

DIAGNOSTICA IN CARDIOLOGIA DELLO SPORT E NELLA DIAGNOSI DELLE ARITMIE

Il test cardiopolmonare: campi di applicazione nell'atleta

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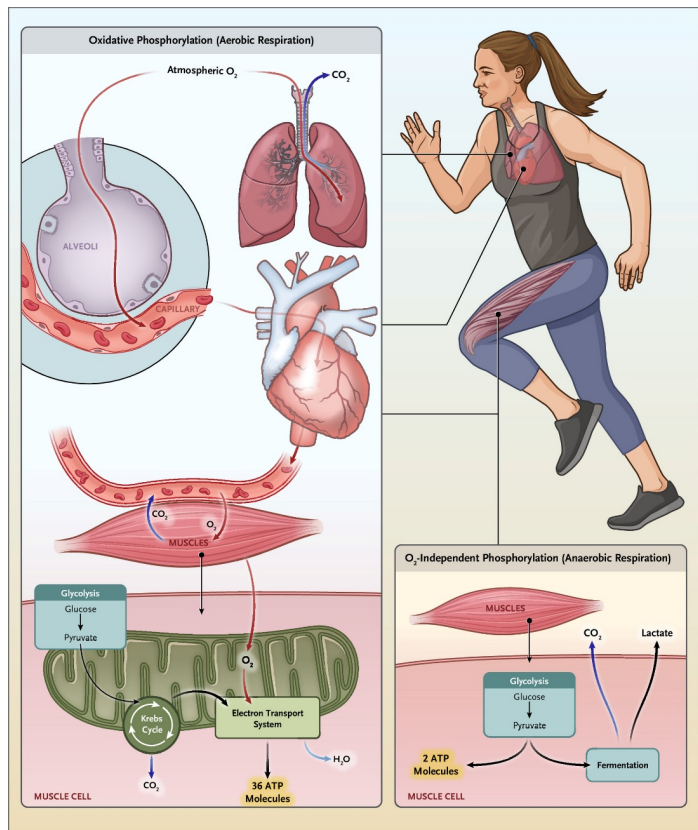
Specialista in Cardiologia e Pneumologia

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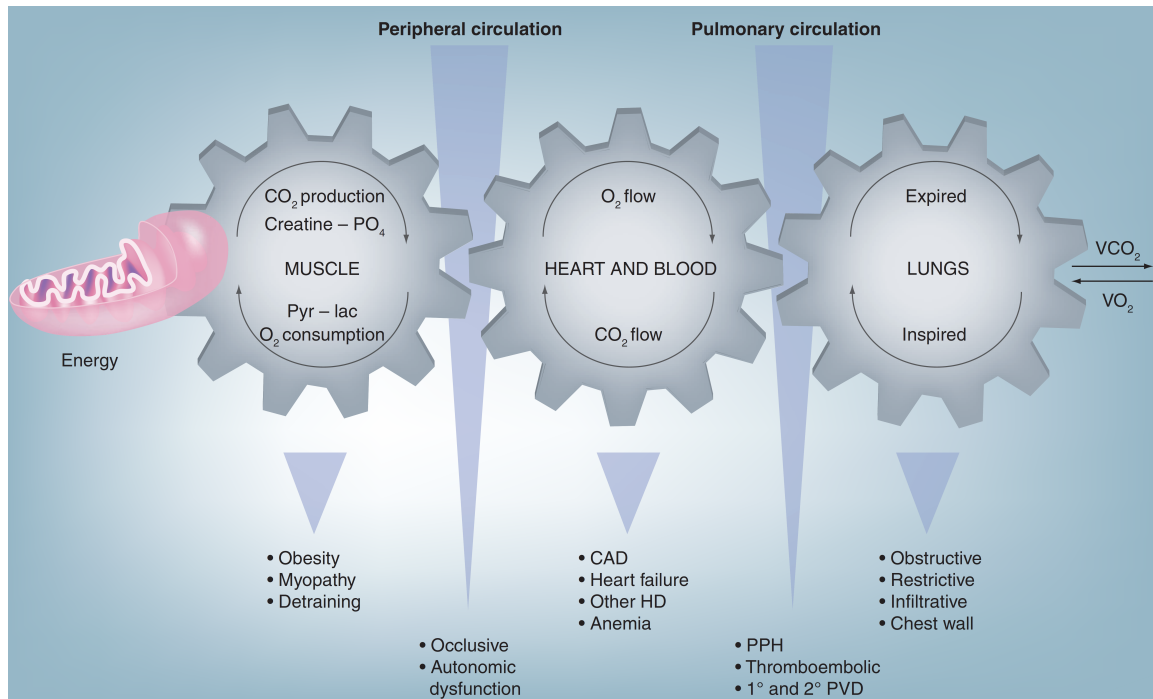
Fondazione Policlinico Universitario Campus Bio-Medico



Valutazione funzionale



Brazile TL et al. NEJM Evid, 2024



Stringer WW. Expert Rev Respir Med, 2010



Why use CPET?

ECG treadmill

- Ischemia/12-lead ECG
- Heart rate/HRR
- Blood pressure, double product
- Estimate of METs
- Symptoms/reason for stopping

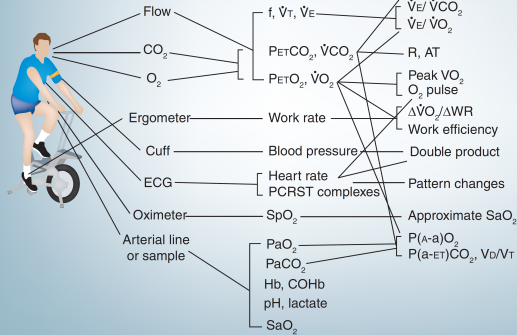
CPET

- Ischemia/12-lead ECG
- Heart rate/HRR
- Blood pressure, double product
- Measured work rate
- Symptoms/ reason for stopping
- Oxygen saturation
- Maximal oxygen uptake ($\dot{V}O_2$ max)
- Lactic acidosis threshold
- Carbon dioxide output ($\dot{V}CO_2$)
- Minute ventilation ($\dot{V}_E$), TV, RR/BR
- Ventilatory equivalents ($\dot{V}_E/\dot{V}O_2$, $\dot{V}_E/\dot{V}CO_2$)
- $\dot{V}O_2$ work rate relationship ($\Delta\dot{V}O_2/\Delta WR$)
- O_2 pulse ($SV \times C(a-v)O_2$ difference)
- Respiratory exchange ratio
- End tidal O_2 , CO_2
- Blood gases/ $COHb$
- $\dot{V}d/\dot{V}t$
- $P(A-a)O_2 \rightarrow$ low $\dot{V}_A/Q$
- $P(a-ET)CO_2 \rightarrow$ high $\dot{V}_A/Q$
- Expiratory flow pattern

Device/analyzer

Primary

Derived



Binder RK et al. Eur J Cardiovasc Prev Rehabil, 2008

Widespread Applications of Cardiopulmonary Exercise Testing

Highly Active Patients

- Athlete and high performance sports evaluation
- Tactical athlete (firefighters, police and military) workplace readiness

All Patients

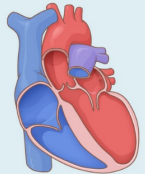
- Evaluation of Unexplained Dyspnea
- Exercise prescription

Patients with Cardiopulmonary Disease

- Establishing prognosis
- Evaluation of treatment effect
- Distinguishing cardiac and pulmonary limitations
- Determining timing of interventions

Examples of Patient Populations:

- Congenital heart disease
- Hypertrophic cardiomyopathy
- Pulmonary hypertension
- Heart failure
- Valve disease



Increasing Underlying Patient Disease

Brazile TL et al. NEJM Evid, 2025



Applicazioni

TABLE I.—*Several applications of cardiopulmonary exercise testing (CPET) in athletes.*

Insights on general cardiovascular efficiency

Response evaluation to exercise training programs

Differential diagnosis of dyspnea (*e.g.*, cardiac or lung etiology)

Suitability for returning to competitive sports participation after an acute cardiovascular disease (*e.g.*, myocarditis or pericarditis), after an injury, or SARS-CoV2 infection

Evaluation of cardiovascular adaptations entity

Identification of overreaching and overtraining conditions

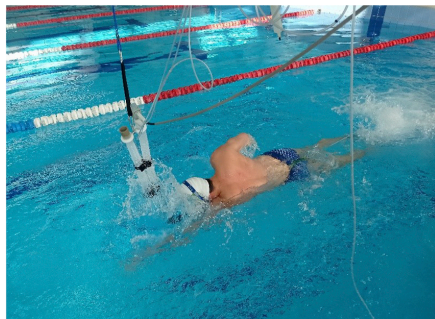
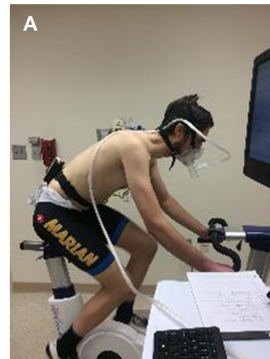
Study of deconditioning grades

Differentiation between athlete's heart from early cardiomyopathy

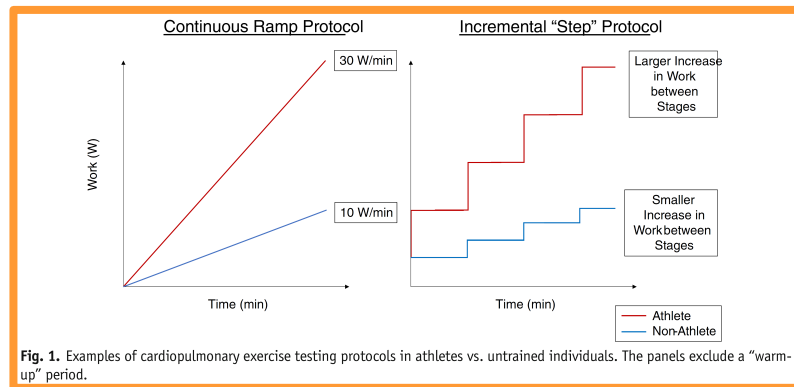
Evaluation of direct performance and cardiorespiratory conditions on the field by portable devices

Segreti A et al. J Sports Med Phys Fitness, 2023





Macfarlane DJ. *Eur J Appl Physiol*, 2017
Parizher G et al. *Clin Sports Med*, 2022
Strzala M et al. *Front Physiol*, 2023



Petek BJ et al. *Curr Treat Options Cardio Med*, 2021



Parametri

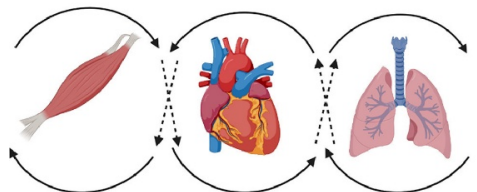
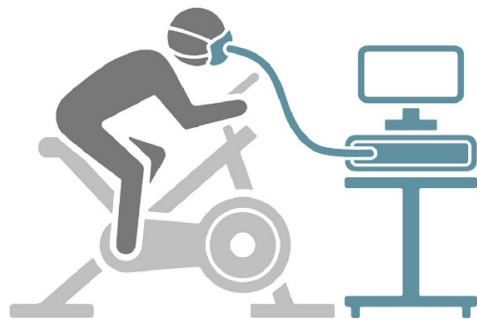


Table 1 Various cardiopulmonary exercise testing parameters in athletes & nonathletes		
CPET Parameter	Similar Between Athletes and Nonathletes	Can be Different in Some athletes
<i>Metabolic/cardiovascular</i>		
$\dot{V}O_2$		Peak $\dot{V}O_2$ can be significantly higher particularly with endurance athletes
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	
<i>Ventilatory/gas exchange</i>		
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	
$VE/\dot{V}CO_2$ 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

Abbreviations: AT, anaerobic threshold; CI, chronotropic index; EIAH, exercise-induced arterial hypoxemia; HR, heart rate; PETCO₂, end-tidal carbon dioxide; RC, respiratory compensation; RER, respiratory exchange ratio; RR, respiratory reserve; SpO₂, oxygen saturation; $\dot{V}CO_2$, rate of carbon dioxide production; $\dot{V}O_2$, rate of oxygen consumption.



Baccelli A et al. Clin Med (Lond), 2025

Taylor JL et al. Front Cardiovasc Med, 2021

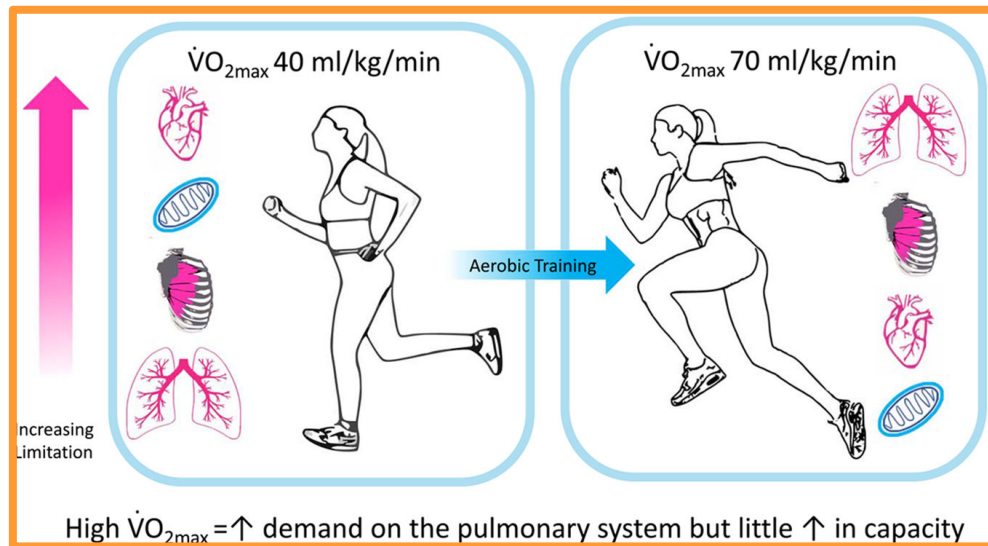


Interpretazione nell'atleta

	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

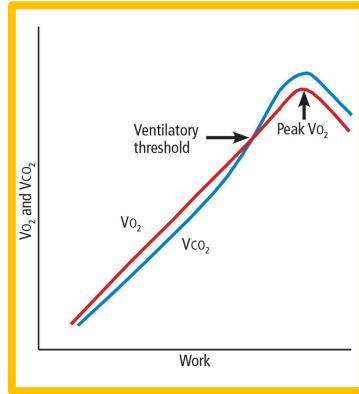
Low intensity
 Medium intensity
 High intensity

Pelliccia A et al. Eur Heart J, 2021

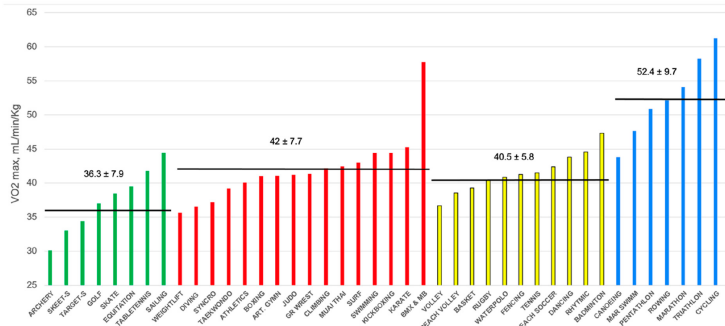


Peters CM et al. Med Sci Sports Exerc, 2023

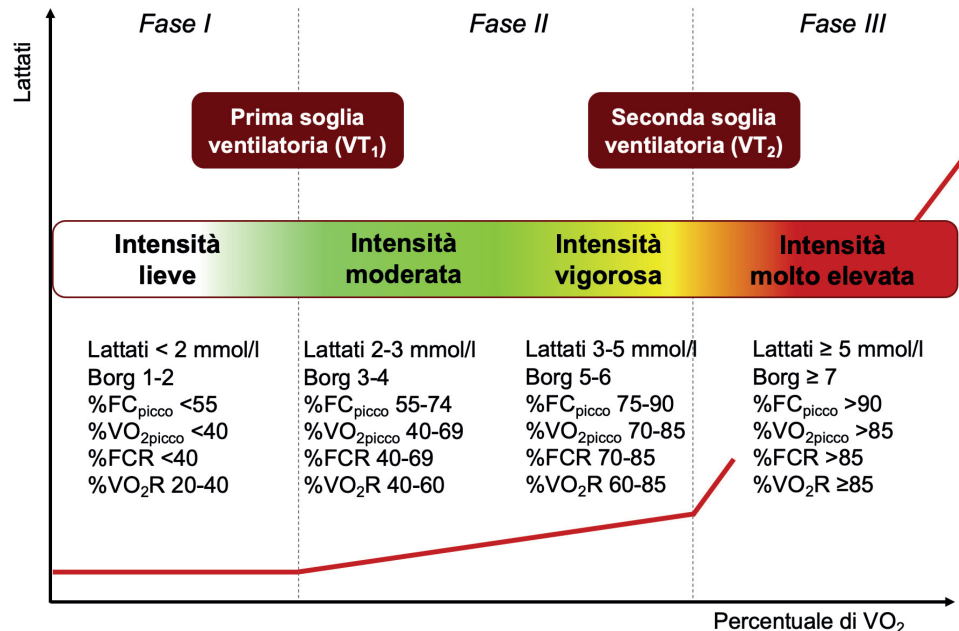
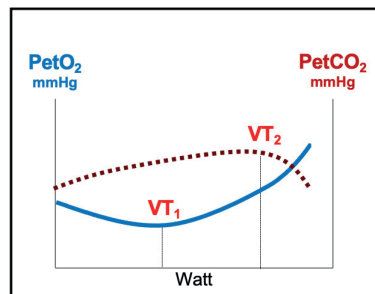
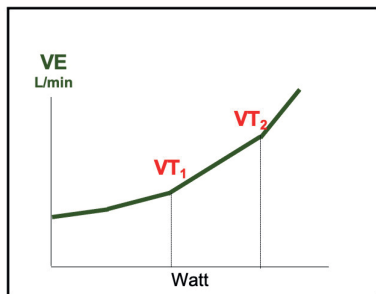
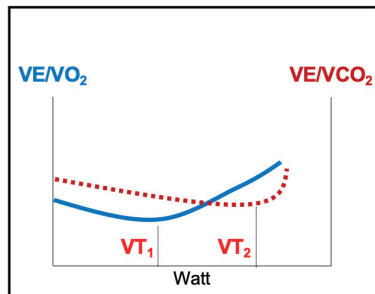
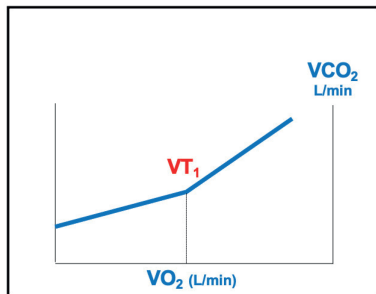




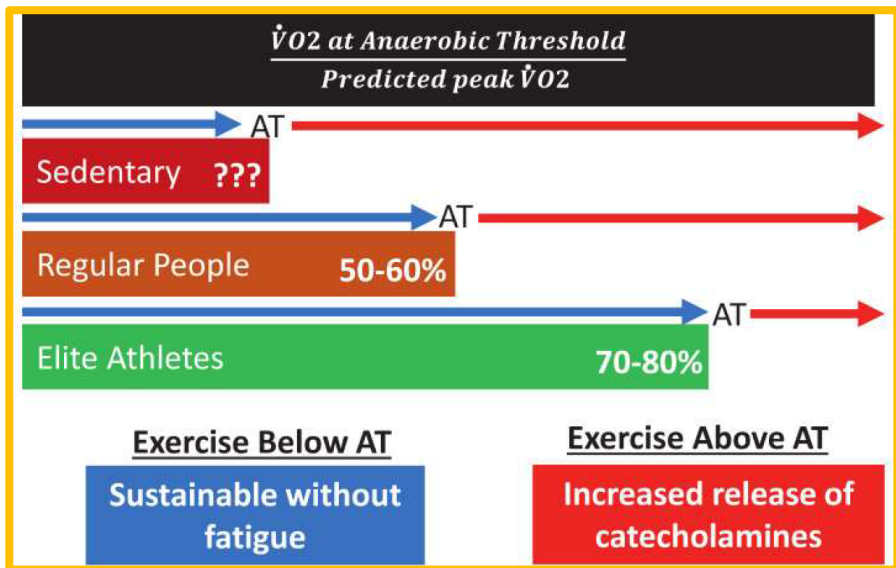
Leclerc K. CCJM, 2017



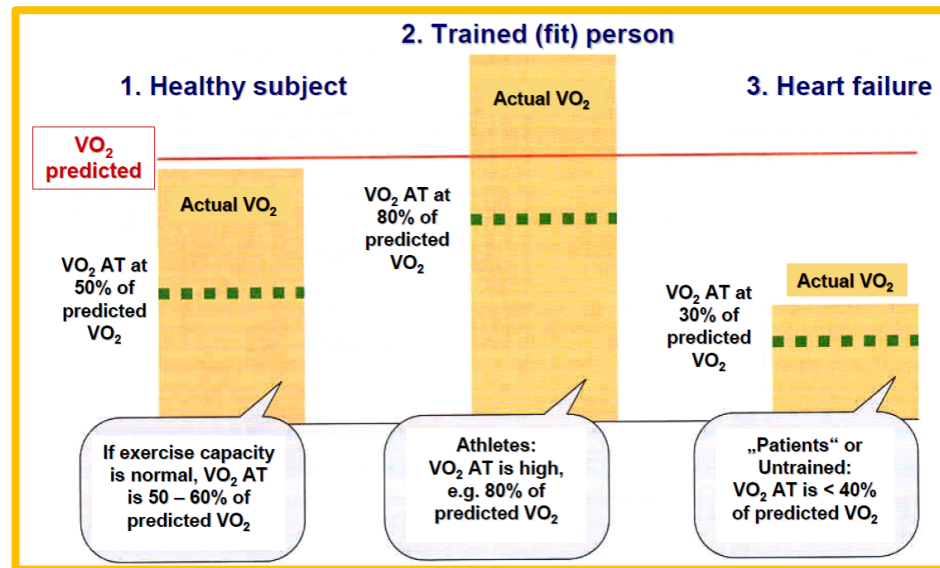
Soglie ventilatorie



Prima soglia ventilatoria



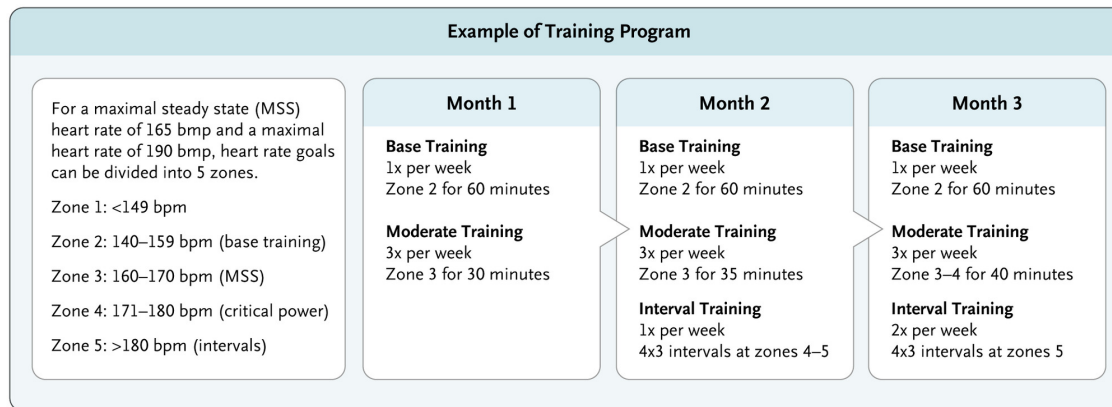
Husaini M et al. *Cardiol Clin*, 2023



Prescrizione dell'esercizio

Intensity	VO ₂ max (%)	HRmax (%)	HRR (%)	RPE Scale	Training Zone
Low intensity, light exercise ^a	<40	<55	<40	10–11	Aerobic
Moderate intensity exercise ^a	40–69	55–74	40–69	12–13	Aerobic
High intensity ^a	70–85	75–90	70–85	14–16	Aerobic + lactate
Very high intense exercise ^a	>85	>90	>85	17–19	Aerobic + lactate + anaerobic

Pelliccia A et al. Eur Heart J, 2021



Brazile TL et al. NEJM Evid, 2025



Risposta cardiovascolare

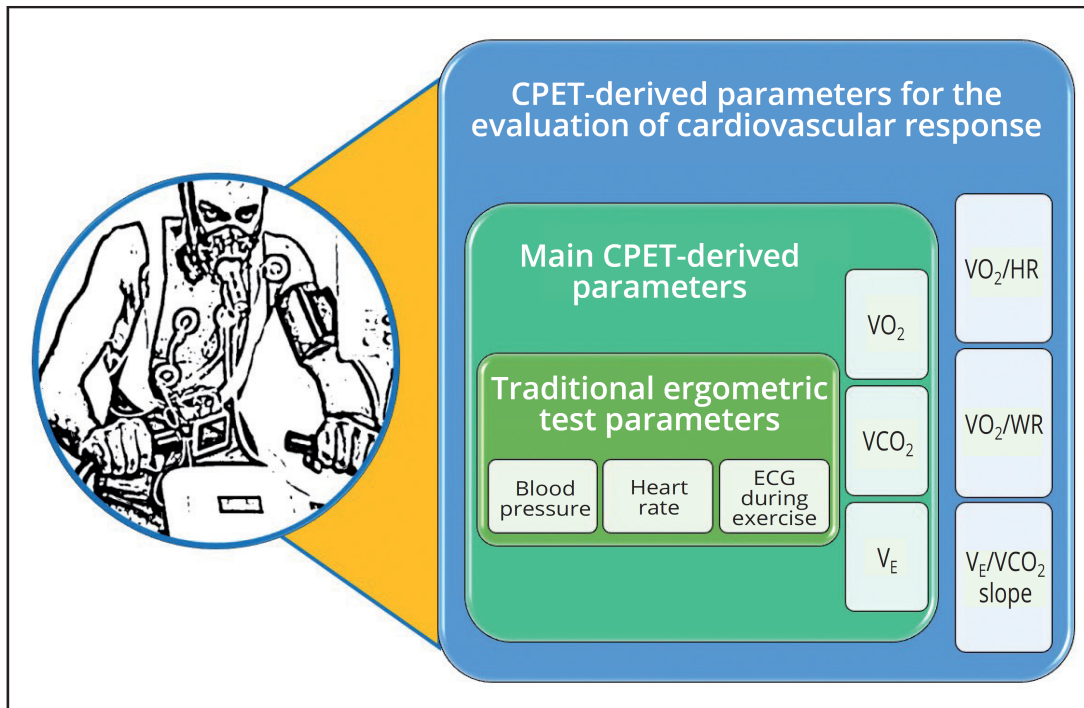


Figure 1.—Parameters of cardiovascular interest obtained by cardiopulmonary exercise testing.

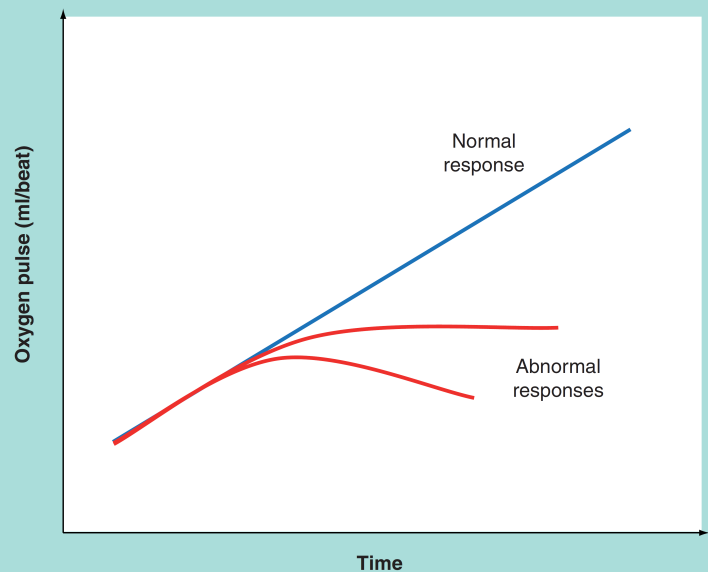
Segreti A et al. *J Sports Med Phys Fitness*, 2023



Polso di O₂

$$\text{VO}_2 = \text{HR} \times \text{SV} \times (\text{CaO}_2 - \text{CvO}_2)$$

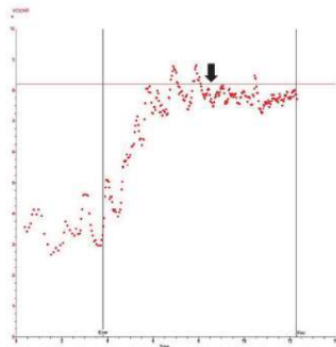
$$\text{VO}_2/\text{HR} = \text{SV} \times (\text{CaO}_2 - \text{CvO}_2)$$



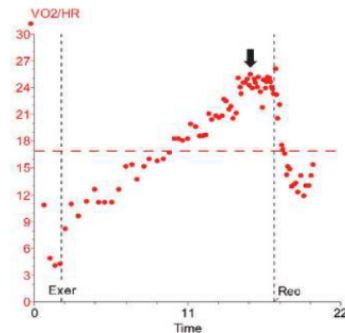
Guazzi M et al. *Circulation*, 2012

$$\text{O}_2 \text{ Pulse} = \frac{\dot{\text{VO}}_2}{\text{HR}} = \frac{\text{Stroke Volume}}{a - v\text{O}_2 \text{ difference}}$$

O₂ pulse plateau below peak $\dot{\text{VO}}_2$ in a nonathlete



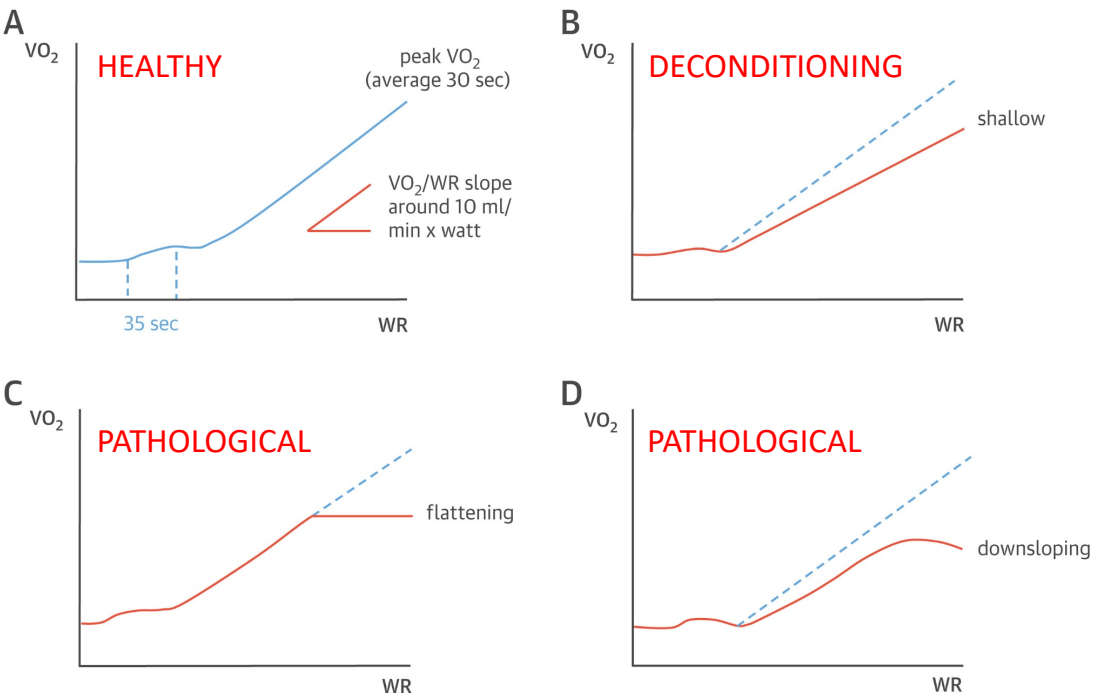
O₂ pulse plateau near $\dot{\text{VO}}_2$ peak in an athlete



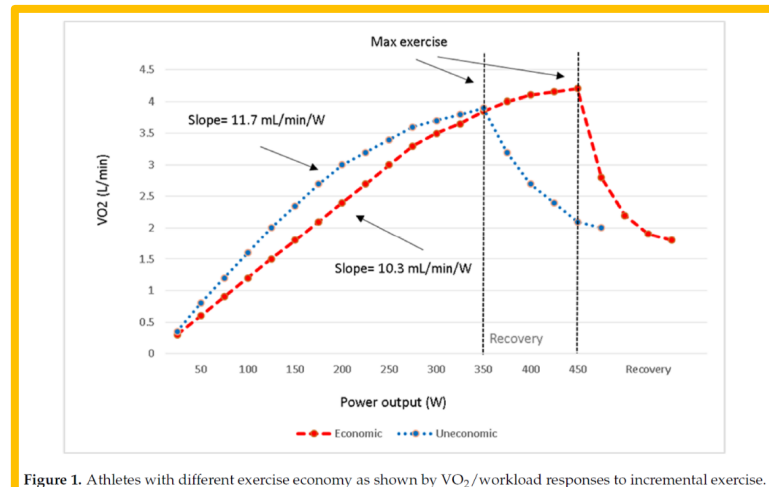
Husaini M et al. *Cardiol Clin*, 2023



Andamento del VO₂



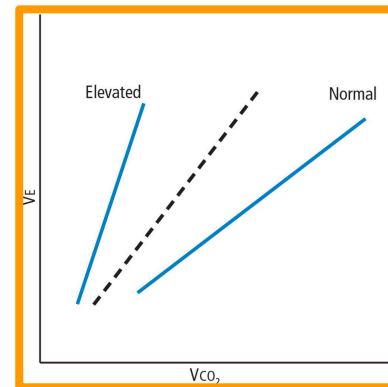
Guazzi M et al. J Am Coll Cardiol, 2017



Mazhaeri R et al. J Clin Med, 2021



Efficienza ventilatoria



Leclerc K. CCJM, 2017

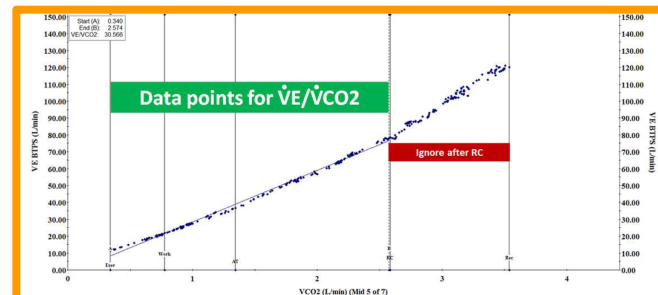
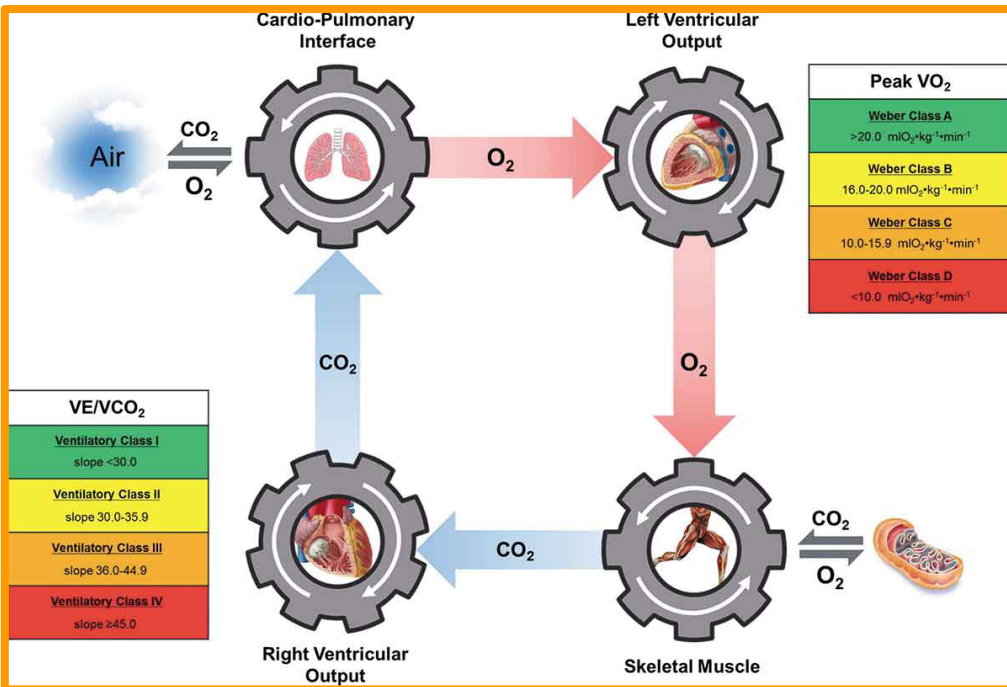


Fig. 3. VE/VCO₂ slope in athletes should be measured up to the respiratory compensation point. Athletes often have a hyperventilatory drive after the respiration compensation point that increases the VE/VCO₂ slope. In this population, the VE/VCO₂ slope should be taken from the start of exercise to the respiratory compensation (RC) point.

Husaini M et al. Cardiol Clin, 2023



Arena R et al. Expert Rev Cardiovasc Ther, 2019



Echocardiographic Parameters and Athlete Performance: Associations and Training Profile Comparisons

Emiliano Guerra ¹, Andrea Segreti ^{2 3 4}, Myriam Carpenito ^{2 3}, Martina Ciano ^{2 3}, Lorenzo Guarino ^{2 3}, Danilo Ricciardi ^{2 3}, Chiara Fossati ⁴, Sergio Suma ⁵, Nicola Gaibazzi ⁵, Renato Rosiello ¹, Corrado Lettieri ⁶, Rocco Papalia ^{7 8}, Fabio Pigozzi ⁴, Giuseppe Boriani ⁹, Francesco Grigioni ^{2 3}

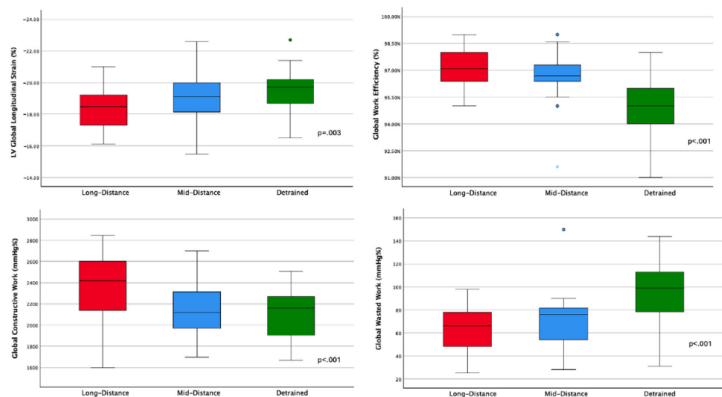


FIGURE 2 | Graphical representation of advanced echocardiographic parameters across three study groups. Comparison of advanced echocardiographic parameters between long-distance, mid-distance and detrained groups. Left upper panel: Graphical representation of LV global longitudinal strain across three study groups. Right upper panel: Graphical representation of LV global work efficiency across three study groups. Left lower panel: Graphical representation of LV global constructive work across three study groups. Left lower panel: Graphical representation of LV global wasted work across three study groups. LV, Left ventricular.

Guerra E et al. Echocardiography, 2026

TABLE 3 | Cardiopulmonary Exercise Test findings of the Three Study Groups.

<i>CPET findings:</i>	Total <i>n</i> = 88	Long-Distance <i>n</i> = 30	Mid-Distance <i>n</i> = 27	Detrained <i>n</i> = 31	<i>p</i> -value
Ramp, (W)	24 ± 7	27 ± 5 ^a	25 ± 6 ^b	19 ± 6	<0.001
RQ	1.15 ± 0.07	1.14 ± 0.05	1.15 ± 0.05	1.15 ± 0.09	0.777
Exercise capacity, (W)	240 ± 75	290 ± 66 ^a	255 ± 56 ^b	179 ± 48	<0.001
Exercise duration, (min)	10.1 ± 1.5	10.6 ± 1.4	10.1 ± 1.5	9.5 ± 1.6	0.117
HR max, (bpm)	166 ± 13	167 ± 10	167 ± 13	164 ± 16	0.477
Peak VO ₂ , (ml/min/kg)	41.5 ± 11.2	50.2 ± 6.2 ^{a,c}	45.5 ± 8.1 ^b	29.5 ± 5.5	<0.001
18	118 ± 32	145 ± 18 ^{a,c}	128 ± 20 ^b	84 ± 14	<0.001
VO ₂ /HR max, (ml/beat)	17.2 ± 4.6	20.0 ± 4.4 ^a	18.1 ± 3.9 ^b	13.6 ± 2.7	<0.001
%Pred-VO ₂ /HR max, (%)	129 ± 33	155 ± 19 ^{a,c}	141 ± 23 ^b	94 ± 15	<0.001
VO ₂ /WR slope, (ml/min/W)	10.5 ± 0.9	10.5 ± 0.7	10.5 ± 0.8	10.5 ± 1.1	0.968
VE/VCO ₂ slope	25.1 ± 3.2	25.9 ± 2.9	25.5 ± 2.4	24.1 ± 3.8	0.063

Note: Data are presented as mean ± SD. Statistical analysis was performed using one-way ANOVA for normally distributed continuous variables and Kruskal-Wallis for non-normally distributed variables. Levene's test was used for homogeneity of variances, with the Brown-Forsythe test applied when variances were unequal. Chi-square tests were used for categorical variables. Post hoc pairwise comparisons were conducted using Bonferroni and Tamhane corrections, with a significance level set at *p* = 0.017. Significant post hoc comparisons:

Abbreviations: HR; Heart Rate; RQ; respiratory quotient; VCO₂; Carbon Dioxide production; VE; Minute Ventilation; VO₂; Oxygen uptake; WR; Work Rate.

^aLong-Distance > Detrained.

^bMid-Distance > Detrained.

^cLong-Distance > Mid-Distance.

Continuous variables are presented as mean ± standard deviation (SD).



Risposta cardiovascolare

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

HR: heart rate; BP: blood pressure; CO: cardiac output; VO₂: oxygen consumption; VO₂/HR: the ratio between oxygen consumption (VO₂) and heart rate (HR); VO₂/WR slope: the slope throughout the exercise of the relationship between oxygen consumption (VO₂) and work rate (WR); LT: anaerobic threshold; V_E/VCO₂ slope: the slope of the relationship between minute ventilation (V_E) and carbon dioxide production (VCO₂).

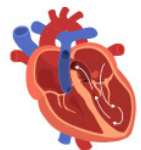
Segreti A et al. J Sports Med Phys Fitness, 2023



Patologie cardiache



Cardiorespiratory fitness



VO₂peak ↓ or ~
VE/CO₂-slope ↑↑

Hypertrophic cardiomyopathy



VO₂peak ↓
Chronotropic competence ↓↓
Heart rate recovery ↓↓
Arrhythmias



VO₂peak ↓ or ~
O₂Ppeak ↓↓
Valve diseases

ROLE OF CPET IN CVD AMONG ATHLETES

SPECIAL AGE GROUPS

■ PEDIATRIC ATHLETES

CPET authorizes safe return to sport after treatment and identifies high-risk congenital heart diseases.

■ MASTER ATHLETES

CPET could be used to assess VO₂peak, and lower VO₂peak could be a risk factor for the development of more vulnerable coronary plaques.

THE MOST COMMON CVD IN ATHLETES

■ HYPERTROPHIC CARDIOMYOPATHY

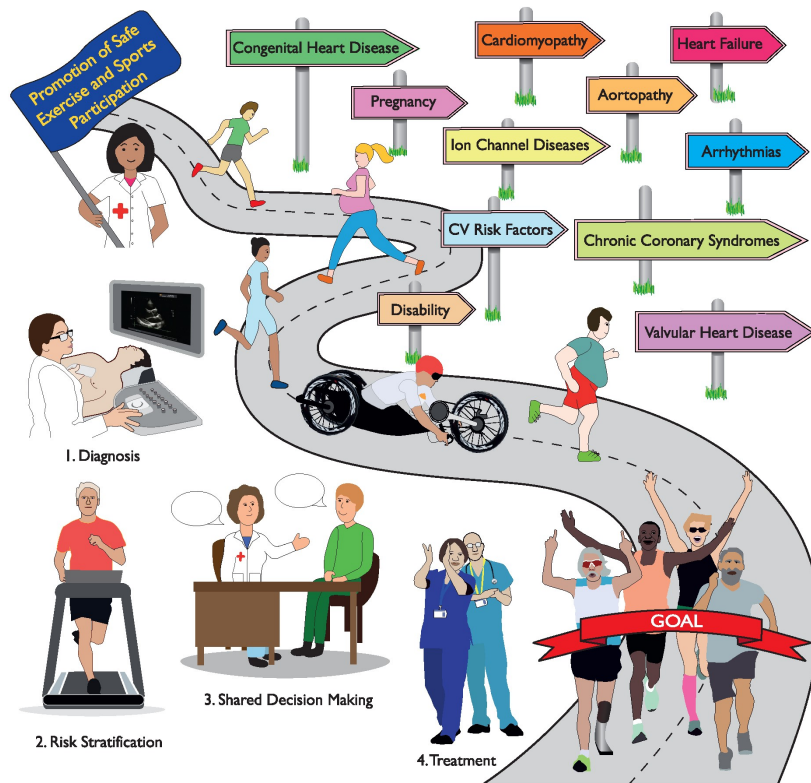
Risk stratification and monitoring of the course requires comprehensive analysis of CPET scores - VO₂peak an VE/VO₂-slope.

■ ARRHYTHMIAS

Exercise-induced arrhythmias are an important diagnostic factor in CVD among athletes.

■ VALVE DISEASES

CPET with stress echocardiography could be used to grade exercise tolerance and response to exercise.



Pelliccia A et al. Eur Heart J, 2021

Kasiak P. Vasc Health Risk Manag, 2026



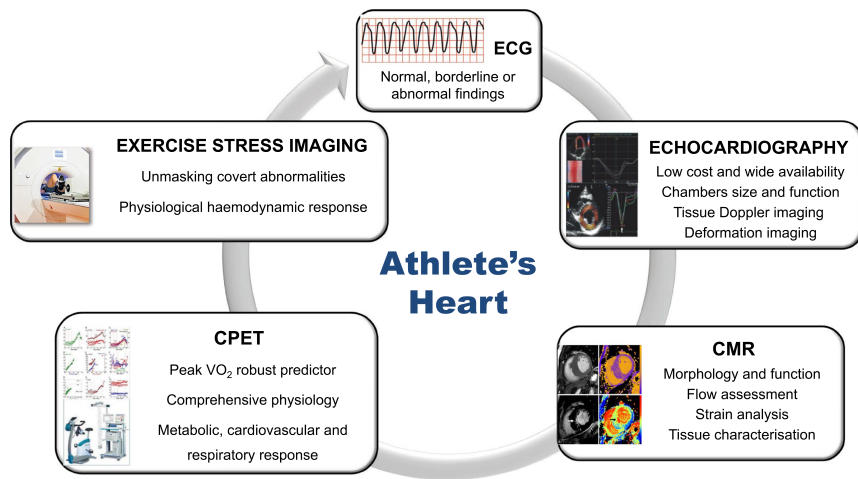


Fig. 1 The diagnostic continuum between exercise-induced cardiac remodeling and pathology. *CPET* cardiopulmonary exercise testing, *CMR* cardiovascular magnetic resonance

De Innocentiis C et al. Sports Med, 2018

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

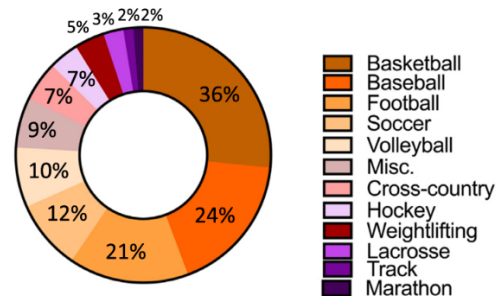
	$\text{VO}_{2\text{peak}}$	VO_2 at LT	V_E/VCO_2 slope	O_2 pulse	VO_2/WR slope	PVCs during exercise with origin and morphology
Athlete's heart	>50 mL/kg/min or >120% of predicted	>70%	Normal	Increased	Increased	- Absent, when present monomorphic - LVOT: LBBB, inferior axis, early transition <V4 - RVOT: 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

VO_2 : oxygen consumption; O_2 pulse: the ratio between oxygen consumption (VO_2) and heart rate (HR); VO_2/WR slope: the slope throughout the exercise of the relationship between oxygen consumption (VO_2) and work rate (WR); LBBB: left bundle branch block; LT: lactate threshold; LVOT: left ventricular outflow tract; PVCs: premature ventricular contractions; RVOT: right ventricular outflow tract; V_E/VCO_2 slope: the slope of the relationship between minute ventilation (V_E) and carbon dioxide production (VCO_2).

Segreti A et al. J Sports Med Phys Fitness, 2023



Distribution of Sports Played

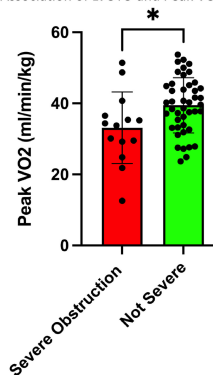


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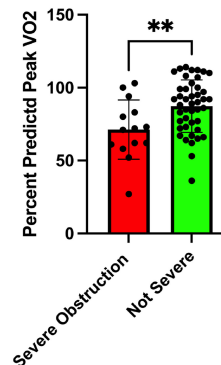
Cardiopulmonary exercise testing

Exercise Time (min)	12.1 ± 2.4
FAC (%)	91 ± 18
Peak VO ₂ (ml/kg/min)	37.9 ± 8.7
Predicted peak VO ₂ (%)	83 ± 19.7
RER	1.16
Major arrhythmia with exercise*	0
Minor arrhythmia with exercise†	13 (20%)
Hypotensive BP response with exercise	7 (12%)
Chronotropic incompetence	11 (19%)

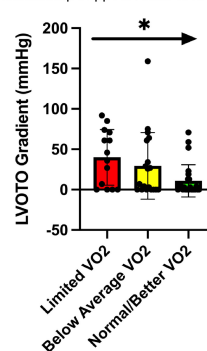
A. Association of LVOTO and Peak VO₂



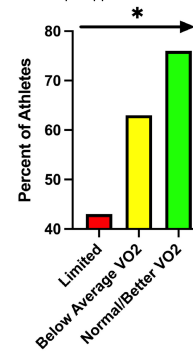
B. Association of LVOTO and ppVO₂



C. Relationship of ppVO₂ Class to LVOTO Gradient



D. Relationship of ppVO₂ Class to High Intensity Sport



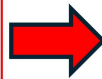
Newman DB et al. Am J Cardiol, 2023



Cardiomiopatie

Cardiopulmonary Exercise Testing Parameters in Healthy Athletes versus Equally Fit Individuals with Hypertrophic Cardiomyopathy

Athletes with HCM frequently display normal to supranormal pVO_2 , limiting this parameter's diagnostic utility in distinguishing between healthy athletes and those with HCM.



Hypothesis:
There will be differences in other CPET parameters between healthy athletes & equally fit individuals with HCM.

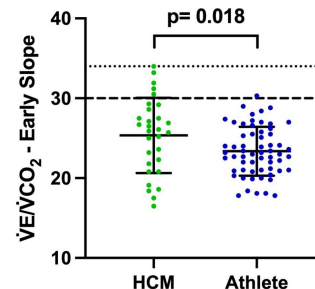
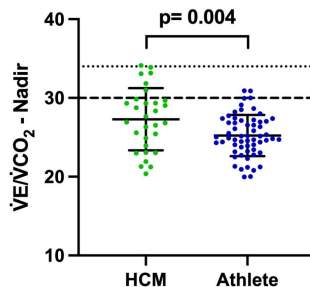
Nonobstructive
HCM (n=30)

Healthy Matched
Athletes (n=60)

Supranormal pVO_2
(125% predicted)



Ventilatory Efficiency Worse
in HCM vs. Healthy Athletes



McHugh C et al. Eur J Prev Cardiol, 2025



HRS Consensus Statement

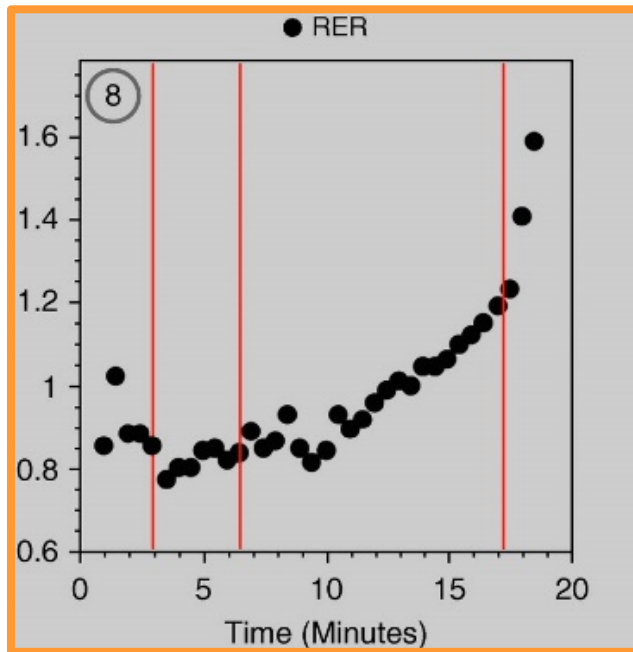
2024 HRS expert consensus statement on arrhythmias in the athlete:

Evaluation, treatment, and return to play

Rachel Lampert, MD, FHRS, (Chair),^{1,*} Eugene H. Chung, MD, MPH, MSc, FHRS, (Vice-Chair),^{2,*} Michael J. Ackerman, MD, PhD,^{3,*} Alonso Rafael Arroyo, MD,^{15,†} Douglas Darden, MD,^{4,*} Rajat Deo, MD,^{5,*} Joe Dolan,[†] Susan P. Etheridge, MD, FAHA, FHRS, FACC, CEP-S,^{6,†} Belinda R. Gray, MBBS, PhD, FHRS, CCDS,^{7,*} Kimberly G. Harmon, MD,^{8,*} Cynthia A. James, PhD, CGC,^{9,*} Jonathan H. Kim, MD, MSc, FACC,^{10,‡} Andrew D. Krahn, MD, FHRS,^{11,*} Andre La Gerche, MBBS, PhD,^{12,**} Mark S. Link, MD, FHRS,^{13,*} Ciorsti MacIntyre, MD,^{3,*} Lluís Mont, MD, PhD, FEHRA,^{14,††} Jack C. Salerno, MD, FHRS,^{16,††} Maully J. Shah, MBBS, FHRS, CCDS, CEPS-P^{17,††}

Athletes may present with symptoms only at very high exercise intensities. As such, it is critical that in the clinical evaluation of the symptomatic athlete, exercise stress testing proceeds to maximal volitional effort (or symptoms) and is not terminated based on heart rate thresholds (eg, 85% maximum predicted heart rate). Maximal effort may be determined by the rating of perceived exertion (eg, Borg scale) or maximum heart rate achieved, although heart rate alone should not be considered a stopping point. Cardiopulmonary exercise testing (CPET) is also useful in adjudicating maximal effort through measured $\text{VO}_{2\text{max}}$, maximum exercise heart rate, surpassing the ventilatory threshold, and the respiratory exchange ratio. CPET that incorporates quantitative gas and metabolic analyses may enhance understanding of a patient's particular physiology and limitations. Exer-

Lampert R et al. Heart Rhythm, 2024



Dumitrescu D et al. Ann Am Thorac Soc, 2017

QUOZIENTE RESPIRATORIO

$$\text{RER} = \text{VCO}_2 / \text{VO}_2$$

Peak RER ≥ 1.10

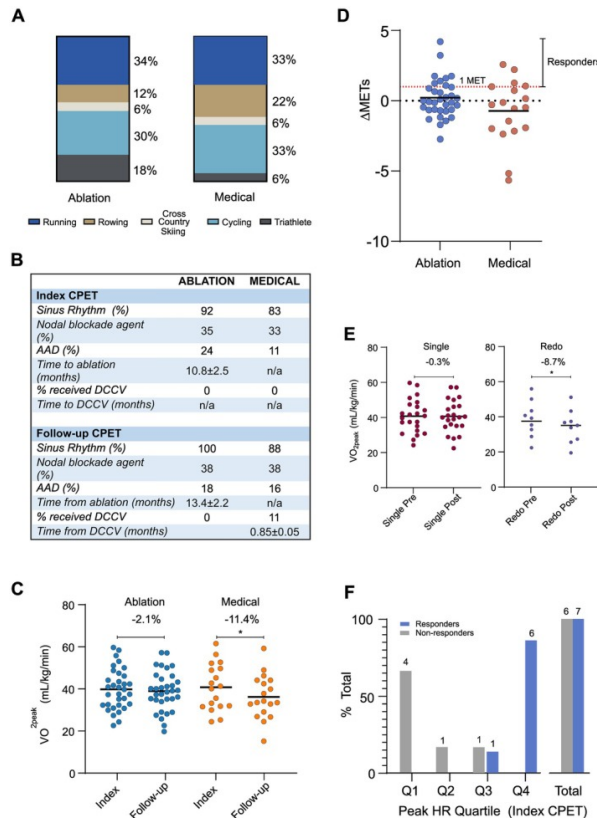
Test massimale



RESEARCH LETTER

Preserved Cardiorespiratory Fitness After Catheter Ablation in Athletes With Atrial Fibrillation

P. Nelson Hsieh , MD, PhD; Mark É. Czeisler, MD; Marius Chukwurah , MD; Katie M. Stewart, CNP; Sarah K. Gustus, MS, ATC; Kristen Steinmetz, BS; Alexa Volfson, BS; Conor D. Barrett, MD, MBA; Timothy W. Churchill , MD; Aaron L. Baggish , MD; James S. Guseh , MD; Eugene H. Chung , MD, MPH; Cardiovascular Performance Program Study Group



Hsieh PN et al. J Am Heart Assoc, 2026



AHA/ACC SCIENTIFIC STATEMENT

Clinical Considerations for Competitive Sports Participation for Athletes With Cardiovascular Abnormalities: A Scientific Statement From the American Heart Association and American College of Cardiology

Jonathan H. Kim, MD, MSc, FACC, Chair; Aaron L. Baggish, MD, FACC, Vice Chair; Benjamin D. Levine, MD, FAHA, FACC, Vice Chair; Michael J. Ackerman, MD, PhD, FACC; Shariene M. Day, MD, FAHA; Elizabeth H. Dineen, DO, FACC; J. Sawalla Guseh II, MD; Andre La Gerche, MBBS, PhD; Rachel Lampert, MD, FHRS, FACC; Matthew W. Martinez, MD, FACC; Michael Papadakis, MBBS, MD, FRCP; Dermot M. Phelan, MD, PhD, FACC; Keri M. Shafer, MD, FACC; on behalf of the American Heart Association Leadership Committee of the Council on Clinical Cardiology; Council on Basic Cardiovascular Sciences; Council on Cardiovascular and Stroke Nursing; Council on Cardiovascular Surgery and Anesthesia; Council on Peripheral Vascular Disease; and American College of Cardiology

Kim JH et al. Circulation, 2025

Review > J Clin Med. 2023 May 19;12(10):3562. doi: 10.3390/jcm12103562.

Mitral and Tricuspid Valve Disease in Athletes

Andrea Segreti^{1,2}, Mihail Celeski¹, Luigi Maria Monticelli¹, Alfonso Perillo¹, Simone Pasquale Crispino¹, Giuseppe Di Gioia^{1,2,3}, Valeria Cammalleri¹, Chiara Fossati², Simona Mega¹, Rocco Papalia^{4,5}, Fabio Pigozzi², Gian Paolo Ussia¹, Francesco Grigioni¹

Affiliations + expand

PMID: 37240669 PMCID: PMC10219091 DOI: 10.3390/jcm12103562

Segreti A et al. J Clin Med, 2023



ESC
European Society
of Cardiology

European Journal of Preventive Cardiology (2021) 28, 1569–1578
doi:10.1093/eurjpc/zwab058

POSITION PAPER

Athletes with valvular heart disease and competitive sports: a position statement of the Sport Cardiology Section of the European Association of Preventive Cardiology

Frank van Buuren^{1,2†}, Sabiha Gati^{3,4†}, Sanjay Sharma⁵, Michael Papadakis⁵, Paolo Emilio Adami⁶, Josef Niebauer⁷, Antonio Pelliccia⁶, Volker Rudolph¹, Mats Börjesson^{8,9}, Francois Carre¹⁰, Erik Solberg¹¹, Hein Heidbuchel¹², Stefano Caselli¹³, Domenico Corrado¹⁴, Luis Serratos^{15,16}, Alessandro Biffi⁶, Axel Pressler^{17,18}, Christian Schmied¹⁹, Nicole M. Panhuyzen-Goedkoop²⁰, Hanne Kruse Rasmussen²¹, Andre La Gerche²², Lothar Faber¹, Nikola Bogunovic¹, Flavio D'Ascenzi²³, and Klaus Peter Mellwig¹

Van Buuren F et al. Eur J Prev Cardiol, 2021



ESC
European Society
of Cardiology

European Heart Journal - Cardiovascular Imaging (2019) 20, 772–780
doi:10.1093/ehjci/ez001

Bicuspid aortic valve behaviour in elite athletes

Araceli Boraita^{1*}, Francisco Morales-Acuna^{1,2†}, Manuel Marina-Breyse^{1,3†}, Maria-Eugenia Heras¹, Alicia Canda⁴, Maria-Eugenia Fuentes⁵, Antonio Chacón⁵, Leonel Diaz-Gonzalez¹, Manuel Rabadan⁶, Begoña Parra Laca⁷, Leopoldo Pérez de Isla⁷, and José Tuñón⁸

Boraita A et al. Eur J Prev Cardiol, 2019



The Spectrum of Coronary Artery Disease in Elite Endurance Athletes-A Long-Standing Debate: State-of-the-Art Review

Mihail Celleski^{1,2}, Giuseppe Di Gioia^{3,4}, Annunziata Nusca^{1,2}, Andrea Segreti^{1,2,4}, Maria Rosaria Squeo³, Erika Lemme³, Federica Mango³, Armando Ferrera^{3,5}, Gian Paolo Ussia^{1,2}, Francesco Grigioni^{1,2}

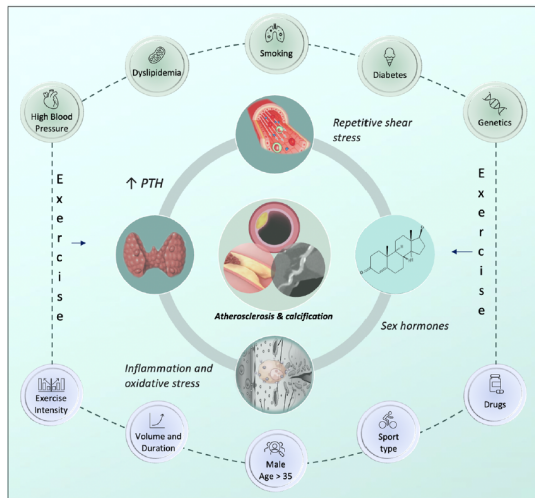
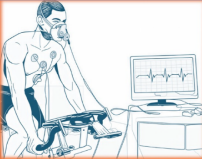


Figure 1. Mechanisms of exercise-related coronary atherosclerosis in athletes and contributing factors. PTH = parathyroid hormone.

Celleski M et al. J Clin Med, 2024

The Complementary Role of Cardiopulmonary Exercise Testing in Coronary Artery Disease: From Early Diagnosis to Tailored Management

Simone Pasquale Crispino¹, Andrea Segreti^{1,2}, Martina Cianoio¹, Dajana Polito¹, Emiliano Guerra^{1,3}, Giuseppe Di Gioia^{2,4}, Gian Paolo Ussia¹, Francesco Grigioni¹

Cardiopulmonary Exercise Testing VS. ECG Stress Testing		
CAD diagnosis	Higher Sensitivity and Specificity ⁵	Lower Sensitivity and Specificity ¹⁵
Baseline ECG alterations	Diagnostic Value ²³	No Diagnostic Value
Beta-blockers medications	Lower Influence On Diagnostic Value ²⁴	Higher Influence On Diagnostic Value
Symptoms of dyspnea	Differentiating Cardiac, Pulmonary, And Muscular Causes ²³	Inability To Make A Differential Diagnosis
Follow-up of CAD	Assessment Of Exercise Capacity And Ischemic Threshold ⁵	Low Clinical And Management Impact
Heart failure	Prognostic Information ^{25,26} Exercise Prescription ^{21,27,28}	Low Prognostic Value
Athletes	Determination Of Aerobic And Performance Capacity ²⁹	Only Wmax and Exercise Time

Crispino SP et al. J Cardiovasc Dev Dis, 2024



Effects of Environmental Conditions on Athlete's Cardiovascular System

Andrea Segreti^{1,2,3}, Mihail Celeski^{1,2}, Emiliano Guerra⁴, Simone Pasquale Crispino^{1,2},
Francesca Vespasiano^{1,2}, Lorenzo Buzzelli^{1,2}, Chiara Fossati³, Rocco Papalia^{5,6}, Fabio Pigozzi³,
Francesco Grigioni^{1,2}

Cold		↑ Heart rate	↓ Stroke Volume	↑ Vasoconstriction	↓ Cardiac output	↓ Performance	↑ Injuries risk
Heat and Humidity		↑ Heart rate	↓ Stroke Volume	↑ Vasodilation	↑ Cardiac output	↓ Performance	↑ Heat-related illnesses
Altitude		Hypobaric Hypoxia	↑ Heart rate	↓ Stroke Volume	↑ Cardiac output	↓ Performance	↑ Altitude illness
Diving		Hyperbaric Hypoxia	↓ Heart rate	↓ Stroke Volume	↓ Cardiac output	↑ Right heart pressure	↑ Dive-related injuries
Air Pollution		↑ Heart rate	↓ Stroke Volume	↓ Cardiac output	↓ Performance	↑ Allergic Diseases Cardiac Diseases Respiratory Diseases	

Segreti A et al. J Clin Med, 2024



Sports Physician Handbook (Fourth Edition)

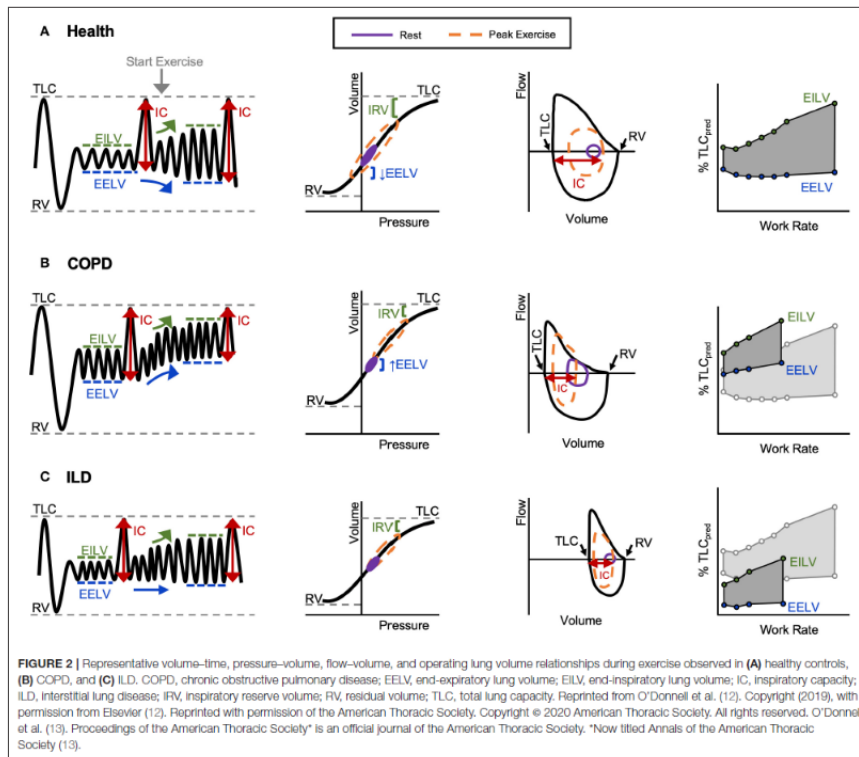
2026, Pages 139-198



Chapter 8 - Relevant medical conditions affecting sports participation

Paolo Borriore¹, Paolo Sgrò¹, Arrigo Giombini¹, Andrea Segreti^{1,2}, Juergen M. Steinacker³,
Fabio Pigozzi¹

Borriore P et al. Sport Physician Manual, 2025

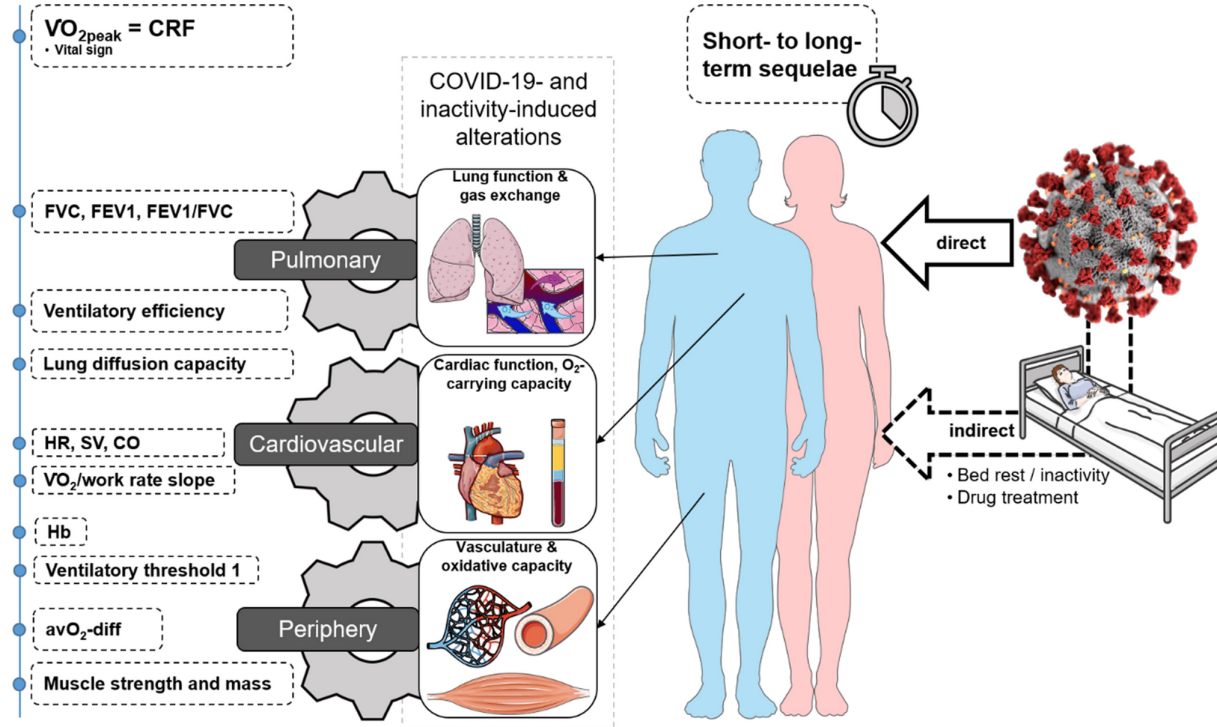


Harbour E et al. Front Physiol, 2022



Ritorno allo sport

Dopo infezione



Schwendinger F et al. Sports Med, 2023



Ritorno allo sport Dopo infortunio

> J Sports Med Phys Fitness. 2024 Jul;64(7):615-623. doi: 10.23736/S0022-4707.24.15496-5.

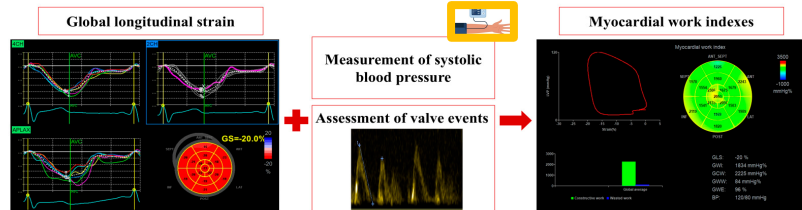
Assessment of cardiopulmonary capacity in deconditioned athletes because of knee injury

Andrea Segreti^{1 2}, Chiara Fossati³, Maria T Mulè⁴, Valerio Fanale⁴, Simone P Crispino⁴, Federica Coletti⁴, Francesco R Parisi^{5 6}, Biagio Zampogna^{5 6}, Sebastiano Vasta^{3 5 6}, Elena Mannacio⁷, Rocco Papalia^{5 6}, Raffaele Antonelli-Incalzi⁸, Fabio Pigozzi³, Francesco Grigioni⁴

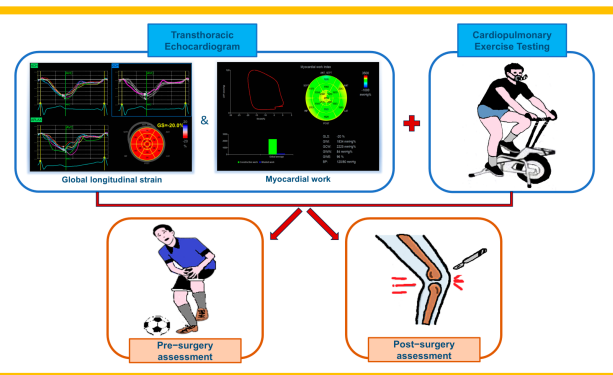
> J Funct Morphol Kinesiol. 2024 Sep 22;9(3):172. doi: 10.3390/jfmk9030172.

Changes in Cardiopulmonary Capacity Parameters after Surgery: A Pilot Study Exploring the Link between Heart Function and Knee Surgery

Andrea Segreti^{1 2 3}, Chiara Fossati³, Luigi Maria Monticelli^{1 2}, Daniele Valente^{1 2}, Dajana Polito^{1 2}, Emiliano Guerra⁴, Andrea Zampoli^{5 6}, Giorgio Albimonti^{5 6}, Biagio Zampogna^{5 6}, Sebastiano Vasta^{3 5 6}, Rocco Papalia^{5 6}, Raffaele Antonelli Incalzi^{7 8}, Fabio Pigozzi³, Francesco Grigioni^{1 2}



Segreti A et al. J Funct Morphol Kinesiol, 2024



Segreti A et al. J Sports Med Phys Fitness, 2024



Grazie per l'attenzione



Oxygen uptake at rest



Oxygen uptake at work (treadle)



Lavoisier A. Traité Élémentaire de Chimie, 1789

