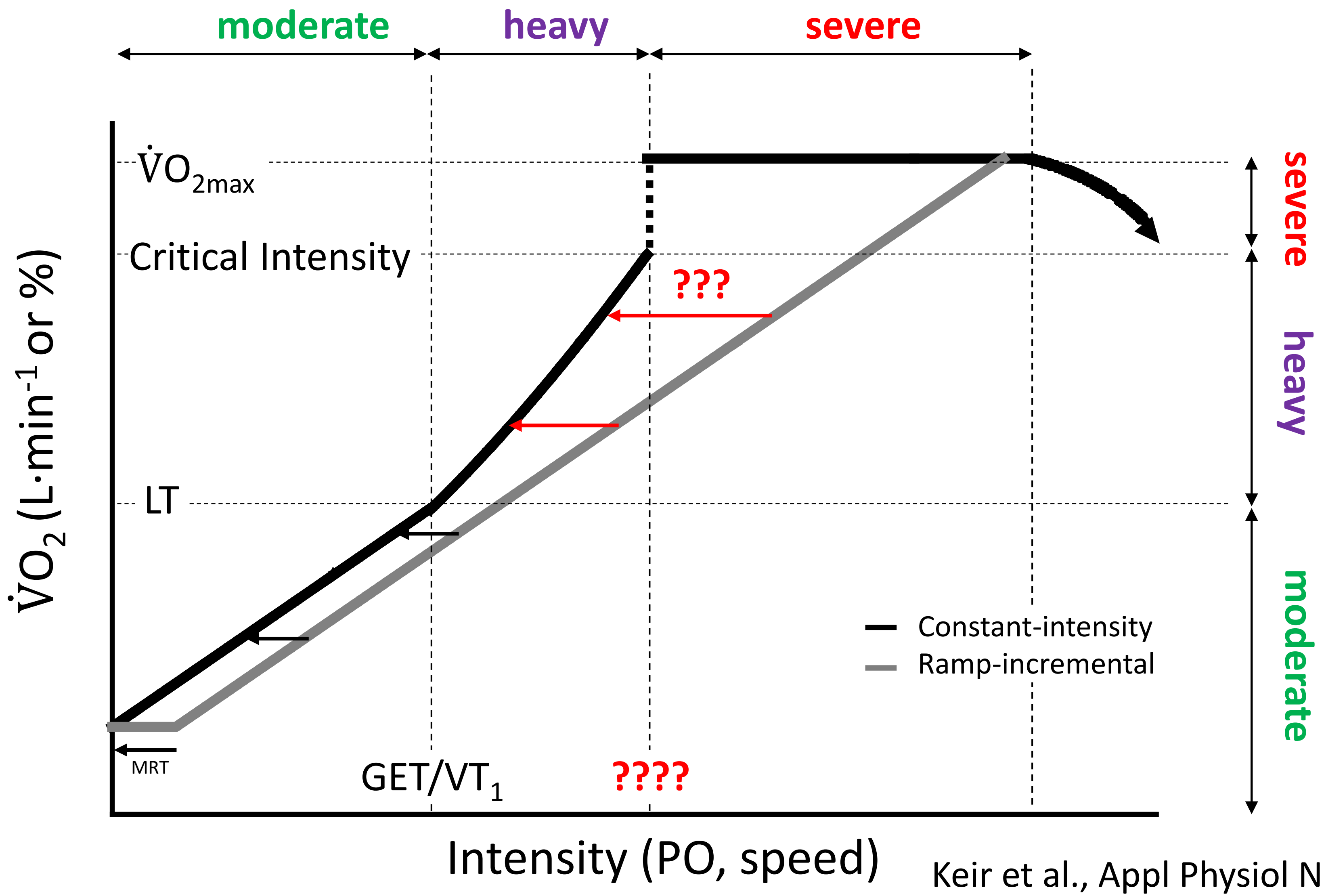
## Solution #2: Using slow ramps




Iannetta et al., Med Sci Sports Exerc (under review)

# Constant PO from ramp Incremental exercise

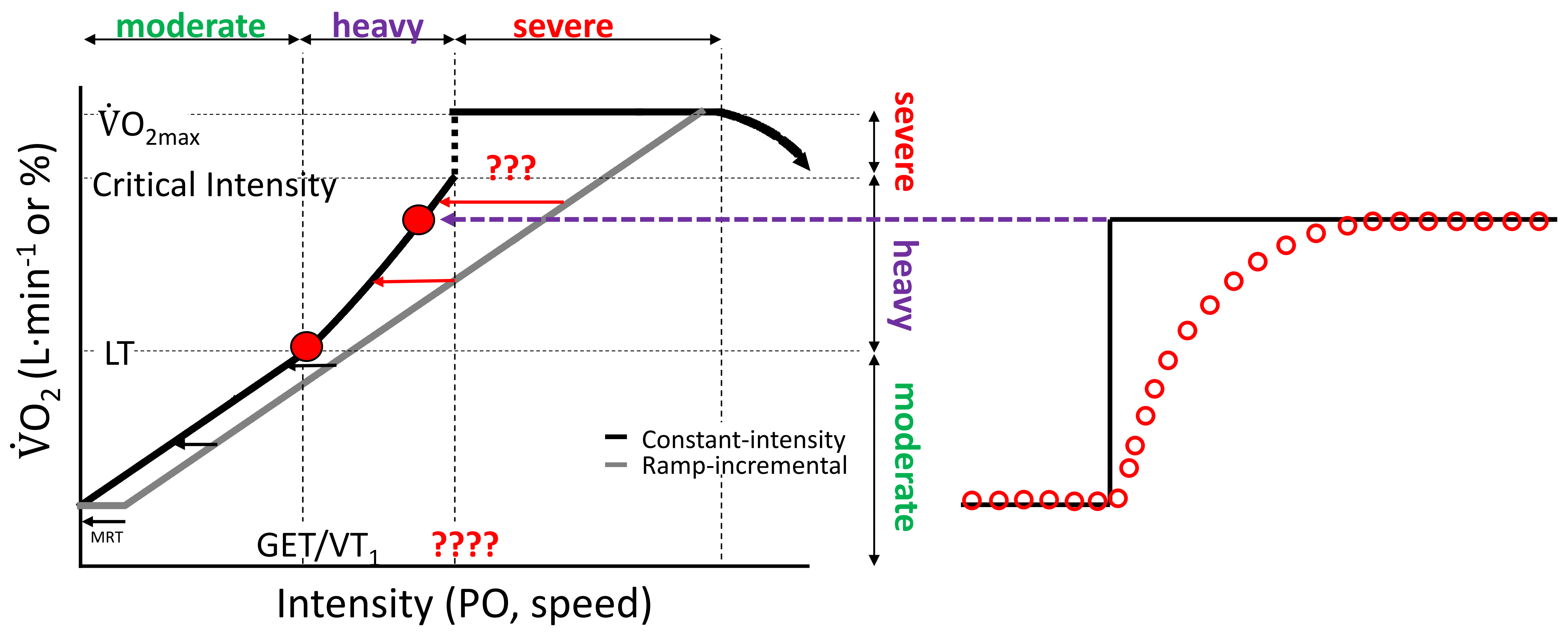
## Solution #3: Interpolating constant load work rate from RI test




Keir et al., Appl Physiol Nutr and Metab, 43(9): 882-892, 2018

# Constant PO from ramp Incremental exercise

## Solution #3: Interpolating constant load work rate from RI test




Keir et al., Appl Physiol Nutr and Metab, 43(9): 882-892, 2018

**We need to find ways of identifying constant-load work rates associated with the exercise intensity domains model**

**No matter what approach is used (i.e., MLSS, CP, or ramp incremental tests), the identified power output needs to be verified**

# Concluding remarks

- We need to find ways of putting people into the right exercise intensity domains when prescribing exercise.
- From a practical/translational perspective, I think we are far from doing a solid work.
- From a research perspective, we have the tools that we need to do a good job. Thus, putting people within the right exercise intensity domains is a decision.
- If we do not know what intensity we are prescribing, then we might be better off by using HIIT or SIT.

# Acknowledgments

- Colleagues
- Students
- Collaborators
- Participants in our studies

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