Intermittent Hypoxic Exposure Protocols to Rapidly Induce Altitude Acclimatization in the SOF Operator

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JSOM Disclaimer: This article is a single anecdotal case report and not a formal study of any kind.

Abstract

In August 2007 a three-man Special Operations Forces (SOF) Team attempted a rapid ascent of Mt Rainier after a five-day intermittent hypoxic exposure (IHE) protocol in a Colorado Exercise Room. The following article discusses the process used by the team to select the five-day IHE protocol as well as the science upon which IHE protocols for altitude acclimatization is based. The experiences of the team as they attempted to summit Mt Rainier at greater than 14,000 feet are summarized with a focus on acute mountain sickness (AMS) and its possible prevention with IHE.

The subject of rapid acclimatization to prevent AMS is important to the SOF community in order to quickly operate at high altitudes without succumbing to AMS or being forced to a lower altitude. Although medical literature is thinly populated with rigorous studies of IHE to prevent AMS, recent good studies, especially from Dr. Stephen Muza at the U.S. Army Research Institute of Environmental Medicine (USARIEM), validate some IHE protocols. This research is reviewed in the following article to help determine an appropriate IHE protocol for the SOF community.

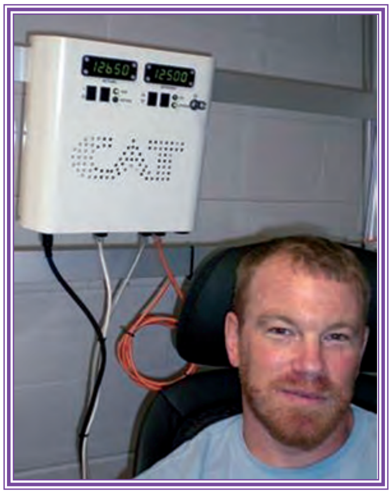
Introduction

Intermittent, normobaric, hypoxic exposure (IHE) protocols may induce ventilatory acclimatization and reduce acute mountain sickness (AMS). SOF Operators such as Pararescuemen (PJ) and other members of SOF ground force teams are more susceptible to AMS because they are called upon to quickly react to objectives at altitudes which may induce AMS. These Operators must physically exert themselves immediately upon arrival to high altitude, without the benefit of slow ascent acclimatization protocols, substantially adding to the risk of developing AMS.

The use of medications such as acetazolamide to prevent AMS are not ideal. Acetazolamide must be taken days before the ascent to high altitude in order to be effective. Acetazolamide also has side-effects such as parasthesias and potentially leads to a performance decrement.

AMS is diagnosed after a rapid ascent of unacclimatized persons. By definition AMS casualties experience a headache early on followed by fatigue, dizziness, and anorexia. Nausea is common. Sleep is fitful. AMS may lead to vomiting, difficulty breathing, and irritability. A useful test which is easily administered to climbers in order to diagnose and grade AMS is the Lake Louise AMS score. This test classifies AMS starting with high-altitude headache, then mild AMS, moderate to severe AMS, and finally high altitude cerebral edema (HACE). AMS may progress to life-threatening HACE.

Susceptibility to AMS is not conclusively understood. Some people are thought to be inherently susceptible to AMS. If an individual developed AMS on a previous ascent, they are more likely to experience AMS on subsequent ascents. What protects individuals from AMS? This is not clear either, although recent sojourns lasting five or more days to high altitude (greater than 3000m) within the previous two months appears protective.[1] In the March 2004 "Altitude Acclimatization Guide" published by the USARIEM, Dr. Stephen Muza advised that IHE protocols using a system such as the Colorado Exercise Room (CER) or a similar mask device or tent may provide ventilatory acclimatization and reduce AMS.[2] These systems provide a normobaric, hypoxic environment typically by replacing oxygen with nitrogen in the inspired air. For instance, in the CER, a hypoxic environment which simulates altitudes up to 15,000 ft is


Inside Hypoxic Chamber at 12,500ft

safely made possible by programming a monitor, then circulating air into oxygen scrubbers, which is then pumped back into the room (see photo). Carbon dioxide (CO_2) monitoring is necessary to maintain a safe concentration of inspired gasses. In early 2008, Dr. Muza published a study of volunteers to determine that a three hour IHE protocol for six to seven days reduced AMS by 20% and increased resting SaO2 by one to three percent.[3] This was a good study, but it did not involve any testing outside of the lab. In other words, all participants were studied in the lab and not on top of a mountain.

While multiple IHE protocols exist, none has been optimized for the SOF community; nor has any one IHE protocol been adequately "street tested." Most studies of IHE for altitude acclimatization are performed in a lab setting. These protocols often are not realistic for SOF operators because they require three to twelve hours of IHE per day for greater than five days. Other protocols to speed acclimatization and/or enhance athletic performance include hypoxic exposures in which the participant exercises in a hypoxic environment for times ranging from less than to greater than one hour. Other protocol questions yet to be answered include how long the effects from the IHE protocol can be sustained. (Some studies indicate that the AMS benefits probably disappear between 24 and 96 hours after the last hypoxic exposure.) A follow-on question is what, if any, maintenance dose of IHE is required to sustain acclimatization. In other words, would it be possible to undergo an initial IHE protocol and then sustain its benefits by "re-dosing" every 72 to 96 hours? The ability to apply this sort of maintenance dosing may allow longer lasting acclimatization with IHE.

With these questions in mind, we determined a protocol with the SOF Operator in mind. We then fielded this protocol with a three-man team who rapidly ascended Mt Rainier (greater than 14,000ft) within 24 hours of the last hypoxic exposure.

Our protocol consisted of 1.5 hours a day of IHE in a CER to 12,500ft for five consecutive days. Based on previous studies we were hopeful by the last day of IHE to experience an increase in resting SaO_2 of 1.5% compared to pre-IHE SaO_2 levels. (Although scientific work remains to help predict who in the SOF community will get AMS, a promising and noninvasive measure of ventilatory acclimatization is an increase in resting SaO_2 by 1 to 3 % from pre-IHE levels.)[3] The following is a summary of the SOF team's experience with an IHE protocol in a Colorado Exercise Room with a follow-on rapid ascent of Mt Rainier.

Results

In our experience, we found that 1.5 hours (which included the 15 to 20 minutes it takes to reach an altitude of 12,500ft in the CER) a day for five days was an acceptable routine. During chamber time, operational and administrative planning was conducted as well as packing gear and performing educational activities such as refreshing mountaineering skills. We also found that by limiting the CER to altitudes of 12,500 ft or below, participants were less likely to experience lightheadedness, fatigue, or other hypoxic symptoms. In our CER, a maximum capacity of four participants could safely perform non-exertional activities without increasing CO_2 levels.

The final day of IHE actually required two chamber exposures within a 24-hour period. Although on days one to three the IHE exposures were spaced apart by approximately 24 hours, on day four, a 1.5-hour chamber exposure ended at 1000 local time with a repeat, fifth chamber exposure occurring at 0100, approximately 15 hours after the morning treatment.

Individual resting SaO_2 measurements were recorded pre- and post-IHE treatments. All individuals experienced a slight increase in resting SaO_2, but only one individual met the goal of a 1.5% increase in resting SaO_2 after the fifth hypoxic exposure. Another experienced an increase in SaO_2 of only 1%. The third had a negligible increase in SaO_2 although he had the highest pre-IHE resting SaO_2 at 12,500ft in the CER of 90% (see Table #1).

Table #1

	Pre-IHE SaO2 (at 12,500ft in CER)	Post-IHE SaO2 (at 12,500ft in CER)
Climber #1	86%	88%
Climber #2	88%	89%
Climber #3	90%	90%

None of the team of climbers had been to high altitude (greater than 9,000ft) for more than five consecutive days within the previous two months, although Climber #2 had been at 9,000ft for four days one month prior to undergoing the IHE protocol. None of the climbers had previously experienced AMS of a severity which required treatment or a descent. All members of the team began their sojourn from the same initial altitude of

300ft ASL. Lastly, other than IHE no climbers used any other measures such as acetazolamide to prevent AMS.

Approximately three hours after the last hypoxic exposure, all climbers flew on a commercial aircraft to Seattle, WA, boarded a commercial vehicle, and by 1200 local, arrived at Mt Rainier National Park. Approximately 12 hours after the last hypoxic exposure, all climbers had trekked to 10,000ft ASL for a three-hour rest. Approximately 24 hours after the last hypoxic exposure, all climbers arrived at about 14,000ft ASL and remained for one hour. Weather conditions prevented an ascent to the summit and all climbers returned to 4,000ft ASL at 36 hours after the last hypoxic exposure. The group spent a total of eight hours above 10,000ft. No climbers experienced moderate or severe AMS; however, during the three-hour rest phase at 10,000ft, no climber was able to sleep despite having undergone a moderate amount of sleep deprivation and exertion during the previous 24 hours. No climber required treatment nor needed to descend due to AMS or any other condition.

A Lake Louise AMS Score, a common and practical measure of AMS, was calculated for each climber after reaching an altitude of approximately 14,000ft (see Table #2). For this calculation, the rest at 10,000ft was included in which the climbers attempted to sleep. When combined with a clinical assessment that includes change in mental status, ataxia, and peripheral edema, a Lake Louise Score of five or more correlates with AMS. None of the team had a score greater than four.

Table # 2	Lake Louise Score
Climber #1	4 (moderate nausea/vomiting + insomnia)
Climber #2	2 (insomnia)
Climber #3	2 (insomnia)

Discussion

Athletes benefit from living at high altitudes and training at low altitudes. The "live high, train low" method results in measurable physiologic changes such as increased hematocrit.[4] The SOF community can benefit from this concept.

A protocol to decrease incidence of AMS during rapid ascent to high altitude using IHE, though not proven, is promising. Other acclimatization protocols such as the seven-day IHE protocol recently studied by Dr. Muza also appear promising.[3] We chose a five-day, 1.5-hour protocol that limited the train-up altitude to 12,500ft in order to minimize symptoms while in the CER and to minimize the train-up time. We found that taking the CER to 15,000ft during the IHE train-up brought about side-effects such as fatigue and dizziness that impaired our ability to perform other tasks such as packing and rehearsing mountaineering techniques. The length of each CER session was 1.5 hours. This time was chosen since it was the minimum exposure time proven effective in Dr. Muza's study.[3]

Our experience using a five-day, 1.5-hour per day IHE protocol was positive. This schedule was acceptable and did not adversely impact other daily duties. By maintaining a chamber altitude no higher than 12,500ft, participants were able to carry on non-exertional activities without experiencing disruptive, hypoxic symptoms. With a non-exertional protocol, multiple participants were able to train-up in the chamber while maintaining safe CO_2 levels.

In our practical application of this IHE protocol, it was possible for climbers to develop AMS. All rapidly ascended to above the 8,000ft threshold in which many will experience AMS.[5] AMS is expected to develop in about 33 to 45% of climbers who rapidly ascend to high altitude at the latitude of Mt. Rainier. The team remained above 8,000ft for approximately 10 hours — an amount of time long enough to induce AMS. Added to this rapid ascent, the climbers immediately exerted themselves, an activity known to increase the incidence of AMS.

The insomnia experienced by the group may have been a symptom of AMS, but no one experienced any additional, debilitating signs or symptoms except Climber #1 who vomited one time. All were able to successfully climb to and sustain an altitude greater than 13,000ft for at least one hour.

It is not conclusive that the five-day, 1.5-hour per day IHE protocol helped in the successful mission completion of this group of SOF Operators. The small number of climbers, the lack of a control group, as well the lack of application of other strict research criteria prevents drawing a correlation between the IHE protocol and the successful ascent to high altitude. Although at least one of the three climbers would be expected to suffer AMS based on the parameters of this sojourn, none developed AMS. AMS did not cause any of the climbers to abort the mission nor were they impaired by AMS. Although physiologic changes were minimal in this group, the simulation of actual high altitude during the IHE protocol may have provided other benefits. The hypoxic environment of the CER may have provided awareness of typical AMS symptoms such as lightheadedness, headache, nausea, and memory/performance difficulties. This awareness of hypoxic symptoms gained at low altitudes may have added awareness at high altitudes and helped with control of AMS symptoms.

Further validation of this protocol is necessary. More direct measurements of physiologic changes such as resting heart rates and SaO_2 changes at high altitude with a control arm of climbers who did not undergo the

IHE protocol would increase validity. A more formal assessment of a larger team to detect signs and symptoms of AMS would increase power and validity. This assessment might consist of recording Lake Louise scores, retinal disk diameter measurements, SaO_2, and other vital signs.

Although the group went to high altitude rapidly, it could have gone higher. In fact, a rapid ascent to extreme altitudes above 18,000ft for longer than four hours would help validate the IHE protocol given that a larger percentage of the team would be expected to experience AMS.

Finally, a protocol shorter than five days, although preferable, is not likely to succeed. Other than providing situational awareness of hypoxic symptoms, a shorter protocol is unlikely to induce significant physiologic changes in that amount of time.

Is a five-day, 1.5-hour per day IHE protocol, even if proven to be effective with further study, acceptable for acclimatization prior to typical SOF missions? A five-day IHE protocol certainly limits the scenarios for IHE's use. One example of a possible application is preparing a rescue team to be available ahead of a high altitude mission.

An additional goal of any IHE protocol is to maintain the acclimatization that is gained from the protocol on a long-term basis. If intermittent, "maintenance" dosing in the CER is performed every 72 to 96 hours, then could a SOF Operator be maintained in an acclimatized state, ready to go to high altitude at a moment's notice?

TSgt Jason Andrews on the trail to base camp at 10,000ft

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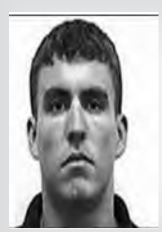

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