Measurement of Energy Expenditure During Exercise

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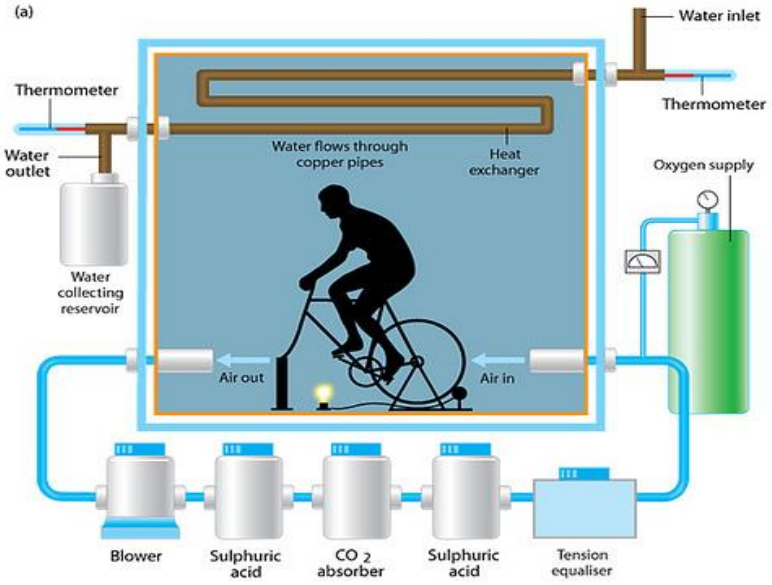


Measurement of Work and Power

- Ergometry
  - Measurement of work and power output
- Ergometer
  - Device used to measure work
    - Bench step ergometer
    - Cycle ergometer
    - Arm ergometer
    - Treadmill

Ergometers Used in the Measurement of Human Work Output and Power

(a) **Bench step**

(b) **Cycle ergometer**

Treadmill

(c)

Arm ergometer

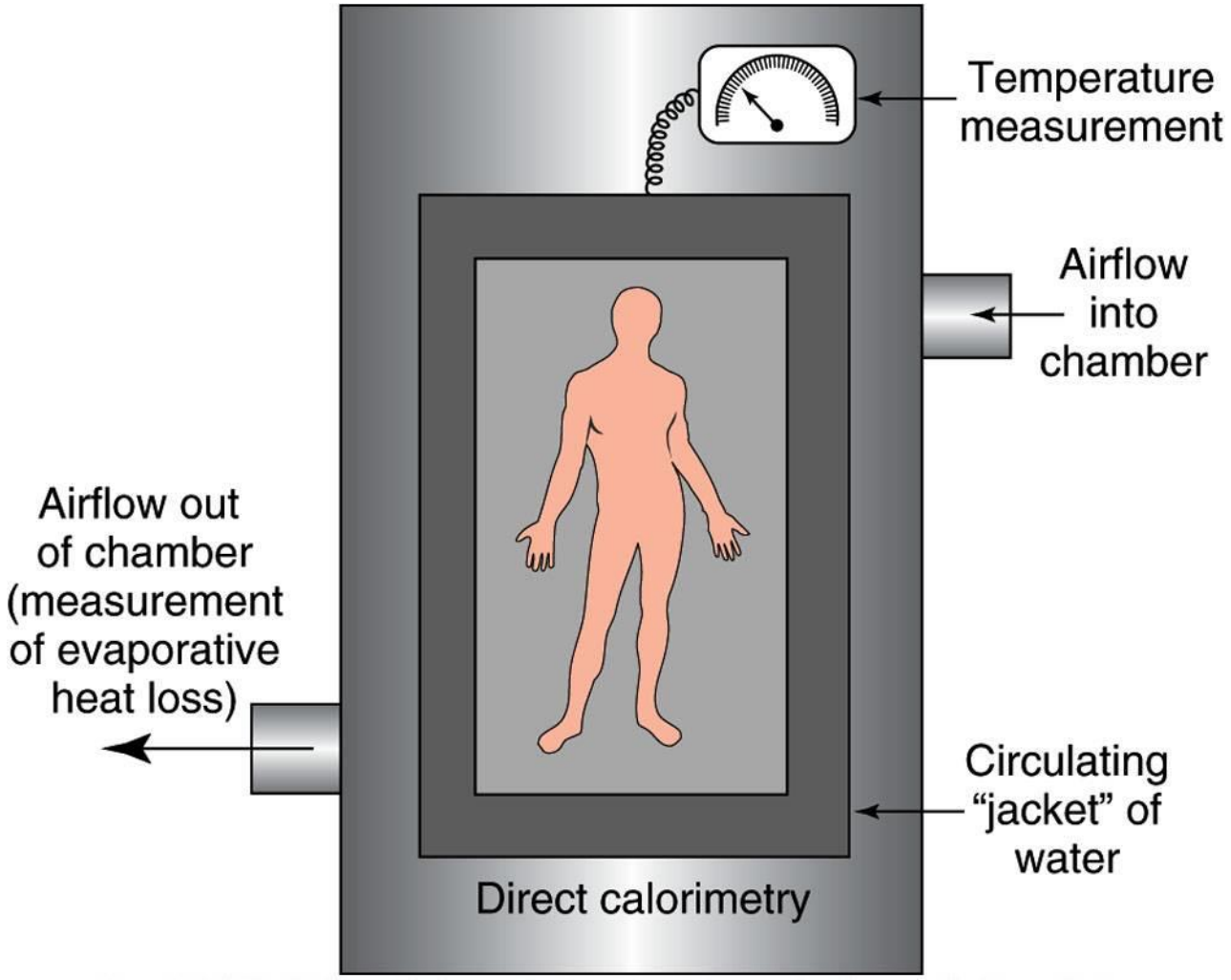
(d)

How Do We Measure Energy Expenditure?

- **Direct calorimetry** measures energy expenditure by assessing body heat loss within a metabolic chamber.

- **Indirect calorimetry** estimates energy expenditure by measuring oxygen consumed and carbon dioxide produced with a metabolic cart.

Diagram of a Simple Calorimeter



Open-Circuit Indirect Calorimetry

When concerned with exercise, the predominant application of indirect calorimetry is for the measurement of **oxygen consumption** (VO2). The measure is used to assess the *metabolic intensity* of the exercise.

Indirect Gas Analysis Calorimetry

Fundamental Principles

1. That the volume of oxygen consumed (**VO2**) by the body is equal to the difference between the volumes of inspired and expired oxygen.

2. That the volume of carbon dioxide produced (**VCO2**) by the body is equal to the difference between the volumes of expired and inspired carbon dioxide.

Indirect Calorimetry

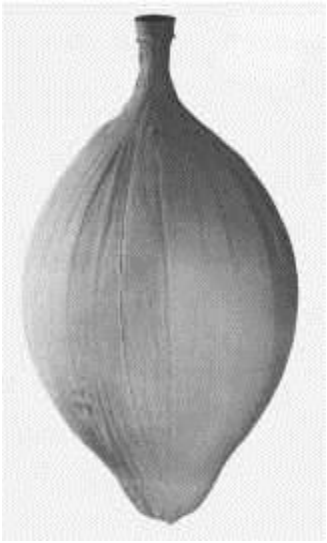


Abb. 2.5-92. Gasstoffwechseluntersuchung während des Radfahrens unter Benutzung des Douglas-Sackes, durchgeführt von Kost 1928 in Berlin (nach Herbst, 1928).

VO_2 ($L \bullet min^{-1}$)

- Example:
  - 60 kg subject
  - Ventilation (STPD) = 60 $L \bullet min^{-1}$
  - Inspired O_2 = 20.93%
  - Expired O_2 = 16.93%

60 $L \bullet min^{-1}$ x (20.93% – 16.93%) = 2.4 $L \bullet min^{-1}$

Estimation of Fuel Utilization During Exercise

- Respiratory exchange ratio (RER or R)

$$R = \frac{VCO_2}{VO_2}$$

- R for fat (palmitic acid)

$$C_{16}H_{32}O_2 + 23\ O_2 \rightarrow 16\ CO_2 + 16\ H_2O$$

$$R = \frac{VCO_2}{VO_2} = \frac{16\ CO_2}{23\ O_2} = 0.70$$

- R for carbohydrate (glucose)

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

$$R = \frac{VCO_2}{VO_2} = \frac{6\ CO_2}{6\ O_2} = 1.00$$

RQ vs RER

- The *RQ and RER are the same measurement*, yet as the components of the measure are *obtained differently* (cell respiration vs exhaled air from the lung), under certain circumstances the *values can differ*.

  The maximal range of RQ is from 0.7 to 1.0

  The range of RER may vary from <0.7 to >1.2

Calculating Energy Expenditure

To calculate energy expenditure most accurately, you need to know the following;

1. VO2
2. RER
3. RER caloric equivalent
4. Exercise duration

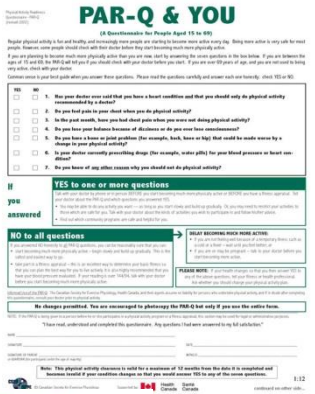
Kcal = VO2 (L/min) x RER caloric equivalent x time (min)

Limitations of Indirect Calorimetry

- 1. Whole body - the sum of all active tissue in body, not just contracting skeletal muscle.
- 2. Needs sophisticated and expensive equipment.
- 3. Highly sensitive to measurement error.
- 4. Can only be accurately used for metabolic intensities, economy, efficiency, and energy expenditure *during steady state exercise*.
- 5. Requires subjects to wear apparatus on face or in mouth.

Additional Methods to Consider When Evaluating Energy Expenditure or Physical Activity

- Pedometers
- Self Report
- Heart Rate plus Motion
- Heart Rate Monitors
- Doubly Labeled Water
- Accelerometers



Methodological Concepts

Validation standard

A predetermined criterion against which the accuracy of the test instrument is measured. The standard is presumably less variable than the test method.

Variety of validation standards in physical activity

Physical Activity Assessment

- *Self-report*

- Diaries, interviews and self-administered surveys
- Varying lengths of recall, all assumed to be indicators of “usual” physical activity
- Varying quality of summary indices
- May not be transferrable among populations
- Most often used in population-based research
- Highly variable and questionable accuracy

Physical Activity Assessment

- *Doubly-labeled water ($750-$1,500 per person)*

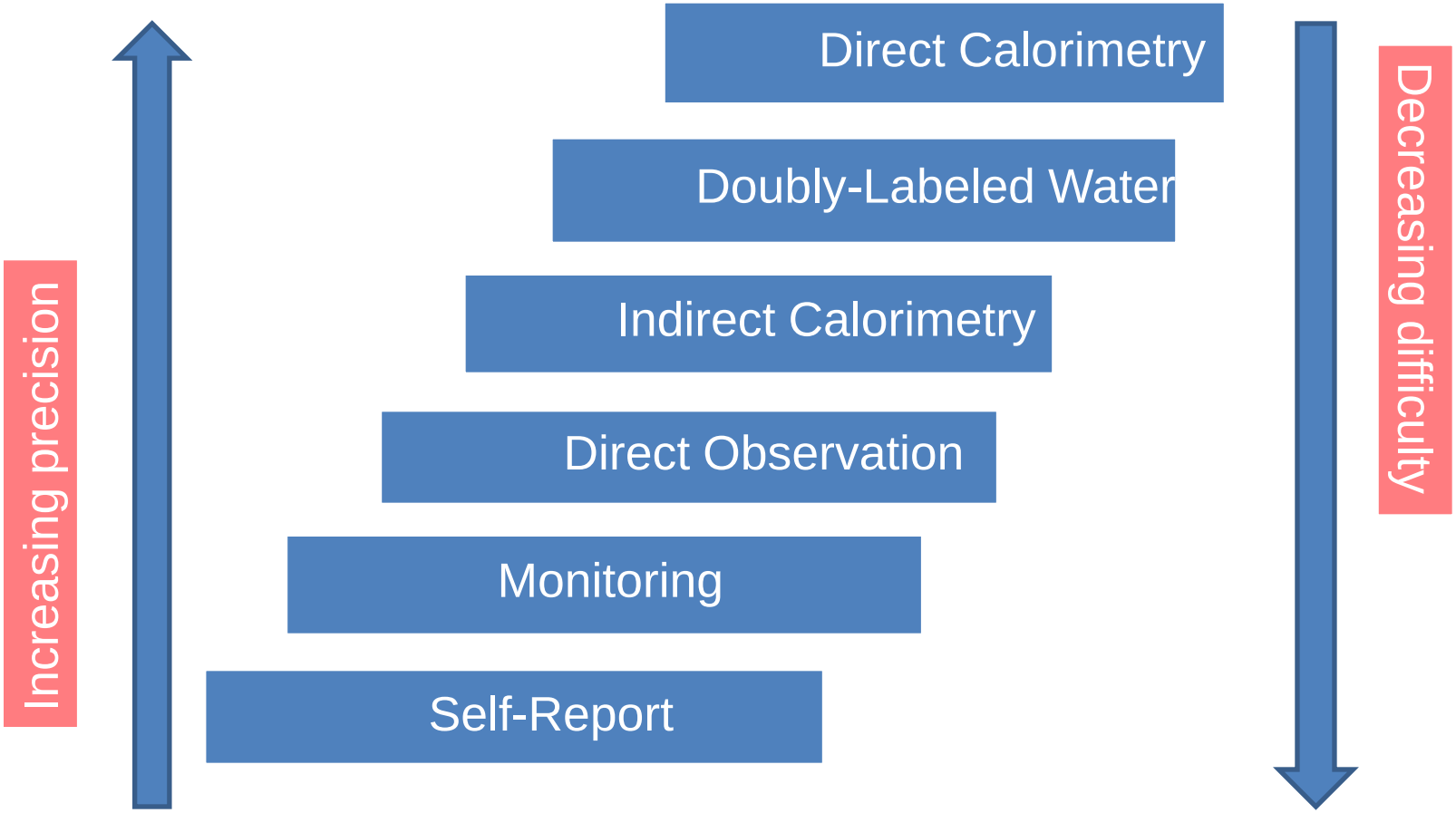
- Based on ingestion of water with radioisotopic labeled hydrogen and oxygen atoms
- Energy expenditure measured by measuring unmetabolized portion of water over period of time
- Highly accurate
- Impractical for large studies

Physical Activity Assessment

- *Monitoring*

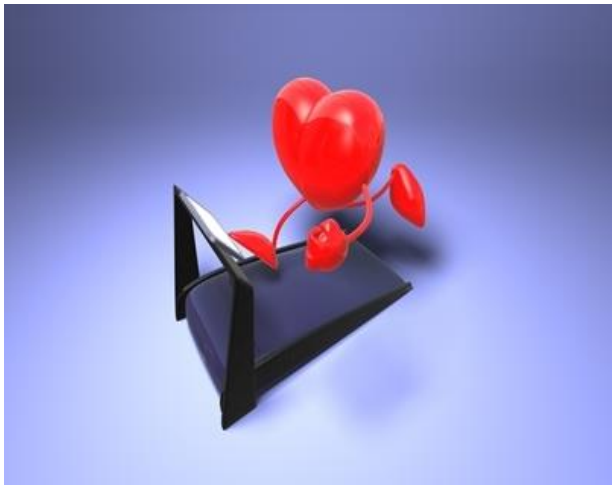
- Heart rate monitors, motion sensors, pedometers, accelerometers
- Assume mathematical relation between measurements and physical activity
- Many can measure quantity and intensity of physical activity
- Recent advances make devices more practical

Physical activity assessment cascade



In Summary

- Measurement of energy expenditure at rest or during exercise is possible using either direct or indirect calorimetry.
- Direct calorimetry uses the measurement of heat production as an indication of metabolic rate.
- Indirect calorimetry estimates metabolic rate via the measurement of oxygen consumption.



Questions??