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Carbon dioxide generation rates for building occupants

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Factors that influencing respiratory quotient

	Effect on *RQ* (↑ increase; ↓ decrease)	**Reference**
Dietary composition (carbohydrate vs. fat)	↑ (carbohydrate) ↓ (fat)	(Toubro et al., 1998b; Schrauwen et al., 1997)
Increased glycogen stores - carbs	↑	(Acheson et al., 1988)
Decreased glycogen stores	↓	(Acheson et al., 1988)
Positive energy balance – eat more than burn	↑	(Saltzman and Roberts, 1996)
Negative energy balance	↓	(Saltzman and Roberts, 1996)
Increased total fat mass (obesity)	↓	(Schutz et al., 1992; Schutz, 2004)
Growth	↓	(Stettler et al., 1992)
Pregnancy	↔ ↑ (3rd trimester)	(Melzer et al., 2014)
Gluconeogenesis - making gluc out of non gluc/protein, not common unless on very low carb	↓	(Schutz and Ravussin, 1980)
De Novo lipogenesis – making fat out non-fat, storage	↑	(Schutz, 2004)
Chronic training	↓	(Barwell et al., 2009)
Genetic factors	↑ ↓	(Jacobson et al., 2006)
Type 1 diabetes	↓	(Wohl et al., 2004)

Exogenous and endogenous factors influencing the *RQ* in acute or chronic conditions.

Adjustments for air density

As noted in the body of the paper, CO_2 generation rates have historically been presented in volumetric units, e.g. L/s or cfm, generally without discussing the effects of air pressure and temperature. In order to be clear and rigorous, the CO_2 generation rates presented in this paper are based on an air pressure of 101.325 kPa and an air temperature of 273.15 K. Under these conditions, a CO_2 generation rate of 1 L/s equals 0.0446 moles/s or 1.965 g/s. If the volumetric generation rates in this paper are to be used under another set of conditions, the rate must be adjusted for air density using the ideal gas law, as described below. Generations rates in units of moles/s or g/s do not need to be adjusted, which is an advantage to their use.

If a CO_2 generation rate in volumetric units G_v, calculated using the equations in this paper, is to be used at a set of conditions other than 101.325 kPa and 273.15 K, the following conversion should be employed:

Convert G_v (L/s) to mole or mass concentrations, G_{mole} (moles/s) or G_{mass} (g/s):

$$G_{mole} = 0.0446\ G_v$$

$$G_{mass} = 1.965\ G_v$$

Calculate $G_{v,PT}$, the CO_2 generation rate at another value of air pressure (P in kPa) and temperature (T in K)

$$G_{v,PT} = 8.314\ G_{mole}\ \mathrm{T/P}$$

In addition, the conversion between volumetric concentration units (e.g. ppm) to mass units (e.g., $\mu g/m^3$) also depends on air pressure and temperature. This conversion is based on the ideal gas law and is conveniently presented in ASHRAE Guideline 28 (ASHRAE 2016). That document presents the following two equations for converting from volume or mole fraction (ppm) C_i to mass concentrations D_i ($\mu g/m^3$) for species i:

$$C_i = \left[{}^{D_i}/_{M_i}\right] / \left[{}^{1000P}/_{(RT)}\right]$$

and

$$D_i = C_i M_i \left[{}^{1000P}/_{(RT)}\right]$$

where M_i is the molecular weight of contaminant i in kg/kmol, P is the air pressure in kPa, R is the universal gas constant (8314 J/kmol•K) and T is the air temperature in K. For convenience, the ASHRAE guideline has a table of values for $1000P/RT$ as a function of altitude (from sea level to about 3000 m in roughly 300 m increments) at a temperature of 298.15 K.

Derivation of Equations 8 through 11

The energy use E associated with a specific activity, characterized by the dimensionless quantity M, is given by:

$$E = M \text{ x } BMR$$

where BMR is the basal metabolic rate in units of MJ/day.

Convert E to kcal/day

$$E = M \text{ x } BMR \text{ x } (238.8 \; kcal/MJ)$$

Calculate the oxygen consumption V_{O2} in L/s associated with E based on the value of 0.206 L of O_2 consumed per kcal of energy, which corresponds to an air pressure of 101.325 kPa and an air temperature of 273.15 K (as described and referenced in body of paper).

$$\begin{aligned} V_{O2} &= E \text{ x } (0.206 \; L \; O_2 \, /kcal \; of \; energy) \text{ x } (1 \; day/ \; 86400 \; s) \\ &= M \text{ x } BMR \text{ x } ((238.8 \text{ x } 0.206)/86400) \end{aligned}$$

$$= M \times BMR \times 0.000569$$

The CO_2 generation rate in V_{CO2} in L/s is expressed as:

$$V_{CO2} = RQ \times V_{O2}$$

$$= RQ\ BMR\ M\ 0.000569 \text{ (Equation 8)}$$

where RQ is the respiratory quotient. Assuming RQ equals 0.85, yields:

$$V_{CO2} = BMR\ M\ 0.000484 \text{ (Equation 9)}$$

At other temperature and pressure conditions, the volume of O_2 consumed per kcal of energy expended must be adjusted for air density. Based on the ideal gas law, the volume V_2 at some pressure P_2 and temperature T_2 for the same amount (moles) of gas is related to the volume V_1 at P_1 and T_1 as follows:

$$V_2/V_1 = (T_2/P_2) / (T_1/P_1)$$

Using 273.15 K and 101.325 kPa for T_1 and P_1 respectively, this expression can be rewritten as:

$$V_2/V_1 = 0.371\ (T_2/P_2)$$

Using this relationship, the above equations (8 and 9) become:

$$V_{CO2} = RQ\ BMR\ M\ (T_2/P_2)\ 0.000211 \text{ (Equation 10)}$$

$$V_{CO2} = BMR\ M\ (T_2/P_2)\ 0.000179 \text{ (Equation 11)}$$

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