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THE EFFECT OF THE ALTITUDE ZONE ON COGNITIVE FUNCTION FOR MALE PILOTS IN INDOCTRINATION AND AEROPHYSIOLOGY TRAINING IN 2019

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ABSTRACT

Objective: A pilot on duty at altitude can be exposed to hypoxia, both mild and severe. The incidence of hypoxia on a flight can be fatal, especially if hypoxia is experienced by a pilot on duty. One manifestation of hypoxia is decreased cognitive function. A pilot is required to carry out multitasking operations using cognitive functions, especially in an emergency. Therefore, decreased cognitive function due to hypoxia in a pilot can cause accidents in flight. This study aims to determine changes in cognitive function with hypoxia exposure at several altitude zones.

Methods: This study used an experimental one-group pretest-posttest design. The subjects were 31 military pilots who participated in Indoctrination and Aerophysiology Training. Subjects filled 6 Cognitive Impairment Test (6 CIT) questionnaires at ground level, efficient physiological zone (10,000 ft), and physiological deficient zone (25,000 ft) in a hypobaric chamber.

Results: There was a change of 6 CIT score at 10.000 ft compared to ground level (Friedman post-hoc Wilcoxon, P = 0.001). There was also a change of 6 CIT score at 25,000 ft compared to ground level (Friedman post-hoc Wilcoxon, P<0.001).

Conclusion: There was a change in cognitive function in the efficient physiological zone and physiological deficient zone, compared to ground level.

Keywords: Altitude, Cognitive Function, Hypoxia, Pilot

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INTRODUCTION

The International Civil Aviation Organization (ICAO) defines altitude as a vertical and upward distance measured from sea level [1]. Environmental conditions at altitude can cause various problems in flight, such as hypoxia, gas expansion, and decompression sickness. Hypoxia is a frightening problem because it happens insidiously, unconsciously, and individually; each person experiences different symptoms [2, 3]. Hypoxia that occurs during flight could be fatal, especially if it is experienced by pilots who are on duty, as was the case in the Helios Airways 737-31S accident in Grammatiko, Greece in 2005 and the Sun Aviation Learjet 35 accident in Aberdeen South Dakota, United States in 1999 [4, 5]. Hypoxia directly or indirectly affects the nervous system, which has a high demand for oxygen [3]. The effects of hypoxia on the nervous system include overconfidence, decreased psychomotor function, and decreased cognitive function [2, 6].

Cognitive function is complex, involving aspects of memory, attention, executive function, perception, language, and psychomotor functions [7]. Complex and dynamic pilot tasks in aviation require good cognitive functions in the process of aeronautical decision-making, especially during an emergency. Short-term and long-term memory will decrease due to a reduction in the partial pressure of oxygen at altitude. A decline in cognitive function in a duty pilot can cause a pilot to make the wrong decision than can lead accidents in flight. Previous studies have found that in the efficient physiological zone, there was a decrease in cognitive function, involving difficulty concentrating, memory disturbances, and reduced vision [2, 3, 8–10]. The aim of this study is to determine changes in cognitive function with hypoxia exposure in several altitude zones. Understanding the changes in cognitive function at altitude is necessary to prevent accidents caused by hypoxia in flight.

MATERIALS AND METHODS

This study used an experimental one-group pretest-posttest design. The research population is military pilots who carried out Indoctrination and Aerophysiology Training (ILA) in Jakarta from 8 May 2019 to 26 June 2019. In determining the sample size, following the recommendation of Roscoe [11], used for the rule of thumb for a sample size of 30 people [11]. A non-probability, the consecutive sampling method was used.

Inclusion criteria

a) All military pilots who carried out ILA in Jakarta when data collection was taking place; b) all pilots who carried out a medical examination before entering the hypobaric chamber; c) all pilots who were willing to take part in the study and sign the informed consent form.

Exclusion criteria

a) Pilots with sinus disorders; b) Pilots with respiratory tract diseases at risk of airborne transmission; c) Pilots with non-sinus rhythm disorders.

Drop-out criteria

All subjects who felt pain in the ear, nose, and sinus cavities when the altitude of the chamber was raised to 5,000 ft for the sinus check.

The independent variable of this study is the altitude zone, while the dependent variable is the cognitive function. The altitude zone refers to the altitude zone's effect on the body. The altitude is measured by altimetry. In this study, the altitude is divided into three zones: ground level, physiological efficient zone (10,000 ft), and physiological deficient zone (25,000 ft). The cognitive function involves aspects of orientation, attention, and memory. The data were obtained by the subject filling out questionnaires before being exposed to hypoxia (at ground level) and when exposed to hypoxia in hypobaric chambers at altitudes of 10,000 ft and 25,000 ft. The measurement method uses the 6 Cognitive Impairment Test (6 CIT) Kingshill version 2000, with a score of 0-28, which consists of six questions for the subjects to answer and was validated in England by Brooke and Bullock in 1999 [12]. The components assessed by the questionnaires were orientation, attention, and memory [12].

This questionnaire was modified in its way of asking and answering; a paper was used due to the conditions in the hypobaric chamber, which made the researchers as observers unable to directly hear the subject's verbal answers. At 10,000 ft and 25,000 ft, the subject filled a sheet of simple math question for 30 seconds, which is mandatory in ILA. It also as exposure to hypoxia, then filled 6 CIT. The given time for answering the first and second questions of the 6 CIT was 15 seconds, and for the third to the sixth questions 30 seconds. The given time based on the time of useful consciousness (TUC) at 25,000ft is three to five minutes [2]. The data were analysed using IBM SPSS Statistics version 20.

After the subjects received an explanation of the intent, purpose, and procedure of the study, they filled in the informed consent form. Then followed by the briefing about the effects of altitude exposure on the body, such as hypoxia, trapped gas, evolved gas and how overcome them if they happen in flight. All subjects filled the 6 CIT at ground level, continued to fly using oxygen up to 5,000 ft in a hypobaric chamber for the sinus check, and then returned to ground level. Subjects who felt pain in the ear and sinus cavity during the sinus check were excluded from the hypobaric chamber. The flight began again at 10,000 ft. At 10,000 ft, the subjects opened the oxygen mask and filled the 6 CIT. After completing the 6 CIT, the subjects used oxygen again and flew to 25,000 ft. At 25,000 ft, the subjects opened the oxygen mask and filled out the 6 CIT. After completing the 6 CIT, the subjects used oxygen and flew back to ground level.

RESULTS

It was found that 31 subjects fulfilled the exclusion and inclusion criteria. There was not any subject that fulfilled the drop-out criteria during the sinus check.

Table 1: Analysis of changes in cognitive function based on altitude level

Altitude	6 CIT score	P-value (Friedman)	P-value (Wilcoxon)
Ground level	0+0	<0,001	Reference
Physiological efficient zone (10,000 ft)	0,00(0-12)		0,001
Physiological deficient zone (25,000 ft)	4,00(0-14)		<0,001

Table 1 shows that there was a significant change in the 6 CIT score at ground level, efficient physiological zone (10,000 ft), and physiological deficient zone (25,000 ft) (Friedman test p<0.001). There was a significant change in 6 CIT scores at ground level and 10,000 ft (Friedman post-hoc Wilcoxon test, P = 0.001). There was also a significant change in 6 CIT scores at ground level and 25,000 ft (Friedman post-hoc Wilcoxon test, P<0.001).

DISCUSSION

In this study, a significant change in cognitive function was found from ground level to 10,000 ft. In hypoxic conditions, there is a decrease in adenosine triphosphate (ATP) production in the body, which causes a malfunction of energy-dependent membrane ion transport. Hence, glutamate transporters cannot carry glutamate from neurons that cause glutamate excitotoxicity [13–15]. The failure of the energy-dependent membrane ion transport function causes an increase in glutamate in neurons. As a consequence of glutamate increase, the glutamate will be bound by N-methyl-D-aspartate (NMDA), which is on the neuron next to it. Increased NMDA will stimulate the opening of calcium ion channels (Ca^{2+}), inducing the entry of calcium ions (Ca^{2+}) into cells. The entry of calcium ions stimulates phospholipase, endonuclease, and protease enzymes that can change the structure of neuron cells [13, 16–19]. Ernsting found that short-term and long-term memory was disrupted when PAO2 drops to 60 mmHg, which occurs at an altitude of 8,000–10,000 ft. Other research conducted by Philmanis *et al.* in 2016 stated that there was a very small change in cognitive function from the ground level to 12,000 ft, reinforcing Ernsting's finding [3, 10].

Of the 31 subjects, one subject had a 6 CIT score of 12 and 30 subjects had a 6 CIT score of 0-6. The authors suspect that the variation of 6 in the CIT scores is influenced by the subject's low tolerance for hypoxia. Tolerance to hypoxia is influenced by smoking, which decreases the ability of hemoglobin to bind with oxygen by 4–7% because the carbon dioxide contained in cigarette acids binds more easily to hemoglobin than does oxygen. Another factor is physical fitness; someone who exercises diligently will be more resistant to hypoxia because exercise can improve the ability of perfusion and ventilation in a person's respiratory system, making it easier to adapt to changes in the cardiorespiratory system caused by hypoxia. An individual's psychological conditions, such as anxiety and anger, can also reduce a person's tolerance for hypoxia because they can cause hyperventilation; emotions also can affect one's metabolic rate, making the subject more exposed to hypoxia [2, 8, 9, 20].

This study found significant changes in cognitive function at 25,000 ft when compared to ground level. This certainly supports previous research that indicated a significant decline in cognitive function in the physiological deficient zone. Asmaro, Mayall, and Ferguson found that at 17,500 ft cognitive decline occurred, especially in the short-term and working memory [21]. This current research supports this finding; with altitude exposure, many subjects answered incorrectly the questions about memory (repeat the five components of the name and address that had been mention by the researchers) and attention (count backward from 20 to 1 and mention the months of the year in reverse).

Memory and attention are important during a flight. When the aircraft is in an emergency condition, pilots are required to carry out multitasking operations using their short-term and working memory; yet their short-term and long-term memory decrease due to the reduced oxygen environment [21]. Tasks in flight are complex and dynamic, incoming information can be overloaded, and complex tasks can quickly exceed a limited attention capacity [22]. Working memory plays a role in decision-making and the implementation of dynamic and sustainable flight tasks. In such situations, the relevant long-term memory storage and automation of actions through experience and training are expected to overcome limitations in working memory [22].

A pilot must know the symptoms of cognitive function decrease due to hypoxia so that if he or his co-worker get hypoxia on duty, an efficient action could be taken immediately to prevent further exposure to hypoxia. Symptoms include not being able to remember the current month and year, not being able to count down from 20 to one, not being able to recite backward the months in a year, and not being able to remember the words given by a Flight Operation Officer (FOO) before flying.

CONCLUSION

There were changes in cognitive function in the efficient physiological zone and the physiological deficient zone, compared to the ground level.

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AUTHORS CONTRIBUTIONS

All authors have contributed equally.

CONFLICT OF INTERESTS

All authors have none to declare.

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