ACSM
Metabolic Calculations

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Purpose of Calculations

- Under steady-state conditions, volume of oxygen (VO_2) provides a measure of the energy cost of exercise
- The rate of oxygen (O_2) uptake during maximal exercise indicates the capacity for O_2 transport and utilization
- Serves as the criterion of cardiorespiratory fitness
- Provides general info about the fuels being utilized for exercise (RER)

Ways to Express VO_2

- Absolute- Liters per minute ($L \bullet min^{-1}$)
  - Used to convert consumption to a rate of energy expenditure
- Relative- ml per kg body weight per min ($ml \bullet kg^{-1} \bullet min^{-1}$)
  - Used to compare VO_2 among varying body sizes
- Gross- Total consumption rate under any circumstances, either in absolute or relative
- Net- Consumption rate above resting oxygen uptake

RER and RQ

- RER-Respiratory Exchange Ratio
  - Ventilatory measurement
  - Reflects gas exchange between lungs and pulmonary blood
  - 0.7 = Fat
  - 1.0 = CHO
  - Exceeds 1.0 during heavy exercise
- RQ-Respiratory Quotient
  - Cellular Respiration
  - Equivalent to RER only under resting conditions
  - Can never exceed 1.0
  - RQ is used to estimate energy expenditure, however, when RQ is not available, assume 5 kcal $\bullet L^{-1}$

Estimation of Energy Expenditure

- When you cannot measure Vo_2 directly, estimations can still be made during steady-state exercise
- Equations are based on relating mechanical work rate to their metabolic equivalents
- Equations are appropriate for general clinical and lab usage

Estimation of Energy Expenditure

- Equations can be used for:
  - Estimating or predicting energy expenditure (Weight loss)
  - Designing exercise programming to determine the exercise intensity associated with a desired level of energy expenditure

Cautionary Notes

- The intersubject variability in Vo_2 may have a SEE as high as 7%
- Appropriate for **steady-state submax aerobic exercise**
- Any variable that changes the metabolic efficiency results in loss of accuracy
- Assumes that machines are calibrated and used properly

Despite these caveats, metabolic equations provide a valuable tool for exercise professionals

Conversion Factors

- 1Liter= 1000 ml
- 1kg= 2.2 pounds (lbs)
- 1 Mi-h^{-1} = 26.8meter/minute
- 1 Mi-h^{-1} =1.609 Km-h-^{1}
- 1lb of fat= 3500k-cal
- 1 MET= 3.5ml·kg-^{1}·min-^{1}
- 1 Watt= 6 kg·m-^{1}min-^{1}
- 1L O_2= 5 k-cal
- 1 in= 0.0254 meters

MEMORIZE

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Walking (1.9 → 3.7 $Mi\text{-}h^{-1}$) (3.05 → 5.95 $Km\text{-}h^{-1}$)

- VO_2 $ml \cdot kg^{-1} \cdot min^{-1}$ = (0.1•S) + (1.8 •S •G) + 3.5

  Horiz. Vert. Rest

Speed= speed in meters/min (convert if needed)

Grade= grade in decimal form

(5% is 0.05), if 0% grade, no vert.

R= resting component

All answers are reported in $ml \cdot kg^{-1} \cdot min^{-1}$

Walking

$VO_2\ ml \cdot kg^{-1} \cdot min^{-1} = (0.1 \bullet S) + (1.8 \bullet S \bullet G) + 3.5$

Horiz. Vert. Rest

- Calculate Vo_2 in ml/kg/min
  - 2.0 $mi\text{-}h^{-1}$ (2.0 x 1.609=3.22 $Km\text{-}h^{-1}$)
  - 10% grade
  - 2.0 X 26.8 = 53.6 m-min
  - 53.6 X .1 = 5.36 $ml \cdot kg^{-1} \cdot min^{-1}$ (H)
  - 1.8 X 53.6 X .10 = 9.65 $ml \cdot kg^{-1} \cdot min^{-1}$ (V)
  - 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (R)
  - 5.36 + 9.65 + 3.5 = **18.5** $ml \cdot kg^{-1} \cdot min^{-1}$

TABLE D-3. Approximate Energy Requirements in METs for Horizontal and Grade Walking

	$mi \cdot h^{-1}$	1.7	2.0	2.5	3.0	3.4	3.75
% Grade	$m \cdot min^{-1}$	45.6	53.6	67.0	80.4	91.2	100.5
0		2.3	2.5	2.9	3.3	3.6	3.9
2.5		2.9	3.2	3.8	4.3	4.8	5.2
5.0		3.5	3.9	4.6	5.4	5.9	6.5
7.5		4.1	4.6	5.5	6.4	7.1	7.8
10.0		4.6	5.3	6.3	7.4	8.3	9.1
12.5		5.2	6.0	7.2	8.5	9.5	10.4
15.0		5.8	6.6	8.1	9.5	10.6	11.7
17.5		6.4	7.3	8.9	10.5	11.8	12.9
20.0		7.0	8.0	9.8	11.6	13.0	14.2
22.5		7.6	8.7	10.6	12.6	14.2	15.5
25.0		8.2	9.4	11.5	13.6	15.3	16.8

Running (>5.0mph)

- VO_2 $ml \cdot kg^{-1} \cdot min^{-1}$ = $(0.2 \bullet S) + (0.9 \bullet S \bullet G) + 3.5$

  Horizontal Vertical Rest

- All variables are the same for walking

Running

VO_2 $ml \cdot kg^{-1} \cdot min^{-1} = (0.2 \bullet S) + (0.9 \bullet S \bullet G) + 3.5$

Horizontal Vertical Rest

Example

Calculate Vo_2 in $ml \cdot kg^{-1} \cdot min^{-1}$

6.0 $mi\text{-}h^{-1}$ (9.65 $Km\text{-}h^{-1}$)

- 10% grade

- 6.0 X 26.8 = 160.8 m-min
- 160.8 X .2 = 32.16 ml/kg/min (H)
- 0.9 X 160.8 X .10 = 14.47 $ml \cdot kg^{-1} \cdot min^{-1}$ (V)
- 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$(R)
- 32.16 + 14.47 + 3.5 = **50.13** $ml \cdot kg^{-1} \cdot min^{-1}$

TABLE D-4. Approximate Energy Requirements in METs for Horizontal and Uphill Jogging/Running

% Grade	mi·h⁻¹ / m·min⁻¹	5 / 134	6 / 161	7 / 188	7.5 / 201	8 / 214	9 / 241	10 / 268
0		8.6	10.2	11.7	12.5	13.3	14.8	16.3
2.5		9.5	11.2	12.9	13.8	14.7	16.3	18.0
5.0		10.3	12.3	14.1	15.1	16.1	17.9	19.7
7.5		11.2	13.3	15.3	16.4	17.4	19.4	
10.0		12.0	14.3	16.5	17.7	18.8		
12.5		12.9	15.4	17.7	19.0			
15.0		13.8	16.4	18.9				

Leg Ergometry

- $VO2 = 1.8$ (Work rate/Mass in kg) + 7
- M= mass of subject NOT resistance
- Work rate is is reported in watts, convert when necessary
  - 1 W= 6 $kg \cdot meters^{-1} \cdot min^{-1}$
  - Power =R •D •f
    - R= resistance in kg
    - D= distance of the fly wheel
      - 6m for Monark
      - 3m for Tunturi
    - F= frequency in rpm
- NOTE: VO_2 is reported as $ml \cdot kg^{-1} \cdot min^{-1}$

R X D X F = Power: VO2= 1.8 (Work rate/Mass in kg)+3.5 $ml \cdot kg^{-1} \cdot min^{-1}$

+ 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$

Example

R=2 kg.meters D= 6 meters (Monark) F= 50 reps

(Power)= 2 X 6 X 50= 600 $kg \cdot m \cdot min^{-1}$

Mass= 70kg

Work rate= 600 $kg.m.min^{-1}$

1.8 X(600/70)+7= 22.42 $ml \cdot kg^{-1} \cdot min^{-1}$

Convert to METs- 22.42/3.5= 6.40 METs

TABLE D-5. Approximate Energy Expenditure in METs During Leg Cycle Ergometry

Body Wt.		Power Output (kg·m·min^{-1} and Watts)						
		300	450	600	750	900	1050	1200 (*kg·m·min^{-1}*)
kg	lb	50	75	100	125	150	175	200 (*Watts*)
50	110	5.1	6.6	8.2	9.7	11.3	12.8	14.3
60	132	4.6	5.9	7.1	8.4	9.7	11.0	12.3
70	154	4.2	5.3	6.4	7.5	8.6	9.7	10.8
80	176	3.9	4.9	5.9	6.8	7.8	8.8	9.7
90	198	3.7	4.6	5.4	6.3	7.1	8.0	8.9
100	220	3.5	4.3	5.1	5.9	6.6	7.4	8.2

Stepping Ergometry

- $VO2 = (0.2 \bullet f) + (1.33 \bullet 1.8 \bullet f \bullet h) + 3.5\ ml \cdot kg^{-1} \cdot min^{-1}$
  - F=stepping rate
  - H=height of step in meters
- NOTE: VO_2 is reported as $ml \cdot kg^{-1} \cdot min^{-1}$

Stepping Ergometry

$VO2\ ml \cdot kg^{-1} \cdot min^{-1} = (0.2 \bullet f) + (1.33 \bullet 1.8 \bullet f \bullet h) + 3.5\ ml \cdot kg^{-1} \cdot min^{-1}$

Example

- Frequency =20 steps/min
- Height = .254 meters (10 inches)

Step 1 (.2 X 20)= 4
Step 2 (1.33 X 1.8 X 20 X .254)= 12.16
Step 3 (Add resting value-3.5)
Step 4 – (sum) = 19.66 $ml \cdot kg^{-1} \cdot min^{-1}$
METs= 5.61

Questions