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Exercise: It's not all about moving

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Cardiopulmonary Exercise Testing (CPET)

– *how to run and interpret the results*

Dr. Zoe Saynor

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@UoPSportScience

Who am I?

Dr. Zoe Saynor
Reader in Clinical Exercise Physiology
Honorary researcher (clinical exercise physiology) at several NHS trusts

- Physical Activity, Health & Rehabilitation Thematic Research Group Lead
- Clinical, Health & Rehabilitation Team (CHaRT) Lead
- Clinical Exercise Physiologist with Josh Llewellyn-Jones (OBE) – athlete with CF
- Partnered with the global CF exercise charity - CF Warriors
- Member of ECFS Exercise Working Group

NHS
Portsmouth Hospitals University
NHS Trust

SOUTHAMPTON
Children's Hospital

University Hospital Southampton NHS
NHS Foundation Trust

CF WARRIORS

ecfs
Exercise Working Group

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Interested in….

- Exercise testing
- Exercise training
- Physical (in)activity
- Nutrition for physical activity & exercise

Goal of this session…..

Provide contemporary best clinical practice guidance for exercise testing (CPET) people with respiratory disease

Focus: promote global standardisation of test procedures (running, interpretation & reporting)

Goal of this session…..

Why this is important……

Exercise testing adds to the toolkit for evaluating physiological change in people with respiratory disease

We need to work together to promote best practice

Exercise Working Group

Regular, ***globally standardised, well conducted*** *testing*

Make full use of exercise testing to guide individualised physical activity & exercise training

…. but it remains underused

Paediatric UK CF Clinics (2010)

	Specialist Centres	Shared clinics
Number of clinics	**16**	**53**
Types of tests used:	-	-
6-minute walk test	4 (25.0%)	5 (9.4%)
12-minute walk test	0	1 (1.9%)
Incremental shuttle walk test	6 (37.5%)	10 (18.9%)
Endurance shuttle walk test	0	2 (3.8%)
Step test	8 (50.0%)	5 (9.4%)
Treadmill test	**2 (12.5%)**	**6 (11.3%)**
Cycle test	**2 (12.5%)**	**1 (1.9%)**

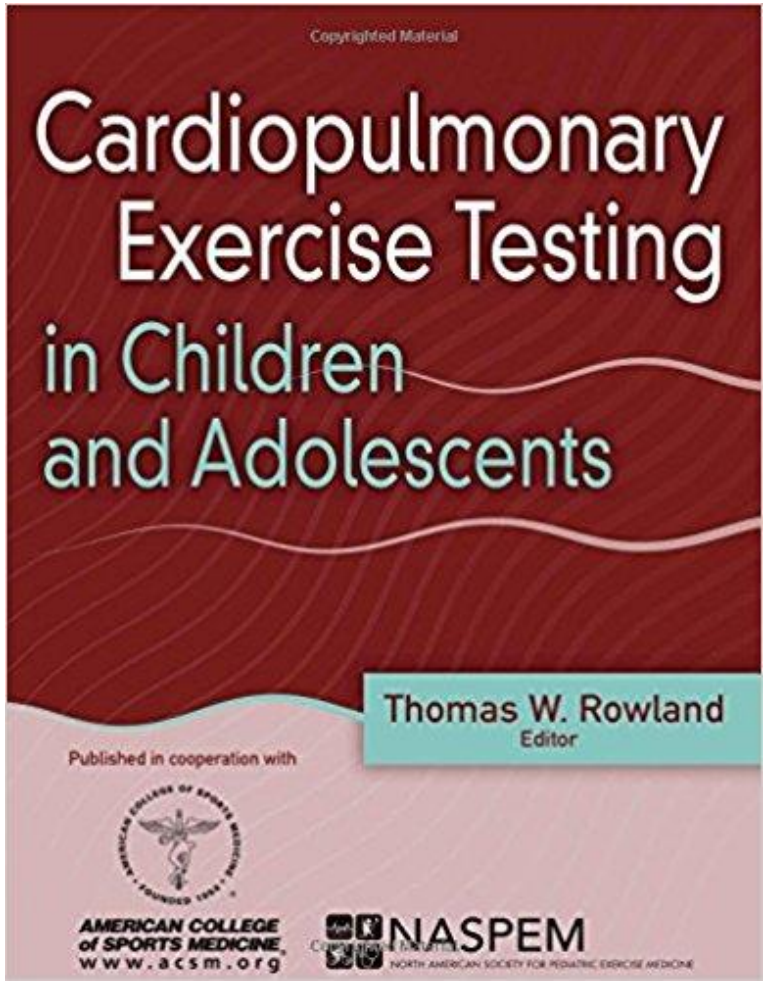
Stevens et al (2010) J Cyst Fibros

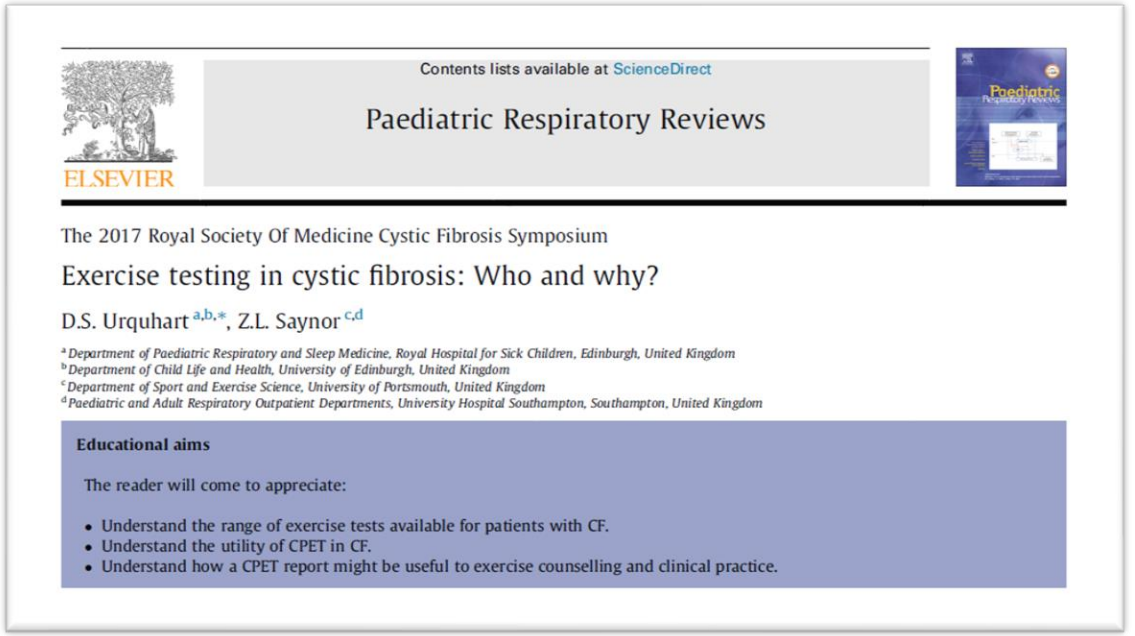
……. even over a decade on!

- 31 CF centres
  - ~ 50% of specialist UK CF clinics
- 94% clinics use exercise testing (up from 53% in 2010)
- 48% of these clinics primarily use CPET
- Exercise testing most commonly occurs at annual review (93%)
- Exercise testing typically supervised by physiotherapists (62%)
- Common barriers:
  - space (69%)
  - time (55%)

Tomlinson et al (2021 - In prep)

Key resources that you have available now…





Contents lists available at ScienceDirect

Paediatric Respiratory Reviews

ELSEVIER

The 2017 Royal Society Of Medicine Cystic Fibrosis Symposium

Exercise testing in cystic fibrosis: Who and why?

D.S. Urquhart [a,b,*], Z.L. Saynor [c,d]

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[b] Department of Child Life and Health, University of Edinburgh, United Kingdom
[c] Department of Sport and Exercise Science, University of Portsmouth, United Kingdom
[d] Paediatric and Adult Respiratory Outpatient Departments, University Hospital Southampton, Southampton, United Kingdom

Educational aims

The reader will come to appreciate:

- Understand the range of exercise tests available for patients with CF.
- Understand the utility of CPET in CF.
- Understand how a CPET report might be useful to exercise counselling and clinical practice.

Key resources that you have available now…

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Statement on Exercise Testing in Cystic Fibrosis

Helge Hebestreit[a] Hubertus G.M. Arets[b,c] Paul Aurora[d] Steve Boas[f]
Frank Cerny[g] Erik H.J. Hulzebos[c] Chantal Karila[j] Larry C. Lands[k]
John D. Lowman[h] Anne Swisher[i] Don S. Urquhart[e]
for the European Cystic Fibrosis Exercise Working Group

Key resources that you have available now…

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ERS statement on standardisation of cardiopulmonary exercise testing in chronic lung diseases

Thomas Radtke[1,2], Sarah Crook[1], Georgios Kaltsakas[3,4], Zafeiris Louvaris[5], Danilo Berton[6], Don S. Urquhart[7], Asterios Kampouras[8], Roberto A. Rabinovich[9,10], Samuel Verges[11], Dimitris Kontopidis[12], Jeanette Boyd[13], Thomy Tonia[14], Daniel Langer[5,15], Jana De Brandt[16], Yvonne M.J. Goërtz[17], Chris Burtin[16], Martijn A. Spruit[16,17,18], Dionne C.W. Braeken[17], Sauwaluk Dacha[5,15,19], Frits M.E. Franssen[17,18], Pierantonio Laveneziana[20,21], Ernst Eber[22], Thierry Troosters[23,24], J. Alberto Neder[25], Milo A. Puhan[1], Richard Casaburi[26], Ioannis Vogiatzis[4,27,29] and Helge Hebestreit[28,29]

Lung function only tells us so much!

Both have an engine capacity of 1.5 L

BUT: which would you rather drive?

What we really want to know……

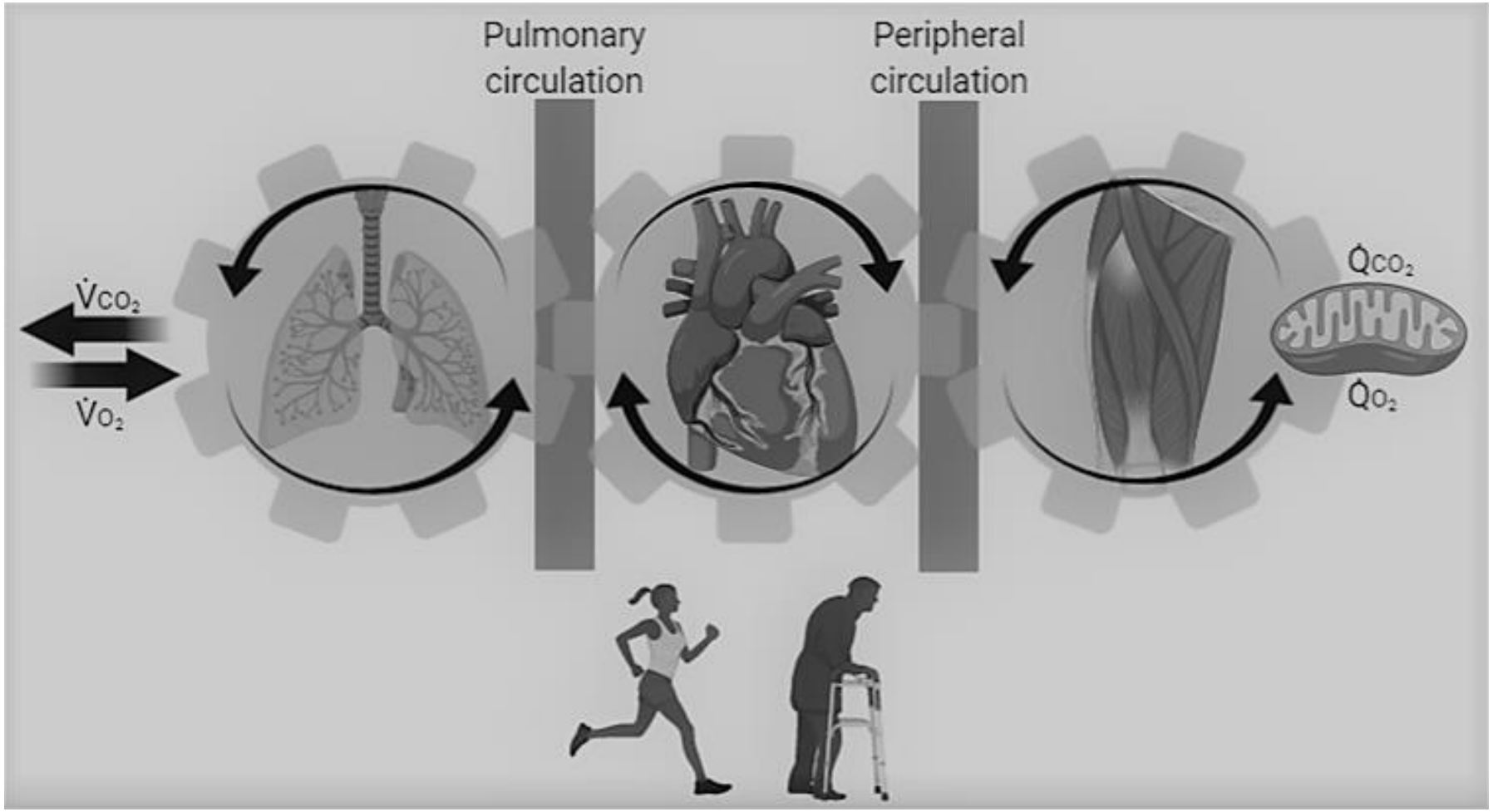


Image source: Saynor et al. (2020) Exp Physiol

Considerations when selecting an appropriate exercise testing protocol

- Indication of the test (what info is needed?)?
- Experience (practitioner and participant)?
- Time, space and equipment available?
- What is the recommended test(s) for this indication/population?
- Is there appropriate normative data available?

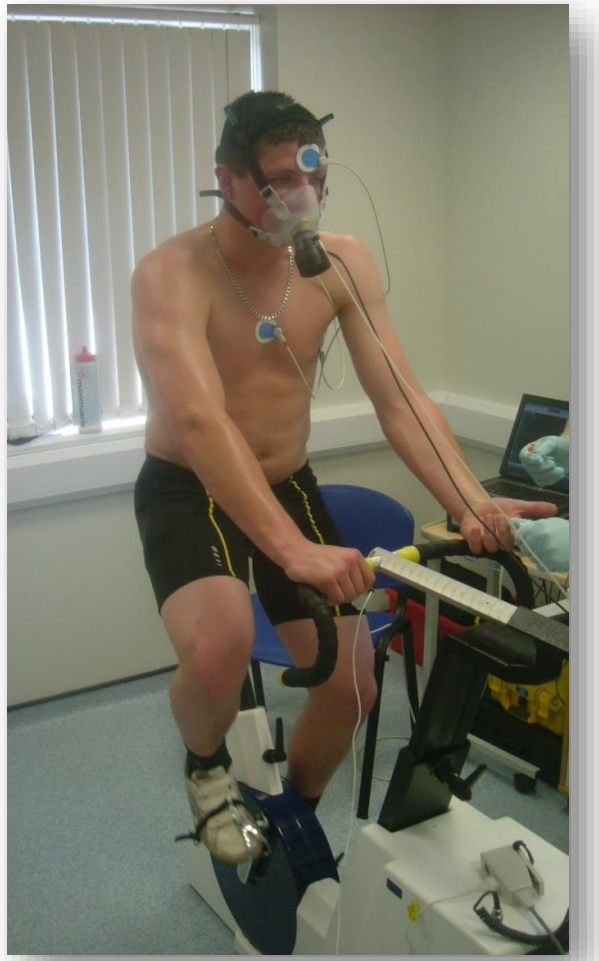
Considerations when selecting an appropriate exercise testing protocol

- Laboratory or field testing?
- Maximal (or submaximal) exercise testing?
- Tests of endurance/power?
- Tests of muscle function?
- Tests of other components of fitness?

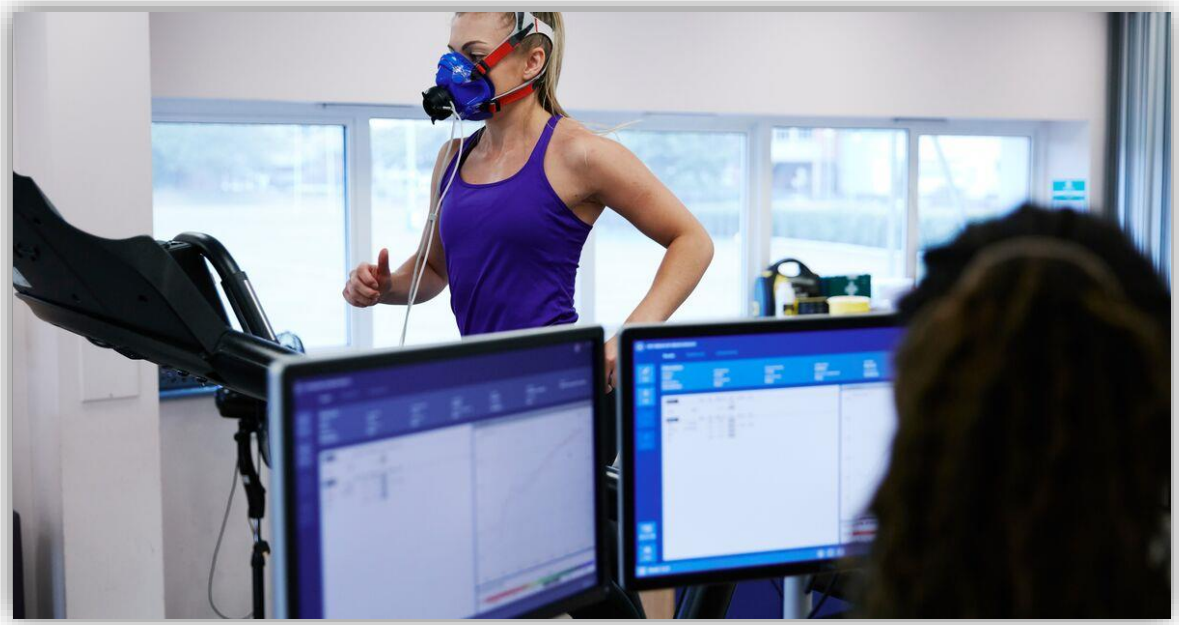
Image courtesy of Dr Don Urquhart

Indications for CPET

- Determine exercise capacity
- Plan a physical training programme
- Monitor the effects of an intervention
- Detect exercise-related adverse reactions
- Obtain prognostic information
- Pre-operative / transplant stratification
- Convince someone and/or their parent/physician that exercise is safe
- Motivate someone to be physically active
- Helps with individualised exercise counselling



….. this is not as new as you may think



Herbst. Deutsches Arch Klin Med (1928)

…..even in kids!

Image courtesy of Don Urquhart

B. Bink Maandschrift Kindergeneeskunde, 1965 (PhD Thesis 1959)

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What is CPET?

Measurements during **C**ardio**P**ulmonary **E**xercise **T**esting

- Work load
- Ventilation
- Gas exchange
- Heart rate & ECG
- Oxygen saturation
- Blood pressure
- …..

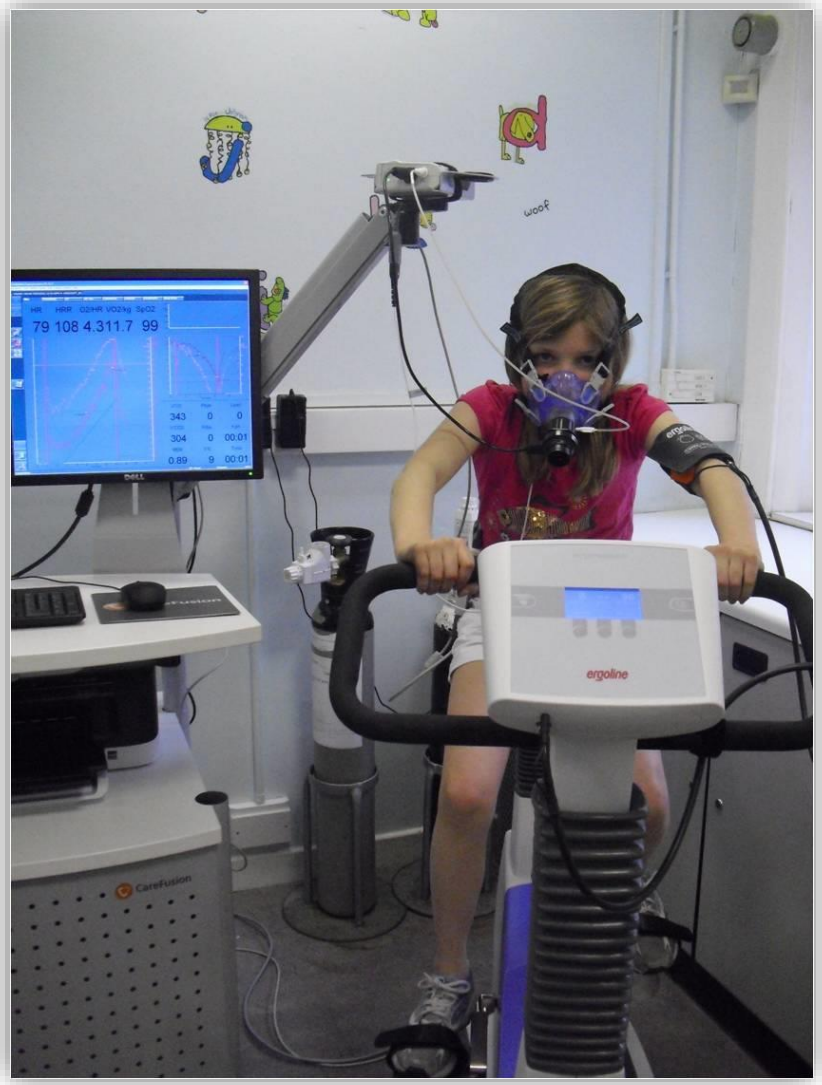
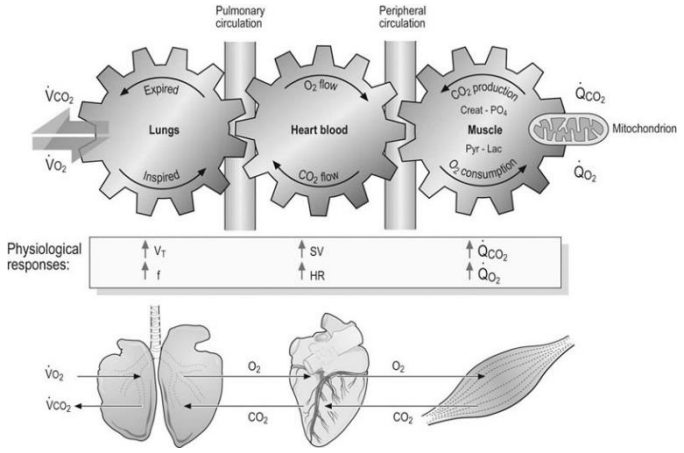


Image courtesy of Don Urquhart

What does CPET tell us?



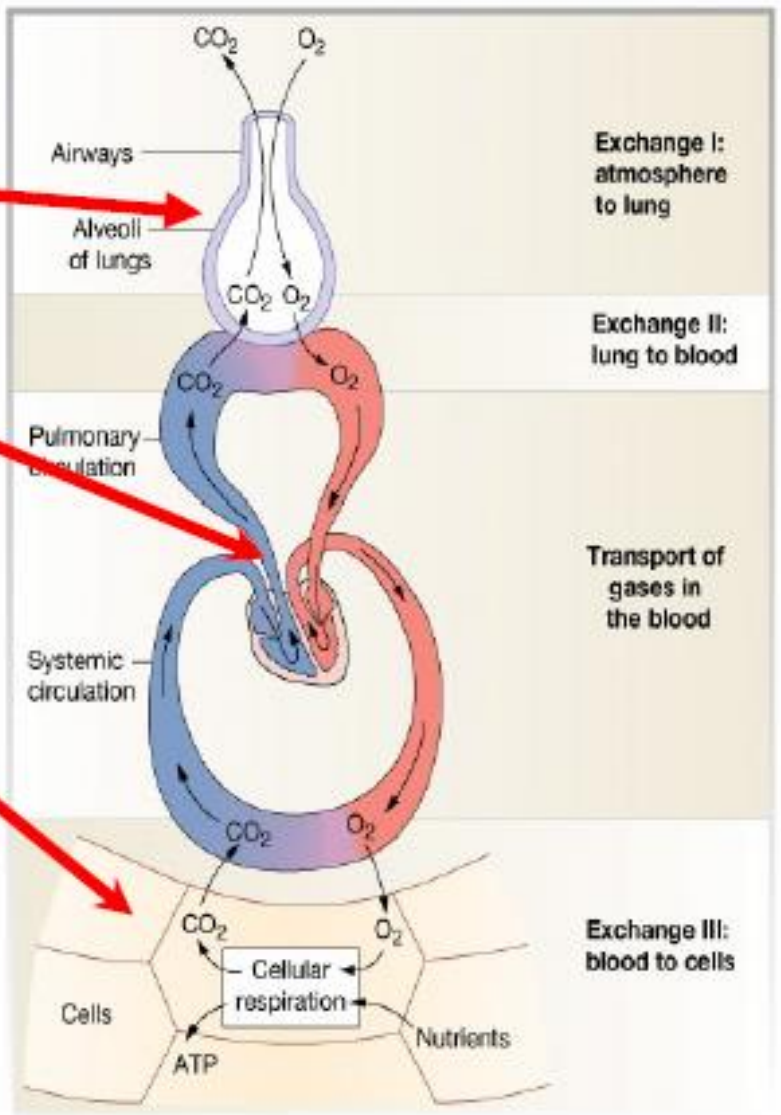
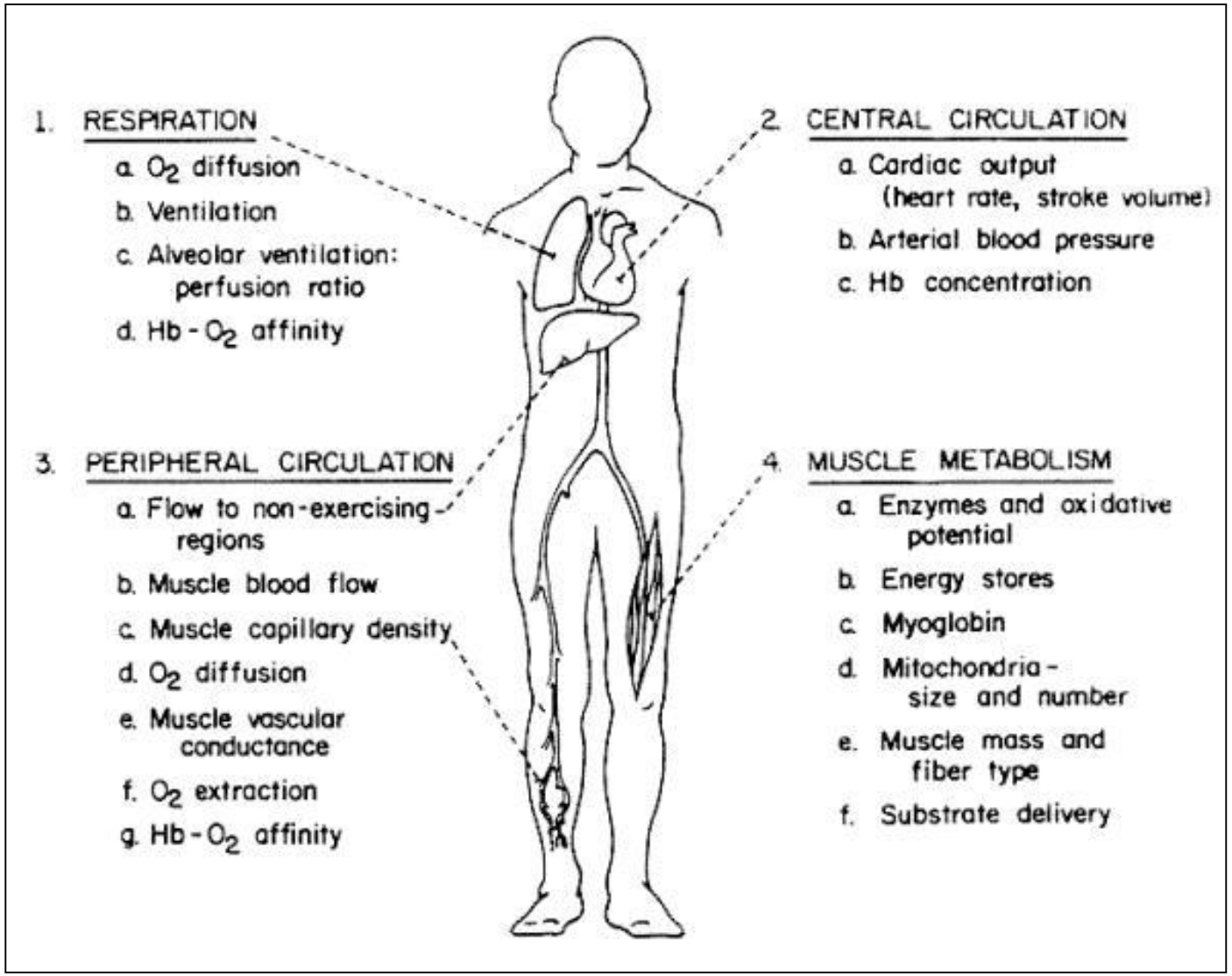


Image courtesy of Erik Hulzebos, Utrecht, The Netherlands

Potential mechanisms of exercise limitation



What do you need to conduct a CPET….?

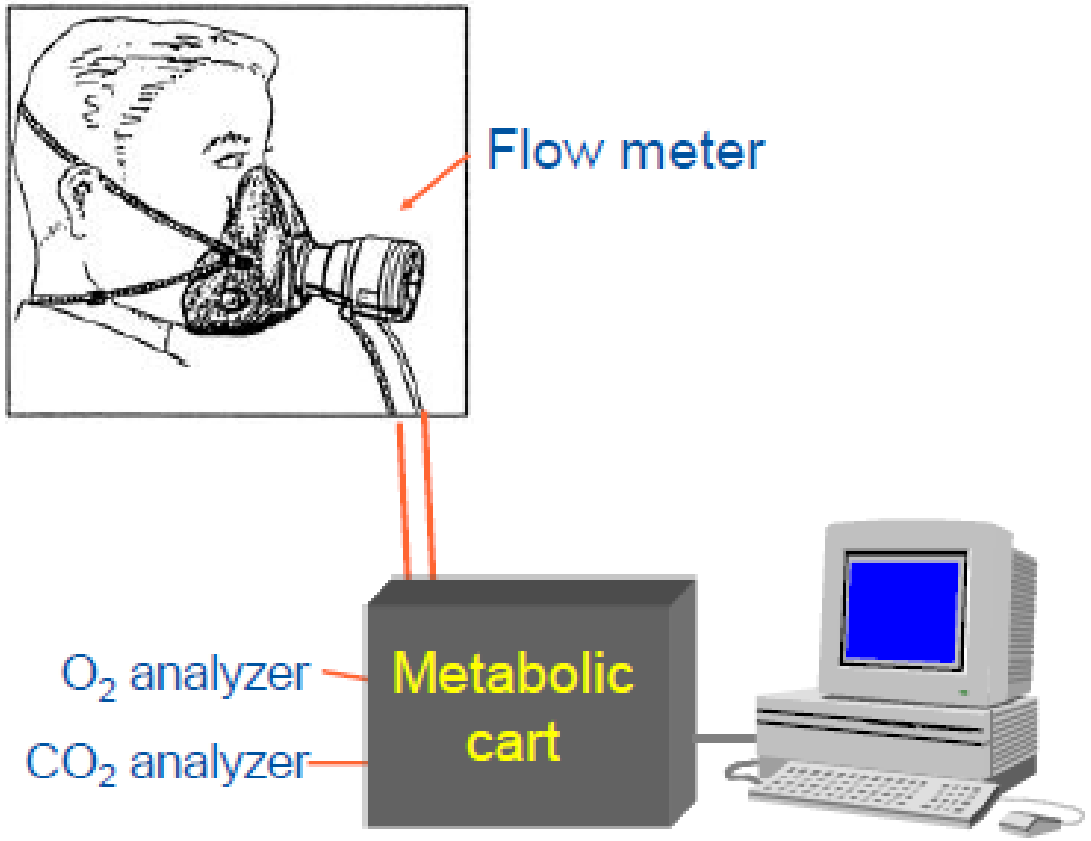


Image courtesy of Tim Takken (Utrecht, The Netherlands)

…. *comprehensive* CPET

Blood pressure monitoring

Baseline lung function

Heart rate monitoring / ECG

Transcutaneous arterial oxygen saturation (SpO_2)

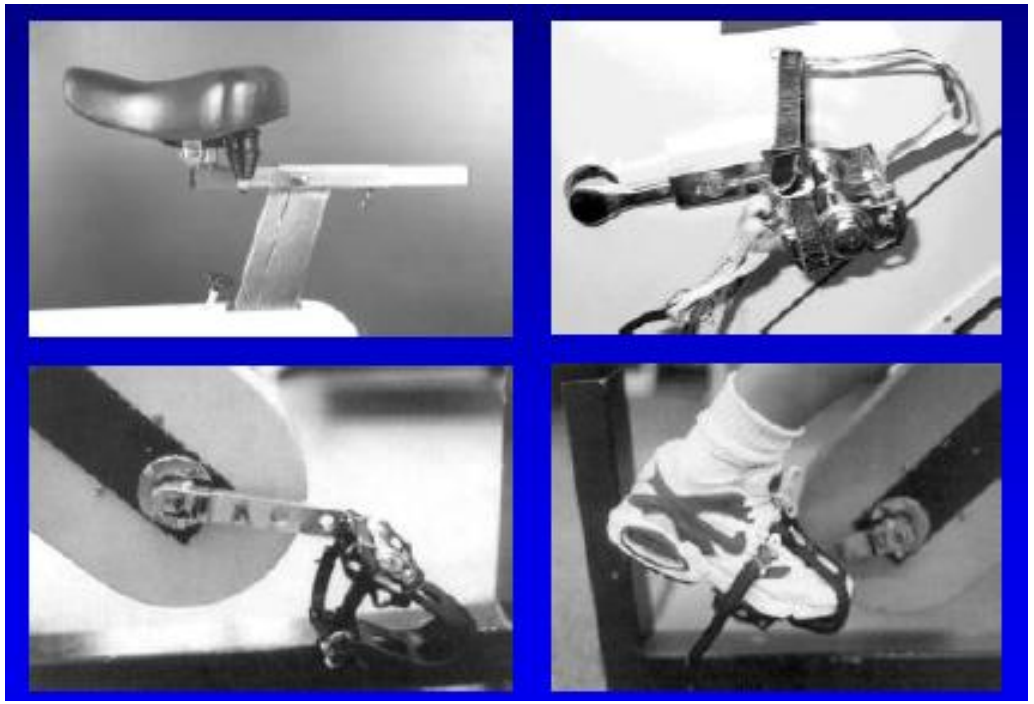
Thoracic impedance cardiography *optional*

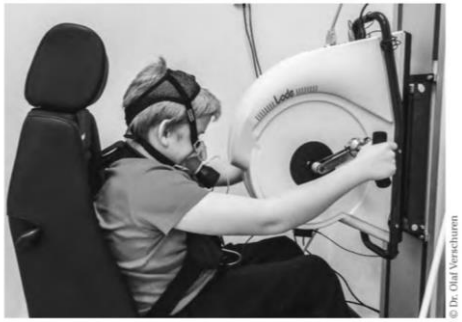
Near-infrared spectroscopy (NIRS) *optional*

Scales to assess dyspnoea & exertion

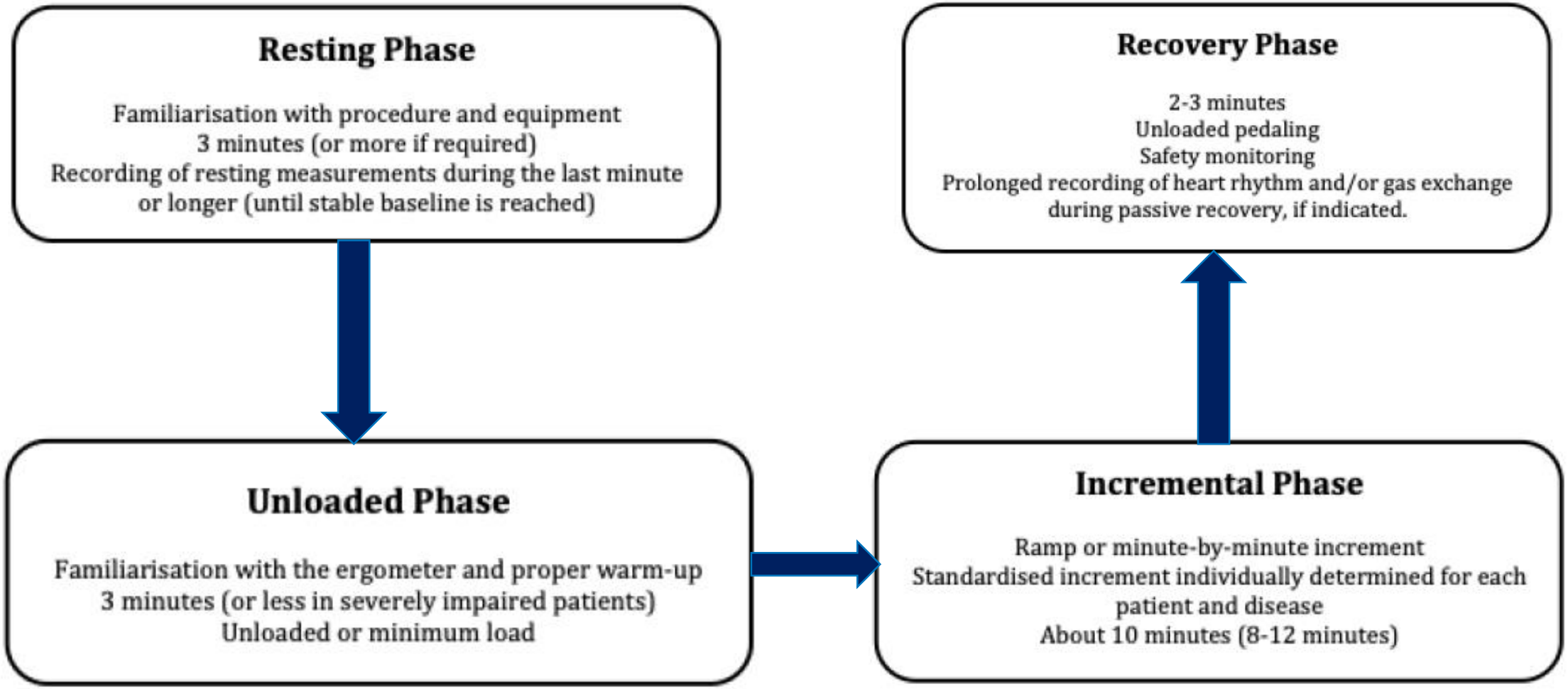
Images courtesy of Zoe Saynor

Ergometer modifications needed children / non-ambulatory





Typical CPET protocol approved for respiratory disease



Radtke et al. (2019) ERS Statement on Standardisation of cardiopulmonary exercise testing in chronic lung disease

What does CPET look like……

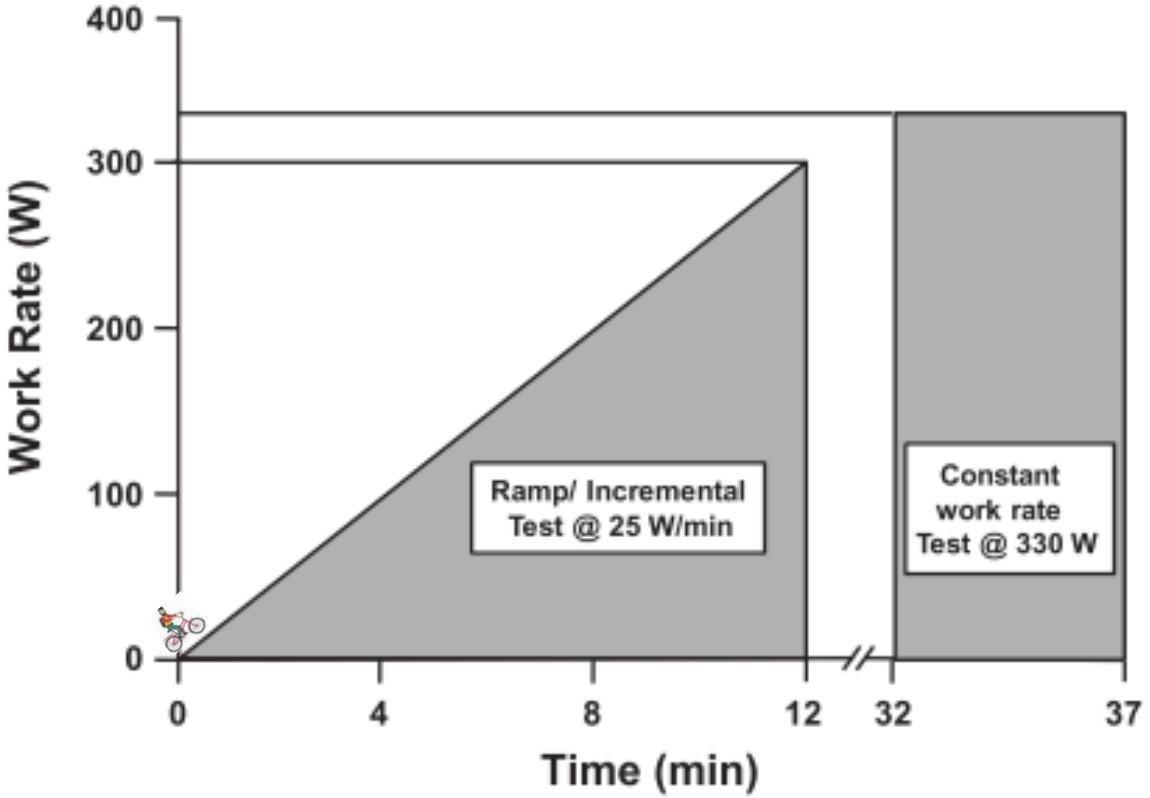


Image source: Zoe Saynor

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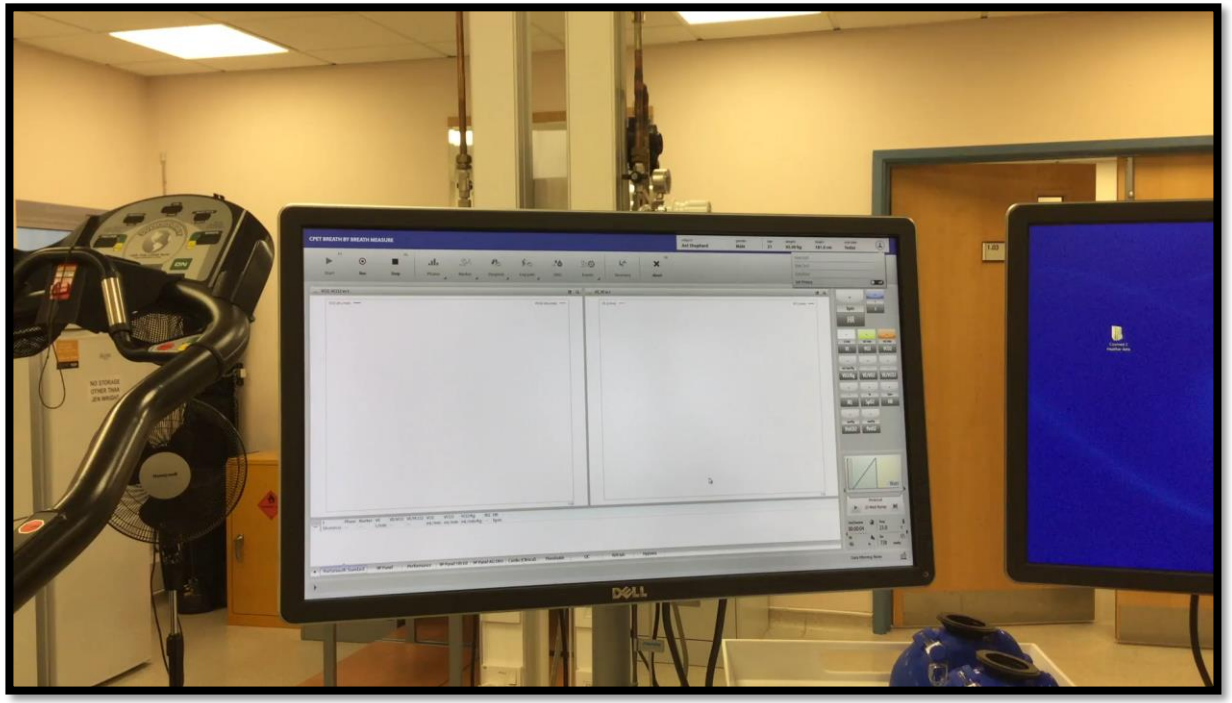

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…but what does it all mean?

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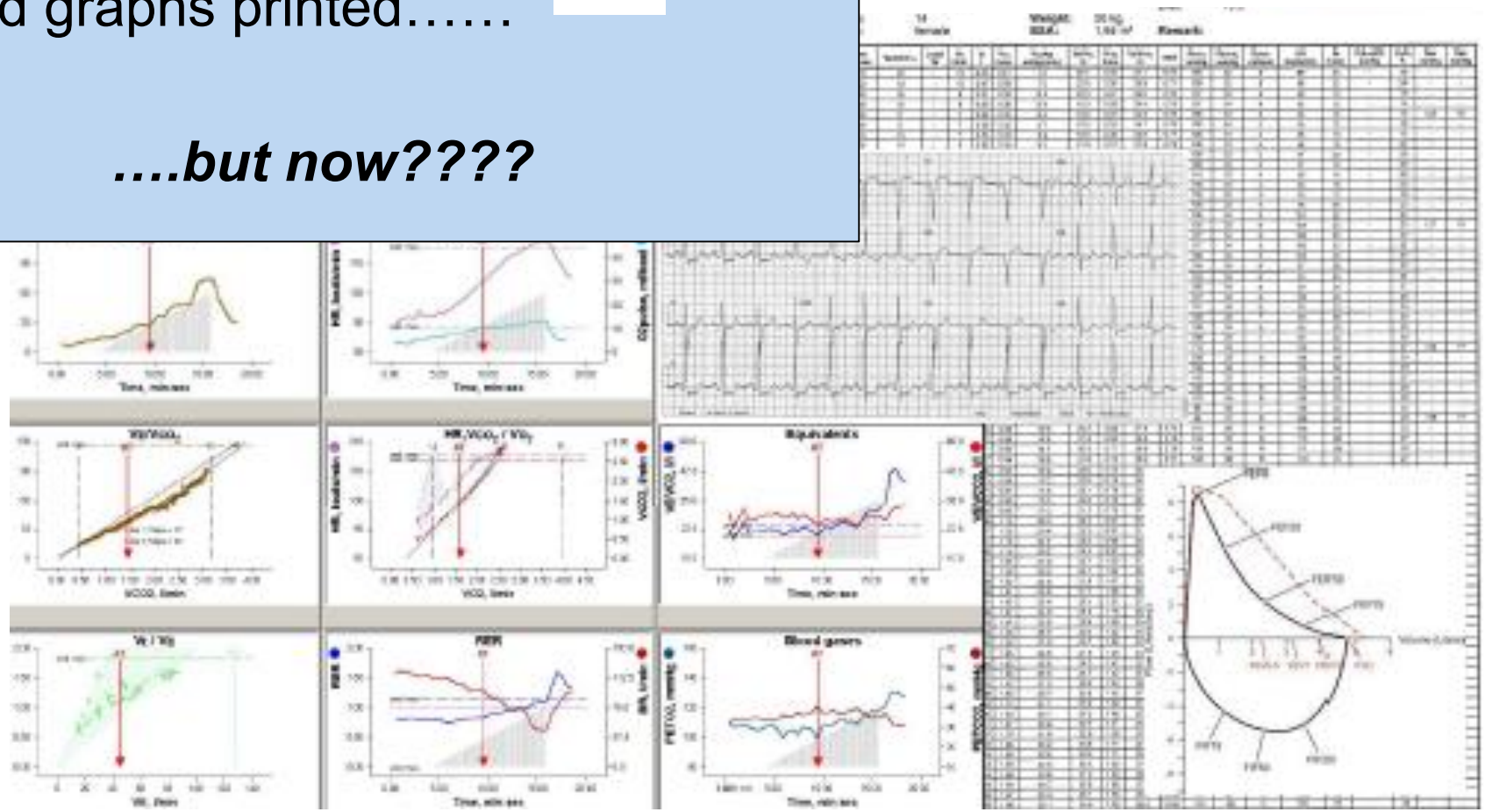
CPET completed….
Data and graphs printed……

✓

….but now????



Determine whether it is a maximal effort, performance was normal and the cause(s) of any exercise limitation

1

MAXIMAL TEST?
At least one of:
- Plateau in $\dot{V}O_2$ [Attainment of $\dot{V}O_2$peak]
- Peak HR >195 (children) or >100% predicted (adults)
- $\dot{V}_E$peak ≥85 % MVV
- RER > 1.05
- Blood lactate ≥ 8 mmol.L^{-1} (adults)

→ No → **EARLY TERMINATION**

ADVERSE EVENT ON EXERCISE e.g., Arrhythmia, Pain etc

SUBOPTIMAL EFFORT

Yes ↓

2

ABNORMAL EXERCISE RESPONSE
At least one of:
Peak $\dot{V}O_2$ < 85% predicted
Peak HR below 90% predicted
$\dot{V}_E$peak > 85% predicted MVV
$\dot{V}O_2$ at AT< 50% predicted $\dot{V}O_2$peak
Desaturation ≥ 5% from baseline
Decrease in IC > 150mL

Yes ↓

3

DETERMINE CAUSE OF EXERCISE LIMITATION

	Respiratory Limitation	***Cardiovascular Limitation***	***Peripheral Muscle Limitation***	***Physical Deconditioning***
Peak $\dot{V}O_2$	Reduced	Reduced	Reduced	Reduced
$\dot{V}O_2$ at AT	Normal	Normal/Reduced	Likely reduced	Reduced
Peak HR	Reduced	Likely normal	Reduced	Normal
$\dot{V}_E$/MVV	>85%	<85%	<85%	<85%
SpO_2	Normal/Reduced	Normal	Normal	Normal

Supramaximal testing can help here

Radtke et al. (2019) ERS Statement on Standardisation of cardiopulmonary exercise testing in chronic lung disease

Other common criteria for determining a maximal effort during CPET

Subjective criteria

- Unsteady walking, running or cycling
- Sweating
- Facial flushing
- Clear unwillingness to continue CPET despite encouragement

Objective criteria

- RER_{peak} > 1.00
- HR_{peak} > 180 b/min
- VO_2 plateau in final minute *(infrequently observed)*

N.B. Never stop test just because the criteria have been met, unless there is a clinical / safety reason for doing so

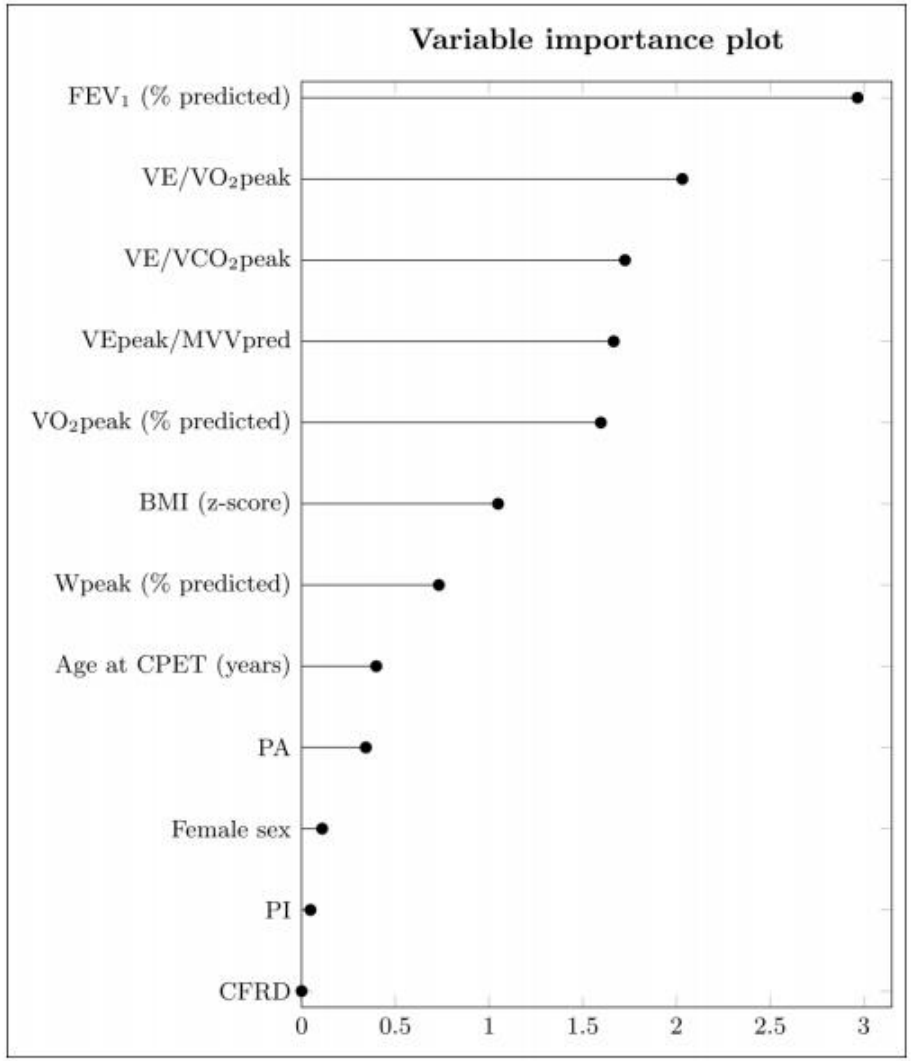
Determine whether ‘performance’ (fitness) was normal….

Indicators of **performance**

- Maximal power (cycle ergometry)
- Stage reached in a standardised exercise protocol
- Endurance time in a standardised exercise protocol
- Peak oxygen uptake (VO_2peak)
- Lactate threshold / ventilatory threshold / anaerobic threshold *(submaximal measure of aerobic fitness)*

Remember though…… CPET is not *1 measure*

- Maximal power (cycle ergometry)
- Stage reached in a standardised exercise protocol
- Endurance time in a standardised exercise protocol
- Peak oxygen uptake (VO_{2peak})
- Lactate threshold / ventilatory threshold



Hebestreit et al. (2019) AJRCCM

ECFS Mortality II currently underway

Determine whether performance / exercise response was ‘normal’

2

Yes

ABNORMAL EXERCISE RESPONSE
At least one of:
Peak $\dot{V}O_2$ < 85% predicted
Peak HR below 90% predicted
$\dot{V}_E$peak > 85% predicted MVV
$\dot{V}O_2$ at AT< 50% predicted $\dot{V}O_2$peak
Desaturation ≥ 5% from baseline
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Yes

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	Respiratory Limitation	***Cardiovascular Limitation***	***Peripheral Muscle Limitation***	***Physical Deconditioning***
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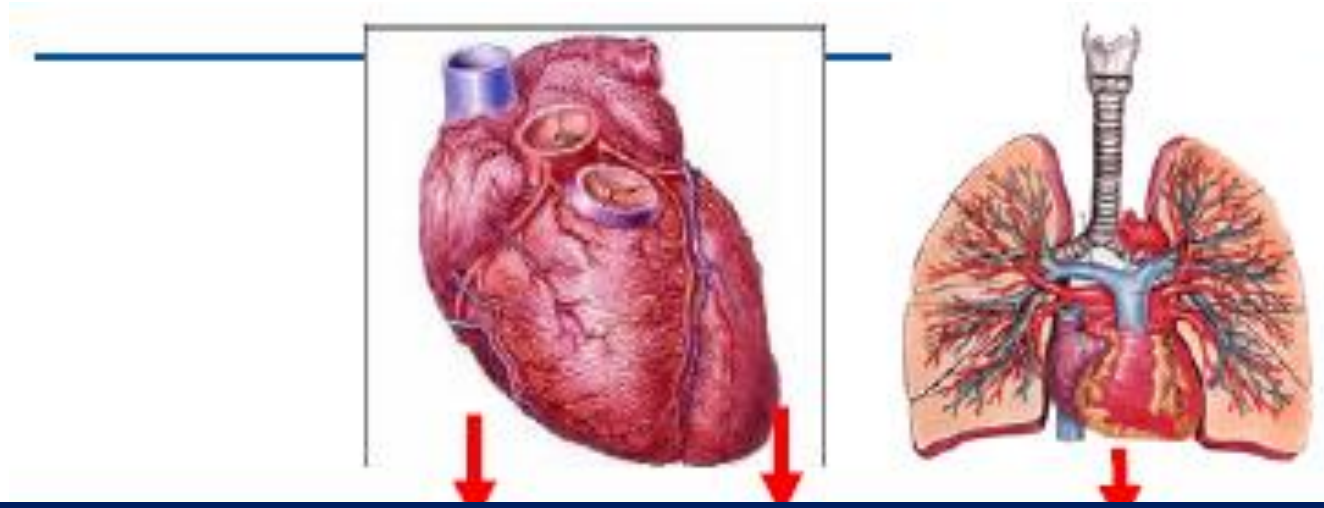
SpO_2	Normal/Reduced	Normal	Normal	Normal

Radtke et al. (2019) ERS Statement on Standardisation of cardiopulmonary exercise testing in chronic lung disease

VO_{2max} can be defined using the Fick equation….

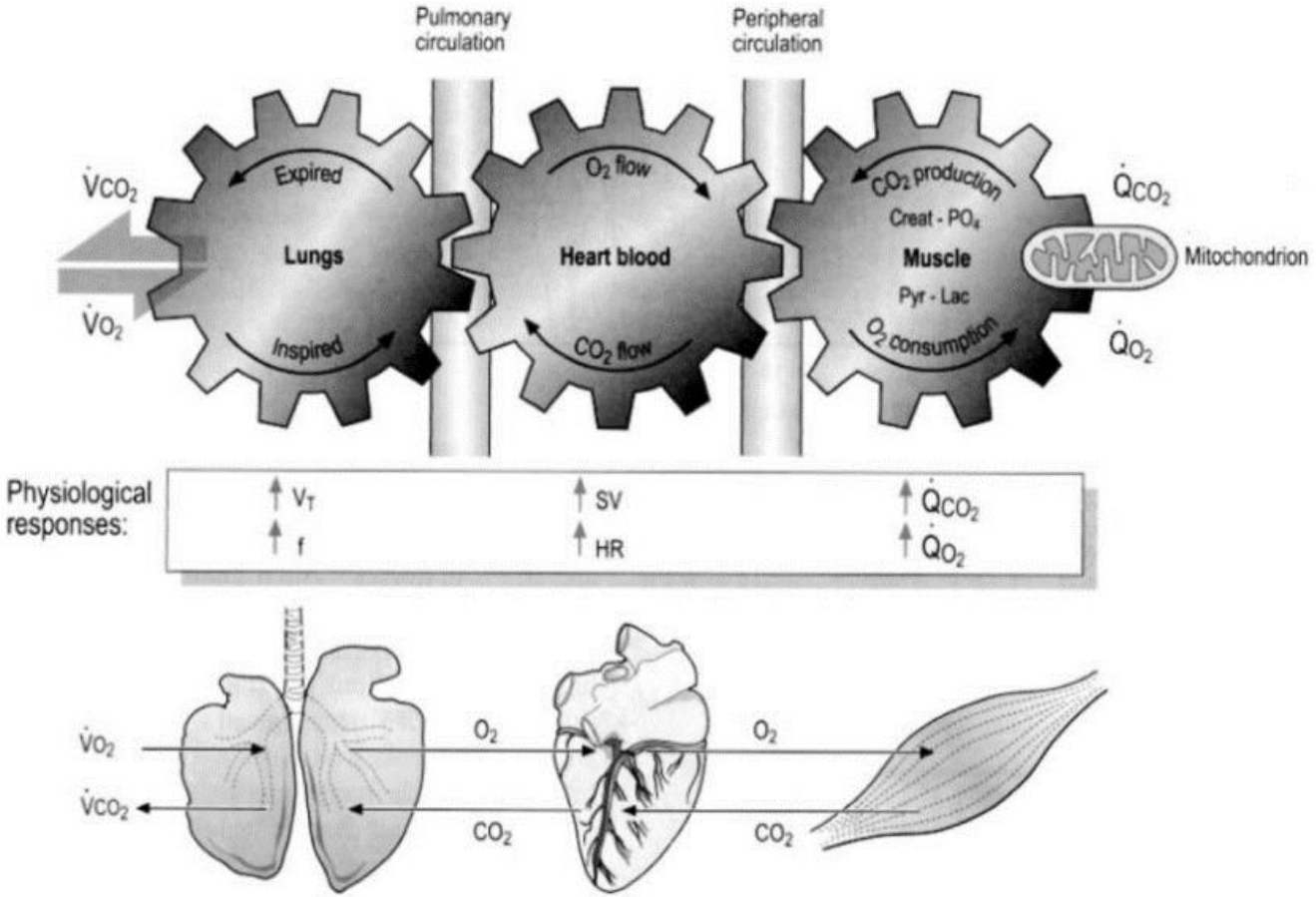
VO_{2max} = Q x (avO_2 difference)



VO_{2max} = stroke volume $_{max}$ x heart rate $_{max}$ x (CaO_2 – CvO_2) $_{max}$

Product of cardiac output and muscle oxygen extraction

If performance was lower than ‘normal’ – *What were the limitations to exercise capacity?*



ABNORMAL EXERCISE RESPONSE

At least one of:

Peak VO_2 < 85% predicted

Peak HR below 90% predicted

$\dot{V}_E$peak > 85% predicted MVV

VO_2 at AT< 50% predicted VO_2peak

Desaturation ≥ 5% from baseline

Decrease in IC > 150mL

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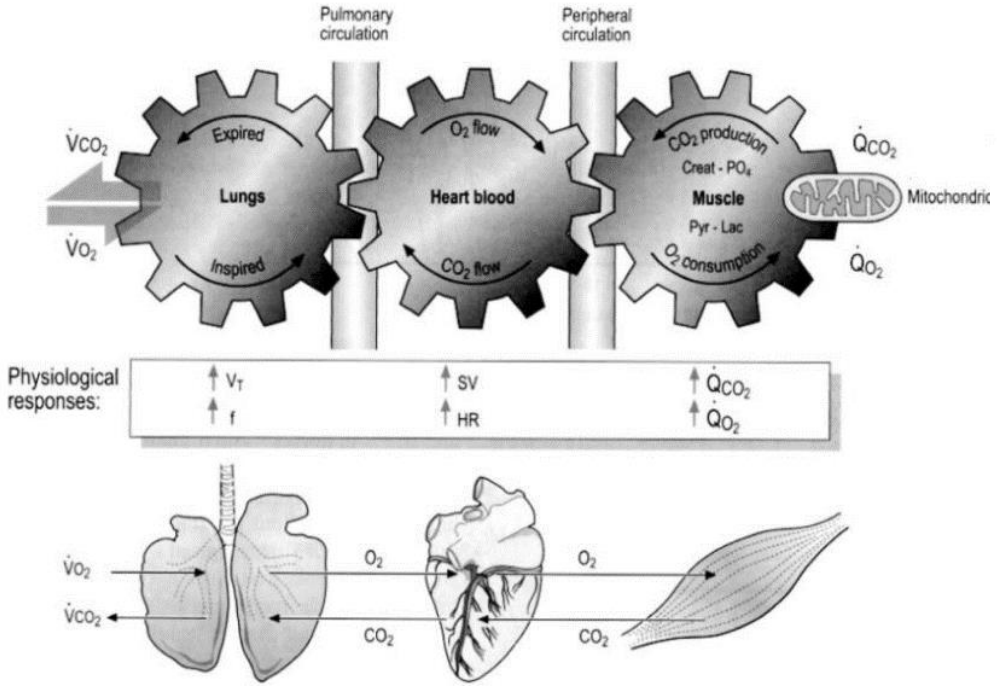
If performance was lower than ‘normal’ – *What were the limitations to exercise capacity?*



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Peak HR	Reduced	Likely normal	Reduced	Normal
$\dot{V}_E/MVV$	>85%	<85%	<85%	<85%
SpO_2	Normal/Reduced	Normal	Normal	Normal

….. so we can do a lot before even looking at the dreaded ‘graphs’

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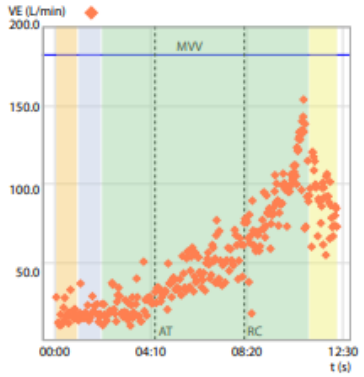
Tabular data can only tell us so much…

Name	ID1	Gender	Age	Weight (kg)	Height (cm)
[redacted]	[redacted]	Male	31	95.00	181.0
D.O.B.	Set				
01-Jan-89	ACSM (Exercise Testing (Healthy))				

1



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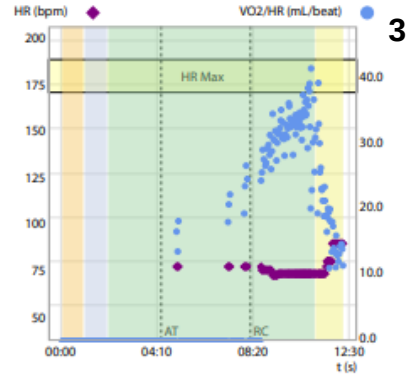

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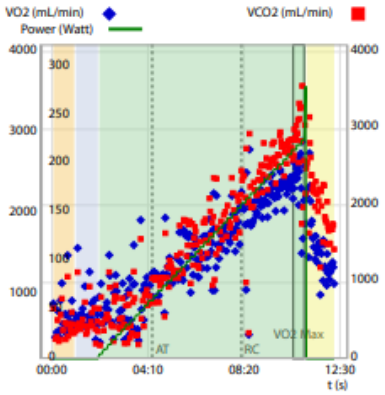

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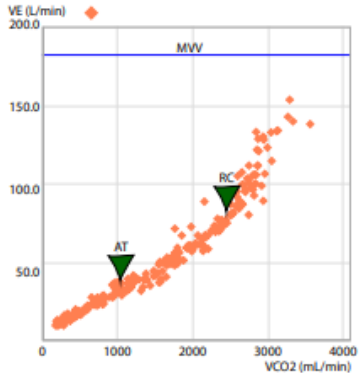

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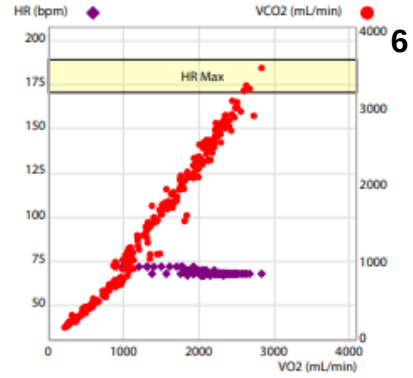

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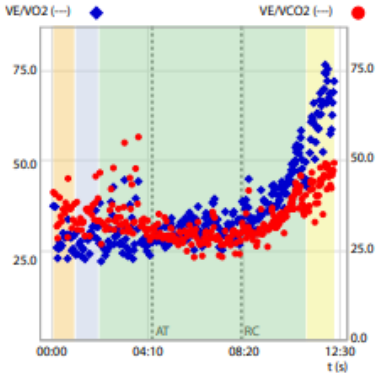

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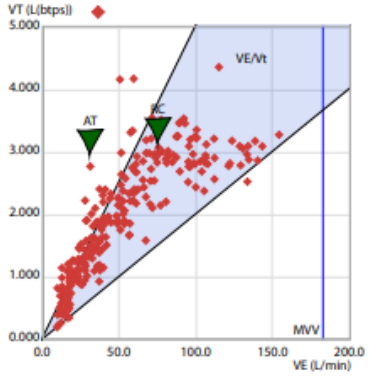

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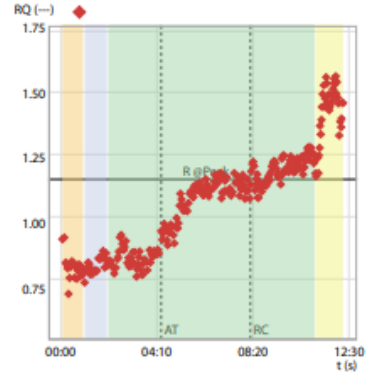

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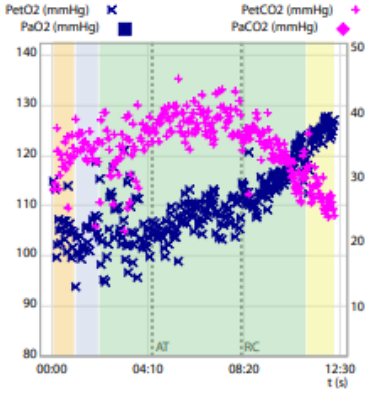
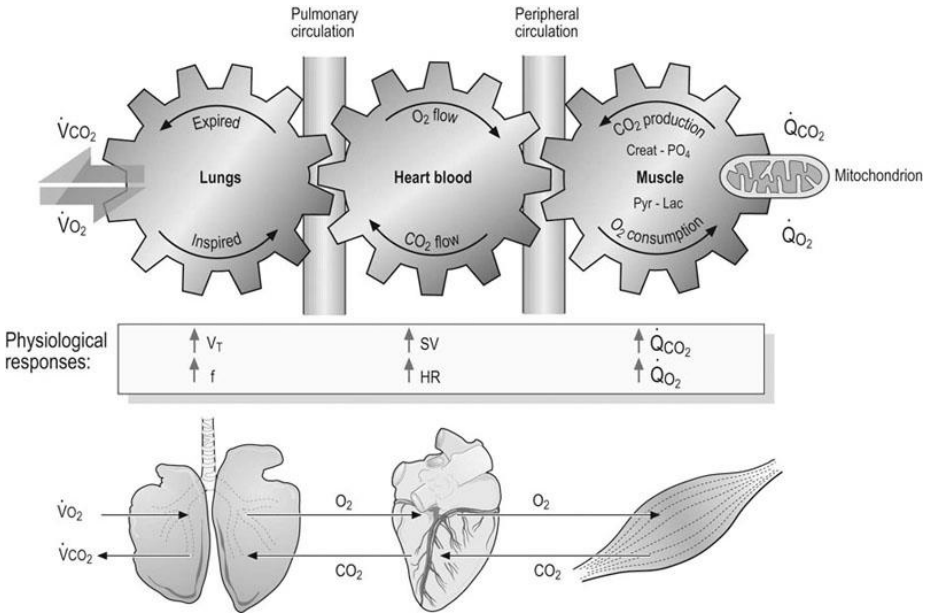


Which panels tell us about which systems?

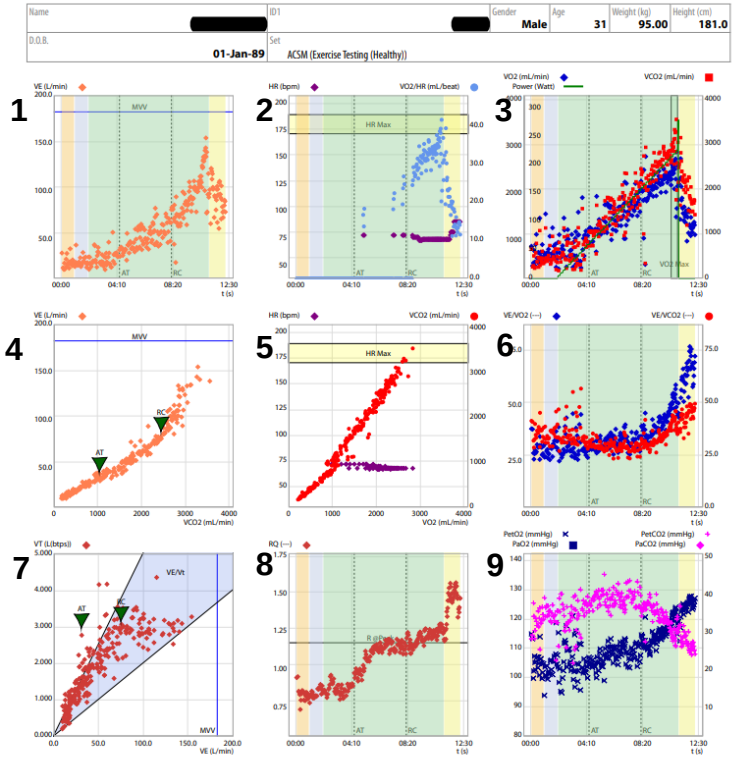
Cardiovascular system: 2, 3, 5

Ventilation: 1, 4, 7

Ventilation-perfusion relationships: 6, 8, 9

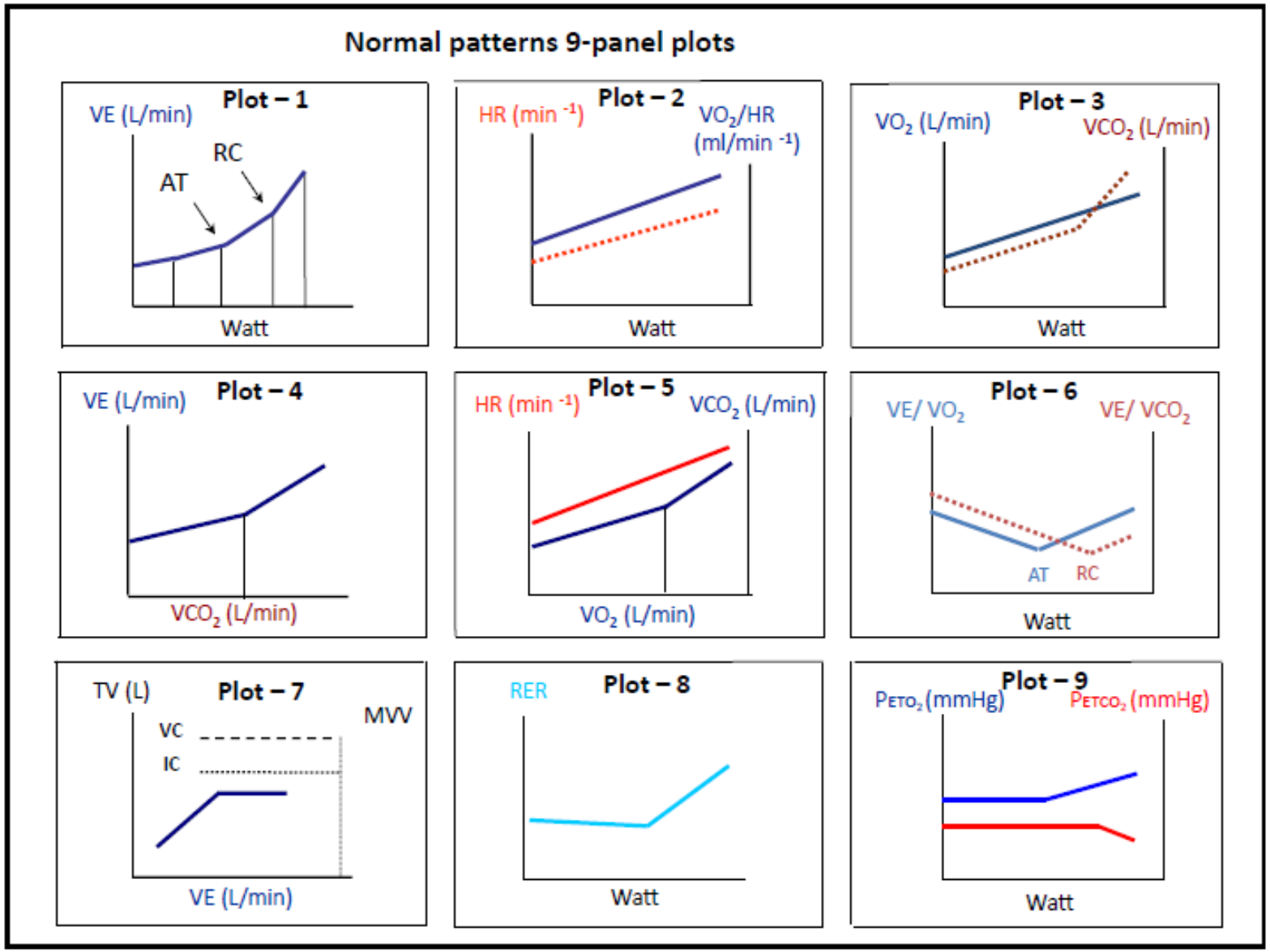


The 9-Panel Plot:
What does each panel tell us?



1. Ventilation vs. Time (or Watts)
2. Heart rate and O_2 pulse vs. Time
3. VO_2 & VCO_2 vs. Time
4. Ventilation vs. VCO_2
5. Heart rate vs. VO_2 / VCO_2 vs. Time
6. V_E/VO_2 & V_E/VCO_2 vs. Time
7. Tidal volume vs. Ventilation
8. RER (V_D/V_T/saturation) vs. Time
9. $PETCO_2$ & $PETO_2$ vs. Time
   (& PaO_2 and $PaCO_2$ if blood gas analysis undertaken)

If you know normal, then you can establish abnormal!



The ‘normal’ CPET 9-Panel Plot

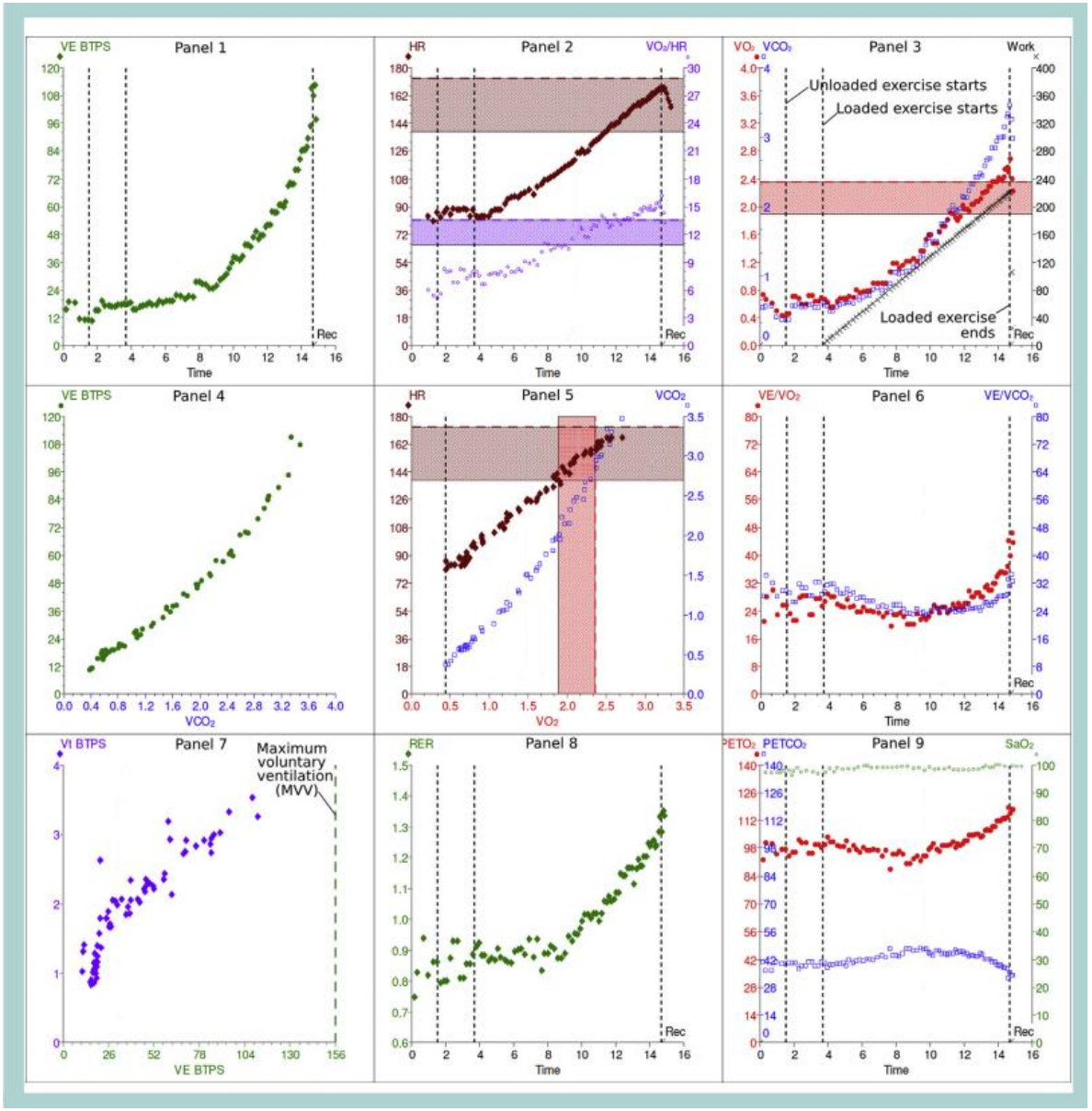
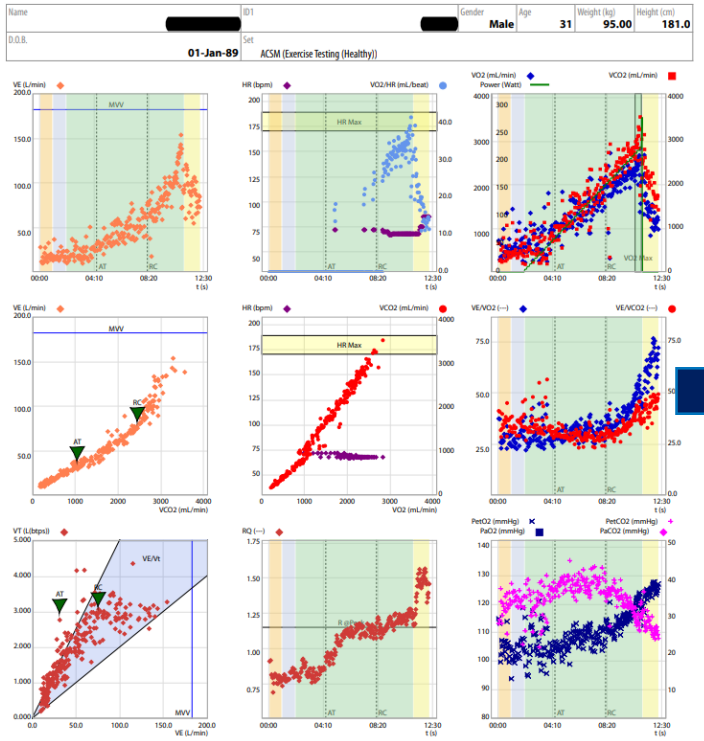


Image from: Chambers & Wisely (2019) BJA Education

Standardised reporting is key!



NHS Portsmouth Hospitals University NHS Trust

UNIVERSITY OF PORTSMOUTH

Cardiopulmonary Exercise Test Report

Hospital No:		Department:	
Surname:	Cyclist	Study Date:	
First Name:	Sample	Test performed:	Maximal CPET
DOB:		Indication:	
Consultant:		Clinical Diagnosis:	Cystic Fibrosis

TECHNICAL

Technical Comments:
Technical criteria are met with an acceptable test duration. Good patient effort was suggested by peak HR and RER data. The subject reported a Borg score of 1 at rest and 9 at peak exercise.

Protocol:
A 20W/minute incremental exercise (Godfrey) protocol was used.

Reason for termination of test:
Test terminated by the test subject due to leg fatigue.

EXERCISE RESPONSE

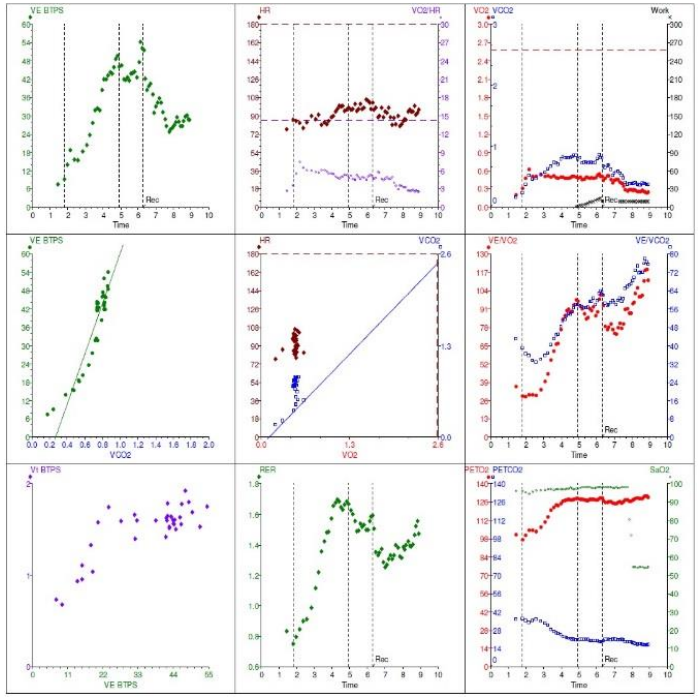
Aerobic/Anaerobic Performance:
A peak VO_2 of 33.0 $ml.min^{-1}.kg^{-1}$ (70% predicted) was achieved in attaining a maximal workload of 132 Watts (50% predicted). Anaerobic Threshold occurred at 41% of predicted VO_2 max which was is below predicted AT onset. Corresponding values for MET's were 5.7 METs at AT and 9.1 METs at peak exercise. VO_2/work slope (9.8) was at the lower limit of normal range.

Cardiovascular response:
Peak HR of 180 bpm was essentially normal (90% predicted). O_2 pulse was within expected range. ECG and BP response to exercise were within expected parameters. Cardiovascular response to exercise was therefore normal.

Ventilatory response:
Maximum Minute Ventilation was 98L/min (107% predicted), with a negative breathing reserve recorded at peak exercise. Ventilatory response to exercise was, therefore abnormal with noted ventilatory limitation.

Gas exchange:

What should be in your CPET report?



- Date
- Indication for CPET
- Medication on test day
- Protocol and ergometer used
- Execution of the test (technical problems/complaints during the test/test duration)
- Reason for stopping
- Quality of the test (HR_{peak}, RER_{peak}, VR)
- Was the test maximal?
- Response during exercise (cardiovascular, ventilatory, gas exchange) – potential limiting factors of dysfunction / reduced fitness is evident
- Compare outcomes with appropriate norms (check which norms are already in the system – not always application for your patient!)
- Compare with disease or sport specific norms – if available
- ECG (if performed): rest, exercise and recovery
- Spirometry (if performed): pre- and post-exercise
- Conclusion
- Recommendations
- Name of the test leader / interpreter

Summary

- CPET is not always the best test
- ERS statement provides key standardised guidance for CPET
- The 9-panel plots and additional tabular data provide an overview of the key parameters during exercise
- Systematic approach exists for a standardised interpretation of the 9-panel plot
- The 9 graphs are helpful for analysis of parameters (e.g. VAT, V_E/VCO_2 slope and $\Delta VO_2/\Delta WR$) and for interpretation
- A well documented ‘normal’ response can enable abnormalities to be identified and diagnosed
- Performance and subjective measures can be used to prescribe individualised, safe and appropriate exercise training

Let’s get testing!

Acknowledgements

All in the Adult and Paediatric Respiratory teams in Southampton

Colleagues in the European Cystic Fibrosis Society Exercise Working Group

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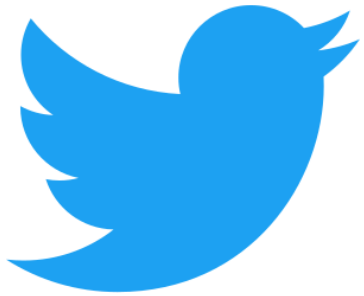
Thank you for your attention

@Zoe_Saynor



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Please get in touch if you still have questions after the discussion…….