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Examining Hypoxia: A Survey of Pilots' Experiences and Perspectives on Altitude Training

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16. Abstract
Federal aviation regulations and Advisory Circulars (ACs) provide requirements and guidance for high-altitude physiological training for pilots and crewmembers. Pilots and crewmembers of flights exceeding 25,000 feet/mean sea level (msl) are required to complete ground training in high-altitude physiology, including hypoxia training; however, regulations do not require altitude chamber training. The present research examined the training experiences and perceptions of pilots about the need for hypoxia training and altitude chamber training.
Method: Sixty-seven male pilots attending a meeting on aviation safety completed a survey assessing their experiences and perceptions of hypoxia training. All pilots indicated that they flew professionally and had logged hours flying for business during the six months prior to the survey date.

Results: Sixty-two pilots reported receiving hypoxia training, and of these, 71% reported having initial altitude chamber training. Pilots reported that their training was informative (97%) and that they would benefit from more hypoxia training (90%). Pilots endorsed (agreed or strongly agreed) that all pilots should receive: introductory hypoxia training (92%), recurrent hypoxia training (86%), initial altitude chamber training (85%), and recurrent altitude chamber training (70%). However, when asked specifically if general aviation pilots flying unpressurized aircraft should receive initial altitude chamber training, only 31% perceived this as being necessary. Initial altitude chamber training received lower endorsements for private (32%) or recreational (10%) pilots than for commercial (74%) and air transport (90%) pilots. When asked if altitude chamber training should be based on the altitude capability of an aircraft, 59% responded affirmatively. It appears that the need for altitude chamber training was based on the likelihood of flying at higher altitudes and not simply the level of certification. When asked if the current regulations (i.e., not requiring altitude chamber training) addressing high-altitude flying (above 25,000 feet/msl) are sufficient, 52% of the current sample disagreed or strongly disagreed.

Conclusions: Generally, these professional pilots perceived that pilot training should include introductory hypoxia training, recurrent hypoxia training, and altitude chamber training. Noted exceptions were initial altitude chamber training for general aviation pilots flying unpressurized aircraft, recreational pilots, and private pilots. However, a caveat should be noted regarding the generalizability of these results. This sample is a small segment of the entire pilot population; therefore, these findings may not generalize to pilots overall. Distributing the survey to a wider audience of pilots would provide additional information regarding perceptions of hypoxia training.

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Examining Hypoxia: A Survey of Pilots' Experiences and Perspectives on Altitude Training

Altitude (hypoxic) hypoxia is a physiological concern in the high-altitude aviation environment. Flying at increasingly higher altitudes is possible due to technological advances; however, higher altitude flight presents the risk of experiencing hypoxia. Specially designed aircraft and pressurization systems protect the operator and passenger(s) while traveling at altitudes that would otherwise be impossible. However, a failure in equipment resulting in a loss of cabin pressure is possible, and the operator(s) must be aware of what to do and what to expect should hypoxia occur in that situation (Pickard, 2002).

The Federal Aviation Administration (FAA) defines hypoxia as "a state of oxygen deficiency in the body sufficient to impair function of the brain and other organs" (FAA, 2002a). Hypoxia impairs vision, judgment, motor control, and can result in incapacitation or, in severe cases, death. The effects of hypoxia are visible in most healthy individuals after reaching 10,000 ft (Green et al., 1996). Due to individual differences in susceptibility, hypoxia may appear at lower altitudes for some (Harding, 1999). Generally, the signs and symptoms are subtle and may include rapid breathing, headache, drowsiness, nausea, behavioral changes (e.g., euphoria, irritability), slurred speech, and diminished thinking capacity (FAA, 2002b; Pickard, 2002).

A pilot experiencing hypoxia has a limited amount of time to recognize signs and symptoms, don an oxygen mask, and begin additional emergency procedures, including descent to a lower altitude. The time of useful consciousness (TUC) ranges from minutes at lower altitudes to seconds at higher altitudes (Pickard, 2002), and it is within this time frame that a pilot must execute the correct decisions.

Numerous individuals have examined factors associated with hypoxia (Bonnon, Noel-Jorand, & Therme, 1995; Ernsting & Sharp, 1978; Nesthus, Rush, & Wreggit, 1997; Reinhart, 1999; Sheffield & Heimbach, 1996; Stivalet et al. 2000). Within the aviation environment, decrements while performing a well-learned task (e.g., maintaining a given air speed) have been reported at 12,000 ft, with higher altitudes (15,000 ft) resulting in poorer performance (Harding, 1999). Nesthus, Rush, and Wreggit (1997) found pilots exposed to simulated altitude conditions of 10,000 ft and 12,500 ft (via differential oxygen concentrations) committed significantly more procedural errors during descent of a flight simulation than pilots breathing sea level concentrations of oxygen. When considering the onset of hypoxia while flying at night, affected altitudes are much lower, with 5,000 ft reported to degrade night vision (Harding, 1999; Mohler, 1966).

Preventing hypoxia within the aviation environment (i.e., hypoxic hypoxia) has included researching possible vulnerabilities (e.g., smoking; Nesthus, Garner, Mills, & Wise, 1997; Yoneda & Watanabe, 1997), timing of the progressive complications (e.g., time of useful consciousness, TUC; Yoneda, Tomoda, Tokumaru, Sato, & Watanabe, 2000), and investigating regulatory requirements including training and education (e.g., use of oxygen, Turner & Huntley, 1991; physiological training, Vogel, 1991; cabin altitude pressures, Ernsting, 2002; and oxygen mask donning, Marotte, Toure, Clere, & Vieillefond, 1990).

The importance of human factors, including awareness of flight physiology, has been described as essential for flying safe (Reinhart, 1999). Indeed, the Code of Federal Regulations (CFR) requires ground training in altitude physiology for pilots operating pressurized aircraft that have "a service ceiling or maximum operating altitude, whichever is lower, above 25,000 ft MSL" (Title 14 of the CFR Part 61, §61.31(g)(1,2), 2003), although certain exceptions apply, as noted in 14 CFR 61.31(g)(3). The subjects that must be covered in the required ground training include the effects, symptoms, and causes of hypoxia and any other high-altitude sickness; duration of consciousness without supplemental oxygen; and physical phenomena and incidents of decompression, 14 CFR 61.31(g)(1)(i-ix).

Advisory Circular (AC) 61-107 (Department of Transportation, FAA, 2003) discusses the training recommendations mandated in 14 CFR 61.31. Specifically, AC 61-107 recommends extending the required ground training to all pilots who fly above 10,000 ft/msl (Chap 1, para.1(a)). Additionally, flight physiology training requirements for pilots and crewmembers are stated in Title 14 of the CFR Parts 121 and 135. Crewmembers conducting flights above 25,000 ft/msl are required under 14 CFR 121 and 135 to receive ground training in altitude physiology as part of the required general emergency training on a recurrent basis (14 CFR 121.417(b)(3)(i) and (e)(1-6), 14 CFR 135.331(b)(3)(i) and (d)(1-6)).

The current FARs do not require altitude chamber training. However, AC 61-107, in a section concerning physiological training for pilots of high altitude aircraft (Chap 1, para. 7), "highly recommends" altitude chamber training. Altitude chamber training is required by the U.S. military services for flight personnel. Additionally, some federal agencies (e.g., National Aviation and Space Administration [NASA], FAA) require their flight personnel to complete flight physiology training, including altitude chamber training (AC 61-107, Chap. 1, para. 8, 2003). Certain corporations also require altitude chamber training for their flight personnel. AC 61-107 (Chap. 1, para. 8, Table 2) lists military locations and government agencies offering altitude chamber training to civilian pilots. This training is also available at some commercial sites.

The Civil Aerospace Medical Institute (CAMI) of the FAA provides altitude chamber training, including oxygen equipment familiarization, night vision experience, rapid decompression experience, and ascent to 25,000 ft for flight crew personnel to experience individual symptoms of hypoxia. The Aerospace Physiology training manual (FAA, 2002b) provided during CAMI classroom training lists the general signs and symptoms resulting from hypoxia. The manual differentiates between signs and symptoms occurring during hypoxia. Signs are external (e.g., rapid breathing, sweating, trembling) and are visible to others, while symptoms are internal (e.g., euphoria, air hunger, nausea) and are sensed by the person suffering from hypoxia (FAA, 2002b).

Educating individuals about their own symptoms within a supervised ground location provides essential information. Generally, a person's symptoms remain consistent across episodes of hypoxia, although factors such as fatigue can increase an individual's susceptibility to hypoxia (Green et al., 1996). Being aware of one's symptoms provides the individual with an experiential foundation. This prior experience (i.e., altitude chamber training) should better prepare individuals to recognize their own hypoxia symptoms. Thus, altitude chamber training allows the hypoxia experience to be less novel and may improve recognition of hypoxia and critical reaction time (FAA, 2002b). Additionally, education about inter-individual differences may be useful in identifying hypoxic reactions in others (Green et al., 1996).

The purpose of the current project was to collect information from pilots regarding their hypoxia training background and their impressions of the content and adequacy of their hypoxia training. Also assessed were pilot perceptions of the need for hypoxia training, altitude chamber training, and recurrent training for all pilots across type of pilot rating and type of aircraft (i.e., pressurized, unpressurized).

METHOD

Participants

Seventy-one male pilots attending an aviation industry-sponsored safety conference completed a survey addressing hypoxia. Pilots who indicated they flew professionally and had logged hours flying for business during the six months prior to the survey were selected for the sample. Four individuals who did not meet these criteria were not included in the final survey sample. The final survey data included 67 male pilots ranging in age from 27 to 67 yrs (M = 46.6, SD = 9.6).

Survey content

The 94-item survey was designed to gather demographic (e.g., age, gender) data as well as information about flight background, level of certification, current medical ratings, types of aircraft flown, average cruise altitude, hypoxia training, and experiences with hypoxia and in-flight altitude decompression. Additionally, items were structured to obtain pilots' perceptions concerning hypoxia training, including ground, altitude chamber, and recurrent for both pilots and crewmembers.

Procedure

Pilots attending an aviation industry-sponsored safety conference were asked to voluntarily complete the hypoxia survey. The survey was distributed and returned during the conference. Later, completed surveys were provided to CAMI. Survey database management and data analysis were coordinated with an independent contractor.

RESULTS

Pilot demographics

Sixty-seven male pilots were included in the final database. The pilots generally reported that they were nonsmokers (91%) and exercised regularly (74%). Their flight backgrounds were varied (see Table 1), with many levels

Table 1. Flight Background of Pilots

Flight Background	%
Corporate	84
General Aviation	67
Air Taxi	27
Military	19
Major Airline	7
Regional Airline	1

Note: Percentages sum to greater than 100 because pilots indicated all flight backgrounds that applied.

of certification: air transport (93%), commercial (55%), flight instructor (51%), flight instructor-instrument (43%), private (22%), and recreational (1%).

Pilot training experiences

Sixty-two pilots reported receiving training on the issue of hypoxia. Pilots' hypoxia training backgrounds were indicated as follows: a basic introductory course on hypoxia (not including altitude chamber training) (61%), a recurrent course on hypoxia (not including altitude chamber training) (34%), and initial altitude chamber training (71%). Additionally, of the pilots who had received hypoxia training, 37% reported attending altitude chamber training on a regular basis[1]. Pilots reported their hypoxia training was informative[2] (97% agree and strongly agree) and covered the topics shown in Table 2.

Pilot attitudes on hypoxia training requirements

Pilot attitudes concerning specific pilot and crewmember hypoxia training requirements were assessed by eight items (see Table 3). More than 90% of respondents agreed or strongly agreed that pilots and crewmembers should receive an introductory hypoxia course. Additionally, 85% felt that pilots should receive an initial altitude chamber course. When asked if the current regulations (i.e., not requiring altitude chamber training) addressing high-altitude flying (above 25,000 ft/msl) are sufficient, 52% disagreed or strongly disagreed.

Over half of the respondents (59%) believed that altitude chamber training should be based on the altitude capability of an aircraft. When asked generally about altitude chamber training, 68% did not believe that the type of pilot license should play a role in determining

Table 2. Topics Covered in Hypoxia Training

Topics	% Yes
Effects, symptoms and causes of hypoxia and any other high-altitude sickness	94
Duration of consciousness without supplemental oxygen	92
Causes and effects of gas expansion and gas bubble formation	90
Respiration	89
Physical phenomena and incidents of decompression	81
Preventative measures for eliminating gas expansion, gas bubble formation, and high-altitude sickness	76
Effects of prolonged usage of supplemental oxygen	58

Note: N = 62; Four pilots who indicated receiving hypoxia training did not select any of the listed topics.

[1]Of the 62 respondents who indicated they had received hypoxia training, three individuals did not respond "yes" or "no" to receiving altitude chamber training on a regular basis. Therefore, N = 59 for this item.

[2]Of the 62 respondents who indicated they had received hypoxia training, four individuals did not respond to this item; therefore, N = 58.

Table 3. Attitudes About Pilot and Crewmember Hypoxia Training Requirements

Statement	% agreement
All pilots should receive basic introductory hypoxia training (not including altitude chamber training).	92
All pilots should receive recurrent hypoxia training (not including altitude chamber training).	86
All pilots should receive initial altitude chamber training.	85
All pilots should receive recurrent altitude chamber training.	70
All crewmembers should receive basic introductory hypoxia training (not including altitude chamber training).	91
All crewmembers should receive recurrent hypoxia training (not including altitude chamber training).	78
All crewmembers should receive initial altitude chamber training.	80
All crewmembers should receive recurrent altitude chamber training.	73

Note: Agree and Strongly agree were added to determine % agreement.

who should receive altitude chamber training. However, when specific hypoxia training needs were assessed for five types of pilot certification (see Table 4), we found that more than 60% of the pilots perceived the need for an introductory hypoxia course (not including altitude chamber training) as necessary, regardless of level of certification. However, type of certification was relevant for initial altitude chamber training with air transport, commercial, and instructor greatly surpassing recreational and private certification. This may initially appear inconsistent with the general sentiment that type of airmen license should not influence altitude chamber training; however, a plausible explanation is that those who would fly at higher cruise altitudes were perceived as having a greater need for altitude chamber training. Thus, the type of license is not the critical factor but, instead, the perceived threat of hypoxia or altitude decompression sickness due to the higher cruising altitude and altitude capability of the aircraft that those pilots fly.

Respondents also identified the training needs of general aviation (GA) pilots flying unpressurized aircraft and pilots flying pressurized aircraft. The majority did not believe (69%) that initial altitude chamber training was necessary for GA pilots flying unpressurized aircraft; however, a basic introductory hypoxia course was perceived as fundamental (82%).

DISCUSSION

Hypoxia is a serious concern in the high-altitude aviation environment. Educating pilots and crewmembers about what to expect and what to do in response to hypoxia is critical. Educating individuals about their own symptoms within a supervised ground location provides essential information. Most of this sample reported receiving hypoxia training, with a few exceptions. We found that pilots perceived a basic introductory course and initial altitude chamber training as necessary for the majority of high-altitude pilots.

As stated earlier, altitude chamber training may improve an individual's recognition of hypoxia and critical reaction time (FAA, 2002b). Though AC 61-107, (Chap 1, para. 7), "highly recommends" altitude chamber training, the current CFRs do not require altitude chamber training. When asked if the current regulations (i.e., not requiring altitude chamber training) addressing high-altitude flying (above 25,000 ft/msl) are sufficient, 52% of the current sample disagreed or strongly disagreed.

Further examination of altitude chamber training indicated pilots believed that the altitude capability of an aircraft was an important factor. Moreover, when pilots considered level of certification, they indicated that air transport pilots, commercial pilots, and instructors should

Table 4. Hypoxia Training Requirements by Type of Certification

Level of Certification	Type of Training Needed	%
Air Transport	Basic introductory course on hypoxia	71
	Recurrent course on hypoxia	57
	Initial altitude chamber training	90
	Recurrent altitude chamber training	65
Commercial	Basic introductory course on hypoxia	72
	Recurrent course on hypoxia	51
	Initial altitude chamber training	74
	Recurrent altitude chamber training	39
Private	Basic introductory course on hypoxia	73
	Recurrent course on hypoxia	33
	Initial altitude chamber training	32
	Recurrent altitude chamber training	12
Recreational	Basic introductory course on hypoxia	61
	Recurrent course on hypoxia	15
	Initial altitude chamber training	10
	Recurrent altitude chamber training	7
Instructor	Basic introductory course on hypoxia	66
	Recurrent course on hypoxia	44
	Initial altitude chamber training	71
	Recurrent altitude chamber training	34

Note: For each level of certification, respondents marked types of training that were perceived as necessary.

receive altitude chamber training. As noted, perhaps these individuals incur the greatest likelihood of flying at an altitude most susceptible to the risk of hypoxia and altitude decompression sickness.

Although the current paper reveals a sample of pilot experiences and perceptions of altitude training, a caveat should be noted regarding the generalizability of these results. The current sample consists of pilots attending an aviation safety conference who indicated they flew aircraft for business purposes. This sample is a small segment of the entire pilot population; therefore, these findings may not generalize to pilots overall. Distributing the survey to a wider audience of pilots would provide additional information regarding perceptions of hypoxia training. Nonetheless, the present paper provides useful information within the noted limitations.

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