ALTERATIONS OF SOME PULSE WAVE PARAMETERS ON VIETNAMESE MILITARY AIRCREWS AT SIMULATED 5,000 METERS ALTITUDE

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SUMMARY

Objectives: *To evaluate alterations of some arterial stiffness and arterial pulse wave time indices in military aircrews under simulating hypoxic conditions at altitude of 5,000 meters.* ***Subjects and methods:*** *The interventional study was conducted on 97 male military aircrews; Hypobaric Oxygen Chamber HPO 6+2 (AMST, Republic of Austria) was used to mimic hypoxia at 5,000m altitude in 20 minutes; and AngioScan M01 (Angio Electronic, Russian), a device was used to perform a noninvasive examination of arteries by assessing some pulse wave parameters.* ***Results:*** *As compared with ground conditions, there was a statistically significant increase in stiffness index at 5,000m (median comparison: 7.9 m/s vs 7.4 m/s; p < 0.001); a decrease in augmentation index (AIp) and augmentation index normalized to heart rate of 75 beats per minute (AIp75): AIp: -22.74 ± 14.75% vs 0.11 ± 14.34%; AIp75: -13.93 ± 11.75 vs -1.34 ± 12.42% (p < 0.001). The decrease of reflection index (RI) was statistically significant: 16.52 ± 7.03% vs 34.31 ± 10.61% (p < 0.001). Paired comparisons on some stiffness parameters at 5,000m altitude: 72.1% with increased stiffness index; 92.8% with decreased AIp; 92.8% with decreased AIp75; 98.97% with decreased RI; statistical significance with p < 0.001. In comparison with ground condition, the duration of the pulse wave (PD): PD was decreased: 646.90 ± 85.46 ms vs 846.13 ± 103.57 ms (p < 0.01). The ejection duration (ED) and percentage of ejection duration (%ED): ED was decreased: 258.05 ± 12.69 ms vs 279.05 ± 14.26 ms; %ED was increased: 40.51 ± 4.46% vs 33.46 ± 3.31% with statistical significance (p < 0.01). This time parameter dTpp (ms) was decreased: 91.06 ± 14.91 ms vs 98.66 ± 15.9 ms, with statistical significance (p < 0.01).* ***Conclusions:*** *The alterations of arterial stiffness index and time parameters of arterial pulse wave at simulated 5,000m altitude reflected a physiological stress and cardia burden in military aircrews exposed to acute hypobaric hypoxia.*

** Keywords: Military aircrew; Pulse wave; Hypobaric chamber; Altitude; Hypoxia.*

INTRODUCTION

The concept of aircrews: The pilot of military aircraft and the person on duty to navigation on military aircraft (Excerpt from Article 2, Regulation of Air Force Medical Examination (2014) [1], military aircrews are special workers, affected by many physiological disadvantages during flight. Hypobaric hypoxia is generally recognized to be the most serious single physiological hazard during flight at high altitude, because of barometric pressure fall, causing changes in cardiovascular physiological function, reduced concentration,

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memory, performance and severely fainting, death while flying. In progress of health examination, hypobaric hypoxia (HH) tests are specific tests, conducted to check the level of endurance and adaptability of the subjects with acute hypoxia. Changes in cardiovascular physiology in response to acute hypoxia are factors to evaluate and predict the aircrew response to disorders exceeding the physiological threshold due to hypoxia that can occur in flight operations [2].

Arterial pulse waves are formed by contraction of the heart to pump blood to the periphery arterial, there are many methods to examine arterial waves with measuring devices and corresponding arterial wave indicators, reflecting the physiological function of the arterial system under normal as well as under hypoxia conditions [3, 4].

Digital volume pulse (DVP) is a non-invasive method of surveying the artery wave contour, providing arterial stiffness indices and pulse wave component timing indicators, which helps to evaluate the function of the arteries [5] .

The study was conducted aiming: *To evaluate alterations of some arterial stiffness and arterial wave time indices measured by AngioScan-01device in aircrews under simulating hypoxic conditions at altitude of 5,000m.*

SUBJECTS AND METHODS

1. Subjects

97 male aircrews with flight hours from 85 - 4,500 hours undergo medical examination at Air Defence-Air Force Medical Institute, from 10/2017 - 8/2018.

* *Inclusion criteria:* Aircrews were performing regular flight missions on military aircraft.

* *Exclusion criteria:* Subjects suffered from acute illness, failed to comply with the requirements of preparation for a hypobaric hypoxia test, or refused to participate in the study.

2. Methods

* *Study design:* Interventions study, with before-after comparison.

* *Methods of research indicators identification:*

- Hypobaric hypoxia test in HPO 6+2 Chamber (AMST-Australia):

+ Preparation of the subject: The subject was given a complete rest at least 12 hours in advance, did not use stimulants and medications, did not perform stress tests, was disseminated the testing process and agreed to participate test.

+ Preparation of main equipment: HPO 6+2 hypobaric chamber was technically tested including complete inspection, control system, internal and external oxygen, communication, safety ensurance and physiological monitoring systems. The chamber stated at 0m, oxygen concentration of 21.9%.

+ Warm-up the hypobaric chamber: Accent it to 5,000m with a speed of 15 m/s according to the procedure, maintain an altitude of 5,000m for 20 minutes, perform the contents of monitoring physiological indicators... After 20 minutes, decent the chamber to 0m at a speed of 15 m/s, then take the subjects out of the room and check them after testing according to the procedure.

- Monitor cardiovascular physiological indicators in the Hypobaric Chamber (HPO):

+ Monitoring device: IntelliVue MX70 system (Phillips, Netherland), with standardized device assemblies placed in the HPO, the monitoring screen and the operation outside the HPO. Blood pressure, blood oxygen saturation were measured continuously in real time; systolic (SBP), diastolic (DBP) and mean arterial (MAP) blood pressure were measured at 5-minute intervals or as determined by the doctor. Time points of evaluation: Right before starting of HH test; time of the first minute and the 20th minute at an altitude of 5,000m. MAP was calculated by the formula: MAP = (SBP-DBP)/3 + DBP (mmHg).

* *Measurement and analysis of arterial pulse waves:* Used an AngioScan-01 non-invasive arterial function measuring device (AngioScan-electronic - Russian federation) with DVP method, the probe used a 960 nm near-infrared wavelength, calculated arterial stiffness indices and time paremeters of pulse wave based on the measurement of the pulse wave contour.

- At rest (0m): Aircrews took a full rest at least 10 minutes in a quiet room, measured in a sitting position, with the probe clamped at the tip of the right index finger of the right hand, the right hand postured horizontal to the right heart. Subjects were minimized movement during the measurement [5].

- At simulated altitude of 5,000m: With the same procedure at the 20th minute of HH testing.

* *Clinical examination and tests:* Health examination procedure described in the Air Force Medical Examination Regulations (2014). Arterial blood pressure was measured by Korotkoff method; Heart rate, height, and weight measured using standard methods.

* *Data processing:* Research data was stored and processed by statistical algorithms on SPSS 22.0 software.

RESULTS AND DISCUSSIONS

1. General characteristics of research subjects

Table 1: General characteristics of research subjects.

Indicators	Aicrews (n = 97)
Age ($\overline{X}$ ± SD)	36.06 ± 7.15
Age distribution (n, %)	
< 30	21 (21.7)
30 - 40	45 (46.4)
> 40 years	31 (31.9)
Height ($\overline{X}$ ± SD) (cm)	171.17 ± 4.27
Weight ($\overline{X}$ ± SD) (kg)	73.15 ± 6.42

Mean flying hours ($\overline{X}$ ± SD) (hours)	712.09 ± 408.37
Flying hours distribution	
< 500	30 (30.9)
500 - 1,000	50 (51.6)
> 1,000	17 (17.5)

The average age of subjects was 36.06 ± 7.15 years, mainly above 30 years old, accounting for 78.3%. The average flying hours was 712.09 ± 408.37 hours. Aicrews had the flight hours of 500 - 1,000 hours, accounting for the largest proportion (51.6%).

2. Alterations of pulse, blood pressure and SpO_2 under hypoxic conditions at simulated altitude of 5,000m

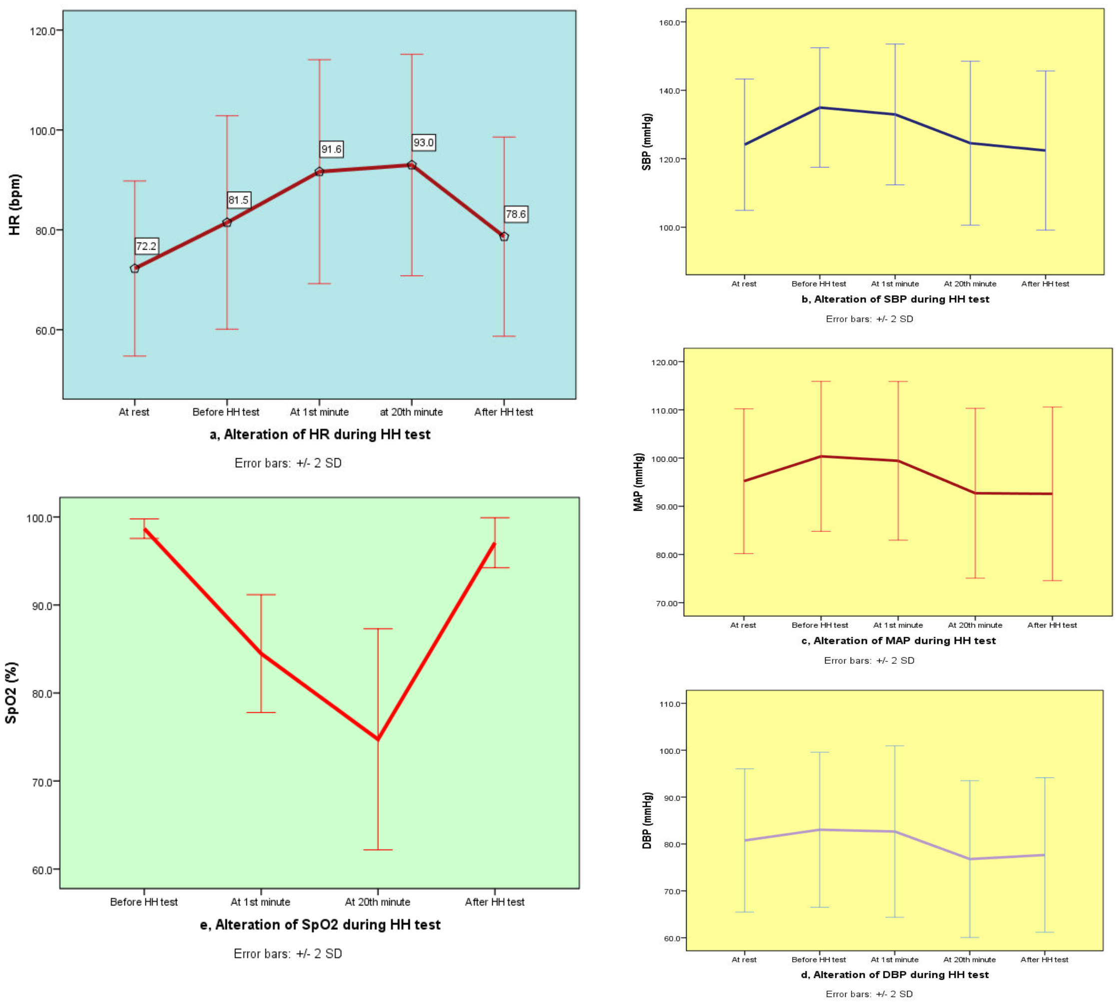

Figure 1: Pulse, blood pressure and SpO_2 under hypoxic conditions at simulated altitude of 5,000m (a: HR; b: SBP; c: MAP; d: DBP; e: SpO_2).

The pulse rate and BP were slightly increased at the time just before the hypoxia test, reflecting the psychological stress of the study subjects. At the 1st minute at the altitude of 5,000m, the heart rate increased statistically and maintained until the 20th minute; BP increased compared with the rest afterward tended to decrease slightly at the final stage of the trial. After returning to the height of 0m, the pulse frequency increased and blood pressure decreased slightly compared with at rest ($p < 0.05$). Peripheral arterial blood oxygen saturation decreased at the first minute and continued to significantly decrease in the 20th minute of the trial. At the recovery phase, there was no difference about SpO_2, compared with just before the HH test ($p > 0.05$).

The research results reflected changes in hemodynamic parameters due to acute hypobaric hypoxia, similar to the Vedam (2009) and Melnikov's finding (2017) on cardiovascular physiological indices in healthy male exposed with acute hypoxia at medium altitude [6, 7].

3. Change of arterial stiffness indices under simulated hypoxic conditions at altitude of 5,000m.

Table 2: Change of arterial stiffness indices under simulated hypoxic conditions at altitude of 5,000m.

Arterial stiffness index	At 0m	At 5,000m - 20th minute	p
SI (m/s)			
Mean	7.48	7.94	
Median	7.4	7.9	< 0.001*
AIp (%)			
$\bar{X} \pm SD$	0.11 ± 14.34	-22.74 ± 14.75	< 0.001
AIp75 (%)			
$\bar{X} \pm SD$	-1.34 ± 12.42	-13.93 ± 11.75	< 0.001
RI			
$\bar{X} \pm SD$	34.31 ± 10.61	16.52 ± 7.03	< 0.001

(: Wilcoxon grading test for two related samples)*

The stiffness index increased when subjects were exposed to acute hypoxia at simulated altitude of 5,000m ($p < 0.001$). AIp and AIp75 as well as RI decreased significantly at oxygen deficient exposure of 5,000m compared with rest at 0m ($p < 0.001$).

Table 3: Variations in arterial stiffness index under hypoxic conditions simulation of 5,000m altitude.

Arterial stiffness index	Compare the after - before the HH test			p*
	Decrease	Unchange	Increase	
SI (m/s)	22 (22.7)	5 (5.2)	70 (72.1)	< 0.001
AIp (%)	90 (92.8)	0 (0.0)	7 (7.2)	< 0.001
AIp75 (%)	90 (92.8)	0 (0.0)	7 (7.2)	< 0.001
RI (%)	96 (98.97)	0 (0.0)	1 (1.03)	< 0.001

(: Non-parametric Wilcoxon test for after-before classification)*

The non-parametric Wilcoxon test for after-before classification of stiffness index showed that the main trend of change in the stiffness index was the increase of the aortic artery wave velocity (72.1%) ($p < 0.001$). Whereas RI indicators showed a decrease in acute oxygen exposure (92.8%) (for AIp and AIp75) and 98.97% (for RI), with $p < 0.001$.

The studies analyzed arterial wave values using different measuring instruments and gave different reference values, but the tendency of alterations in the arterial wave indices under similar conditions of the degree and duration of exposure to hypoxia is quite similar. Vedam (2009) studied healthy subjects, using the Sphygmocor device (AtCor Medical, Australia), the results showed that there was a 6.7% reduction in Aix for every increasing 10 heartbeats due to oxygen deficiciency with 60-minute exposure time. Similarly, Melnikov (2017) found that after 10 minutes of exposure to normobaric hypoxia (10% oxygen concentration), the Aix value reduced 114% [6, 7].

Studies by Boos (2007, 2012) on subjects exposed to hypoxia at different altitudes, the result showed an increase in reflexion index and stiffness index in the first 45 minutes of hypoxia exposure at 4800m, and reflexion index tend to decrease with increasing altitude to 5,140m [8, 9].

4. Alterations of the arterial pulse wave interval under hypoxic conditions simulated at a altitude of 5,000m.

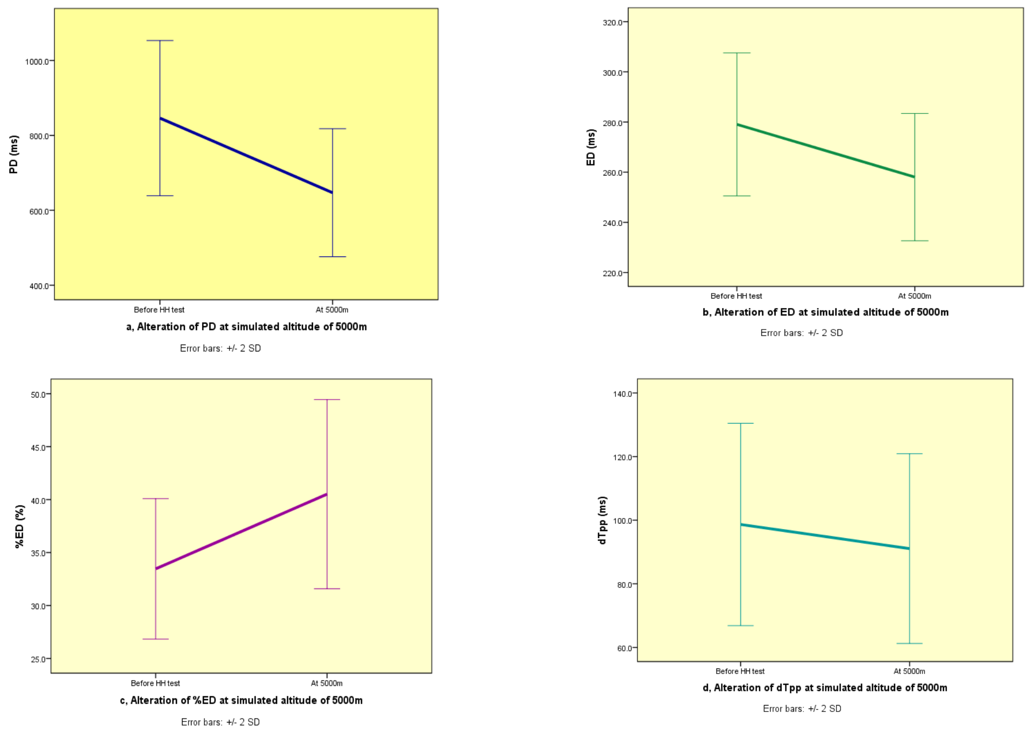

Figure 2: Alterations of arterial pulse wave parameters under hypoxic conditions at stimulated altitude 5,000m (a: PD; b: ED; c: %ED; d: dTpp).

The study results showed that the index of ED, PD, T_1, T_2 decreased at the altitude of 5,000m, these results were consistent with the fact that acute hypoxic exposure increase heart rate. In addition, ED increased in an excess of 40%, in some cases, which indirectly reflected the decrease in diastolic time relative to the total pulse cycle time, thus reducing the duration of coronary perfusion. The dTpp index decreased at an altitude of 5,000m, reflecting the less elasticity of the aorta, which means that the aorta was "stiffer", so the impact of reflected waves on the heart was stronger, increase afterload.

In the studies by Vedam (2009) and Melnikov (2017), the reflection wave period parameters Tr (% Tf - length of the cardiac cycle) increased, left ventricular ejection time (% Tf) increased and DD (% Tf) decreased, the trend of variation was similar to the arterial wave time parameters in this study, reflecting changes the in physiology of arterial system in acute hypoxic condition [6, 7].

Under conditions of acute hypoxia exposure, tachycardia increased myocardial oxygen demand, which leads to decreased coronary perfusion due to an increase of %ED and afterload because of "stiffer" aorta. All of the alterations of arterial pulse wave suggested that acute hypoxia had synergistic effects, which increased burden on the cardiovascular system, requiring strong physiological adaptation process.

CONCLUSIONS

In 20-minutes hypoxia exposure at 5,000m simulated altitude, stiffness index increased and AIp, AIp75, reflexion index indices decreased statistically significant. PD, ED, dTpp decreased and %ED increased statistically significant compared to the grounded condition.

The alterations in arterial stiffness indices and time parameters of arterial pulse wave at simulated altitude 5,000m reflected physiological stress and cardia burden in military aircrews exposed to acute hypobaric hypoxia.

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