ỨNG DỤNG CPET
TRONG Y HỌC THỂ THAO

TS. BS Nguyễn Ngọc Phương Thư

Trường ĐHYK Phạm Ngọc Thạch

Khoa TMTQ – Bệnh viện Nhân dân 115

NỘI DUNG

1. Tầm quan trọng của CPET trong YHTT
2. Tổng quan về CPET
3. Đáp ứng CPET ở VĐV
4. Trình tự diễn giải kết quả CPET
5. Ứng dụng CPET trong YHTT

1. TẦM QUAN TRỌNG CỦA CPET TRONG Y HỌC THỂ THAO

TỔNG QUAN Y HỌC THỂ THAO

- Phòng ngừa, chẩn đoán, điều trị và

phục hồi các chấn thương liên quan đến thể thao và hoạt động thể chất

- VĐV chuyên & không chuyên, dân số chung ít hoạt động thể lực….

- Kết hợp kiến thức y khoa với khoa học vận động

=> tối ưu hóa chương trình và hiệu quả tập luyện, giảm nguy cơ


Lovia
SYS
128
DIA
81
PULSE
99
START
STOP
MEM


OK


Zone 2
148-159 bpm
Anaerobic
Threshold
172 bpm
VO2Max
48
ml/kg/min
Fitness Rating
Excellent

CPET

CHỈ ĐỊNH CPET

1. Đánh giá hiệu quả của chương trình can thiệp
2. Cá thể hóa chương trình tập luyện
3. Chẩn đoán nguyên nhân khó thở khi gắng sức
4. Đánh giá trước khi trở lại tập luyện sau bệnh lý cấp (Covid-19, VCT, VMNT…)

CHỈ ĐỊNH CPET

5. Xác định overtraining

6. Đánh giá không dung nạp gắng sức và mức độ tàn tật

7. Phân biệt tim VĐV & BCT giai đoạn sớm

8. Tiên lượng bệnh tật & tử vong

(J Sports Med Phys Fitness 2023;63:873-90)

9. Tất cả VĐV thi đấu (nhất là VĐV đỉnh cao)

(Liên đoàn các Hội Y học thể thao Châu Âu)

CHỐNG CHỈ ĐỊNH CPET

Hội chứng vành cấp

Ngất

Rối loạn nhịp chưa kiểm soát

Suy tim mất bù

Phù phổi cấp

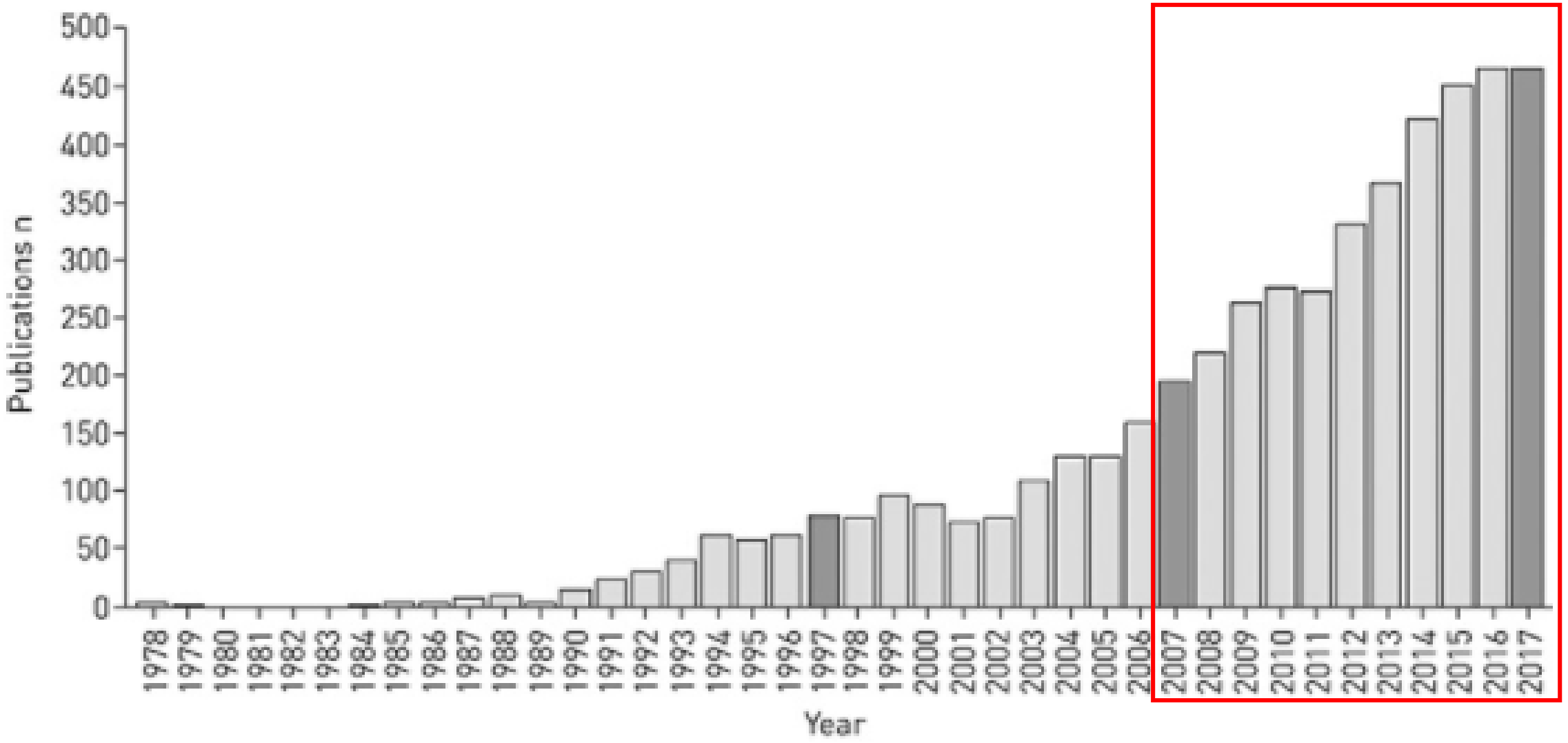
Nghi phình ĐMC

Suy thận cấp

Cường giáp chưa điều trị

Nhiễm trùng cấp

Hẹp van tim nặng


Publications n
500
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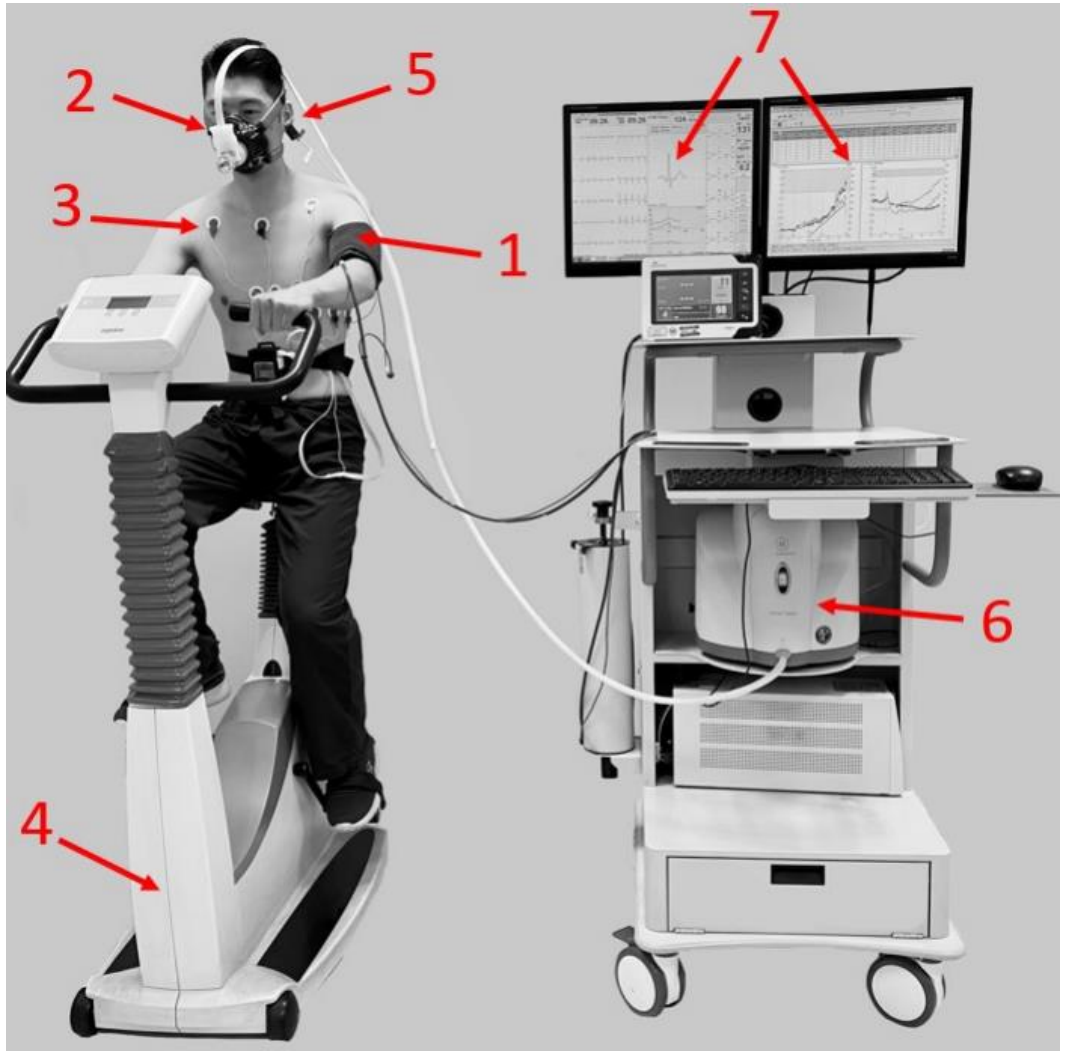
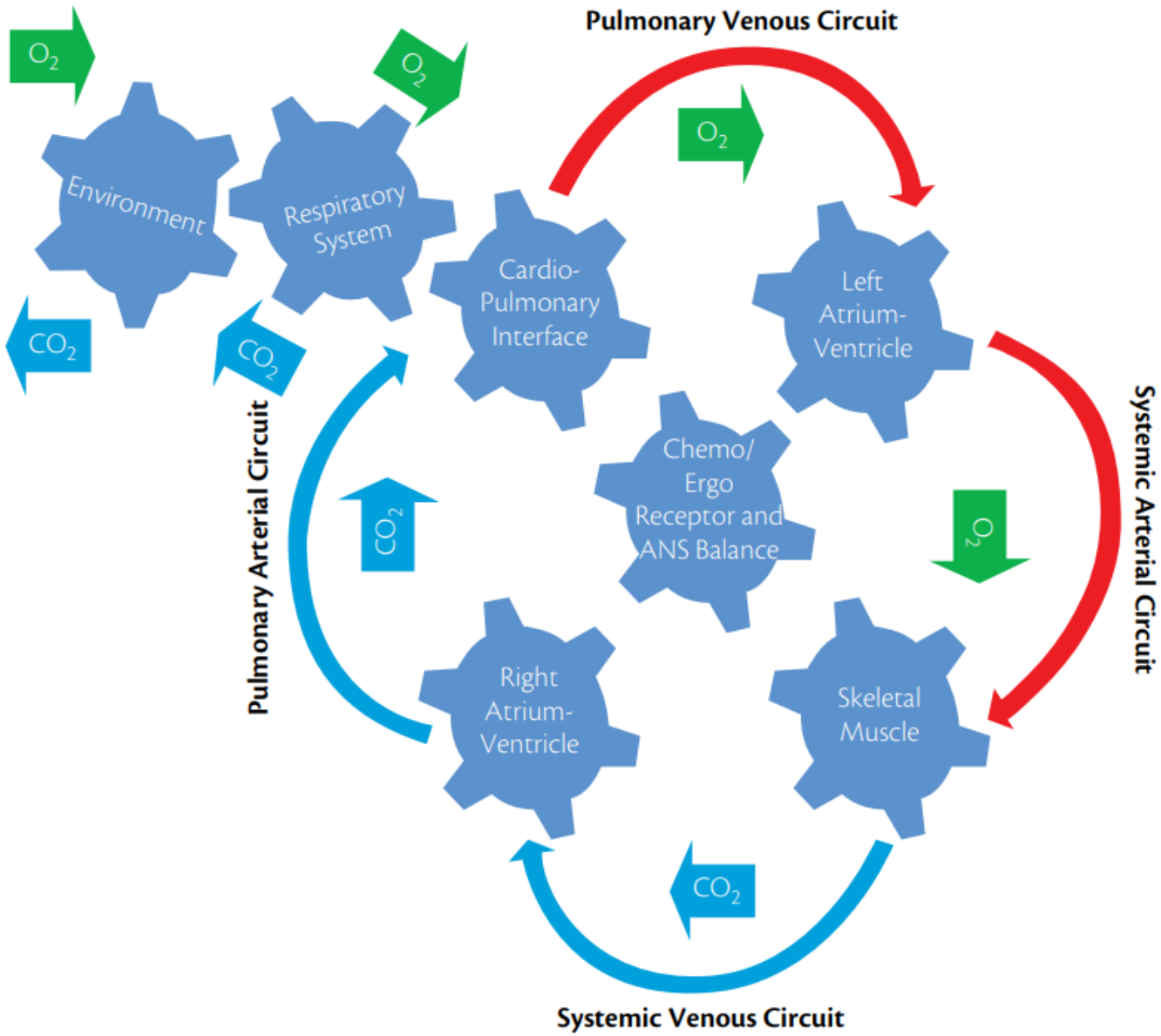
2. TỔNG QUAN VỀ CPET

GIỚI THIỆU CPET

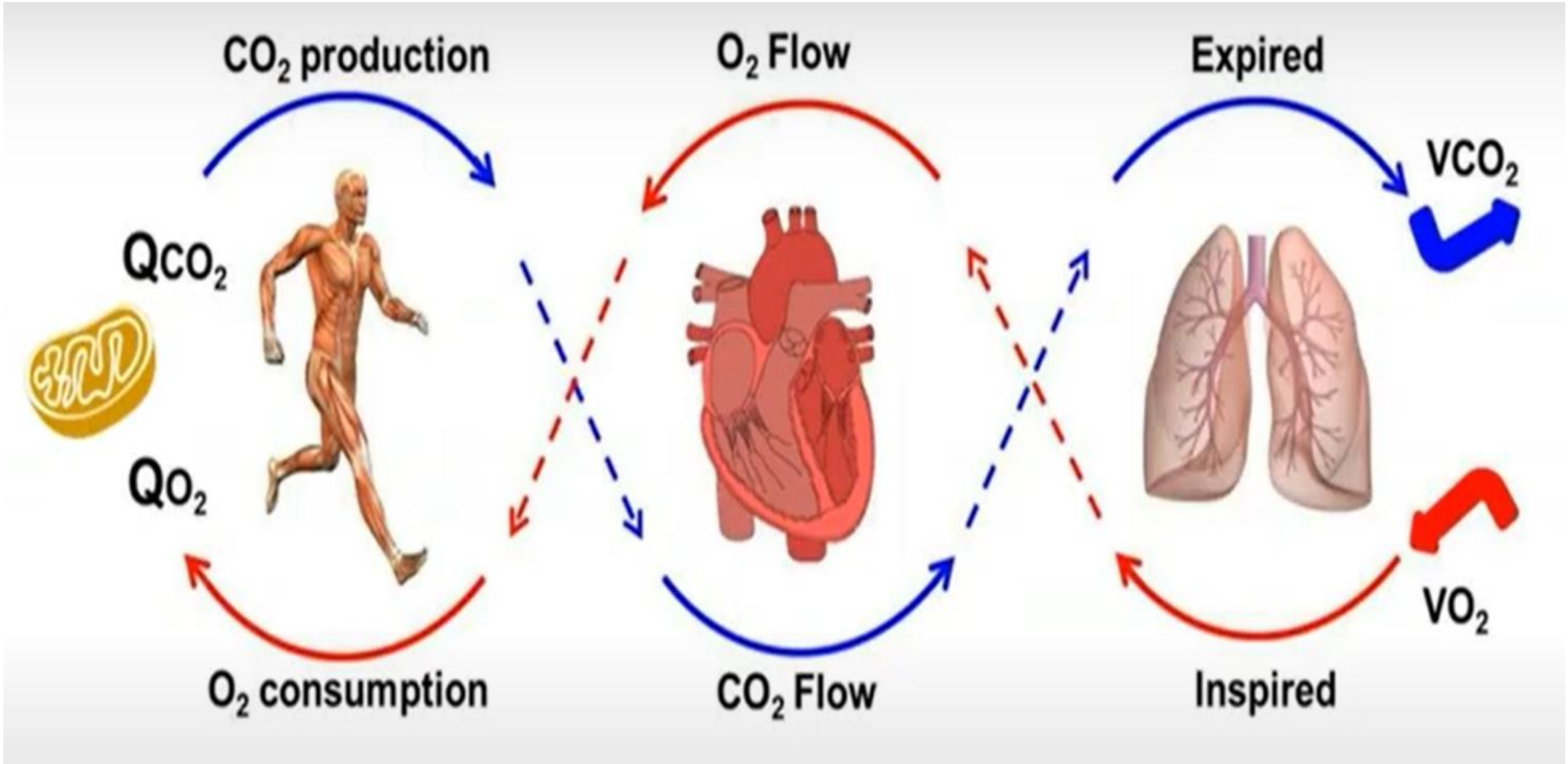


- Test thử thách, dựa trên chứng cứ
- Được Hoa Kỳ và Châu Âu ủng hộ > 50 năm
- Nhân sự, cơ sở trang bị đầy đủ thiết bị hồi sinh tim phổi nâng cao

NGUYÊN LÝ CPET



QUI TRÌNH TẠO NĂNG LƯỢNG KHI VẬN ĐỘNG



CÁC THÔNG SỐ CPET CHÍNH

CPET-derived parameters for the evaluation of cardiovascular response

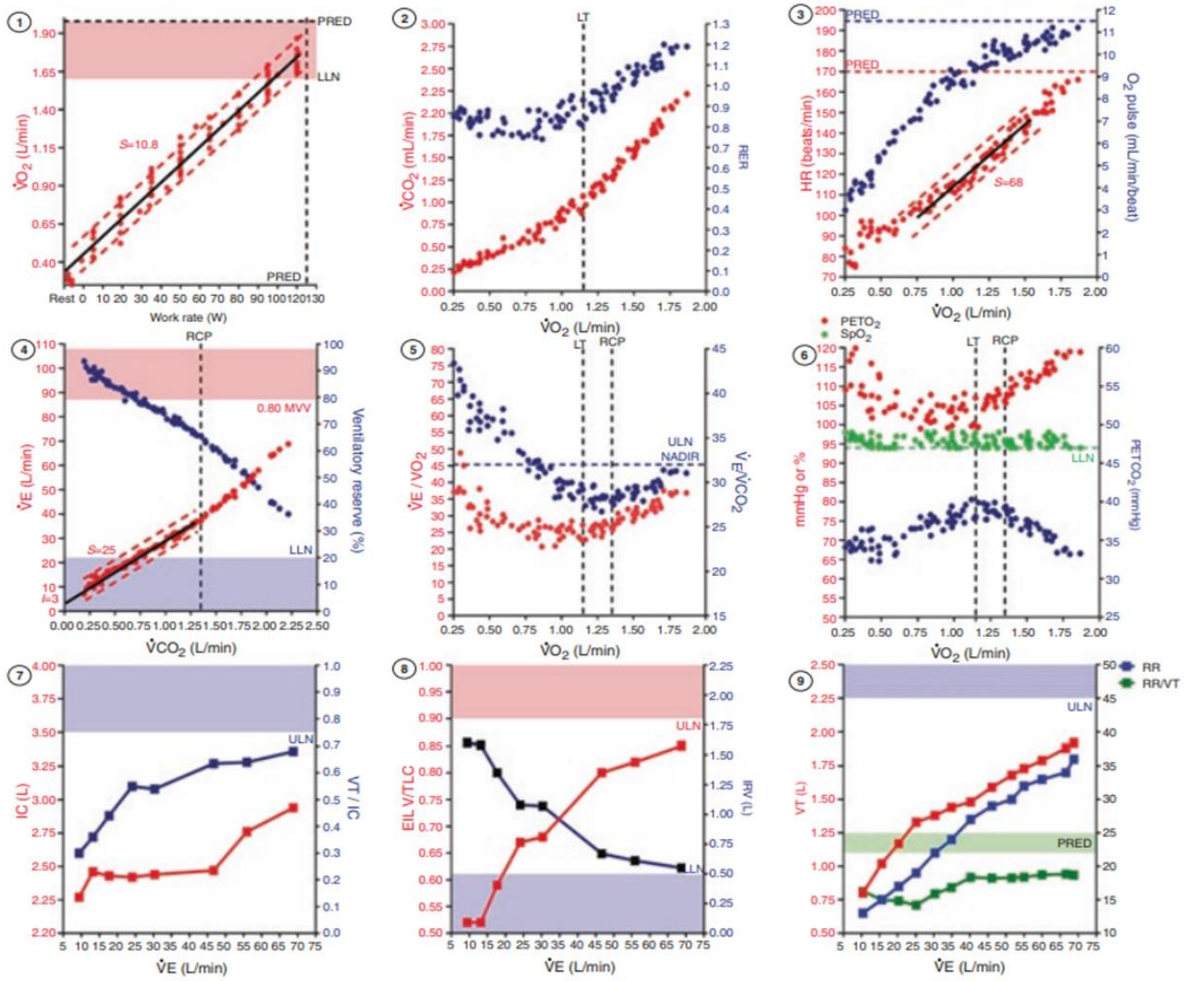
Main CPET-derived parameters

Traditional ergometric test parameters

- Blood pressure
- Heart rate
- ECG during exercise

- VO_2
- VCO_2
- V_E

- VO_2/HR
- VO_2/WR
- V_E/VCO_2 slope



THÔNG SỐ CHUYỂN HÓA

Thông số	Diễn giải	Đỉnh gs
VO_2	Lượng oxy tiêu thụ	≥ 84%
WR	Tải	≥ 80%
$\Delta VO_2/\Delta WR$	Mối liên hệ VO_2 và tải	Slope: 10
RER	Tỷ lệ trao đổi hô hấp (VCO_2/VO_2)	≥ 1,1
VO_2 at VT_1	Lượng oxy tiêu thụ tại ngưỡng thông khí 1	≥ 40%

ATS/ACCP Statement on Cardiopulmonary Exercise Testing, 2001

THÔNG SỐ TIM MẠCH

Thông số	Diễn giải	Đỉnh gs
HR	Biến thiên tần số tim và tần số tim tối đa	≥ 85%
Recovery at 1 min	Tần số tim ở phút thứ nhất của giai đoạn hồi phục	≥ 12
HA	Biến thiên HA và HA tại đỉnh gắng sức	< 225/90
O_2pulse	Lượng oxy cho 1 nhịp tim	≥ 80%
HR Reserve	Dự trữ tần số tim	± 15
Chronotropic Index (CI)		≥ 0,8
$\Delta HR/\Delta VO_2$	Mối liên hệ giữa tần số tim và lượng oxy tiêu thụ	

ATS/ACCP Statement on Cardiopulmonary Exercise Testing, 2001

THÔNG SỐ THÔNG KHÍ

Thông số	Diễn giải	Đỉnh gs
VR	Dự trữ thông khí	≥ 20%
RR	Tần số hô hấp	< 60
Flow Volume Loop	Đường cong lưu lượng thể tích	

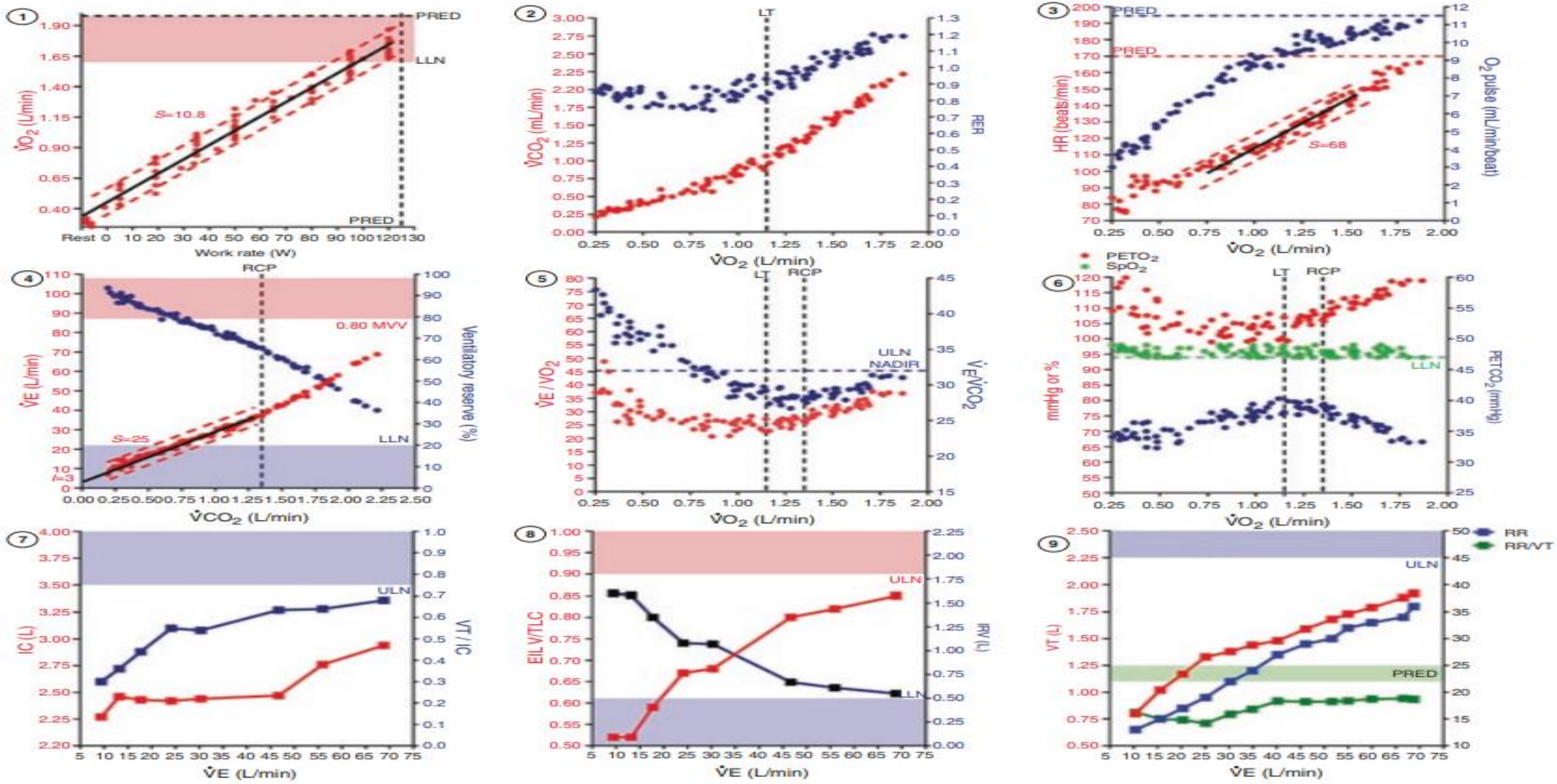
ATS/ACCP Statement on Cardiopulmonary Exercise Testing, 2001

THÔNG SỐ TRAO ĐỔI KHÍ

Thông số	Diễn giải	Đỉnh gs
VD/Vt	Tỷ lệ thông khí khoảng chết/thể tích khí lưu thông	
VEqCO$_2$	Tương đương thông khí CO$_2$	< 30
VEqO$_2$	Tương đương thông khí oxy	
PETCO$_2$	Áp lực riêng phần CO$_2$ cuối thì thở ra	
PETO$_2$	Áp lực riêng phần O$_2$ cuối thì thở ra	
SpO$_2$	Độ bão hòa oxy theo mạch đập	

ATS/ACCP Statement on Cardiopulmonary Exercise Testing, 2001

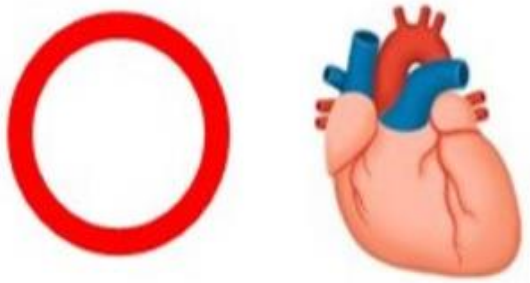
ĐÁP ỨNG SINH LÝ BÌNH THƯỜNG KHI GẮNG SỨC



3. ĐÁP ỨNG CPET Ở VĐV

ATHLETE HEART

NORMAL HEART

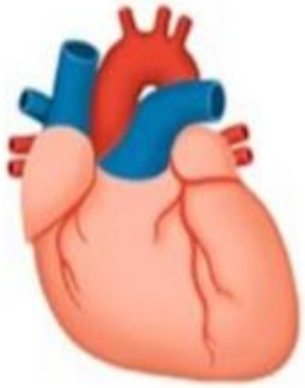


ENDURANCE-TRAINING

\+ LV Wall thickening
++ LV Volume

STRENGTH-TRAINING

++ LV Wall thickening
\+ LV Volume



- Gia tăng lành tính khối lượng tim, với những thay đổi chuyên biệt về hình dạng tim và tuần hoàn, thể hiện sự đáp ứng về mặt sinh lý với việc tập luyện có hệ thống

LV = Left Ventricle

PHYSIOLOGICAL HYPERTROPHY
(Mongaroth 1975)

Morganroth´s cardiac hypertrophy hypothesis (1975)

ẢNH HƯỞNG CÚA MÔN THỂ THAO ĐẾN THAM SỐ CPET

TABLE III.—*Types of sport disciplines and relative effects on CPET-derived parameters. Modified from Pelliccia* et al.[22, 23]

	Skill	Power	Mixed	Endurance
				
HR	Mild-to-moderate increase	Moderate-to-huge increase	Moderate-to-huge increase	Very huge increase
BP	Mild-to-moderate increase	Very huge increase	Moderate-to-huge increase	Moderate-to-huge increase
CO	Mild increase	Mild-to-moderate increase	Moderate-to-huge increase	Very huge increase
VO_2	No significant change	Mild-to-moderate increase	Moderate-to-huge increase	Very huge increase
VO_2/HR	No significant change	Mild-to-moderate increase	Moderate increase	Moderate-to-huge increase
VO_2/WR slope	No significant change	Mild-to-moderate increase	Moderate increase	Moderate-to-huge increase
V_E/VCO_2 slope	No significant change	No significant change	No significant change	No significant change
Cardiac remodeling	No significant change	Moderate increase	Moderate-to-huge increase	Very huge increase

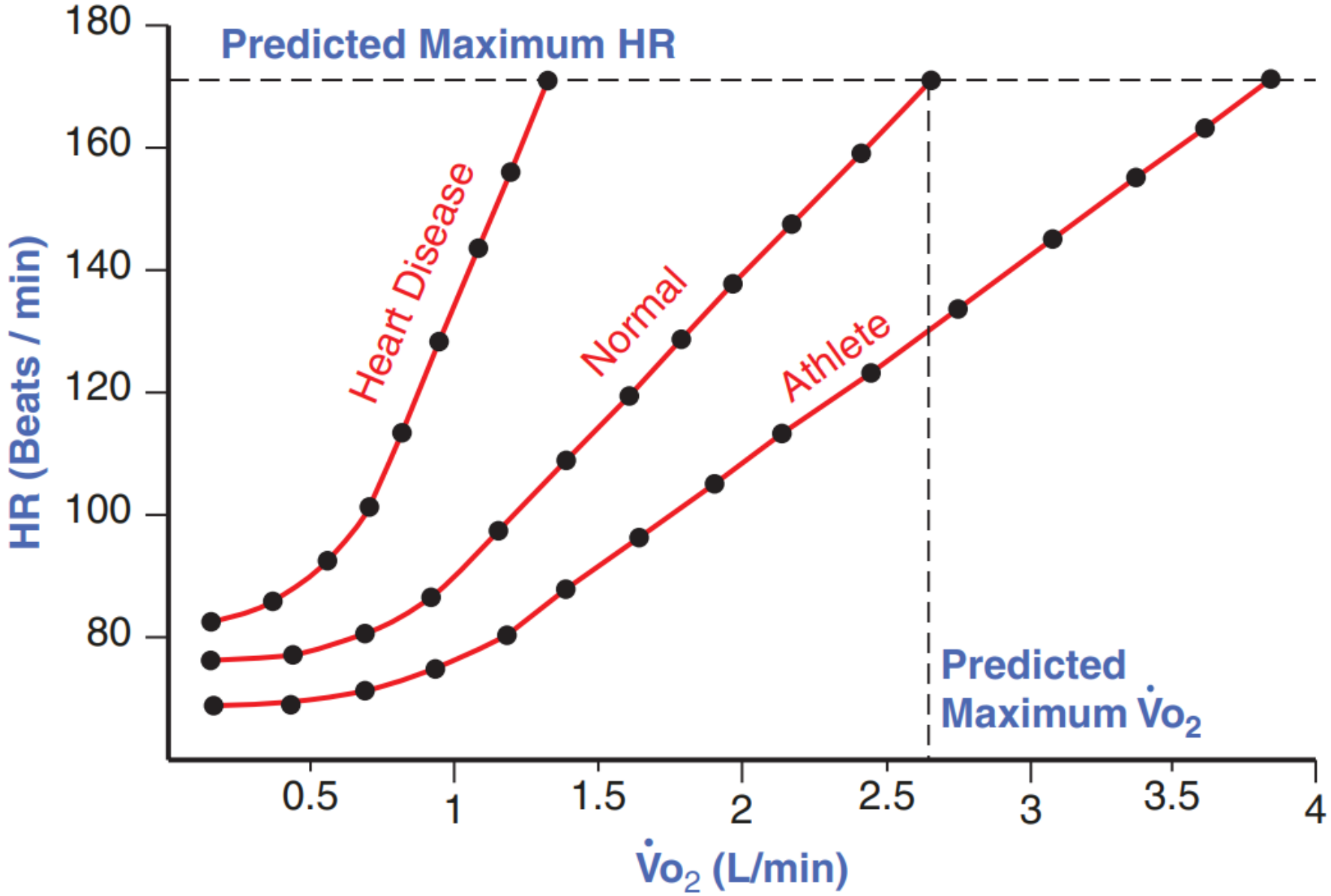
	Skill	Power	Mixed	Endurance
				
LOW	Golf (buggy)	Shot putting	Soccer (adapted)	Jogging
	Golf (18 holes walking)	(recreational)	Basketball (adapted)	Long distance walking
	Table tennis (double)	Discus (recreational)	Handball (adapted)	Swimming (recreational)
	Table tennis (single)	Alpine skiing	Volleyball	Speed walking
	Shooting	(recreational)	Tennis (double)	Mid/long distance running
MEDIUM	Curling	Short distance running	Ice-Hockey	Style dancing
	Bowling	Shot putting	Hockey	Cycling (road)
	Sailing	Discus	Rugby	Mid/long distance swimming
	Yachting	Alpine skiing	Fencing	Long distance skating
	Equestrian	Judo/karate	Tennis (single)	Pentathlon
HIGH		Weight lifting	Waterpolo	Rowing
		Wrestling	Soccer (competitive)	Canoeing
		Boxing	Basketball (competitive)	X-country skiing
			Handball (competitive)	Biathlon
				Triathlon

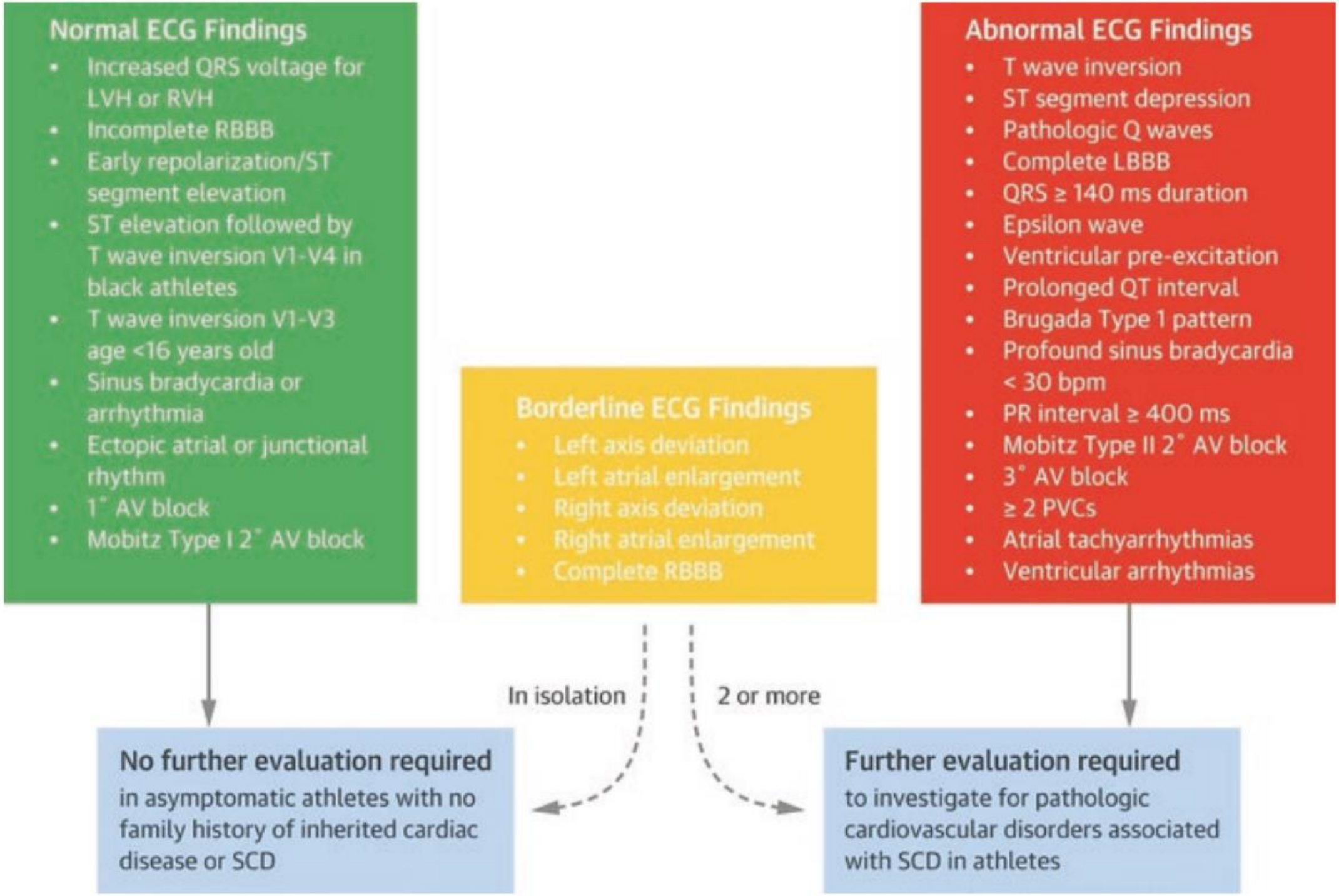
Low intensity

Medium intensity

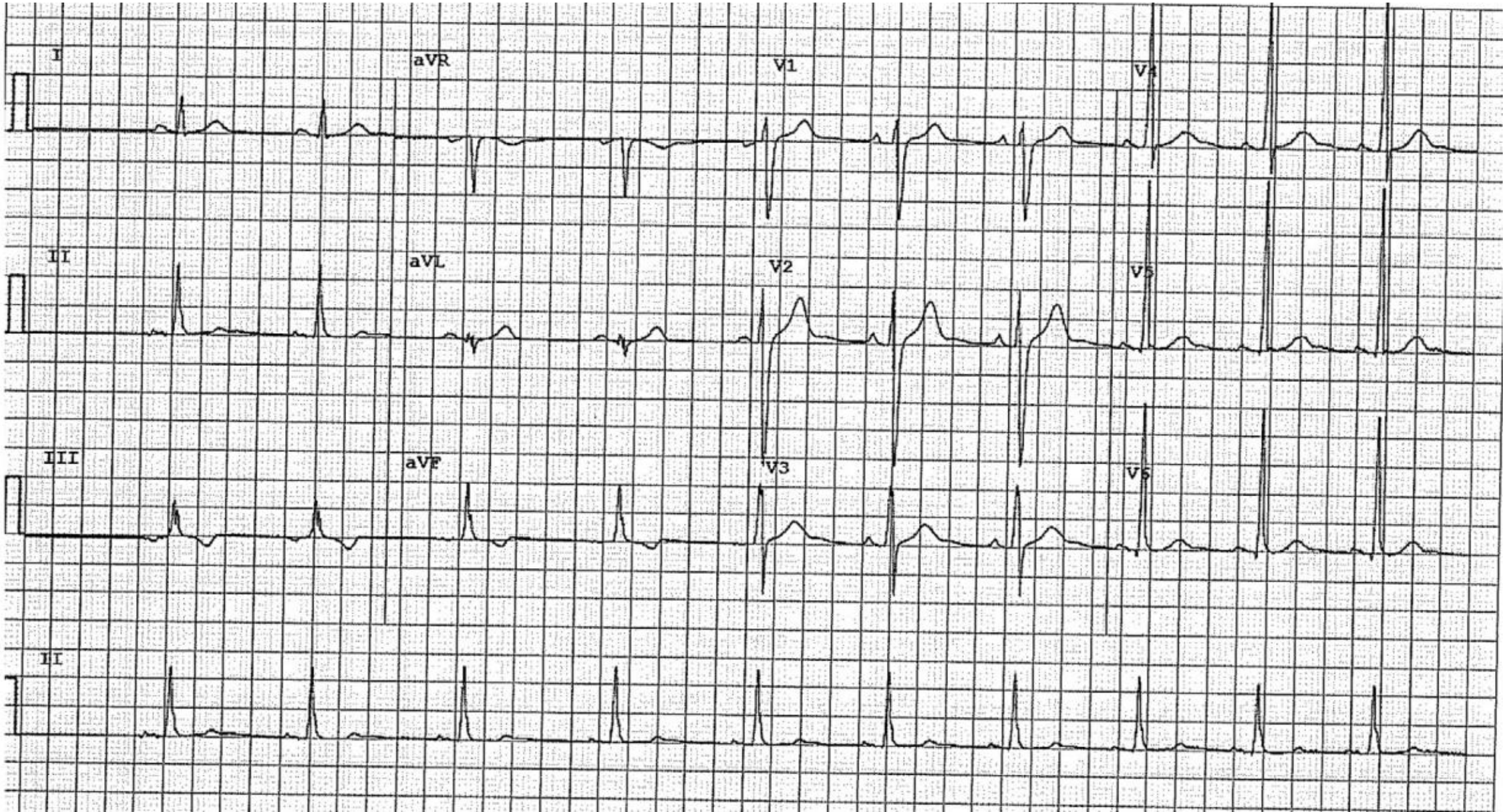
High intensity

TẦN SỐ TIM

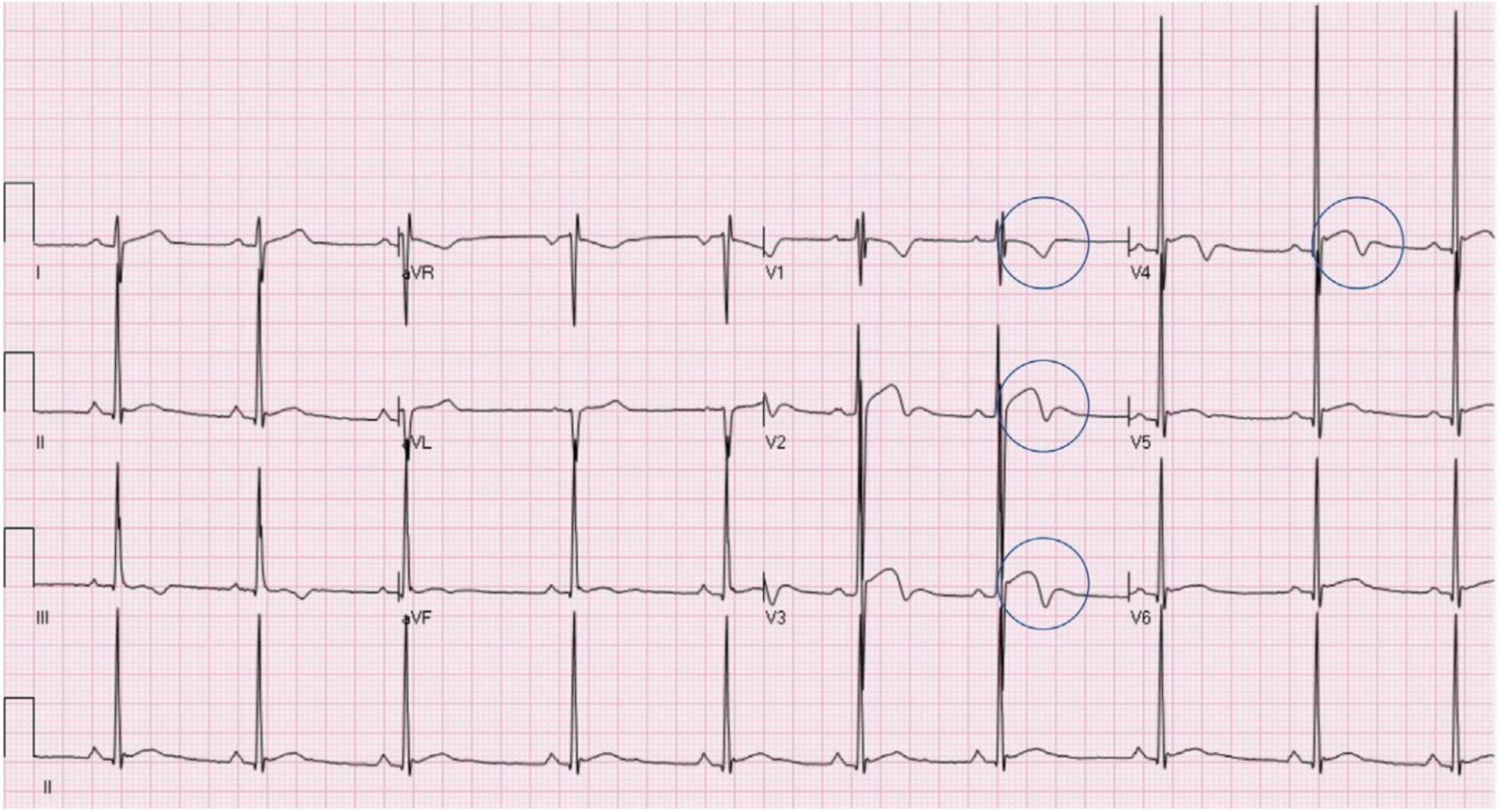

Predicted Maximum HR
Heart Disease
Normal
Athlete
Predicted
Maximum V̇O2
HR (Beats / min)
V̇O2 (L/min)
180
160
140
120
100
80
0.5
1
1.5
2
2.5
3
3.5
4


Normal ECG Findings
• Increased QRS voltage for LVH or RVH
• Incomplete RBBB
• Early repolarization/ST segment elevation
• ST elevation followed by T wave inversion V1-V4 in black athletes
• T wave inversion V1-V3 age <16 years old
• Sinus bradycardia or arrhythmia
• Ectopic atrial or junctional rhythm
• 1° AV block
• Mobitz Type I 2° AV block
Borderline ECG Findings
• Left axis deviation
• Left atrial enlargement
• Right axis deviation
• Right atrial enlargement
• Complete RBBB
Abnormal ECG Findings
• T wave inversion
• ST segment depression
• Pathologic Q waves
• Complete LBBB
• QRS ≥ 140 ms duration
• Epsilon wave
• Ventricular pre-excitation
• Prolonged QT interval
• Brugada Type 1 pattern
• Profound sinus bradycardia < 30 bpm
• PR interval ≥ 400 ms
• Mobitz Type II 2° AV block
• 3° AV block
• ≥ 2 PVCs
• Atrial tachyarrhythmias
• Ventricular arrhythmias
In isolation
2 or more
No further evaluation required
in asymptomatic athletes with no family history of inherited cardiac disease or SCD
Further evaluation required
to investigate for pathologic cardiovascular disorders associated with SCD in athletes

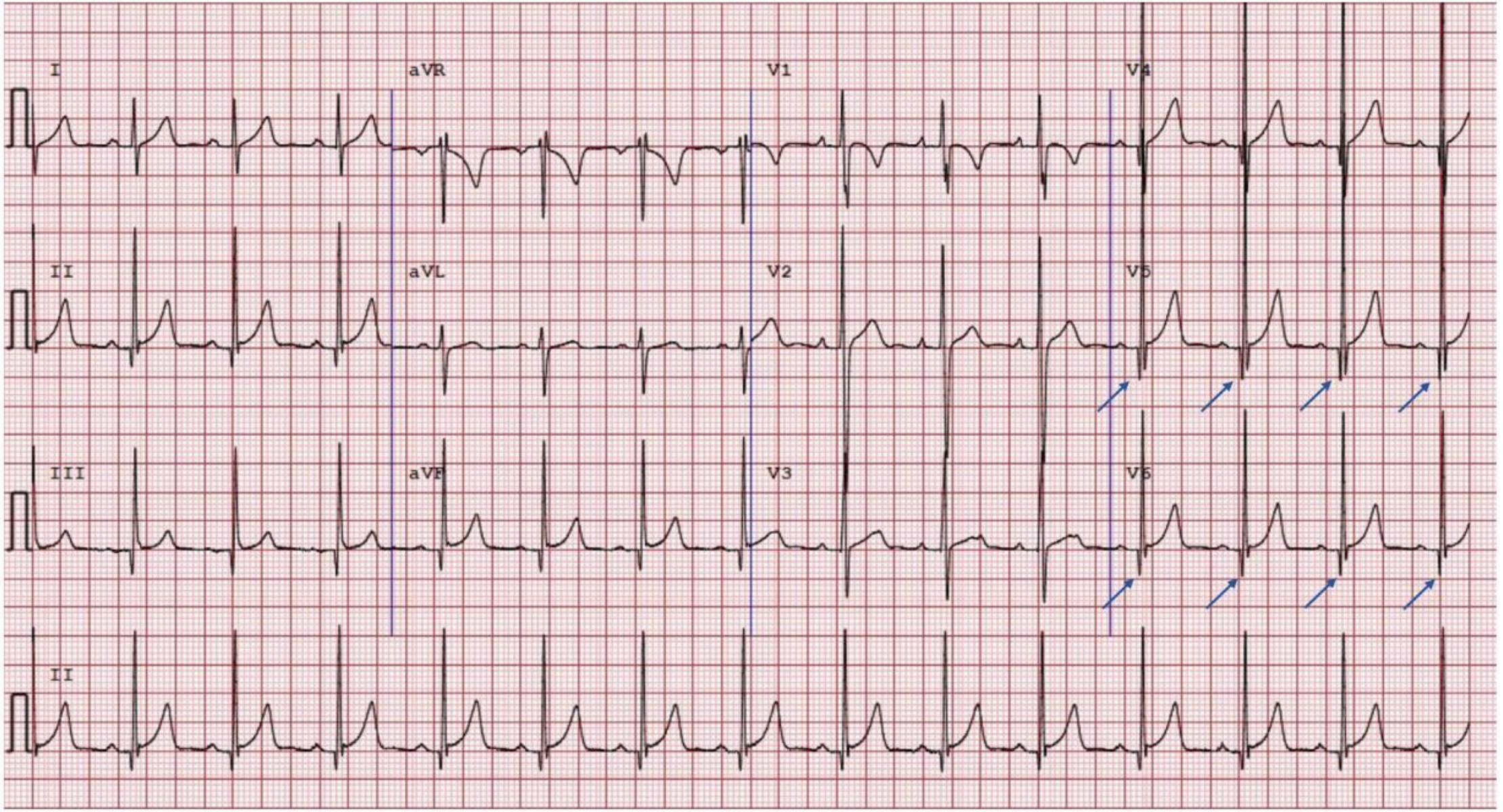
BIẾN ĐỔI TRÊN ECG



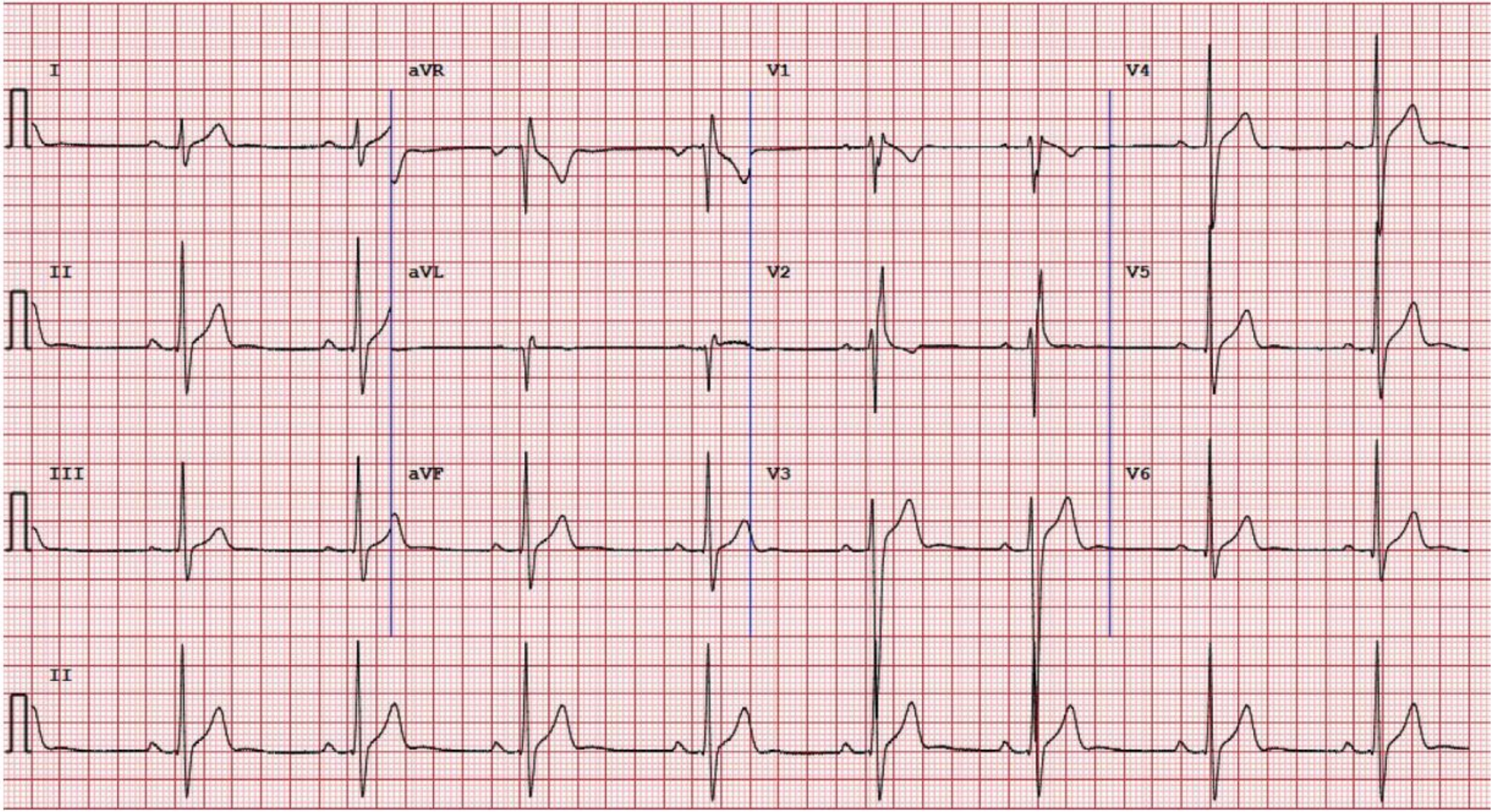
BIẾN ĐỔI TRÊN ECG



BIẾN ĐỔI TRÊN ECG



BIẾN ĐỔI TRÊN ECG



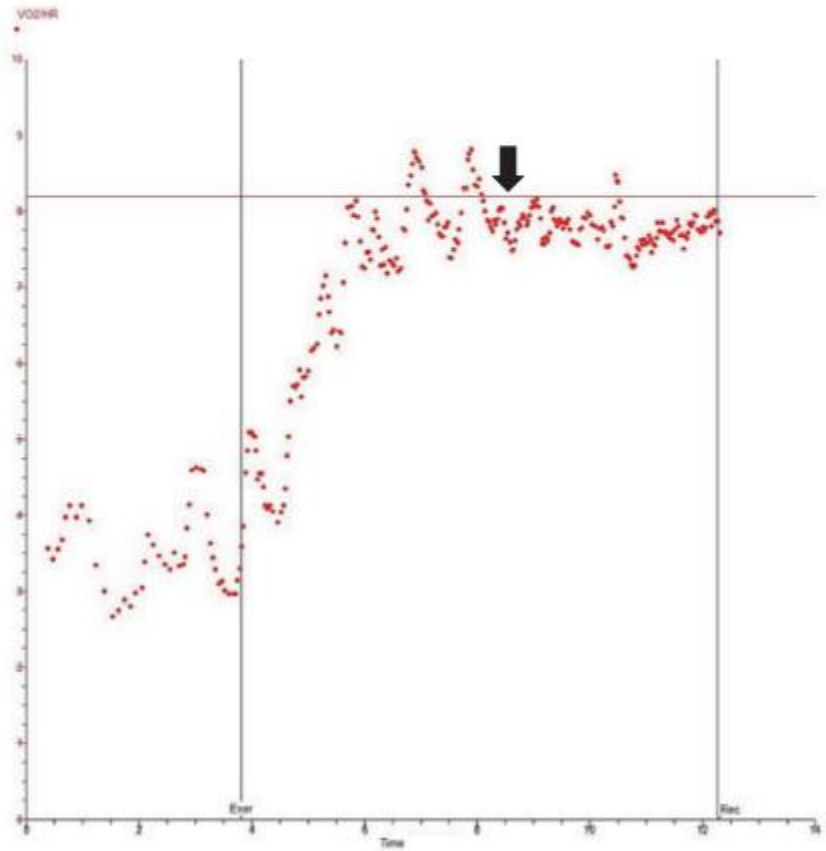
CHRONOTROPIC INDEX

The chronotropic index (CI) is a comparison of the HR reserve to metabolic reserve at peak exercise and is essentially the slope in the relationship between HR to VO2 trajectory

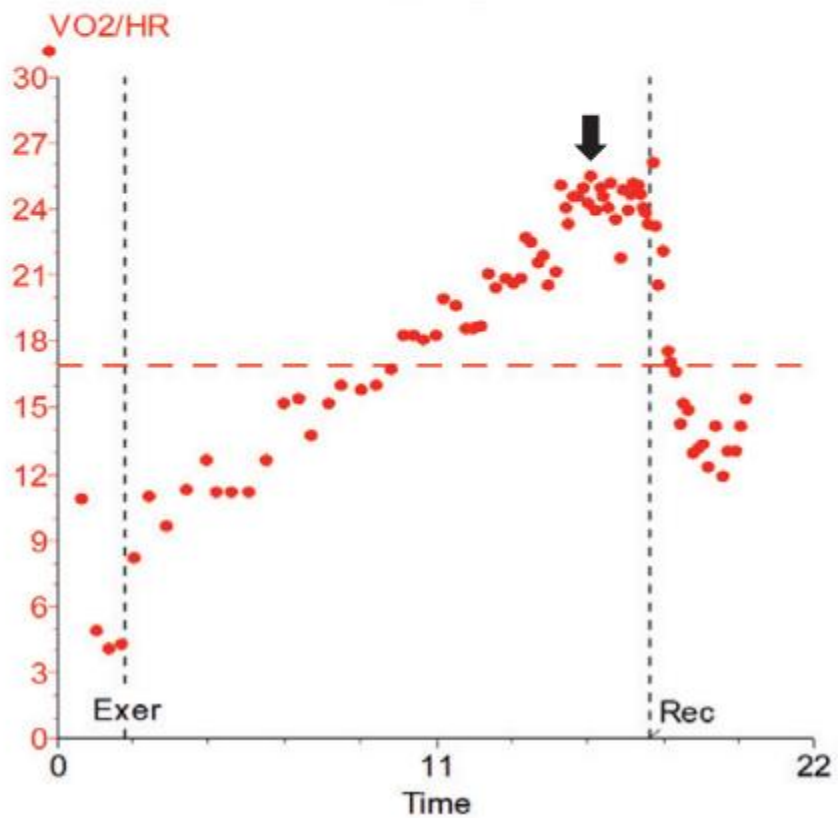
$$Chronotropic\ Index\ (CI) = \frac{\left(\frac{Peak\ HR - Baseline\ HR}{Predicted\ peak\ HR - Baseline\ HR}\right)}{\left(\frac{Peak\ V\dot{O}2 - Baseline\ V\dot{O}2}{Predicted\ Peak\ V\dot{O}2 - Baseline\ V\dot{O}2}\right)}$$

BÌNH NGUYÊN O_2pulse

O2 pulse plateau below peak V̇O2 in a nonathlete



O2 pulse plateau near V̇O2 peak in an athlete

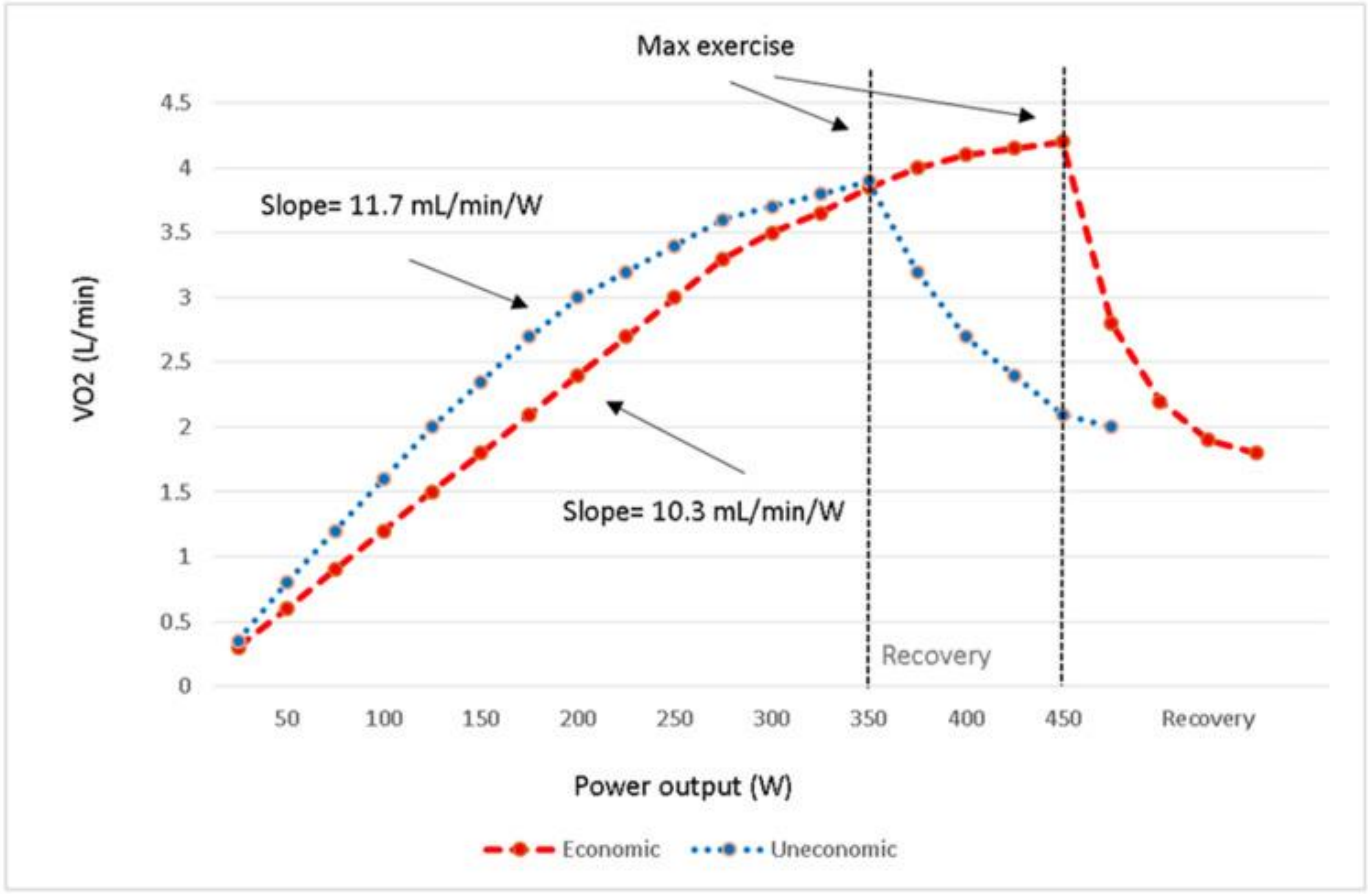


GIẢM OXY MÁU DO GẮNG SỨC

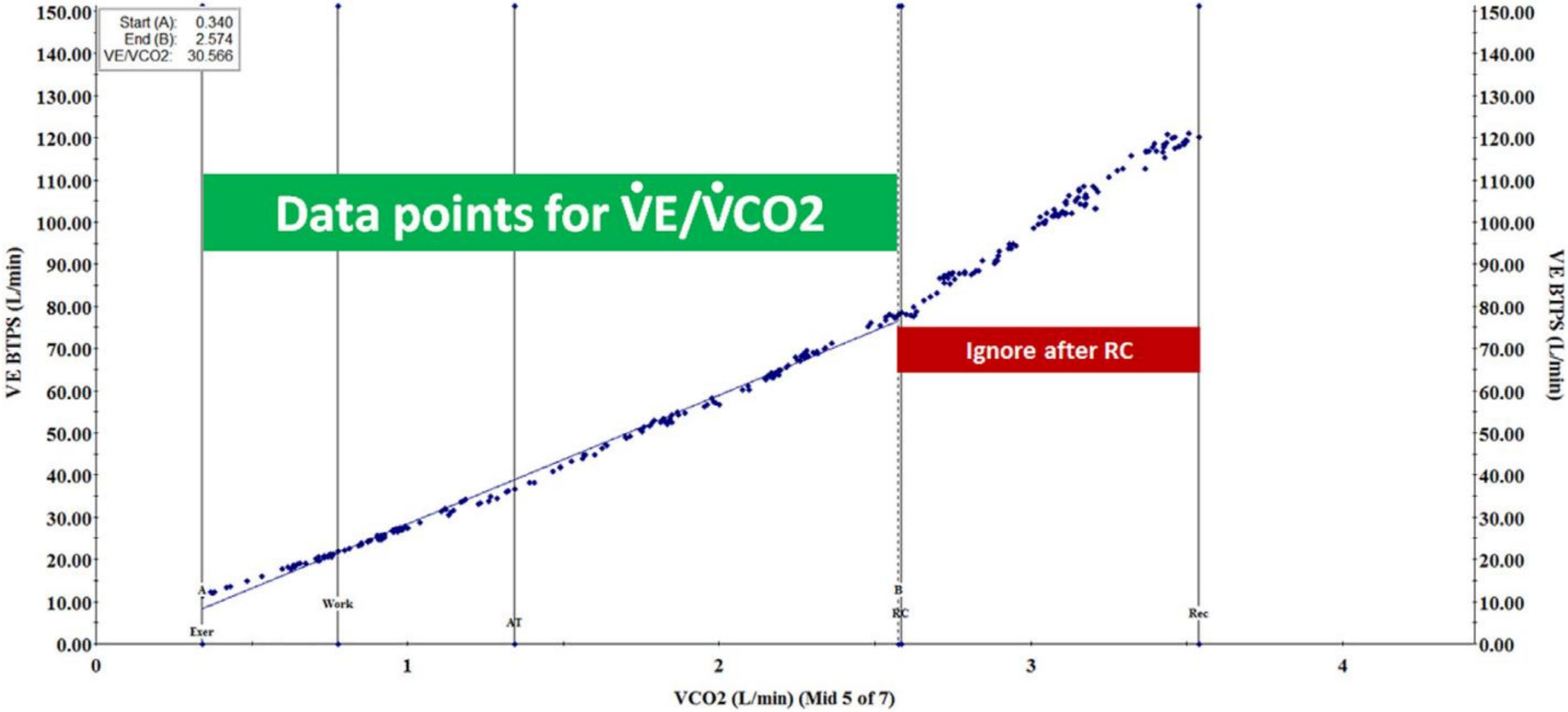
- SpO2 ≤ 95% hoặc giảm ≥ 3% so với giá trị lúc nghỉ
- Ở gần hoặc ngay đỉnh gắng sức tối đa, thảm lăn >> đạp xe
- Cơ chế thứ phát, do chênh áp $P(A\text{-}a)O_2$ quá mức kết hợp với giảm thông khí và sự dịch chuyển sang phải do pH axit của đường cong Hgb-O_2
- Không triệu chứng + khả năng gắng sức siêu đẳng + giảm SpO2 ở gần thời điểm gắng sức tối đa + độ dốc hoặc điểm thấp nhất của VE/VCO_2 bình thường + cấu trúc tim bình thường trên hình ảnh (hoặc phù hợp với việc tái cấu trúc tim do gắng sức)
- Máy đo SpO_2 chất lượng cao

Exercise economy

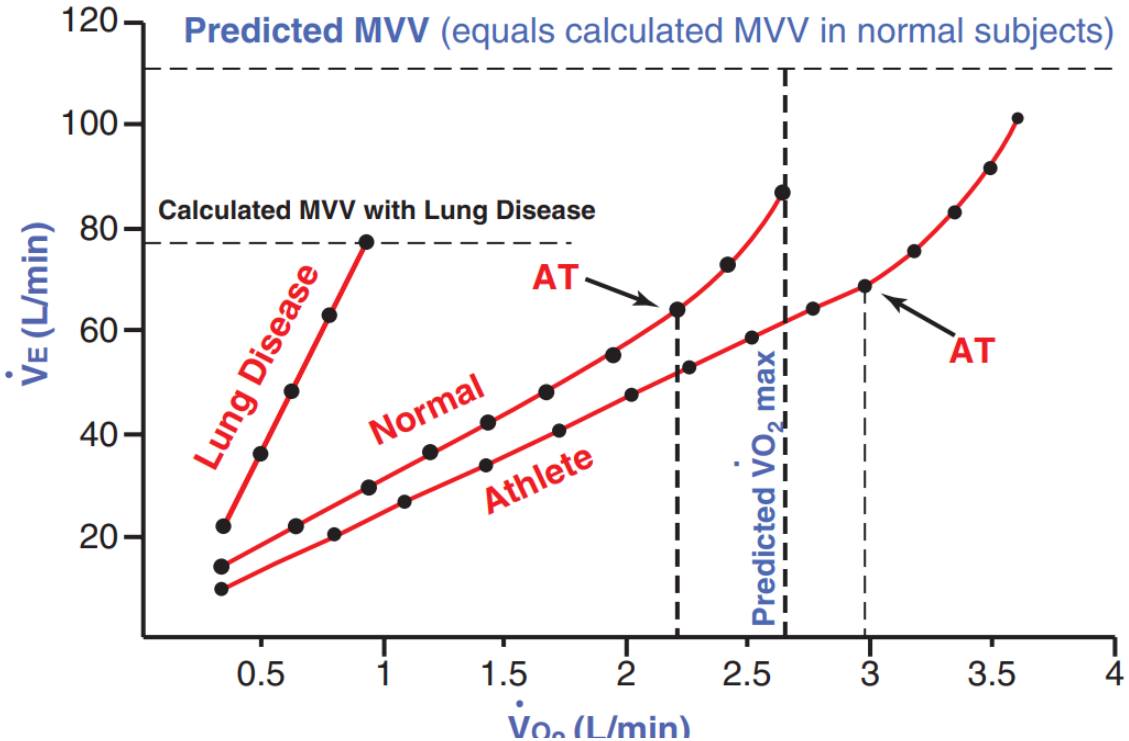
- Là mức tiêu hao năng lượng cho cường độ tập luyện tuyệt đối nhất định
- Thể hiện tính kinh tế của việc tập luyện và là thước đo gián tiếp về cung lượng tim và ATP được tạo ra trong quá trình tập luyện
- Bình thường: độ dốc trung bình là 10 mL/phút/W

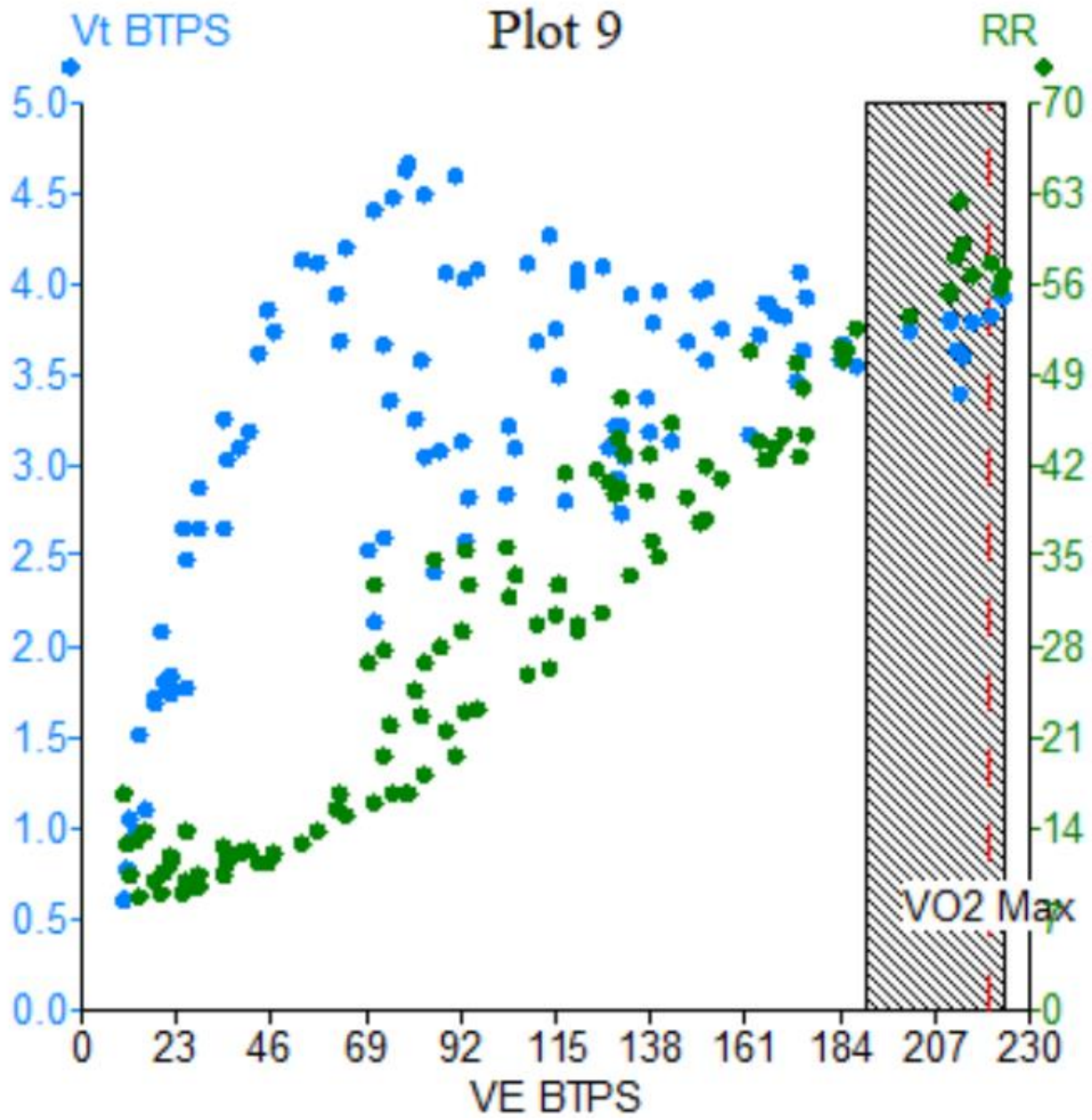


$VEqCO_2$


Start (A): 0.340
End (B): 2.574
VE/VCO2: 30.566
Data points for V̇E/V̇CO2
Ignore after RC
VE BTPS (L/min)
VCO2 (L/min) (Mid 5 of 7)
A
Exer
Work
AT
B
RC
Rec
150.00
140.00
130.00
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
1
2
3
4

Vt, VE & RR


Predicted MVV (equals calculated MVV in normal subjects)
Calculated MVV with Lung Disease
Lung Disease
Normal
Athlete
AT
AT
Predicted VO2 max
V̇E (L/min)
V̇O2 (L/min)
120
100
80
60
40
20
0.5
1
1.5
2
2.5
3
3.5
4


Plot 9
Vt BTPS
RR
VO2 Max
VE BTPS
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
70
63
56
49
42
35
28
21
14
7
0
0
23
46
69
92
115
138
161
184
207
230

4. DIỄN GIẢI KẾT QUẢ CPET

TRÌNH TỰ ĐỌC

1. Chuẩn bị trước đọc
2. Đánh giá HHK cơ bản
3. Đánh giá BN có gắng sức tối đa
4. Đánh giá hạn chế GS
5. Đánh giá đáp ứng tim mạch
6. Đánh giá đáp ứng hô hấp
7. Tóm tắt

CHUẨN BỊ TRƯỚC ĐỌC

- Chỉ định CPET: nguyên nhân KT, mức độ hạn chế gắng sức, đánh giá tiền phẫu, hiệu quả điều trị…
- BS + LS + CLS
- Protocol GS
- Lý do ngừng GS
- Điểm Borg tại thời điểm ngừng GS

TRÌNH TỰ ĐỌC

1. Chuẩn bị trước đọc
2. Đánh giá HHK cơ bản
3. Đánh giá BN có gắng sức tối đa
4. Đánh giá hạn chế GS
5. Đánh giá đáp ứng tim mạch
6. Đánh giá đáp ứng hô hấp
7. Tóm tắt

ĐÁNH GIÁ GS TỐI ĐA

- VO_2 peak
- VE peak
- WR peak
- HR peak
- RER
- Borg

ĐÁNH GIÁ MỨC ĐỘ HẠN CHẾ GS

1. Bình thường:

- VO_2peak > 84%
- WRpeak > 80%

2. Mức độ hạn chế GS:

- Nhẹ
- Trung bình
- Nặng

Altalag et al. Exercise testing (2019) - Springer

ĐÁNH GIÁ ĐÁP ỨNG TIM MẠCH

Normal cardiovascular responses:

- Heart rate increases linearly with VO_2 up to >90% predicted maximum
- BP increases gradually during exercise, but increase in diastolic pressure <20 mmHg
- Peak oxygen pulse (VO_2/HR) >80% predicted and does not plateau early
- AT occurs at >40% of predicted maximal VO_2
- Nadir of V_E/VCO_2 is <34 or slope of V_E versus VCO_2 <32
- No evidence of arrhythmia or ischemic changes on ECG

Uptodate 2021

ĐÁNH GIÁ ĐÁP ỨNG HÔ HẤP

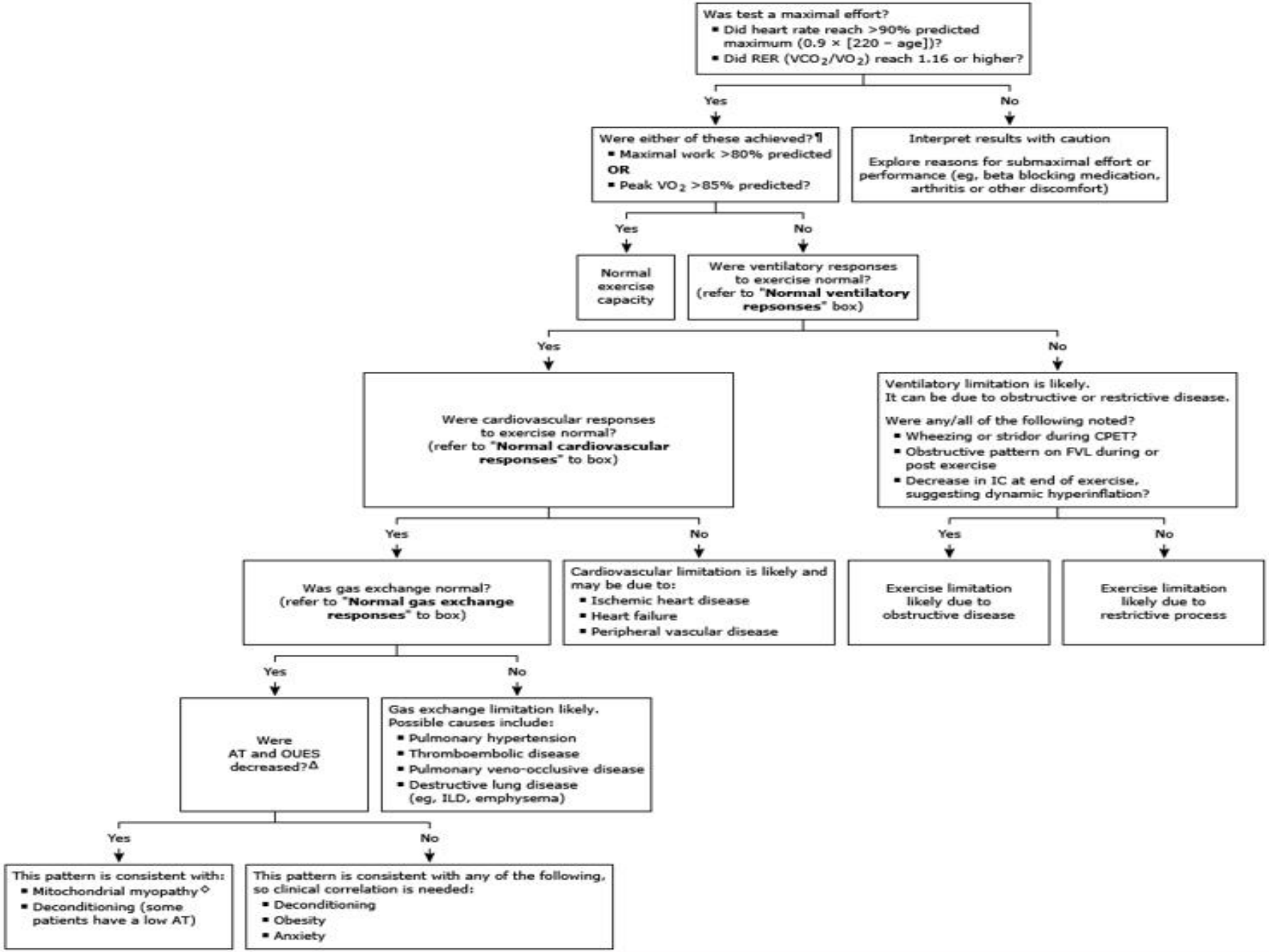
Normal ventilatory repsonses:
▪ Respiratory rate increases throughout exercise ▪ Tidal volume at least doubles over baseline ▪ Tidal volume reaches 50 to 60% of FVC or 70% of IC ▪ Breathing reserve 30 to 40%§ ▪ VD/VT <0.3 to 0.4 at rest and 0.2 with exercise
Normal gas exchange responses:
▪ SaO_2 >96% at rest and minimal or no decrease with exercise ▪ A-a O_2 difference with exercise <35

Uptodate 2021

TÓM TẮT

- Bất thường CPET chính
- Mối liên hệ CPET-LS
- Giải quyết câu hỏi lâm sàng

Our approach to interpretation of cardiopulmonary exercise tests in adults*



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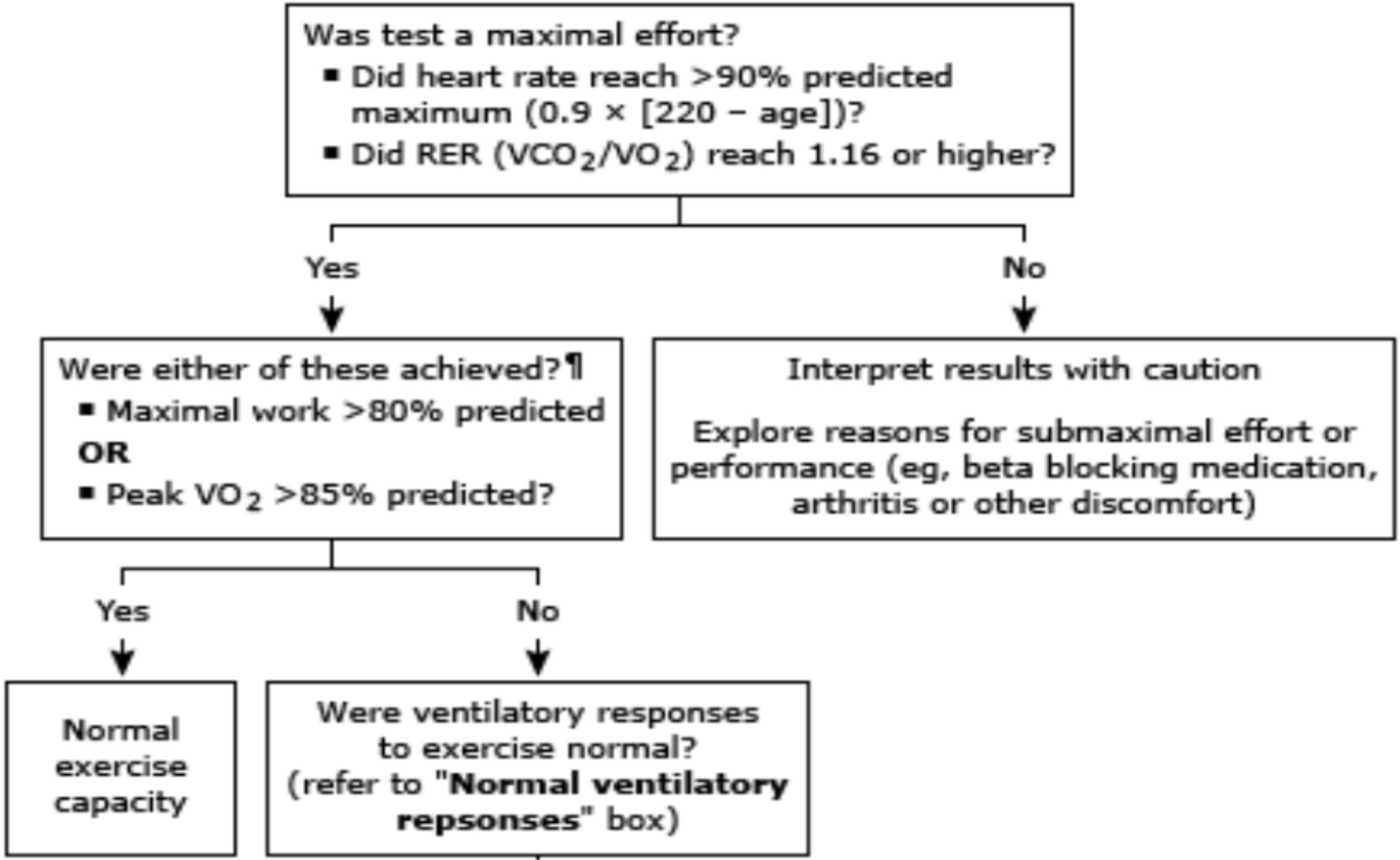
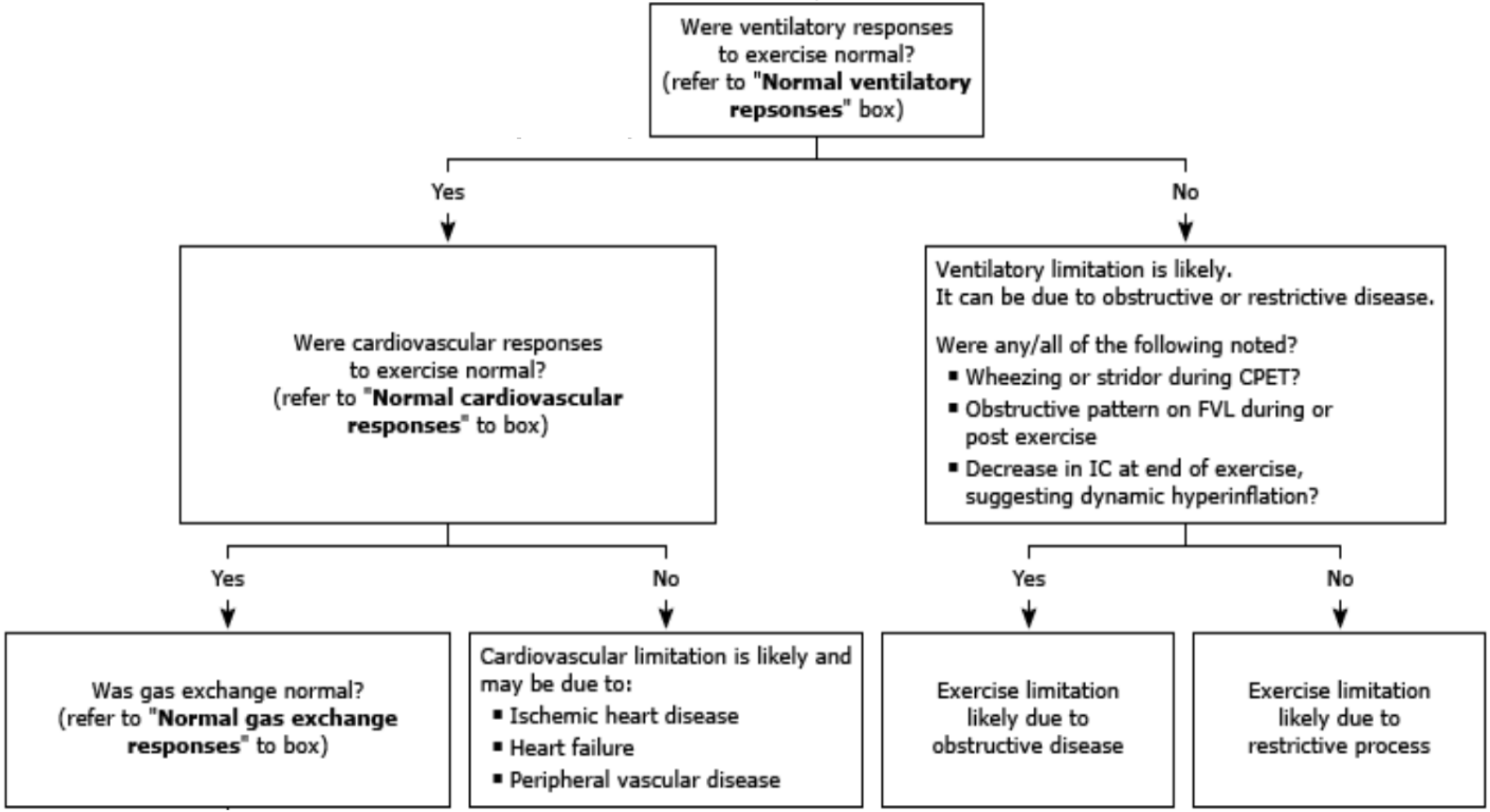
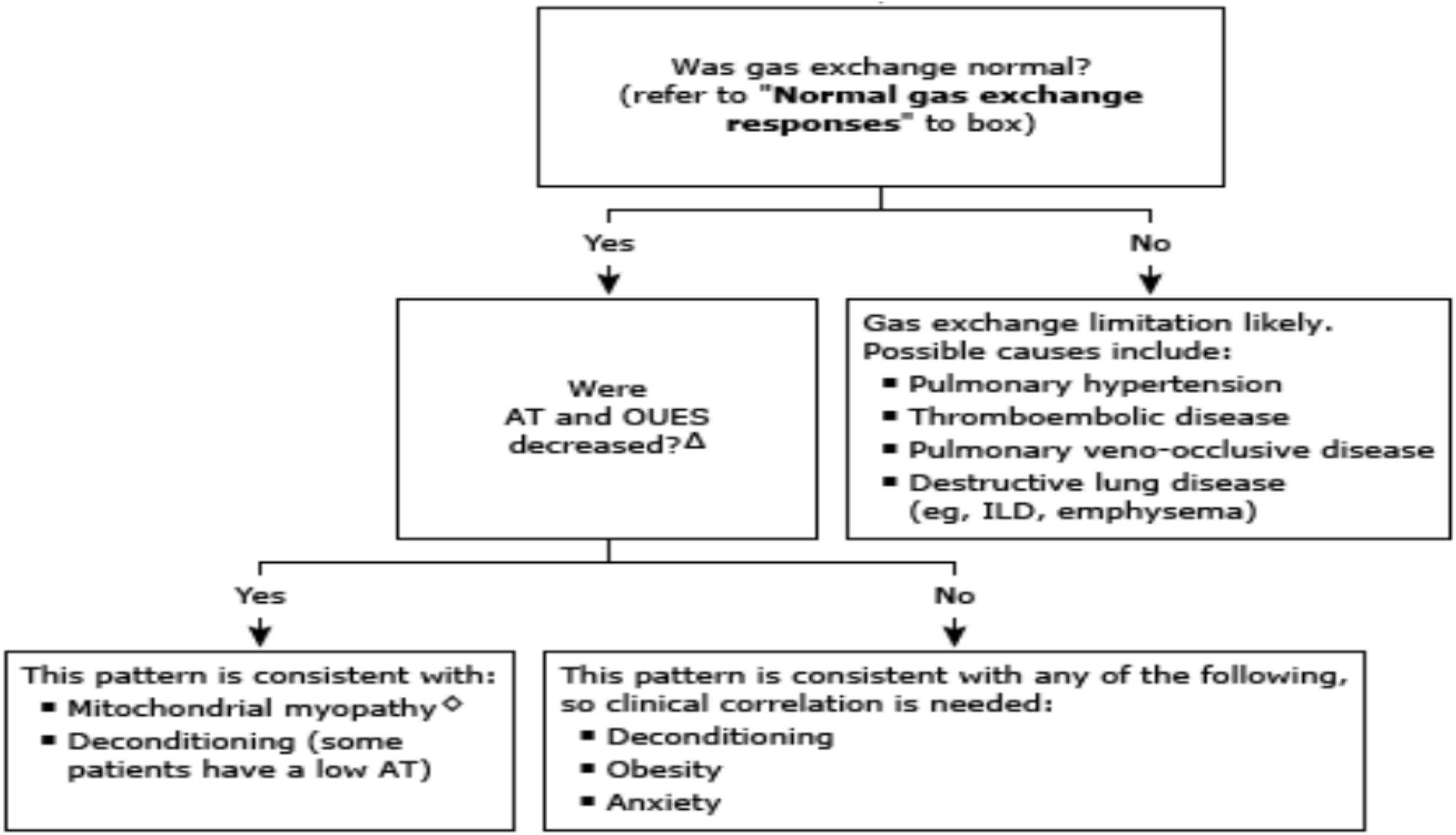

Was test a maximal effort?
Did heart rate reach >90% predicted maximum (0.9 × [220 − age])?
Did RER (VCO_2/VO_2) reach 1.16 or higher?
Yes
No
Were either of these achieved?¶
Maximal work >80% predicted
OR
Peak VO_2 >85% predicted?
Interpret results with caution
Explore reasons for submaximal effort or performance (eg, beta blocking medication, arthritis or other discomfort)
Yes
No
Normal exercise capacity
Were ventilatory responses to exercise normal? (refer to "Normal ventilatory repsonses" box)


Were ventilatory responses to exercise normal? (refer to "Normal ventilatory repsonses" box)
Yes
No
Were cardiovascular responses to exercise normal? (refer to "Normal cardiovascular responses" to box)
Ventilatory limitation is likely.
It can be due to obstructive or restrictive disease.
Were any/all of the following noted?
Wheezing or stridor during CPET?
Obstructive pattern on FVL during or post exercise
Decrease in IC at end of exercise, suggesting dynamic hyperinflation?
Yes
No
Yes
No
Was gas exchange normal? (refer to "Normal gas exchange responses" to box)
Cardiovascular limitation is likely and may be due to:
Ischemic heart disease
Heart failure
Peripheral vascular disease
Exercise limitation likely due to obstructive disease
Exercise limitation likely due to restrictive process


Was gas exchange normal?
(refer to "Normal gas exchange responses" to box)
Yes
No
Were
AT and OUES
decreased?Δ
Gas exchange limitation likely.
Possible causes include:
Pulmonary hypertension
Thromboembolic disease
Pulmonary veno-occlusive disease
Destructive lung disease
(eg, ILD, emphysema)
Yes
No
This pattern is consistent with:
Mitochondrial myopathy◇
Deconditioning (some
patients have a low AT)
This pattern is consistent with any of the following,
so clinical correlation is needed:
Deconditioning
Obesity
Anxiety

5. ỨNG DỤNG CPET/YHTT

Đánh giá hiệu quả chương trình tập luyện

- VO2peak, động học hồi phục VO2, VT1, VT2, HRRecovery

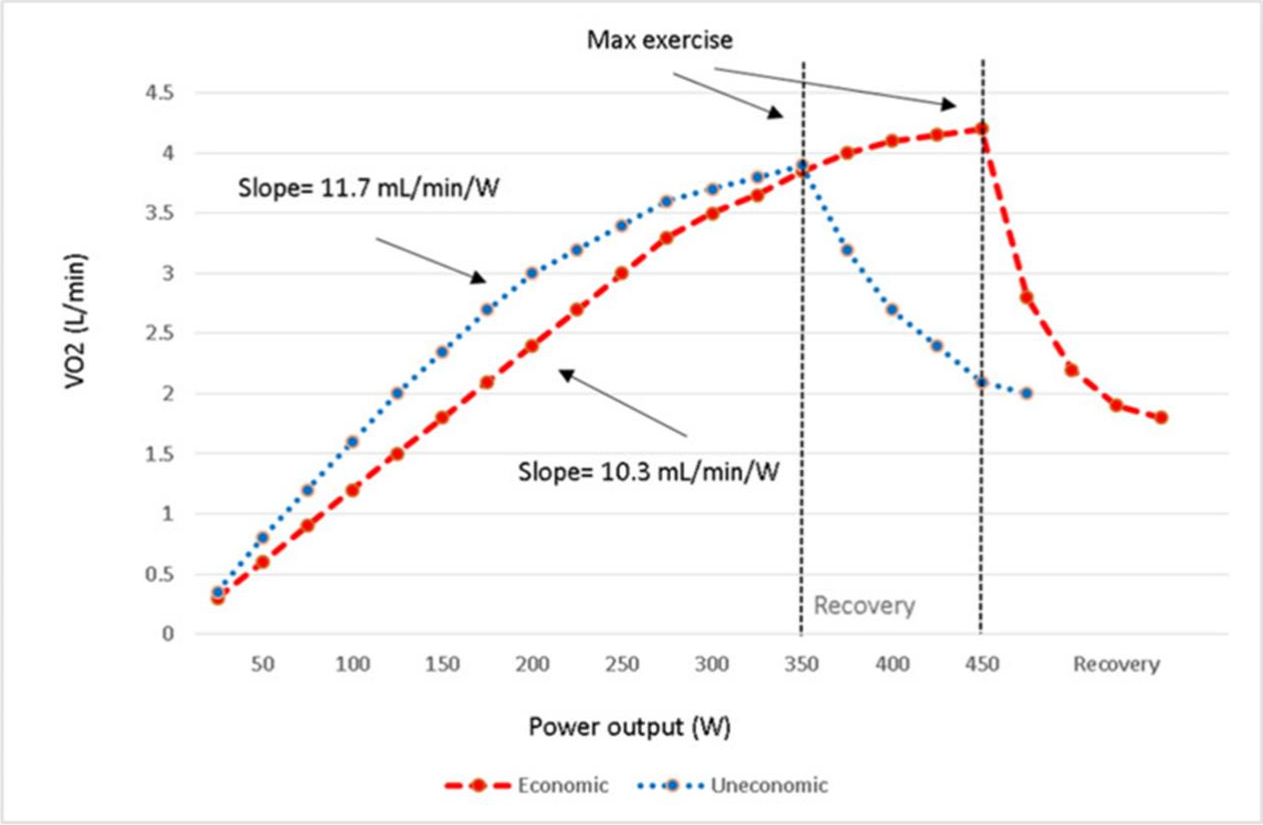
VO2 tại VT1/VO2 dự đoán

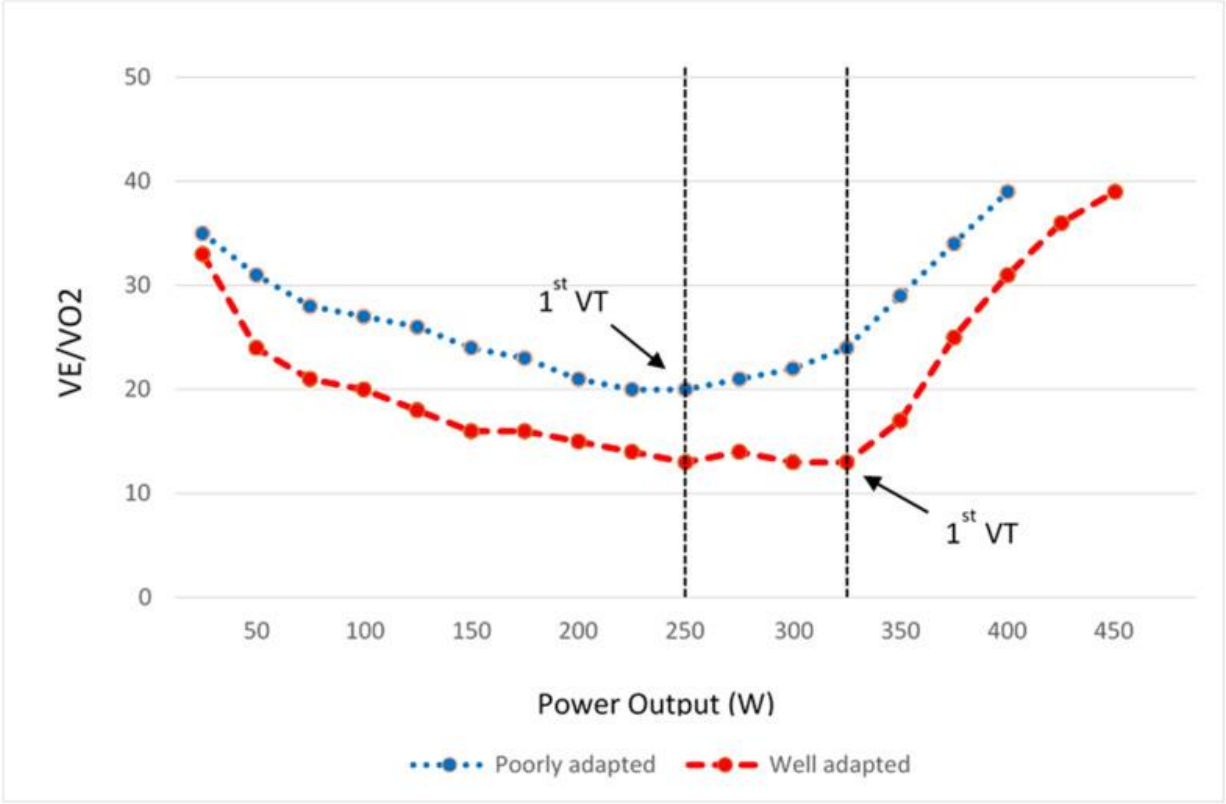
- HRR:

VĐV nhanh hơn người không tập

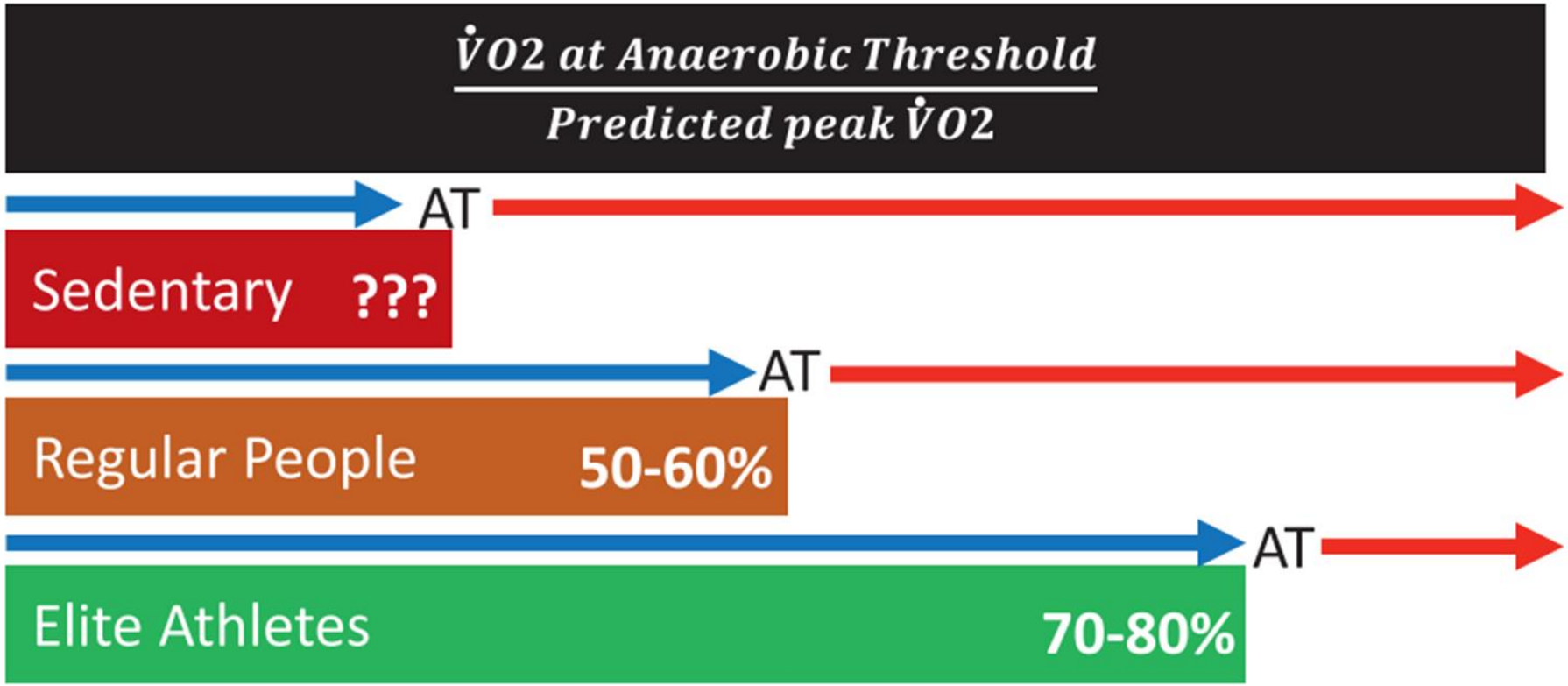
Giảm ở VĐV sau 4 tuần không tập

Đánh giá hiệu quả chương trình tập luyện





Đánh giá hiệu quả chương trình tập luyện



Exercise Below AT

Sustainable without fatigue

Exercise Above AT

Increased release of catecholamines

Cá thể hóa chương trình tập luyện

Frequency:
- Sessions/week
- Bouts of exercise

Intensity:
- Endurance: %VO_2 peak or % peak HR or %HRR
- Strength or Power: % 1RM or % 5RM or %peak HR or %HRR for mixed exercise

Time:
- Duration of
  - exercise programme in weeks or months
  - training days per week
  - training session times per day
  - duration of training session in hours.

Type:
- Endurance (running, cycling, rowing, walking, swimming)
- Strength or resistance training
- Speed and speed endurance
- Flexibility (sit & reach, back stretch test, lateral mobility test)
- Coordination and balance

Mode of exercise training:
- Metabolic: *aerobic vs. anaerobic*
- Muscular work:

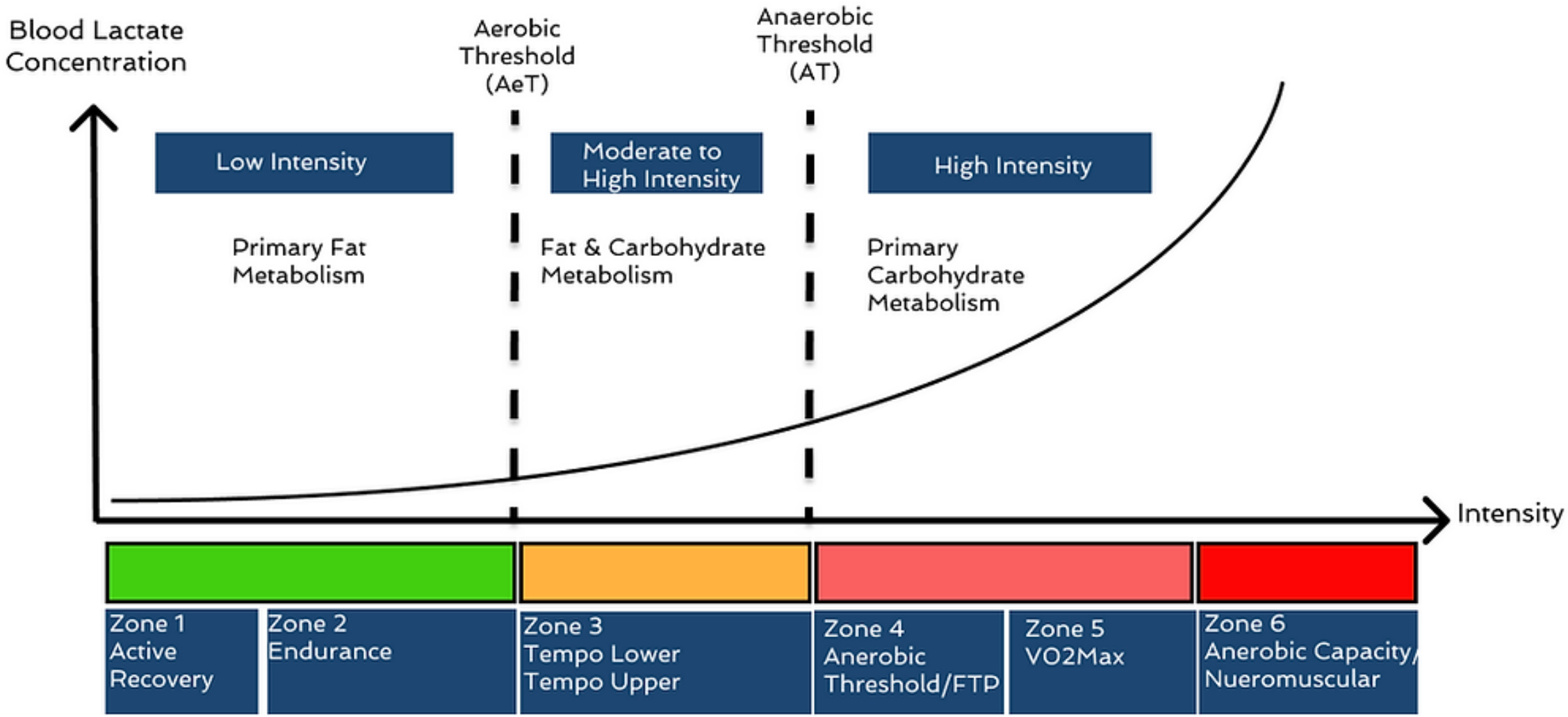
  isometric – isotonic

  dynamic (concentric, eccentric) vs. static

  continuous vs. interval

  large or small muscular groups

Cá thể hóa chương trình tập luyện



Cá thể hóa chương trình tập luyện

Training zones based on exercise testing results*

Zone	Training Effect	Purpose	%VO_2max	% VT (run)	% VT (bike)	% Max HR
1	Active recovery	Recovery	55%-65%	<85%	<81%	60%-70%
2	Aerobic threshold	Aerobic endurance	66%-75%	85%-89%	81%-89%	71%-75%
3	Tempo	Preparation and base	76%-80%	90%-94%	90%-93%	76%-80%
4	Sublactate threshold	Further develop base	81%-90%	95%-99%	94%-99%	81%-90%
5a	Anaerobic threshold	Improve VO_2max	91%-93%	100%-102%	100%-102%	91%-93%
5b	Anaerobic endurance	Increase anaerobic tolerance	94%-98%	103%-106%	103%-106%	94%-98%
5c	Anaerobic capacity	High-end sprinting	98%-100%	>106%	>106%	98%-100%

VO_2 max = maximal oxygen uptake; VT = ventilatory threshold; HR = heart rate.

* Data from Friel [35].

Chẩn đoán nguyên nhân khó thở gắng sức

	Cardiovascular			Ventilatory				Metabolic
	VO2 max or VO2 peak	Peak HR	πO2	(VE/MVV) x100= VR	VD/VT	VE/VCO2 (at AT1)	PaO2	AT1
Pathology								
Cardiovascular								
Heart Failure	**Decreased**	Variable	**Decreased**	Normal or decreased	**Increased**	**Increased**	Normal	**Decreased**
Coronary artery disease	**Decreased**	NA	**Decreased**	NA	NA	Normal/increased	Normal	Normal/decreased
Respiratory								
COPD	**Decreased**	Decreased, normal in mild	Normal (or decreased)	**Increased**	**Increased**	**Increased**	Variable	Normal (decreased/intermediate)
ILD	**Decreased**	Decreased	Normal (or decreased)	**Normal or increased**	**Increased**	**Increased**	**Decreased**	Normal (or decreased)
PVD	**Decreased**	Normal or slightly decreased	**(Normal) or decreased**	Normal	**Increased**	**Increased**	**Decreased**	**Decreased**
Neuromuscular								
Other								
Deconditioning	**Decreased**	Normal or slightly decreased	**Decreased**	Normal	Normal	Normal	Normal	Normal or decreased
HV	Normal	Normal	Normal	NA	NA	**Increased**	Normal	Normal
Obesity	Decreased for actual (normal for ideal weight)	Normal or slightly decreased	Normal	Normal (or increased)	Normal	Normal	Normal	Normal (or decreased)

Khó thở CRNN

- Có thể do nhiều nguyên nhân
- 1/3 trường hợp là đa nguyên nhân
- Thường không thể chẩn đoán chỉ dựa vào lâm sàng
- Khó chọn phương pháp chẩn đoán phù hợp
- Khó xác định chuyên khoa nào có vai trò chính

=> BN “được cho” làm quá nhiều kỹ thuật chẩn đoán

Khó thở CRNN

Causes of unexplained and persistent dyspnea across different diagnostic algorithms.

	Del Paso et al (16)	Martinez et al (18)	Pratter et al (17)	Huang et al (22)
Patients	N = 77	N = 50	N = 123	N = 530
Diagnosis made in n =	63	49	122	530
Respiratory	36% Asthma Intrathoracic focal obstruction of a large airway Extrathoracic upper airway obstruction	32% Hyperactive airways Interstitial lung disease Other lung diseases	53% Airflow obstruction Interstitial lung diseases Other lung diseases	17% Pulmonary hypertension
Cardiovascular /circulatory	14% Coronary artery disease Arrhythmias Constrictive pericarditis	10% Ischemic Heart Disease Heart Failure with preserved ejection faction Atrial septal defect	16% Congestive heart failure/other cardiomyopathies Valvular heart disease Other	18% Heart failure with preserved ejection fraction
Non-cardiopulmonary	50% Hyperventilation syndrome Poor conditioning Gastroesophageal Reflux disease Thyroid disease Unexplained	60% Obesity/deconditioning Psychogenic, normal Gastroesophageal Reflux disease	31% Obesity Psychogenic Deconditioning Others	65% Primary hyperventilation Dysautonomia Oxidative myopathy Others

Expert Review of Respiratory Medicine, 2022, Vol. 16, No. 5, 511–518

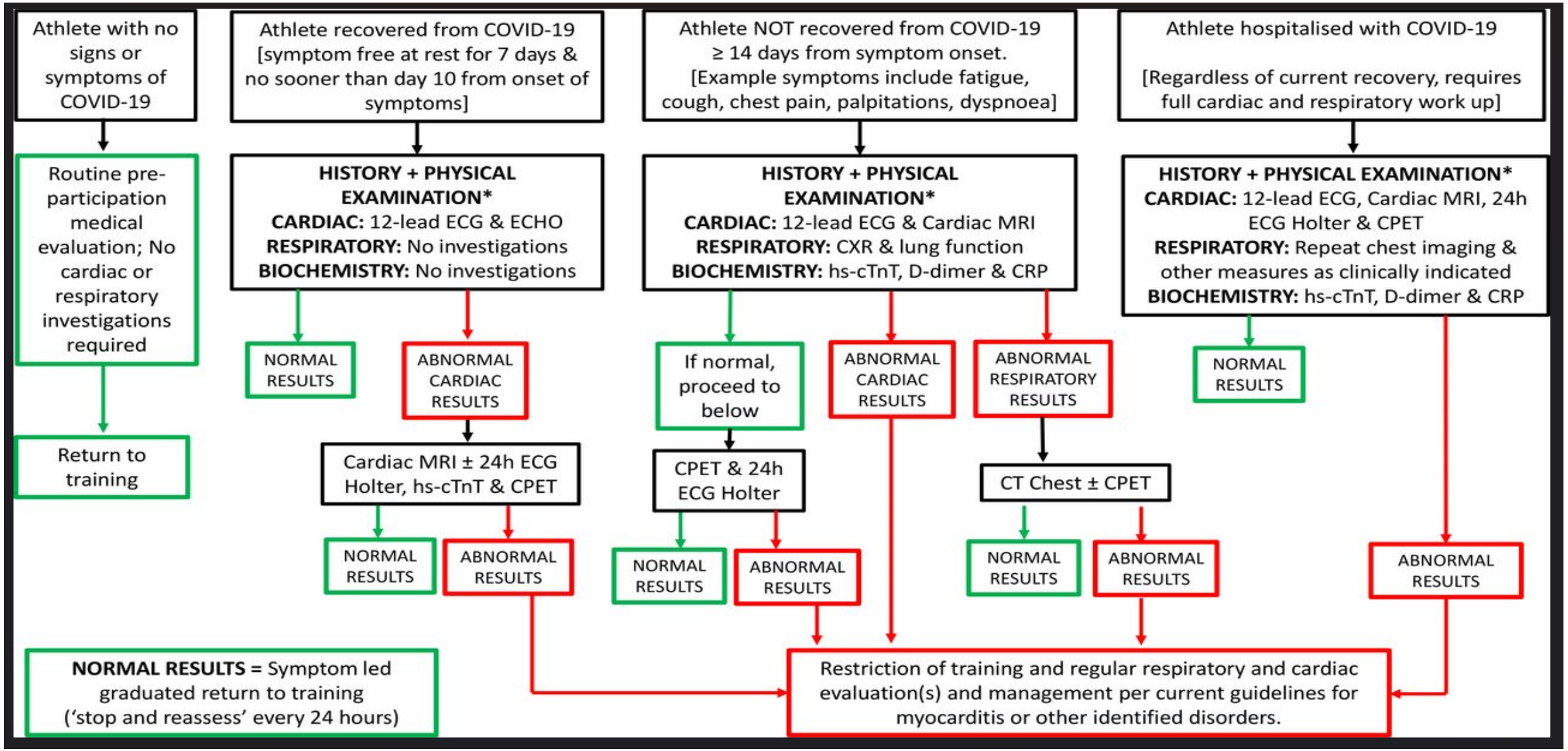
EIB ở VĐV

Diagnostic tests for EIB in elite athletes

Test	Criteria (FEV_1)
Bronchodilation test	↑ FEV_1 > 12% and 200 ml
Eucapnic voluntary hyperventilation	↓ FEV_1 > 10%
Exercise test	↓ FEV_1 > 10%
Methacholine test	↓ FEV_1 > 20%
Hyperosmolar test (saline, mannitol)	↓ FEV_1 > 15%

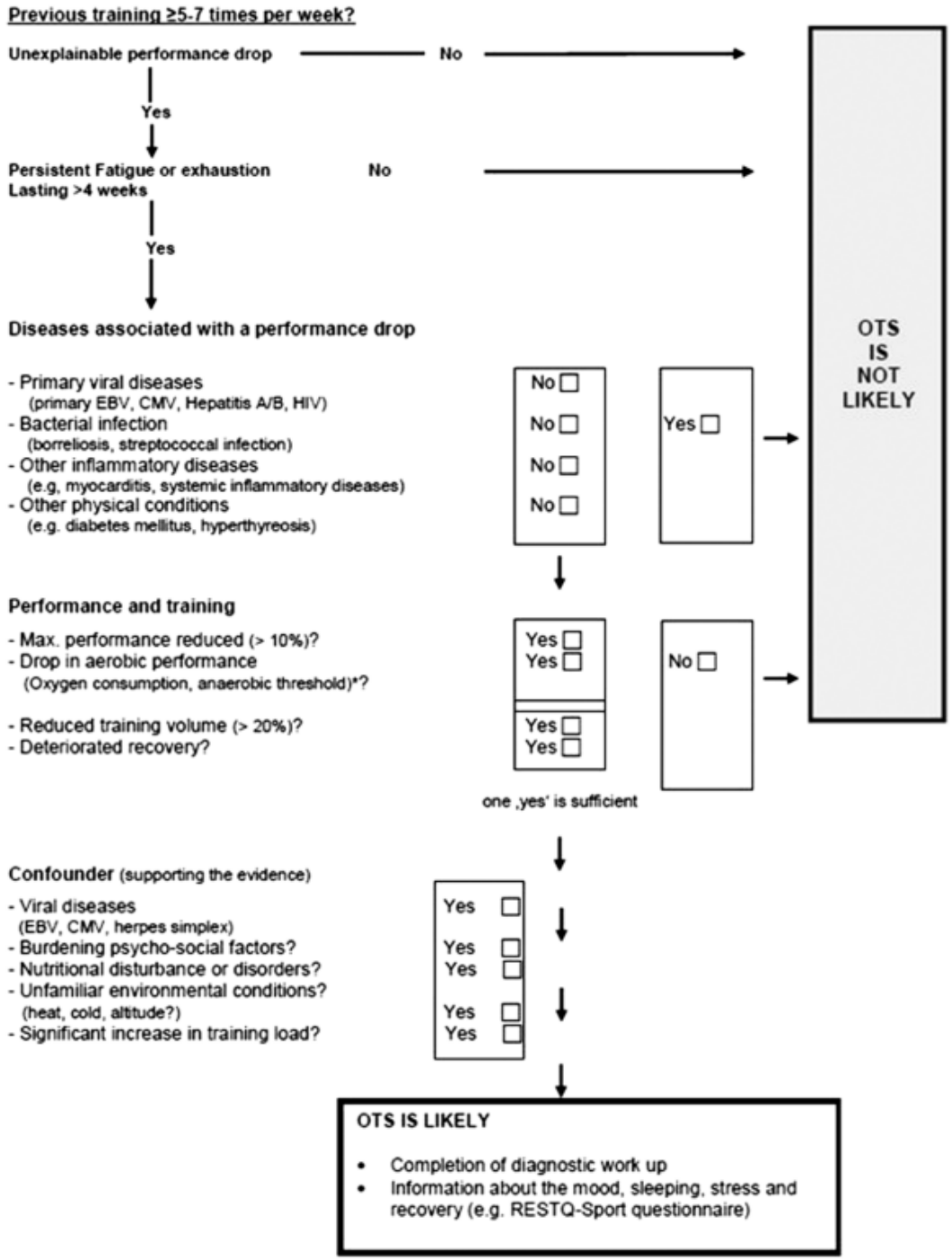
Cureus. 2022 Jan; 14(1): e20898

Đánh giá trước khi trở lại tập luyện sau bệnh lý cấp



Wilson MG, et al. Br J Sports Med 2020;54:1157–1161

Xác định overtraining



Đánh giá không dung nạp GS

eTable 33.1 Estimating an Individual's $\dot{V}O_{2max}$ From the History

Activity Limitations	Approximate $\dot{V}O_{2max}$ (mL/kg/min)
Participates in competitive sports with sustained activity like rowing, basketball, and soccer. Engages in regular, endurance training. Tolerates sustained heavy labor well	>40
Tolerates sustained heavy labor well; can play recreational soccer or full-court basketball	35–40
Participates in recreational cross-country skiing or half-court basketball with minimal limitation	30–35
Performs heavy labor with difficulty; downhill skiing somewhat limited by fatigue	25–30
Heavy housework or yard work causes dyspnea; cannot play singles tennis	20–25
Dyspnea with two flights of stairs at own pace; cannot play golf while carrying bag or pulling a cart	17–20
Unable to vacuum average room or change sheets without rest	14–17
Difficulty walking slowly with peers in shopping mall	12–14
Dyspnea while brushing hair, dressing, showering	<12

Đánh giá mức độ suy giảm thể chất

TABLE 5.1 **Fitness Levels for Aerobic Capacity* in Males and Females**

	Age				
Males	**20 to 29**	**30 to 39**	**40 to 49**	**50 to 59**	**60 to 69**
Superior	66.3 or higher	59.8 or higher	55.6 or higher	50.7 or higher	43.0 or higher
Excellent	57.1 to 66.2	51.6 to 59.7	46.7 to 55.5	41.2 to 50.6	36.1 to 42.9
Good	50.2 to 57.0	45.2 to 51.5	40.3 to 46.6	35.1 to 41.1	30.5 to 36.0
Fair	44.9 to 50.1	39.6 to 45.1	35.7 to 40.2	30.7 to 35.0	26.6 to 30.4
Poor	38.1 to 44.8	34.1 to 39.5	30.5 to 35.6	26.1 to 30.6	22.4 to 26.5
Very poor	38.0 or lower	34.0 or lower	30.4 or lower	26.0 or lower	22.3 or lower
	Age				
Females	**20 to 29**	**30 to 39**	**40 to 49**	**50 to 59**	**60 to 69**
Superior	56.0 or higher	45.8 or higher	41.7 or higher	35.9 or higher	29.4 or higher
Excellent	46.5 to 55.9	37.5 to 45.6	34.0 to 41.6	28.6 to 35.8	24.6 to 29.3
Good	40.6 to 46.4	32.2 to 37.4	28.7 to 39.9	25.2 to 28.5	21.2 to 24.5
Fair	34.6 to 40.5	28.2 to 32.1	24.9 to 28.6	21.8 to 25.1	18.9 to 21.1
Poor	28.6 to 34.5	24.1 to 28.1	21.3 to 24.8	19.1 to 21.7	16.5 to 18.8
Very poor	28.5 or lower	24.0 or lower	21.2 or lower	19.0 or lower	16.4 or lower

*Aerobic capacity or $\dot{V}O_{2max}$ expressed in $mL \cdot kg^{-1} \cdot min^{-1}$.

Adapted by permission from American College of Sports Medicine, 2018.

Đánh giá mức độ tàn tật

eTable 33.2 Impairment Determined by Cardiopulmonary Exercise Testing

$\dot{V}O_{2max}$ (mL/kg/min)	Description of Work
>25	Capable of all but most physically demanding jobs
15–25	Able to work at the specific job that does not require frequent and extended work above 40% of maximum $\dot{V}O_2$
<15	Unable to perform most jobs

Phân biệt tim VĐV & BCT giai đoạn sớm

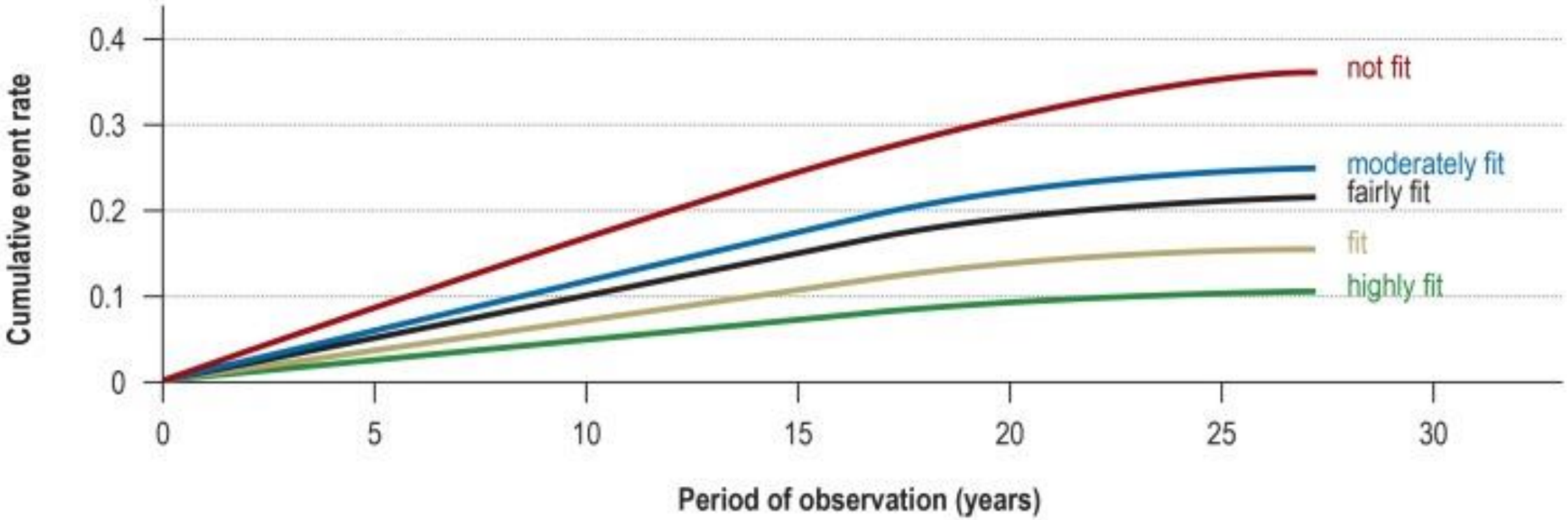
TABLE IV.—*CPET parameters of essential value in the differential diagnosis of the athlete's heart.*

	VO_{2peak}	VO_2 at LT	V_E/VCO_2 slope	O_2 pulse	VO_2/WR slope	PVCs during exercise with origin and morphology
Athlete's heart	>50 mL/kg/min or >120% of predicted	>70%	Normal	Increased	Increased	• Absent, when present monomorphic • LVOT: LBBB, inferior axis, early transition <V4 • RVOT: LBBB, inferior axis, late transition ≥V4 • Fascicular: typical RBBB, QRS<130 msec, inferior axis (left anterior fascicle), superior axis (left posterior fascicle) • Reduction or resolution with increasing effort (may return in recovery)
Left ventricle cardiomyopathy	<50 mL/kg/min or <120% of predicted	50-70%	Slight increase	Normal or reduced with early flattening	Reduced (with possible flattening)	• Polymorphic, repetitive • LV: atypical RBBB-like morphology QRS ≥130 msec • Induced by increasing effort
Right ventricle cardiomyopathy	<50 mL/kg/min or <120% of predicted	50-70%	Moderate increase	Normal or reduced with early flattening	Reduced (with possible flattening)	• Polymorphic, repetitive • RV free wall or moderator band: LBBB with intermediate or superior axis • Induced by increasing effort

PHÂN BIỆT BỆNH CƠ TIM PHÌ ĐẠI & TIM VĐV

Hypertrophic Cardiomyopathy	"grey zone" LVWT 13-16 mm T-wave inversion	Athlete`s Heart
General information		
• Female gender		• Male gender
• Positive family history for HCM		• Negative family history for HCM
ECG		
• Additional ECG abnormalities such as ST-segment depression, deep T-wave inversion in inferolateral leads		• Isolated Sokolow-Lyon criteria for LV hypertrophy, no ST-segment depression and/or T-wave inversion
Echocardiography		
• LV cavity < 54 mm		• LV cavity > 54 mm
• Bizarre patterns of LVH, LA > 50mm, LVOT obstruction		• No or only mild LVH, LA < 50mm, no LVOT obstruction
• Impaired systolic or diastolic LV-function		• Normal systolic and diastolic LV-function
Exercise testing and/or holter monitoring		
• NSVT/VT during exercise testing or holter monitoring		• No NSVT/VT during exercise testing or halter monitoring
• Abnormal BP response during exercise testing		• Normal BP response during exercise testing
• Peak VO_2 < 50ml/kg/min or < 120% predicted		• Peak VO_2 > 50 ml/kg/min or > 120% predicted
Cardiac magnetic resonance imaging		
• Delayed gadolinium enhancement		• No delayed gadolinium enhancement

Tiên lượng bệnh tật & tử vong



KẾT LUẬN

- CPET “valid and indispensable” cho Y học & thể thao, định lượng chính xác thể lực tim mạch - hô hấp, nhận diện cơ chế sinh lý bệnh làm giới hạn khả năng vận động, đánh giá thể lực và tiên lượng khả năng gắng sức dựa trên chức năng đa hệ thống nhưng áp dụng trong YHTT còn hạn chế

- Hiểu rõ sinh lý gắng sức ở VĐV & cần thận trọng khi giải thích những bất thường CPET ở VĐV. Diễn giải nên **đặt trong bối cảnh lịch sử tập luyện của VĐV**

- **Hỏi bệnh sử kỹ lưỡng, khám lâm sàng và xét nghiệm thường quy là rất cần thiết**

Various cardiopulmonary exercise testing parameters in athletes & nonathletes

CPET Parameter	Similar Between Athletes and Nonathletes	Can be Different in Some athletes
Metabolic/cardiovascular		
$\dot{V}O_2$		Peak $\dot{V}O_2$ can be significantly higher particularly with endurance athletes
AT		Occurs at a higher percentage of peak $\dot{V}O_2$ particularly with endurance athletes
Max HR	↔	Variable when using age predicted equations
CI		Often <0.8 owing to relative "normal" HR response with exceptional peak $\dot{V}O_2$ particularly in endurance athletes
$\dot{V}O_2$/h (O_2 pulse)		Well above predicted values with potential plateau near peak exercise
RER	X	
$\dot{V}O_2$/work slope	X	
Ventilatory/gas exchange		
SpO_2		EIAH can be seen near peak exercise in some athletes with very high peak $\dot{V}O_2$
$PETCO_2$	X	
RC	X	
$\dot{V}E/\dot{V}CO_2$ nadir/slope	↔	Slope can be elevated if taken through end exercise
Breathing reserve		Can be lower in athletes with exceptional fitness
RR		Can be higher (>50 breaths/min) in athletes usually with exceptional fitness

Various cardiopulmonary exercise testing parameters in athletes & nonathletes

TRÂN TRỌNG CẢM ƠN

QUÝ THẦY CÔ & QUÝ ĐỒNG NGHIỆ

CA LÂM SÀNG 1

Cựu VĐV điền kinh và marathon, 61 tuổi

Khó thở nặng khi gắng sức và ↓ thành tích

Tiền sử: CABG sau NSTEMI với EF = 60%

YTNC tim mạch: THA, RLLM

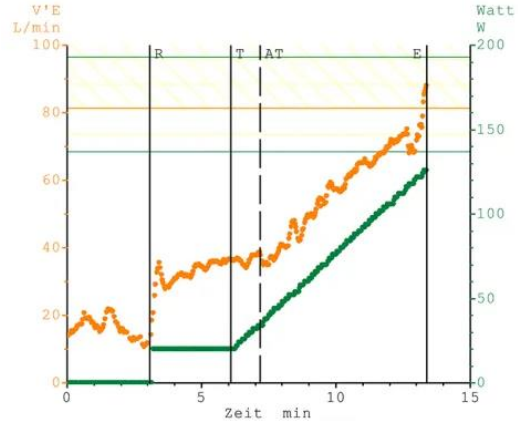
CA LÂM SÀNG 1

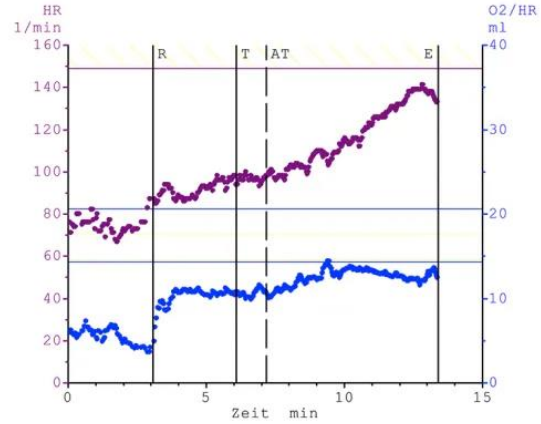
- HHK: Không hạn chế hoặc tắc nghẽn

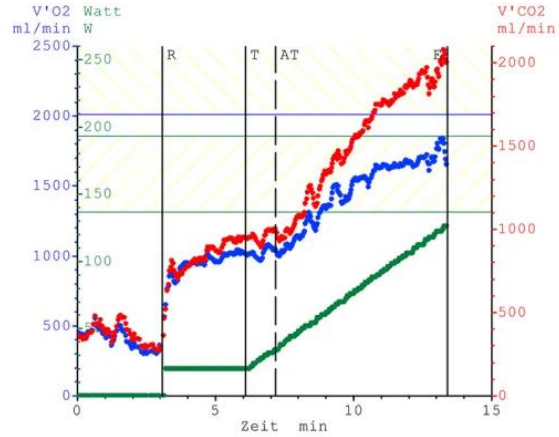
- ECG và siêu âm tim lúc nghỉ: bình thường

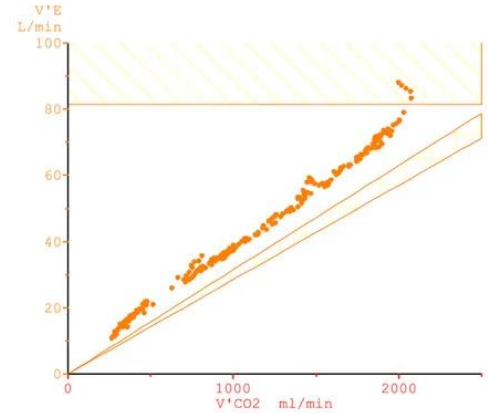
- ECG gs: bình thường

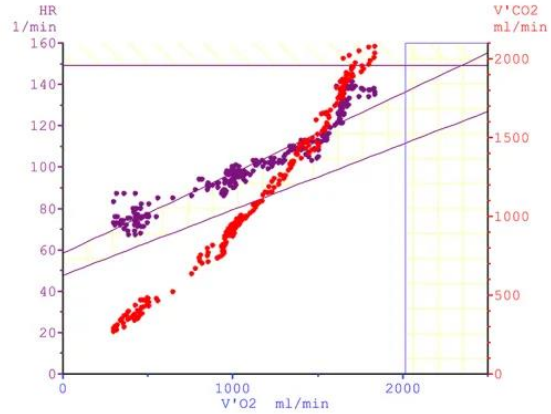
- CPET: VO2peak = 78%, khó thở khi gắng sức, nhưng không có cơn đau thắt ngực, không có dấu hiệu thiếu máu cục bộ cơ tim.

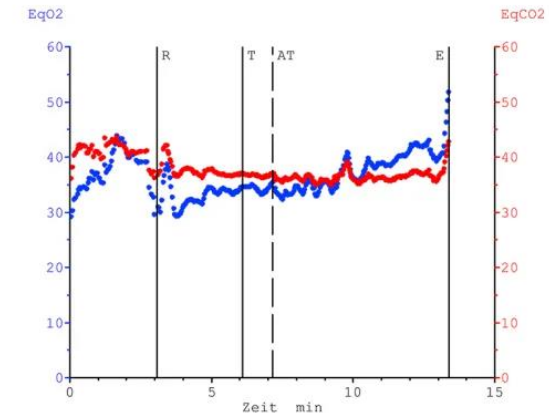

V'E
L/min
Watt
W
R
T
AT
E
Zeit min

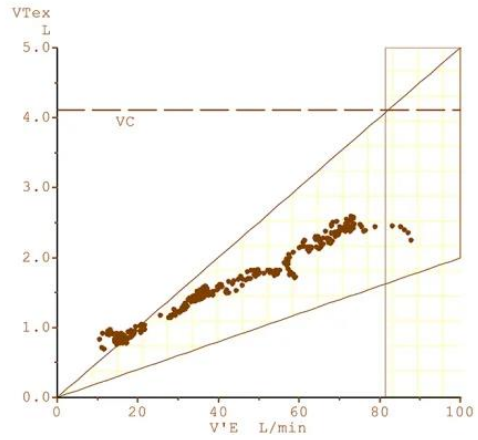

HR
1/min
O2/HR
ml
R
T
AT
E
Zeit min

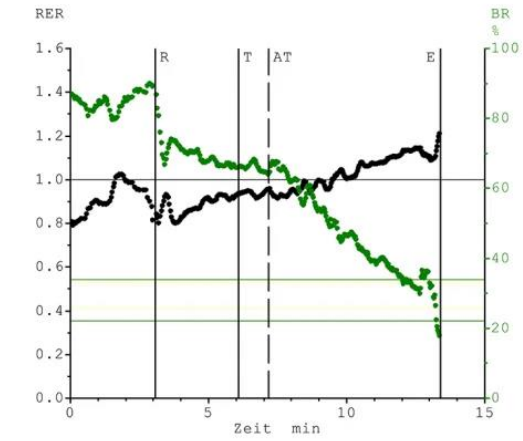

V'O2 Watt
ml/min W
V'CO2
ml/min
R
T
AT
E
Zeit min

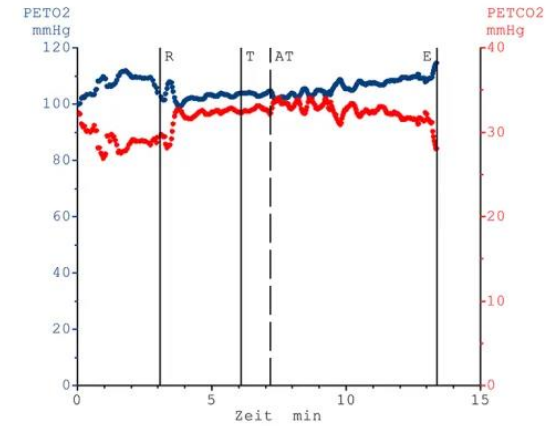

V'E
L/min
V'CO2 ml/min


HR
1/min
V'CO2
ml/min
V'O2 ml/min


EqO2
EqCO2
R
T
AT
E
Zeit min


VTex
L
VC
V'E L/min


RER
BR
%
R
T
AT
E
Zeit min


PETO2
mmHg
PETCO2
mmHg
R
T
AT
E
Zeit min

CA LÂM SÀNG 2

Nữ 25 tuổi, chạy bộ trong thời gian rảnh, khó thở và nặng ngực khi gắng sức

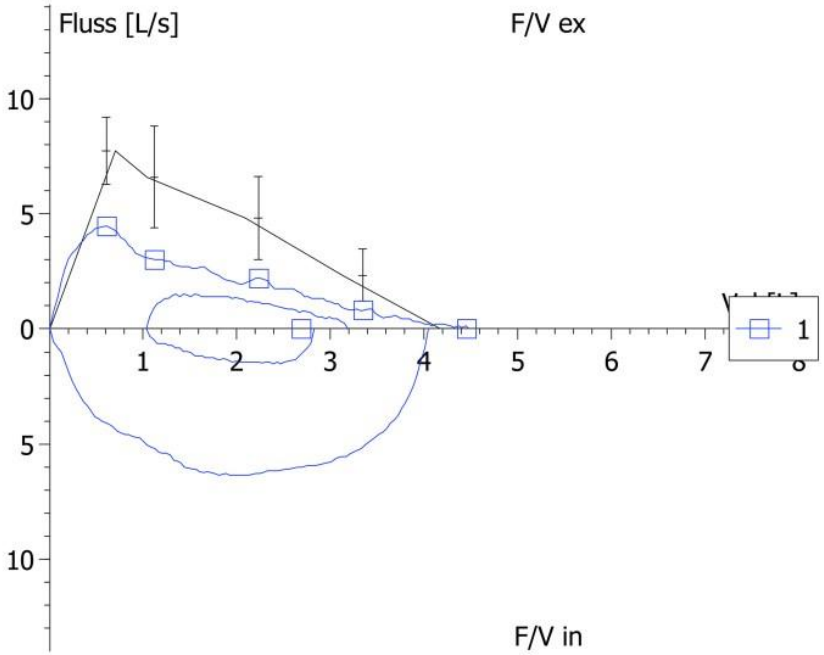
TS: hen dị ứng từ tuổi vị thành niên, ICS và beta-2 tác dụng dài
Không hút thuốc

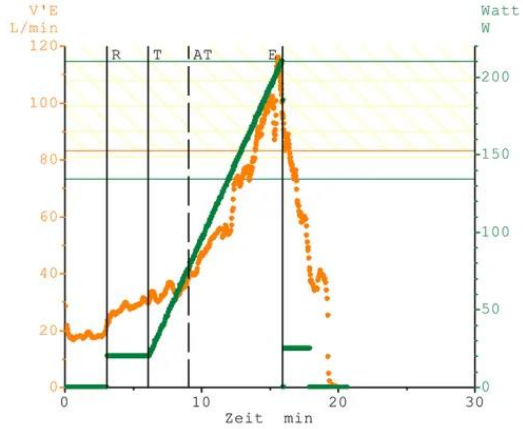
Không tiền sử gia đình bệnh tim

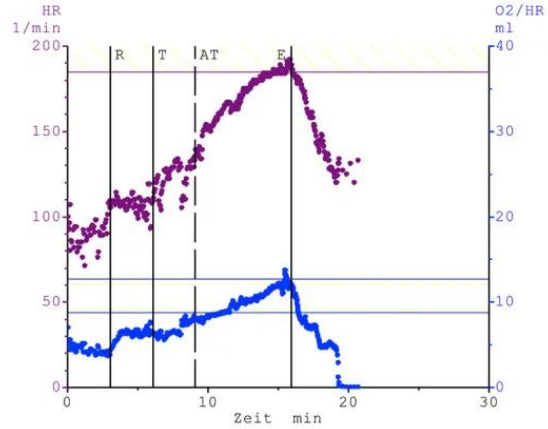
Không dấu nhiễm trùng

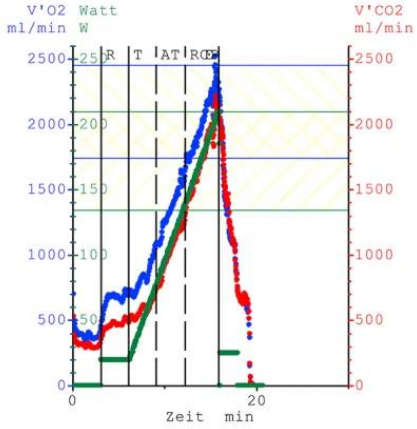
HHK: FEV1 = 75% dự đoán, Tiffeneau = 60%

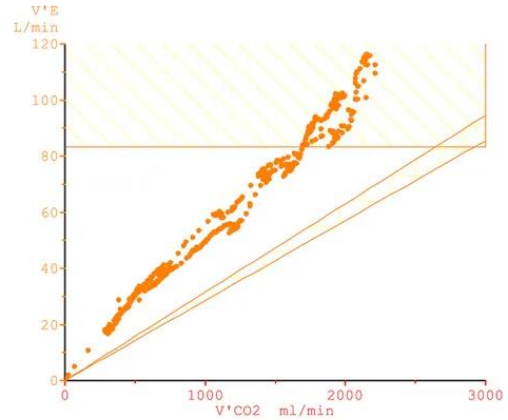
ECG lúc nghỉ bình thường

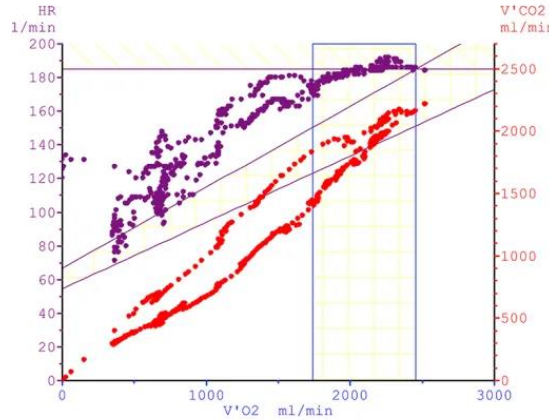

Fluss [L/s]
F/V ex
F/V in
1

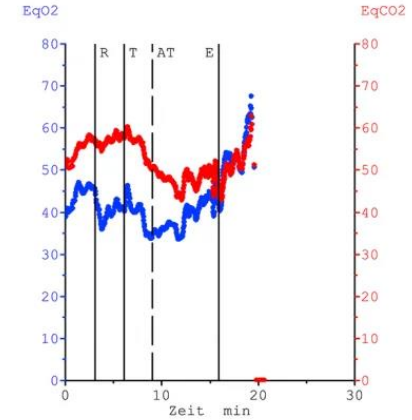

V'E
L/min
Watt
W
R
T
AT
E
Zeit min

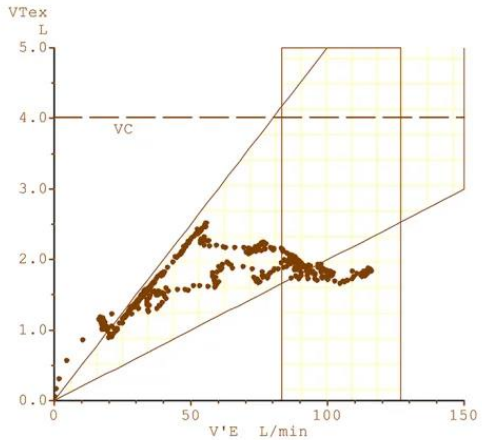

HR
1/min
O2/HR
ml
R
T
AT
E
Zeit min

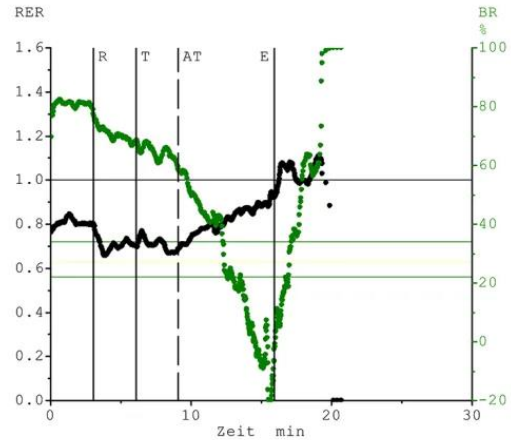

V'O2 Watt
ml/min W
V'CO2
ml/min
R
T
AT
RCP
E
Zeit min

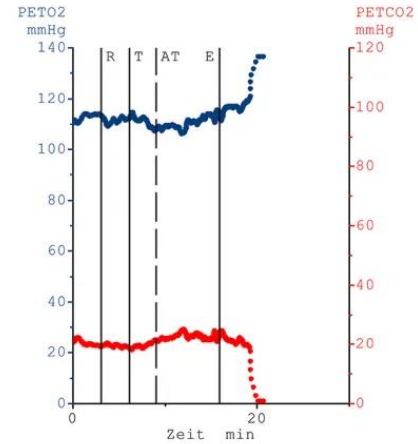

V'E
L/min
V'CO2 ml/min

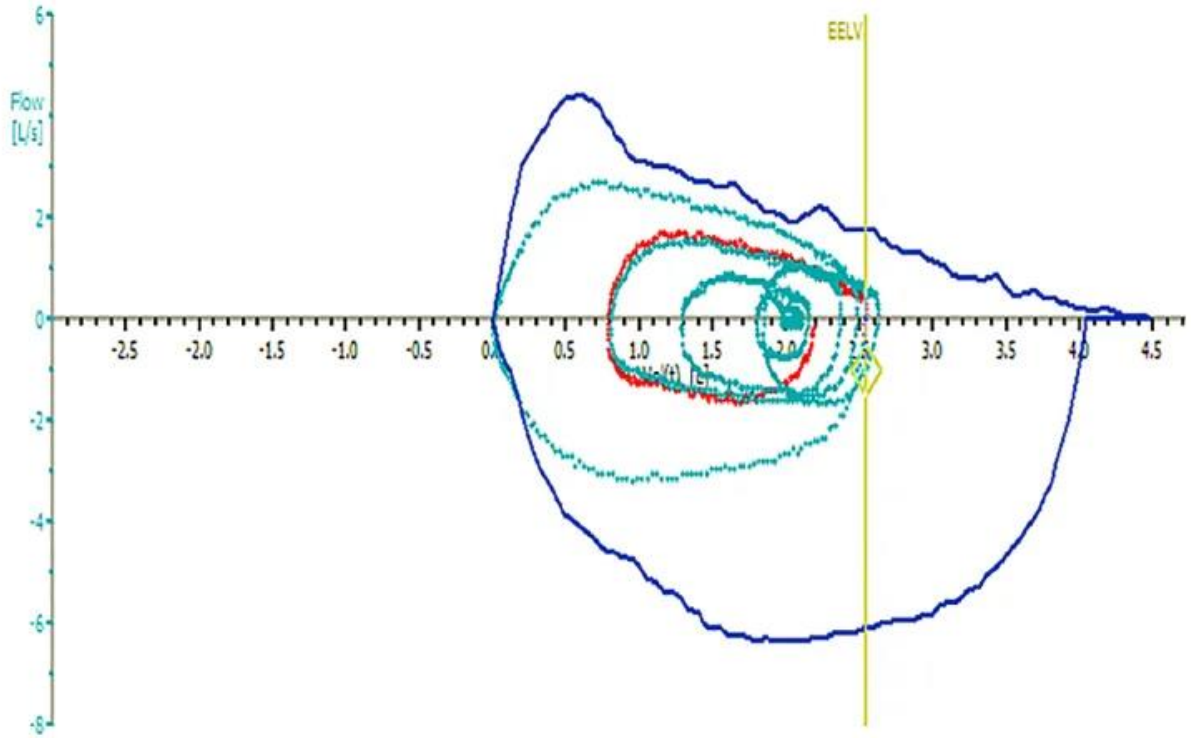

HR
1/min
V'CO2
ml/min
V'O2 ml/min

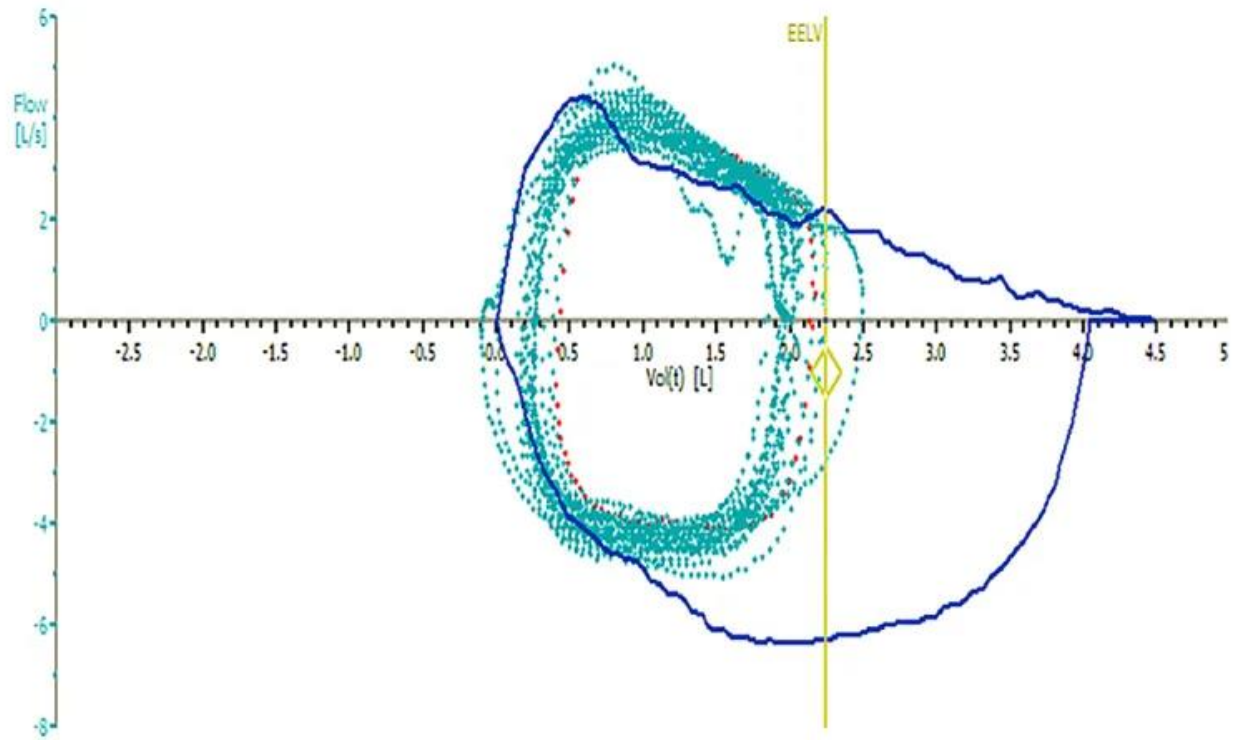

EqO2
EqCO2
R
T
AT
E
Zeit min


VTex
L
VC
V'E L/min


RER
BR
%
R
T
AT
E
Zeit min


PETO2
mmHg
PETCO2
mmHg
R
T
AT
E
Zeit min


EELV
Flow
[L/s]
6
2
0
-2
-4
-6
-8
-2.5
-2.0
-1.5
-1.0
-0.5
0.5
1.0
1.5
2.0
3.0
3.5
4.0
4.5


EELV
Flow
[L/s]
6
2
0
-2
-4
-6
-8
-2.5
-2.0
-1.5
-1.0
-0.5
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5
Vol(t) [L]

CA LÂM SÀNG 3

Nam, 39 tuổi, VĐV nghiệp dư, môn sức bền

Tập từ năm 18 tuổi, 10 - 25 giờ/tuần

KT cấp khi gắng sức

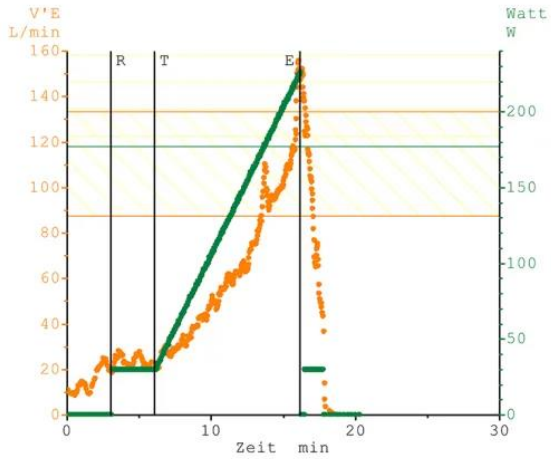
Sa sút phong độ và nhịp tim tăng chậm khi tập luyện trong 6 tháng trước

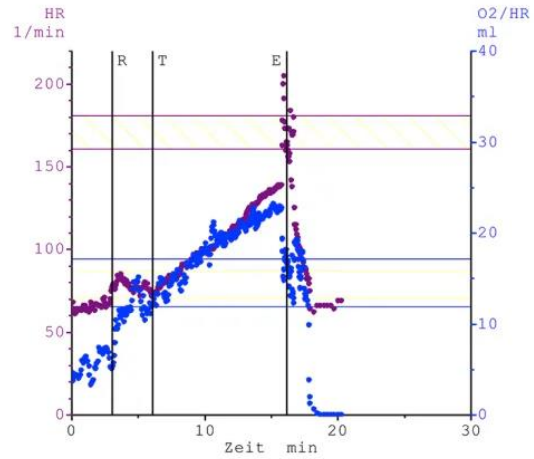
Không tiền sử bệnh nội khoa và không YTNC tim mạch

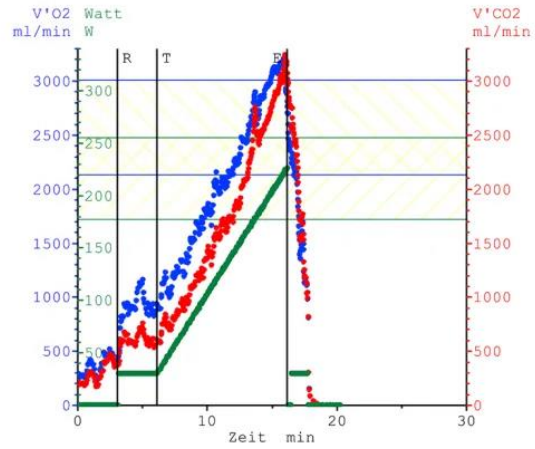
HHK lúc nghỉ: không hạn chế hoặc tắc nghẽn

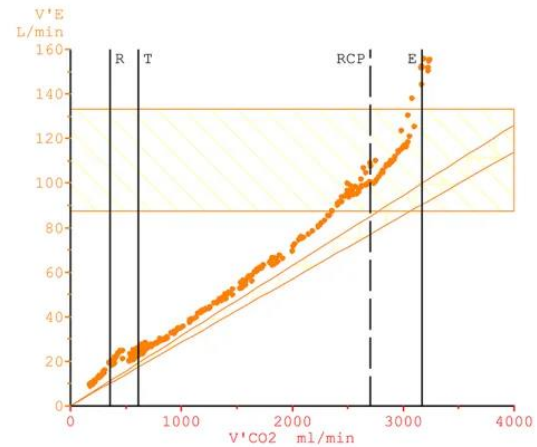
ECG lúc nghỉ bình thường

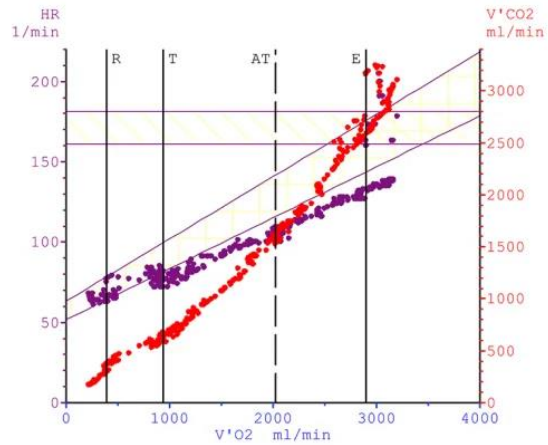
SAT: chức năng tâm thu và tâm trương bình thường, dãn các buồng tim

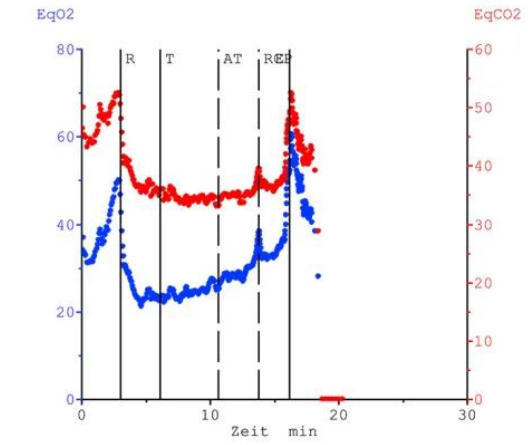

V'E
L/min
Watt
W
R
T
E
Zeit min

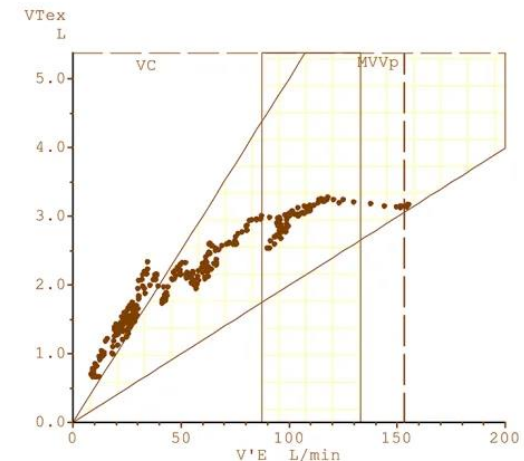

HR
1/min
O2/HR
ml
R
T
E
Zeit min

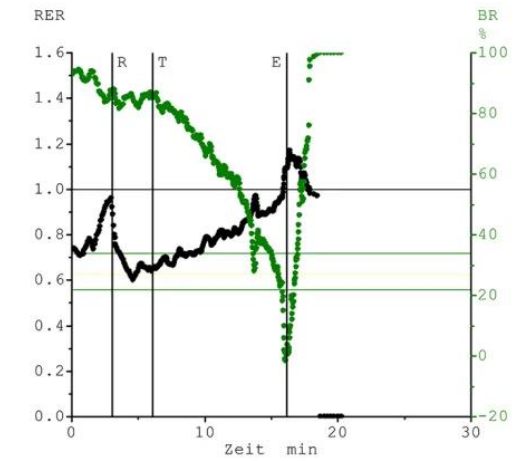

V'O2 Watt
ml/min W
V'CO2
ml/min
R
T
E
Zeit min

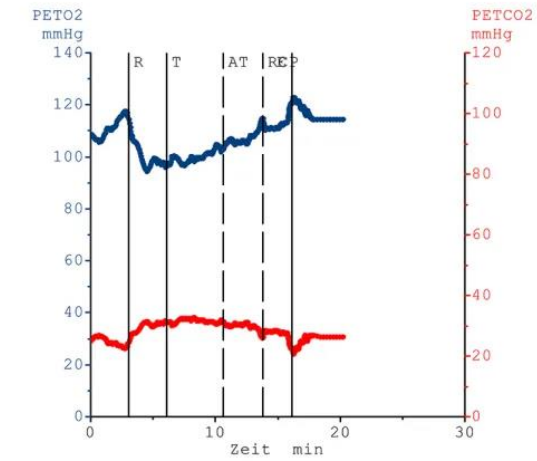

V'E
L/min
R
T
RCP
E
V'CO2 ml/min


HR
1/min
V'CO2
ml/min
R
T
AT
E
V'O2 ml/min


EqO2
EqCO2
R
T
AT
RCP
Zeit min


VTex
L
VC
MVVp
V'E L/min


RER
BR
%
R
T
E
Zeit min


PETO2
mmHg
PETCO2
mmHg
R
T
AT
RCP
Zeit min

CA LÂM SÀNG 4

VĐV nam 28 tuổi, kickboxing chuyên nghiệp, > 11 năm thi đấu, nhiều chức vô địch

Chuẩn bị cho giải đấu quốc tế tháng tới, VĐV có một chương trình tập luyện cường độ cao với chế độ ăn uống cân bằng hợp lý

Phàn nàn về tình trạng mỏi cơ sớm giống như chứng tích tụ lactate trước đây và sa sút phong độ mà không có bất kỳ triệu chứng nào khác.

Tiền sử cá nhân và gia đình bình thường

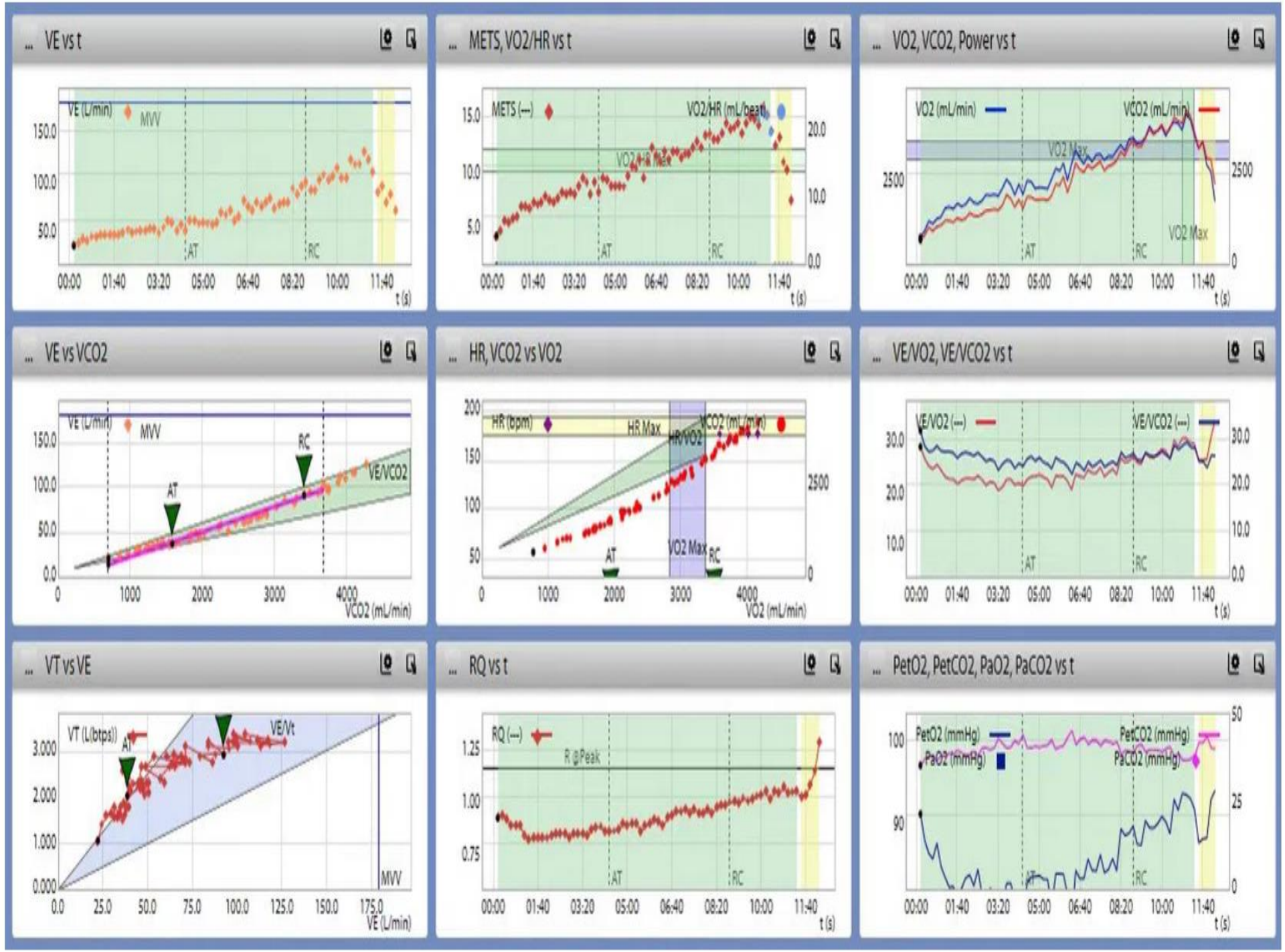
Khám thực thể bình thường

Mệt mỏi sớm và sa sút phong độ trong 4 tuần qua

Test	Result	Reference Range
Hematology		
White blood cell (×1000/mic)	6.5	4,4–11
– Neutrophils (%)	67.5	
– Lymphocyte (%)	26.9	
– Mix (%)	5.6	
Red blood cell (×million/m)	4.79	4.5–5.9
Hemoglobin (g/dL)	14.1	14–17.5
Hematocrite (%)	42.5	41.5–50.4
Mean Corpuscular Volume (fL)	88.7	80–96
Mean Cell Hemoglobine (pg)	29.4	27.5–33.2
Platelets (×1000/mic)	272	150–450
Red cell Distribution Width (%)	13.4	11.6–14.6
ESR (mm/hr)	6	< 15

Hormone Analysis		
Testosterone (ng/mL)	3.2	2.8–8.0
Cortisol 8 am (ng/mL)	83.2	54.94–287.56
TSH (micIU/ml)	1.49	0.27–4.2
T4 (micg/dL)	4.98	5.52–12.6
PTH (pg/mL)	18	15–65
25 OH Vitamin D3 (ng/mL)	38.8	29–100

Parameters	Meas.	Pred	% Pred
FVC (L)	7.08	4.95	143
FEV1 (L)	4.48	4.18	107
FEV1/FVC	63.40	82.20	77
PEF (L/s)	8.56	9.63	89


VE vs t
VE (L/min)
MVV
AT
RC
t (s)
METS, VO2/HR vs t
METS (---)
VO2/HR (mL/beat)
VO2 Max
AT
RC
t (s)
VO2, VCO2, Power vs t
VO2 (mL/min)
VCO2 (mL/min)
VO2 Max
AT
RC
t (s)
VE vs VCO2
VE (L/min)
MVV
AT
RC
VE/VCO2
VCO2 (mL/min)
HR, VCO2 vs VO2
HR (bpm)
HR Max
HR/VO2
VCO2 (mL/min)
AT
VO2 Max
RC
VO2 (mL/min)
VE/VO2, VE/VCO2 vs t
VE/VO2 (---)
VE/VCO2 (---)
AT
RC
t (s)
VT vs VE
VT (L/btps)
AT
VE/Vt
MVV
VE (L/min)
RQ vs t
RQ (---)
R @Peak
AT
RC
t (s)
PetO2, PetCO2, PaO2, PaCO2 vs t
PetO2 (mmHg)
PaO2 (mmHg)
PetCO2 (mmHg)
PaCO2 (mmHg)
AT
RC
t (s)

Variable	value
Peak VO_2 (ml/kg/min)	51.72
Percent predicted peak VO_2 (%)	114.88
Ventilatory threshold (VT) (ml/kg/min)	27.57
VT (% of VO_2max)	53.3
Peak respiratory exchange ratio	1.03
VE/VCO_2 slope	27.8
$P_{ET}CO_2$ rest (mmHg)	37

Variable	value
$P_{ET}CO_2$ at VT level (mmHg)	45
VE/VO_2 at peak	29.6
VE/MVV	0.64
O_2 pulse max (mL/beat)	22.02
METs max	14.77
HR max (beat/min)	178
HR recovery at 1 min (beat/min)	39
Blood Pressure max (mmHg)	222/94

CA LÂM SÀNG 4

VT1: 53,3%, quá thấp đối với VĐV chuyên nghiệp

Luyện tập cường độ cao giai đoạn chuẩn bị => hội chứng tập luyện quá mức (overtraining) => VT giảm => giảm thành tích thể thao

Tối ưu hóa chu kỳ hồi phục-tập luyện rất quan trọng để đạt được hiệu suất mong muốn ở VĐV đỉnh cao

Sau 3 tuần nghỉ ngơi và hồi phục, VĐV thi đấu quốc tế và chiến thắng

Abnormal ECG findings	Definition
Abnormal T wave inversion (TWI)	≥1 mm in depth in two or more contiguous leads; excludes aVR, III, and V1
Anterior	V2–V4 Excludes black athletes with J-point elevation and convex ST elevation followed by TWI in V2–V4; athletes age <16 with TWI in V1–V3; and biphasic T waves in only V3
Lateral	I and aVL, V5 *and/or* V6 (only one lead of TWI required in V5 or V6)
Inferolateral	II and aVF, V5–V6, I and aVL
Inferior	II and aVF
ST depression	≥0.5 mm in depth in two or more contiguous leads
Abnormal Q waves	Q/R ratio ≥0.25 or ≥40 ms in duration in two or more contiguous leads
Complete left bundle branch block (LBBB)	QRS ≥120 ms, predominately negative QRS complex in lead V1 (QS or rS), and upright notched or slurred R wave in leads I and V6

Epsilon wave	Distinct low amplitude signal (small positive deflection or notch) between the end of the QRS complex and onset of the T wave in leads V1–V3
Ventricular pre-excitation	PR interval <120 ms with a delta wave (slurred upstroke in the QRS complex and wide QRS (≥120 ms)
Prolonged QT interval	QTc ≥470 ms (female) QTc ≥480 ms (male) QTc ≥500 ms (marked QT prolongation)
Brugada type 1 pattern	Coved pattern: initial ST elevation ≥2 mm (high take-off) with downsloping ST elevation followed by a negative symmetric T wave in >1 leads in V1–V3
Profound sinus bradycardia	<30 beats/min or sinus pauses ≥3 s
Profound 1° AV block	≥400 ms
Mobitz type II 2° AV block	Intermittently non-conducted P waves with a fixed PR interval
3° AV block	Complete heart block
Atrial tachyarrhythmias	Supraventricular tachycardia, atrial fibrillation, atrial flutter

Atrial tachyarrhythmias	Supraventricular tachycardia, atrial fibrillation, atrial flutter
Premature ventricular contractions (PVC)	≥2 PVCs per 10 s tracing
Ventricular arrhythmias	Couplets, triplets, and non-sustained ventricular tachycardia
Borderline ECG findings	*These ECG findings in isolation do not represent pathologic cardiovascular disease in athletes, but the presence of two or mor borderline findings may warrant further investigation*
Left axis deviation	−30° to −90°
Left atrial enlargement (LAE)	Prolonged P wave duration of >120 ms in leads I or II with negative portion of the P wave ≥1 mm in depth and ≥40 ms in duration in lead V1
Right axis deviation	> 120°
Right atrial enlargement	P wave ≥2.5 mm in II, III, or aVF
Complete right bundle branch block (RBBB)	rSR' pattern in lead V1 and an S wave wider than R wave in lead V6 with QRS duration >120 ms

Table 11.3 Suggested cutoffs for key variables of interest to clinical CPET interpretation

	20 years		40 years		60 years		80 years	
	Males	Females	Males	Females	Males	Females	Males	Females
Metabolic								
$\dot{V}O_2$ peak (% pred)	˃83	>83	˃83	>83	˃83	>83	˃83	>83
$\Delta \dot{V}O_2/\Delta$ WR (mL/min/W)	˃9.0	>8.5	˃9.0	>8.5	˃9.0	>8.5	˃9.0	>8.5
$\dot{V}O_2$ at the LT (%$\dot{V}O_2$ peak pred)	˃35	>40	˃40	>40	˃45	>50	˃55	>60
Cardiovascular								
HR peak (bpm)	˃175	>170	˃160	>155	˃150	>145	˃130	>125
O_2 pulse (mL/min/beat)	˃12	>10	˃10	>8	˃9	>7	˃7	>6
$\Delta HR/\Delta \dot{V}O_2$ (beat/L/min)	˂60	<85	˂70	<90	˂80	<100	˂90	<105
Ventilatory/gas exchange								
$\dot{V}_E$ peak/MVV	˂0.80	<0.75	˂0.80	<0.75	˂0.80	<0.75	˂0.80	<0.75
$\dot{V}_E$ peak/MVV at the LT	˂0.35	<0.40	˂0.40	<0.40	˂0.45	<0.45	˂0.50	<0.50
$\Delta \dot{V}_E/\Delta \dot{V}CO_2$	˂26	<28	˂28	<30	˂30	<32	˂32	<32
$\dot{V}_E/\dot{V}CO_2$ nadir	˂30	<32	˂32	<34	˂32	<34	˂34	<34
f peak (breaths/min)	˂50	<50	˂50	<50	˂45	<50	˂45	<45
f/V_T peak	˂28	<30	˂28	<30	˂28	<35	˂30	<40
V_T/IC peak	˂0.70	˂0.75	˂0.70	˂ 0.75	˂0.70	˂ 0.75	˂0.70	˂ 0.75
P_{ET} CO_2 at the LT (mmHg)	˃43	>41	˃41	>40	˃39	>39	˃37	>37
SpO_2 peak (%)	>93	>93	>93	>93	>93	>93	>93	>93
SpO_2 rest -peak (%)	<5	<5	<5	<5	<5	<5	<5	<5

Table 14.6 Criteria for positive exercise ECG stress test.

Horizontal or downsloping ST-segment depression of ≥1 mm at 60–80 ms during or after exercise
Upsloping ST segment depression ≥2 mm 80 ms beyond the J-point during or after exercise (may be considered an equivocal response)
ST segment elevation ≥1 mm during or after exercise in the absence of Q waves
Exercise-induced hypotension
Inversion of U-waves
Frequent multifocal ventricular premature contraction (VPCs), grouped (three or more) VPCs, ventricular tachycardia (VT) at low-exercise workload
Exercise-induced typical angina
Third or fourth heart sounds, or heart murmur

Table 14.3 Abnormal responses to exercise.

Electrocardiographic changes
Diagnostic ST-segment alterations
ST-segment depression (horizontal or downsloping)
ST-segment elevation (without prior MI)
Additional ST-segment change with pre-existing ECG abnormalities
Significant arrhythmias
Inversion of U-waves
Intraventricular blocks (not diagnostic for CAD)
Increased R-wave amplitude
Acute MI
Hemodynamic changes
Hypotension/blunted BP response
Slowing of HR
Impaired HR response
Marked hypertension
Signs and symptoms
Signs: Third or fourth heart sounds, murmurs, precordial bulging, double cardiac impulse, pulses alternans
Symptoms: angina, dyspnea, pallor, cyanosis, syncope, etc.

Table 14.2 Expected physiologic responses to exercise.

Progressive increase in HR and BP
Shortening of the QT interval
Physiologic ST-segment alterations
Functional (J-point) ST-segment depression with duration less than 60–80 ms
Orthostatic ECG changes
Labile T-wave change
Reynold's syndrome
Alteration of T-wave direction or morphology
Decrease in R-wave amplitude
Shortening of PR-interval
Downward sloping of PR-segment
Decrease in T-wave amplitude in early exercise, followed by increase in T-wave amplitude

Các giai đoạn luyện tập

PROCESS	TRAINING (overload)	INTENSIFIED TRAINING		
OUTCOME	ACUTE FATIGUE	FUNCTIONAL OR (short-term OR)	NON-FUNCTIONAL OVERREACHING (extreme OR)	OVERTRAINING SYNDROME (OTS)
RECOVERY	Day(s)	Days – weeks	Weeks – months	Months - …
PERFORMANCE	INCREASE	Temporary performance decrement (e.g., training camp)	STAGNATION DECREASE	DECREASE