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The Relationship Between Anaerobic Performance Test and Time of Useful Consciousness Determined in Low-Altitude Chamber (25.000 Feet) with Heart Rate Variability

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Research Article
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Abstract

The aim of this research is to investigate the relationship between anaerobic capacity and TUC determined in a low-altitude chamber (LAC), in terms of performance and heart rate variability (HRV), in healthy males. Thirty male participants were included in the study as volunteers (mean age: 23.2±0.8 years; height: 180.6±6.0 cm; weight: 77.0±8.2 kg). In the scope of the research, participants were exposed to oxygen in a LAC at an atmospheric level of 25.000 feet after body measurements were taken on the first day, and TUC was determined. Anaerobic capacities of the participants were determined the following day using the Wingate Anaerobic test (WAnT). Differences in both time-domain and frequency-domain measurements were significant in terms of TUC. In terms of the relationship between anaerobic capacity and time to achieve TUC, TUC showed a non-significant negative correlation with relative peak power (r=-0.03; p=0.86), and non-significant positive correlations with total peak power (r=0.19; p=0.31) and total mean power (r=0.23; p=0.23). The most striking result of this research is the lack of significant relationship between TUC duration and anaerobic performance of the participants. According to the results of this research, anaerobic exercises are not a priority in terms of performance and HRV change to increase TUC. Anaerobic performance may not be the primary criterion for personnel selection for high altitude missions.
Keywords: Anaerobic performance, Time of useful consciousness, Heart rate variability, Hypoxia, Low-pressure

Anaerobik Performans Testi ile Alçak Basınç Odasında (25.000 Feet) Belirlenen Faydalanılabilir Bilinç Zamanının Kalp Atım Hızı Değişkenliği İlişkisi

Öz

Bu araştırmanın amacı, sağlıklı erkeklerde anaerobik kapasite ile alçak basınç odasında (LAC) belirlenen TUC arasındaki ilişkiyi performans ve kalp hızı değişkenliği (HRV) açısından incelemektir. Çalışmaya gönüllü olarak 30 erkek katılımcı dahil edildi (ortalama yaş: 23.2±0.8 yıl; boy: 180.6±6.0 cm; kilo: 77.0±8.2 kg). Araştırma kapsamında katılımcılar, ilk gün vücut ölçüleri alındıktan sonra 25.000 fit atmosferik seviyede bir LAC içinde atmosferik oksijene maruz bırakıldı ve TUC belirlendi. Katılımcıların anaerobik kapasiteleri ertesi gün Wingate Anaerobik testi (WAnT) kullanılarak belirlendi. Hem zaman-alan hem de frekans-alan ölçümlerinde farklılıklar TUC açısından anlamlıydı. Anaerobik kapasite ile TUC'a ulaşma süresi arasındaki ilişki açısından, TUC, relatif zirve gücü ile anlamlı olmayan bir negatif korelasyon (r=-0.03; p=0.86) ve toplam zirve gücü (r=0.19; p=0.31) ve toplam ortalama güç (r=0.23; p=0.23) ile anlamlı olmayan pozitif korelasyon gösterdi. Bu araştırmanın en çarpıcı sonucu, katılımcıların TUC süresi ile anaerobik performansları arasında anlamlı bir ilişkinin olmamasıdır. Bu araştırmanın sonuçlarına göre, anaerobik egzersizler TUC'u artırmak için performans ve HRV değişimi açısından bir öncelik değildir. Anaerobik performans, yüksek irtifa görevleri için personel seçiminde birincil kriter olmayabilir.
Anahtar Kelimeler: Anaerobik performans, Faydalanılabilir bilinç zamanı, Kalp atım hızı değişkenliği, Hipoksi, Alçak basınç

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INTRODUCTION

As altitude increases, the pressure of oxygen decreases. The decrease in oxygen pressure results in reduced oxygenation of body tissues. The occurrence of physical, physiological, and psychological reactions in the body due to insufficient oxygenation is called hypoxia (Smith, 2008). Individuals working in the aviation industry and engaging in sports activities such as mountaineering begin to exhibit symptoms of hypoxia as they ascend to higher altitudes. Although it is more commonly observed in aviation during situations such as cabin pressure loss or failure of oxygen systems, hypoxia can also occur in medium altitudes during operations in non-pressurized aircraft without cabins (such as helicopters) or during sport and military parachute jumps. Especially its effects can lead to adverse and unwanted situations in critical decision-making processes in the central nervous system (CNS) (Heratika et al., 2020; Petrassi et al., 2012). To increase awareness of the symptoms of hypoxia when experienced, training sessions are conducted in low-altitude chambers (LAC) by institutions and organizations worldwide. It is known that individuals who have received prior training in LAC are able to recognize the symptoms of hypoxia, making it easier for them to perform lifesaving maneuvers in a real altitude hypoxia scenario. The time from the onset of hypoxia in an individual to the moment they can rescue themselves is called time of useful consciousness (TUC). This term is defined as the time elapsed from when ambient air begins to be breathed at an altitude of 25.000 feet (7.62 km) until the person manages to recover from hypoxia. The height at which suitable conditions exist for measuring TUC is indicated as 25.000 feet in NATO standards. TUC is defined as the time between oxygen deprivation and performance failure and is frequently used in the evaluation of decision-making in the CNS. Furthermore, TUC defines the duration during which a pilot can efficiently perform flight duties in a chamber with insufficient oxygen supply, for example, TUC at 25.000 feet is approximately 3-5 minutes (DeHart & Davis, 2002).

Previous research has reported impairments in both simple and complex cognitive functions under hypoxic conditions (Taylor et al., 2016; Yan, 2014), and it has been noted that these impairments vary among individuals (McMorris et al., 2017; Shaw et al., 2021). TUC is influenced by various factors, including altitude, total surface area for gas exchange in the lungs, total hemoglobin content available to bind oxygen, and resting oxygen consumption rate. Individuals who can increase the amount of oxygen they can extract from the blood in muscle and brain tissue are more tolerant to hypoxia (Self et al., 2013). In hypoxia and TUC, an increase in the depth and rate of breathing and the amount of blood pumped by the heart (increased heart rate) is observed. Therefore, variations are also observed in parameters related to heart rate variability (HRV). HRV is a physiological phenomenon consisting of oscillations in the intervals between consecutive heartbeats, which are controlled by the autonomic nervous system (ANS) (Baek et al., 2015). HRV is an objective indicator that helps understand human performance by measuring the continuous interaction between sympathetic and parasympathetic effects on heart rate (Taralov et al., 2015). HRV is a non-invasive indicator of cardiovascular-autonomic modulation that has been viewed as a promising method recently. Human performance can be indexed through HRV as a measure of ANS via HRV (Giles & Draper, 2018; Plews et al., 2012).

No study has been found in the literature that evaluates the TUC time and HRV change determined by O_2 at atmospheric level at an altitude of 25,000 feet in a low-pressure chamber and the anaerobic performance determined by the Wingate test in a laboratory environment. In previous studies, the acute and chronic effects of training performed for a certain period with anaerobic test at optimum high performance in a low-pressure chamber were investigated (Andersen et al., 2020; Coudert, 1992; Takei et al., 2020).

Since aerobic metabolism is critical for staying active and maintaining movement in the cold, aerobic performance is a performance characteristic particularly suited to hypoxia at high altitudes (Cheviron et al., 2012; Hayes & O'Connor, 1999). However, hypoxia can have debilitating effects on aerobic performance, which may limit locomotor activity or impair thermogenesis, resulting in hypothermia (McClelland & Scott, 2019). The capacity formed using the anaerobic energy system of the muscles in maximal exercises is defined as anaerobic capacity (Yıldız, 2012). Although there are limited studies on the relationship between aerobic capacity and TUC, there is no research on its relationship with anaerobic capacity. WAnT, which is one of the laboratory tests, is frequently used to determine anaerobic capacity. The relationship of anaerobic capacity in terms of hypoxia and TUC and HRV parameters is curious. Anaerobic capacity with TUC the importance of anaerobic properties in tolerance to hypoxia will be tried to be determined by determining the relationship between HRV parameters. The aim of this study is to investigate the relationship between anaerobic capacity and the TUC determined in LAC in terms of performance and HRV in healthy men. Our hypothesis is that there will be a positive significant relationship between TUC and high anaerobic capacity, and between WanT performance and TUC performance in terms of HRV parameters.

MATERIAL AND METHOD

Participants

Thirty male participants who had a valid health report, no known chronic or acute health problems that would prevent participation in the measurements, and exercised at a recreational level voluntarily were included ($\bar{x}$ age: 23.2±0.8 years; height: 180.6±6.0 cm; body weight: 77.0±8.2 kg). Participants signed the voluntary consent form within the scope of the study.

Explanatory consent form was signed by the participants on the first day of the study. Data collection for each participant was done in the morning hours (09:00-12:00) on weekdays. Participants were warned not to do any physical activity the day before the tests and not to use stimulants such as food, medicine, coffee two hours before the test days. The day before the test, sleep conditions and pre-test excessive excitement were checked by asking questions. The tests were carried out in groups of 5 on different days of the week for three months. On the first day, anthropometric measurements were made in the low-pressure chamber at 25.000 feet until the TUC time was determined (3-5 minutes). On the second day, the Wingate test was performed to determine the maximum anaerobic capacity. A doctor and medical equipment were available during the tests. In both tests, the chest strap Polar H7 was attached to the participants and heart rate data were recorded.

Ethical Approval

Ethical compliance approval was obtained for this research from Eskişehir Technical University Science and Engineering Sciences Scientific Research and Publication Ethics Committee with the Ethics Committee Decision 5/5 on 09.01.2023.

Measurements

Height, Weight, and Fat Ratio: The height of the participants was measured as recommended by the International Society for the Advancement of Kinanthropometry (ISAK) with an accuracy of 1/10 cm (Holtein Harpenden 601, Holtain Ltd., UK). The body weights of the participants were measured with a 1/10 kg balance using the balance of the InBody brand 270 model (Biospace Co., S. Korea) body analyzer. To obtain the Body Mass Index (BMI) values of the participants, InBody brand 270 model (Biospace Co., S. Korea) body analyzer was used, and measurements were made according to the procedure specified in the device manual. The obtained data were recorded as %.

Low-Pressure Chamber: In the low-pressure 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 outside atmosphere. He was allowed to inhale 100% O_2 for 30 minutes at ground level. At the end of this period, the participants were brought to the atmospheric conditions at an altitude of 25.000 feet in 10 minutes. 100% O_2 support was cut and the O_2 rate in the atmosphere was brought to 21%. The participants' TUC duration was initiated from this moment. TUC duration was determined by the changes observed by the participants themselves (air hunger and O_2 demand-fear and excitement-feeling confusion-headache-dizziness-fatigue-nausea-blurred vision) or the changes determined by the observer in the participants (increased respiratory rate and depth-cyanosis (bruising) -mind confusion-excessive self-confidence-muscle coordination disorder) was terminated. In addition, the O_2 saturation measurement recorded by the device was also monitored, and if it fell below 70%. The test is terminated. The Air and Space Physician watched the participants throughout the test. The measurement was within the scope of routine physiological training.

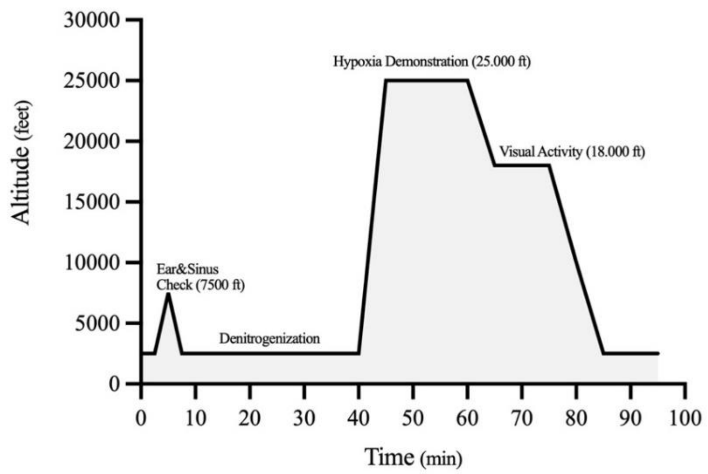

Figure 1. Altitude changes in low-pressure test

As shown in Figure 1, the low-pressure test starts at ground level and ascends to 7.500 feet and returns to 2.500 feet after the ear sinus scan. During the denitrogenization period, 100% O_2 is given for 30 minutes, and the climb is started in this way, and at the end of 5 minutes, a height of 25.000 feet is reached. Then, the participants are exposed to 21% O_2 as 3 people. Especially after 2 minutes, O_2 levels start to decrease rapidly, and the test is terminated at 70 level and below.

TUC Determination Criteria: The decision to determine the participant's end point of TUC duration was at the discretion of the supervising physiological training operator and aerospace physician. The assessment was mostly based on the subject's subjective findings and impairment in neuro-cognitive function. Inclusion criteria for TUC determination: (I) Presence of significant cyanosis, (II) Any impairment in speech, (III) Loss of short-term memory and communication delay, (IV) Incorrect response to a simple command, (V) Marked euphoria, (VI) Major error in simulator flight controls, (VII) Flickering, (VIII) Looking (glass eyed) and (IX) Fixation. The presence of any of the above observations or combinations resulted in termination of the TUC period and immediate wearing of the mask (Cipova, 2014).

Oxygen Saturation Determination: Oxygen saturation level was measured with a pulse oximetry device (ITAM-BlueECG-204P-Poland). Participants were evaluated and observed by an Aerospace Medicine Specialist before, during and after the test. The lowest SpO_2 levels were collected from the Oximeter Report to determine the physiological parameters of oxygen saturation associated with TUC (Oximeter reading was collected every 10 seconds from 1500 feet to mask wearing).

Anaerobic capacity (WanT): Anaerobic capacity testing of volunteers was performed using a Wattbike brand ergometer using WanT (Wattbike WPM ModelB, Wattbike Ltd., UK). Reliability study for 30 second test on Wattbike has been done previously (Driller et al., 2013). It records a calculation of the average power over each 5-second interval of a 30-second test and provides a peak power value based on the highest 5-second average and a degradation rate. During this test, participants were verbally encouraged to make maximum effort. Average power, maximum power and relative power were measured and recorded by WanT.

Heart Rate Variability: Heart rate was measured with the Elite HRV 4.7.2 IOS version Heart Rate Monitor and the Polar H7 band (Polar Electro, Kempele, Finland). HRV analyzes were processed by time, frequency, and nonlinear field analysis in Kubios HRV standard software for Mac (Biosignal Analysis and Medical Imaging Group, Department of Physics, Kuopio University, Finland, version 3.1.0.1). For the low-pressure test, heartbeat monitoring tapes were attached to the participants at the start of the test. Recordings were taken when 100% O_2 was given for 30 minutes, during the TUC when the O_2 level was reduced to 21%, and again for 5 minutes when 100% O_2 was given. Prior to exercise testing, each subject was instructed to lie down on an exercise mat for 10 minutes in a dimly controlled climate-controlled laboratory, following accepted recommendations (ESC et al., 1996). HRV was recorded 1 minute before the test, during the test (30 seconds), and 1 minute after the test. The recordings can be accessed by Kubios for later offline analysis. HRV values were recorded by transferring to HRV version 3.3.1 software (Tarvainen et al., 2014). HRV, as time domain, includes heart rate (beats per minute) and mean of R-R intervals in milliseconds (MeanRR), standard deviation of R-wave and R-wave intervals (SDNN), root mean square of consecutive R-R intervals (RMSSD), three frequency domains of the heart As a measure, the normalized absolute power of the low frequency band (Lfnu), the normalized absolute power of the high frequency band (Hfnu), and the ratio of LF-HF power (LF/HF) and ratio variability parameters were evaluated.

Statistical analysis

SPSS 26 for Mac statistical package program was used for the statistical analysis of the research. Data were presented with mean and standard deviation values. The Kolmogorov-Smirnov test was used to investigate the normality of the data distribution. One-way repeated analysis of variance (ANOVA) was used to compare the heart rate variability values before-during-post anaerobic capacity test and before-during-post low-pressure test. Bonferroni test was used for pairwise comparisons and the effect size value was calculated. Pearson correlation test was used to determine the relationship between TUC duration and anaerobic capacity. To calculate the sample size of the study, a minimum of twenty-eight subjects were analyzed using the G*Power 3.1 program with values of $f = 0.25$, $\alpha = 0.05$ (5% type 1 error probability) and $\beta = 0.80$ (80% power). Significance level was accepted as $p<0.05$. In our study, the margin of error was determined to be $d=0.05$ at the $\alpha=0.01$ significance level.

FINDINGS

Descriptive characteristics of the participants are presented in Table 1. The differences in WanT and LAC HRV parameter changes between pre-test, during the test, and post-test are shown in Table 2. The changes in HRV parameters during WanT and LAC (TUC) before, during, and after the tests are displayed in Figure 2. The distribution of absolute power, mean power, and relative peak power values determined during WanT and their correlation with TUC duration are illustrated in Figure 3.

The results are as follows:

The participants described in Table 1 had normal weight and low body fat percentage (ACSM, 2013). Additionally, their anaerobic capacities were low (Zupan et al., 2009).

Table 1. Descriptive characteristics of participants (n=30)

Descriptive Characteristics	$\bar{X}$	±	SD	Min.	Max.
Age (year)	23.2	±	0.8	22.0	25.0
Height (cm)	180.6	±	6.0	166.9	190.0
Weight (kg)	77.0	±	8.2	63.7	103.9
BMI (kg/m^2)	23.6	±	2.3	20.6	30.6
Fat Rate (%)	14.7	±	4.5	7.3	29.1
Anaerobic Relative Peak Power (W/kg)	7.1	±	0.9	5.3	9.1
TUC (sec)	169.4	±	33.9	116.0	255.0

Table 2. Illustrates the differences in WanT and LAC HRV parameter changes between pre-test, during the test, and post-test (n=30)

HRV	Test	Pre-Test ($\bar{x}$ ± SD)	Test ($\bar{x}$ ± SD)	Post-Test ($\bar{x}$ ± SD)	F	Binary Comparison	η_p^2
MeanRR (bpm)	WanT	511.3 ± 54.9	373.5 ± 31.2	369.3 ± 25.0	218.4***	1-2***; 1-3***	0.89
	LAC	729.1 ± 82.9	603.9 ± 56.7	695.8 ± 83.7	52.0***	1-2***; 1-3***; 2-3***	0.64
SDNN (ms)	WanT	30.8 ± 19.6	13.8 ± 10.9	12.4 ± 9.5	21.1***	1-2***; 1-3***	0.47
	LAC	61.6 ± 18.7	35.1 ± 13.5	59.6 ± 20.9	40.7***	1-2***; 2-3***	0.59
RMSSD (ms)	WanT	25.6 ± 20.9	16.7 ± 15.4	18.8 ± 17.4	1.3		0.05
	LAC	53.0 ± 19.1	30.6 ± 17.4	51.1 ± 24.5	31.2***	1-2***; 2-3***	0.53
Lfnu (ms^2)	WanT	69.8 ± 19.8	66.9 ± 27.3	53.8 ± 26.4	6.0**	1-3*	0.17
	LAC	56.8 ± 13.4	55.2 ± 17.1	62.2 ± 13.6	1.7	1-3*; 2-3**	0.07
Hfnu (ms^2)	WanT	30.3 ± 20.4	32.8 ± 27.1	44.5 ± 26.0	3.6*	1-3*	0.11
	LAC	43.1 ± 13.4	44.7 ± 17.0	37.7 ± 13.6	6.0**	1-3*; 2-3**	0.17
LF/HF	WanT	4.5 ± 4.0	5.7 ± 8.3	3.2 ± 4.3	1.6		0.06
	LAC	1.6 ± 0.9	1.9 ± 2.4	2.3 ± 2.4	2.5		0.08

The changes in HRV parameters for both tests are presented in Table 2. The changes in MeanRR and SDNN were significant for both test stages (p<0.001), while the change in RMSSD was only significant for LAC (F=31.2***). Among the frequency domain parameters, the change in Lfnu was significant for WanT pre-test, during the test, and post-test (F=6.0**), and the changes in Hfnu were significant for LAC (F=6.0**) and WanT (F=3.6*).

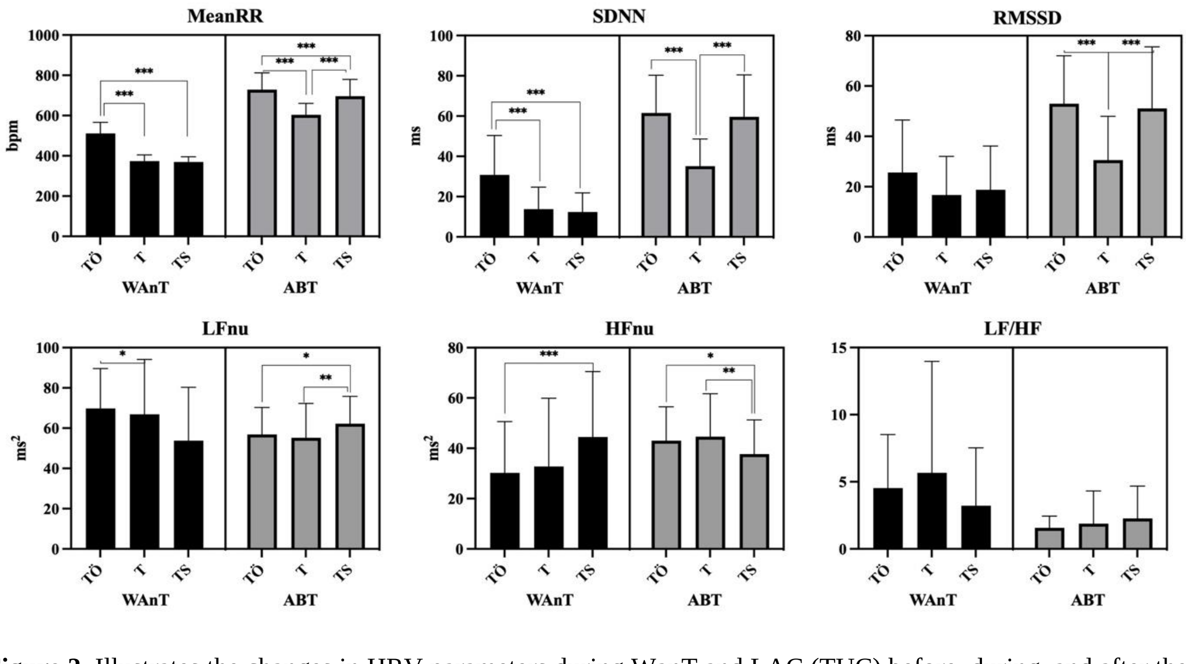

Figure 2. Illustrates the changes in HRV parameters during WanT and LAC (TUC) before, during, and after the tests (n=30)

The changes in HRV in terms of time and frequency domain parameters before, during, and after the WanT and LAC are shown in Figure 2. It can be observed that the recovery is significantly achieved in LAC compared to WanT.

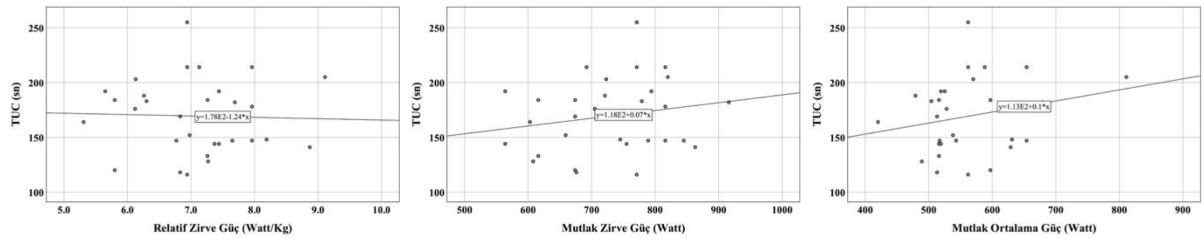

Figure 3. Presents the distribution of absolute power, mean power, and relative peak power values determined in the WanT in relation to TUC duration (n=30)

A non-significant negative correlation was found between the TUC and the Relative Peak Power determined in the WanT (r=-0.03; p=0.86), while there were non-significant positive correlations with Total Peak Power (r=0.19; p=0.31) and Total Mean Power (r=0.23; p=0.23).

DISCUSSION AND CONCLUSION

The aim of this study was to examine the relationship between anaerobic capacity and TUC determined in a LAC in terms of HRV. The research questions were as follows: Is there a significant relationship between anaerobic performance and usable consciousness time in a LAC? And are there significant differences in HRV parameters between the pre-test, during-test, and post-test periods for anaerobic performance and TUC? We assumed that there would be a significant relationship for the first question and differences for the second question.

According to the findings of our study, the changes in time domain parameters (MeanRR, SDNN) and frequency domain parameter (Hfnu) of HRV were significant for both WanT and LAC in the pre-test, during-test, and post-test periods. The changes in RMSSD were significant for LAC, while the changes in Lfnu were significant for WanT. Binary comparisons, there was a significant difference between the pre-test and during-test periods for WanT, but no significant difference between the during-test and post-test periods. For LAC, there were significant differences between the pre-test and during-test periods, as well as between the during-test and post-test periods. Regarding the relationship between anaerobic capacity and TUC duration, there was no statistically significant relationship between TUC duration and relative peak power (r=-0.03, p=0.86), while there were positive but statistically insignificant relationships between TUC duration and total peak power (r=0.19, p=0.31) and total mean power (r=0.23, p=0.23).

As blood oxygen decreases, hypoxic effects begin, and serious problems can occur when it falls below 70% SpO_2. Previous studies have found that training in hypoxic or normoxic conditions can lead to aerobic improvements at submaximal levels but does not enhance VO_{2max} and anaerobic capacity (Coudert, 1992b; Friedmann et al., 2007; Fulco et al., 1998; Tadibi et al., 2007). Some studies have reported positive effects on aerobic development (Czuba et al., 2011; Ramos-Campo et al., 2018), while others have shown no significant effects (Dufour et al., 2006; Prommer et al., 2007). The evaluation of anaerobic capacity is limited in the literature. In a study conducted with Korean Air Force pilots, Kim et al. (2022) reported that although not statistically significant, TUC duration showed a negative correlation with running, push-up, and sit-up tests and a negative correlation with fat percentage. A study conducted with Indonesian Air Force pilots indicated that physical fitness and aerobic performance were not related to TUC (Sucipta et al., 2018). A study with 929 Korean Republic pilots analyzed variables that showed significant correlation with TUC by controlling blood parameters, physical fitness tests, respiratory function tests, and lifestyle. As a result, total flight time, degree, and smoking duration showed negative correlation with TUC, while body mass index, respiratory function tests, and flexibility showed positive correlation (C. Kim et al., 2001).

In research on anaerobic performance at altitude, Coudert (1992), as a result of his study on anaerobic training at altitude, reported that high altitudes up to 5.200 m did not change anaerobic performance and that muscle mass began to decrease after this period. It has been reported in another study that Wingate exercise repeated on four separate days in a hypobaric chamber may be an effective strategy for athletes aiming to maintain training quality in hypobaric hypoxia corresponding to 3.050 m by highly trained athletes (Andersen et al., 2020). Meeuwsen et al. (2001) investigated the extent to which intermittent altitude exposure in a hypobaric chamber could improve performance at sea level and noted that intermittent hypobaric training could improve both aerobic and anaerobic energy supply systems. The results of these studies argue that anaerobic performance can be improved in the low-pressure chamber. Akgül et al. (2022) stated that anaerobic training performed in a low-pressure room does not create a significant difference in terms of performance. In our study, high anaerobic performance does not affect the TUC duration, so it is compatible with the result of this study. Aebi et al. (2020) measured HRV and SpO_2 while sitting for a period of 6 minutes with fifteen young pilot candidates in a low-pressure chamber at an altitude of 3000-5200 m, and for HRV, RMSSD and LF, HF, LF/HF ratio and total analyzed for power (TP). Gas exchanges were collected at rest for 10 min following HRV recording. As a result, a hypobaric effect that was not significant in terms of HRV change in normoxia or hypoxia was reported. In our study, while HRV changes were not significant for RMSSD, they were significant for LFnu and HFnu. This may be because the elevation in our study was 25,000 feet (7.620 m) higher.

The most striking result of this study is the lack of a significant difference between TUC duration and anaerobic performance of the participants. Additionally, in terms of changes in HRV parameters, recovery was significant after TUC in LAC, but no recovery was observed after WAnT. Our hypothesis, which we created in parallel with the study results showing the positive effects of anaerobic training at high altitude, was rejected. According to the results of this research, anaerobic exercises are not a priority in terms of performance and HRV change to increase TUC. Anaerobic performance may not be the primary criterion for personnel selection for high altitude missions. Including a wider range of participants by gender or using elite groups and control groups in future studies may contribute to the literature.

Conflict of Interest: There is no personal or financial conflict of interest within the scope of the study.

Researchers' Statement of Contribution Rate: Research Design TA, RA, NK; Statistical analysis TA, DŞ, NA; Preparation of the article, TA, RA, DŞ, LŞ; Data Collection was carried out by TA, NK, YT.

Information on Ethics Committee Permission

Committee Name: Eskişehir Technical University Science and Engineering Sciences Scientific Research and Publication Ethics Committee

Date: 09.01.2023

Issue/Decision Number: 5/5

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