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General Aviation Hypoxia and Reporting Statistics

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Abstract

Hypoxia is defined as a lack of oxygen throughout the body, which can be caused by several factors at any altitude. General aviation pilots carry the hazardous attitude that their aircraft cannot attain altitudes where one might be more affected by hypoxia. This invincibility attitude is alarming considering that out of the 590,038 certificated pilots in the US, a little over 30% of them are general aviation pilots.[1] The problem is that unlike airline pilots or military pilots, the general aviation community lacks the training tools and education of causes, symptoms and recovery of hypoxia. Furthermore, there is no requirement that, if a pilot does experience hypoxia, to report it to a safety and statistics agency such as NASA. Without these reporting statistics of hypoxia, there is no way to observe trends through the years of reported hypoxia that could help prevent other general aviation pilots from experiencing the same hazard. To attain this information, an anonymous survey was distributed through an electronic newsletter via the Aircraft Owners and Pilots Association (AOPA) and Curt Lewis & Associates, a safety forum and recommendation service for the aviation industry. Some of the questions of this survey recount the pilot's experience at the time, flight condition and any previous flight physiology training they may have had. The information attained was analyzed to determine how often hypoxia occurs for general aviation pilots, reporting statistics and how effective flight physiology training is for the general aviation population.

Keywords: Aviation, Hypoxia, Statistics

1. Introduction

The general aviation community was the concentration for this hypoxia study due to the common belief that general aviation aircraft, that have usually single, normally aspirated engines, cannot attain higher altitudes where one might be more affected by hypoxia. This invulnerable attitude, in combination with the lack of resources available for flight physiology training to the general aviation community, made this population of the aviation industry prime candidates for this study.

It should be noted that the Federal Aviation Regulation 91.211 does not require pilots to use supplemental oxygen until cruising at 12,500 feet in altitude for 30 minutes or more. The training requirement for the Private Pilot Airman Certification Standards is have the student understand the causes, effects and recovery methods of hypoxia, no further practical training is required. It should also be noted that pilots, whether commercial operators or general aviation, have no legal requirement to report their hypoxic event, and it is because of this that the research team believes there are no statistics on frequency, commonality or severity of general aviation hypoxia.

2. Methodology

To have the most candid answers of the general aviation community in regards to their experience with hypoxia, an anonymous survey consisting of 15 questions was drafted. In order to certify the most ethical practices in conducting the survey to collect responses with informed consent, the primary researcher and faculty advisors completed training on the Collaborative Institutional Training Initiative (CITI). Once the CITI training was complete, the primary researcher then submitted an Institutional Review Board (IRB) application answering the mission of the research, any risk to the human subject involved, safeguarding of the data and a draft of the survey to be submitted as well as the methods of distribution. The IRB contacted the research team within two weeks with their letter of approval to carry out the survey. The survey was then created in Survey Monkey with the idea that the survey could be accessed by anyone to partake in anonymously through a web link.

The targeted audience was pilots that had experienced a hypoxic event during non-commercial flight operations. Therefore, these individuals may have experience or hold a job in the commercial aviation industry but when they experienced the hypoxic event, it was in a general aviation aircraft, in not-for-hire operations. In an attempt to reach the desired audience of specifically general aviation pilots and not commercial pilots the survey was distributed through the Aircraft Owners and Pilots Association (AOPA), an organization that has a well-known history of promoting general aviation, protecting private pilot's rights and offering various safety courses. Curt Lewis & Associates who sends weekly emails to various people within the aviation industry regarding safety advancements and scholarly articles also distributed the survey. It was attempted to have the FAA send the survey, as they would know the certificates held by every pilot in the U.S.; however, the contact at the Airmen Certification Branch in Oklahoma City informed the research team that would not be possible. A letter of explanation was sent as an attachment along with the link to the survey through an email to members of AOPA that used email, as well as people that subscribed to Curt Lewis & Associates' email. AOPA has roughly 400,000 members and roughly 36,000 people subscribe to Curt Lewis & Associates. There were 344 total responses to the survey.

The survey questions first asked if the participant had experienced hypoxia during normal, non-commercial flight operations; if they answered no, the participant would be routed to the final question which was a free response question asking for suggestions in regards to flight physiology training. The purpose of this routing was to immediately discard those who had not experienced hypoxia from further participation in the questions specific to their hypoxic event but allow those who hadn't experienced hypoxia but were concerned pilots could voice their opinion. The questions then went on to ask their experience level as a pilot such as their hours, certificates and age at the time of the event. The survey then asked specifics about the event such as their altitude, the symptoms they experienced and whether or not they were the pilot in command at the time. Lastly, participants were asked about any previous flight physiology training they may have had before the event, whether or not they reported the event, if they did report, to whom did they report it to and what suggestion did they have for future flight physiology training.

3. Literature Review

In general, hypoxia has never really been a concern for general aviation pilots because they are under the impression that because they fly at lower altitudes, the possibility of hypoxia is less likely. However a study "evaluating perceptual-motor performance during hypobaric chamber exposures at pressure-altitude equivalents of 7,000 and 12,000 ft. found that significantly slower response times occurred during both altitudes, compared with a sea-level control[2]…" The report goes on to explain how the experiment had general aviation pilots flying at various altitudes and performing everyday navigation tasks, which showed a significant decrease in their performance. However, the report has no statistics for how often a hypoxic event might occur in general aviation flight operations and what flight configuration would be the most detrimental. The study accentuates the importance of understanding the effects of hypoxia on the body and its effect on performance, especially at altitudes familiar to general aviation pilots, but does not fulfill the purpose of this research.

Hypoxia is thought to be more of a risk for airline pilots, who receive regular training how to recognize the symptoms of hypoxia due to the higher altitudes they use on a regular basis. During a transatlantic flight, an airliner experienced what is known as a 'stuck valve,' which causes a pressurization leak. "…the cabin altitude reached between 15,000 and 20,000 ft MSL (between 4572 and 6096 m). The pilot in command had recognized the issue, donned his oxygen mask, and descended to below 10,000 ft (3048 m) as corrective action while the senior crew chief took over the emergency procedures checklist to resolve the valve malfunction[3]." This study has a focus of pressurized aircraft,

which would typically be airliners and jets that can fly at higher altitudes. The report then details how quickly the pilots can recover from various periods of time in a pressurization leak. This report highlights the fact that the pilot in this scenario was able to recognize his symptoms and don his oxygen mask, a luxury most general aviation pilots do not have. It is rare to find general aviation pilots using oxygen equipment, even though there are a large majority of general aviation aircraft that are able to reach altitudes where performance is affected, as seen in the previous FAA study. It should also be noted that airline pilots receive routine training on recognition of hypoxia symptoms, something that is not required or promoted in general aviation. While this report articulates the short time pilots have to recover from such a dangerous situation, it does not report the frequency of the event or techniques used to recover from the hypoxic event.

Because any form of flight physiology training is not required for general aviation, it is rare to find a general aviation pilot that has taken a flight physiology course. The organization that carries the most intense physiology training is by far military aviation. Annual hypobaric chamber training is required for all fixed-wing crewmembers. "The U.S. Air Force showed that 80% of pilots who had not received previous training required up to 15 s [*sic*] to don their oxygen masks. However, there was no comparison with those who did have previous training[4]." This study stresses the importance of previous training based on reaction time of recognizing symptoms. It is widely taught that experience in a hypobaric chamber can help pilots recognize their own personal symptoms of hypoxia faster and therefore react faster. The study goes on to say, "an analysis of reported hypoxia incidents in the Australian Defense Force from June 1990 through March 2001 revealed that 76% of cases were self-recognized, while 10% were recognized by another crewmember, and 14% were unrecognized[4]." While nearly all-military flight activities involve more than one crewmember, general aviation flight is very capable with only one pilot and therefore does not have that other crewmember to recognize their hypoxic symptoms. This report articulates the problem that general aviation pilots are mostly single resource management and do not require flight physiology training, which leads to higher risks of unrecognized symptoms of hypoxia.

There is a similar study from the military aviation field that focuses on previous physiological training reaction and recognition versus acute experience. The study found that "during acute hypoxia, 65% of aircrew experienced the five symptoms they remembered to be dominant from previous training; 57% of aircrew remembered from previous training the symptoms that dominated their experience of acute hypoxia[7]." While this study carries over a crucial point, it involved the use of military pilots with equipment that is readily available to them for training.

There are numerous studies done on how effected pilots can become even at altitudes familiar to general aviation pilots. One such study "was to examine how oxygen deprivation below 14,000 ft. affects pilot performance… at simulated altitudes of 5,000 ft. and 14,000 ft[5]." While these studies are focusing on flight conditions that would affect the general aviation community, they do not maintain any statistics of level of experience or recognition of symptoms, a critical piece to this research.

Everyone in the aviation community has heard of hypoxia accidents caused by pilot error or equipment malfunctions that have ended in death. But very rarely do they ever hear of those pilots that survive the hypoxic event without a scratch on them or the aircraft. The aviation community does not even have statistics as to how often such detrimental physiological effects occur.

Without these statistics the general aviation world has little knowledge of the common causation or how these pilots are able to recover from the impairment. One of the rare exceptions of these hypoxia survival stories is the flight of Kalitta KFS-66. En-route from Manassas, VA to Detroit Willow Run Airport at flight level 320, " the primary controller Jay McCombs tried to understand, with the help of a second pilot in another aircraft, what the crew was reporting; his colleague Stephanie Bevins tuned the radio frequency and recognized that the crew was suffering from severe hypoxia[6]." With the help of Cleveland air traffic controllers, the flight was able to descend to 11,000 feet and land safely. Currently there are no statistics for the way pilots recover from hypoxia, be it from their own recognition and action or the assistance of another crewmember or air traffic control. Although Kalitta KFS-66 is a great example of a flight crew that did survive a hypoxic event in normal flight operations, it is not safe to assume that air traffic control plays a role in helping pilots recover from hypoxia in every situation and that many instances go unreported.

There may be many reasons why a pilot chooses not to report a hypoxic event, such as fear of retribution for lack of training, any unsafe conditions that may have developed from their impairment or, because they survived the condition, they felt a report was not necessary. It is hard to determine the exact reasons why every pilot chooses to not file a report, even anonymously, or know the rate of how often reports are filed because the data is confidential. Without these reports the aviation community does not have a baseline of data to build mitigation and training to prevent more of these incidents from occurring.

4. Results of Study

"Pilots must understand that the signs and symptoms of hypoxia are as varied and individual as the person experiencing them. Pilots who are hypoxic will experience (most of the time) similar signs and symptoms. However, the signs and symptoms may appear in a different order and in varying intensities[1]."

While not everyone will experience the same symptoms when they encounter hypoxia, there are a few symptoms that are commonly reported such as lightheadedness, headache, shortness of breath, dizziness, cyanosis, tunnel vision, and air hunger. Unfortunately, because hypoxia has at least four different causes, it is possible to experience hypoxia at any altitude. Out of the 200 respondents of the study, 15% of them experienced their hypoxic event at altitudes of 10,000 feet or below, an altitude, which by law, is not required to carry or use supplemental oxygen.

Of that 15%, several pilots had specific responses as to what they experienced. One commented that they "could not interpret the altimeter," while others reported sleepiness, blurred vision and color detection deterioration. This data shows that like the study done of pilots between 5,000 and 14,000 feet, pilots can experience symptoms of hypoxia that make controlling the aircraft safely exponentially more unlikely. These symptoms are more harmful if one considers that general aviation pilots are less experienced than commercial pilots, as seen by the average survey demographic of 25-45 years of age, the highest certificate of private pilot and 1,000-5,000 hours of flying time.

10,000 Feet or Less	Reduced Vision	Mental Confusion	Dizziness	Sleepiness	Lightheaded	Headache	Euphoria	Other
Symptoms (26 participants)	**11%**	**36%**	**23%**	**16%**	**39%**	**16%**	**13%**	**42%**

Figure 1. Hypoxic Event at Altitudes of 10,000 Feet or Less

10,000 – 20,000 Feet	Reduced Vision	Mental Confusion	Dizziness	Sleepiness	Lightheaded	Headache	Euphoria	Other
Symptoms (130 participants)	**12%**	**16%**	**18%**	**19%**	**42%**	**29%**	**17%**	**39%**

Figure 2. Hypoxic Event at Altitudes of 10,000 – 20,000 Feet or Less

There were no definitive trends of altitude levels with common symptoms experienced, as seen in Figure 1 and Figure 2, most likely due to the various health histories and different body sizes of the pilots involved. The category of "other" is a free response of participants that allowed them to describe uncommon symptoms that did not fit the categories available, such as warming sensations, tingling, irritability and anxiety. The largest reported altitude range that participants experienced hypoxia was between 10,000 and 20,000 feet at 72%. This significance demonstrates that pilots can experience the detrimental effects of hypoxia at altitudes that are accessible to general aviation aircraft and at altitudes that do not legally require oxygen.

With symptoms such as mental confusion and sleepiness, it is easy to see why so many pilots have perished experiencing hypoxia. Many may not even recognize what they are experiencing is hypoxia. The fortunate individuals who survived their hypoxic occurrence in this study were asked if they reported their event to any recording agency or authority; out of the 200 respondents, 94% did not report their hypoxic event to anyone. Of the 6% that did, the authority that they did report to varied from air traffic control centers, to their flight instructor, to a flight surgeon and medical examiners. This large degree of variance to whom the event was reported was most likely due to the fact that there is not a specifically designated reporting agency for flight physiology events and there is no legal requirement to report any such event.

10,000 Feet or Less	Out of 26 Participants
Did Report	**8%**
Did Not Report	**92%**

Figure 3. Reported Hypoxia Altitude Conditions at 10,000 Feet or Less

10,000 – 20,000 Feet	Out of 130 Participants
Did Report	**3%**
Did Not Report	**97%**

Figure 4. Reported Hypoxia Altitude Conditions at 10,000 – 20,000 Feet or Less

As for the 94% that did not report their hypoxia, their reasoning for why not was mostly that there was no requirement to report it, they did not recognize that it was hypoxia or the significance of it, and/or that they recovered safely by descending or applying oxygen. There was one pilot that reported they were not allowed to fly at high altitudes and therefore feared retribution by reporting their event; two other pilots that claimed they were not acting as pilot in command and therefore felt it was not their place to report it. There were two pilots that said they did not know how to report their experience. There was a small difference in the number that reported their hypoxia in a lower altitude condition than the 10,000 to 20,000 feet group, as seen in Figure 3 and Figure 4. This could simply be because the pool of responses was larger at the 10,000 to 20,000 feet range. Had there been a way for these pilots to report their hypoxic event, statistics on frequency and symptoms compared with altitude and pilot experience could have shown trends of hypoxic experience and therefore provided insight to hypoxia prevention at these altitudes significant to general aviation.

Participants were also asked if they had had any previous hypoxia training, such as a hypobaric chamber, stemming from the military study that showed a significant reduction in recognition time for those that had previously experienced hypoxia. Surprisingly, there was not a large difference in those that had a hypobaric chamber experience and those that had not. Even comparing the pilots in Figure 5 and Figure 6 at low altitude, to those between 10,000 and 20,000 feet does not have a significant difference of those with chamber experience.

10,000 Feet or Less	Out of 27 Participants
Previous Physical Hypoxia Training	**41%**
No Previous Hypoxia Training	**59%**

Figure 5. Hypobaric Chamber Experience at 10,000 Feet or Less

10,000 - 20,000 Feet	Out of 135 Participants
Previous Physical Hypoxia Training	**36%**
No Previous Hypoxia Training	**64%**

Figure 6 Hypobaric Chamber Experience at 10,000 – 20,000 Feet or Less

This may be the most interesting data, in that it is widely recognized that having a hypobaric chamber ride is very effective in allowing one to experience their specific symptoms of hypoxia; however, the average price to participate in one chamber ride is approximately $200 and the free hypobaric chamber ride course sponsored by the FAA in Oklahoma City has a waiting list of at least 6 months. In other words, a hypobaric chamber is not readily accessible to most pilots, particularly in general aviation. It is very common to see that pilots get a chamber ride in the military, as it is required annually for fixed-wing pilots. Out of the 78 participants that had completed a hypobaric chamber ride prior to their hypoxic event, 53% had their chamber ride in the military. However, the pilots who had a civilian chamber ride were then asked if they were required to participate by their training program or if they went on their own initiative. This would show if pilots found personal motivation in learning more about hypoxia. Out of the 69 participants who answered affirmative regarding civilian training, 83% went on their own initiative. This significance in personal motivation shows that despite the scarcity of required training of hypoxia, the general aviation community

has an interest in bettering their understanding of the effects and severity of hypoxia. Perhaps if training devices were more readily available, more general aviation pilots would use them.

5. Recommendations

The problems that were identified in this study demonstrated there is personal curiosity from the general aviation community to learn more about hypoxia from training devices such as a hypobaric chamber, but lack the availability and regulation to do so. This lack of availability of training devices most likely stems from the attitude that general aviation aircraft are less likely to encounter altitudes that would be more susceptible to hypoxia; however, as seen in the data from this study, general aviation pilots experienced severe symptoms of hypoxia even at lower altitudes of 10,000 feet or less. Even more damaging is the fact that hypoxia is happening to less trained and unsuspecting general aviation pilots who may not recognized their symptoms as hypoxia.

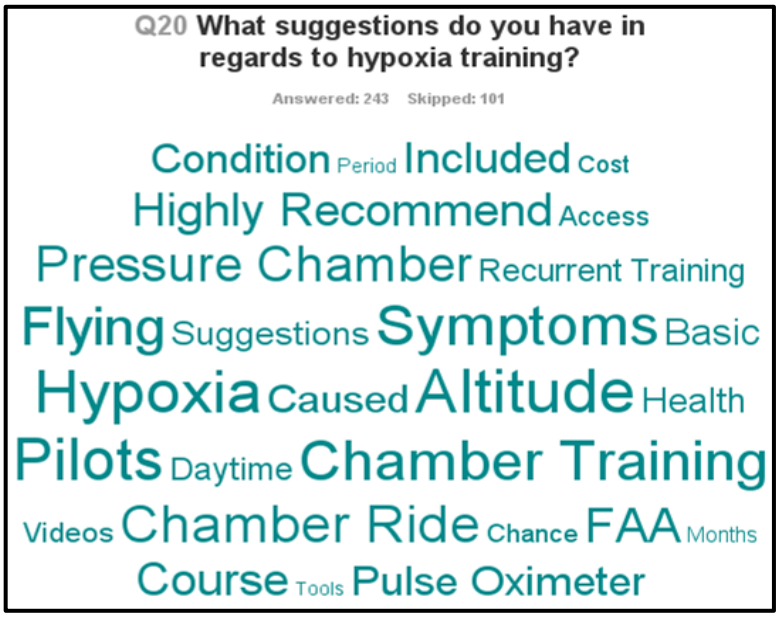

Figure 7. Suggestions Participants Had Regarding Hypoxia Training

The final question of the survey was a free response question open to everyone who took the survey, including those that had not experience hypoxia. The question, as seen in Figure 7 asked participants what suggestions they had in regards to hypoxia training. Figure 7 displays a word cloud that identifies the most used words in a free response format; the bigger the word shown, the more it was used. Out of the 243 responses, 10% said they wanted more availability of hypobaric chamber rides, which speaks to the 83% of those that did a hypobaric chamber ride on their own initiative, in that most of the general aviation population would likely do a hypobaric chamber ride if it was more available. Almost 40% of responses suggested having pilots do at least one chamber ride in order to recognize their symptoms before certain high altitude flights or higher certificates. Out of all the responses, the most common recommendation was to put an emphasis on or add to hypoxia training as well as highly recommend regular training, either annually or by certificate. Therefore, the conclusion can be made that training tools such as hypobaric chamber rides and pulse oximeters should be more widely available, so as to help general aviation pilots better recognize the symptoms of hypoxia.

The other major issue besides training tools being available is the absence of a singular reporting authority of flight physiology events. Most of the responses of the 94% that did not report their hypoxic event claimed that it was not required and that they did not see the significance of reporting it. If a single authority reporting channel was advertised as an anonymous source to help fellow pilots from experiencing similar hazards, pilots would be more likely to report their hypoxia experiences. The more data provided from general aviation pilots who experienced hypoxia, the more likely further research into common symptoms for people with certain health conditions and body masses could be

conducted. Furthermore, the results from that data, showing the disturbing fact that 15% of pilots who experience hypoxia at lower altitudes where oxygen is not required, would put an emphasis on training general aviation pilots of the hazards of hypoxia.

Embry-Riddle Aeronautical University, Prescott Campus sits at an elevation of over 5,000 feet, with a flight program that uses general aviation aircraft and sees hundreds of flights per day. This large amount of flights, with altitudes flown between 5,000 and 11,500 feet regularly, the flight program at Embry-Riddle Prescott would be a prime data-logging point for general aviation hypoxia studies. Further research could be done on the student pilots of Embry-Riddle Prescott by having them carry pulse oximeters, while monitoring and recording their performance data over a period of time. This research could provide insight into the effects of higher elevation flying, particularly the effects of this condition over time.

6. Conclusion

This study showed the common perception that general aviation pilots are less susceptible to hypoxia is invalid and that should hypoxia-training tools, such as a hypobaric chamber, become more available, they would be put to great use in the general aviation community. Additionally, it was seen that pilots who do experience hypoxia do not report their experience due to the absence of a single reporting authority and the lack of emphasis put on hypoxia in general aviation training. The change of reporting and the change of attitude towards hypoxia in the general aviation community could help prevent future hypoxia-related accidents.

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