

ORIGINAL ARTICLE

Subjective Symptoms In Hypoxia of Military Aircraft Aircrews, Relationship With Age And Oxygen Saturation: A Cross-Sectional Study

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ABSTRACT

Introduction: Hypobaric hypoxia is a condition that occurs at altitudes above 25,000 feet, where a decrease in barometric pressure causes reduced oxygen availability. This condition impacts physiological and psychological function, causing symptoms such as dizziness, fatigue, headaches, and decreased oxygen saturation. Although this condition is essential for military aircraft crews who frequently operate at these altitudes, there is a lack of research that explicitly explores its impact, especially regarding subjective symptoms and oxygen saturation. **Objective:** To evaluate and understand the effect of hypoxia on the subjective symptoms experienced by military aircrew and its effect on their oxygen saturation when operating at high altitudes and determine the relationship of subjective symptoms differentiated by age and saturation. **Methods:** This is a prospective, controlled, cross-sectional study conducted at a single center, recruiting 64 military aircrew members for a one-time session that includes an intermediate phase and subsequent hypoxia exposure in a high-altitude chamber. **Result:** The study gathered data on physiological responses to hypobaric conditions at 25,000 feet in a hypobaric chamber, detailing subjective symptoms and reduced oxygen saturation levels during hypoxia at this altitude. Noted hypoxia symptoms included dizziness, tingling, a floating feeling, and memory lapses. Additionally, oxygen saturation levels were observed to drop below 70%. The hypoxia observed in the study was attributed to altitude, with an understanding that higher elevations result in lower partial pressure. **Conclusion:** These findings conclude that physiological changes in subjective symptoms and oxygen saturation occur in military aircraft crew experiencing hypoxia at an altitude of 25,000 feet. No significant correlation was found between age, saturation and the subjective symptoms experienced, except for muscle weakness, which appears to be more common in individuals over 33 years of age.

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INTRODUCTION

Hypoxia is a threat in carrying out flying duties, especially in the military, because the flight environment is dynamic.(1) Damage to the pressurized cabin system, damage to the oxygen source in the aircraft, or because the pilot does not use an oxygen mask when climbing at altitudes above 10,000 feet are causes of hypoxia,

which is a threat to flight safety.(1,2) Over the last decades in the United States there have been problems with cabin pressure, causing hypoxia in several military fighter pilots including the F/A-18 Hornet, F-22 Raptor, F-35 Joint Strike Fighter, A-10 Thunderbolt, and T-45 Jet aircraft. Data from the United States Air Force (USAF) states that from 1981 to 2003, 221 or about 21% of incidents related to hypoxia were caused by pressure problems in the cabin. (2) Reports from the United States Navy also showed an increase in incidents of hypoxia on military flights. The navy from 2010 to 2017, wherein 2010 hypoxic events occurred 12 times out of 100,000 flight hours, and in 2017 occurred more than 101 times

out of 100,000 flight hours.(3) Hypoxia, often associated with altitude in flight, is referred to as hypobaric hypoxia.

One sign of hypoxia is impaired cognitive function due to a lack of oxygen supply to brain cells. This cognitive impairment causes reduced working memory, impaired decision-making, adverse effects on oculomotor activity, and decreased performance in flying tasks. This cognitive impairment affects the loss of the pilot's ability to implement emergency recovery procedures in critical flight conditions.(3,4) The slightest decreased cognitive function while flying can cause life-threatening errors and flight safety. One study found that more than 20% of research subjects did not take emergency action when experiencing hypoxia.(2,5) research in 2019 showed a significant decrease in cognitive function at an altitude of 25,000 feet without supplemental oxygen in 41.9% of research subjects, whereas 58.1% did not experience impaired cognitive function.(5)

This study aims to analyze the relationship between the level of hypoxic exposure at an altitude of 25,000 feet with the severity of subjective symptoms and decreased oxygen saturation among military aircraft crew. Meanwhile, the benefits are to develop intervention strategies, safety protocols, and technological innovations designed to improve the performance and safety of flight crews when operating at high altitudes while minimizing the risks and adverse effects of hypoxia.

MATERIALS AND METHODS

Approval for the research was granted by the Ethical Committee of the Faculty of Medicine at the University of Indonesia – Cipto Mangunkusumo Hospital, evidenced by the reference number KET-1253/UN2.F1/ETIK/PPM.00.02/2022. This study adopted a cross-sectional methodology and purposive sampling technique to examine the impact of hypoxia on military aircrews, selecting individuals frequently exposed to high-altitude conditions. This study aimed to understand the dynamics between hypoxia and its effects on physiological and psychological health at 25,000 feet by including 64 military aircraft crew members in the sample. This sample size was chosen to ensure the statistical validity of the findings while considering recruitment challenges and the uniqueness of the population studied.

The study's eligibility criteria included pilots undergoing the Medical Examination (MEDEX) and Aerophysiology Training Indoctrination (ILA) at Lakespra dr Saryanto Jakarta during the research period, who expressed their willingness to participate by signing a consent form. The study excluded pilots with respiratory conditions that posed risks of airborne or cardiovascular transmission, sinus issues, or incomplete dental fillings. Additionally, pilots were disqualified if they had abnormal results on

psychiatric evaluations, were obese according to their Body Mass Index (BMI), used medications impacting the central nervous system (such as antidepressants, antihistamines, or cold remedies), consumed alcohol within 24 hours before the study, experienced pain in their ears, nasal passages, sinuses, or teeth, or had smoked within 5 hours before undergoing the examination.

Sixty-four pilots were observed at altitudes of 25,000 and more than 25,000 feet without oxygen masks and subsequently evaluated their cognitive function. Cognitive and mathematical tests are performed for about 3-4 minutes. During this process, observers closely monitored participants' oxygen saturation levels and overall health. The number of observers in this study was 1 person. The collected data is then processed and further analyzed.

Chi-square test analysis was applied to evaluate subjective symptoms, oxygen saturation, and age of subjects in this study. Statistical significance was set at the $p < 0.005$ level, indicating that results with a probability of less than 0.005 were considered statistically significant.

RESULT

Table I provides a detailed description of the effects of hypobaric conditions at 25,000 feet on the 64 study subjects, highlighting the subjective symptoms experienced, their oxygen saturation levels, and their age profile. Data analysis showed that the most common subjective symptom reported by respondents was a feeling of floating (31.3%), followed by tingling (26.6%), dizziness (25%), and forgetfulness (21.9%), with other symptoms such as blurred vision, shortness of breath. Shortness of breath, muscle weakness, flatulence, chills, and headaches have also been reported. A decrease in oxygen saturation levels below 70%, experienced by 65.6% of respondents, indicates the significant impact of hypoxia at this altitude. Demographically, respondents were divided into two age groups, with more than half (54.7%) under 33 years of age, while the remainder (45.3%) were over 33 years of age, indicating a reasonably even age distribution among study participants. This table effectively highlights how the subjective experience of hypoxia, changes in oxygen saturation, and age variables are interrelated in extreme environments, providing important insight into the impact of hypobaric conditions on individuals.

Table II analyses the relationship between respondents' age and the subjective symptoms they experienced. It was analyzed using the chi-square test and correlation coefficient in a study involving 64 flight crew members. Data is divided into two age groups: those aged 33 years and under and those over 33 years. The analysis includes a variety of subjective symptoms such as floating feelings, tingling, dizziness, forgetfulness, blurred vision, shortness of breath, muscle weakness, flatulence, chills,

Table I. Description of Subjective Symptoms, Saturation, and Age of Respondents

Variables	Category			
	Yes	%	No	%
A. Subject symptoms				
Feeling like floating	20	31.3	44	68.8
Tingling	17	26.6	47	73.4
Dizziness	16	25	48	75
Easy to forget	14	21.9	50	78.1
Blurred vision	13	20.3	51	79.7
Short of breath	12	18.8	52	81.3
Weak muscles	11	17.2	53	82.8
Bloated	9	14.1	55	85.9
Shiver	8	12.5	56	87.5
Headache	4	6.3	60	93.8
Etc	12	18.8	52	81.3
B. Saturation				
≤ 70%	42	65.6		
> 70%	22	34.4		
C. Ages				
≤ 33 yo	35	54.7		
> 33 yo	25	45.3		

headaches, etc. The results showed that most subjective symptoms had no significant relationship with the age group, indicated by P values generally higher than 0.05 and low correlation coefficients. However, there is an exception for the symptom of muscle weakness, where all cases were reported by respondents over 33 years, indicating a stronger and more significant relationship between age and this symptom, as evidenced by a P value of 0.000 and a correlation coefficient of 0.448. In conclusion, the findings from Table II indicate that although most subjective symptoms are not significantly affected by age, there are indications that some specific conditions, such as muscle weakness, may be more common or severe in certain age groups.

Table II. Relationship Between Age and Subjective Symptoms

Subject symptoms	≤ 33yo (N=35)		> 33 yo (N=29)		Total N(%)	p-value*	CC**	
	N (%)		N (%)					
	Yes	No	Yes	No				
No								
1 Feeling like floating	12 (60)	23 (52.3)	8(40)	21(47.7)	20(31.25)	44(68.75)	0.76	0.07
2 Tingling	7 (41.2)	28 (59.6)	10(58.8)	19(40.4)	17(26.56)	47(73.44)	0.31	0.16
3 Dizziness	8 (50)	27 (56.2)	8(50)	21(43.8)	16(25)	48(75)	0.89	0.05
4 Easy to forget	7 (50)	28 (56)	7(50)	22(44)	14(21.88)	50(78.13)	0.92	0.05
5 Blurred vision	7 (53.8)	28 (54.9)	6(46.2)	23(45.1)	13(20.31)	51(79.69)	1.00	0.01
6 Short of breath	8 (66.7)	27 (51.9)	4(33.3)	25(48.1)	12(18.75)	52(81.25)	0.55	0.12
7 Weak muscles	0 (0)	35 (66)	11(100)	18(34)	11(17.19)	53(82.81)	0.00**	0.45
8 Bloated	6(66.7)	29(52.7)	3(33.3)	26(47.3)	9(14.06)	55(85.94)	0.49	0.10
9 Shiver	5 (62.5)	30 (53.6)	3(37.5)	26(46.4)	8(12.5)	56(87.5)	0.72	0.06
10 Headache	2(50)	33(55)	2(50)	27(45)	4(6.25)	60(93.75)	1.00	0.02
11 Etc	4(33.3)	31(59.6)	8(66.7)	21(40.4)	12(18.75)	52(81.25)	0.19	0.20

* Chi-square test; ** CC=Correlation coefficient; p< 0.05 is significant value and significance strong correlation

Table III explores the relationship between oxygen saturation levels and subjective symptoms among 64 flight crew members, categorizing data based on ≤ 70% and > 70% oxygen saturation levels. The analysis

Table III Relationship Between Saturation and Subjective Symptoms

No	Subject symptoms	≤ 70% (N=42)				> 70% (N=22)				Total	p-value*	CC**
		Yes		No		Yes		No				
		N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)			
1	Feeling like floating	16(80)	26(59.1)	4(20)	18(40.9)	20(31.25)	44(68.75)	1.00	0.00			
2	Tingling	12(70.6)	30(63.8)	5(29.4)	17(36.2)	17(26.56)	47(73.44)	0.18	0.20			
3	Dizziness	9(56.2)	33(68.8)	7(43.8)	15(31.2)	16(25)	48(75)	0.84	0.06			
4	Easy to forget	10(71.4)	32(64)	4(28.6)	18(36)	14(21.88)	50(78.13)	0.54	0.11			
5	Blurred vision	8(61.5)	34(66.7)	5(38.5)	17(33.3)	13(29.31)	51(79.69)	0.76	0.07			
6	Short of breath	6(50)	36(69.2)	6(50)	16(30.8)	12(18.75)	52(81.25)	0.75	0.04			
7	Weak muscles	8(72.7)	34(64.2)	3(27.3)	19(35.8)	11(17.19)	53(82.81)	0.31	0.16			
8	Bloated	6(66.7)	36(65.5)	3(33.3)	19(34.5)	9(14.06)	55(85.94)	0.74	0.07			
9	Shiver	6(75)	36(64.3)	2(25)	20(35.7)	8(12.5)	56(87.5)	1.00	0.01			
10	Headache	2(50)	40(66.7)	2(50)	20(33.3)	4(6.25)	60(93.75)	0.70	0.07			
11	Etc	7(58.3)	35(67.3)	5(41.7)	17(32.7)	12(18.75)	52(81.25)	0.60	0.09			

* Chi-square test; ** CC=Correlation coefficient, p< 0.05 is significant value and significance strong correlation

covered a range of subjective symptoms, such as feelings of floating, tingling, dizziness, forgetfulness, blurred vision, shortness of breath, muscle weakness, flatulence, chills, and headaches, assessing the strength and significance of their association with oxygen saturation through P values and correlation coefficients. Results indicated no significant relationship between most subjective symptoms and oxygen saturation levels, with P values typically above 0.005 and minimal correlation coefficients, suggesting a weak link. For instance, the floating sensation showed a P value of 1.000 and a correlation coefficient of 0.002. Furthermore, the chi-square test findings revealed no statistically significant difference in the prevalence of subjective symptoms across different oxygen saturation levels. This suggests an equitable distribution of symptoms among participants, irrespective of their oxygen saturation being below or above 70%. This comprehensive analysis concludes that there is no substantial correlation between oxygen saturation levels and the occurrence of subjective symptoms in the study's flight crew sample.

DISCUSSION

Each high-altitude zone of the atmosphere has different characteristics based on altitude and physical and chemical components. The division of zones based on the physiological impact on the human body is divided into three zones, namely the Physiological efficient zone (0-10,000 feet), the Physiological deficient zone (10,000-50,000 feet), and the space equivalent zone (above 50,000 feet).(2,6) The physiological deficient zone is the altitude zone where most aircraft perform cruising.(7) The physiological deficient zone is divided into several zones, namely(8): zones of complete compensation at 10,000 feet - 15,000 feet. In this zone, oxygen saturation will drop to 80-87%, which causes an increase in heart rate and ventilation, where human efficiency drops to around 25%; the zone of incomplete compensation is at an altitude of 15,000 - 23,000 feet. In this zone, oxygen saturation drops to around 65-70%. Even in resting conditions, substantial vegetative, psychological, and motor symptoms begin to appear, and the last is the critical zone, which occurs at an altitude of 23,000 feet to 50,000 feet. This zone is where all the human body functions will fall rapidly.(7)

One sign of hypoxia is impaired cognitive function due to a lack of oxygen supply to brain cells. This cognitive impairment causes reduced working memory, impaired decision-making, negative effects on oculomotor activity, and decreased performance in flying tasks. This cognitive impairment affects the loss of the pilot's ability to apply emergency recovery procedures in critical flight conditions.(3,4) The slightest decreased cognitive function while flying can cause life-threatening errors and flight safety.

One study found that more than 20% of research subjects did not take emergency action when experiencing hypoxia. Research in 2019 showed a significant decrease in cognitive function at an altitude of 25,000 feet without supplemental oxygen in 41.9% of research subjects, whereas 58.1% did not experience impaired cognitive function.(9)

The first objective of the study was to evaluate and understand the effect of hypoxia on subjective symptoms experienced by military aircrew and its effect on their oxygen saturation when operating at high altitude. In addition to evaluating descriptively, this study explores further according to existing data on patients, namely examining the relationship between age and saturation factors with subjective symptoms. In this study, the division of subjective symptoms of age in less than more than 33 years is based on the results of statistical testing, namely from the median value of the data. Testing based on the median is a common thing to do in statistics if the theoretical basis for age division is still relatively weak. While saturation above and below 70%

because saturation below 70% is saturation that begins to endanger and even fatal to the body.

The individual factor that influences a pilot's tolerance of hypoxia is age.(10) This study showed that the results of tests on subjective symptoms showed no significant difference between the ages of <33 years and >33 years. In other words, there was no significant relationship between subjective symptoms, including a feeling of floating, tingling, dizziness, forgetfulness, blurred vision, shortness of breath, flatulence, tremors, headaches, and others with the patient's age demographic profile. Age is associated with degenerative processes in neuron cells, which, of course, affect cognitive function. However, age also has a protective factor against the emergence of hypoxic symptoms due to the experience of hypoxia and flying experience, which increases with age, so this is relevant to the results of this study.(11)

Acute exposure to hypobaric hypoxia results in decreased oxygen saturation, compensatory increases in heart rate or tachycardia, blood pressure, cardiac output, total peripheral resistance, vasoconstriction, and ventricular contractility.(12,13) Cardiovascular changes also influence hypoxia-induced respiratory adaptations. The heart is the main organ responsible for pumping blood throughout the body and ensuring optimal oxygen delivery to each organ system.(13)

The chi-square test results in this study show that the relationship between age and the most significant subjective symptom felt by aircrew is a symptom of muscle weakness. This means that in the age group > 33 years, symptoms of muscle weakness are more common than in those aged < 33 years. However, in this study, it was also known that patients who stated that they did not experience subjective symptoms had a distribution almost the same as patients who experienced subjective symptoms. This shows that patients who feel subjective symptoms and those who do not think subjective symptoms are distributed virtually the same at saturation < 70% and > 70%. Even though the data in the group that said yes, there were subjective symptoms was at saturation <70%, the percentage was still not too big a difference from the saturation group > 70% and those who said they did not feel symptoms, so the test results were not significantly related. The absence of differences in subjective symptoms in this study is due to pilots who have been exposed to hypoxic conditions so that their bodies have adapted physiologically.

Based on the research findings, specific recommendations are made for educational institutions and pilots regarding the risk of hypoxia. Educational institutions offering pilot training programs are encouraged to integrate materials covering the risks of hypoxia, symptom identification, and management strategies into their training curriculum. This includes the importance of hypobaric condition simulation sessions to adequately

prepare prospective pilots to recognize and respond to hypoxia symptoms, emphasizing health and flight safety. For pilots, increasing awareness and knowledge about hypoxia, readiness to take corrective actions, and the importance of undergoing regular health examinations are crucial to minimizing risks.

The limitation of this study is that it uses a cross-sectional design and does not conduct longitudinal or long-term studies to see the relationship between hypoxia and subjective symptoms. Furthermore, researchers highlight the necessity for further research, particularly longitudinal studies evaluating the long-term effects of hypoxia and its potential impact on the health of flight crew. Research on more effective hypoxia prevention technologies and strategies, as well as studies focusing on individual response differences to hypoxia—including genetic factors and health conditions—are critically needed. These efforts are expected to strengthen flight crews' safety and health and identify more effective and personalized hypoxia prevention and management approaches.

CONCLUSION

This study indicates that at an altitude of 25,000 feet, participants' commonly experienced subjective symptoms include feelings of floating, tingling, dizziness, and forgetfulness. A decrease in oxygen saturation below 70% was experienced by participants, indicating impact of hypoxia at that altitude. However, no significant correlation was found between age and the subjective symptoms experienced, except for muscle weakness, which appears to be more common in certain age groups. The results also suggest that there is no substantial correlation between oxygen saturation levels and the occurrence of subjective symptoms. This conclusion implies the importance of a deeper understanding of the body's response to hypoxia and the need for further research to identify the factors influencing these subjective symptoms.

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REFERENCES

1. Gradwell D, Rainford D, editors. *Ernsting's Aviation and Space Medicine* 5E. CRC Press; 2016 Jan 20.
2. Shaw DM, Cabre G GN. Hypoxic hypoxia and brain function in military aviation: basic physiology and applied perspectives. *Front Physiol.* 2021; 17:12:665821. doi: 10.3389/fphys.2021.665821.
3. Leinonen A, Varis N, Kokki H, Leino TK. Normobaric hypoxia training in military aviation and subsequent hypoxia symptom

- recognition. *Ergonomics*. 2021;64(4):545–52. doi: 10.1080/00140139.2020.1842514
4. Pun M, Guadagni V, Bettauer KM, Drogos LL, Aitken J, Hartmann SE, et al. Effects on cognitive functioning of acute, subacute and repeated exposures to high altitude. *Front Physiol*. 2018;9:1131. doi: 10.3389/fphys.2018.01131
 5. Bailey DM. Oxygen and brain death; back from the brink. *Exp Physiol*. 2019;104(12):1769–79. doi: 10.1113/EP088005
 6. Dewi S, Mulyawan W, Wanandi SI, Sadikin M. The effect of intermittent hypobaric hypoxia on oxidative stress status and antioxidant enzymes activity in rat brain. *Acta Biochim Indones*. 2018;1(2):46–51. doi.org/10.32889/actabioina.v1i2.16
 7. Davis JR, Johnson R, Stepanek J et al. *Fundamentals of aerospace medicine: Fourth edition*. 2011.
 8. Wirth D, Rumberger E. *Fundamentals of aviation physiology*. Princ Pract Aviat Med Singapore World Sci Publ. 2009;71–149.
 9. Bustamante-Sánchez Á, Delgado-Ter6n M, Clemente-Su6rez VJ. Psychophysiological response of different aircrew in normobaric hypoxia training. *Ergonomics*. 2019;62(2):277–85. doi: 10.1080/00140139.2018.1510541.
 10. Dzhililova D, Makarova O. Differences in tolerance to hypoxia: physiological, biochemical, and molecular-biological characteristics. *Biomedicines*. 2020;8(10):428. doi: 10.3390/biomedicines8100428.
 11. Sucipta IJ, Adi NP, Kaunang D. Relationship of fatigue, physical fitness and cardiovascular endurance to the hypoxic response of military pilots in Indonesia. In: *Journal of Physics: Conference Series*. IOP Publishing; 2018. p. 42044. doi:10.1088/1742-6596/1073/4/042044
 12. Theunissen S, Balestra C, Bolognāsi S, Borgers G, Vissenaeken D, Obeid G, et al. Effects of acute hypobaric hypoxia exposure on cardiovascular function in unacclimatized healthy subjects: A “rapid ascent” hypobaric chamber study. *Int J Environ Res Public Health*. 2022;19(9):5394. doi:10.3390%2Fijerph19095394
 13. Lindsey BG, Nuding SC, Segers LS, Morris KF. Carotid bodies and the integrated cardiorespiratory response to hypoxia. *Physiology*. 2018;33(4):281–97. doi:10.1152%2Fphysiol.00014.2018