APPROXIMATE SIMULATION OF ACUTE HYPOBARIC HYPOXIA WITH NORMOBARIC HYPOXIA

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INTRODUCTION. Some manufacturers of reduced oxygen (O2) breathing devices claim a comparable hypobaric hypoxia (HH) training experience by providing F1O2 < 0.209 at or near sea level pressure to match the ambient O2 partial pressure (iso-pO2) of the target altitude. METHODS. Literature from investigators and manufacturers indicate that these devices may not properly account for the 47 mmHg of water vapor partial pressure that reduces the inspired partial pressure of O2 (PIO2). Nor do they account for the complex reality of alveolar gas composition as defined by the Alveolar Gas Equation. In essence, by providing iso-pO2 conditions for normobaric hypoxia (NH) as for HH exposures the devices ignore PAO2 and PACO2 as more direct agents to induce signs and symptoms of hypoxia during acute training exposures. RESULTS. There is not a sufficient integrated physiological understanding of the determinants of PAO2 and PACO2 under acute NH and HH given the same hypoxic pO2 to claim a device that provides isoxygen. Isoxyhypoxia is defined as the same distribution of hypoxia signs and symptoms under any circumstances of equivalent hypoxic dose, and hypoxic pO2 is an incomplete hypoxic dose. Some devices that claim an equivalent HH experience under NH conditions significantly overestimate the HH condition, especially when simulating altitudes above 10,000 feet (3,048 m). CONCLUSIONS. At best, the claim should be that the devices provide an approximate HH experience since they only duplicate the ambient pO2 at sea level as at altitude (iso-pO2 machines). An approach to reduce the overestimation is to at least provide machines that create the same PIO2 (iso-PIO2 machines) conditions at sea level as at the target altitude, a simple software upgrade.

Learning Objectives:

1. Applying basic principles of respiratory physiology to the design of reduced oxygen breathing devices.
2. Working toward a better understanding of hypoxia.
Reduced O₂ breathing devices create a normobaric hypoxic (NH) environment by providing an F IO2 < 0.209, breathed either through a mask or within a “hypoxia tent”. Some manufacturers claim an equivalent acute hypoxic (HH) experience when normobaric hypoxia (NH) is convertible to the equivalent of altitude. This eliminates the need for an expensive hypobaric chamber and the risk of decompression sickness associated with hypoxic exposure, creating an cost-effective hypoxia training niches used in these devices—hypoxic NH training as promoted.

**INTRODUCTION**

Reduced O₂ breathing devices create a normobaric hypoxic (NH) environment by providing an F IO2 < 0.209, breathed either through a mask or within a “hypoxia tent”. Some manufacturers claim an equivalent acute hypoxic (HH) experience when normobaric hypoxia (NH) is convertible to the equivalent of altitude. This eliminates the need for an expensive hypobaric chamber and the risk of decompression sickness associated with hypoxic exposure, creating an cost-effective hypoxia training niches used in these devices—hypoxic NH training as promoted.

**METHODS**

The method to convert effect altitude to ambient pressure was never specified, a necessary detail to determine the operation of these devices. But through analysis, it appears that Eq. 1 is used. Eq. 1 defines a “Standard Atmosphere - 1976” where distance in kilometers is converted to the equivalent ambient pressure as mmHg.

\[ P_{\text{ambient}} (\text{mmHg}) = 760 \times (288.15 - 0.65 \times \text{altitude (km)})^{(1/1.225)} \]

Eq 1

**RESULTS**

The difficulty in using the upper curve in Fig. 3 is that when you provide a F IO2 at sea level to match the PIO2 at the target altitude you create a PIO2 that is greater than the target PIO2, a consequence of ignoring pHO2.

It is best to provide a F IO2 at sea level defined by the lower curve in Fig. 3 that at least produces the equivalent PIO2 at sea level as at the target altitude, ambient pressure, inspired O2 tension, which would account for pHO2.

Example: 9.0% F IO2 at 1 ATA on the display of an iso-O2 machine would indicate that you are at about 5000 feet altitude with a PIO2 of 68.5 mmHg (6). But PIO2 at 1 ATA is 64.1 mmHg, equivalent to breathing air at 19,700 feet, so an iso-o2 machine overestimates the PIO2 by 1.850 feet. This is a consequence of ignoring the contribution of pHO2.

Even accounting for pHO2 is not sufficient to account for PIO2 and PACO2, as more direct agents to induce signs and symptoms of hypoxia during acute exposures. RESUS. There is not a sufficient integrated physiological understanding of the determinants of PIO2 and PACO2 under acute NH and HH given the same hypoxic pO2 or HH training experience by providing F IO2 < 0.209 at or near sea level pressure to match manufacturers indicate that these devices may not properly account for the 47 mmHg of water vapor partial pressure that reduces the inspired partial pressure of O2 (PIO2). Nor do they account for the complex reality of breathing either through a mask or within a “hypoxia tent”.

**CONCLUSIONS**

The hypothesis that the integrated PIO2 and PACO2 over the same exposure time is less than NH for the same hypoxic PIO2.

Some devices that claim an equivalent NH experience under NH conditions significantly overstate the HH condition, especially when simulating altitudes above 10,000 feet MSL.

At least, the claim should be that the devices provide an approximate NH environment since they only duplicate the ambient pO2 at sea level as at altitude of isoo2 machines.

A first step a approach to the reduction is to at least provide the ambient pO2 at sea level as at altitude of isoo2 machines.

**REFERENCE**


**TABLE 1.** Approximate Simulation of Acute Hypobaric Hypoxia with Normobaric Hypoxia

<table>
<thead>
<tr>
<th>NH Example PIO2 (mmHg)</th>
<th>HH Example PIO2 (mmHg)</th>
<th>NH Example PACO2 (mmHg)</th>
<th>HH Example PACO2 (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.0</td>
<td>57.0</td>
<td>40.0</td>
<td>40.0</td>
</tr>
</tbody>
</table>

**TABLE 2.** Unresolved Issues Given Same Hypoxic PIO2

<table>
<thead>
<tr>
<th>NH</th>
<th>HH</th>
<th>NH time constant (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 3.** Approximate Simulation of Acute Hypobaric Hypoxia with Normobaric Hypoxia

<table>
<thead>
<tr>
<th>NH Example PIO2 (mmHg)</th>
<th>NH Example PACO2 (mmHg)</th>
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**FIGURES**

1. The relationship between pressure and altitude as above mean sea level (MSL) is given by two equations.

2. F IO2 needed at 760 mmHg to provide the equivalent of PIO2 by breathing air at the given altitude.

3. F IO2 needed at 760 mmHg to provide the equivalent of PIO2 by breathing air at the given altitude.

4. Equation 3 converts the PIO2 under normoxic conditions (PIO2) to provide for iso-P IO2.

5. Hyperventilation of deoxygen in this example acutely places NH trainee on the 1.4 RQ diagonal given the conditions in Table 1, column 2.

