Nomogram to calculate oxygen consumption

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SUMMARY A nomogram has been devised for the rapid derivation of the oxygen consumption from the expired minute volume and the fractional concentrations of expired CO₂ and O₂.

The oxygen consumption is a prerequisite for determining the cardiac output by the Fick method. It is obtained after breathing room air for a known period of time, by measuring the minute volume, and the fractional concentrations of carbon dioxide, and oxygen of the expired air.

As the calculation of the oxygen consumption is a tedious one to perform, a nomogram has been devised to help. The nomogram may also be useful in cross-checking rapidly a large number of calculations.

Theory

Oxygen consumption = volume of inspired - volume of expired oxygen, or

\[ \dot{V}_{O_2} = \dot{V}_I \times F_{I\,O_2} - \dot{V}_E \times F_{E\,O_2} \quad \ldots \ldots (1) \]

where

\[ \dot{V}_{O_2} = \text{oxygen consumption (l/min)} \]
\[ \dot{V}_I = \text{inspired volume of air (l/min)} \]
\[ F_{I\,O_2} = \text{fractional concentration of inspired O}_2 = 0.2093 \]
\[ \dot{V}_E = \text{expiratory minute volume of air (l/min) measured at ATPS} \]
\[ F_{E\,O_2} = \text{fractional concentration of expired O}_2 \]

Since, in a steady state the body neither produces nor consumes nitrogen, inspired volume of nitrogen = expired volume of nitrogen, or

\[ \dot{V}_I \times F_{I\,N_2} = \dot{V}_E \times F_{E\,N_2} \quad \ldots \ldots (2) \]

Table Conversion factors to reduce saturated gas volume at ambient temperature and pressure to STPD

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Fig. 1 Nomogram for estimation of oxygen consumption. CO₂, fractional concentration of expired CO₂; O₂, fractional concentration of expired O₂; Vₑ, expired minute volume l/min ATPS; Vₒ₂, computed O₂ consumption l/min; Vₒ₂ corr, corrected O₂ consumption l/min; A, adjustment factor.

A straight line joining CO₂ and O₂ intersects the unscaled line x. A second straight line drawn between the point on x and Vₑ is extended to Vₒ₂. A third straight line is then drawn between the point on Vₒ₂ and A to intersect Vₒ₂ (corr) to obtain corrected oxygen consumption.

where the fractional concentration of inspired nitrogen (Fᵢ N₂) = 1 - Fᵢ O₂ - Fᵢ CO₂ = 1 - 0.2093 - 0 or 0.7907, as fractional concentration of inspired carbon dioxide (Fᵢ CO₂) is considered to be negligible.

Fₑ N₂ is the fractional concentration of expired nitrogen = 1 - Fₑ CO₂ - Fₑ O₂, where Fₑ CO₂ is the fractional concentration of expired carbon dioxide; or

\[ \dot{V}_I = \frac{\dot{V}_ₑ (1 - Fₑ CO₂ - Fₑ O₂)}{0.7907} \quad \text{...(3)} \]

Substituting for \( \dot{V}_I \) in equation (1) from equation (3) we get:

\[ \dot{V}_ₒ₂ = \left[ \frac{\dot{V}_ₑ (1 - Fₑ CO₂ - Fₑ O₂)}{0.7907} \times Fᵢ O₂ \right] - \left[ \dot{V}_ₑ \times Fₑ O₂ \right] \]

as Fᵢ O₂ = 0.2093 we get on simplification:

\[ \dot{V}_ₒ₂ = (0.265 \times \dot{V}_ₑ) - (1.265 \times \dot{V}_ₑ \times Fₑ O₂) - (0.265 \times \dot{V}_ₑ \times Fₑ CO₂) \quad \text{............(4)} \]
The expired minute volume \((V_E)\) is adjusted to standard temperature and atmospheric pressure, i.e. 0°C and 760 mmHg dry (STPD) by the relation:

\[
V_{STPD} = A \times V_E \quad \ldots (5)
\]

where \(A\) is an adjustment factor which can be obtained from the Documenta Geigy Scientific Tables (1962), a modification of which is depicted in the Table.

For STPD conditions:

\[
A = \frac{273}{273 + T} \times \frac{P - P_{H_2O}}{760} \quad \ldots (6)
\]

where \(T\) = ambient temperature (°C)

\(P\) = ambient barometric pressure (mmHg)

\(P_{H_2O}\) = water vapour pressure at temperature, \(T\) (mmHg).

From (4) and (5) we have corrected \(\dot{V}O_2\)

\[
\dot{V}O_2 = A \left[ (0.265 \times V_E) - (1.265 \times V_E \times F_E \co_2) - (0.265 \times V_E \times F_E \o_2) \right] \quad \ldots (7)
\]

Equation (7) was used to calculate the oxygen consumption depicted in the nomogram in Fig. 1.

### Application

With a sharp point of a calliper, mark the fractional concentration of expired \(CO_2\) on the line \(CO_2\) and fractional concentration of expired \(O_2\) on line \(O_2\). Join the two points with a straight line to cross the unscaled line \(x\). By joining the point so obtained on line \(x\) and the expired volume \((V_E)\) on line \(V_E\) a straight line may be extended to meet line \(\dot{V}O_2\) yielding the oxygen consumption (l/min).

The corrected oxygen consumption \((\dot{V}O_2\ corr)\) may then be obtained by joining the point on line \(\dot{V}O_2\) to the adjustment factor \(A\) on line \(A\) with a straight line and extending it to meet the line \(\dot{V}O_2\ corr\) (example A). If the oxygen consumption is expected to exceed 0.8 l/min, use half the value of \(V_E\) and double the resultant oxygen consumption (example B). In strenuous exercise it may be necessary to use 1/10th the value of \(V_E\) and multiply the resultant \(O_2\) consumption by 10.

### Examples (Fig. 2)

(A) \(F_E \co_2 = 0.05, F_E \o_2 = 0.18, V_E = 5\ l/min, A = 0.9\)

Then \(\dot{V}O_2 = 0.120\ l/min, \dot{V}O_2\ corr = 0.108\ l/min\) by nomography and calculation.

![Fig. 2 Illustrated use of nomogram using two examples as described in the text (A and B).](http://heart.bmj.com/)
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(B) \( F_{E\ CO_2} = 0.08, \ F_{E\ O_2} = 0.14, \ \dot{V}_E = 18 \text{ l/min}, \ A = 0.7 \)

Then \( \dot{V}O_2 \text{ corr} = 0.420 \text{ l/min} \) from nomogram using \( \dot{V}_E = 9 \text{ l/min}, \ F_{E\ CO_2} = 0.08, \ F_{E\ O_2} = 0.14, \ A = 0.7 \).

Hence corrected \( \dot{V}O_2 = 2 \times 0.420 \) or 0.840 l/min when \( \dot{V}_E = 18 \).

Reference


Requests for reprints to Dr F. Saksena, Adult Cardiology, Cook County Hospital, 1825 West Harrison Street, Chicago, Illinois 60612, USA.
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