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Accuracy of Physiological Altitude Simulation

Dear Editor:

In response to the commentary by J. Conkin (3), hypoxicators are designed, constructed, and used to provide hypoxia experiences for pilots with maximum fidelity to what occurs in aircraft. That is, hypoxicators supply the same P_IO_2 and humidity at temperatures found in the cockpit of the airplane during slow cabin depressurisation or oxygen system failure. Manufacturers assume that 20.9% oxygen (by volume) at a barometric pressure of 760 mmHg corresponds to "sea-level." If subjects breathe reduced oxygen air with a balance of nitrogen, this approximates the nominal altitude for the reasons described in **Table I**.

The device class for normobaric hypoxia training is best defined by the term "hypoxicator" (2,8). Hypoxicators induce hypoxia and limit oxygen supply. "Breathing device" is commonly used for any apparatus that protects against hypoxia, providing oxygen supply in harsh environments or medical emergency situations.

Influence of Alveolar Water Vapor on F_IO_2?

From Ernsting's aviation medicine handbook (4) and Table I, it follows that alveolar air is fully saturated with water vapor and PH_2O in the lungs is constant at 47 mmHg at 37°C, which is unchanged with altitude. This condition is called body temperature and pressure saturated with water vapor (BTPS).

It is important to consider the influence of water vapor for spirometry or when exhaled gases are bag-collected; such conditions are called ambient temperature and pressure saturated with water vapor (ATPS)(4). However, for the purpose of inducing hypoxia, only oxygen partial pressure in inspired air (P_IO_2) is important. These measurements are called ambient temperature and pressure (ATP)(4).

In hypobaric chambers, the target simulated altitude is set by using an altimeter without special compensation for PH_2O and, most importantly, for the ambient temperature. In normobaric hypoxia, the same physiological effect is achieved by reducing F_IO_2. Dalton's Law states that the pressure exerted by a gas mixture equals the sum of pressures that each would exert if it alone occupied the space filled by the mixture (4).

Thus the partial pressure of oxygen (PO_2) in the dry atmosphere at mean sea-level pressure is:

$$P_{O_2} = \frac{20.94}{100} \times 760 = 159 \text{ mmHg}$$

At altitude of 25,000 ft:

$$P_{O_2} = \frac{20.94}{100} \times 282 = 59 \text{ mmHg}$$

Therefore PO_2 is 159/59 = 2.7 times lower at 25,000 ft than at sea le[...] and if we lower the P_IO_2 in a normobaric gas mix in the same pro[...]tion, i.e. 20.95%/2.7 = 7.76%, we produce a normobaric oxygen equ[...]alent. This calculation does not distinguish ambient temperatures [...] sea level and at real altitude, nor does it examine P_aO_2. This water [...]por does influence P_aO_2 in all situations as part of the normal phys[...]ogy (4). However, these two physical facts are separate: 1) the [...] of alveolar PH_2O determined by body temperature; and 2) how ma[...] oxygen molecules enter a trainee's respiratory system is determ[...] by F_IO_2.

Should the alveolar PH_2O and the accuracy of normobaric ph[...]ological simulation be linked? The same question should be pos[...] to the accuracy of hypobaric chamber calibration.

Hypoxicators are intended for physiological demonstration [...] education and in our experience using GO_2Altitude's® hypox[...] system (9), the incidence of various symptoms was similar and [...]cacy comparable to the traditional chamber (10).

Of much higher importance and priority for this relatively [...] technology is its safety for users (5,6).

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TABLE I. FEATURES OF HYPOXICATORS USED FOR AVIATION HYPOXIA AWARENESS TRAINING.

Altitude simulation method/ parameter	Traditional hypobaric chamber	ROBD	GO_2Altitude®	Normobaric hypoxia [...] tent/chamber
Technology to induce hypoxic hypoxia	Ambient air pressure reduction by vacuum pumps	Industrial gas mixer of bottled gases: N_2, O_2, air (1)	On-site semipermeable air-separation, medical grade hypoxic and hyperoxic gases	Filling tent/chamber [...] hypoxic air or nitrogen
Ambient Temperature (standard atmosphere at 25,000 ft is −34.5°C)	Below room temperature unless controlled (11)	Ambient room temperature	Ambient room temperature	Higher than room temperature unless air-conditioned
Alveolar PH_2O at body core temperature	47 mmHg	47 mmHg	47 mmHg	47 mmHg
Relative humidity in inspired air	If uncontrolled (7): 20–50%	0–10%(*)	10–20%*	50–100% (H_2O exp[...] by subjects)
F_ICO_2	>0.0003	<0.0003	<0.0003	0.0003–0.01
P_IO_2 during oxygen recovery	250 mmHg(**)	760 mmHg(**)	300 mmHg	760 mmHg**

ROBD = reduced oxygen breathing device.
* Ignoring oxygen mask dead space.
** +5 mmHg regulator safety pressure.

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