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FLIGHT HOURS AND BMI AGAINST TUC IN HYPOBARIC CHAMBER ALTITUDE 25.000 FEET

JAM TERBANG DAN IMT TERHADAP WSE DI RUBR KETINGGIAN 25.000 KAKI

Original Research Article
Penelitian

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A B S T R A C T

Background: *Time of Useful Consciousness (TUC) is the time interval a person can survive carrying out flight duties due to a decrease in oxygen pressure and the point at which there is a decrease in the level of consciousness. The TUC time interval is influenced by various factors including Body Mass Index (BMI) and flying hours which affect the increase in the duration of the body's exposure to hypoxic conditions in pilots.* ***Purpose:*** *This research was conducted to determine the relationship between total flight hours and BMI on TUC.* ***Method:*** *This research employed observational analytic research with a cross-sectional method. Sampling was taken by simple random sampling technique. The sample for this research included active flight crew members from Lakespra dr. Saryanto 202 who met the inclusion criteria.* ***Result:*** *There were 53 research subjects, with the results showing that 48 subjects (90.6%) had a TUC <4 minutes, and 5 subjects had a TUC >4 minutes. There were 47 subjects (88.7%) with total flight hours >1000 hours and 6 subjects (11.3%) with total flight hours <1000 hours. In BMI, 37 subjects (69.8%) had an overweight BMI, and 16 subjects (30.2%) had a normal BMI.* ***Conclusion:*** *After examining 53 subjects, it was found that there was no relationship between total flight hours and TUC (p-value = 1.000) or BMI and TUC(p-value = 0.307) in the hypobaric chamber at an altitude of 25.000 feet.*

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A B S T R A K

Latar belakang: Waktu Sadar Efektif (WSE) adalah interval waktu seseorang mampu bertahan melakukan tugas penerbangan akibat penurunan tekanan oksigen dan titik dimana adanya penurunan tingkat kesadaran. Interval waktu WSE dipengaruhi oleh berbagai faktor diantaranya yaitu Indeks Massa Tubuh (IMT) dan jam terbang yang mempengaruhi peningkatan durasi tubuh terpapar oleh kondisi hipoksia pada penerbang. **Tujuan:** Penelitian ini dilakukan untuk mengetahui hubungan total jam terbang dan IMT terhadap WSE. **Metode:** Penelitian menggunakan jenis penelitian analitik observasional dengan metode *cross-sectional*. Pengambilan sampel diambil dengan teknik *simple* random sampling. Sampel penelitian ini adalah awak pesawat aktif Lakespra dr. Saryanto tahun 2021 yang memenuhi kriteria inklusi. **Hasil:** Terdapat 53 subyek penelitian dengan hasil sebanyak 48 subyek (90,6%) memiliki WSE <4 menit dan 5 subyek memiliki WSE >4 menit, dengan total jam terbang >1000 jam sebanyak 47 subjek (88,7%) dan total jam terbang <1000 jam sebanyak 6 subjek (11,3%). Pada IMT didapatkan sebanyak 37 subjek (69,8%) memiliki IMT *overweight* dan 16 subjek (30,2%) memiliki IMT normal. **Kesimpulan:** Setelah dilakukan penelitian terhadap 53 subyek penelitian didapatkan hasil menunjukkan tidak terdapat hubungan antara total jam terbang dengan WSE (*p-value* = 1.000) dan IMT dengan WSE (*p-value* = 0.307) dalam Ruang Udara Bertekanan Rendah (RUBR) ketinggian setara 25.000 kaki.

Kata kunci:
Indeks massa tubuh, RUBR, Waktu sadar efektif, Total jam terbang

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INTRODUCTION

Based on data monitoring, *American Standart Testing Material* (ASTM) discovered the fact that there were many cases where humans fell unconscious more often on airplanes than on the ground due to hypoxic conditions. According to the United States Air Force Safety Center database, in 2005 there were 221 incidents involving unconscious hypoxia (Files *et al*., 2005). In fact, there were several cases of plane crashes due to hypoxic conditions, particularly a case that shocked the aviation world, namely the crash of the Helios B737 in Greece in 2005. Hypoxia is a condition where there is a decrease in oxygen availability that can occur in individuals when at pressures below 10.000 feet with non-pressure aircraft and at higher altitudes with pressurized aircraft (Shaw *et al*., 2021). When you are at an altitude of 8.000 feet, physiological disturbances arise due to hypoxia and at an altitude above 15.000 feet, brain function worsens until you lose consciousness (Gradwell and Rainford, 2016). As a form of preventive measures against hypoxic events in pilots, a hypoxic assessment is carried out through Aerophysiology Training Indoctrination training using a hypobaric chamber, which is a closed room that can simulate pressure at certain altitudes, aims to measure the value of *Time of Useful Consciousness* (TUC), provide an overview of basic physiology and knowledge related to flight hypoxia, and discuss the usefulness of hypoxic recognition training (TNI-AU, 2020)

The assessment indicator to determine the conscious time used when taking a deep breath is the TUC (TNI-AU, 2020). Based on other literature, TUC is the time interval a person is able to survive carrying out flight tasks due to a decrease in oxygen pressure and the point at which there is a decrease in the level of consciousness (Gradwell and Rainford, 2016). The TUC time interval is influenced by various factors including altitude, pulmonary ventilation response, hemoglobin level, age, smoking habits, physical fatigue, level of training and previous hypoxic experience (Gradwell and Rainford, 2016; Gunarsih, 2014).

In addition to the above factors, several studies have stated that *Body Mass Index* (BMI) may affect the increase in the duration of the body's exposure to hypoxic conditions in pilots. According to previous research, BMI has a positive correlation with total body fat (Ministry of Health, 2017). A study of subjects with higher BMI showed decreased TUC results (Gunarsih, 2014). In addition, according to a study by Kim *et al*. (2022), BMI has a significant relationship with TUC because excess BMI, accompanied by excess body fat, can lead to various diseases, including heart disease, diabetes, and hypertension, and can also affect cognitive function, thus can affect TUC.

Apart from that, a study discovered that having more than 1000 flying hours carries a 2.65 times greater risk of having a TUC of less than 4 minutes compared to subjects with fewer than 1000 flying hours. This is because flying hours are always associated with pilots' fatigue. However, based on the results of the research tests that have been carried out, there is no significant relationship with the number of flying hours. This is in line with previous research, which states that pilots have more expertise and experience, so they are able to recognize the body's response to initial hypoxia and overcome it earlier during training in the hypobaric chamber (Sucipta *et al*., 2018).

MATERIAL AND METHOD

This study employed observational analytic research and cross-sectional methods to determine the relationship between total flight hours and *Body Mass Index* (BMI) on *Time of Useful Consciousness* (TUC), in a hypobaric chamber at an altitude equivalent to 25.000 feet among active flight crews at Lakespra dr. Saryanto in 2021. A cross-sectional study employs the independent variable as a risk factor and the dependent variable as an effect factor obtained simultaneously (Adiputra *et al*., 2021).

The research sample collection technique was carried out using a simple random sampling method. Simple random sampling is a sampling technique where all members of a population have an equal opportunity of being selected, ensuring that all possible combinations have equal opportunities (Sugiyono and Nuryanto, 2007). The research data used met the inclusion criteria: (1) Aircraft crew including fighter pilots, transport aircraft pilots, helicopter pilots, navigators, air engineers, air radiomen, air loaders, air gunners, flight doctors, air nurses, (2) The crew is still actively flying, (3) Active flight crew undergo aero physiology training once every year, (4) Flight attendants aged 30 - 39 years. Secondary data used in this study were obtained indirectly by using medical record aids, consisting of demographic data of hypoxia complaints in respondents and other medical record data used to describe respondents' characteristics, namely, such as total flight hours, BMI, altitude of 25.000 feet, and TUC value.

The data analysis for this study utilized univariate and bivariate analysis. Bivariate analysis was conducted to examine the relationship between the independent variables, namely total flight hours, BMI, and an altitude equivalent to 25.000 feet, and the dependent variable, namely TUC. Bivariate analysis involved the use of the *Chi-square* statistical test, with the independent variable as an ordinal risk factor and the dependent variable as an ordinal effect factor, forming a 2 x 2 table. The *Chi-square* test was employed for hypotheses involving unpaired categorical variables, under the condition that all cells have an expected count >5 and a maximum of 20% of the total number of cells. If these conditions are not met, the *Chi-square* test's requirements will be substituted with an alternative test, namely the

Fisher test. It is important to underline that if the *p-value* < 0.05, the relationship between the independent and dependent variables is considered meaningful or significant (Dahlan, 2019).

The calculation of the sample size for this research refers to Sucipta *et al*. (2018), utilizing a 2 x 2 table measurement (Dahlan, 2019). Based on the literature and using type 1 error at 5%, and type 2 error at 10%, this study requires 43 subjects per group. Considering a 10% probability of drop-out, the total number of sample respondents for the research will be 48 subjects.

RESULT

The research was carried out at the Lakespra dr. Saryanto in November - December 2022. The Institute for Aviation and Space Health or Lakespra dr. Saryanto is the Health Service of the Indonesian Air Force, which has served as a medical examination center (General Medical Check Up) since 1973 and has been a center for indoctrination and ILA since 1967. In its development, Lakespra dr. Saryanto has expanded its services, such as coaching health checks, as well as providing various supporting training programs for *Occupational Safety and Health* (OSH) in aviation, general public, and other industries (Herlani, 2020). After searching for the required data, a sample of 150 subjects was obtained, including 97 subjects who failed to meet researcher's criteria and were excluded from the analysis, resulting in a final number of respondents totaling 53 subjects, according to the calculation results of the minimum sample size. The selected sample met both inclusion and exclusion criteria, and was subsequently analyzed using both univariate and bivariate analysis.

Distribution of sample characteristics

The characteristics of the sample in this study include age, *Body Mass Index* (BMI), *Time of Useful Consciousness (*TUC), and total flight hours. The distribution of flight crew according to these characteristics can be seen in Table 1.

Table 1. Distribution of respondent characteristics

Characteristics	N	%
Age		
30 – 34 years	35	66
35 – 39 years	18	34
***Body Mass Index* (BMI)**		
Normoweight (18.5 - 22.9 kg/m^2)	16	30.2
Overweight (>23 kg/m^2)	37	69.8

Based on Table 1, the age criteria in this study were grouped into 2 categories. Ages 30 - 34 years and 35 - 39 years, it was found that there were many subjects with an age range of 30 - 34 years, namely 35 subjects (66%).

Regarding BMI, according to the Asia - Pacific category, 16 subjects (30.2%) were classified as having a normal BMI, while 37 subjects (69.8%) were classified as having an overweight BMI.

Overview of *Body Mass Index* (BMI) on flight crew

Based on Table 2, it is revealed that subjects with an overweight BMI constitute 69.8% of the flight crew, whereas those with a nomal BMI account for 30.2%.

Table 2. Overview of *Body Mass Index* (BMI) in flight crew

***Body Mass Index* (BMI)**	**N = 53**	**%**
Normal (18.5 - 22.9 kg/m^2)	16	30.2
Overweight (>23 kg/m^2)	37	69.8

Overview of *Time of Useful Consciousness* (TUC) on flight crew

The results of the TUC inspection at an altitude equivalent to 25.000 feet on the flight crew are divided into 2 categories based on previous research, namely TUC <4 minutes and TUC >4 minutes (Shaw *et al*., 2021). Based on Table 3, it is evident that 90.6% of the subjects have a TUC <4 minutes, indicating that this result is more common compared to a TUC >4 minutes.

Table 3. Overview of *Time of Useful Consciousness (*TUC) on the flight crew

***Time of Useful Consciousness* (TUC)**	**N = 53**	**%**
<4 minutes	48	90.6
>4 minutes	5	9.4

Overview of total flight hours flight crew

Based on the results in Table 4, it was found that 47 subjects (88.7%) had total flight hours >1000, while the remaining 6 subjects (11.3%) had flying hours <1000 hours.

Table 4. Overview of total flight hours for aircraft crew

Total flight hours	**N = 53**	**%**
<1000 hours	6	11.3
>1000 hours	47	88.7

Overview of total flight hours flight crew

Based on the results (Table 5) of alternative statistical tests using *Fisher's* alternative tests , it is shown that there is no significant relationship between BMI and TUC (*p-value* = 0.307), which is greater than α = 0.05.

Total flight hours relationship with *Time of Useful Consciousness* (TUC) on the crew

Based on the results (Table 6) of alternative statistical tests using the *Fisher's* test shows that there is no significant relationship between total flight hours and TUC (*p-value* = 1.000), which is greater than α = 0.05.

Table 5. The relationship between *Body Mass Index* (BMI) and *Time of Useful Consciousness (*TUC) in flight crew

***Body Mass Index* (BMI)**	***Time of Useful Consciousness* (TUC)**						***p-value***
	<4 minutes			**>4 minutes**			
	N	**%**	**Expected count**	**N**	**%**	**Expected count**	
Normal (18.5 – 22.9 kg/m²)	16	100	14.5	0	0	1.5	0.307
Overweight (>23 kg/m²)	32	86.49	33.5	5	13.51	3.5	

Table 6. The relationship between total flying hours and *Time of Useful Consciousness (*TUC) for aircraft crew

***Body Mass Index* (BMI)**	***Time of Useful Consciousness* (TUC)**						***p-value***
	<4 minutes			**>4 minutes**			
	N	**%**	**Expected count**	**N**	**%**	**Expected count**	
<1000 hours	6	100	5.4	0	0	0.6	1.000
>1000 hours	42	89.36	42.6	5	10.64	4.4	

DISCUSSION

Based on Table 2, *Body Mass Index (*BMI) is a method used to assess the nutritional status of adults (>18 years), especially for those with excess weight and deficiency (Supariasa *et al*., 2016). BMI is calculated by dividing a person's weight in kilograms by their height in meters squared (kg/m^2) (Irianto and Yeskha, 2017). However, BMI has several limitations, such as not fully reflecting the amount of body fat and lacking information about body mass (Nuttall, 2015). According to research Pradana *et al*. (2014), BMI is influenced by other factors such as age, genetics, diet, physical fitness, gender and environmental factors, described as follows (1) Age: with increasing age, individuals may engage in less physical activity, leading to weight gain and affecting BMI (Arisman, 2011), (2) Dietary habits: diet, including the types, proportions, and frequency of meals, can impact BMI. Consuming larger portions and more frequent meals may lead to higher BMI (Abramovitz, 2004), (3) Physical activity: every individual's physical activity will be inversely proportional to BMI. If physical activity increases, BMI results will be more normal, but if physical activity decreases, BMI increases (Ramadhani, 2013), (4) Gender: according to research by Asil *et al*. (2014), men are more likely to have excess body weight, while women have higher obesity rates, and the distribution of body fat differs between men and women.

Based on Table 3, TUC results on flight crews can be influenced by various dominant factors, namely, hemoglobin levels, BMI, physical fitness, age, and flying hours. According to previous studies, the results showed that the higher the BMI, age, and flying hours, the shorter the TUC. While the higher hemoglobin, the longer the TUC, and the better the physical fitness (Gunarsih, 2014). Based on Table 4, a study indicated that the length of service and age of the flight crew while they are still actively flying are related to these results (Gunarsih, 2014).

The relationship between *Body Mass Index* (BMI) and *Time of Useful Consciousness* (TUC) in flight crew

Based on the results (Table 5), in line with previous research conducted by Sucipta *et al*. (2018), it was explained that there was no significant relationship between BMI (normal to overweight) and changes in TUC, as indicated by a *p-value* of 0.218. This lack of significance may be because the flight crew did not have central obesity, thus fat in the body, particularly in the abdomen, did not restrict lung function. Additionally, according to research by Lopez *et al*. (2000), the subjects in the study likely had considerable experience with hypobaric chamber exercises and generally had good tolerance for hypoxia; therefore, they could last longer during training.

While there are differences in results, according to research by Gunarsih (2014), BMI is linked to TUC outcomes and can cause a decrease in TUC by 3.3 seconds. This finding aligns with the theory underlying Gunarsih's (2014) research, which states that individuals with overweight BMI typically have higher body fat mass, especially in the abdomen, obstructing the movement of the stomach below the diaphragm during inspiration, thus compliance in the respiratory tract decreases and this can lead to decreased lung function and restricted lung capacity.

This pulmonary restriction will reduce *Forced Ekspiratory Volume* (FEP) and FEP1. When individuals with good vital lung capacity demonstrate an increased ability of lung function, oxygenation to the lungs and body tissues will also be better. Well-oxygenated body tissues, in turn, increase tolerance to hypoxic conditions (Ajmani *et al*., 2012; Lad *et al*., 2012). Meanwhile, another study indicated that the value of pulmonary diffusion capacity and spirometry examination in pilots were generally normal. However, a small number experienced a mild decrease, but there was no significant relationship between *Diffusing Capacity of The Lungs for Carbon Monoxide* (DLCO) parameters and age, BMI, combat flight hours, total flight hours, and sports minutes (Ningsih *et al*., 2020).

In addition, according to Kim *et al*. (2022), BMI has a correlation with TUC because excess BMI in the presence of excess body fat can cause various diseases, including heart disease, diabetes, and hypertension, which also affect cognitive function. In a hypoxic environment, body fat can negatively influence the brain, which requires a large and continuous supply of oxygen to maintain cognitive abilities and awareness, thereby shortening the TUC.

The relationship between total flight hours and *Time of Useful Consciousness* (TUC) on the crew

The result (Table 6) is consistent with research by Sucipta *et al*. (2018), which explains that there is no significant relationship between total flight hours and TUC, with a *p-value* of 0.008. This is because flight crew with flight hours >1000 hours have a 2.65 times greater risk of experiencing TUC <4 minutes compared to the flight crew with flight hours <1000 hours. Additionally, this could be because pilots with more expertise and experience are able to recognize the body's response to initial hypoxia and can overcome it earlier during training in the hypobaric chamber (Sucipta *et al*., 2018).

Meanwhile, according to research by Gunarsih (2014), there were different results, with a *p-value* of 0.000, which indicated a significant relationship between flight hours and TUC, which tended to cause a decrease in TUC. This is because flight hours are always associated with pilot fatigue. According to Federal Aviation Administration, the main factors causing fatigue among flight crew are the length of time on duty, reduced sleep time, high workload, accumulation of sleep deprivation, and length of working hours/long hours of flight. In a study, it was stated that longer flight duration would cause fatigue in flight crew (Drongelen *et al*., 2013).

In addition, research by Saputra (2020) shows that most pilots, both women and men, experience a high workload/overload, resulting in fatigue and stress, which can affect their decision-making, so they tend to be stiff and inflexible. Observing changes that influence on TUC results is crucial because low TUC results can lead to fatal plane crashes.

CONCLUSION

There was no significant relationship between total flying hours and TUC in the flight crew at Lakespra dr. Saryanto in 2021, with *p-value* = 1.000. Similarly, research on BMI also illustrates that there is no significant relationship between BMI and TUC on the flight crew at Lakespra dr. Saryanto in 2021 with *p-value* = 0.307.

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