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FORUM***HYPOXIA AWARENESS TRAINING USING NORMOBARIC
LAB TECHNOLOGY AS A TRAINING SYSTEM***

Glenn L. Harmon

Introduction

Walking across the ramp of almost any general aviation airport ramp it is easy to spot an array of high performance aircraft like the Cirrus or Diamond that have joined the ranks of Cessna and Pipers with capabilities of flying at altitudes above 18,000 feet. With the current popularity of new personal Very Light Jets (VLJs) capable of reaching 41,000 feet, a growing number of pilots are flying at altitudes for which they have little understanding or training, especially in the event of loss of pressurization. If you diligently search the Code of Federal Regulations (CFR) part 61.31g and Advisory Circular (AC) 61-107A, you will find some regulatory guidance for high altitude ground training, but there is a lack of specific standardization in training skills for flight at these altitudes. Pilots are not adequately trained to understand their personal and equipment limitations at altitudes above 10,000 feet. Military aircrews receive initial and recurrent academic and hypobaric chamber training in the recognition and recovery from hypoxia as part of their flight training. General aviation and even airline training only requires an academic and procedural knowledge of high altitude operations, but does not require a pilot to ever experience their symptoms of hypoxia or recovery effectiveness of 100% oxygen. The National Transportation Safety Board (NTSB) lists hypoxia as a factor in many altitude related accidents, and these accidents represent a wide range of pilot skills and levels of expertise. In a 1991 study, the U.S. NTSB documented at least 40 aircraft accidents related to hypoxia between 1965 and 1990. More recently, hypoxia was determined to be the cause of a Greek Helios Airways B-737 crash that killed 121 people in 2005 and the Learjet crash that killed professional golfer Payne Stewart and five others aboard a Learjet in 1999. The consensus of the study was that "a more complete knowledge of high altitude physiology issues relevant to civilian flight is needed." But how and where do civilian pilots get this training?

Methods

All of our military aviation branches and most air forces of the world require initial and recurrent hypoxia recognition and recovery training. From an aviation university perspective, the challenge was to develop an economical and efficient system in which to train a large volume of students and also conduct future research. Embry Riddle Aeronautical University (ERAU) has taken the lead to become the first university to use a normobaric laboratory enclosure to conduct high altitude hypoxia awareness training for aviation purposes. The creation and acquisition of a normobaric hypoxia training lab is designed to support the university's AS 357 Flight Physiology course which teaches the causes and symptoms of hypoxia. Currently, there is an average of 195 students per semester enrolled in the AS 357 Flight Physiology course. Existing training systems such as hypobaric chambers were too costly and mixed gas breathing devices involved negative training such

as wearing a mask to become hypoxic. This would not be realistic for civilian pilot operations. In his book [Into Thin Air](#), the author John Krakauer detailed his preparation and acclimatization required for the fateful climb to the top of Mt. Everest. New normobaric technology was becoming popular not only in mountain climbing to aid in acclimatization and preventing acute mountain sickness, but in other sports to simulate higher altitudes for athletes. Could this technology be adapted for aviation use?

ERAU chose to adopt the normobaric technology which reduces oxygen content vs. pressure to achieve a hypoxic environment and offers no risk of trapped gasses and decompression sickness (DCS). ERAU partnered with Colorado Altitude Training (CAT) to develop a 10'x18'x7' clear Mylar® and aluminum enclosure that seats 8 students and reaches an altitude of 30,000 feet. The High Altitude Lab (HAL) is efficient to operate with a simple control panel, communications and oxygen controls, and only

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requires a crew of two instructors and no medical personnel on standby. Operational costs are low. ERAU chose communications and commercial style oxygen masks that replicate those found on business, regional or airline aircraft. The heart and brains of the HAL are the air machines that use a molecular sieve technology, or zeolite crystals that attract and separate oxygen molecules from the air and pump the remaining hypoxic air into the enclosure. The altitude controller and oxygen sensor sends commands to the machines to maintain a set point altitude by extracting oxygen until a predetermined percentage is reached. For example, at 30,000 feet equivalent altitude, the controller has reduced the inside oxygen content to 6.6% and also monitors carbon dioxide levels.

As air machines extract oxygen from the enclosure creating a hypoxic environment inside, students perform cognitive, motor, and flight-related tasks under the guidance of qualified instructors. Coordination and motor function is tested by performing such tasks as a block puzzle, calculator functions, crew coordination exercises and recording symptoms on a worksheet. Cognitive tasks include chain math problems, playing card recognition, reading checklists and locating information on a sectional chart. Other tasks such as color discrimination and peripheral vision tests are used to demonstrate visual disturbance caused by hypoxemia. In one research study involving mild hypoxia, the Automated Neuropsychological Assessment Metrics (ANAM), cognitive test on laptop computers was used. The ANAM tasks measured spatial orientation, math functions and response time. Pulse oximeters are used to monitor oxygen saturation or SpO₂ and heart rate in each student to preclude excessively low SpO₂ or tachycardia, excessively fast heartbeat. As students experience their warning signs of hypoxia, they don oxygen masks before their decision making becomes clouded or they become incapacitated.

Although the normobaric lab presents few medical risks, medical screening similar to that required by the military and Civil Aeromedical Institute (CAMI) in the hypobaric chamber was necessary to safely allow students to train in this low oxygen environment. In an article entitled "Weighing the Risks of Hypoxia Training", Dr. Quay Snyder outlined six key elements for hypoxia training. These guidelines along with consultation with our own university physician-AME, flight surgeons and CAMI helped develop the medical screening checklist and risk management/liability procedures approved by our Office of General Counsel and Risk Management. Also, the seven HAL instructors were selected from the aeronautical science faculty, most with prior military flight experience, and two students with CFI/AGI credentials who are all current in CPR/AED training. Each instructor will conduct about 2-4 HAL sessions per month.

The ERAU HAL sessions are initiated at 30,000 feet. Students enter the enclosure, conduct a mask and

communication check and four students on one side remain on oxygen while the four sitting opposite remove their masks and experience their signs and symptoms of hypoxia. The training advantage in this is to be able to observe the objective symptoms in others as well as yourself. It also presents a manageable work load for the inside instructor who is on oxygen leading the demonstration. An explanation of low-grade hypoxia may also be performed by removing the masks, dimming the lights and locating information on a sectional chart or color wheel while mildly hypoxic. Once all students have recovered satisfactorily, the pressure demand mode is selected to demonstrate the mask capability and difficulty of breathing and communication with ATC and other crewmembers while pressure breathing.

Results

The HAL normobaric lab has the capacity to train approximately 200 university flight students each semester. The physiology concepts are taught and assessed in class, while the lab provides a means for demonstration and application. Following each lab, a student-centered debrief is conducted discussing student's subjective symptoms, reactions and responses on the hypoxia worksheet. Student course critiques indicate that this hands-on training solidifies the knowledge they acquired in class and gives them a true understanding of the potential dangers at high altitudes. The addition of a Digital Video Recorder in the HAL provides the opportunity to "mark" noteworthy episodes during the HAL training and review it during the debrief. This has proven invaluable in allowing students to see their actual hypoxic behavior especially since there are periods of amnesia as one's disturbance progresses. It is generally accepted that a person's symptoms of hypoxia remain fairly consistent over time and are similar regardless of whether they occur in a hypobaric, normobaric or aircraft environment. HAL instructors with prior military flight experience and students who have completed both hypobaric and normobaric training report the validity of the symptoms experienced. The learning objective for the HAL session is to enable students to recognize and identify their personal symptoms of hypoxia. Since Embry-Riddle Aeronautical University is in the business of educating and training pilots, the university has opened this training to external customers also. Flight schools and corporate/charter companies can take advantage of this available training to complement their programs and obtain high altitude endorsements or possibly receive insurance discounts for recurrent training.

Discussion

Unlike military pilots, civilian pilots have fewer opportunities to receive proper physiology training to adequately prepare them for the challenges of the high altitude environment. There are fewer pilots out there now who have had military training and flying experience and there are fewer military bases with hypobaric training capacity for civilian pilots to take advantage of. Besides

ERAU, there are only three other universities in the US who have the capability to provide high altitude hypoxia training for aviation purposes. Aviation universities and flight schools should consider the feasibility of providing or outsourcing hypoxia awareness training in their curriculum to produce safer, better prepared pilots who fly today's high performance aircraft.

Embry-Riddle just added a certificate program to their curriculum in which individuals who have a four year degree and at least a private pilot certificate can earn additional flight ratings. Hypoxia awareness training and a high altitude endorsement IAW 14 CFR 61.31g and AC 61

107A will likely be an integral part of this professional training. Additionally, research is an important part of any university and ERAU has already begun to measure various aspects of human performance and human factors by assessing levels of degradation of performance while experiencing hypoxia. You may soon anticipate an evolution of hypoxia training from hypobaric, mixed-gas, normobaric and eventually hybrid systems. The objective will be to provide realistic high altitude training not normally available today to as many pilots as possible in a cost effective manner. Education and training of today's pilots is an investment in safety for tomorrow. →

Glenn Harmon (Lt Col, USAF, Ret.) is an assistant professor of aeronautical science at Embry-Riddle Aeronautical University in Daytona Beach, Florida teaching the AS 221 Instrument Pilot Operations course and his signature AS 357 Flight Physiology course. As an aerospace physiologist, he designed and implemented the first-ever high altitude hypoxia awareness lab for aviation at Embry Riddle using innovative normobaric technology that allows flight students to recognize and experience their personal symptoms of hypoxia. Additionally, he was invited to join the Bombardier Safety Standdown Team as a physiology and aerospace medicine subject matter expert. He brings a varied aviation background to the Embry-Riddle classroom including military, airline and general aviation experience. Professor Harmon is passionate about creative learning, and is an active participant in the university's Center For Teaching and Learning Excellence. He was chosen as the 2010 runner up for outstanding teacher of the year award.

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