ARE AEROBIC CAPACITY, ANAEROBIC THRESHOLD, AND RESPIRATORY COMPENSATION VALUES DETERMINANTS FOR THE TIME OF USEFUL CONSCIOUSNESS AT 25000 FEET?

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Abstract:

The higher the altitude, the higher the risk of hypoxia exposure. Good fitness status or aerobic capacity (AC) of persons with the military or civil aviation sector and those interested in high-altitude sports have been thought of great importance to encounter hypoxic risk. It is unclear whether a difference in maximal oxygen consumption (VO_{2max}) capacity would result in differential tolerance in hypoxia responses. The present study aims to determine the relationship between AC, anaerobic threshold (AT), respiratory compensation (RC), and time of useful consciousness (TUC) of people working in the military or civil aviation sector and those interested in high-altitude sports. Eighty-seven healthy males were recruited on a volunteer basis (age = 24.2 ± 1.6 years; height = 177.0 ± 5.1 cm; weight = 76.4 ± 8.1 kg). The 25000 feet test was applied to the participants in the hypobaric chamber. During the test, participants' TUC levels were recorded. The Bruce protocol was used for the VO_{2max} test, and the maximal oxygen consumption value, AT, and RC regions were recorded. Participants were divided into four groups according to their VO_{2max} values. AT and RC values were higher in the group with high VO_{2max}, although not significant ($p>.05$). There was no statistically significant difference between the TUC levels of the groups. There was no statistically significant difference between the groups' TUC level, peripheral oxygen saturation (SpO_2), and heart rate levels ($p>.05$). The results clearly show that there is no significant relationship between VO_{2max} determined on the treadmill with a gas analyzer and TUC determined in the hypobaric chamber at 25000 feet. For future studies, the relationship between anaerobic capacity and hypoxia or studies in which different physical and physiological characteristics are evaluated together in the same participants may contribute to the literature.

Keywords: *effective performance time, oxygen consumption, hypoxia, aviation*

Introduction

In aviation and sports branches such as mountaineering-related to altitude, hypoxic effects begin to be observed gradually with the increase in altitude. Although it is more common in aviation in cases such as cabin pressure loss or oxygen systems failure, hypoxia can also be encountered in non-cabin pressure less aircraft (helicopters, etc.) operating at medium altitudes or in parachute jumps for sportive and military purposes. Hypoxia is defined as the insufficient partial pressure of oxygen to body tissues, the low atmospheric pressures, which generates a variety of physical, physiological, and psychological responses in humans (Smith, 2008). Especially, the effects may cause negative and undesirable situations in critical decision-making processes in central nervous system (CNS) (Heratika, et al., 2020; Petrassi, Hodkinson, Walters, & Gaydos, 2012; Sullivan-Kwantes, Cramer, Bouak, & Goodman, 2022). Time of useful consciousness (TUC) is defined as the time elapsed between additional oxygen loss and performance failure and is frequently used in the evaluation of decision-making in the CNS. TUC is also defined as the length of time in which a pilot can perform flying duties efficiently in an environment of inadequate oxygen supply and is based on time left until unconsciousness occurs, e.g., the TUC at 25000 feet is approximately 3-5 minutes (DeHart & Davis, 2002). In other words, if arterial and tissue deoxygenation does not stabilize, brain function progressively declines, which occurs exponentially at a very low partial arterial oxygen pressure (PIO2) The initial phase is referred to as the TUC and is the duration of effective and safe performance of operational tasks, which is followed by mental confusion and unconsciousness (Hall, 1949; Hoffman, Clark, & Brown, 1946). Effective performance time (EPT) or TUC at that altitude is a function of circulation time. Exercise of even modest levels shortens the EPT due to decreased circulation time and increased peripheral demand resulting in a faster loss of oxygen (Davis, Johnson, & Stepanek, 2008). Hypoxia impairs a spectrum of cognitive domains as previously described in the narrative (Petrassi, et al., 2012; Taylor, Watkins, Marshall, Dascombe, & Foster, 2016; Yan, 2014) and systematic reviews (McMorris, Hale, Barwood, Costello, & Corbett, 2017). Both simple (e.g., simple and choice reaction speed) and complex (e.g., processing speed, working memory, short-term memory, attention, executive function, and novel task learning) tasks are negatively affected by hypoxia, the degree of which can vary greatly between individuals (McMorris, 2017; Shaw, Cabre, & Gant, 2021). TUC duration is affected by many individual and environmental factors apart from altitude. TUC values are based on data that represent average values and reflect wide variation among individuals in time to incapacitation. This variation results from differences in an individual's total surface area for gas exchange in the lungs, total amount of hemoglobin available in the blood to bind oxygen, and oxygen consumption rate at rest (related to body mass index). Other sources of variation are the extent to which hypoxia stimulates increases in depth and rate of breathing and increases in the amount of blood the heart pumps (faster heart rate). Finally, individuals able to increase the amount of oxygen they can extract from the blood in muscle and brain tissue are more hypoxia-tolerant (Self, Mandella, White, & Burian, 2013).

Aerobic performance is a particularly appropriate performance trait in hypoxia at high altitudes, as aerobic metabolism is critical for staying active and maintaining movement in the cold (Cheviron, Bachman, Connaty, McClelland, & Storz, 2012; Hayes & O'Connor, 1999). Because hypoxia is both inevitable and persistent at high altitudes, some short-term mechanisms (e.g., metabolic depression, anaerobic metabolism) to cope with O2 deprivation have limited efficacy and the ability to maintain aerobic metabolism is critically important. However, hypoxia can have debilitating effects on aerobic performance, which can limit locomotor activity or impair thermogenesis, causing hypothermia (McClelland & Scott, 2019). Traditional aerobic-based training in hypoxia has received much attention. This method improves oxygen-carrying capacity by increasing erythropoietin secretion and hemoglobin mass and increases VO2max, anaerobic threshold (AT), bringing improvements to exercise performance (Ramos-Campo, et al., 2018). Both the heart and blood vessels respond to exercise in a variety of ways. AT and respiratory compensation (RC) values are important indicators of the degree of aerobic capacity (AC) (Fox, Bowers, & Foss, 1993; McArdle, Katch, F.I., & Katch, V.L., 2010). At the same time, the test using a gas analyzer, which is considered the gold determination standard of AC, is an indicator of cardiovascular endurance (Poole & Jones, 2017). AT and RC points can also be determined during the VO2max test (Jamnick, Botella, Pyne, & Bishop, 2018).

In the literature review, no study was found regarding the comparison of VO_{2max}, AT, and RC, on the one hand, and TUC value at 25000 feet, on the other, in a hypobaric chamber. The present study aims to determine whether there is a significant difference in TUC at 25000 feet in a hypobaric chamber between groups categorized according to AC, AT, and RC values in healthy men. According to the results of this study, the importance of improving aerobic characteristics, AT and RC values of people working in the civil and military aviation sector and those who are interested in high-altitude sports will be determined in terms of TUC.

Methods

Participants

Ninety-one healthy men were recruited on a volunteer basis from the military and civil aviation sector and those interested in high-altitude sports (mountaineering and climbing, parachuting). Four participants dropped out from the current study due to busy schedules. The final sample comprised eighty-seven individuals. Subjects were divided based on their VO_{2max} capacities according to Heyward (1997) protocol: excellent (46.5-52.4 $ml.kg^{-1}.min^{-1}$), good (42.5-46.4 $ml.kg^{-1}.min^{-1}$), fair (36.5-42.4 $ml.kg^{-1}.min^{-1}$), and poor (33.0-36.4 $ml.kg^{-1}.min^{-1}$). Four different groups were created with the participants according to their VO_{2max} capacity (Group 1: n=24, 24.0±1.6 years, 176.3±5.1 cm, 73.8±7.9 kg, BMI 23.8±2.5 $kg.m^{-2}$, body fat 16.6±4.3 %, VO_{2max} 49.4±2.6 $ml.kg^{-1}.min^{-1}$; Group 2: n=24, 24.1±1.2 years, 176.1±5.8 cm, 75.9±8.6 kg, BMI 24.5±2.3 $kg.m^{-2}$, body fat 18.8±4.3 %, VO_{2max} 40.0±1.1 $ml.kg^{-1}.min^{-1}$; Group 3: n =22, 24.3±1.7 years, 177.0±5.3 cm, 78.0±7.7 kg, BMI 24.9±2.0 $kg.m^{-2}$, body fat 21.8±3.7 %, VO_{2max} 43.5±1.4 $ml.kg^{-1}.min^{-1}$; Group 4: n =17, 24.3±1.7 years, 177.0±5.3 cm, 78.0±7.7 kg, BMI 24.9±2.0 $kg.m^{-2}$, body fat 21.8±3.7 %, VO_{2max} 34.2±1.8 $ml.kg^{-1}.min^{-1}$). All participants reported to be free from illness and injury in the last six months and medical drugs usage in the past week before the experiments took place. Signed informed consent was obtained from all participants. The study included men aged between

20-29 years, who had no known health problems and signed the voluntary consent form. The experiments were approved by the Eskişehir Technical University Research Ethics Committee (approved date July 5, 2022, under the number E-8914409-050.06.04-79145).

Study design

The explanatory consent form was signed by the participants on the first day of the study. Data collection for each participant occurred on the weekday during the morning hours (i.e., from 09:00 a.m. to 12:00 p.m.). Moderate water consumption was allowed for each volunteer during the tests. The participants were warned not to perform any physical activity the day before the tests and not to use stimulants such as food and medicine or coffee for two hours before the test hours. The researchers conducted the tests in groups of 5-6 subjects. Two days were allocated for the measurements. Anthropometric measurements and a hypobaric chamber test were applied on the first day. The height, weight, and fat percentage of the participants were recorded. Hypobaric chamber test measurements were performed in a quiet and air-conditioned (temperature 17-18°C, humidity 55-58%) room. The 25000 feet test was applied to the participants in the custom-made hypobaric chamber. During the test, participants' TUC durations were recorded. Participants were allowed to inhale 100% O_2 for 30 minutes at ground level for denitrogenation. At the end of this period, they were brought to the atmospheric conditions at an altitude of 25000 feet in 10 minutes. 100% O_2 support was cut off and the O_2 rate in the atmosphere was brought to 21%. From this moment onwards, the participants began their TUC period. O_2 saturation was monitored with a pulse oximetry device and the test was terminated when O_2 saturation fell below 70% or voluntarily when the person felt unwell. The TUC time of each participant was recorded separately.

On the second day, the Bruce protocol was used for the maximal oxygen consumption test (temperature 22-24°C, humidity 33-45%), and the VO_{2max} value, anaerobic threshold, and respiratory threshold regions were recorded.

Instrumentation and data collection

Measurement of body composition. The height of the participants was measured as recommended by the International Society for the Advancement of Kinanthropometry (ISAK) and with a 1/10 cm sensitivity (Holtain Harpenden 601, Holtain Ltd., UK). The body mass of the participants was measured with a scale of 1/10 kg using the scale model of the InBody brand 270 models (Biospace Co., S. Korea) body analyzer. To obtain the body mass index (BMI) values of the participants InBody brand 270 models (Biospace Co., S. Korea) body analyzer was used, and measurements were performed according to the procedure specified in the device manual. The data obtained were recorded in % (Alparslan, Arabacı, Güngör, Şenol, & Küçük, 2022).

Determination of maximal oxygen uptake (Bruce Protocol). The treadmill test with the gas analyzer is accepted as the gold standard for the determination of aerobic endurance and maximal oxygen consumption. The Bruce protocol (h/p/cosmos quasar med 170-190/65, h/p/cosmos & medical GMBH, Germany) was performed. The staged protocol began at 1.7 mph at 10% grade with increasing work rate (speed and grade) every 3-minutes until VO_{2max} was reached. Expired gas fractions (oxygen and carbon dioxide) were collected at the mouth and analyzed with a metabolic cart (Cosmed Quark CPED metabolic cart, Roma, IT). Measurements were processed in Omnia-Standalone software for Microsoft Windows version 1.4. The criteria for VO_{2max} were predetermined as two of the following: if there was a plateau in oxygen consumption despite an increased work ($\pm$ 2 $ml.kg^{-1}.min^{-1}$); the respiratory exchange ratio of >1.10; and a heart rate within ten beats of age-predicted maximum (220-age). Bruce protocol was applied after a 10-minute warm-up period. The gas analyzer system was calibrated before each test using the manufacturer's recommendations. While determining VO_{2max}, the data were analyzed by taking the average values in 15-second time intervals. In the threshold calculations, a new data group created by taking the average values of the data for 5 seconds was used. RC was determined by the V-slope method. This method is an algorithm in which VCO_2 is evaluated with VO_2 data (Ekkekakis, Thome, Petruzzello, & Hall, 2008).

Hypobaric chamber test. In the hypobaric chamber (Hypobaric Chamber-103435 Environmental Tectonic Crop, USA), a flight helmet and a flight mask were attached to the participants to isolate them from the external atmosphere. During the test, observers were present on the control panel both inside and outside the cabin. Inner observers and survey participants were not left above 18000 feet for more than 30 minutes. During the adjustment of the masks to the face, the oxygen equipment, and interphone controls, the participants wore masks, and the regulators were adjusted to the 100% oxygen position. For ear and sinus control, the height was increased to 7500 feet and returned to ground level in a 1-minute without exceeding 7500 feet. The 30-minute denitrogenation period was completed before the ascent to the altitude to be tested. 25000 feet were climbed by 5000 feet per minute. After the consciousness time limits were determined for the participants at 25000 feet, oxygen was re-administered to 100% and the participants were checked. Return to ground level was done at 2500 feet per

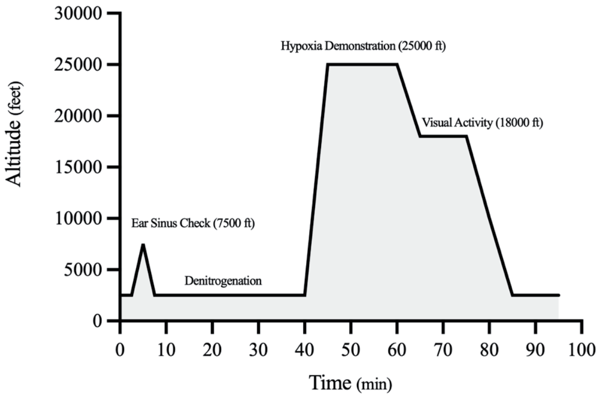


Figure 1. Hypobaric chamber flight profile.

minute (Sucipta, Adi, & Kaunang, 2018).

Criteria for TUC determination. The decision to determine the end point of a subject's time of TUC while undergoing high-altitude chamber training was at the discretion of the supervising flight physician. The decision was based on the physician's assessment skills as it pertained to the subject. The assessment was most often based on subjective findings by the subject as well as deterioration in neurocognitive functioning. The following criteria were utilized by the supervising physician for TUC determination: (i) any combination of three signs or symptoms noted by the subject, (ii) the presence of significant cyanosis, (iii) any disturbance in speech, (iv) loss of short-term memory and delay in communications, (v) incorrect response to a simple command, (vi) significant euphoria, (vii) significant mistake in flight controls of the simulator, (viii) tremor, (ix) staring (glassy-eyed), and (x) fixation. The presence of any of the above observations or combinations determined the end point of TUC and resulted in the immediate donning of the mask (Cipova, 2014).

Heart rate and oximeter device and data collection and analyses. Heart rate and oxygen saturation level were measured with a pulse oximeter device (ITAM-BlueECG-204P-Poland). Participants were evaluated and observed by an aerospace medicine specialist before, during, and after the test. Maximum HR was needed to determine the physiological parameters of the change in heart rate (HR) associated with the new ascent-based TUC. The maximum heart rate per subject and maximum heart rate per all subjects were collected from the Oximeter Report. The maximum heart rate per subject was compared to a heart rate at rest of a Cardiac Pulse Index (CPI). The lowest peripheral oxygen saturation (SpO_2) levels were collected from the Oximeter Report to determine the physiological parameters of oxygen saturation associated with the ascent-based TUC (every 10-second oximeter readout of the data from 5000 feet to donning mask was collected).

Statistical analyses

In the current research, descriptive statistics (mean, SD) were used for the description and explanation of data (TUC, lowest SpO_2 levels, net change CPI, physical characteristics, and VO_{2max}, AT, RC). The Kolmogorov-Smirnov test was used for investigating the normality of the data distribution. One-way analysis of variance (ANOVA) was calculated to compare anaerobic threshold, respiratory threshold, VO_{2max}, and TUC time values between the groups, the Bonferroni test for pairwise comparisons, and Cohen's d value for effect size was calculated. Pearson correlation test was used for the relationship between TUC duration and VO_{2max} value. Effect size Cohen's d-value was calculated; this value was considered small (0.20), medium (0.50), or large (0.80). All calculations were performed with SPSS version 26, statistical software (SPSS Inc., Chicago, IL, USA) and the significance level was determined as $p<.05$.

Results

Descriptive data regarding age, height, weight, BMI, body fat (%), TUC (sec), VO_{2max} ($ml.kg^{-1}.min^{-1}$), AT (sec), and RC (sec) for the groups are presented in Table 1. AT and RC times, TUC, and VO_{2max} levels of the groups by performance are presented in Figure 2. A-D, respectively. The change in HR and SpO_2 in the hypobaric chamber test and the threshold values in the AC test of G1, G2, G3, and G4 are presented in Figure 3. The comparison of TUC times of the groups separated by aerobic performance is presented in Figure 4. The relationship between the participants' anaerobic threshold and respiratory threshold values with TUC is presented in Table 2.

When the demographic data of the groups were compared, there was no statistical difference in terms of age, height, weight, and BMI ($p>.05$) (Table 1). In the between-groups comparison, body fat (%) in the G1 group was significantly lower than in the G4 group ($p<.05$).

Figure 2A-D shows TUC level of G1 (195.9±39.3), G2 (202.0±47.9), G3 (193.6±38.0), and G4 (191.5±42.3) ($p>0.05$). Also, the G1 group displayed higher VO_{2max} ($ml.kg^{-1}.min^{-1}$) values than the other groups. The AT and RC values were consistently higher, although the difference was not always statistically significant in the G1 group compared with the other groups ($p>.05$).

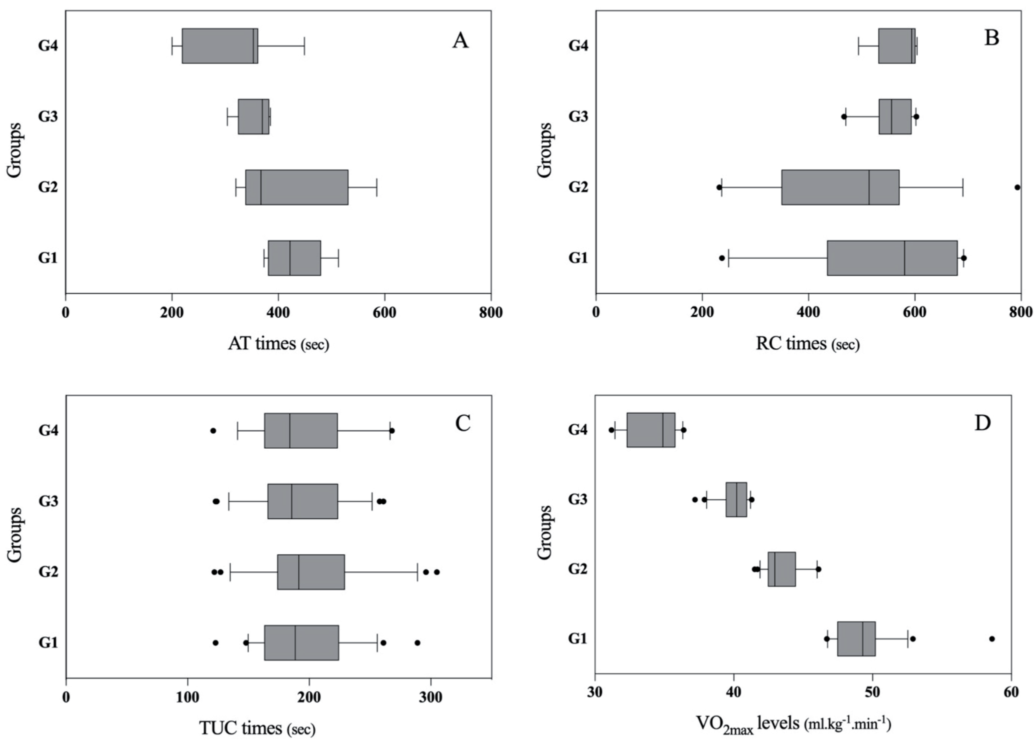
As seen in Figure 3, there was no statistically significant difference in the TUC levels between the groups.

The relationship between the AT and RC with TUC is shown in Table 2. The relationship between TUC and AT determined in the VO_{2max} test and RC was not significant ($p>.05$).

Table 1. Descriptive analysis of data of the groups (n=87)

Descriptive analysis of data	G1 (n=24) Mean ± SD	G2 (n=24) Mean ± SD	G3 (n=22) Mean ± SD	G4 (n=17) Mean ± SD	p	F	Binary comparisons
Age (years)	24.0 ± 1.6	24.1 ± 1.2	24.1 ± 1.3	24.3 ± 1.7	0.79	0.34	
Height (cm)	176.3 ± 5.1	176.1 ± 5.8	178.5 ± 4.2	177.0 ± 5.3	0.40	0.10	
Weight (kg)	73.8 ± 7.9	75.9 ± 8.6	78.6 ± 7.6	78.0 ± 7.7	0.20	1.57	
BMI ($kg.m^{-2}$)	23.8 ± 2.5	24.5 ± 2.3	24.6 ± 1.8	24.9 ± 2.0	0.41	0.98	
Body fat (%)	16.6 ± 4.3	18.8 ± 4.3	18.4 ± 4.1	21.8 ± 3.7	0.003**	5.02	1-4
TUC (sec)	195.9 ± 39.3	202.0 ± 47.9	193.6 ± 38.0	191.5 ± 42.3	0.86	0.25	
VO_2max ($ml.kg^{-1}.min^{-1}$)	49.4 ± 2.6	43.5 ± 1.4	40.0 ± 1.1	34.2 ± 1.8	0.31	1.23	
AT (sec)	428.6 ± 55.3	413.4 ± 105.5	371.2 ± 103.9	358.7 ± 119.6	0.07	2.68	
RC (sec)	595.6 ± 35.4	574.6 ± 43.6	547.1 ± 40.1	530.8 ± 59.6	0.000***	240.4	1-2; 1-3; 1-4; 2-3; 2-4; 3-4

Note. Values are mean ± SD; a Significantly different with pre-test at p<.001.
BMI: body mass index; TUC = time of useful consciousness, AT = anaerobic threshold, RC = respiratory compensation.



Note. TUC = time of useful consciousness, AT = anaerobic threshold, RC = respiratory compensation.

Figure 2. A-D. AT, RC times, TUC, and VO_{2max} levels of the groups by performance.

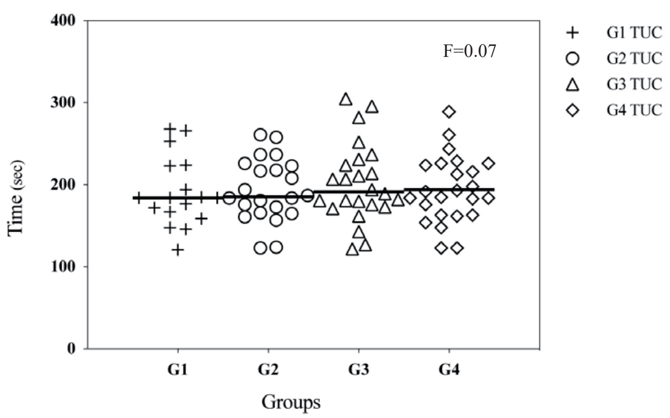
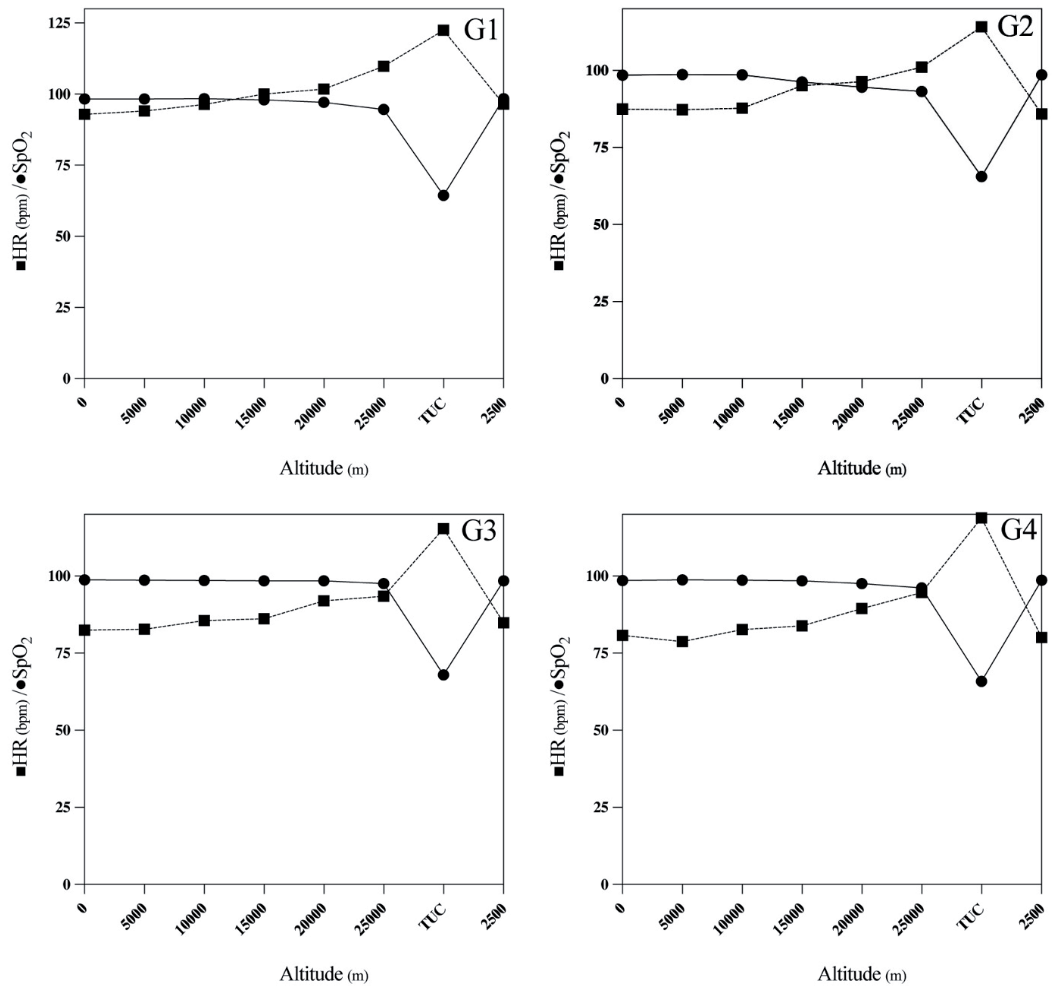


Figure 3. Comparison of TUC level of the groups separated by aerobic performance.

Table 2. The relationship of the participants' anaerobic threshold and respiratory threshold values with TUC

Pearson's R		AT (sec)	RC (sec)	VO_{2max} (ml.kg^{-1}.min^{-1})	Age (years)	Body fat (%)	BMI (kg.m^{-2})
Groups	TUC (sec)	0.19	0.08	0.07	-0.05	0.01	-0.06
	p	0.27	0.65	0.51	0.66	0.94	0.59
G1	TUC (sec)	-0.14	0.33	0.17	-0.16	0.11	-0.20
	p	0.83	0.59	0.45	0.64	0.64	0.38
G2	TUC (sec)	0.34	-0.02	-0.17	-0.18	-0.03	0.09
	p	0.42	0.96	0.42	0.41	0.89	0.68
G3	TUC (sec)	0.27	0.28	-0.44	0.14	0.13	0.13
	p	0.37	0.36	0.04*	0.53	0.55	0.55
G4	TUC (sec)	0.65	0.64	0.67	0.07	-0.13	-0.31
	p	0.08	0.09	0.003**	0.79	0.62	0.22

Note. TUC = time of useful consciousness, AT = anaerobic threshold, RC = respiratory compensation, BMI = body mass index.

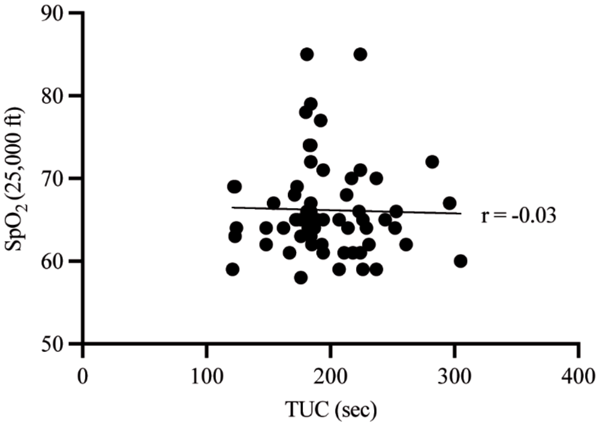


Note. HR= heart rate, SpO_2= peripheral oxygen saturation.

Figure 4. Comparison of SpO_2 and HR at the TUC level of the groups separated by aerobic performance.

As seen in Figure 4, there was no statistically significant difference between the groups' TUC level, SpO_2, and HR levels ($p>.05$).

It is shown in Figure 5 that the relationship between TUC and SPO_2 was not significant (r= -0.02) ($p>.05$).



Note. TUC = time of useful consciousness, SPO_2= peripheral oxygen saturation

Figure 5. Comparison of SpO_2 and TUC level.

Discussion and conclusions

The higher the altitude, the higher the risk of hypoxia exposure. Good fitness status or AC of the military or civil aviation sector persons and those interested in high-altitude sports have been thought of great importance to encounter hypoxic risk. In recent years, studies examining the relationships between AC and cognitive performance have been increasing. Aerobic activity is a powerful stimulant for the development of mental health and cerebral structural changes (Ankaralı & Bayramlar, 2019; Hendrikse, et al., 2022; Klil-Drori, Cinalioglu, & Rej, 2022). While an increase in hippocampal neuron number and cerebral blood volume (CBV) was observed in these studies with aerobic activity, increases in hippocampus volume and CBV were reported in human studies. Therefore, it can be expected that the cognitive performance of people with high AC who exercise will be better (Thomas, Dennis, Bandettini, & Johansen-Berg, 2012). It is unclear whether a difference in VO2max capacity would result in a differential time of useful consciousness tolerance in hypoxia responses. The present study aimed to determine the relationship between AC, anaerobic threshold, respiratory threshold, and time of useful consciousness of people working in the military or civil aviation sector and those interested in high-altitude sports.

Hypoxia is a serious aviation problem and may be a source of dangerous aerospace accidents (Kim, Ahn, Lee, & Kim, 2001). At altitude, the reduction in barometric pressure decreases arterial oxygen saturation (arterial SO_2) and arterial oxygen content (CaO_2) (Fulco, Rock, & Cymerman, 1998). Even for pilots in a pressurized cabin, hypoxia poses a risk at altitude. At night, at an altitude of 4940 feet, the effects begin to appear with reduced vision, and impaired cognitive ability becomes more pronounced as altitude increases. This significantly affects flight performance and safety (Rainford & Gradwell, 2006). As oxygen in the blood decreases, hypoxic effects begin, and when it starts to drop below 70% SpO_2, serious problems may begin. Hypoxia tolerance has been evaluated by the TUC, subjective symptoms, hypoxic ventilatory responses (HVR), and cardiovascular changes. It is not clear which physiological factors relate to the former parameters (Kim, et al., 2001). In the present study, it was assumed that there would be a significant difference between the TUC times of groups formed with participants with different aerobic capacities. However, the most striking result of this research is that the AC of the groups, which is accepted as the determinant of oxygen utilization capacity, did not make a significant difference in terms of TUC at 25000 feet. Also, the relationship between AT, RC, and TUC of groups was not significant. AT and RC values were better in groups with better aerobic performance, but this did not make a significant difference in TUC duration. Reference studies that can enrich our discussion are very limited. Previous studies evaluated the effect of training in hypoxic conditions on aerobic performance. While some studies have reported a positive effect (Czuba, et al., 2011; Mayo, Miles, Sims, & Driller, 2018; Ramos-Campo, et al., 2018), it has been shown to have no significant effect in some studies (Dufour, et al., 2006; Prommer, et al., 2007; Tadibi, Dehnert, Menold, & Bärtsch, 2007). An increase in oxygen-carrying capacity can be seen in those who perform endurance training in a hypoxic environment. Participants with higher VO_{2max} values did not train in any way in a normobaric or hypoxic environment. From this point of view, there may be differences between VO_{2max} developed in a hypoxic environment and VO_{2max} developed in physical activities at sea level (Ramos-Campo, et al., 2018). It has been shown in the study that exercise-induced movement and subsequent adaptation in hypoxia is less effective than expected in developing VO_{2max} in people living at high altitudes, and sometimes even lower when compared to those living at sea level. However, it has been stated that these individuals are more resistant to the effects of hypoxia on VO_{2max} (McClelland & Scott, 2019). Therefore, TUC is measured by testing pilots' hypoxic response in a simulated hypobaric chamber at an altitude of 25000 ft. The average TUC at this altitude is 3-5 minutes (Self, Mandella, White, & Burian, 2011; Shaver, 2009; Yoneda, Tomoda, Tokumaru, Sato, & Watanabe, 2000). According to Sucipta et al. (2018), military pilots stated that those with a lower TUC had higher fitness levels. In our study, AC, which is one of the determinants of fitness level, did not make a significant difference in terms of TUC. This was under the theory that people with high levels of physical fitness tend to have high oxygen consumption and so would be susceptible to hypoxia. The result was also consistent with that obtained in the study by Sucipta et. al (2018) where there was no relationship between the level of physical fitness and TUC in air force patients. The measurement procedure may also had effect on the absence of a relationship between physical fitness level and TUC in the current study. The difference in previous studies was obtained after the direct measurement using the treadmill with the gas analyzer, which is accepted as the golden criterion in the measurement of VO2max, the result of the direct measurement used for TUC reveals the relationship with each other. There are limitations in our research. Because the overall sample of participants were men, only men were included in the study and there were no experimental-control groups. Data on smoking were not collected. VO_{2max} test was not performed in the hypobaric chamber because there may be a risk of decompression due to the high altitude. For future studies, the relationship between anaerobic capacity and hypoxia or studies in which different physical and physiological characteristics are evaluated together in the same participants may contribute to the body of knowledge.

In conclusion, the results clearly show that there is no significant relationship between VO_{2max} determined on the treadmill with a gas analyzer and TUC determined in the hypobaric chamber at 25000 feet. For this reason, it is wondered whether high VO_{2max} plays a role in delaying hypoxia, and more importantly, it has been questioned whether it can be used in the personnel selection stages for the job. However, there is no significant relationship between VO_{2max} and TUC. Therefore, these data do not provide a valid criterion for personnel selection.

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