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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 CO_2 and O_2.

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

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$$\dot{V}O_2 = \dot{V}_I \times F_{I\,O_2} - \dot{V}_E \times F_{E\,O_2} \ldots\ldots (1)$$

where $\dot{V}O_2$ = oxygen consumption (l/min)

$\dot{V}_I$ = inspired volume of air (l/min)

$F_{I\,O_2}$ = fractional concentration of inspired O_2 = 0·2093

$\dot{V}_E$ = expiratory minute volume of air (l/min) measured at ATPS

$F_{E\,O_2}$ = 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

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

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

T °C \ *P mmHg*	*700*	*705*	*710*	*715*	*720*	*725*	*730*	*735*	*740*	*745*	*750*
15	0·857	0·863	0·870	0·876	0·882	0·888	0·895	0·900	0·907	0·913	0·919
16	0·853	0·859	0·866	0·872	0·880	0·884	0·890	0·897	0·903	0·909	0·915
17	0·849	0·855	0·861	0·868	0·874	0·880	0·886	0·892	0·899	0·905	0·911
18	0·845	0·851	0·857	0·863	0·870	0·876	0·882	0·888	0·894	0·900	0·907
19	0·841	0·847	0·853	0·859	0·865	0·872	0·877	0·884	0·890	0·896	0·902
20	0·837	0·843	0·849	0·855	0·861	0·867	0·873	0·880	0·886	0·891	0·900
21	0·832	0·839	0·845	0·851	0·857	0·863	0·869	0·875	0·881	0·887	0·893
22	0·828	0·834	0·840	0·846	0·853	0·859	0·865	0·871	0·877	0·883	0·889
23	0·824	0·830	0·836	0·842	0·848	0·854	0·860	0·866	0·872	0·878	0·885
24	0·819	0·826	0·832	0·838	0·844	0·850	0·856	0·862	0·868	0·874	0·880
25	0·815	0·821	0·827	0·833	0·839	0·845	0·851	0·857	0·863	0·869	0·875
26	0·811	0·817	0·823	0·829	0·835	0·841	0·847	0·853	0·859	0·865	0·871
27	0·806	0·812	0·818	0·824	0·830	0·836	0·842	0·848	0·854	0·860	0·866
28	0·801	0·807	0·813	0·819	0·825	0·831	0·837	0·843	0·849	0·855	0·861

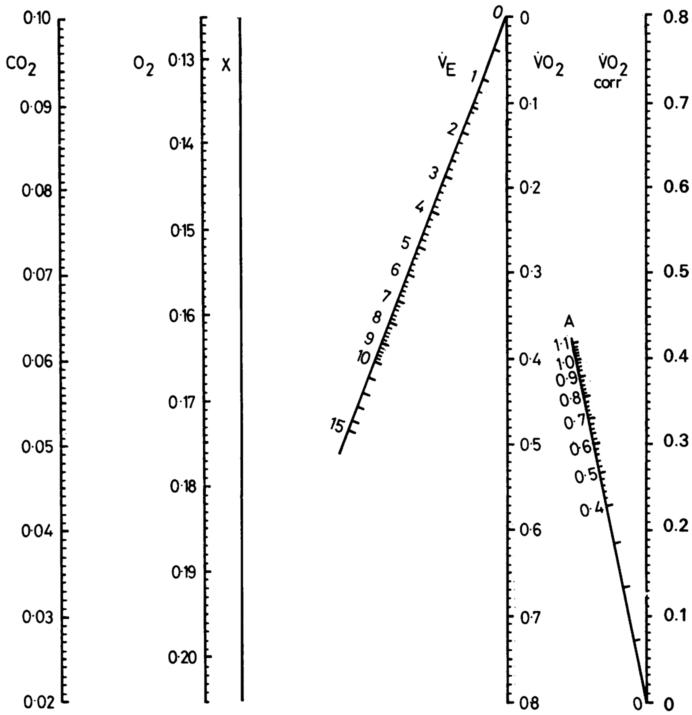

Fig. 1 *Nomogram for estimation of oxygen consumption. CO_2, fractional concentration of expired CO_2; O_2, fractional concentration of expired O_2; V_E, expired minute volume l/min ATPS; V_{O_2}, computed O_2 consumption l/min; V_{O_2} corr, corrected O_2 consumption l/min; A, adjustment factor.*
A straight line joining CO_2 and O_2 intersects the unscaled line x. A second straight line drawn between the point on x and V_E is extended to V_{O_2}. A third straight line is then drawn between the point on V_{O_2} and A to intersect V_{O_2} (corr) to obtain corrected oxygen consumption.

755	*760*	*765*	*770*	*775*	*780*
0·926	0·932	0·938	0·944	0·951	0·957
0·921	0·928	0·934	0·940	0·946	0·952
0·917	0·923	0·930	0·936	0·942	0·948
0·913	0·919	0·925	0·931	0·937	0·944
0·908	0·915	0·921	0·927	0·933	0·939
0·904	0·910	0·916	0·922	0·929	0·935
0·900	0·906	0·912	0·918	0·924	0·930
0·895	0·901	0·907	0·913	0·919	0·926
0·891	0·897	0·903	0·909	0·915	0·921
0·886	0·892	0·898	0·904	0·910	0·916
0·881	0·887	0·893	0·899	0·905	0·911
0·877	0·883	0·889	0·895	0·901	0·907
0·872	0·878	0·884	0·890	0·896	0·902
0·867	0·873	0·879	0·885	0·891	0·897

where the fractional concentration of inspired nitrogen ($F_{I\,N_2}$) $= 1 - F_{I\,O_2} - F_{I\,CO_2} =$ $1 - 0{\cdot}2093 - 0$ or 0·7907, as fractional concentration of inspired carbon dioxide ($F_{I\,CO_2}$) is considered to be negligible. $F_{E\,N_2}$ is the fractional concentration of expired nitrogen $= 1 - F_{E\,CO_2} - F_{E\,O_2}$, where $F_{E\,CO_2}$ is the fractional concentration of expired carbon dioxide; or

$$\dot{V}_I = \frac{\dot{V}_E\,(1 - F_{E\,CO_2} - F_{E\,O_2})}{0{\cdot}7907} \quad \ldots.(3)$$

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

$$\dot{V}O_2 = \left[\frac{\dot{V}_E\,(1 - F_{E\,CO_2} - F_{E\,O_2})}{0{\cdot}7907} \times F_{I\,O_2}\right] - \left[\dot{V}_E \times F_{E\,O_2}\right]$$

as $F_{I\,O_2} = 0{\cdot}2093$ we get on simplification:

$$\dot{V}O_2 = (0{\cdot}265 \times \dot{V}_E) - (1{\cdot}265 \times \dot{V}_E \times F_{E\,O_2}) - (0{\cdot}265 \times \dot{V}_E \times F_{E\,CO_2}) \quad \ldots\ldots\ldots\ldots(4)$$

The expired minute volume ($\dot{V}_E$) is adjusted to standard temperature and atmospheric pressure, i.e. 0°C and 760 mmHg dry (STPD) by the relation.

$$\dot{V}_{STPD} = A \times \dot{V}_E \qquad \ldots(5)$$

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:

$$A = \frac{273}{273 + T} \times \frac{P - P_{H_2O}}{760} \qquad \ldots(6)$$

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 $\dot{V}O_2$

$$= A\,[(0{\cdot}265 \times \dot{V}_E) - (1{\cdot}265 \times \dot{V}_E \times F_{E\,O_2}) - (0{\cdot}265 \times \dot{V}_E \times F_{E\,CO_2})] \qquad \ldots(7)$$

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 ($\dot{V}_E$) on line $\dot{V}_E$ 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 $\dot{V}_E$ and double the resultant oxygen consumption (example B). In strenuous exercise it may be necessary to use 1/10th the value of $\dot{V}_E$ and multiply the resultant O_2 consumption by 10.

Examples (Fig. 2)

(A) $F_{E\,CO_2} = 0{\cdot}05$, $F_{E\,O_2} = 0{\cdot}18$, $\dot{V}_E = 5$ l/min, $A = 0{\cdot}9$

Then $\dot{V}O_2 = 0{\cdot}120$ l/min, $\dot{V}O_2$ corr $= 0{\cdot}108$ l/min by nomography and calculation.

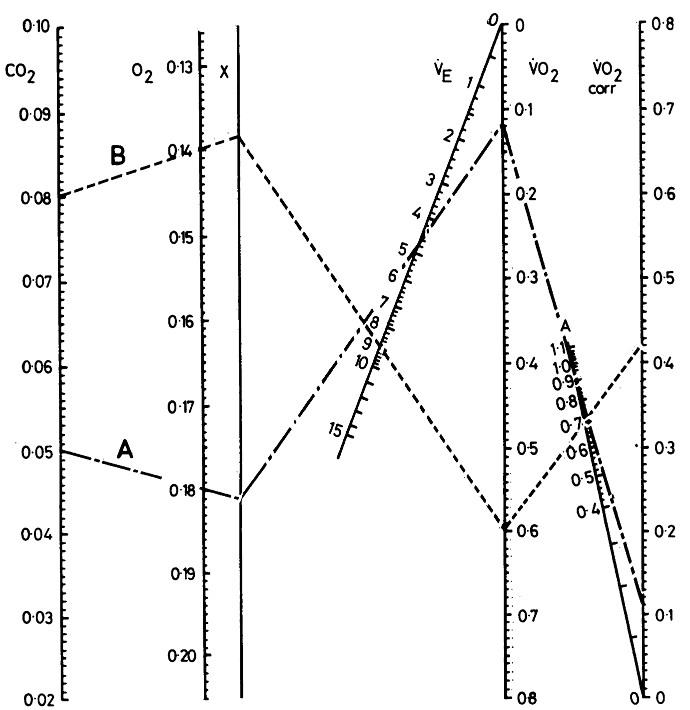

Fig. 2 *Illustrated use of nomogram using two examples as described in the text (A and B).*

(B) $F_{E\,CO_2} = 0{\cdot}08$, $F_{E\,O_2} = 0{\cdot}14$, $\dot{V}_E = 18$ l/min, $A = 0{\cdot}7$
Then $\dot{V}O_2$ corr $= 0{\cdot}420$ l/min from nomogram using $\dot{V}_E = 9$ l/min, $F_{E\,CO_2} = 0{\cdot}08$, $F_{E\,O_2} = 0{\cdot}14$, $A = 0{\cdot}7$.

Hence corrected $\dot{V}O_2 = 2 \times 0{\cdot}420$ or $0{\cdot}840$ l/min when $\dot{V}_E = 18$.

Reference

Documenta Geigy Scientific Tables (1962). 6th ed., pp. 300–309 ed K. Diem. Geigy Pharmaceuticals, Ardsley, New York.

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