VO_2max Measurement and Analysis

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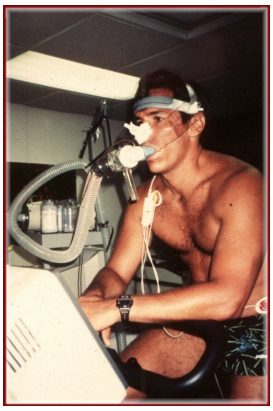

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Early History

Archibald Vivian Hill

"*In running the oxygen requirement increases continuously as the speed increases, ….; the actual oxygen intake, however, reaches a maximum beyond which no effort can drive it. The oxygen intake may attain its maximum and remain constant merely because it cannot go any higher owing to the limitations of the circulatory and respiratory system*."

(Hill A.V. and H. Lupton. QQ J Med 1923; 16:135-171.)

In performing his research, Hill used,

- 6-7 subjects
- limited running speeds
- discontinuous running protocols
- combined data from multiple subjects

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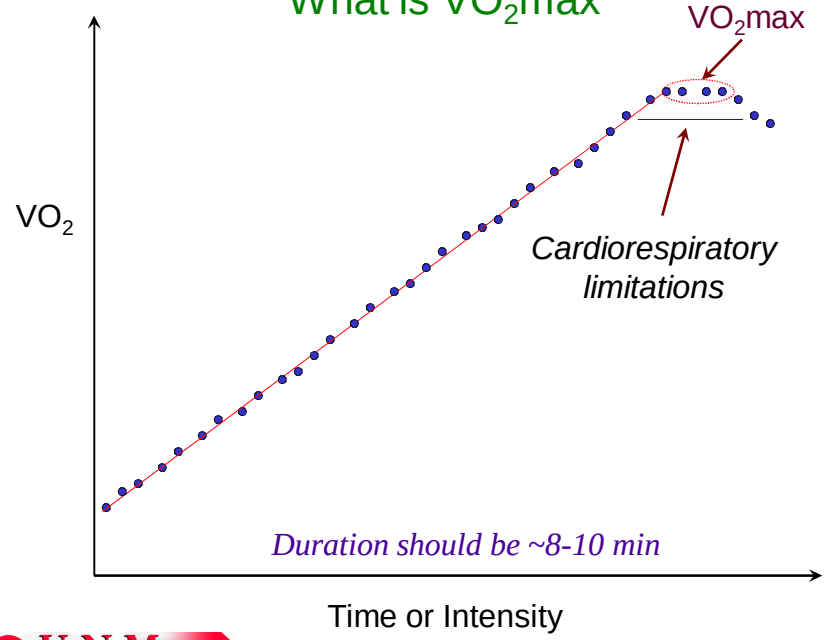
What is VO_2max



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Definitions:

- The maximum rate oxygen can be taken in (pulmonary), transported (circulatory), and utilized (peripheral) for energy production.
- The maximal ***rate*** at which the body can consume oxygen during exercise.

Other "less correct" terms!

"aerobic power" "aerobic capacity"

"maximal cardiorespiratory capacity"

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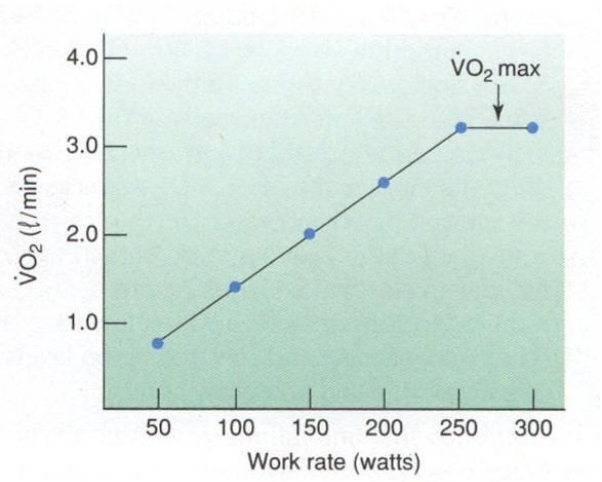
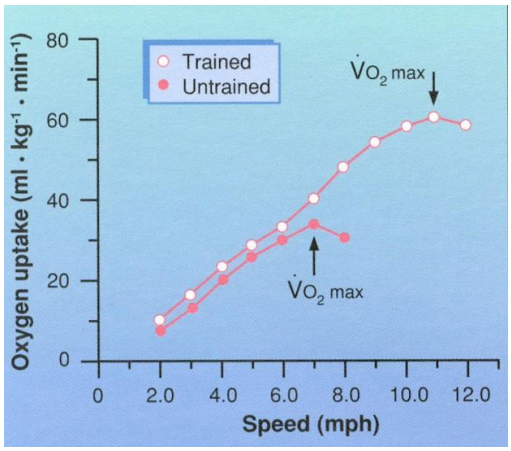


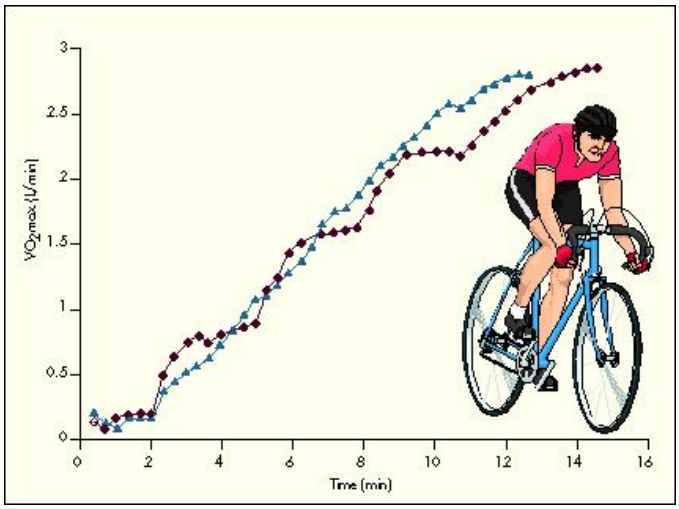
Powers and Howley, 1997, p: 50

"*VO_2max represents the physiological ceiling for the ability of the oxygen transport system to deliver O_2 to contracting muscles*."



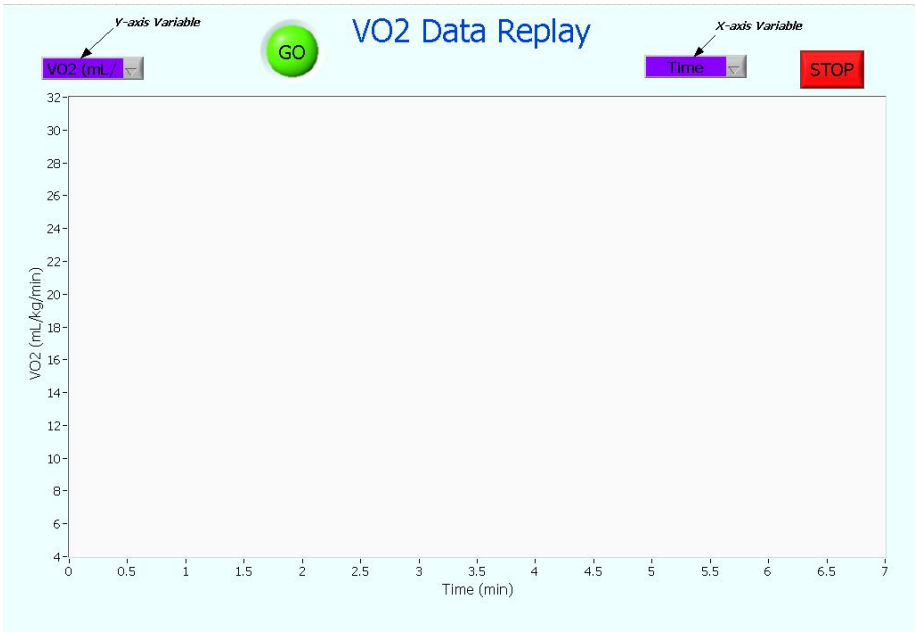
Wilmore and Costill, 1994, p: 11

"*…. Oxygen consumption peaks and remains constant or drops slightly, even though work intensity continues to increase…. The best single measurement of cardiorespiratory endurance and aerobic fitness*."

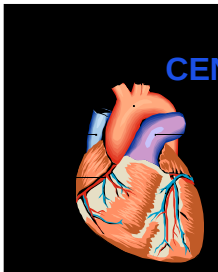


Robergs and Roberts, 1998, p: 227

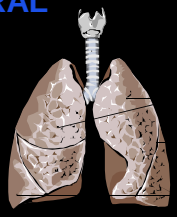
"*… the maximal rate that the body can consume oxygen during exercise… detected as a plateau despite further increases in exercise intensity…*"



Determinants of VO_2max



CENTRAL



PERIPHERAL

HR x SV

Cardiac Output

Δ A-aPO_2

SaO_2 [Hb]

oxygen delivery

PO_2 gradients

capillary density

muscle mass

fiber dimensions

O_2 supply demand relationshi

$VO_2max = Qmax \times a\text{-}vO_2\Delta max$

Peripheral Oxygen Diffusion

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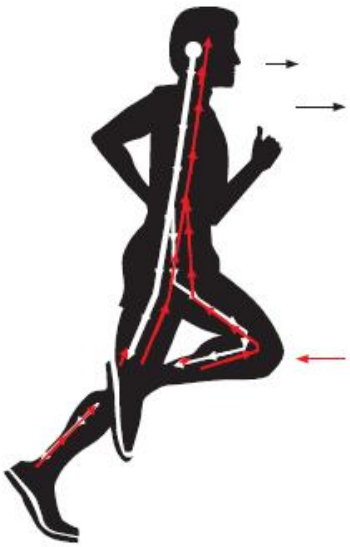

Physiological and Psychological inputs before exercise:

- Physiological state
- Expected distance/ duration
- Previous experience/ motivation/external competition

Continuous feedback from various body systems is integrated to regulate the exercise intensity by continously modifying the number of motor units recruited in the exercising limbs

Feedback during exercise:

- Fuel reserves
- Rate of heat accumulation
- Hydration state
- Self-belief

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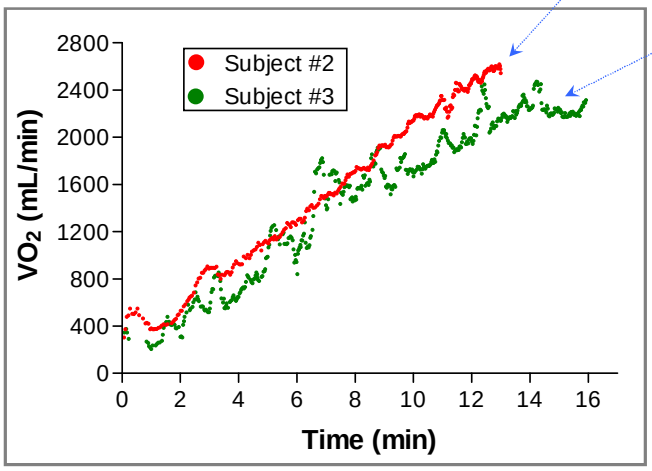

For 34 subjects, breath-by-breath data with an 11 breath average, and based on $\Delta VO_2 \leq 50$ mL/min for VO_2max and closest neighboring data point.

VO_2 plateau incidence = 86%

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Background

- No universally recommended procedures for processing VO_2 data from breath-by-breath indirect calorimetry, or from time averaged systems.
- No standardized criteria or recommended methods for detecting either of a VO_2 plateau, the maximal rate of oxygen consumption (VO_2max), or a peak VO_2 in the absence of a VO_2 plateau (VO_2peak).
- Increasing use of breath-by-breath indirect calorimetry in education, research and professional practice
- The lack of any objective criteria to follow when processing decreases the validity of measurement.

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Challenges

- How do researchers in exercise physiology currently collect and process data?
- How long should the protocol be?
- What type of protocol should be used?
- What causes the “noise” in breath-by-breath VO_2 data?
- Should this “noise” be reduced? If so, how?
- What is a VO_2 plateau?
- How can a VO_2 plateau be objectively determined?
- What is VO_2max vs. VO_2peak?
- How can VO_2max and VO_2peak be objectively determined?

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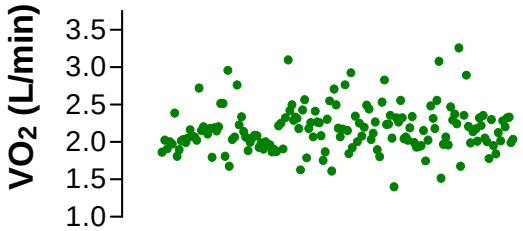
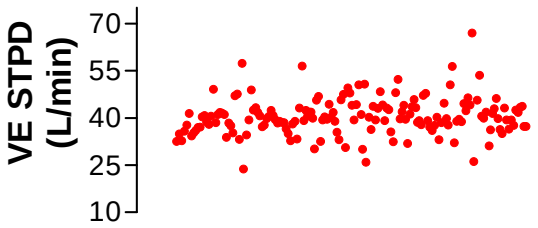
What causes the “noise” in breath-by-breath VO_2 data?



2.17 ± 0.3 L/min, with a range of 1.4 – 3.3 L/min



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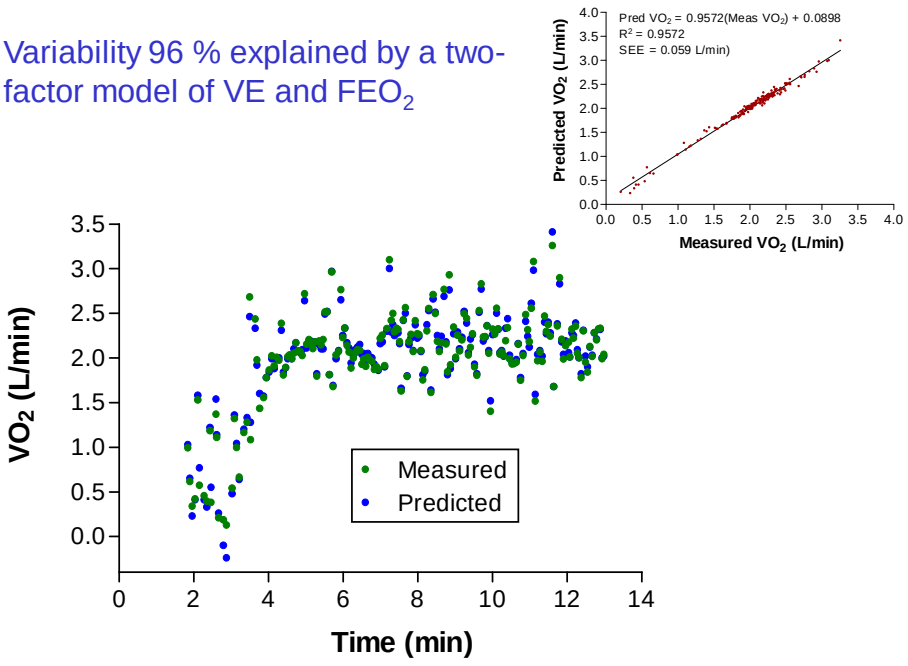
Variability 96 % explained by a two-factor model of VE and FEO_2



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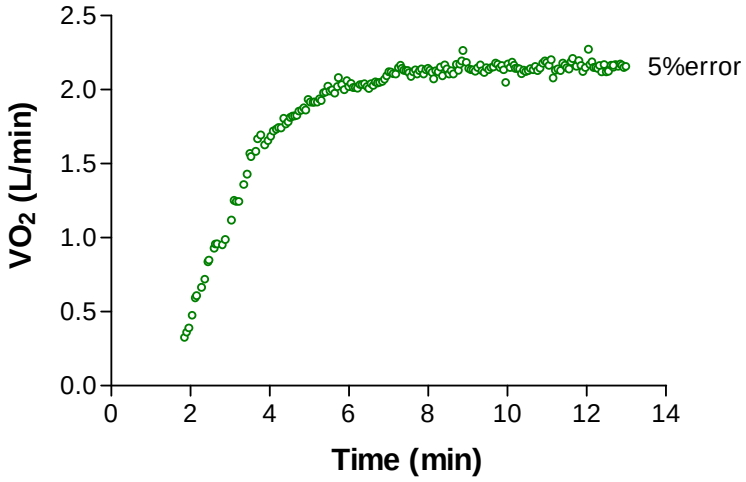
Variability Remaining



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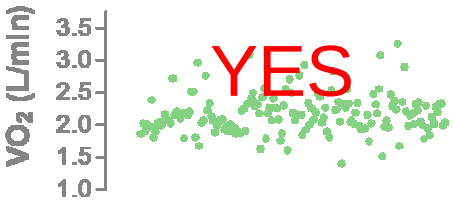
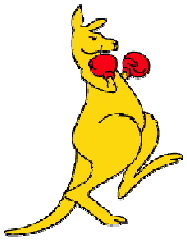
Should this "noise" be reduced?



How should this "noise" be reduced?



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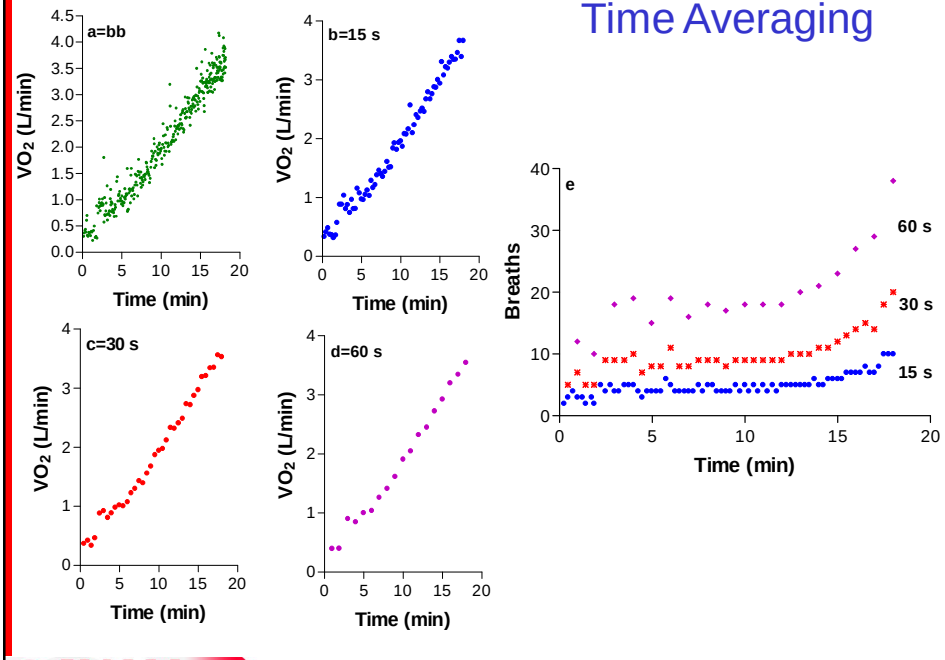
Time Averaging



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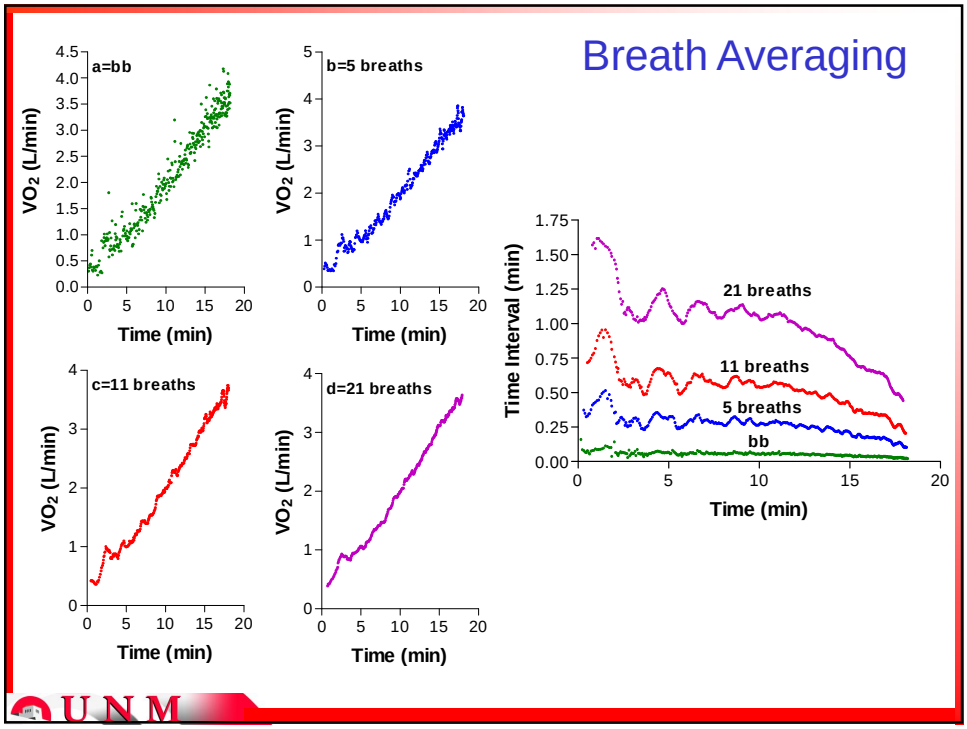
Breath Averaging
a=bb
b=5 breaths
c=11 breaths
d=21 breaths
VO2 (L/min)
Time (min)
Time Interval (min)
21 breaths
11 breaths
5 breaths
bb
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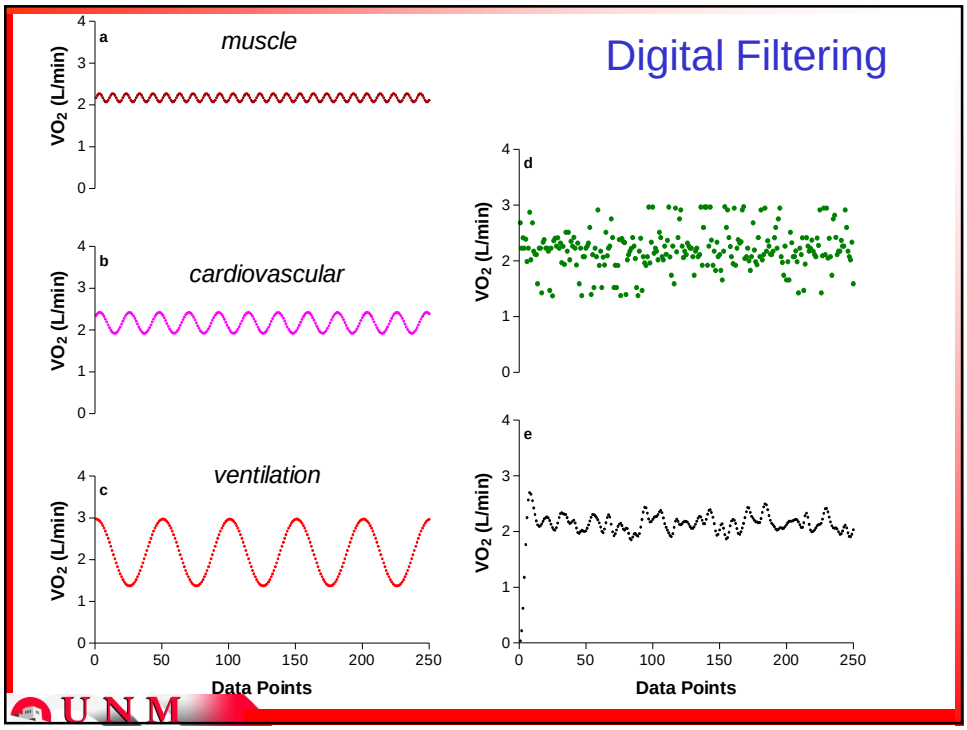
Digital Filtering
muscle
cardiovascular
ventilation
a
b
c
d
e
VO2 (L/min)
Data Points
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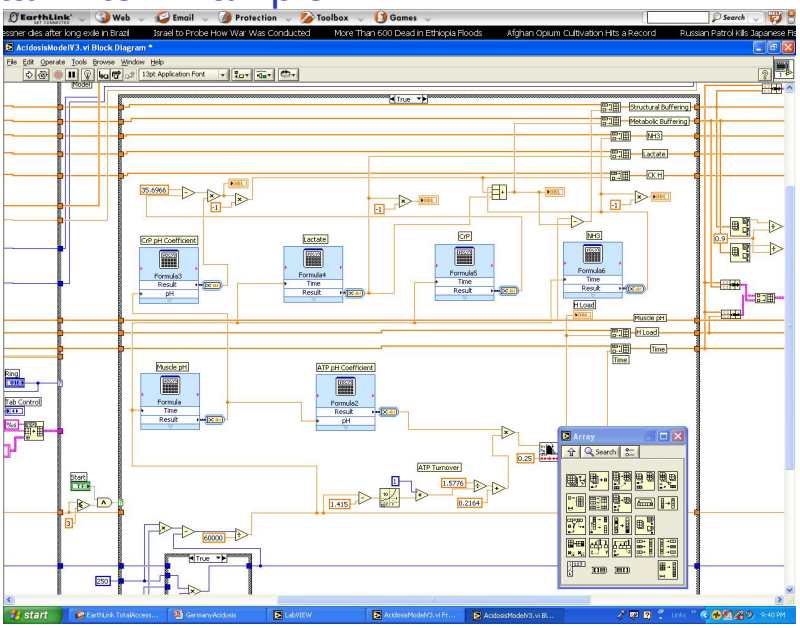
Digital Filter Example



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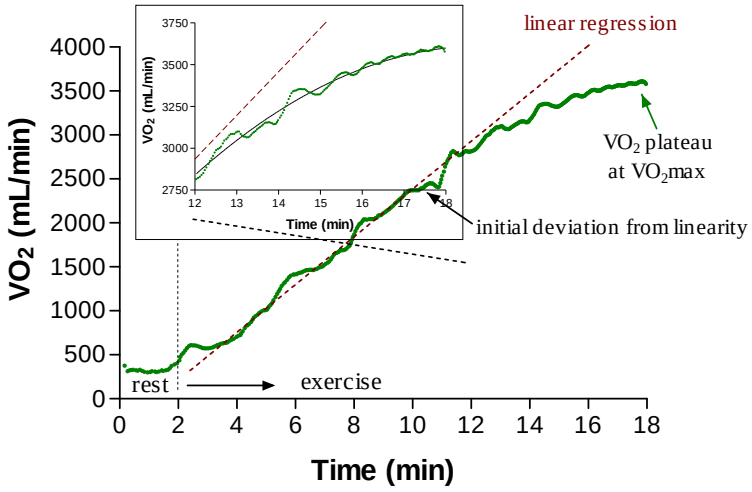
What is a VO_2 plateau?



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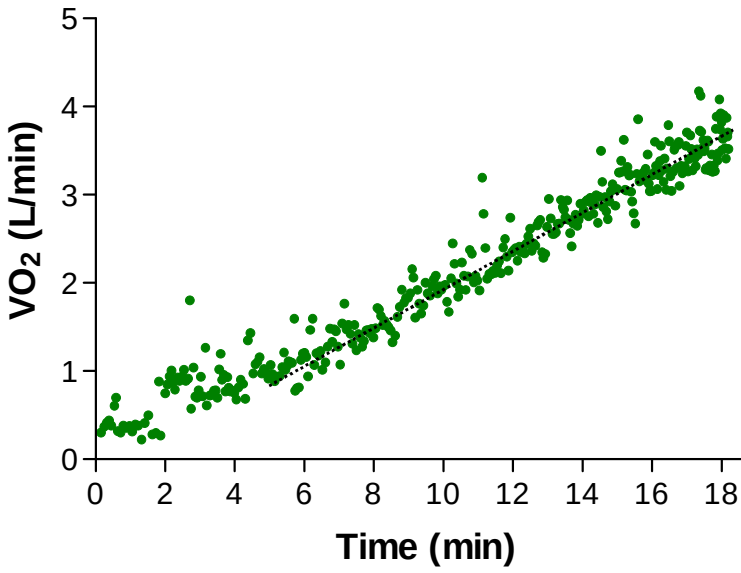
What is VO_2max or VO_2peak?



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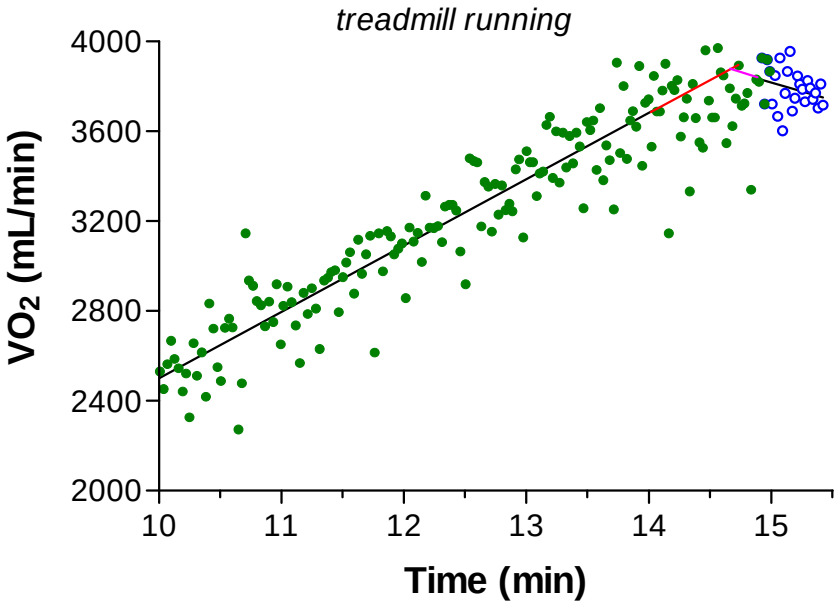
Data Example



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Conclusions

- Clear rationale for processing breath-by-breath VO_2 data to decrease "noise".
- Processing best done by digital filtering
- Still formulating and debating criteria and methods to quantify VO_2 plateau, VO_2max, VO_2peak
- In the absence of a VO_2 plateau, what are valid criteria to use to verify a "true" VO_2max?

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