

Reabilitação Cardiovascular: Novas Fronteiras

Prova de Esforço Cardiorrespiratória na Reabilitação Cardiovascular

– Essencial ou Acessória?

Miguel Mendes



Hospital de Santa Cruz

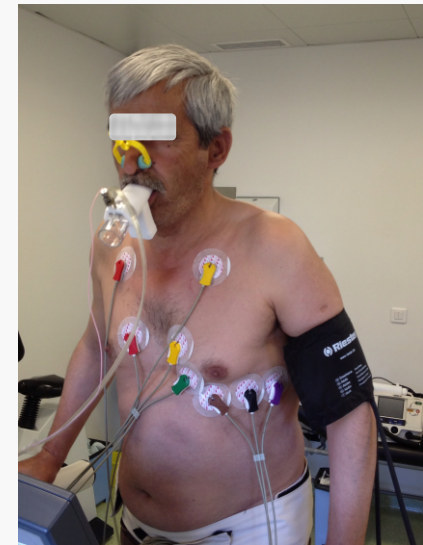
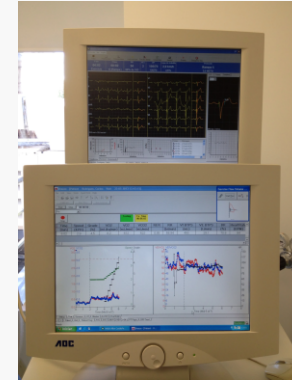
Disclosure

- None

Centro Hospitalar de Lisboa Ocidental



CPET



CPET - parameters

CPET

- Peak VO₂ (ml/min; ml/Kg/min)
- % predicted peak VO₂
- Peak RER
- VO₂ at VT1 & VT2
- Peak O₂ pulse
- Oxygen uptake efficient slope
- Ventilation
- Breathing frequency
- VE-VCO₂ slope
- O₂ and CO₂ equivalents
- Exercise oscillatory ventilation

Standard ET

- Exercise duration
- Heart rate reserve
- HR decrease in recovery
- Blood pressure change
- Ischemia
- Arrhythmias

Evolving Role of Exercise Testing in Contemporary Cardiac Rehabilitation

Gordon R. Reeves, MD, MP†; Shuchita Gupta, MD; Daniel E. Forman, MD

Symptom-limited (maximal) exercise testing before cardiac rehabilitation (CR) was once an unambiguous standard of care. In particular, it served as an important screen for residual ischemia and instability before initiating a progressive exercise training regimen. However, improved revascularization and therapy for coronary heart disease has led many clinicians to downplay this application of exercise testing, especially because such testing is also a potential encumbrance to CR enrollment (delaying ease and efficiency of enrollment after procedures and hospitalizations) and patient burden (eg, added costs, logistic hassle, and anxiety). Nonetheless, exercise testing has enduring value for CR, especially because it reveals dynamic physiological responses as well as ischemia, arrhythmias, and symptoms pertinent to exercise prescription and training and to overall stability and prognosis. Moreover, as indications for CR have expanded, the value of exercise testing and functional assessment is more relevant than ever in the growing population of eligible patients, including those with heart failure, valvular heart disease, and posttransplantation, especially as current patients also tend to be more clinically complex, with advanced ages, multimorbidity, frailty, and obesity. This review focuses on the appropriate use of exercise testing in the CR setting. Graded exercise tests, cardiopulmonary exercise tests, submaximal walking tests, and other functional assessments (strength, frailty) for CR are discussed.

KEY WORDS

cardiac rehabilitation
exercise testing
functional assessment

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The authors declare no conflicts of interest.
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- Peak VO₂ normalized by body weight (CPET), is a much more accurate measure of cardio respiratory fitness than estimated METs (GXT).
- A CPET overcomes many of the limitations that reduce the accuracy of GXT:
 - Normalizes for the differences in performance that occur when patients clench the handrails while walking on a treadmill.
 - A respiratory exchange ratio (RER) > 1.1 demonstrates that a maximal or near-maximal effort was attained;
- The CPET is recognized to assess prognosis and gauge therapeutic interventions in HFrEF and also in CHD, hypertrophic cardiomyopathy, pulmonary hypertension, COPD.

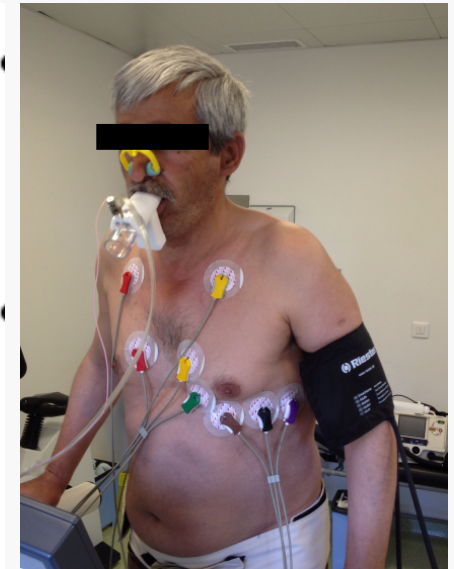
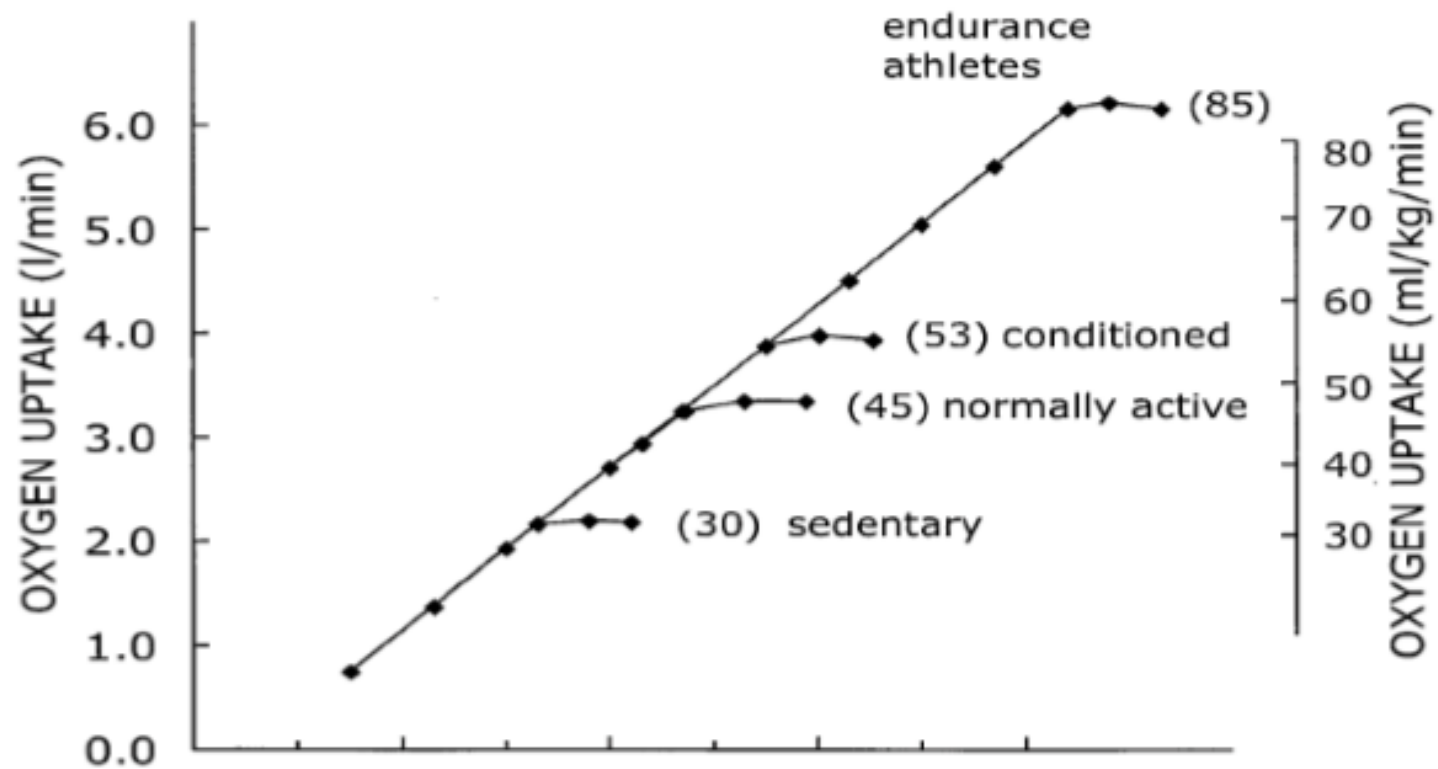
CPET in CR

- Risk stratification
- Individualized exercise prescription
- Exercise training evaluation

CPET in CR

- Risk stratification
- Individualized exercise prescription
- Exercise training evaluation

Functional capacity assessment



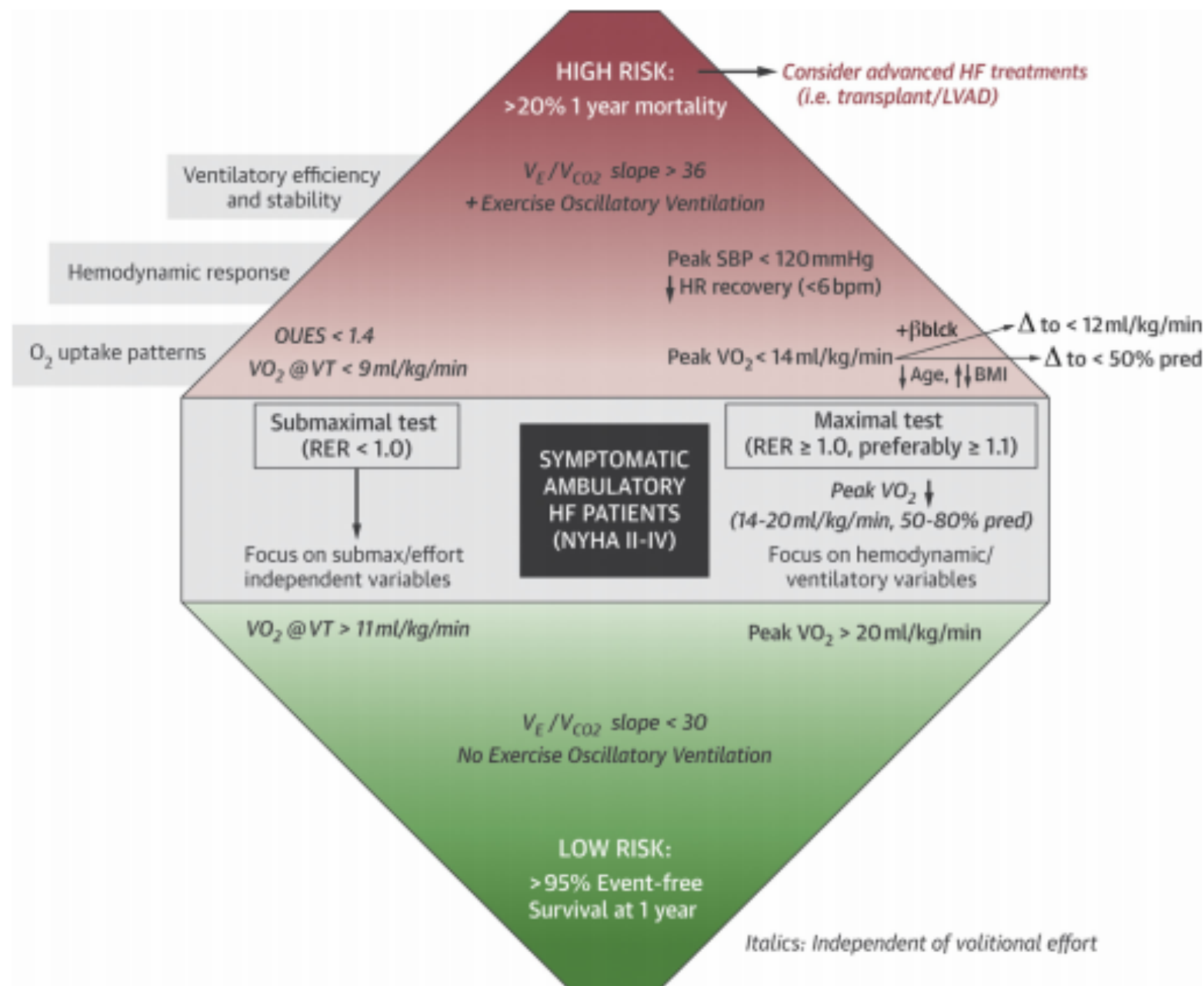
Heart failure

Weber Classification

*Exercise capacity, in patients with HF, based on
Peak Oxygen Uptake and Ventilatory Anaerobic Threshold*

	VO2 (ml/Kg/min)			
Weber	AT	Peak	Max CI (l/min/m ²)	Functional limitation
A	> 14	> 20	> 8	None to mild
B	11-14	16-20	6-8	Mild to moderate
C	8-11	10-16	4-6	Moderate to severe
D	< 8	< 10	< 4	Severe

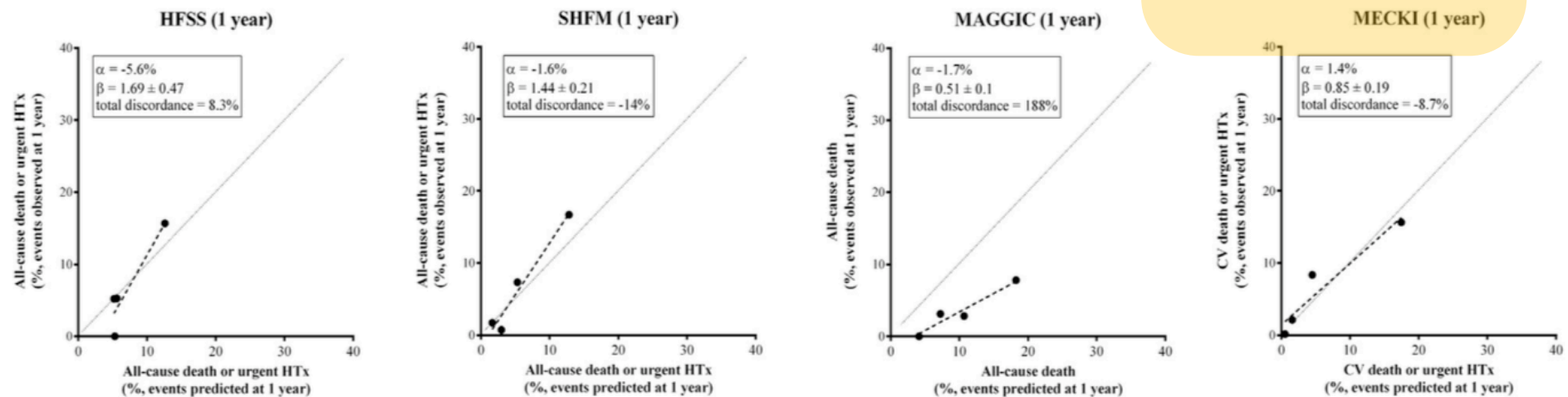
CENTRAL ILLUSTRATION Integrated Assessment of CPET Variables for Risk Stratification in HF



Comparative Analysis of Four Scores to Stratify Patients With Heart Failure and Reduced Ejection Fraction

Pedro Freitas, MD*, Carlos Aguiar, MD, António Ferreira, MD, António Tralhão, MD, António Ventosa, MD, and Miguel Mendes, MD

There are several **prognostic risk scores** available for patients with heart failure with reduced ejection fraction (HFrEF) that can aid in the **decision of listing candidates for heart transplant (HTx)**. A direct comparison between these scores has not been performed. Therefore, our objective was to evaluate the calibration and discriminative power of 4 contemporary HF scores. A retrospective analysis of 259 patients with HFrEF who underwent cardiopulmonary exercise test was conducted. The **Heart Failure Survival Score (HFSS)**, **Seattle Heart Failure Model (SHFM)**, **MAGGIC**, and **MECKI** were evaluated.



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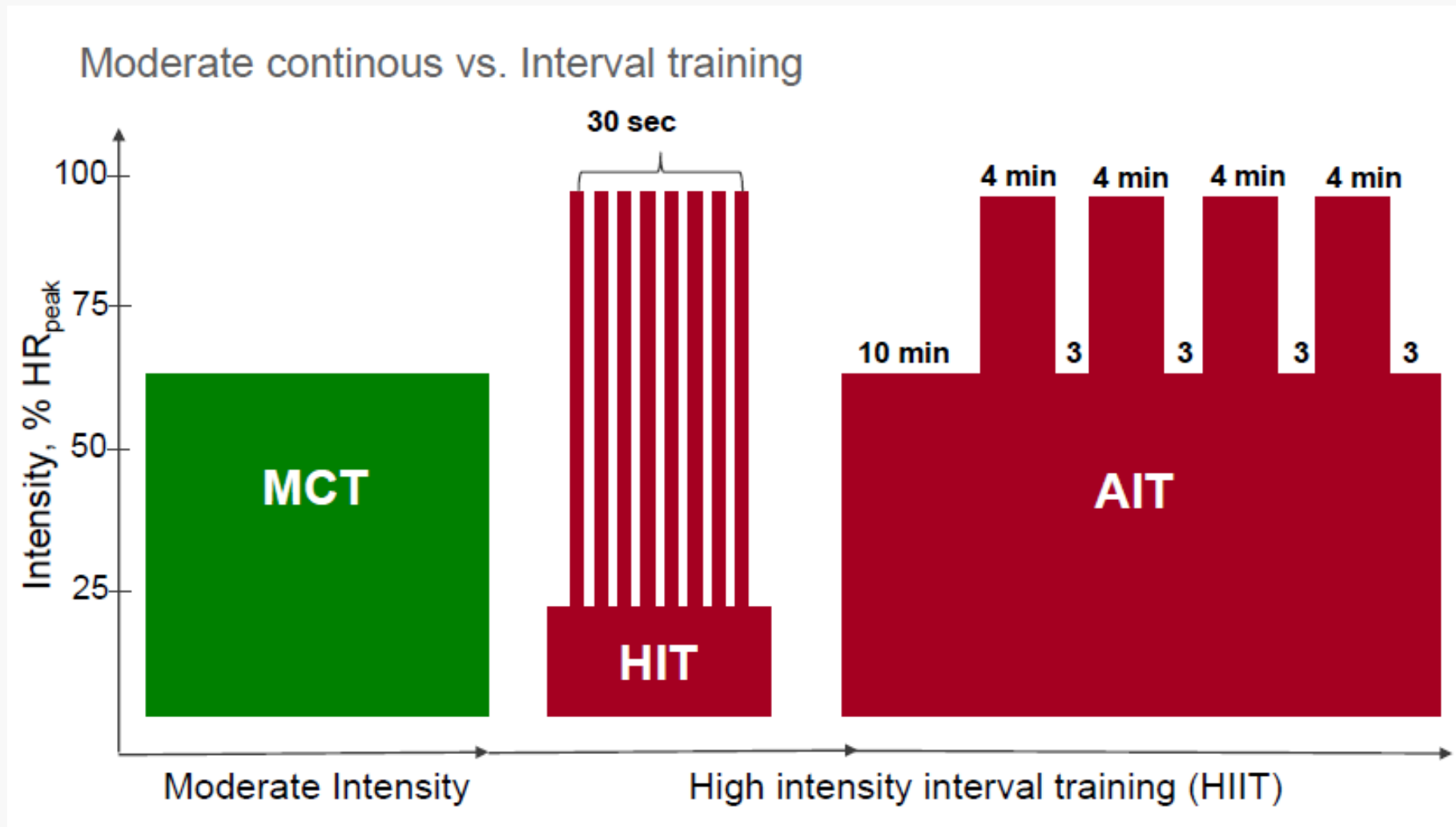
Risk - AACVPR

	Low	M	High
NYHA class	I e II	o	III - IV
Funcional capacity	> 7 METs	d	< 5 METs
Ejection fraction	> 50%	e	< 40%
Ischemia	Absent	r	Present
HR e BP during exercise	Adequate	a	Abnormal
Ventricular arrhythmias	Absent	t	Complex
Self-monitorization	Possible	e	Unable

CPET in CR

- Risk stratification
- **Individualized exercise prescription**
- Exercise training evaluation

Aerobic training modalities



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

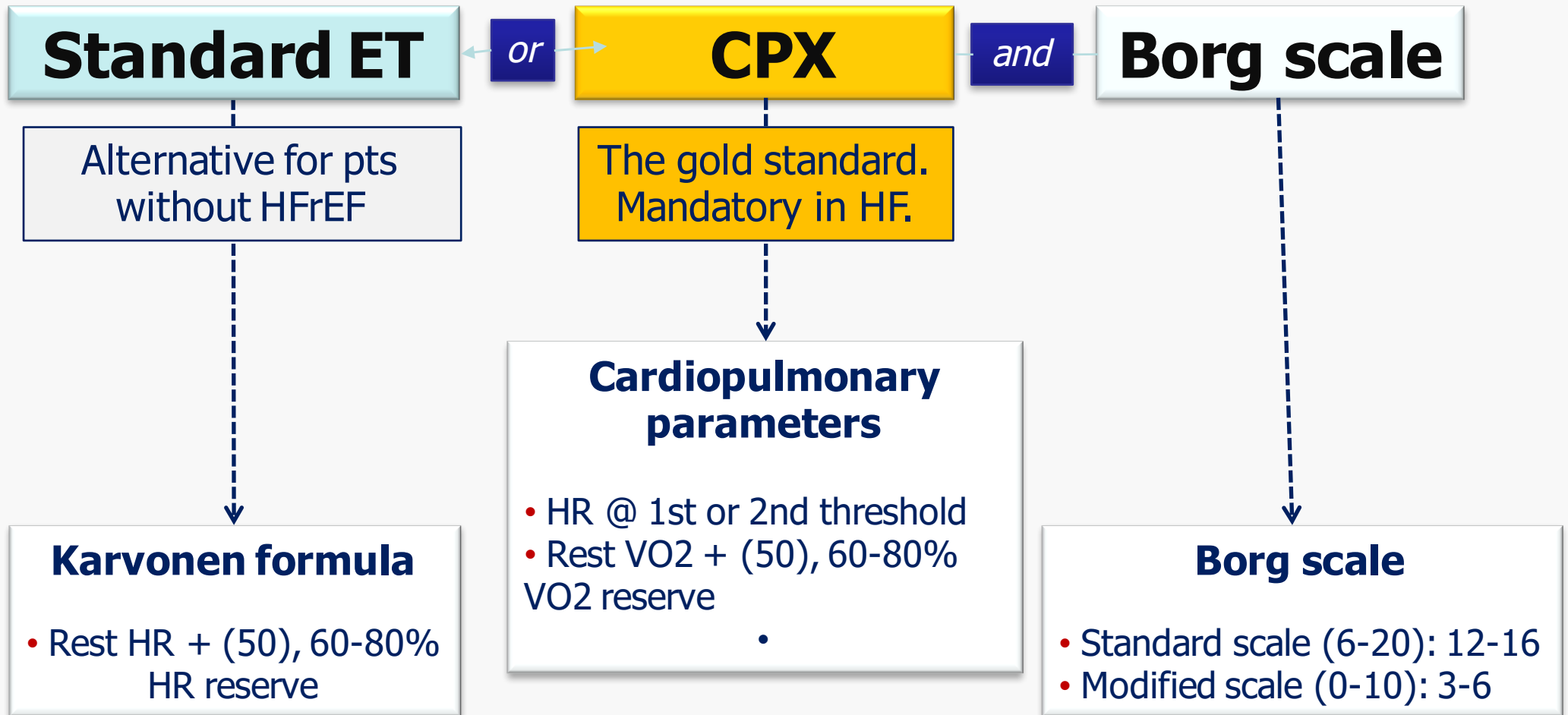
**Alessandro Mezzani^{1*}, Larry F Hamm^{2*}, Andrew M Jones³,
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Axel Urhausen⁷ and Mark A Williams⁸**

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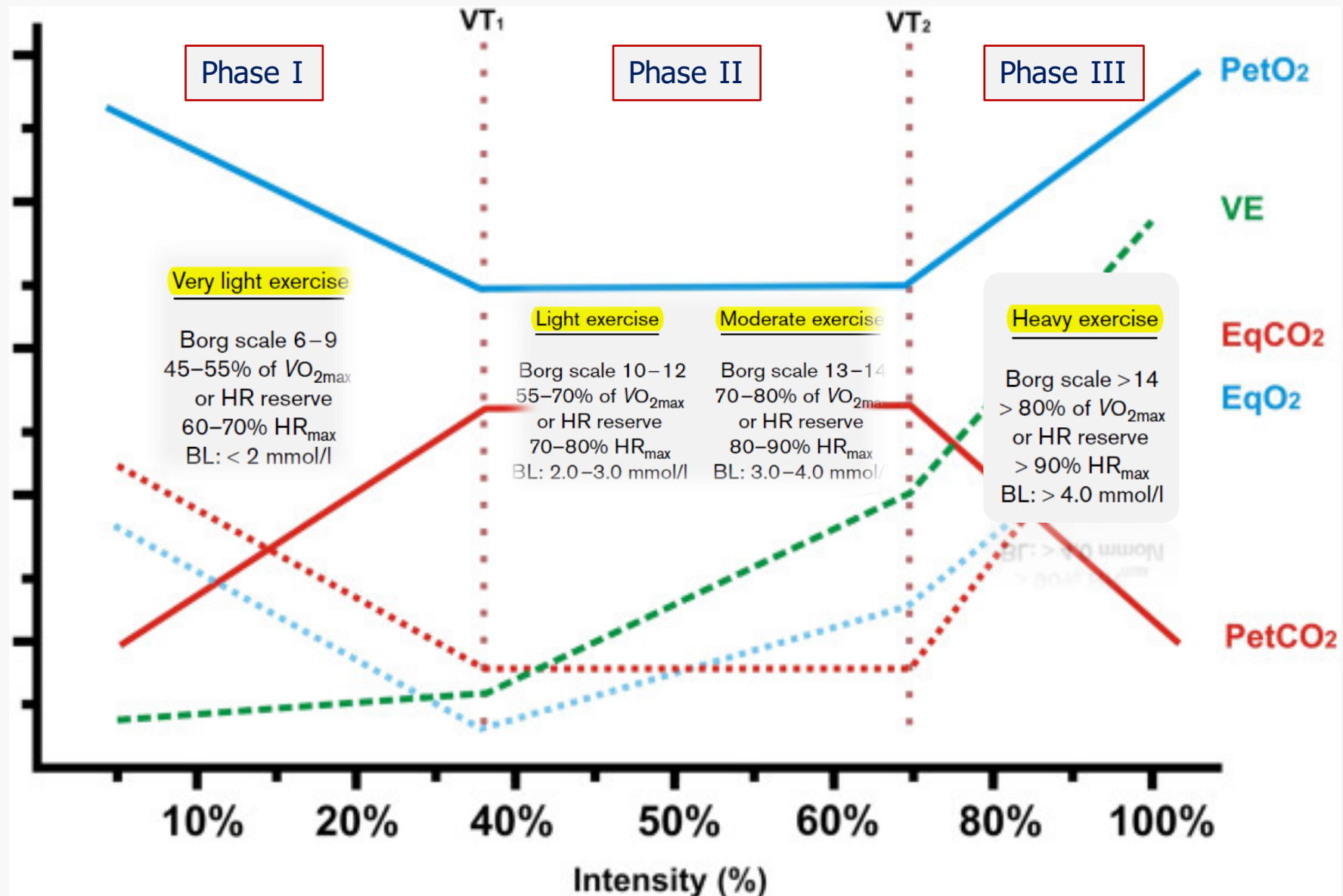

Abstract

Aerobic exercise intensity prescription is a key issue in cardiac rehabilitation, being directly linked to both the amount of improvement in exercise capacity and the risk of adverse events during exercise. This joint position statement aims to provide professionals with up-to-date information regarding the identification of different exercise intensity domains, the methods of direct and indirect determination of exercise intensity for both continuous and interval aerobic training, the effects of the use of different exercise protocols on exercise intensity prescription and the indications for recommended exercise training prescription in specific cardiac patients' groups. The importance of functional evaluation through exercise testing prior to starting an aerobic training program is strongly emphasized, and ramp incremental cardiopulmonary exercise test, when available, is proposed as the gold standard for a physiologically comprehensive exercise intensity assessment and prescription. This may allow a shift from a 'range-based' to a 'threshold-based' aerobic exercise intensity prescription, which, combined with thorough clinical evaluation and exercise-related risk assessment, could maximize the benefits obtainable by the use of aerobic exercise training in cardiac rehabilitation.

Aerobic training intensity prescription



3 metabolic phase during a CPET



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, MD,^{1*} Larry F. Hamm, PhD,^{2*} Andrew M. Jones, PhD,³ Patrick E. McBride, MD, MPH,⁴ Trine Moholdt, PhD,⁵ James A. Stone, MD, PhD,⁶ Axel Urhausen, JP, MD, MPH, PhD,⁷ and Mark A. Williams, PhD⁸

ABSTRACT: Aerobic exercise intensity prescription is a key issue in cardiac rehabilitation, being directly linked to both the amount of improvement in exercise capacity and the risk of adverse events during exercise. This joint position statement aims to provide professionals with up-to-date information regarding the identification of different exercise intensity domains, the methods of direct and indirect determination of exercise intensity for both continuous and interval aerobic training, the effects of the use of different exercise protocols on exercise intensity prescription and the indications for recommended exercise training prescription in specific cardiac patients' groups. The importance of functional evaluation through exercise testing prior to starting an aerobic training program is

KEY WORDS

Aerobic training
energy expenditure
peak VO₂
ventilatory thresholds
cardiac rehabilitation

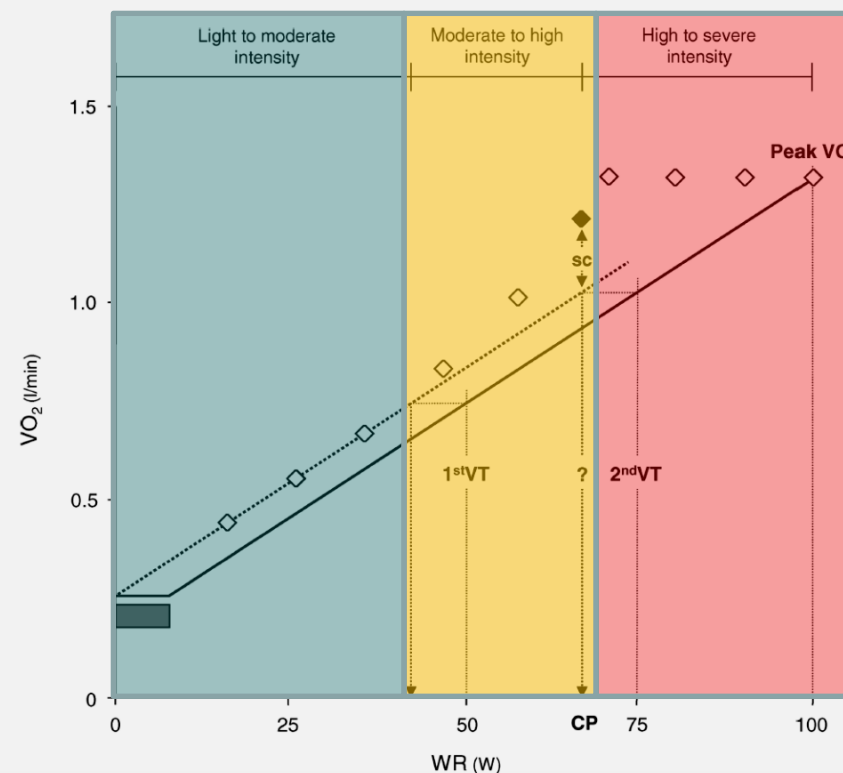


Table 1 • Physiological Characteristics of the Different Intensity Domains for Constant-Work-Rate Exercise

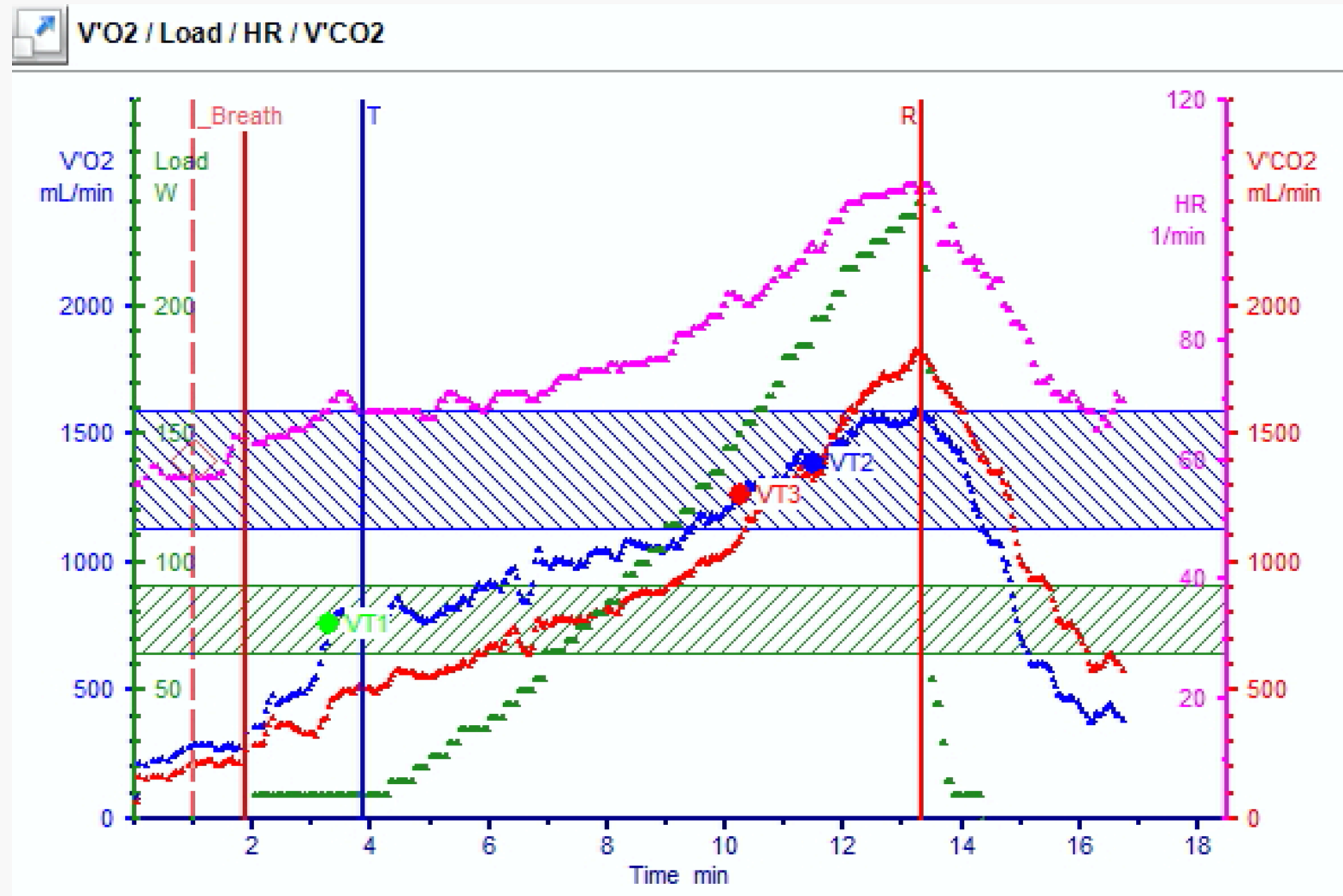
	VO ₂ Steady-state	Lactate Steady-state	Exercise Duration	VO ₂ vs. WR Linear Relationship	Training Modality
Light to moderate	Yes	NA	>30 min	Yes	Continuous
Moderate to high	Yes	Yes	~20–30 min	No	Continuous
High to severe	No	No	~3–20 min	NA	Interval
Severe to extreme	No	No	≤3 min	NA	Interval

WR: work rate; NA: not applicable.

VO₂ max?

- **Definitive:**
 - Failure of VO₂ and/or HR to increase with further increases in work rate
- **Possible:**
 - Peak respiratory exchange ratio (VCO₂/VO₂) > 1.10
 - Post-exercise blood lactate concentration > 8 mmol/L
 - Rating of perceived exertion (RPE) >18 in the Borg (6-20) > 8 in the Borg (0-10)
 - Patient appearing exhausted.

Prova máxima?



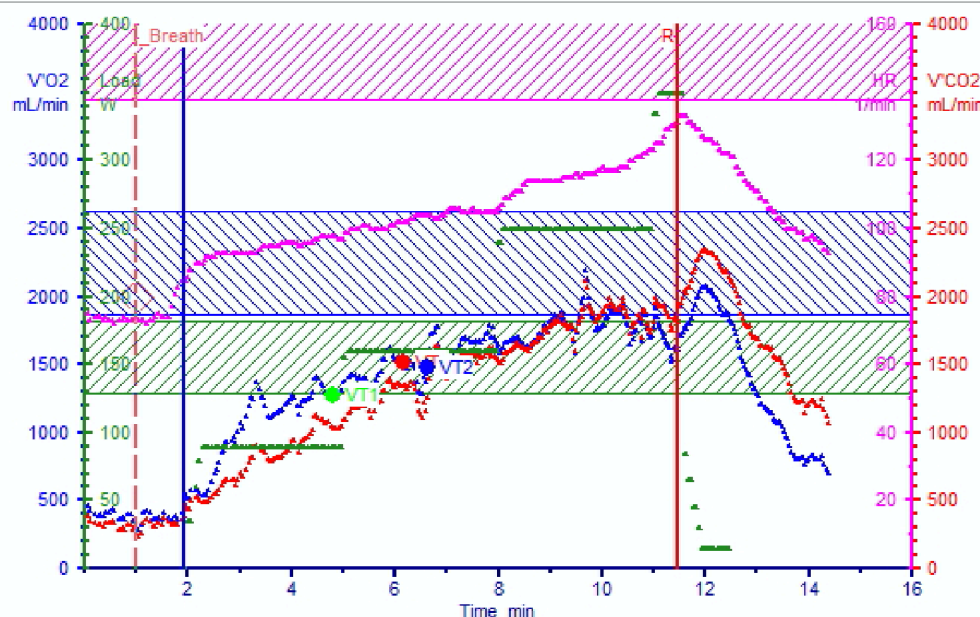
MVO2

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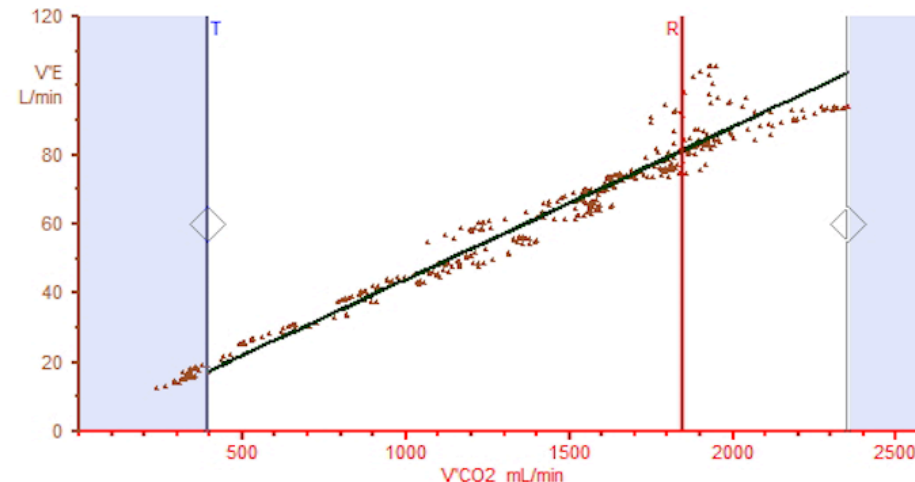
IDENTIFICAÇÃO

V'O₂ / Load / HR / V'CO₂

Nº Hospitalar 13415117



V'E=f(V'CO₂)



CONCLUSÕES

Sem alteração ventilatória: Espirometria prévia: CVF=4.31 (100% do previsto); FEV1=3.55 (105% do previsto); Sem evidência de isquemia miocárdica por critérios clínicos e electrocardiográficos, sob medicação.

PE máxima demonstrando capacidade funcional normal, limitada por causa circulatória.

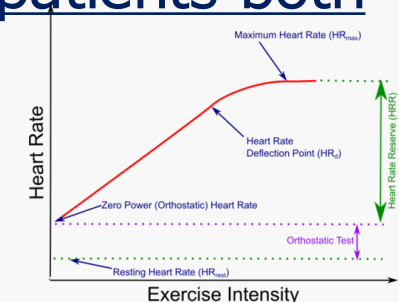
Classe de Weber: A; VO₂ máx= 22.4 ml/Kg/min (86% do previsto; normal >85% do previsto). VO₂ de repouso: 4.3 ml/Kg;

Rampa VE/VCO₂= 44,1 ; VE= 102 L/min; FR= 41 cpm. Sem dessaturação durante a prova; 1ºVT=15.0 mL/Kg/min (FC 97bpm); 2ºVT=15.2 mL/Kg/min (FC 104 bpm). QR= (PE máxima se >1.10). PetCO₂ repouso= 25 mmHg (normal>=33);

PetCO₂ no 2º VT= 31 mmHg (normal: incremento de 3-8mmHg). *Exercise oscillatory ventilation*: presentes.

No linearity VO_2 vs WR and HR

- in general, near and by peak VO_2
- in patients in whom chronotropic incompetence may be present due to age, pathology and/or drug (beta-blockers) related sinus node dysfunction.
- a very high uncertainty in predicting % VO_2R values on the basis of %HRR has been demonstrated in CHF patients both on and off-beta-blockers.



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- Witte KK, Cleland JG and Clark AL. Chronic heart failure, chronotropic incompetence, and the effects of beta-blockade. *Heart* 2006; 92: 481–486.
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Programming exercise intensity in patients on beta-blocker treatment: the importance of choosing an appropriate method

Isabel Díaz-Buschmann^{1,2}, Koldo Villeda Jaureguizar²,
Maria José Calero^{1,2} and Rosa Sánchez Aquino^{1,2}

Abstract

Aim: To verify the usefulness of current recommended level of target exercise heart rate (HR) and of different HR-based methods for calculating target HR in patients with and without beta-blocker treatment.

Methods: We studied 53 patients not treated with beta-blocker and 159 patients on beta-blocker treatment. All patients underwent a maximal exercise test with gas analysis, and first ventilatory threshold (VT1 or aerobic threshold), second ventilatory threshold (VT2 or anaerobic threshold), time of exercise, maximum load, metabolic parameters, HR at rest (HR_{rest}), HR_{VT1} , HR at VT1 (HR_{VT1}) and at VT2 (HR_{VT2}), and 75, 80, and 85% of HR_{max} ($HR_{75\%}$, $HR_{80\%}$, $HR_{85\%}$) were calculated. Exercise HR was also determined using the Karvonen formula, applying 60, 70, and 80% of the heart rate reserve (HRR) ($HR_{Karv0.6}$, $HR_{Karv0.7}$, and $HR_{Karv0.8}$).

Results: This study included 102 patients on a beta-blocker and 39 not treated with negative chronotropic effect drugs. Maximum load, metabolic parameters, HR_{rest} , HR_{VT1} , and HR_{VT2} were significantly lower in patients on beta-blocker treatment. The proportion of patients with a $HR_{75\%}$, $HR_{80\%}$, $HR_{85\%}$, $HR_{Karv0.6}$, $HR_{Karv0.7}$, and $HR_{Karv0.8}$ <VT1 and >VT2 was very high and depended on whether patients were on beta-blocker treatment.

Conclusions: Prescribed exercise intensity should be within VT1 and VT2, so that the efficacy and safety is guaranteed. If determining VT1 and VT2 is not possible, HR-based methods can be used, but with caution. In fact, there will be always a proportion of patients training below VT1 or above VT2. On the other hand, recommendations for patients on a beta-blocker should be different from patients not receiving a beta-blocker. Patients not treated with a beta-blocker should exercise at $HR_{Karv0.7}$ or at $HR_{85\%}$. In patients on a beta-blocker, we recommend preferentially a target HR of $HR_{Karv0.6}$ or $HR_{80\%}$.

Keywords

Beta-blocker, cardiac rehabilitation, exercise intensity, Karvonen's method, target heart rate

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Proportion of patients treated with BB or without negative chronotropic drugs with a HR exercise intensity prescribed by Karvonen formula over VT1 and VT2

Parameter	Treated with BB		Not treated with BB	
	$\geq HR_{VT1}$	$\geq HR_{VT2}$	$\geq HR_{VT1}$	$\geq HR_{VT2}$
$HR_{Karv0.6}$	86.3	3.9	79.5	2.6
$HR_{Karv0.7}$	99.0	27.5	92.3	10.3
$HR_{Karv0.8}$	100	49.0	97.4	33.3

Values are %.

HR - based exercise prescription:

- Must be individualized, considering the patient's status, underlying disease and treatment.
- The behaviour of HR during incremental exercise is not always linear or uniform.
- HR can be used in patients with a maximum exercise test.
- The optimal limits of exercise based on a HR range are narrow.
- HR-based methods are only valid for the same dose of beta-blocker during the programme.
 - Training must occur at a similar hour of the day of the performed exercise test

Cardio-Pulmonary Exercise Testing Parameters

Time [min]	Load [W]	V'E [L/min]	BF [l/min]	BRmax% [%]	V'O2/kg [(mL/min)/kg]	V'O2 [mL/min]	V'CO2 [mL/min]	RR [1/min]	FiO2	FaCO2	PETCO2 [mmHg]	HR [1/min]	O2pulse [mL]	SpO2 [%]
00:00 Rest														
00:20	0	15	10	91	3.2							69	60	
00:40	0	17	22	89	3.8							70	70	
01:00	0	5	11	97	1.7							68	30	
01:20	0	17	21	89	5.1							68	90	99
01:40	0	5	9	97	1.4							67	30	100
02:00	0	16	18	90	5.0							68	90	100
02:20	0	14	12	91	3.8							68	70	100
02:40	0	7	8	96	2.1							65	40	100
03:00	0	17	17	89	4.8							73	80	99
03:20	0	19	20	88	5.5							71	100	99
03:40	0	13	15	91	3.2							67	60	99
03:51	0	13	12	92	4.0							68	70	97
03:54 Test														
04:00		13	19	92	3.6	448	332	0.74	22.9	30.9	30	69	60	97
04:20	136	24	18	84	7.6	944	701	0.74	23.1	31.1	31	82	120	97
04:40	136	27	28	82	7.7	953	723	0.76	24.6	32.5	31	88	110	95
04:44 VT1														
05:00	136	34	22	78	11.4	1416	984	0.69	21.5	31.0	32	92	150	95
05:20	136	39	17	75	12.0	1586	1182	0.74	23.0	30.9	34	95	170	97
05:40	136	47	23	70	13.5	1675	1373	0.82	26.1	31.8	33	96	170	98
06:00	136	47	24	69	13.6	1681	1401	0.83	26.2	31.4	34	100	170	99
06:20	136	51	27	67	13.9	1725	1480	0.86	27.2	31.7	33	100	170	97
06:25 VT3														
06:40	136	52	27	66	14.3	1773	1546	0.87	27.2	31.2	34	100	180	98
07:00	236	53	28	66	14.5	1797	1592	0.89	27.5	31.0	34	102	180	98
07:02 VT2														
07:20	240	56	26	64	14.8	1834	1637	0.89	28.7	32.1	33	106	170	100
07:40	240	68	31	56	15.8	1958	1908	0.97	32.3	33.2	32	110	180	99
08:00	240	65	26	58	15.6	1929	1920	1.00	31.7	31.8	35	111	170	97
08:20														
08:20	240	80	29	48	17.4	2154	2279	1.06	35.4	35.5	32	111	190	95
08:40	240	80	31	48	16.1	1997	2226	1.11	38.0	34.1	32	115	170	97
09:00	240	92	37	40	16.9	2093	2417	1.15	41.6	36.0	30	118	180	97
09:20	240	100	38	36	16.9	2094	2508	1.20	45.0	37.6	29	121	170	94
09:40	240	107	43	31	18.4	2283	2680	1.17	44.3	37.8	29	121	190	94
10:00														
10:00	240	107	41	31	19.2	2379	2695	1.13	42.5	37.5	30	122	190	95
10:20														
10:20	368	117	43	25	17.7	2200	2661	1.21	50.4	41.7	27	123	180	94
10:25														
10:25	368	113	47	20	17.8	2207	2790	1.26	53.0	41.9	26	126	180	92
6:30 min														
10:40	68	124	47	20	16.6	2057	2716	1.32	57.0	43.2	25	122	170	92
11:00	27	115	45	26	18.1	2245	2784	1.24	48.5	39.1	28	127	180	92
11:20	27	105	39	32	17.2	2129	2614	1.23	46.8	38.1	28	117	180	99

Aerobic exercise intensity prescription

- Threshold' s method:
 - Lower level: VT1 = 92 bpm
 - Upper level: VT2 = 111 bpm
- VO2 reserve method:
 - Lower level: VO2R 60% = 13,5 > 96 bpm
 - Upper level: VO2R 70% = 14,9 > 106 bpm
- Karvonen method:
 - Lower level: HRR 60% = 93 bpm
 - Upper level: HRR 70% = 99 bpm

♂, 64 years old; STEMI >> PCI LAD (DES) 09/12; EF=24%; CDI 02/13; NYHA

III;

Time [min]	Load [W]	V'E [L/min]	BF [l/min]	BRmax% [%]	V'O2/kg [(mL/min)/kg]	V'O2 [mL/min]	V'CO2 [mL/min]	RER	EqO2	EqCO2	PETCO2 [mmHg]	HR [1/min]	O2pulse [mL]	SpO2 [%]	
00:00 Rest															
00:20	0	19	20	85	5.8							26	71	60	100
00:40	0	19	20	85	5.9							25	71	60	100
01:00	0	19	25	85	5.4							24	71	50	99
01:20	0	17	23	86	5.1							24	71	50	100
01:40	0	17	24	87	5.0							24	72	50	100
01:51	0	22	28	82	7.2							25	71	70	99
01:54 Warmup															
02:00	2 Km/ 0%	27	24	78	7.5							24	72	70	99
02:20	8	30	25	76	7.3							24	78	60	99
02:40	8	29	24	77	6.4							23	81	50	99
03:00	8	29	20	77	7.9							24	82	70	99
03:20	8	30	20	76	9.0							24	83	70	99
03:40	8	28	19	78	8.7							24	83	70	99
03:51	8	26	16	79	8.7							25	83	70	98
03:54 Test															
04:00	27 Km/ 3,5 %	28	23	77	9.9							25	83	80	98
04:20	8	27	22	78	9.2							25	84	70	98
04:40 VT1															
04:40	15	28	24	77	9.3	635	533	0.84	40.2	48.0	25	85	70	98	
05:00	19	31	21	75	10.7	730	618	0.85	39.4	46.5	26	85	90	98	
05:20	27	34	21	73	10.4	708	657	0.93	44.3	47.8	24	87	80	98	
05:40	30	30	20	76	9.4	638	598	0.94	43.5	46.4	24	88	70	98	
06:00	3,5 Km/ 7,5 %	32	19	74	10.6	723	664	0.92	41.2	44.8	24	87	80	98	
06:20	40	33	19	73	10.5	716	674	0.94	43.6	46.3	24	89	80	98	
06:40	50	32	18	75	10.0	677	643	0.95	43.7	46.1	25	89	80	98	
07:00	55	35	20	72	11.0	746	691	0.93	43.4	46.9	25	90	80	98	
07:20	60	33	17	74	10.4	705	681	0.97	44.2	45.8	25	93	80	98	
07:33 VT2															
07:40	72	35	19	72	11.3	771	734	0.95	43.3	45.5	26	94	80	98	
08:00															
08:00	4,3 Km/ 11,5 %	38	19	70	11.4	773	751	0.97	46.0	47.4	25	96	80	98	
08:20	50	40	20	68	11.5	782	771	0.99	48.3	49.0	25	97	80	98	
08:40	96	38	16	70	11.4	773	772	1.00	46.2	46.3	26	98	80	98	
08:46 VT3															
09:00	110	39	20	69	11.8	803	781	0.97	46.2	47.4	26	100	80	96	
09:20	117	41	21	67	12.3	837	818	0.98	46.5	47.6	26	103	80	98	
09:40	124	47	22	62	13.0	886	911	1.03	50.8	49.4	24	104	90	95	
10:00	147	47	22	63	12.6	855	911	1.06	51.9	48.7	25	107	80	95	
10:20	139	50	23	60	13.1	891	947	1.06	52.8	49.7	25	109	80	95	
10:40	155	56	26	55	13.3	905	1016	1.12	58.8	52.3	24	111	80	91	
11:00	172	56	28	55	13.2	900	1004	1.12	59.1	53.0	24	113	80	90	
11:20	172	62	28	50	14.3	975	1123	1.15	60.9	52.9	23	114	90	89	

Aerobic exercise intensity prescription

1. Threshold' s method:

- Lower level: VT1 = 83 bpm
- Upper level: VT2 = 94 bpm

2. VO2 reserve method:

- Lower level: VO2R 60% = 89 bpm
- Upper level: VO2R 70% = 97 bpm

Aerobic exercise intensity prescription

1. Threshold's method:

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9:20 min 5,4 Km/ 15,8 %

Exercise test in CR

- Risk stratification
- Individualized exercise prescription
- **Exercise training evaluation**

how to assess exercise training

After a successful CRP program, should be found:

– Cardiopulmonary exercise test:

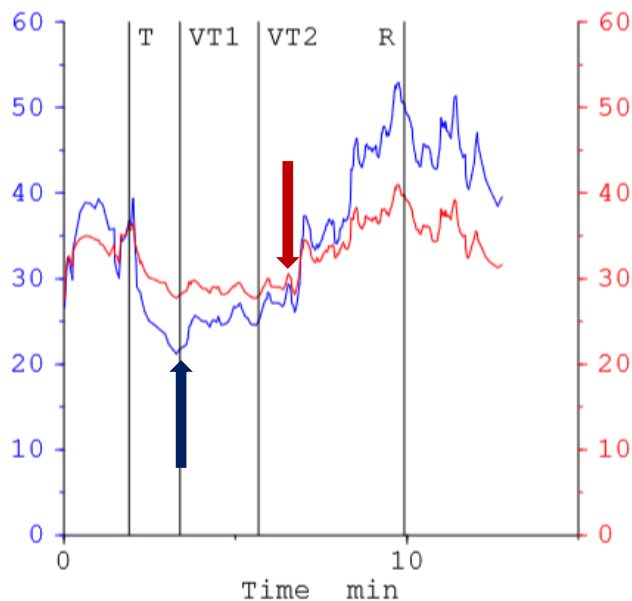
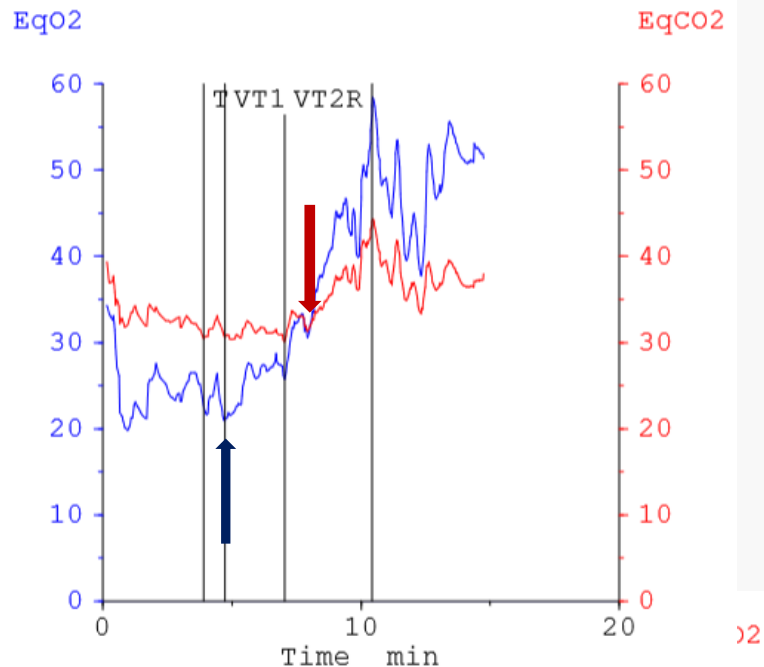
- ✓ Higher VO₂ at peak exercise
- ✓ Higher VO₂ at the VT1 & VT2
- ✓ Decreased VE/VCO₂ slope

– Standard ET:

- ✓ Higher duration/load attained (estimated METs)
- ✓ Lower HR& BP levels at rest and @ submaximal levels.
- ✓ Faster normalization of HR in the recovery period
- ✓ Ischemia, starting later during the test, usually at the same DP
- ✓ Lower frequency and complexity of ventricular arrhythmias

Benefits of training

♂, 42y NSTEMI > LAD PCI (DES) 06/2015
EF<40% ICD 08/15 HF



1st CPET
17/10/2017

Peak VO2

19,2

2nd CPET
22/02/2018

22,2

VO2 @ VT2

15,8

17,4

HR @ VT2

111

120

VO2 @ VT1

11,4

13,6

HR @ VT1

92

100

Take home message

- A PECR **é essencial** em RC para:
 - a estratificação do risco nos doentes com insuficiência cardíaca.
 - prescrever com segurança a intensidade do exercício aeróbio
 - avaliar com rigor os ganhos do treino
- A PECR **não é acessória** mesmo nos doentes coronários de baixo risco



Obrigado pela vossa atenção