FORUM EUROPÉEN, CŒUR, EXERCICE & PRÉVENTION

Apport du test d'effort dans la dyspnée : synthèse et discussion générale

Pierantonio LAVENEZIANA

Paris, 09/03/2023

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Service des Explorations Fonctionnelles de la Respiration, de l'Exercice et de la Dyspnée (EFRED)
Hôpitaux Universitaires Pitié-Salpêtrière, Tenon et Saint-Antoine
Département Médico-Universitaire "APPROCHES"
Département "R3S" (Respiration, Réanimation, Réhabilitation, Sommeil)

Groupe Hospitalier AP-HP.Sorbonne Université
Charles-Foix • Pitié-Salpêtrière • Rothschild • Saint-Antoine • Tenon • Trousseau/La Roche-Guyon

UMRS 1158 « Neurophysiologie Respiratoire Expérimentale et Clinique »
INSERM - Sorbonne Université
Paris, France

Conflits d'intérêts

Liens d'intérêt : GSK, Chiesi

Liens d'intérêt en relation avec la présentation : aucun

13.45 **Exploration fonctionnelle d'effort dans la dyspnée**

Avec le partenariat de la Société de Pneumologie de Langue Française

Modérateurs : A. Cohen Solal, P. Laveneziana, Paris

- Interpréter une Exploration Fonctionnelle Respiratoire (EFR) J. Frija, Paris
- Apport du test d'effort dans la dyspnée : le point de vue du pneumologue S. Matecki, Montpellier
- Apport du test d'effort dans la dyspnée : le point de vue du cardiologue J.-Y. Tabet, Paris
- Apport du test d'effort dans la dyspnée : synthèse et discussion générale P. Laveneziana, A. Cohen Solal, J. Frija, S. Matecki, J.-Y. Tabet

Commonly (but avoidable) mistakes

- Known nothing about the patient and his/her clinical history
- Ignore symptoms and reasons for stopping exercise
- Don’t pay attention to CPET comments from who is running the CPET
- Focus ONLY on numbers
- Rely (almost exclusively) on predefined algorithms to interpret CPET

The key variables and their meaning

Quantitative approach

(“give me a number please”….
% predicted….

Qualitative approach

(response profile and or kinetics)

Step 1

Assessment of patient' effort : is the test maximal?

- **Patient achieves predicted VO_2 or evidence of a plateau in VO_2?**
- **RER ≥1.05?**
- **HR > 90% predicted max?**
- **Patient exhaustion/Borg score >9/10?**
- **[Lactate] max > 8 mmol·l-1 and/or (fall in pH <0.04) during the immediate recovery phase**
- **Wpeak exceeds Wpeak predicted**
- **Evidence of a ventilatory limitation: breathing reserve <15-20% and/or significant EFL and/or decrease in IC?**

Laveneziana P et al, ERJ and ERR 2019

Step 1

Assessment of patient' effort : is the test maximal?
- **Patient achieves predicted VO_2 or evidence of a plateau in VO_2?**
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- **Evidence of a ventilatory limitation: V'Epeak ≥85% MVV and/or significant EFL and/or decrease in IC?**

Step 2

Evaluation of $V'O_2$ peak or $V'O_2$ max if applicable

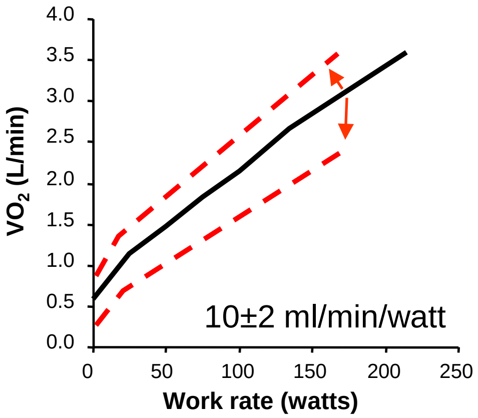
Step 3a

Graphic and tabular representations of CPET variables

METABOLIC

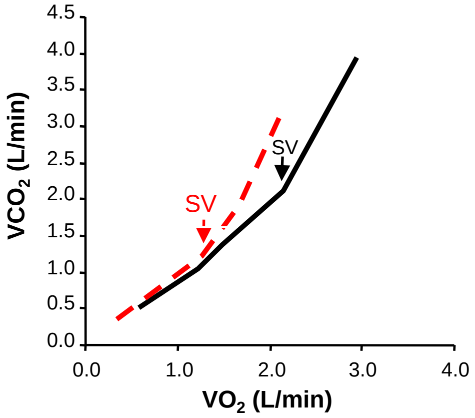
WR= work rate
VO_2= oxygen uptake
VCO_2= carbon dioxide output
R= VO_2/ VCO_2

Laveneziana P et al, Eur Respir Rev 2021; 30: 200187



Obesity
↓ Type I fibers
↑ Type II fibers

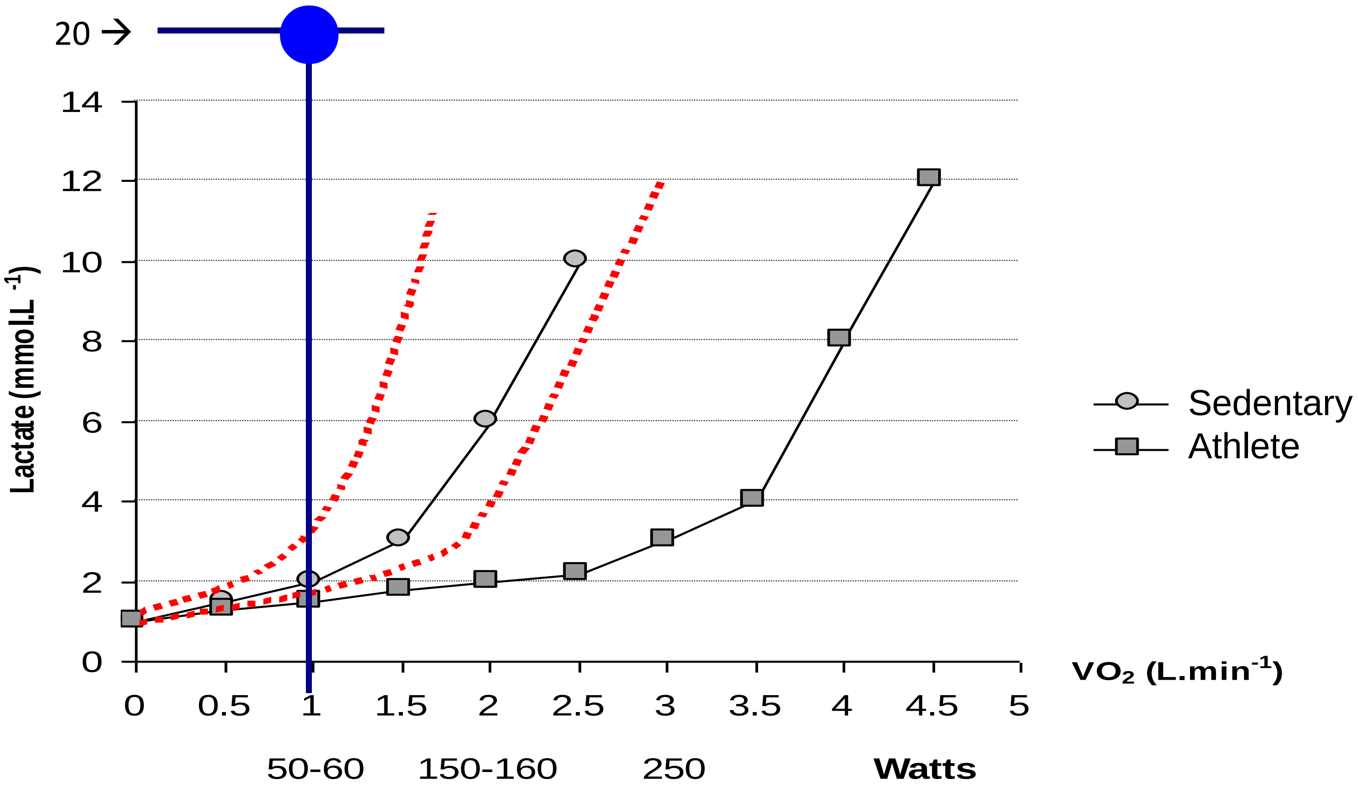
↓ débit cardiaque
↓ IMC
Myopathies mitocondriales
↓ Hb, COHb
Hémoglobinopathies



Déconditionnement
↓ débit cardiaque
Myopathies mitocondriales
↓ Hb, COHb
Hémoglobinopathies

Laveneziana et al. La lettre du pneumologue 2015

Muscle adaptation to exercise



Laveneziana et al. La lettre du pneumologue 2015

Peripheral muscle limitation to exercise (myopathies and/or deconditioning) can be difficult to detect and some variables may help define it:

- a reduced V′O2peak
- a reduced slope or late plateau of the V′O2 trajectory (i.e. a reduced V′O2 /Work-Rate relationship ⩽8)
- a premature AT <40% pred
- and anomalies in blood lactate at peak or during the immediate recovery phase
  - for example, serum lactate may fail to rise with an undetectable AT in metabolic myopathies such as McArdle disease
  - while relatively higher serum lactate levels matched for the work rates or the V′O2 could indicate the presence of deconditioning
- ratings of leg discomfort on a Borg scale greater than dyspnoea score at the end of exercise may also be present in a patient limited by locomotor muscle anomalies

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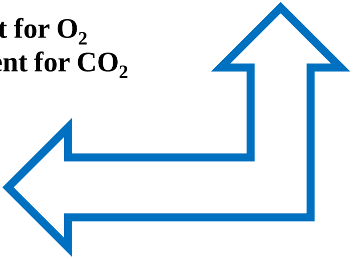

V_E/VO_2=ventilatory equivalent for O_2
V_E/VCO_2=ventilatory equivalent for CO_2
$P_{ET}O_2$= end-tidal O_2
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RESPIRATORY

VENTILATORY
GAS EXCHANGE

V_E= ventilation
V_T= tidal volume
f= frequency
IC= inspiratory capacity
Tidal flow-volume loop
SpO_2= O_2 saturation

Laveneziana P et al, Eur Respir Rev 2021; 30: 200187

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P_{ETO_2}= end-tidal O_2
V_E/VCO_2=ventilatory equivalent for CO_2
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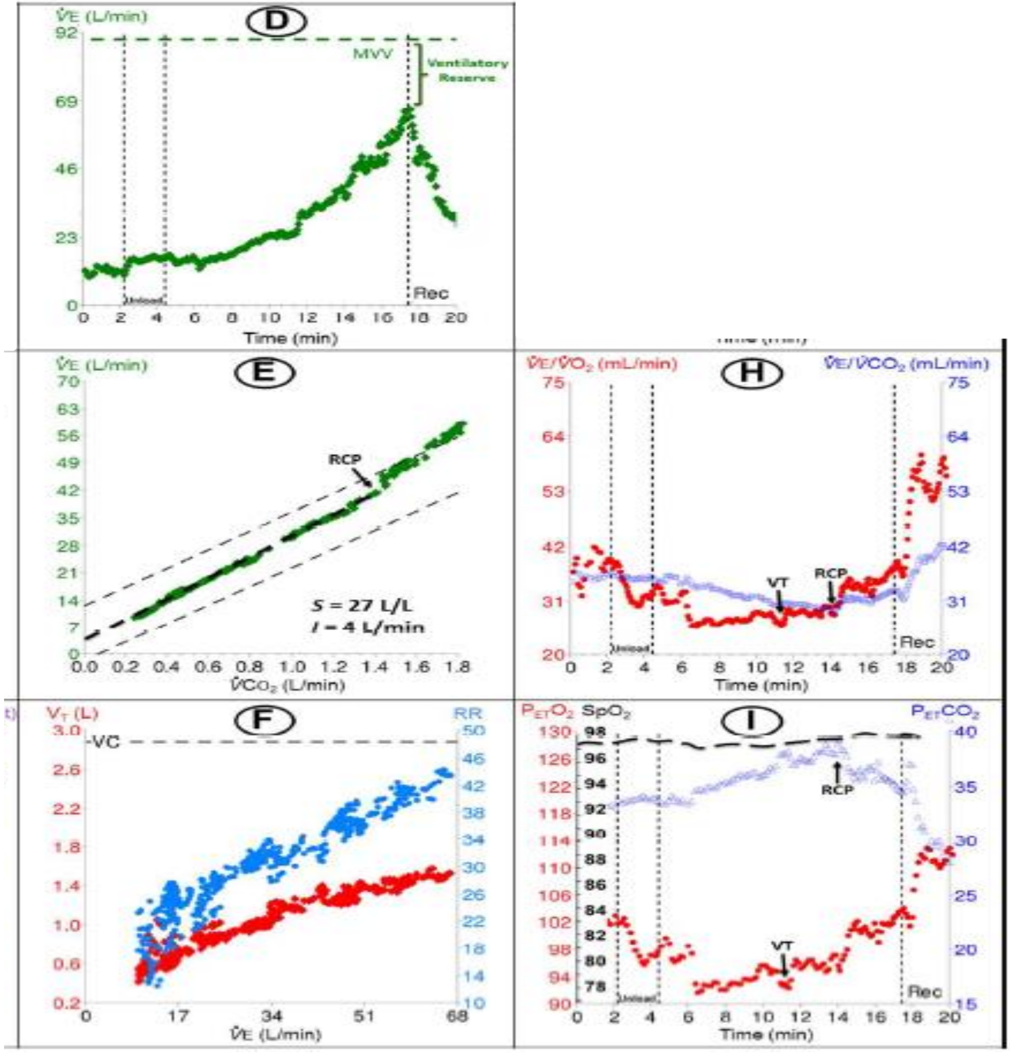
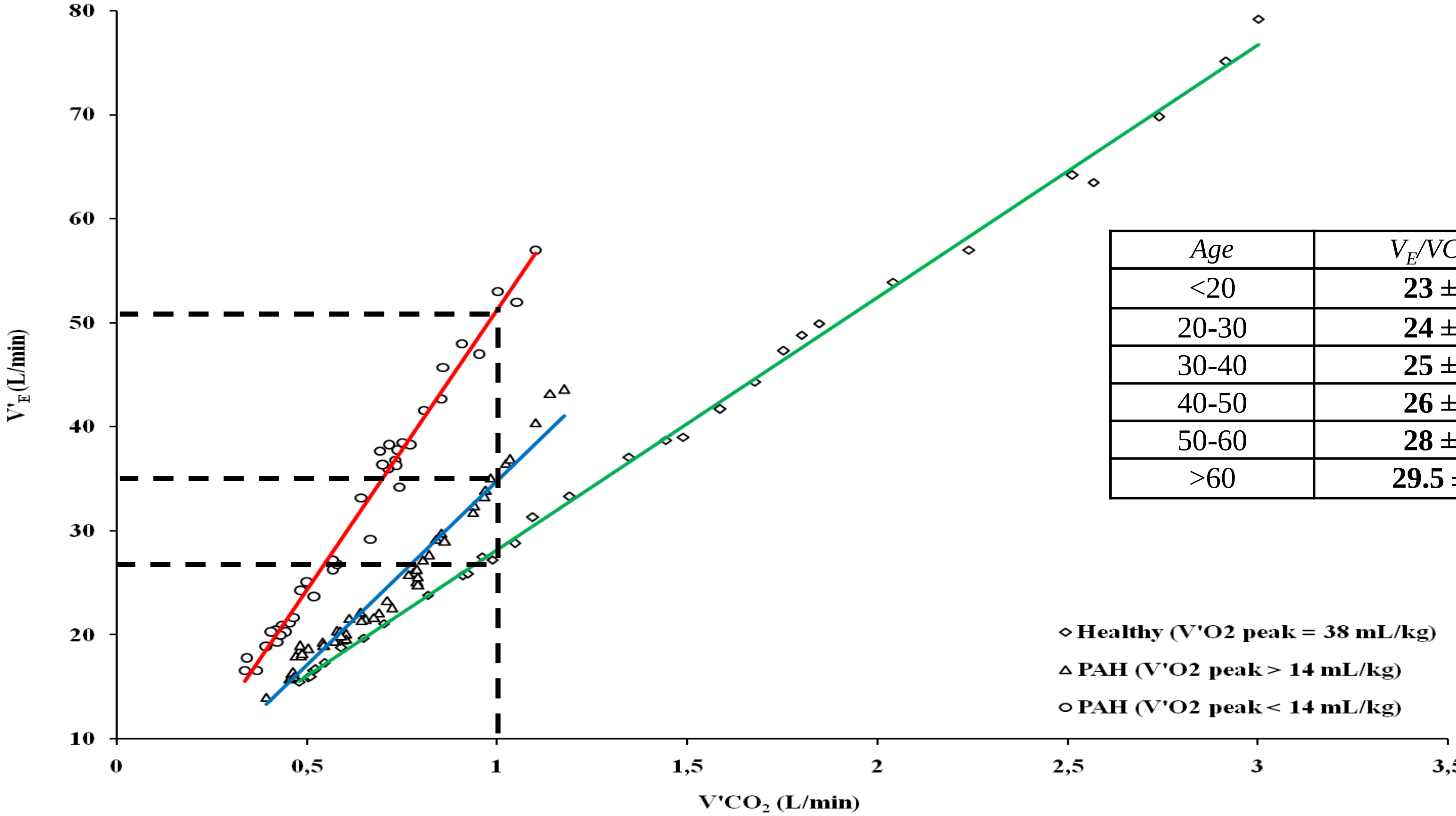


Ventilatory Efficiency



Age	*V_E/VCO2*
<20	**23 ± 2**
20-30	**24 ± 2**
30-40	**25 ± 2**
40-50	**26 ± 2**
50-60	**28 ± 2**
>60	**29.5 ± 2**

Laveneziana P, Eur Respir J 2013
Laveneziana P, Montani D, et al Eur Respir J 2014

$V'_E/V'O_2$ at its nadir (AT) and $V'_E/V'CO_2$ at its nadir (RC)

$V'_E/V'O_2$	*$V'_E/V'CO_2$*
22-27	**26-30**

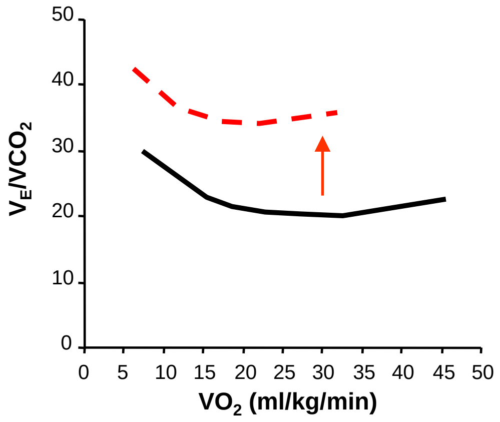
$V'_E/V'O_2$ and $V'_E/V'CO_2$ at AT (for sedentary, middle-aged men)

$V'_E/V'O_2$	*$V'_E/V'CO_2$*
26.5±4.4	**29.1±4.3**

Mean values for women and men over 60 should be slightly higher (1-2); for men under 30, slightly lower (1-2).

NB: normal values of $V'E/V'O_2$ and $V'E/V'CO_2$ at AT with a $PETCO_2$ of approximately 40 mmHg suggest a normal V_D/V_T and uniform matching of alveolar ventilation (V_A) to pulmonary perfusion (Q) (V_A/Q).

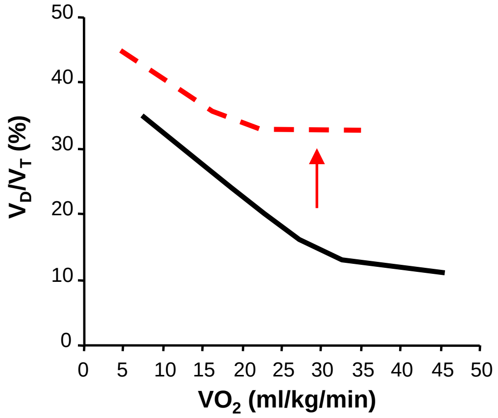
Laveneziana and Weatherald, Frontiers in Physiology 2020



Hyperventilation

↑ V_D/V_T

$$V_E/VCO_2 = \frac{863}{PaCO_2 \times (1 - V_D/V_T)}$$

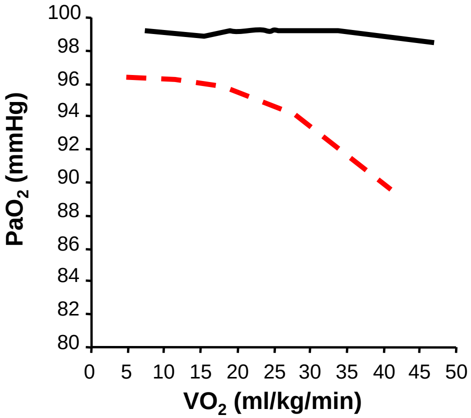


HTAP

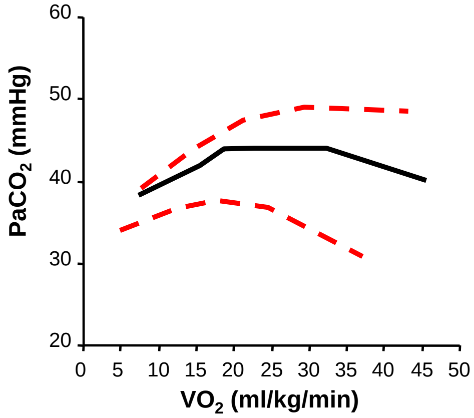
BPCO

Pneumopatie interstitielle

Insuffisance cardiaque chronique



- ↓ ventilation alvéolaire
- anomalies rapport ventilation/perfusion
- shunt droit/gauche
- troubles de la diffusion
- acidose métabolique
- shift à droite de la curbe de dissociation de l'O2



Hypoventilation alvéolaire

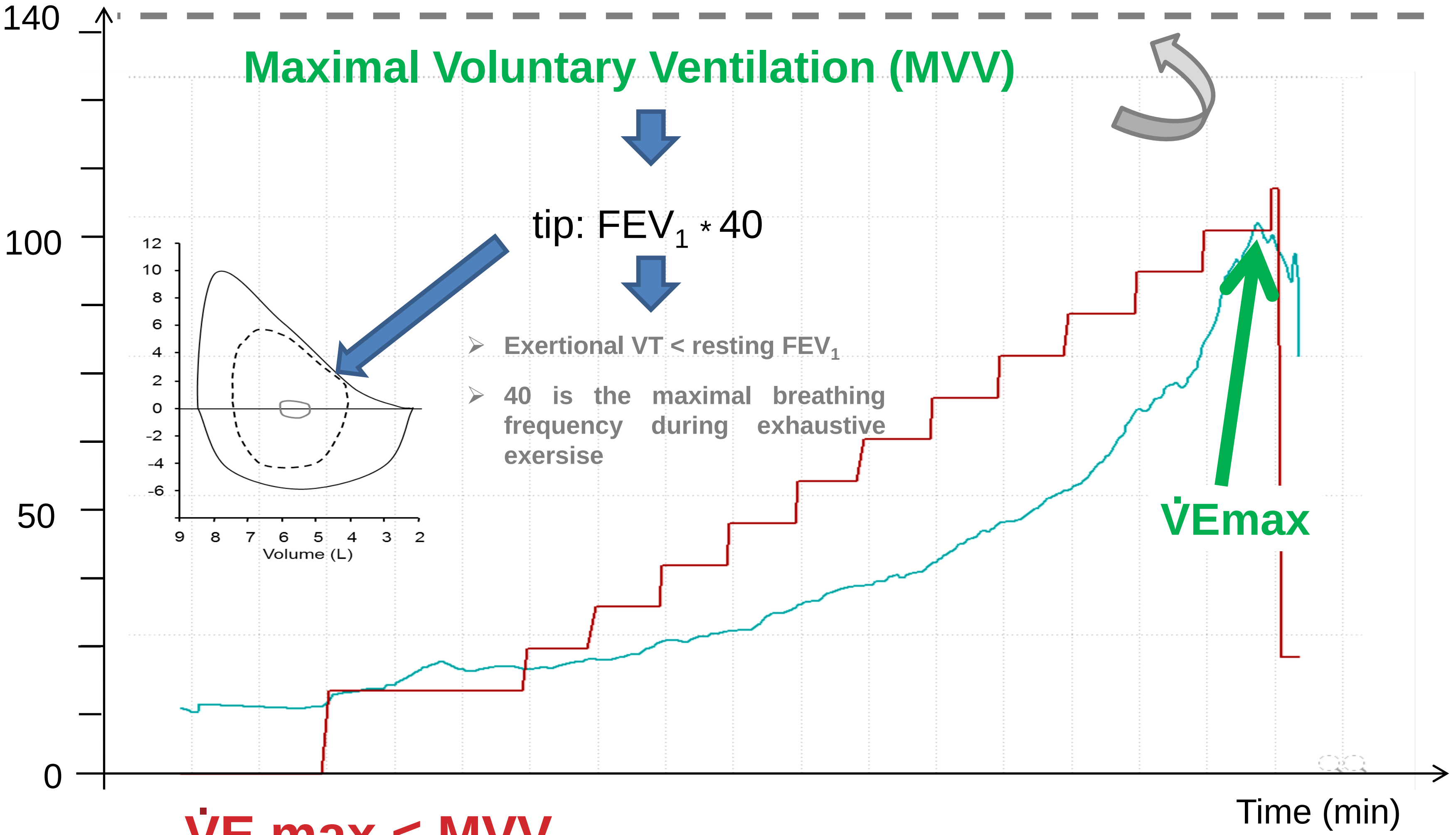
Hyperventilation alvéolaire

Pulmonary vascular limitation to exercise is not easy to define and may rely on evidence of:

- increased V′E/V′CO_2 slope and ratio at AT
- other typical features of pulmonary vascular disease are:
  - low levels of $P_{ET}CO_2$ at AT
  - a VD/VT which remains stable or increases or fails to decrease from baseline
  - a P(a-ET)CO_2 which fails to became negative during exercise and, sometimes
  - P(A–a)O_2 which widens on exertion
- Associated low levels of haemoglobin will enhance oxygen flow deficiency
- Electrocardiographic or blood pressure anomalies during CPET

Pulmonary gas exchange limitation to exercise is not straightforward either, and may rely on evidence of:

- inefficient CO_2 exchange
  - which can be signalled by high VD/VT
  - and often by high exercise V′E/V′CO_2
- or (alone or in combination with) inadequate O_2 exchange
  - signalled by low PaO_2
  - or, less directly, by desaturation at pulse oximetry
  - and a reduced V′O_2peak

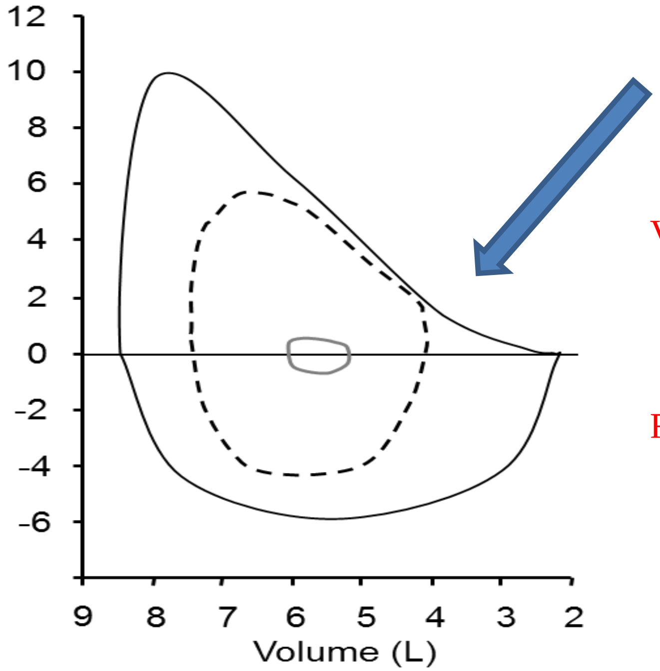


140
100
50
0
Maximal Voluntary Ventilation (MVV)
tip: FEV1 * 40
Exertional VT < resting FEV1
40 is the maximal breathing frequency during exhaustive exersise
12
10
8
6
4
2
0
-2
-4
-6
9 8 7 6 5 4 3 2
Volume (L)
V̇Emax
Time (min)

V̇E max < MVV

Tiffeneau R, Pinelli A. Air circulant et air captif dans l'exploration de la fonction ventilatrice pulmonaire.

Paris Méd 1947; 37: 624–628.



CPUE (Capacité pulmonaire utilisable à l'effort), 1947

VEMS (volume expiratoire maximum seconde), Paris 1954

FEV_1 (forced expiratory volume in one second), 1957 British Thoracic Society

Exertional V_T < resting FEV_1

✓ Ventilatory or Breathing Reserve:

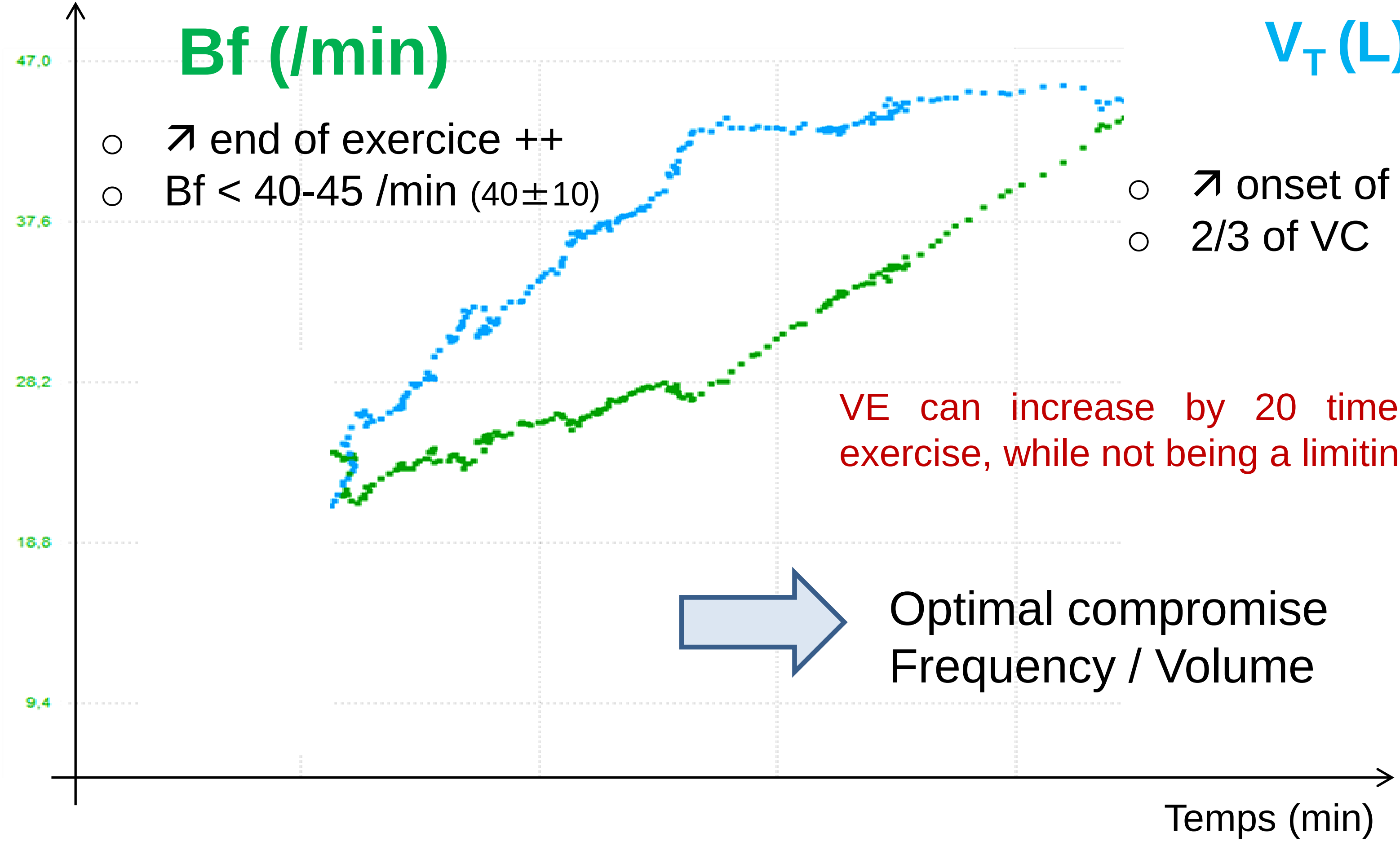
$$\frac{MVV - \dot{V}E_{peak}}{MVV} \times 100 = 15\text{-}20\,\%$$

Ventilatory ceiling not reached

=

Ventilation not a limiting factor

$$\mathbf{\dot{V}E_{peak} \leq 85\%\ MVV}$$



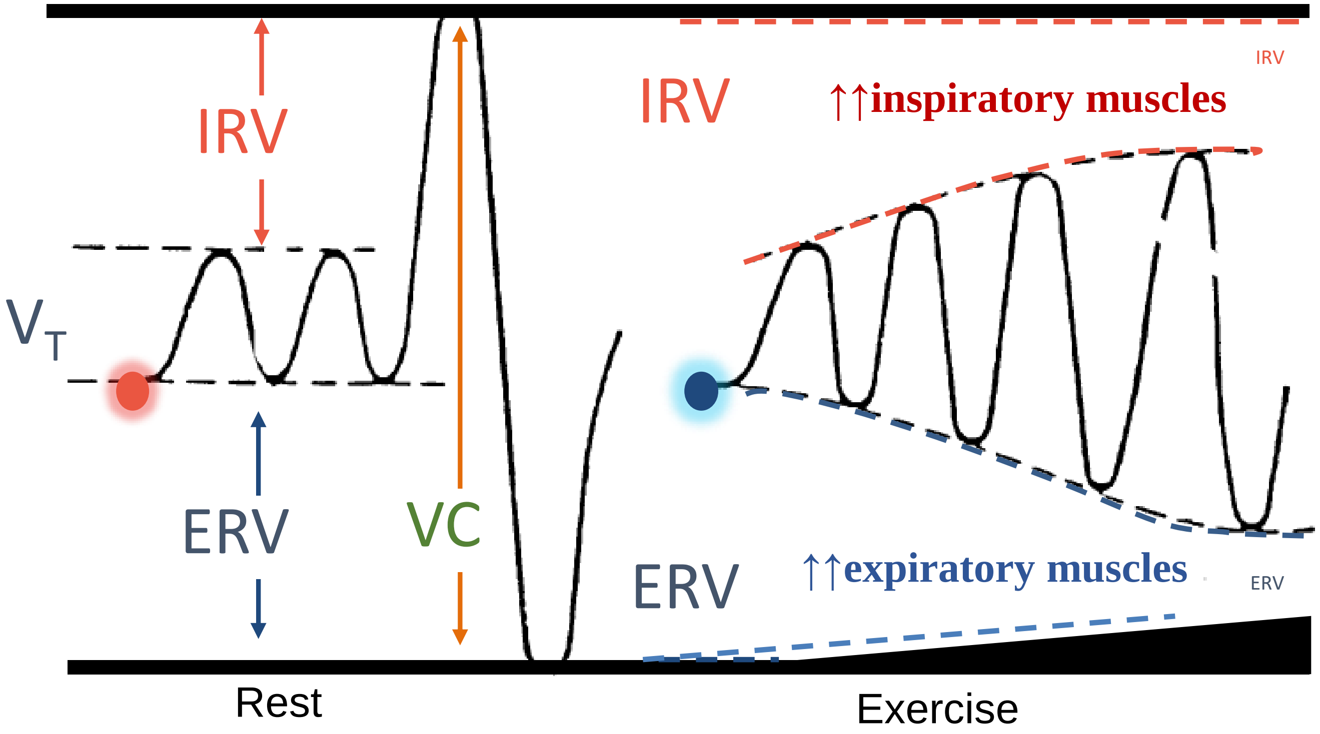
- ↗ end of exercice ++
- Bf < 40-45 /min (40±10)

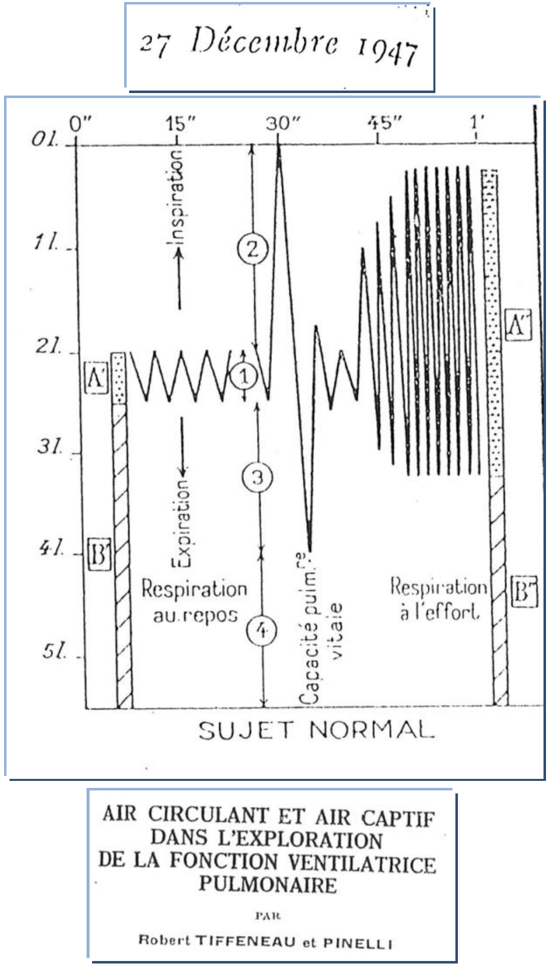
- ↗ onset of exercice
- 2/3 of VC

VE can increase by 20 times during exercise, while not being a limiting factor

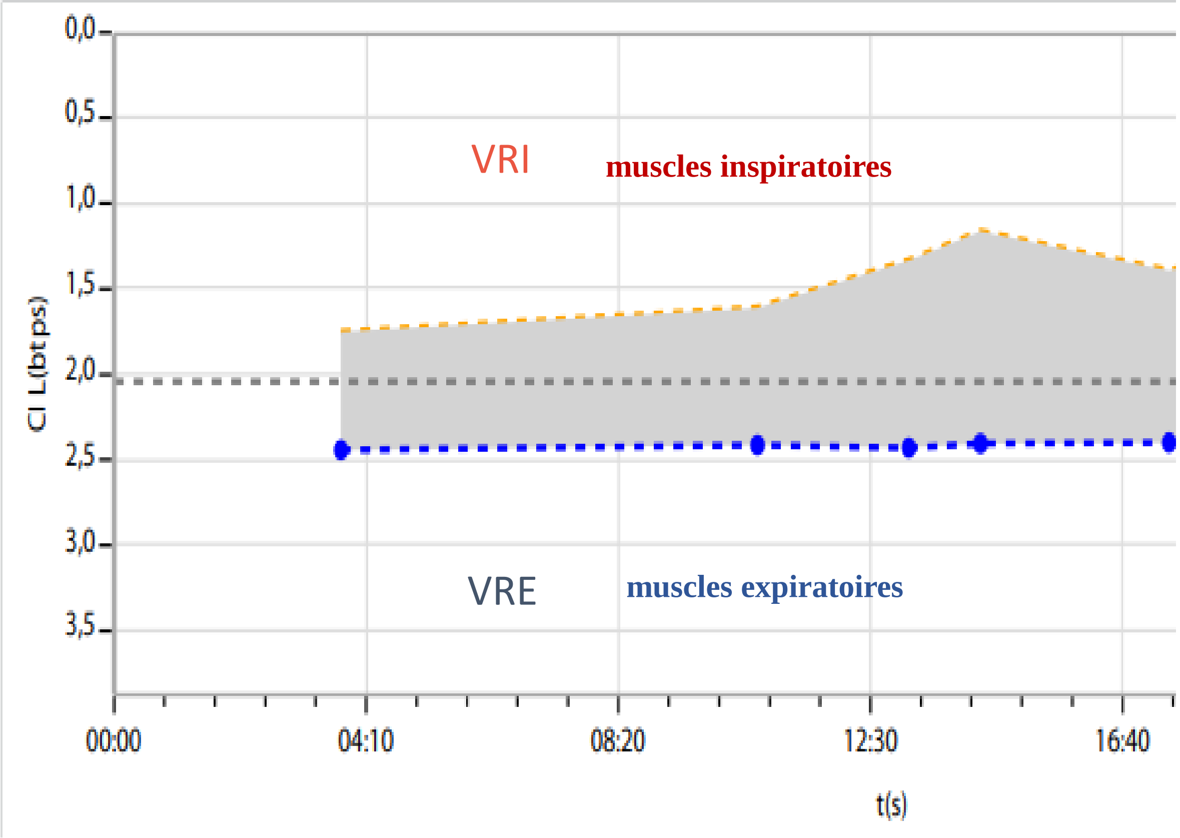
Optimal compromise
Frequency / Volume

V_T at peak exercise = 60-70% (55 ± 10%) Vital Capacity

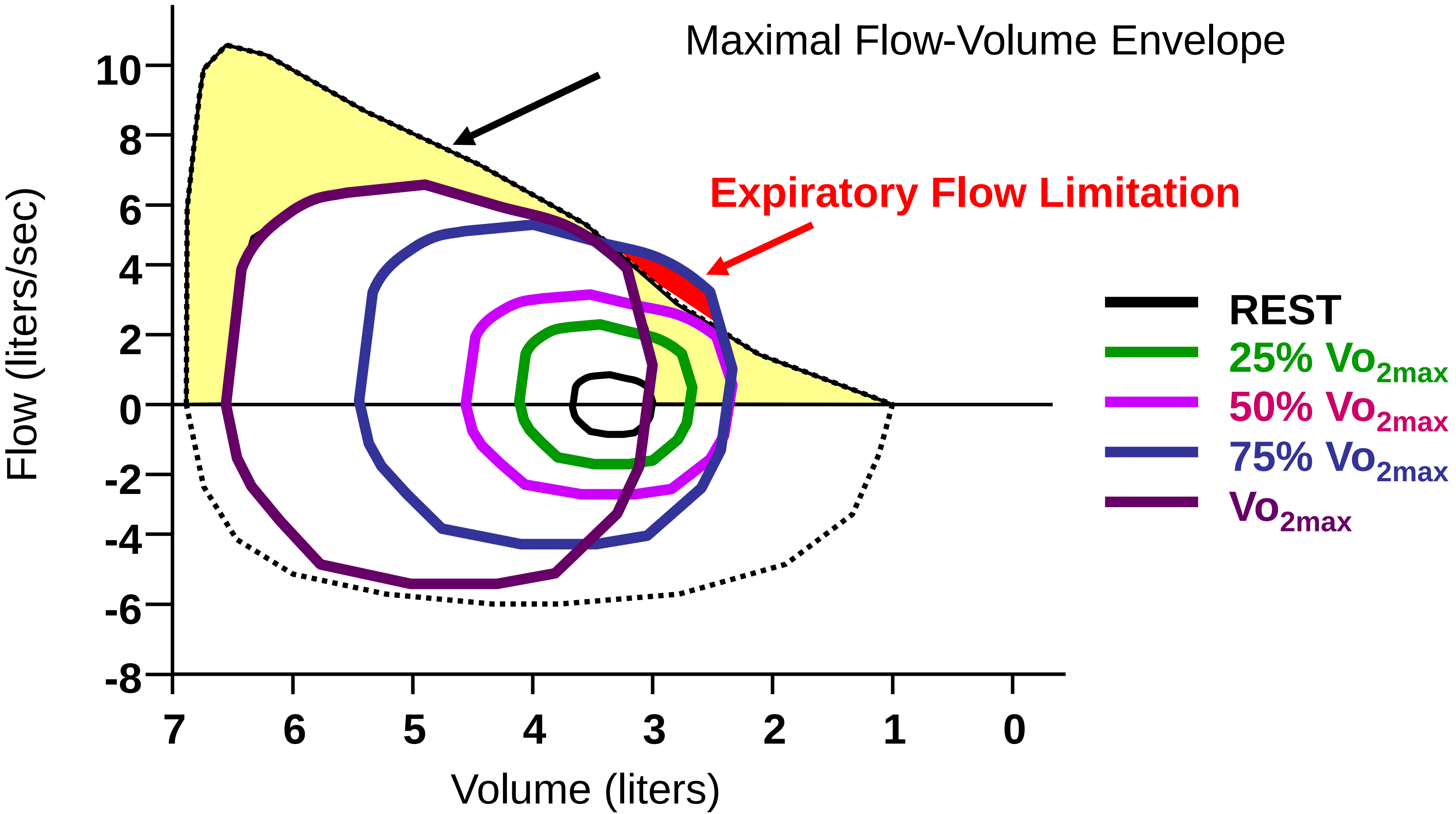


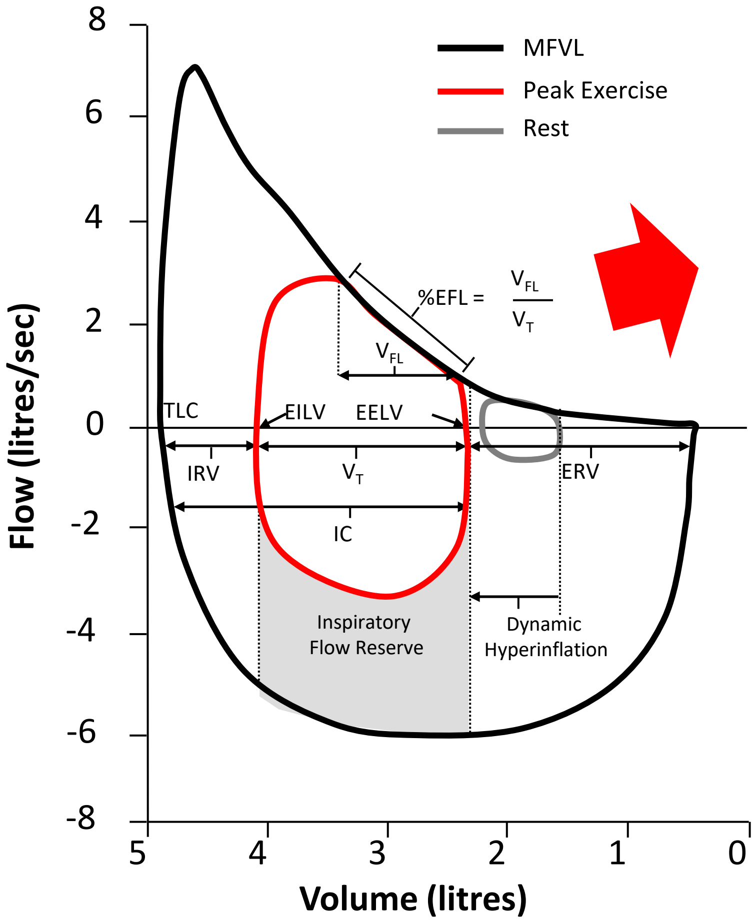


Maladie NeuroMusculaire



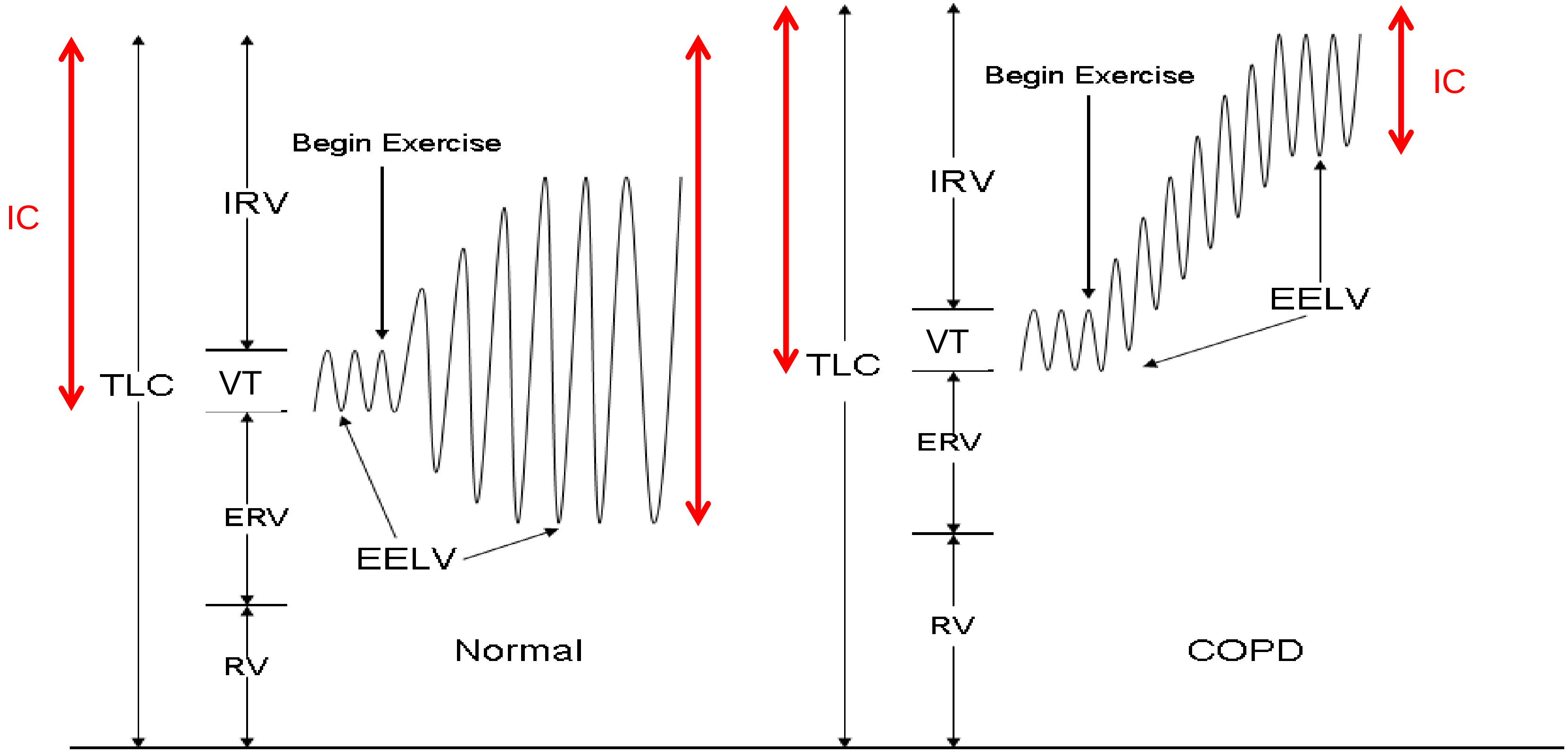
Respiratory mechanics: maximal and tidal flow-volume loops



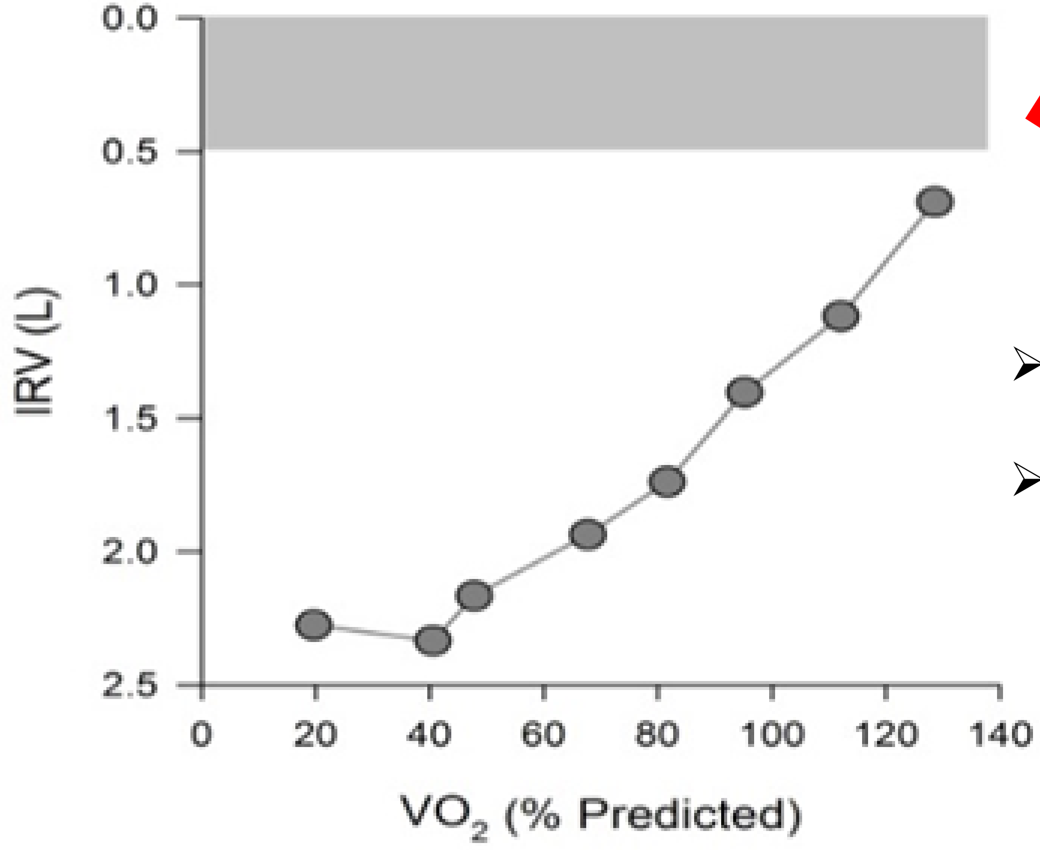


Acceptable EFL < 25% of V_T

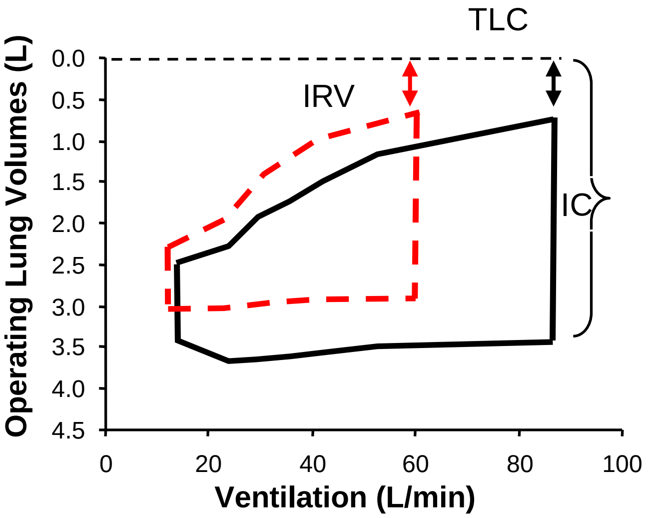
Development of significant EFL >40-50% of V_T

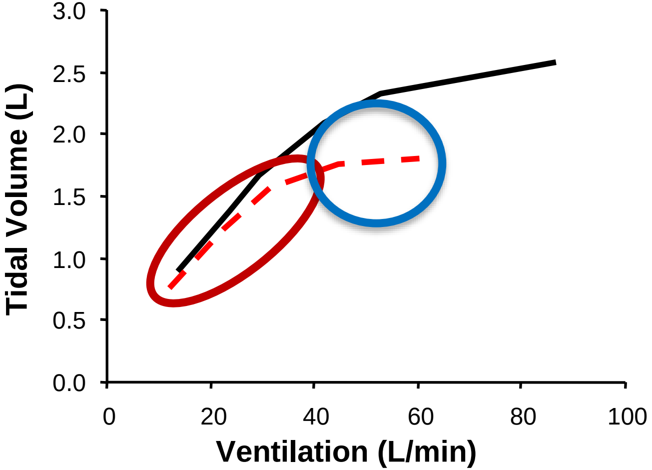

IC
TLC
IRV
Begin Exercise
VT
ERV
EELV
RV
Normal
TLC
IRV
Begin Exercise
VT
ERV
RV
EELV
IC
COPD

Volume reserve



- Acceptable IRV > 0.4-0.6
- EILV (EELV + V_T) <90% of TLC – (reasonable elastic work)





Mechanical restriction:

Muscle weakness

ILD

CW restriction

COPD

Dynamic hyperinflation

Asthma (Laveneziana P et al, RPNB 2012)

CHF (Laveneziana P et al . JAP 2009)

PAH (Laveneziana et al. ERJ 2013 and 2015)

Ventilatory Constraints

- EFL >25% overlap at peak (normally <25% in health)
- Early V_T plateau
- IRV < 0.4-0.6L and/or EILV >90 %TLC – low volume reserve or high elastic work
- V_T = IC or > 60-70% of VC (normally 55±10% of VC) at peak
- V_T/IC > 70% (if restrictive pattern) – normally V_T/IC = 70 ± 10% at peak
- Dynamic Hyperinflation (dynamic decrease in IC > 140mL)

Laveneziana P et al. ERR 2021

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- **RER ≥1.05?**
- **HR > 90% predicted max?**
- **[Lactate] max > 8 mmol·l-1 and/or (fall in pH <0.04) during the immediate recovery phase?**
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Evaluation of V'O_2 peak or V'O_2 max if applicable

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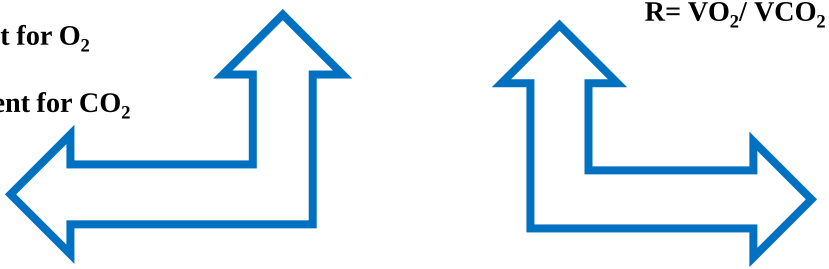
Graphic and tabular representations of CPET variables

METABOLIC

WR= work rate
VO_2= oxygen uptake
VCO_2= carbon dioxide output
R= VO_2/ VCO_2



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VENTILATORY GAS EXCHANGE

V_E= ventilation
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f= frequency
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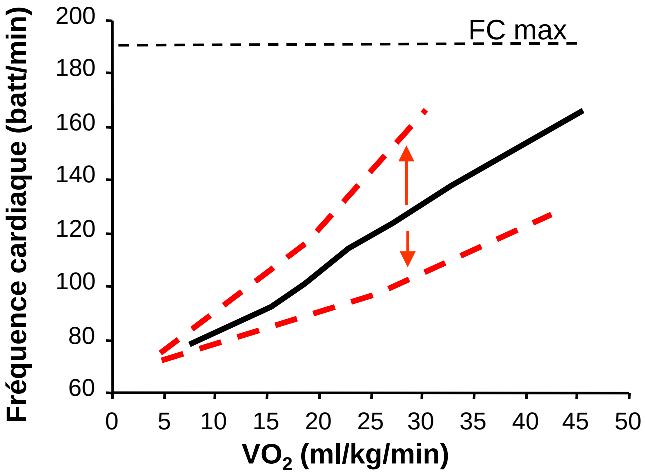
Tidal flow-volume loop
SpO_2= O_2 saturation

CARDIO-VASCULAR

ECG
BP
HR= heart rate
O_2 Pulse = **VO_2/HR**

Laveneziana P et al, Eur Respir Rev 2021; 30: 200187

Limitation Cardiovasculaire



déconditionnement

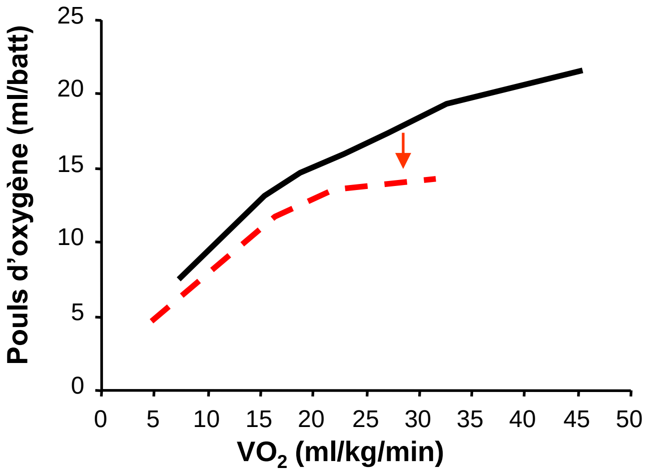
↓ volume ejection

↑ débit cardiaque

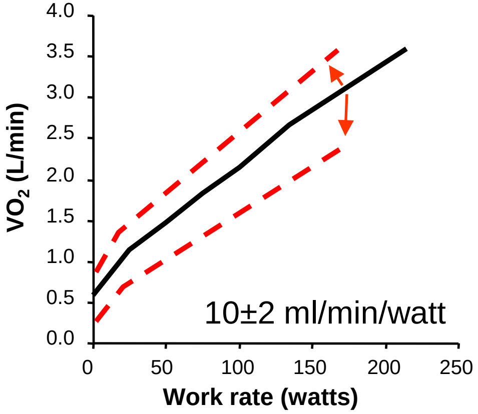
↓ Hb

médicaments

dysautonomie



↓ débit cardiaque



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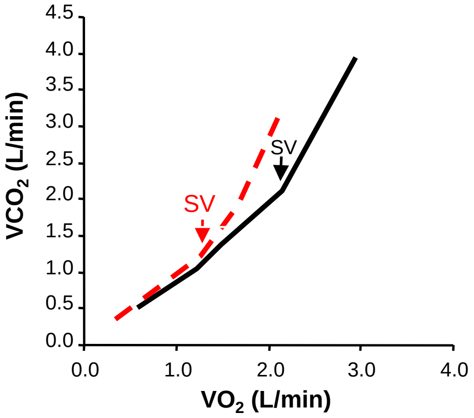

Déconditionnement
↓ débit cardiaque
Myopathies mitocondriales
↓ Hb, COHb
Hémoglobinopathies

Laveneziana et al. La lettre du pneumologue 2015

Cardiovascular limitation to exercise is complex and may be defined by certain interrelated variables, such as:

- a reduced V′O2 peak
- a reduced slope of the V′O2 trajectory (i.e. a reduced V′O2/work-rate relationship ⩽8)
- or a late plateau of the V′O2 trajectory
- a premature anaerobic threshold (AT <40% pred)
- or plateau (early or late during exercise) of the oxygen pulse (V′O2/HR ratio)
- or an abnormal HR/V′O2 slope (>50)

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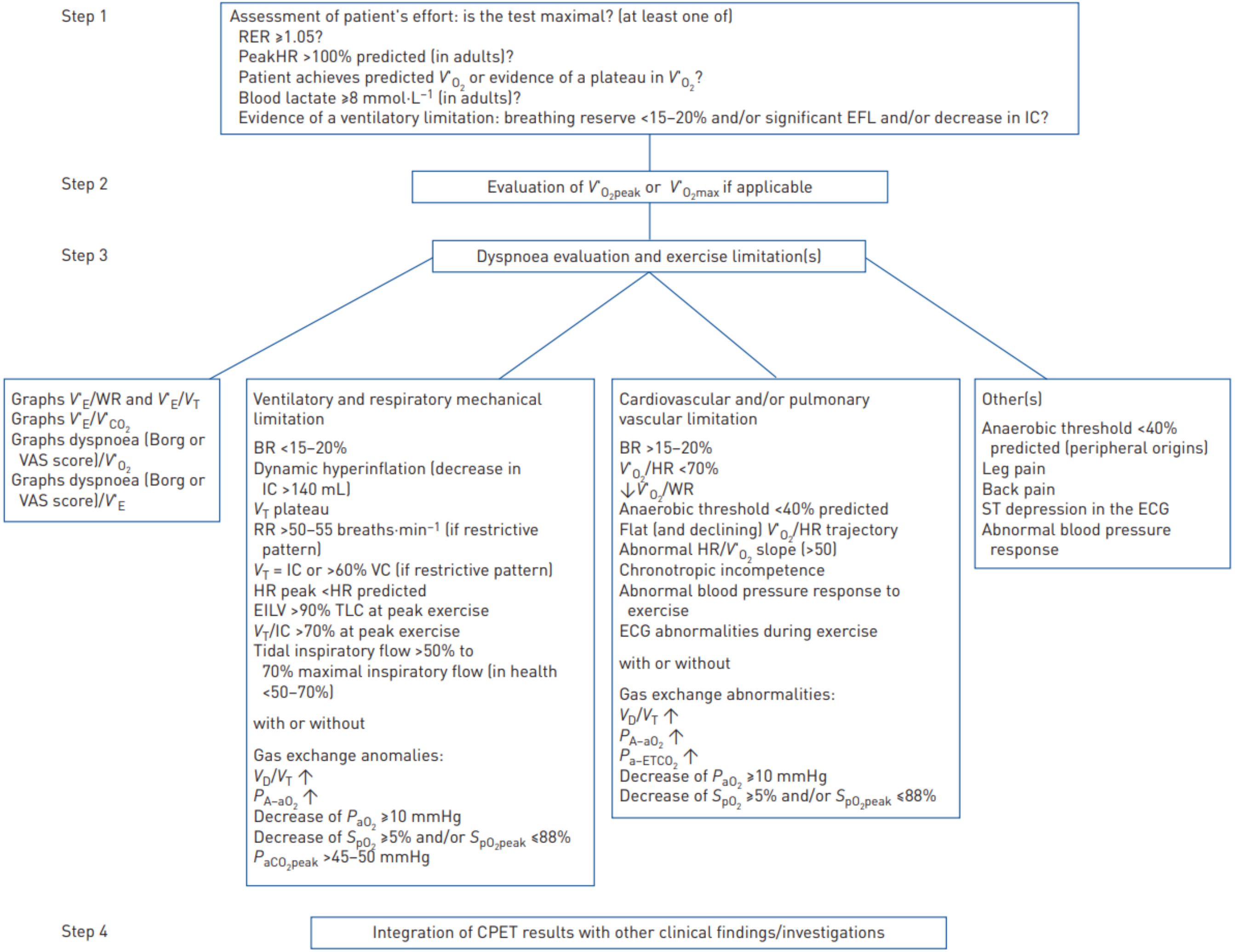
CARDIO-VASCULAR

ECG
BP
HR= heart rate
O_2 Pulse = **VO_2/HR**

SYMPTOMS

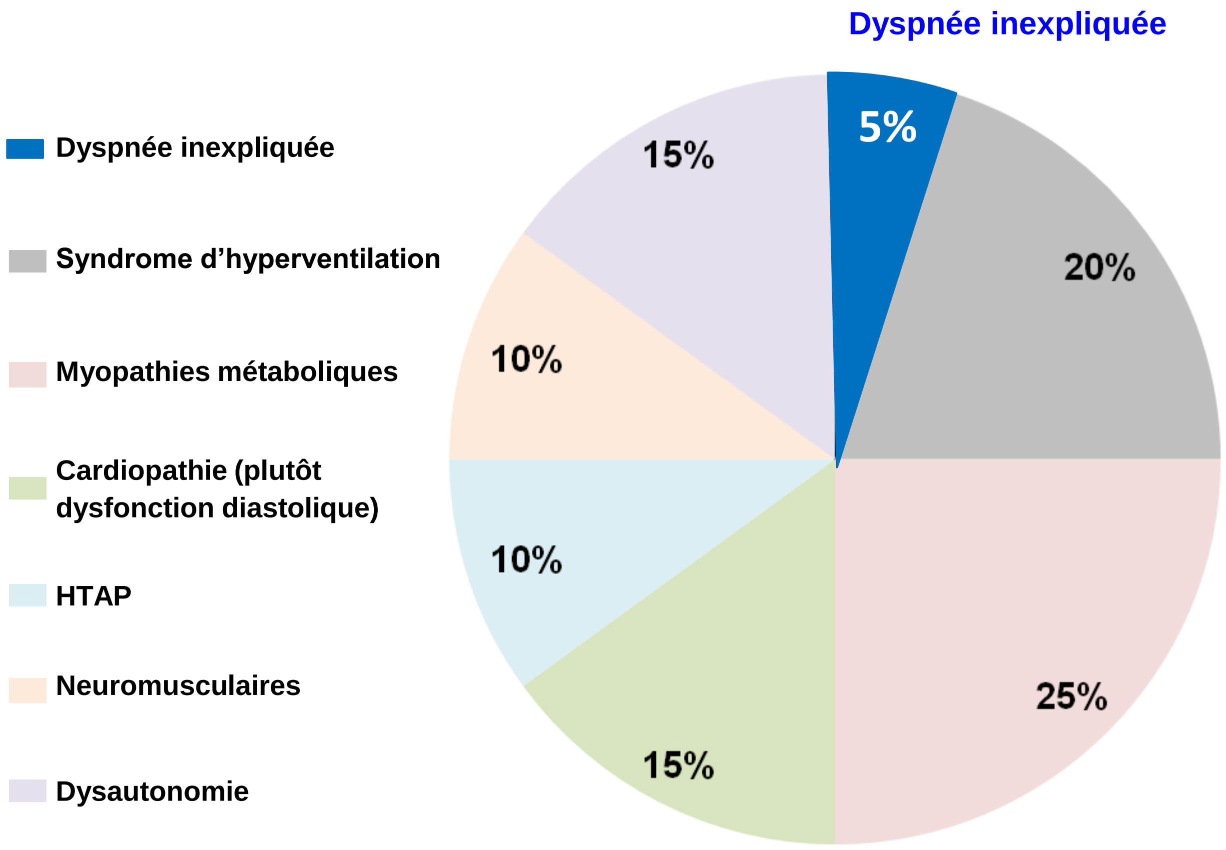
Dyspnoea
Leg effort
Fatigue
Chest Pain
Others

Laveneziana P et al, Eur Respir Rev 2021; 30: 200187

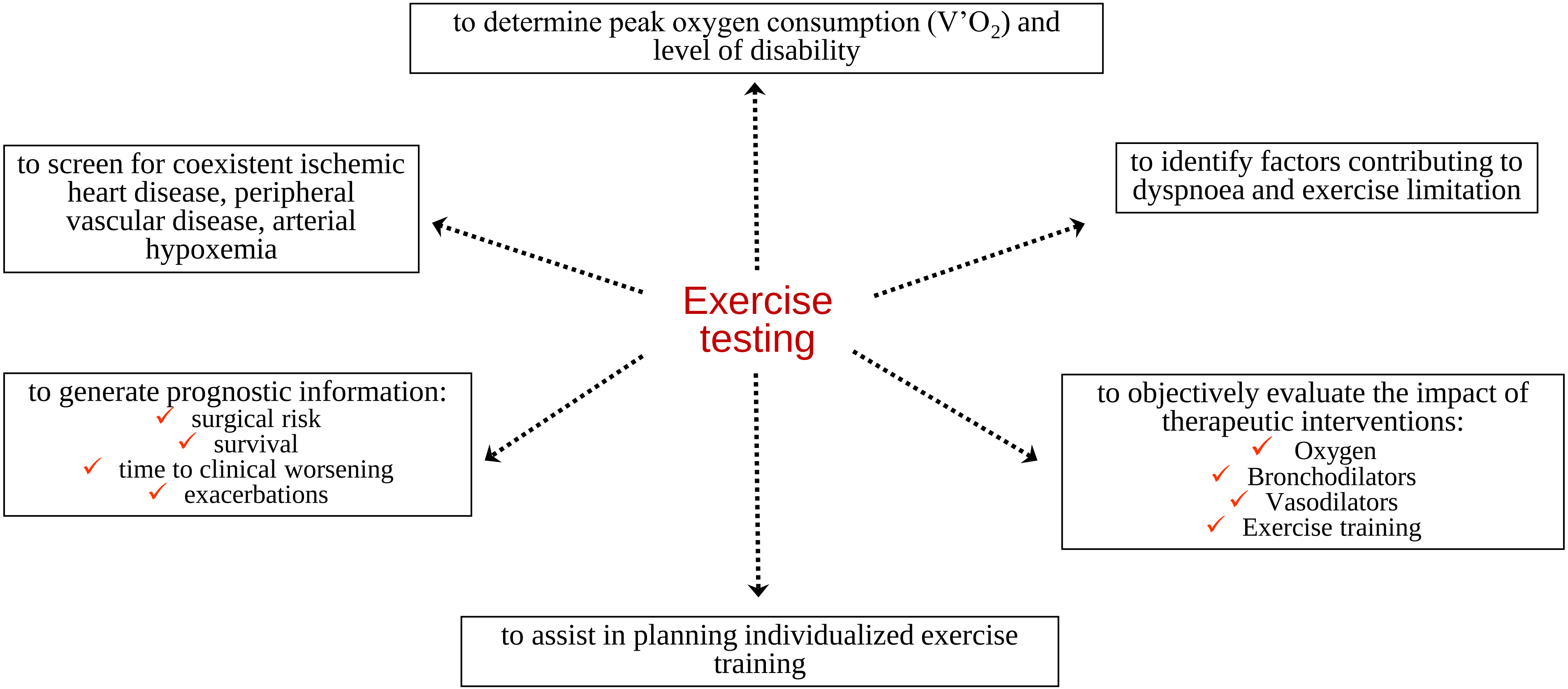


Laveneziana P et al, Eur Respir Rev 2021; 30: 200187

Performance diagnostique des dyspnées inexpliquées



Clinical Utility of CardioPulmonary Exercise Testing (CPET)



MERCI POUR VOTRE ATTENTION !