Aerobic exercise training after a cardiac event

Daniel Keir, PhD, CEP

Associate Professor, University of Western Ontario, London, Ontario, Canada

dkeir@uwo.ca

Western HealthSciences

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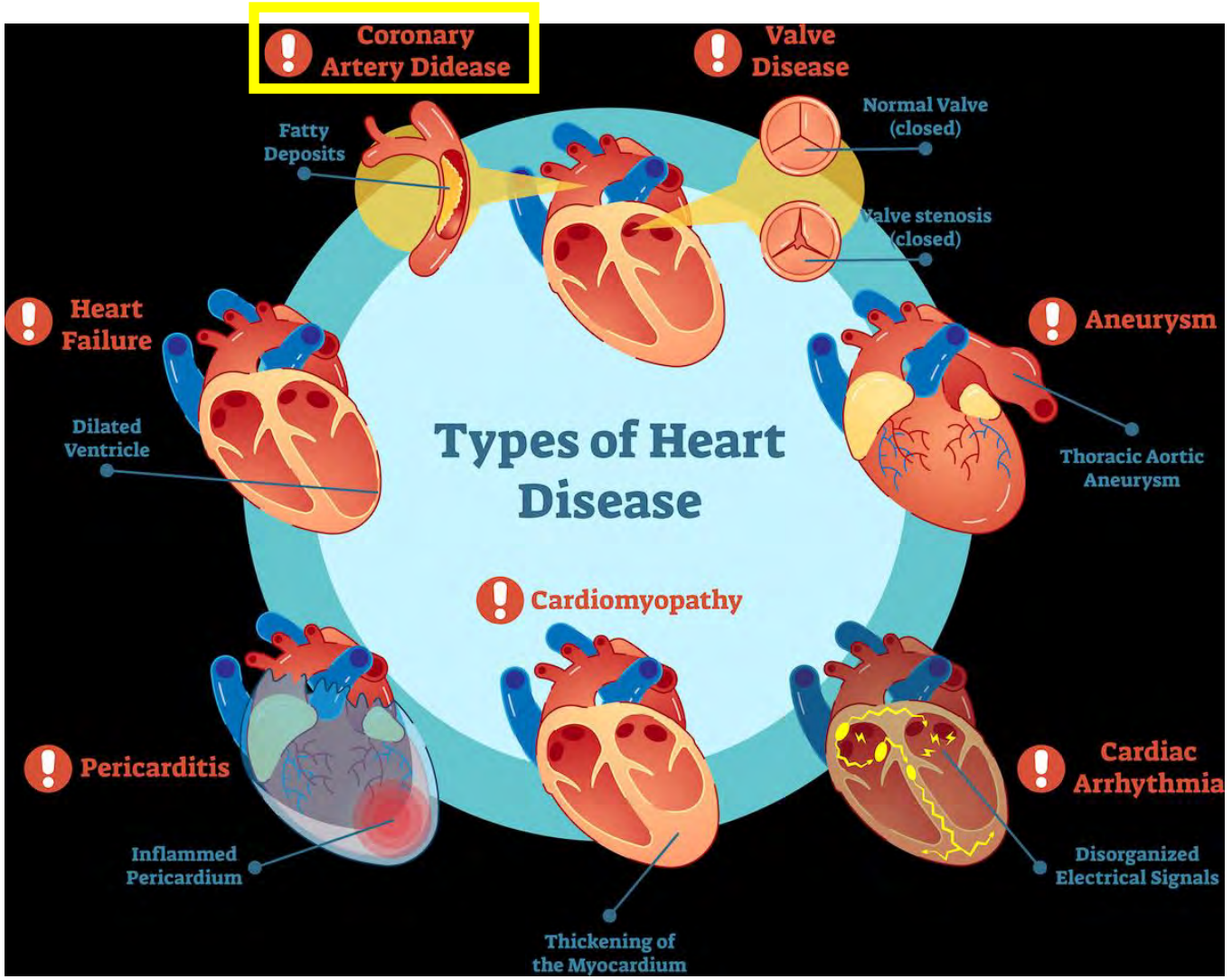
St Joseph's Health Care London

Objectives

- Discuss the value and safety of exercise training interventions after a cardiac event
- Provide an update on the effectiveness of current programs and guidelines
- Showcase new approaches that we are using to optimize aerobic exercise training in these populations

Heart Disease

Any condition that affects the structure or function of the heart



HEART DISEASE *in* CANADA

It is the 2nd leading cause of death *among Canadians*

Also known as ***ischemic heart disease*** **or** ***coronary heart disease***, ***heart disease*** refers to the buildup of plaque in the heart's arteries that could lead to a heart attack, heart failure, or death.

According to **2012/13** data from the Public Health Agency of Canada's *Canadian Chronic Disease Surveillance System (CCDSS):*

ABOUT 1 *in* 12

(or ***2.4 million***) Canadian adults age 20+ live with diagnosed **heart disease**

EVERY HOUR

12 Canadian adults age 20+ with diagnosed **heart disease** die

DEATH RATE *is*

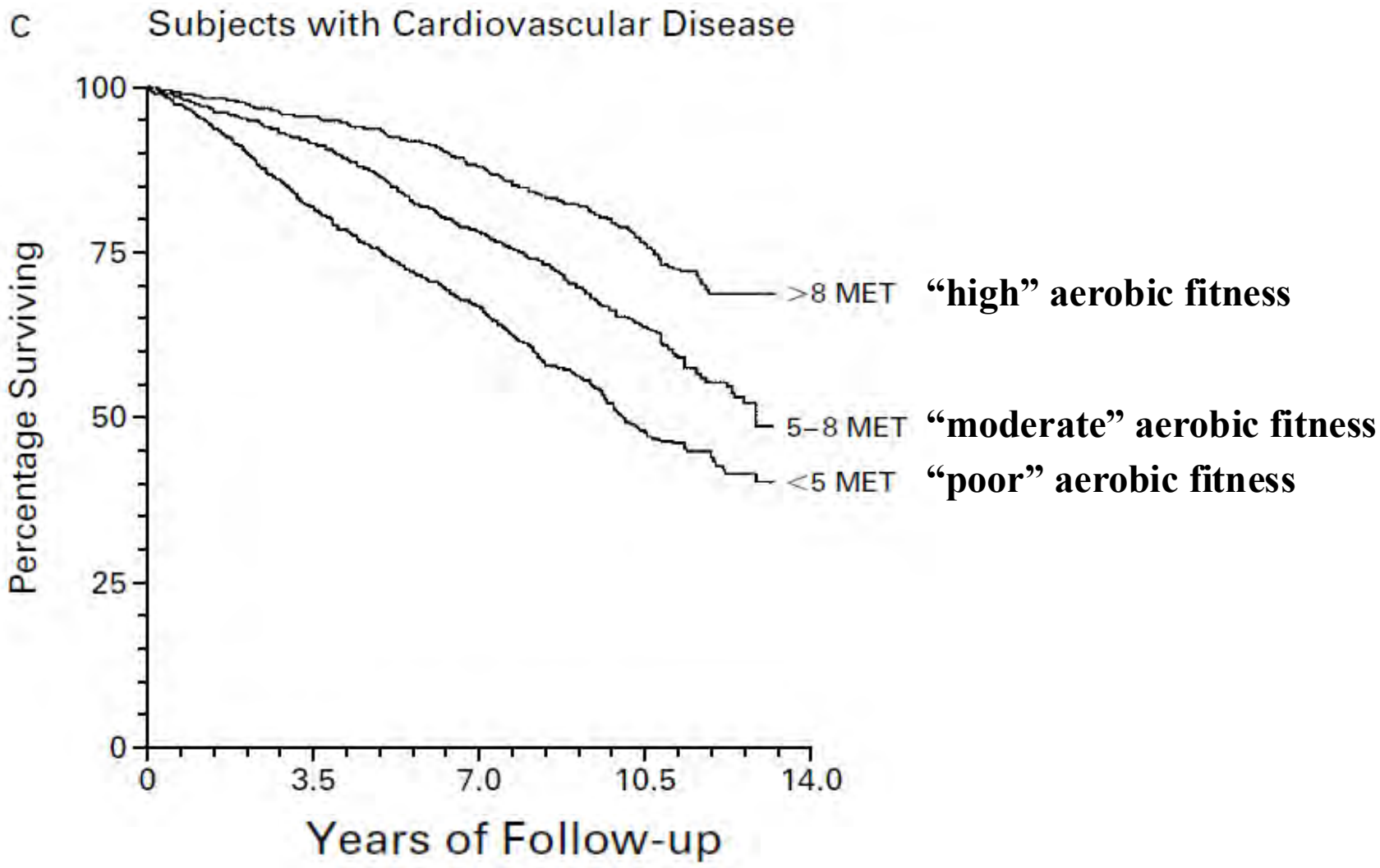
3x ***higher*** among **adults age 20+** with diagnosed **heart disease** vs those without

4x ***higher*** among adults age 20+ who had a **heart attack** vs those without

6x ***higher*** among adults age 40+ with diagnosed **heart failure** vs those without

Aerobic Fitness & Outcomes in Heart Disease

Higher aerobic fitness reduces risk of death



“high” aerobic fitness

“moderate” aerobic fitness

“poor” aerobic fitness

Myers et al. (2002) *NEJM* 4346:793-801

Recommendations for Aerobic Exercise in Heart Disease Management

Canadian Journal of Cardiology 30 (2014) 249–263

Society Guidelines

The 2013 Canadian Cardiovascular Society Heart Failure Management Guidelines Update: Focus on Rehabilitation and Exercise and Surgical Coronary Revascularization

Rehabilitation and Exercise in HF

Exercise training in patients with HF

RECOMMENDATION

1. We recommend that all patients with stable New York Heart Association (NYHA) class I-III symptoms be considered for enrollment in a supervised tailored exercise training program, to improve exercise tolerance and quality of life (Strong Recommendation, Moderate-Quality Evidence).

"Given the significant benefits that cardiac rehabilitation (CR) programs bring to CV disease prevention, every recent major evidence-based guideline from [international cardiology societies] ….. about the management and prevention of chronic heart disease provides a Class I–level recommendation for referral to a CR for those patients with recent MI or acute coronary syndrome, chronic stable angina, heart failure, or after coronary artery bypass surgery or percutaneous coronary intervention."

Balady et al. (2011) Circulation 124;2951-60

Exercise Training Heart Disease Patients: Is it Safe?

Aerobic Ex Indicated for Clinically "Stable" Patients

- Optimal drug and device therapy
- Controlled angina
- Controlled arrhythmia (device)
- Mentally and physically capable of exercise

TABLE 2. Summary of Contemporary Exercise-Based Cardiac Rehabilitation Program Complication Rates

Investigator	Year	Patient-Exercise Hours	Cardiac Arrest	MI	Fatal Events	Major Complications*
Van Camp and Peterson[35]	1980–1984	2 351 916	1/111 996†	1/293 990	1/783 972	1/81 101
Digenio et al[36]	1982–1988	480 000	1/120 000‡	1/160 000	1/120 000	
Vongvanich et al[38]	1986–1995	268 503	1/89 501§	1/268 503§	0/268 503	1/67 126
Franklin et al[37]	1982–1998	292 254	1/146 127§	1/97 418§	0/292 254	1/58 451
Average		1/116 906	1/219 970	1/752 365	1/81 670	

Thompson et al. (2007) *Circulation* 115(17):2358-68

Table 1. The Number of Patients, Exercise-Hours, and the Corresponding Number of Cardiovascular Events Associated With Moderate- and High-Intensity Exercise, Respectively

Center	Patients, n	Total Training, h	Moderate Intensity, h	High Intensity, h
Ålesund	775	25 720 (1)	15 232	10 488 (1)
Feiring	2629	85 208 (2)	63 032 (1)	22 176 (1)
Røros	1442	64 892	51 192	13 700
Total	4846	175 820	129 456	46 364
Event rates				
Cardiac arrest, fatal			1	0
Cardiac arrest, nonfatal			0	2
Myocardial infarction			0	0
Risk of events		1/58 607	1/129 456	1/23 182

The numbers in parentheses indicate the number of events in each center according to intensity.

Rognmo et al. (2012) *Circulation* 126(16):1436-40

Is exercise safe?

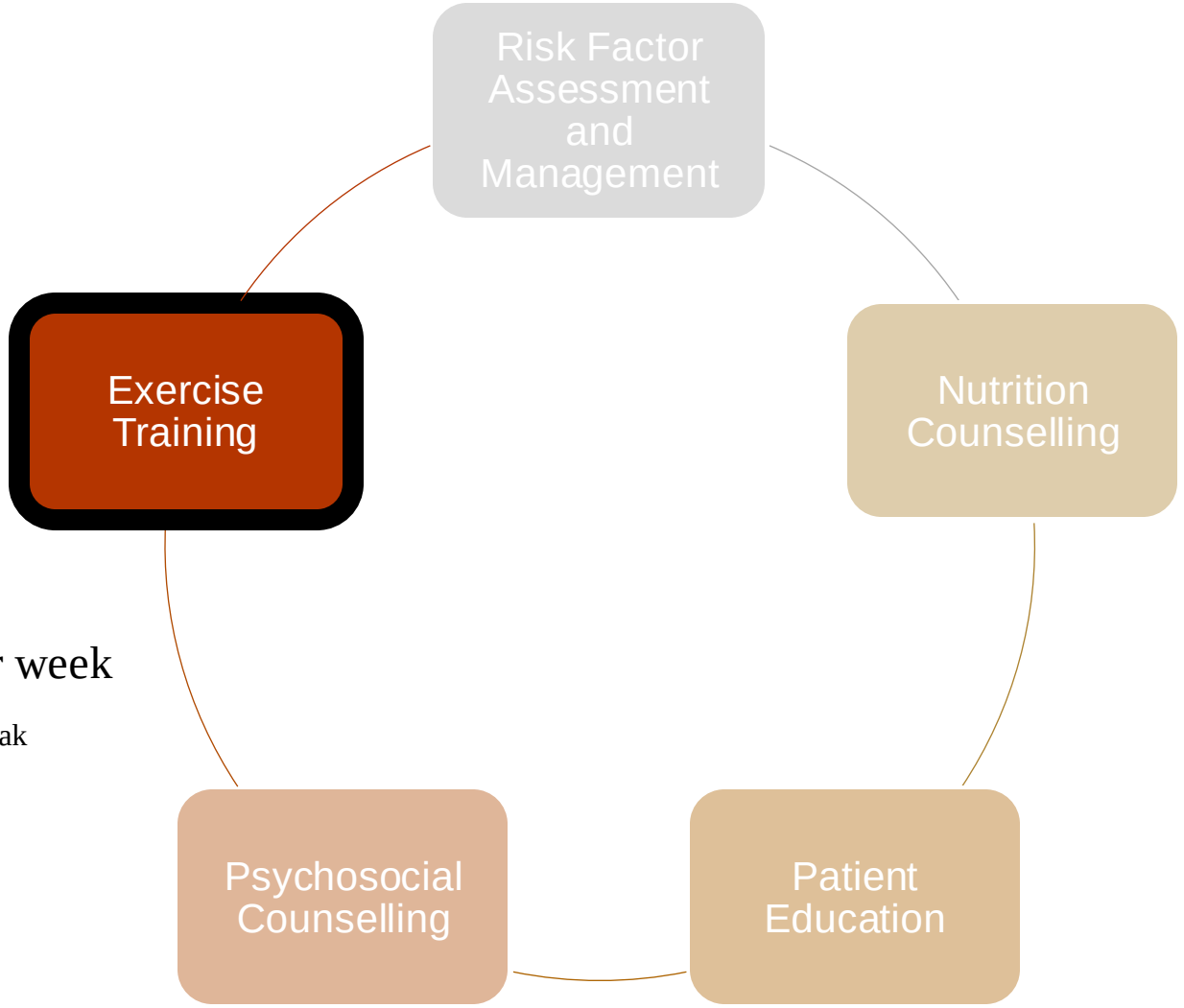
Table 1. Estimated Annual Incidence Rates of Exertion- or Sports-Related SCD According to Population Subgroups

Study Population	Estimated Annual Incidence Rates of Exertion-Associated SCD*
Overall	0.31–2.1[49,50,51,75]
Age	
<35 y of age	0.3[49]
>35 y	3.0[49]
Athletes	
Competitive	0.4–0.9[51,55,57]
Noncompetitive	0.2[51]
Sex	
Women	0.04–0.3[49,76]
Men	0.5–5.5[49,76]

SCD indicates sudden cardiac death.

*Rates are reported per 100 000 individuals. For comparison, annual incidence rates of SCD not related to exertion are estimated to be 43 to 55 per 100 000 individuals.[50,75]

Cardiac Rehabilitation

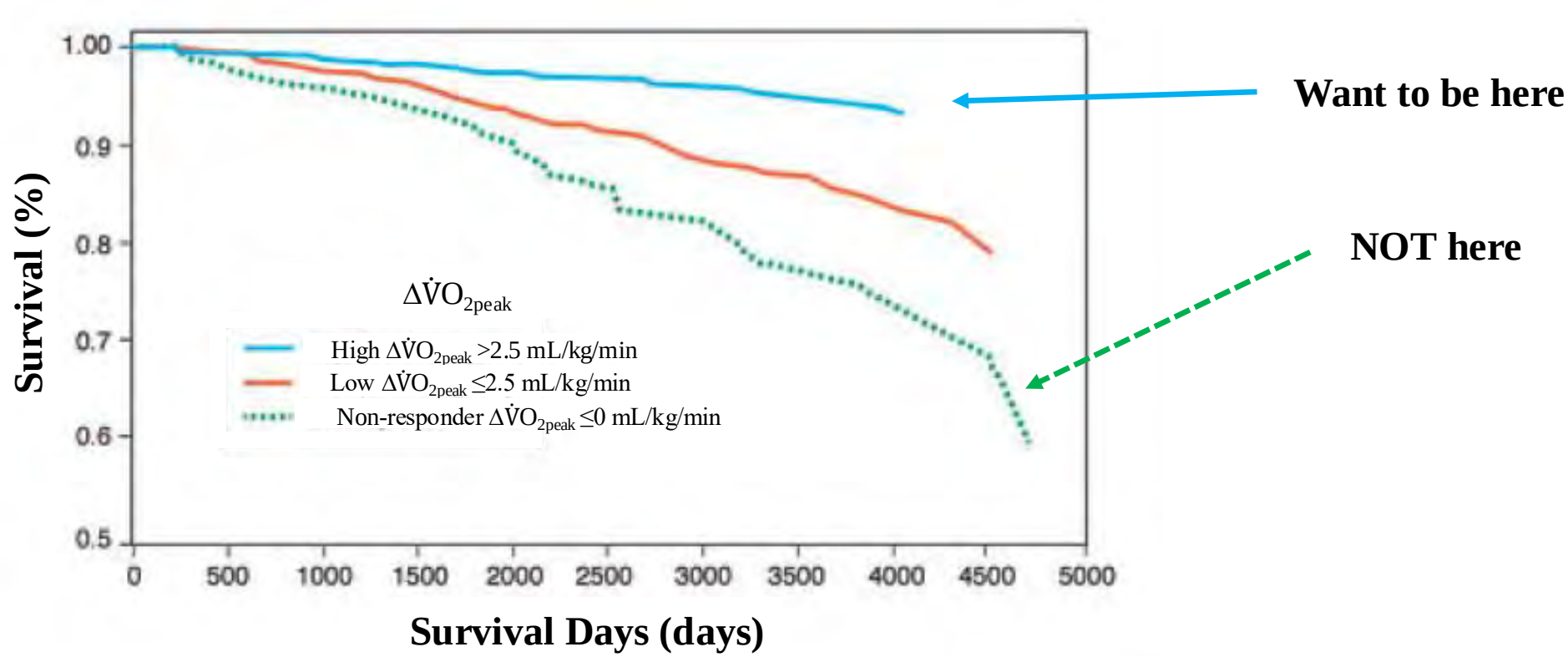


F = 2 supervised sessions per week
I = 40-80%$\dot{V}O_{2peak}$ or %HR_{peak}
T = 20-40 min
T = aerobic

Duration = 6 months

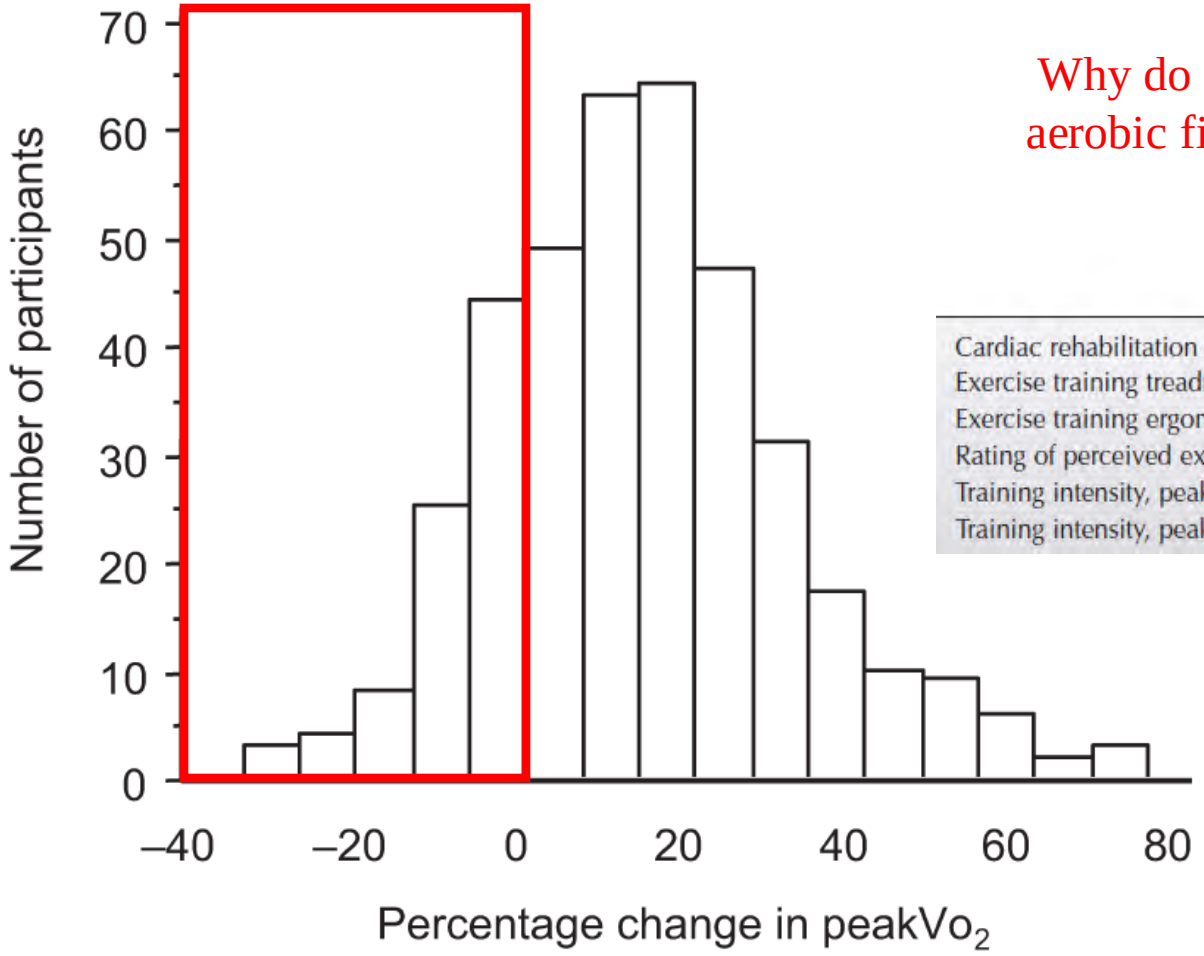
Training-induced $\Delta\dot{V}O_{2peak}$ and mortality

Greater improvement in aerobic fitness post-CR reduces risk of death



De Schutter et al. (2018) Eur H J 4;173-79

Individual training-induced $\Delta\dot{V}O_{2peak}$ in CR



Why do so many (~¼) fail to improve aerobic fitness after months of exercise training?

	Nonimprovers (n = 81)	Improvers (n = 304)
Cardiac rehabilitation sessions attended	24.5 ± 10	23.8 ± 8.9
Exercise training treadmill time, min	29.6 ± 5.7	31.0 ± 7.0
Exercise training ergometer time, min	24.2 ± 7.5	24.2 ± 7.6
Rating of perceived exertion	12.6 ± .8	12.8 ± .8
Training intensity, peak oxygen uptake, %	72.7 ± 10.9	79.2 ± 12.5
Training intensity, peak heart rate, %	79.0 ± 10.6	82.9 ± 10.4

Savage et al. (2009) JCRP 29:284-91
Ross et al. (2015) Mayo Clin Proc 90(11):1506-14
De Schutter et al. (2018) Eur H J 4;173-79

Exercise prescription based on %$\dot{V}O_{2peak}$

EAPC
European Association
of Preventive Cardiology
European Society of Cardiology

Intensity	VO_2max (%)	HRmax (%)
Low intensity, light exercise[a]	<40	<55
Moderate intensity exercise[a]	40–69	55–74
High intensity[a]	70–85	75–90
Very high intense exercise[a]	>85	>90

moderate

Rapid achievement of $\dot{V}O_2$ steady-state
- ✓ No metabolic acidosis
- ✓ No disruption to homeostasis
- ✓ "comfortably sustainable"

heavy

Delayed achievement of $\dot{V}O_2$ steady-state
- ✓ Slight metabolic acidosis
- ✓ Homeostasis challenged but maintained
- ✓ "uncomfortably sustainable"

severe

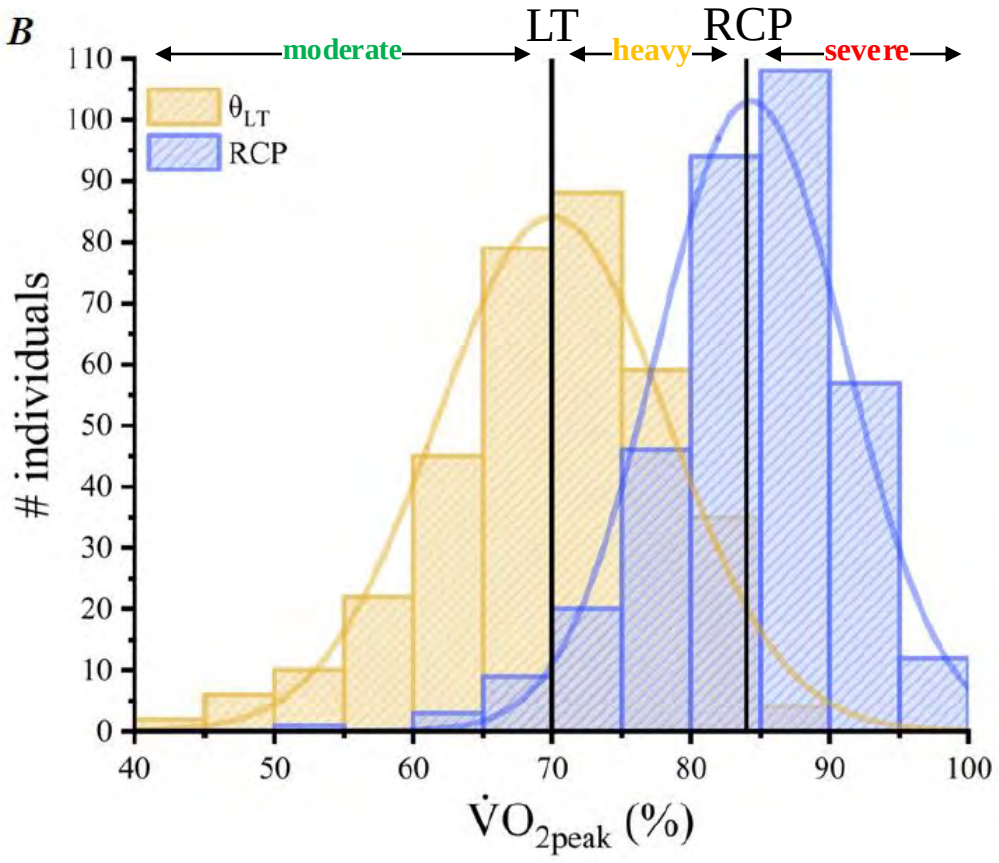
No achievement of $\dot{V}O_2$ steady-state
- ✓ Worsening metabolic acidosis
- ✓ Homeostasis lost
- ✓ "uncomfortably unsustainable"

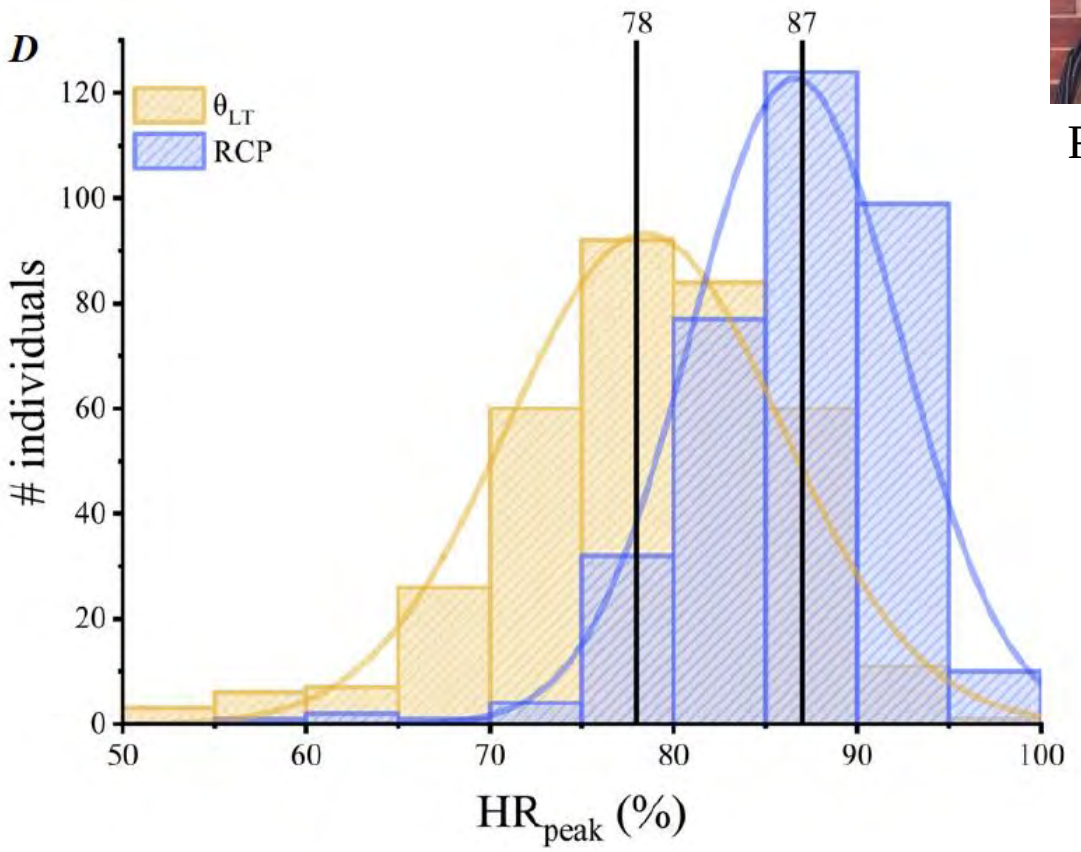
moderate-heavy boundary = **70%$\dot{V}O_{2max}$** (**75%HR_{max}**)

heavy-severe boundary = **85%$\dot{V}O_{2max}$** (**90%HR_{max}**)

Variability of Domain Boundaries in CR

n=350, 43 F; 25-89 yrs





Randi Keltz

St JOSEPH's HEALTH CARE LONDON

Keltz et al. *Can J Cardiol* 2023;39(11):1701-11

Guidelines vs domains in CR patients

Intensity	VO_2max (%)	HRmax (%)
Low intensity, light exercise[a]	<40	<55
Moderate intensity exercise[a]	40–69	55–74
High intensity[a]	70–85	75–90
Very high intense exercise[a]	>85	>90

EAPC
European Association of Preventive Cardiology
European Society of Cardiology

A

Intensity	$\dot{V}O_{2peak}$ Range (%)	$\%\dot{V}O_{2peak}$ Distribution
Low	<40	
Moderate	40–69	
High	70–85	
Very High	>85	

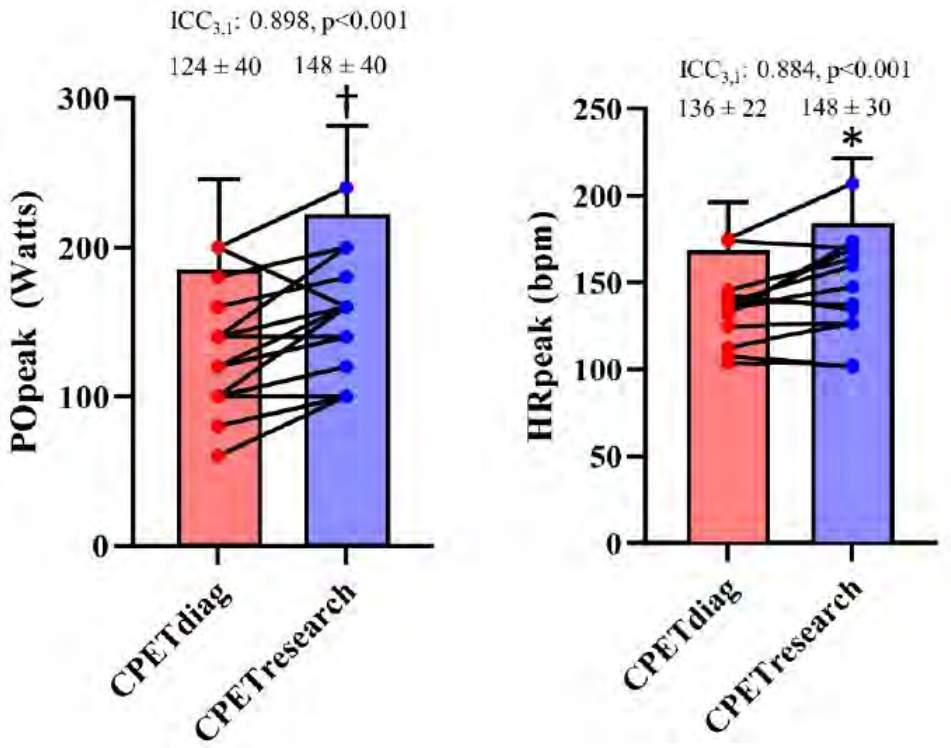
B

Intensity	HR_{peak} Range (%)	$\%HR_{peak}$ Distribution
Low	<55	
Moderate	55–74	
High	75–90	
Very High	>90	

Keltz et al. *Can J Cardiol* 2023;39(11):1701-11

The other problem with %$\dot{V}O_{2peak}$…

What if $\dot{V}O_{2peak} \neq \dot{V}O_{2max}$?



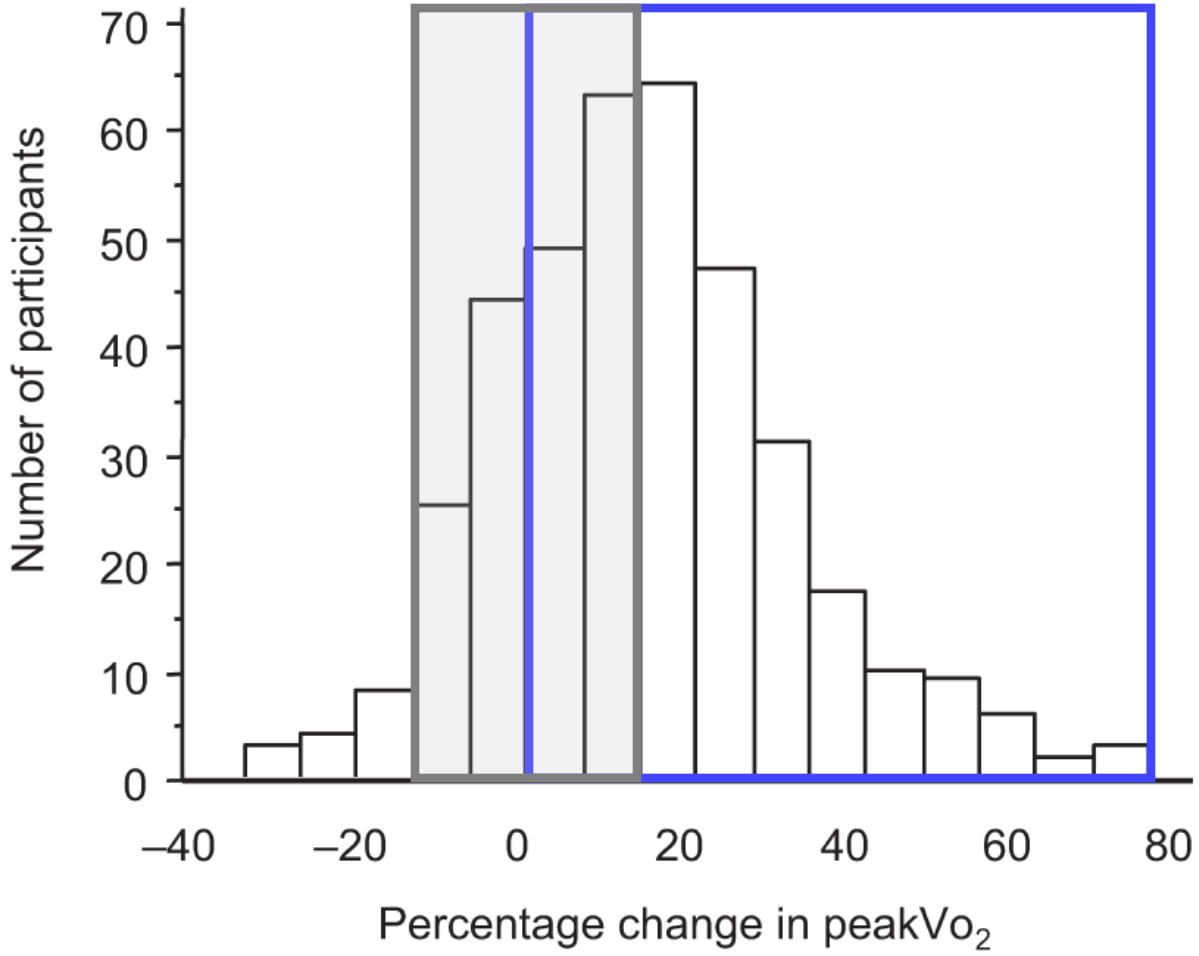
Terada et al. *APNM* 2024;54(12):2993-3003

In many cases, $\dot{V}O_{2peak}$ is submaximal

If $\dot{V}O_{2peak}$ is 70% of $\dot{V}O_{2max}$ and training target is 50%$\dot{V}O_{2peak}$; actual training intensity is **35%$\dot{V}O_{2max}$**!

Quantifying individual improvement

How do we measure real change in $\Delta\dot{V}O_{2peak}$?



Do ¾ of patients actually improve?

How do we define reliable change?

Practice Exposure
Biological Variability
Measurement Errors

Savage et al. (2009) JCRP 29:284-91
Ross et al. (2015) Mayo Clin Proc 90(11):1506-14
De Schutter et al. (2018) Eur H J 4;173-79

Quantifying individual improvement

How do we measure real change in $\Delta\dot{V}O_{2peak}$?

Robin Faricier

Coronary Artery Disease

Reasons for patient referral:

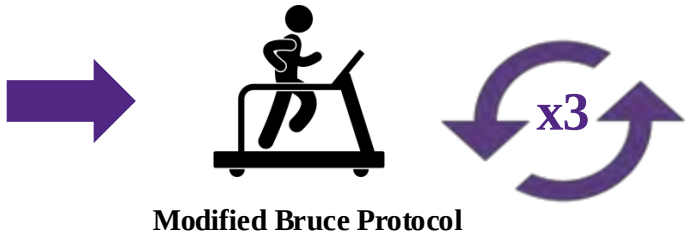
- **MI - Myocardial Infarction (n=33)**
- CABG - Coronary Artery Bypass Graph (n=14)
- PCI - Percutaneous Intervention (n=13)
- ACS - Acute Coronary Syndrome (n=6)

n = 66

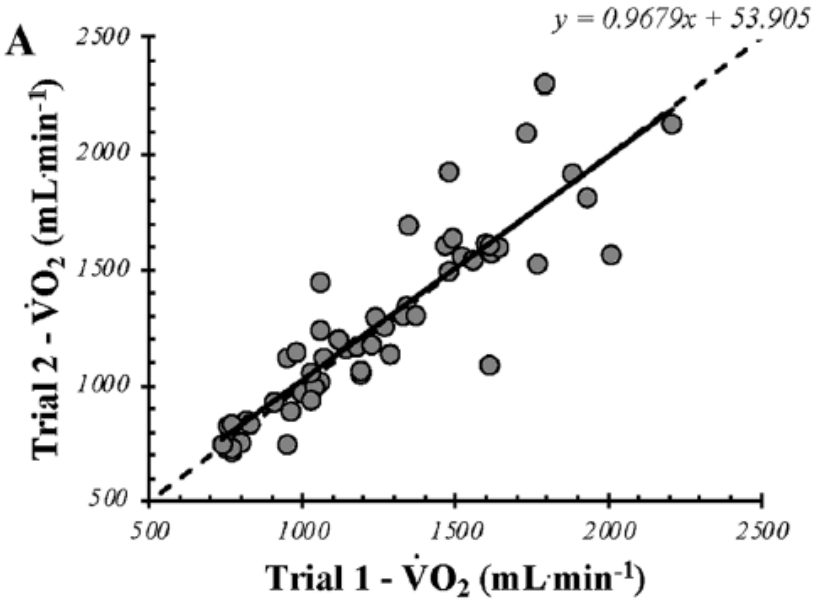
♀ 19 | 47 ♂

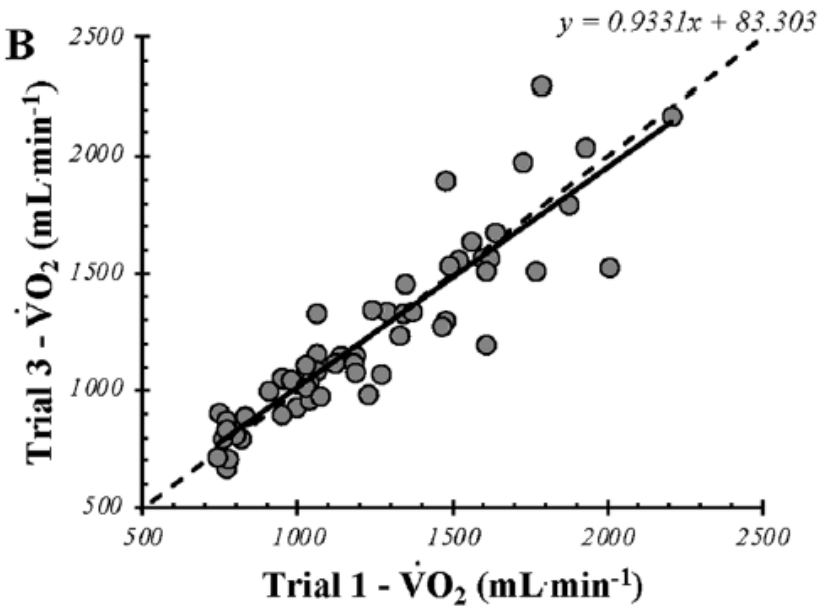
Left Ventricular Ejection Fraction:

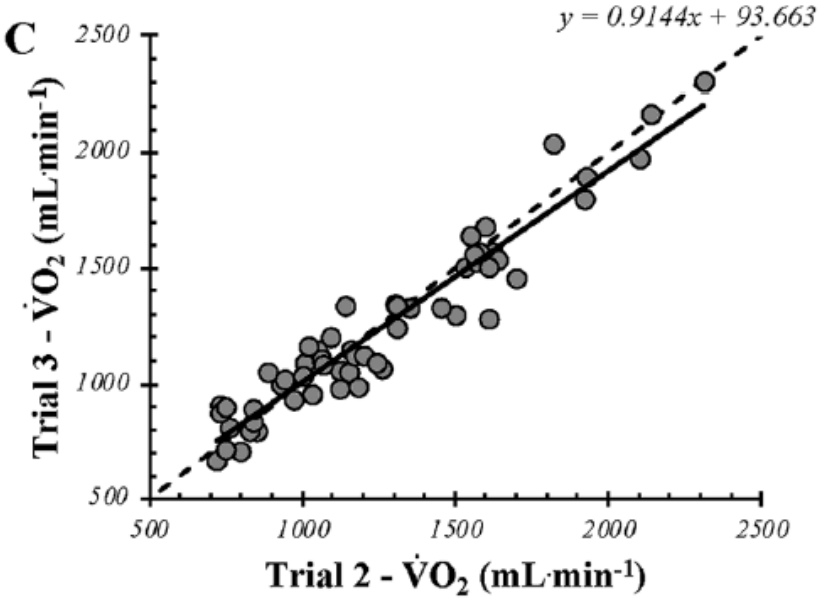
- **"Normal" (>50%) (n=47)**
- "Mild Dysfunction" (41-47%) (n=14)
- "Moderate Dysfunction" (<40%) (n=2)
- Not Obtained (n=3)



Modified Bruce Protocol

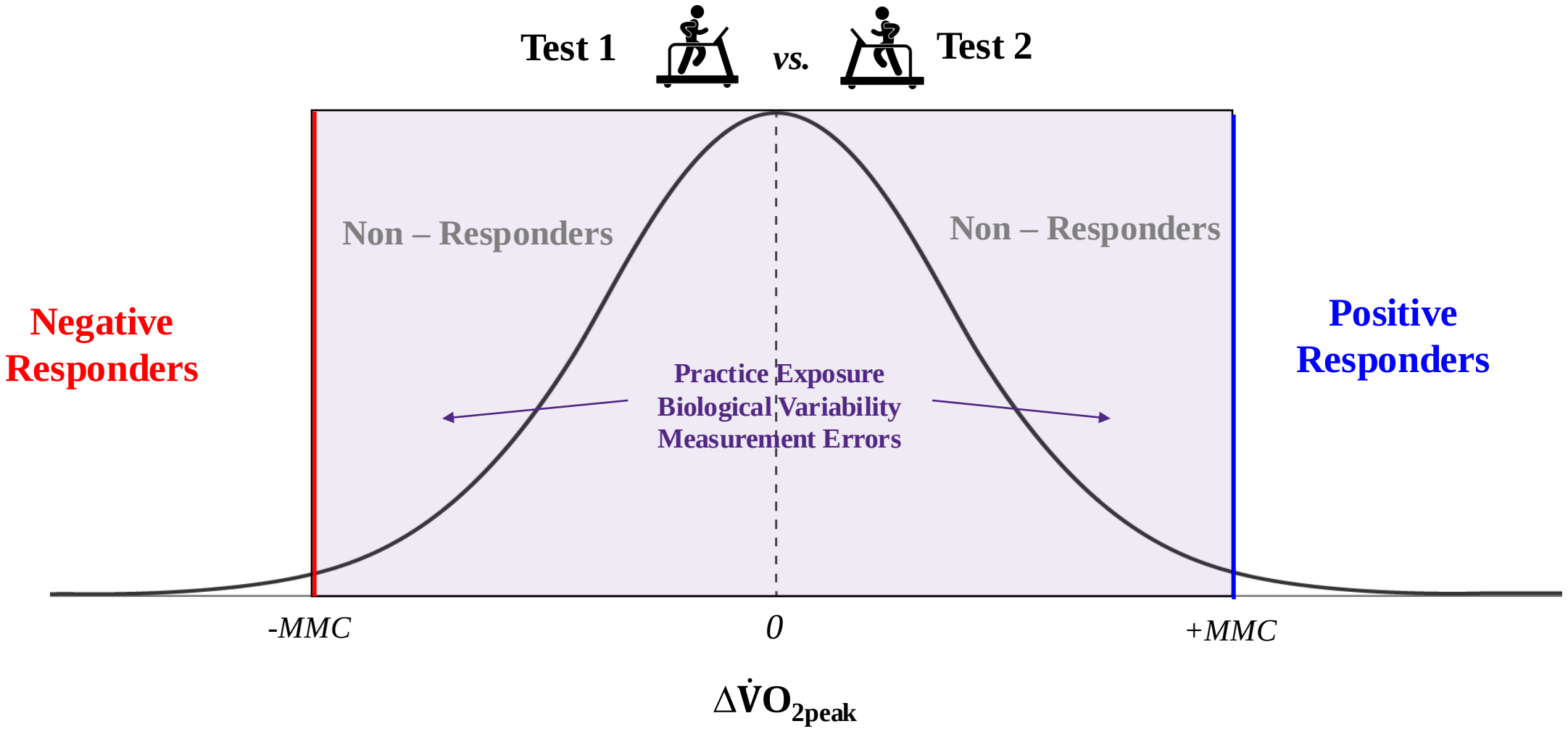






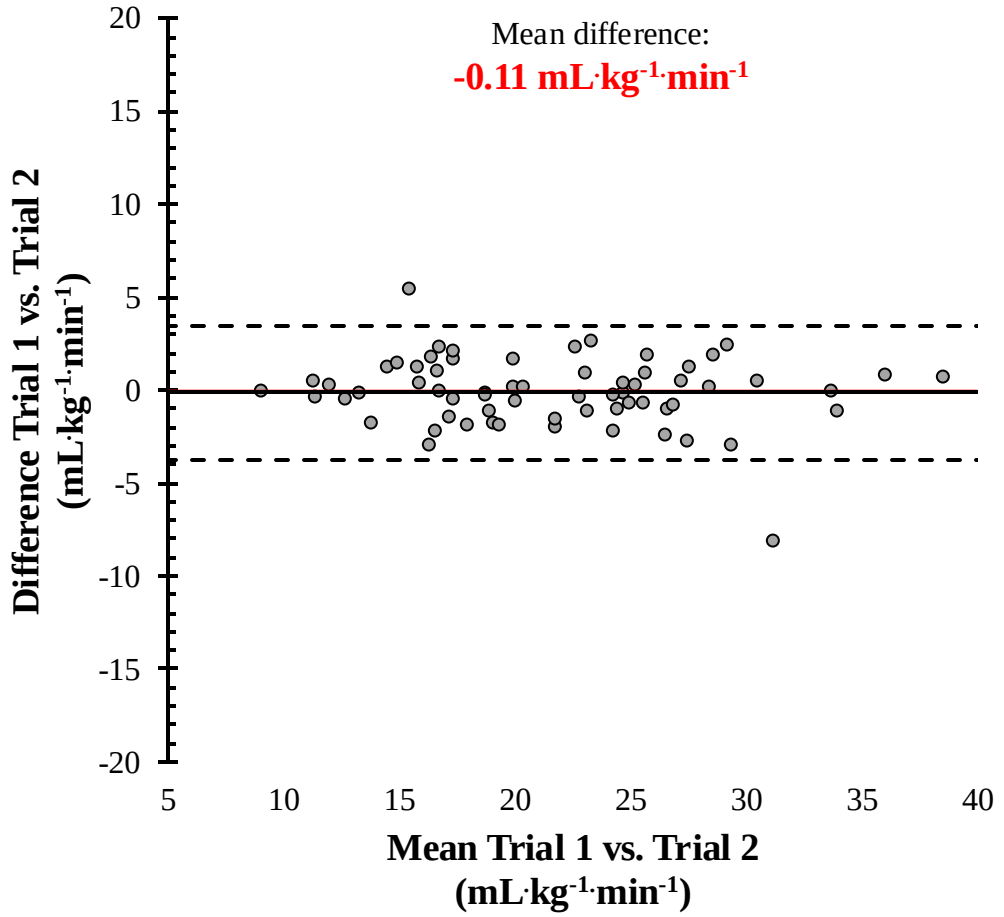
Faricier et al. *JCRP* 2024;44:121-30

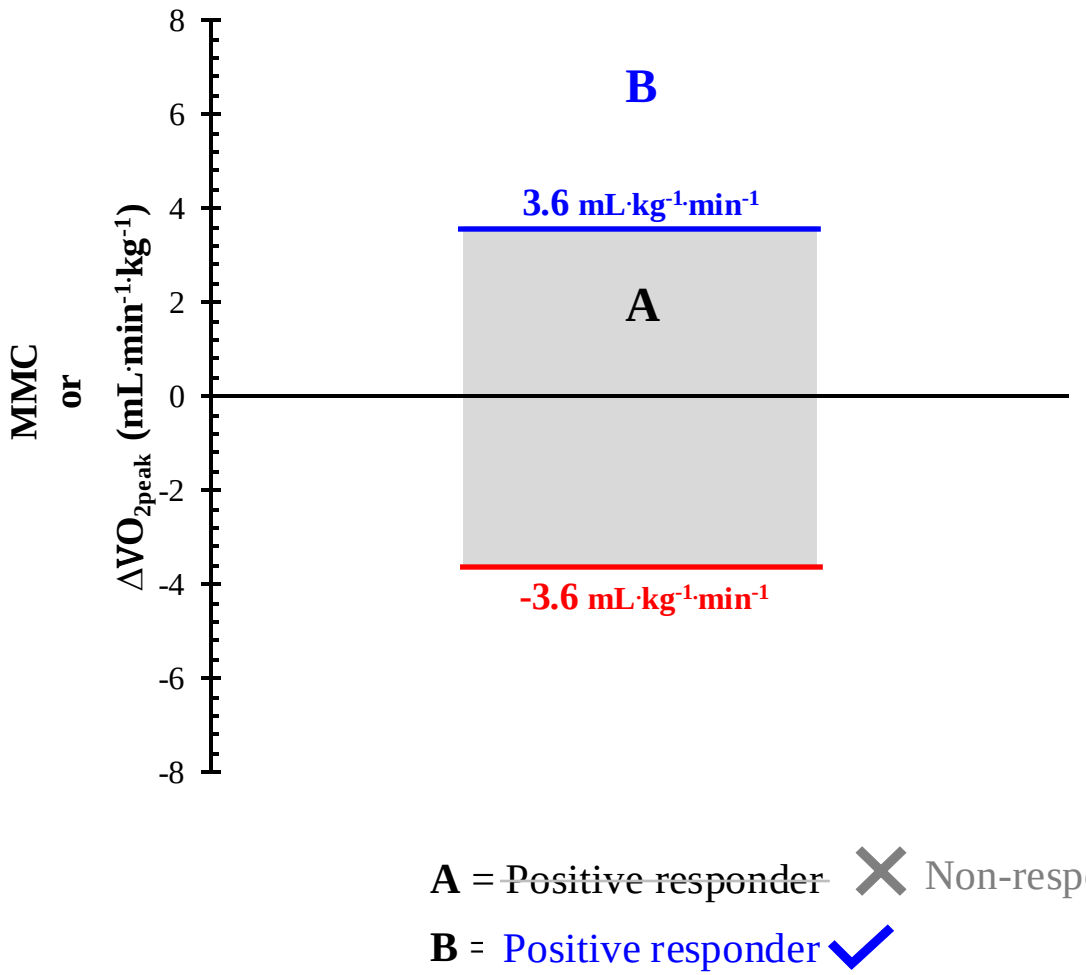
Determining minimal meaningful change in $\dot{V}O_{2peak}$



Faricier et al. *JCRP* 2024;44(2):121-30

Reproducibility of $\dot{V}O_{2peak}$ in CR and MMC





A = ~~Positive responder~~ ✗ Non-responder

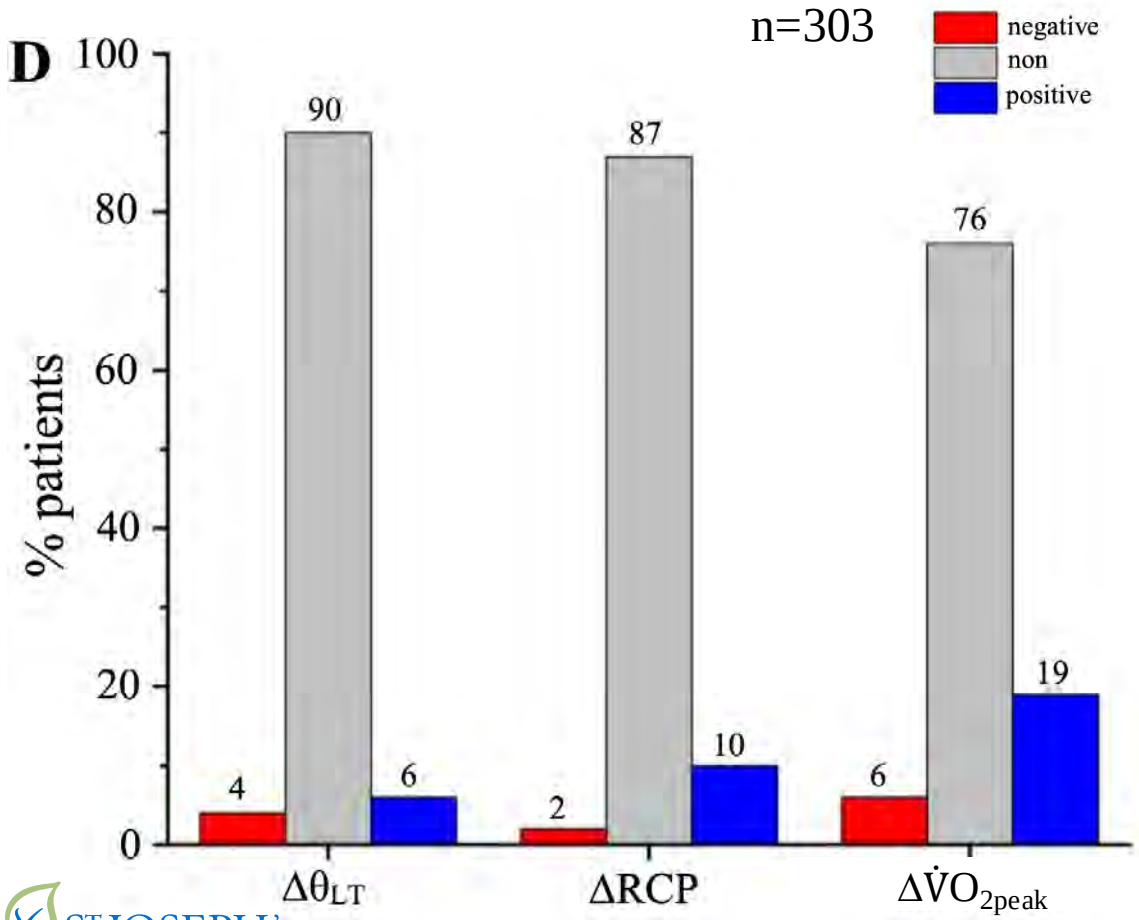
B = Positive responder ✓

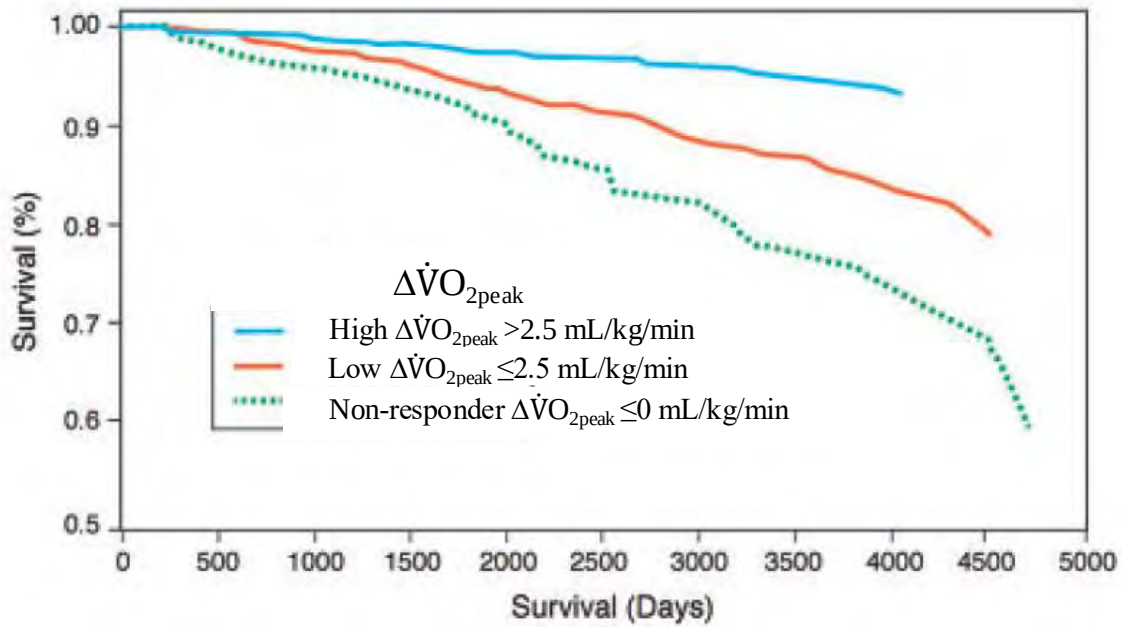
MMC *reduced* to **2.8 mL·kg^{-1}·min^{-1}** if familiarization included (i.e., Trial 2 v Trial 3)

Faricier et al. *JCRP* 2024;44(2):121-30

Changes in aerobic fitness at St. Joe's

Pre-to-post changes in $\dot{V}O_{2peak}$ and $\dot{V}O_2$ at LT and RCP following **6 months** of supervised exercise training in CR





St JOSEPH'S HEALTH CARE LONDON

Keltz et al. *Int J Cardiol* 2024;412:132335

De Schutter et al. *Eur Heart J* 2018;4:173-9

Can we do better?

Domain-based EX Rx in CR – is this new?

European Journal of Preventive Cardiology

EUROPEAN SOCIETY OF CARDIOLOGY®

Policy statement

European Journal of Preventive Cardiology
20(3) 442–467

DOI: 10.1177/2047487312460484
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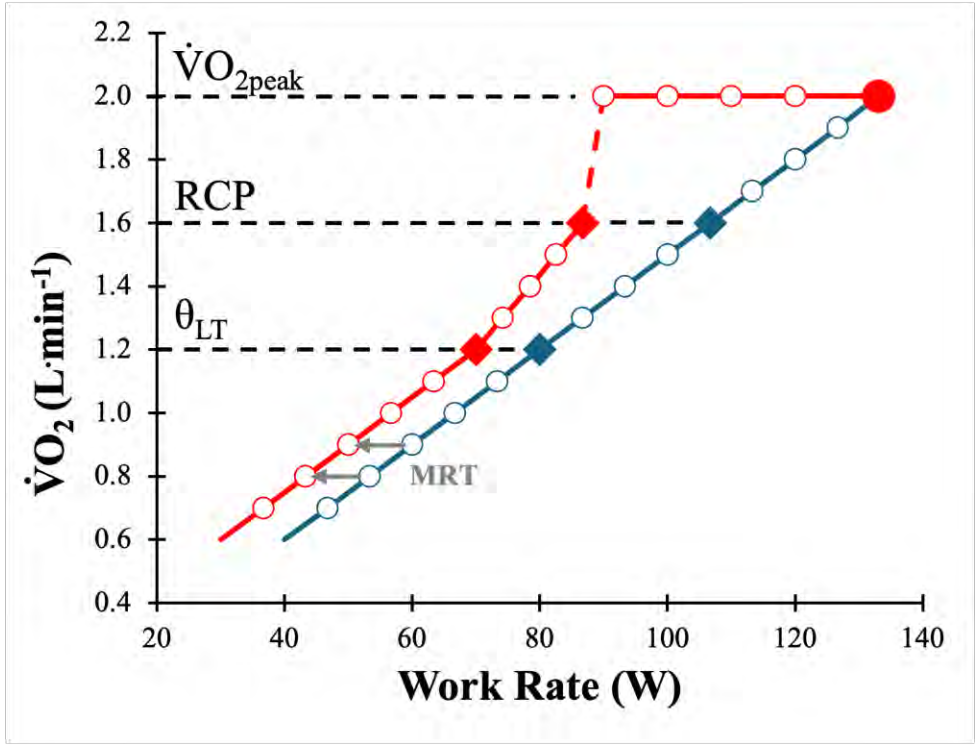
Aerobic exercise intensity assessment and prescription in cardiac rehabilitation: a joint position statement of the European Association for Cardiovascular Prevention and Rehabilitation, the American Association of Cardiovascular and Pulmonary Rehabilitation and the Canadian Association of Cardiac Rehabilitation

Alessandro Mezzani[1]*, Larry F Hamm[2]*, Andrew M Jones[3], Patrick E McBride[4], Trine Moholdt[5], James A Stone[6], Axel Urhausen[7] and Mark A Williams[8]

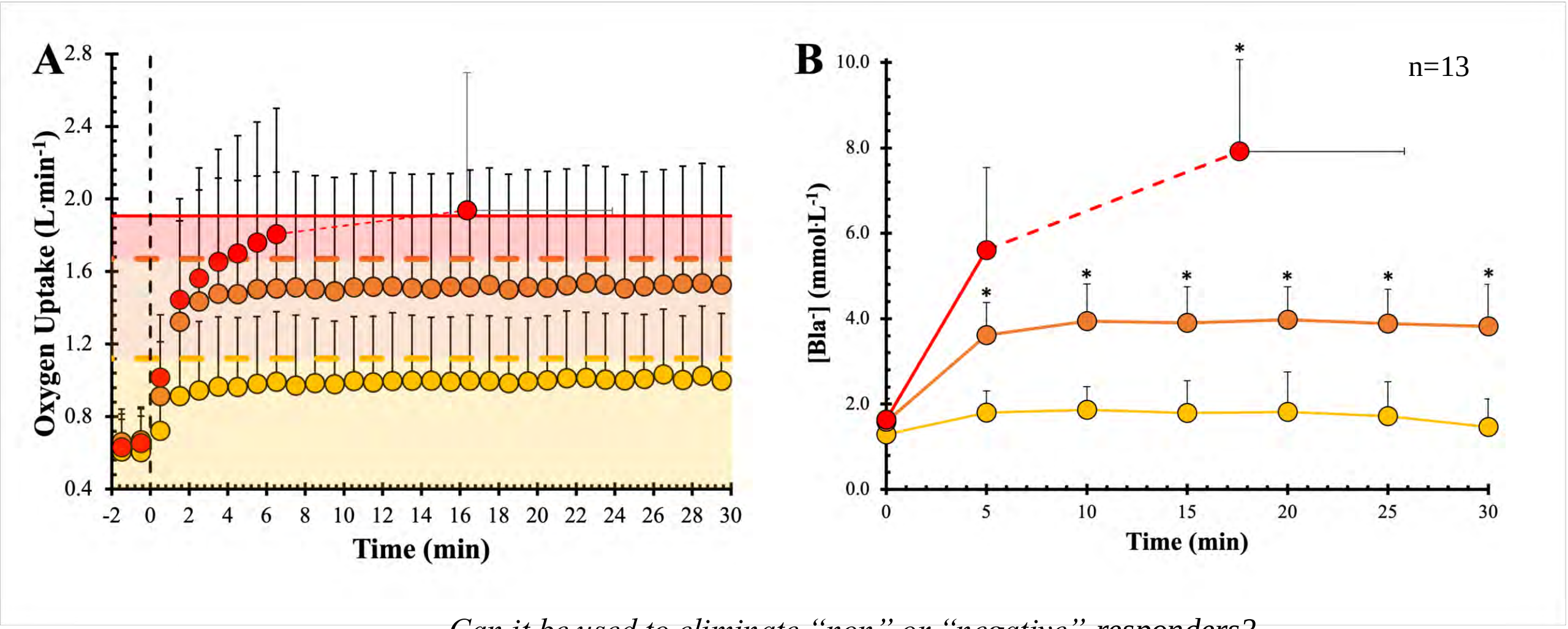
Incremental vs Constant Exercise



Faricier et al. (2025) *MSSE* 57(7):1593-02

Domains in CAD

✓ *Domain-based exercise prescription is feasible in patients with CAD*

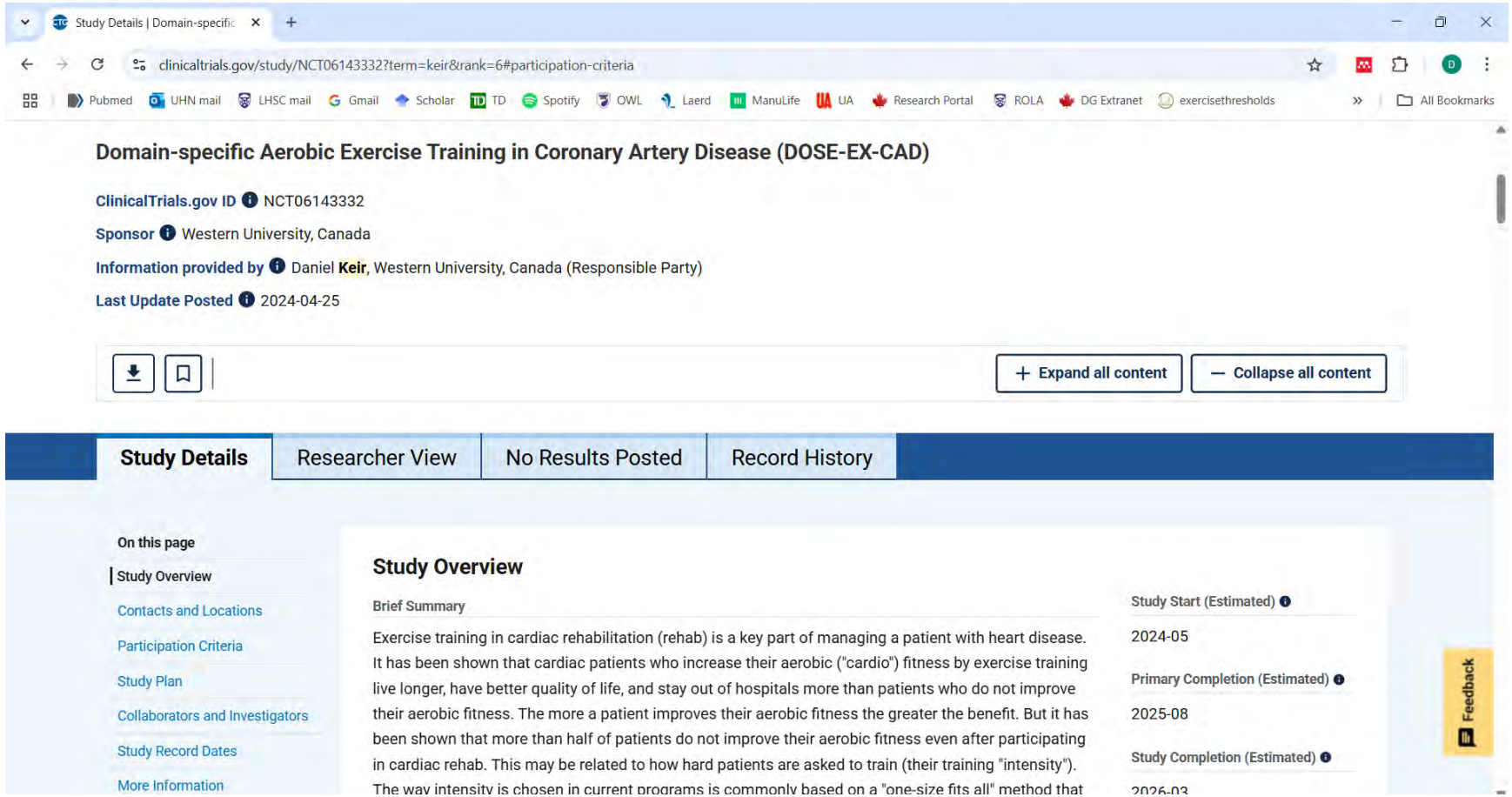


Can it be used to eliminate "non" or "negative"-responders?

Does intensity matter?

Faricier et al. (2025) *MSSE* 57(7):1593-02

DOSE-EX-CAD



Inclusion

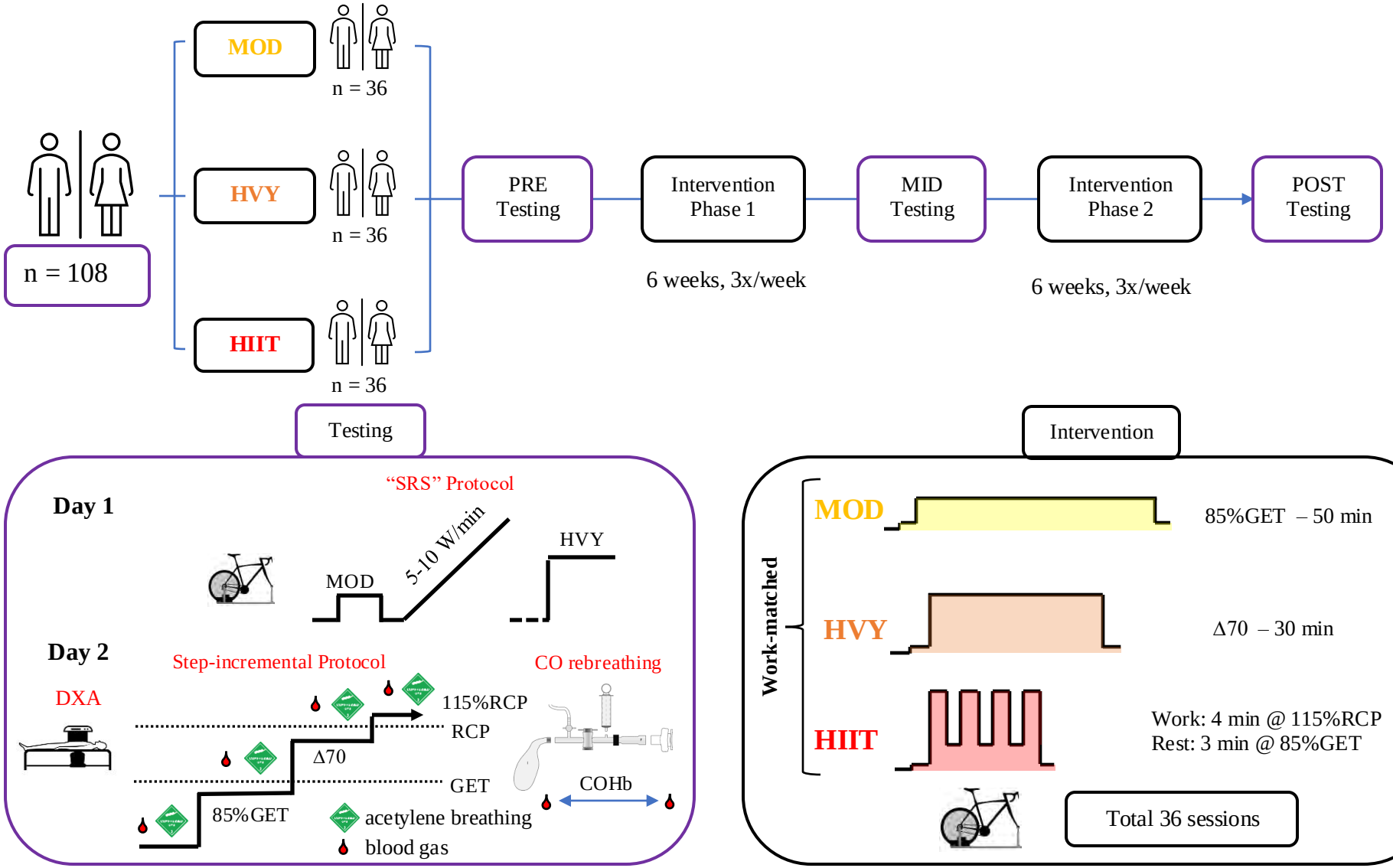
- ✓ Referral to CRSP
- ✓ 1° referral reason of ACS/PCI/CABG
- ✓ Cleared (no contraindications) to exercise

Exclusion

- ✗ Referral for non-ACS events (HF, valve repair, stenosis, arrhythmia, etc)
- ✗ LV dysfunction (LVEF <50%)
- ✗ Respiratory or MSK issues that impede cycling ability
- ✗ PCI/CABG scheduled in the next 2 months

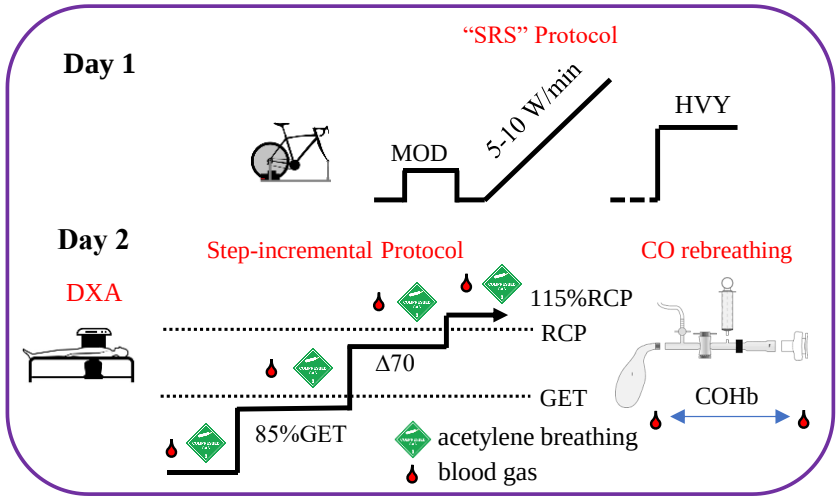
DOSE-EX-CAD

DOSE-EX-CAD

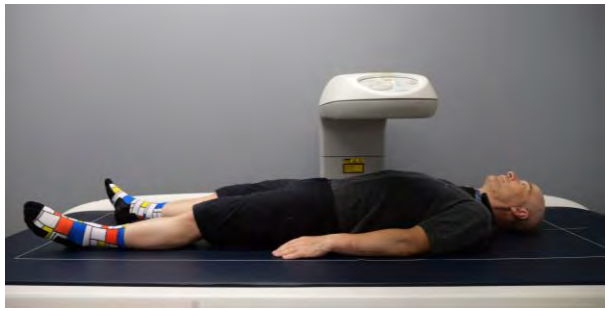

MOD
n = 36
HVY
n = 36
HIIT
n = 36
n = 108
PRE Testing
Intervention Phase 1
6 weeks, 3x/week
MID Testing
Intervention Phase 2
6 weeks, 3x/week
POST Testing
Testing
Day 1
"SRS" Protocol
MOD
5-10 W/min
HVY
Day 2
DXA
Step-incremental Protocol
115%RCP
RCP
Δ70
GET
85%GET
CO rebreathing
COHb
acetylene breathing
blood gas
Intervention
Work-matched
MOD
85%GET – 50 min
HVY
Δ70 – 30 min
HIIT
Work: 4 min @ 115%RCP
Rest: 3 min @ 85%GET
Total 36 sessions

DOSE-EX-CAD

testing

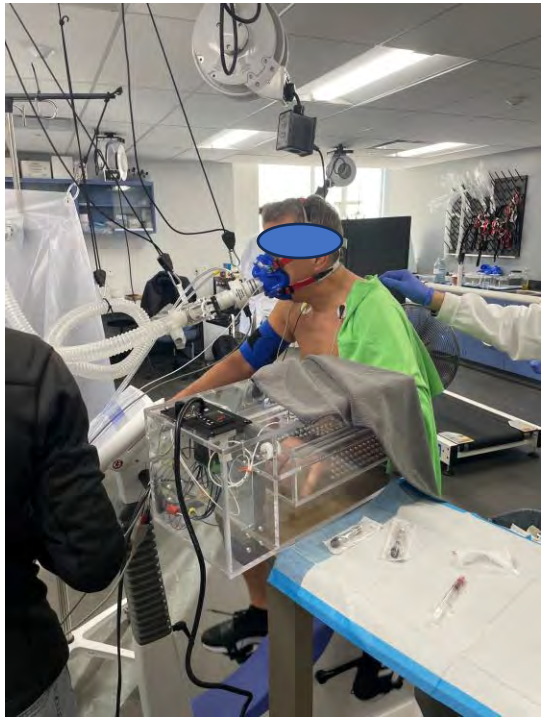


Θ_{LT}, RCP, and $\dot{V}O_{2peak}$



body composition

exercise $\dot{V}O_2$, $\dot{V}_E$, $\dot{Q}$, SV, HR, BP, a-vO_{2diff}

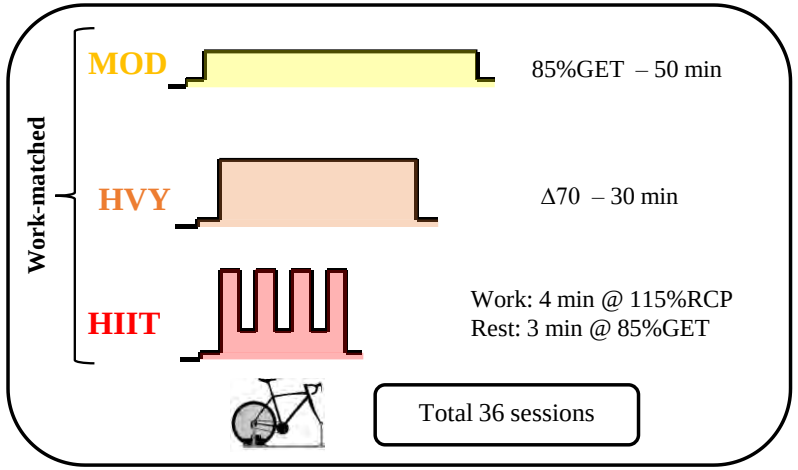


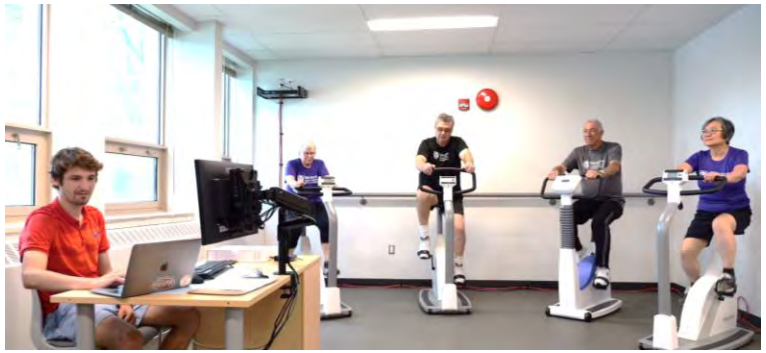
exercise blood gas ($PaCO_2$), metabolites

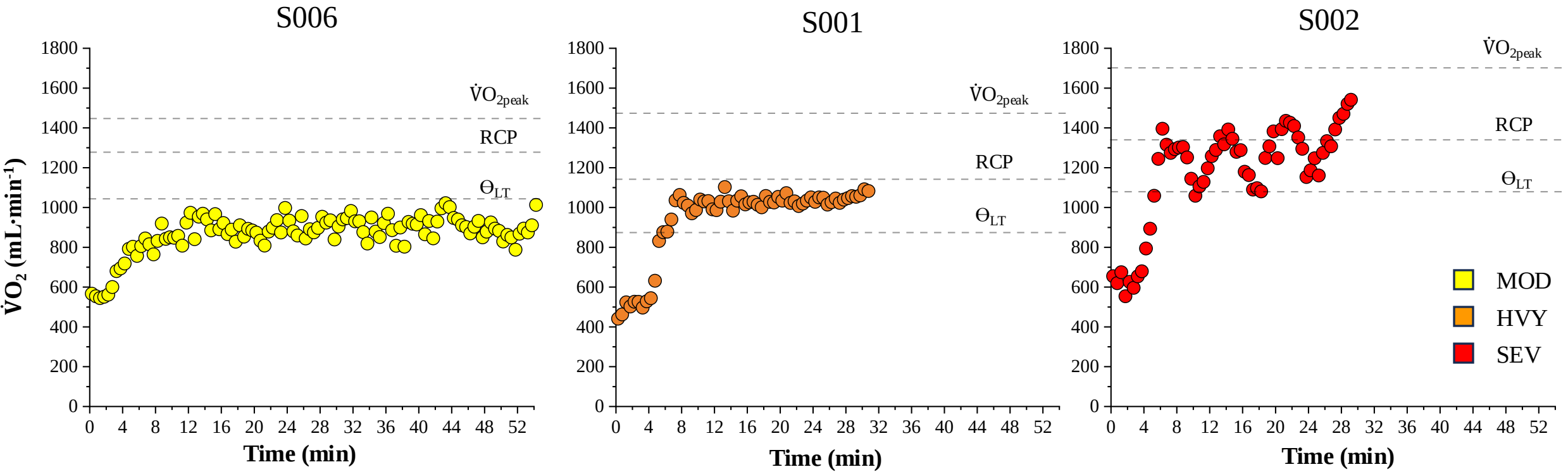
blood and plasma volume, Hb_{mass}

DOSE-EX-CAD

training

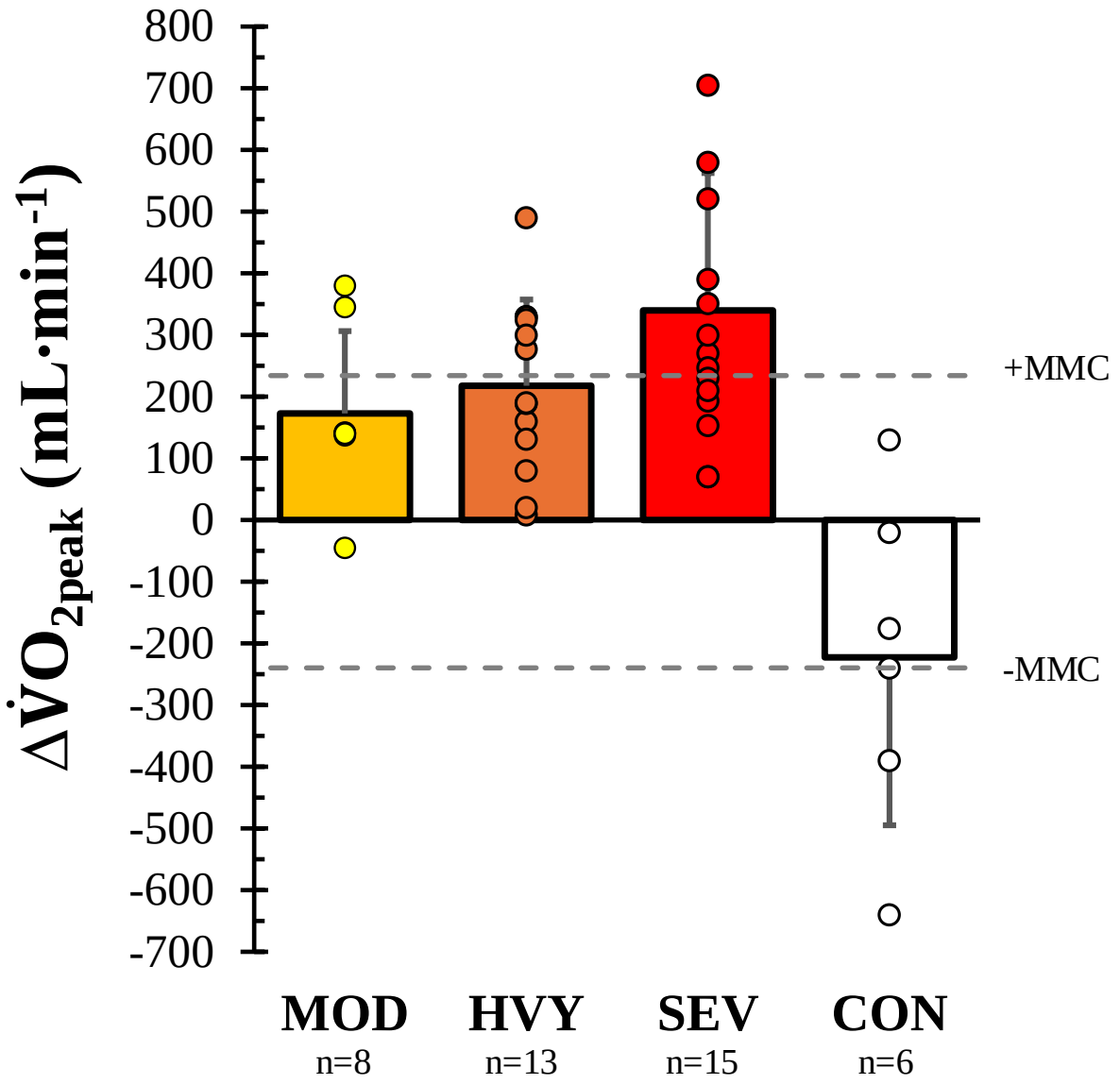






DOSE-EX-CAD

"responders" vs "non-responders(?)"



Summary

1. Exercise is a safe and effective strategy for improving outcomes after a cardiac event
2. We must consider interindividual differences in metabolic thresholds when prescribing aerobic exercise
3. Variability in "responsiveness" of $\dot{V}O_{2peak}$ to aerobic training may stem from inaccurate exercise prescription based on $\%\dot{V}O_{2max}$
4. Studies of accurately prescribed, domain-specific exercise (e.g. DOSE-EX-CAD) will help identify optimal training strategies in those who stand to benefit most

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Randi Keltz*

Nasimi Guluzade

Daniel Gregory

Tania Pereira

Youmna Hassanein

Nathan MacKay

Kira Nishidera

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CSEP | SCPE THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

Western HealthSciences