

Peculiarities of body adaptation to moderate altitude conditions in military personnel

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Abstract.

This study aimed to explore the influence of extreme factors on the body's adaptive capabilities and neurodynamic functions in military personnel. The research involved 26 cadets with an average age of 19.7 years; the study was conducted at an altitude of 1100 m above sea level. The cadets engaged in a 5-kilometer forced march at an air temperature of -15°C , with data measured using a Garmin Fenix 6S Pro watch. The adaptive capabilities of the functional state were assessed using the "MPFI rhythmograph-1" system and EasyHRV software, while sensorimotor functions were evaluated using the "DIAGNOST-1" computer system. Statistical analysis, employing non-parametric methods, was applied to the collected data. The results indicate that extreme factors significantly influenced the adaptation capabilities of the cadets. According to the median, the time of passing the distance was 29 min 23 s with an average heart rate of 159.5 bpm and an energy expenditure of 333.5 kcal. Duration of high-intensity activity was 12.28 min in the heart rate zone of 162-181 bpm-1, and zero time was spent in the maximum heart rate zone. The latter may be related to the impact of temperature conditions on the intensity of physical exertion. Indicators of heart rate variability (HRV) showed a statistically significant increase after the 5-kilometer run ($p < 0.01$). Parametric pulse amplitude and normalization index also increased after running ($p < 0.01$) indicating increased cardiovascular function. We found a decrease in the overall HRV at the median from 1313.5 to 1038.5 ms^2 after the forced march, however this change was not statistically significant ($p = 0.06$). A decrease in HRV was observed in the low-frequency and high-frequency ranges. There was also an increase in the dominance of low-frequency HRV at the median from 0.63 to 0.78 ($p = 0.02$) and a decrease in the high-frequency range at the median from 0.37 to 0.22 ($p = 0.02$). The analysis of the sensorimotor functions showed an improvement in the accuracy of the sensorimotor reaction after running ($p = 0.02$). The number of anticipations decreased significantly indicating a decrease in the number of false responses to a moving object ($p = 0.02$). The number of delays increased ($p = 0.04$) after physical exertion which may be related to fatigue. Conclusions. The results are important as they provided additional data on the functional state of the body after specific physical exertion. Monitoring HRV and sensorimotor functions can be a useful tool for assessing the body's recovery after physical exertion, determining optimal physical exertion, and identifying possible disruptions in the body's adaptive capabilities.

Key words: extreme conditions, military personnel, heart rate variability, cognitive functions, aerobic endurance

Introduction.

The analysis of literary sources points to the relevance of the problem of studying the peculiarities and physiological mechanisms of adaptation to various factors of the external environment of the cadets of higher military educational institutions (HMEI) (Petrachkov, Yarmak, Biloshitsky, 2023). As a separate direction of research, it is worth considering the peculiarities of the body adaptation of military personnel to adverse factors in the moderate altitude conditions related to their professional activities. The vast majority of scientific studies which have dealt with the issue of the peculiarities of the physiological mechanisms of adaptation of the body have been carried out on the athletes. Specialists (Cherkes, et al. 2014; Khodaei et al. 2016; Isaev et al. 2016;) note that mountain training is an integral part of the modern training process, especially cycling activities and kind of sports, where athletes have to compete in both short and long distances. The high level of achievements in modern sports requires constant improvement of all aspects of an athlete's training. Together with the continued use of traditional methods of athletes' versatile training, the development and use of non-traditional means and methods of training in the moderate altitude conditions is becoming more and more important. They are aimed at expanding the cross-functional capabilities of the athlete's body, their aerobic and anaerobic productivity which largely determine the level of work capacity (Cherkes, et al. 2014; Khodaei et al. 2016).

V.V. Sosnovsky et al (2019) in his scientific research notes that during functional loads (active orthotest) in middle mountain conditions a decrease in vegetative reactivity was observed in most athletes due to the

weakening of vagal influences. As a result, it was unable to ensure the maintenance of vegetative homeostasis at the required level during orthostasis. At the same time, athletes, who during the initial period of adaptation to the moderate altitude conditions had high values of heart rate variability, had unstable states and states with high stress of regulatory mechanisms at rest and during an active orthotest, which indicated overstrain of adaptation processes in the moderate altitude conditions and a decrease in resistance to functional loads. Compared with the athletes, whose indicators were in the range of moderate intensity of regulatory processes and balance of sympathetic and parasympathetic influences during the initial period of adaptation to the moderate altitude conditions, the activity factor of the adaptation mechanisms of the cardiovascular system was significantly reduced and the factors of unstable states and centralization of regulatory mechanisms were increased. Studying the mechanisms of adaptation to physical exertion has been one of the main problems of modern physiology and medicine because in the process of life, the human body is constantly faced with changes in homeostasis that occur during the movement execution (Chatterjee et al. 2017; Aandstad et al. 2020; Alvarez-Alvarado, 2021).

According to Samoylenko T.V. (2012) for athletes, training in the moderate altitude conditions is quite an effective means of increasing special work capacity. The positive effect of staying in the mountains can be used to increase the body's resistance to extreme influences during training for the professional activities of military personnel and to improve athletes' sports results.

The military and professional activity of the armed forces personnel is accompanied by the influence of many negative environmental factors (Jayaswal et al. 2001; Petrachkov 2011; Lechner et al 2018; Petrachkov et al. 2023). The essence of military professional activity is the planned, systematic and flexible training of service personnel, which enables them to perform their assigned functional duties successfully. The dynamic development of information technologies, weapons and military equipment is changing the nature and methods of conducting combat operations, as well as approaches to improving the content of combat training. Nevertheless, physical training remains one of the main components of combat training, which ensures the physical and psychological readiness of service personnel to act in extreme conditions and assumes the presence of a high level of development of special physical qualities (Volf et al. 2018; Kostiv et al. 2021; Petrachkov et al. 2022; Alemany et al. 2022). Chamberlin R.A et al. (2020) have noted that the formation of special operations force units also requires the development of measures to ensure the readiness of soldiers to act in conditions that are significantly different from those that exist in places of permanent deployment. Therefore, managers and specialists who are directly involved in the combat training of military units should know the peculiarities, means and methods of ensuring the body's preparation for adverse factors of the external environment and possess the methodology of preliminary adaptation of personnel to them. Thus, the study of the physical state of the human body during intense physical exertion in the moderate altitude conditions becomes especially relevant.

An analysis of the literature indicates that there are studies that are mainly devoted to the impact of high altitude conditions on military operations (McLaughlin et al. 2017). The authors examine the psychological aspects of service in high mountain conditions (Rajesh et al. 2021), as well as their impact on the physiological state of the military contingent (Saini et al. 2021). However, there are few scientific reports related to the study of the adaptive capabilities of the cadets' body in the moderate altitude conditions, which is essential for ensuring optimal physical preparedness of personnel, especially in the context of military professional activities. Furthermore, the examination of adaptation processes is becoming key to understanding not only physiological aspects but also their impact on neurodynamic functions. The study of the central nervous system's response to extreme conditions will reveal the mechanisms of adaptation and their impact on cognitive processes, including sensorimotor reactions. The identification of these aspects will improve the methods of physical training and increase the tolerance of military personnel to extreme conditions. Therefore, the search for a deeper understanding of physiological and neurodynamic responses to extreme conditions determines the strategic importance and relevance of further research in this area.

Materials and methods

Study participants. 26 cadets, whose average age was 19.7, were examined for the study of the influence of stress factors in the moderate altitude conditions on the adaptation capabilities of the body and neurodynamic functions. The study was conducted in a mountainous area at an altitude of 1100 m above sea level. As part of the experiment, the cadets of HMEI engaged in a 5-kilometer forced march across mountainous terrain at an air temperature of -15°C. Before the start of the experiment, each of the subjects signed an informed consent form, which contained a detailed description of the procedure and the risks associated with its implementation.

Organization of the study.

The indicators of the time, average speed of running, and average heart rate (HR) were measured during a 5-kilometer forced march using a Garmin Fenix 6S Pro sports watch, equipped with a mobile GPS navigation system; the peak HR for each cadet, the energy expenditure of the main metabolism, and the cardiovascular function during running in intensity zones were recorded.

To achieve the goal, we conducted a comprehensive study of the functional state of the cardiovascular system, which included the assessment of heart rate variability (HRV), which makes it possible to assess the degree of tension or tone of the sympathetic or parasympathetic nervous system in cadets. For this, we used a

hardware and software complex consisting of the multifunctional device “MPFI rhythmograph-1” and EasyHRV software. That software complex is designed to study the state of the cardiovascular and central nervous systems by indicators of HRV and T-wave parameters of the PQRS complex. We chose the optimal duration of electrocardiogram recording with 5 min duration (300 s). The electrocardiogram was recorded while sitting in front of a computer monitor in accordance with the “International Standard” (Task Force of the European of Cardiology, 1996). The research included two stages. The first stage involved determination of HRV in a state of relative rest; at the second stage, HRV was immediately determined after a 5-kilometer run across mountainous terrain. The protocol of the multifunctional device “MPFI rhythmograph-1” contained spectral indicators of HRV, time indicators that additionally characterized the distribution of cardio intervals, and indicators of autocorrelation analysis. Figure 1 shows the research protocol. The stress index was determined based on heart rate variability indicators using the following formula: $\text{Stress Index} = \text{Moda} \cdot \text{AMO} / 2 \cdot \text{deltaX}$; where: Moda (ms) - the magnitude of the amplitude of the frequently occurring complex; AMO (%) - the ratio of the number of amplitudes corresponding to Moda to the total number of amplitudes, expressed as a percentage; deltaX (ms) - the difference between the maximum and minimum values of the amplitudes of the complex. The results were evaluated using a grading scale, where a low level corresponded to 56.36 units of measurement or less, below average level from 56.37 to 64.79 units of measurement; average level from 64.80 to 81.64 units of measurement; above average level from 81.65 to 90.06 units of measurement; high level 90.06 units of measurement or above.

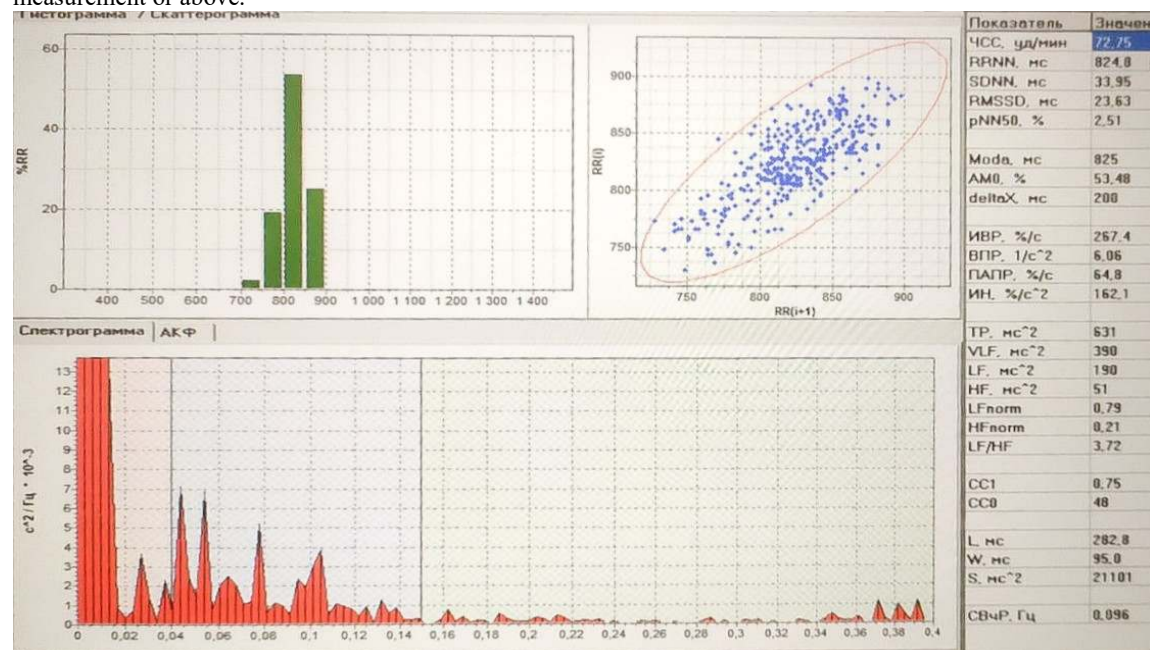


Figure 1. Protocol of the multifunctional device “MPFI rhythmograph-1” while studying the variability of HMEI cadets’ HR in the moderate altitude conditions

With the help of the “DIAGNOST-1” computer system, which was developed by N.V. Makarenko and V.S. Lyzogub (2018) we determined the individually typological properties of higher nervous activity and sensorimotor functions of the cadets of HMEI with processing visual information of various complexity degrees in the state of relative rest and after a 5-kilometer forced march. The cadets’ reaction to a moving object was determined by a movement time of 1000 ms. A total of one series of reactions was performed during which 30 attempts were made with the determination of the total amount of deviations during the movement time, the average deviation during the movement time, and the number of reactions both anticipated and delayed.

Statistical analysis. The obtained results were subjected to detailed statistical analysis using the highly functional software “Statistics 10.0” (StatSoft Inc., USA). Before conducting further analysis, we paid special attention to checking the conformity of the experimental data to a normal distribution, using the Shapiro-Wilk statistical test. This criterion allowed us to assess how closely our observations fitted the expected normal distribution. The test results revealed deviations from the normal distribution, so we applied non-parametric statistical methods. For further data analysis, we used the median (Me), which represents the central tendency indicator, as well as the upper (25%) and lower (75%) percentiles. These metrics allowed us to estimate the distribution of the values of the studied variables and to carry out the analysis without reference to a specific theoretical distribution. To compare the results between dependent samples, we used the non-parametric Wilcoxon test with the selected critical level of significance $p < 0.05$. That approach allowed us to evaluate the

obtained results more objectively and accurately providing a reliable statistical basis for our conclusions and recommendations.

Results

The obtained results have provided scientific information regarding the level of physical endurance and functional status of the studied group. Table 1 shows the obtained results. The study participants covered a 5-kilometer distance in medium-mountain conditions with an average time of 29 min 23 s. During the forced march, the average HR was 159.5 bpm. This indicates a high level of functional activity of the cardiovascular system during the exercise, and may be the result of adaptation of the cardiovascular system to training and high physical activity, which is accompanied by an increase in cardiac output and blood flow to the muscles. It is known that the pace of running can affect the performance of the obtained results.

Table 1. Results of the 5 km forced march in the moderate altitude conditions, n=26

Parameter	Statistical characteristics					
	Me	25th percentile	75th percentile	Min	Max	V, %
Time for completing the 5 km forced march, min. s	29.23	26.10	30.17	23.10	30.38	8.6
Average heart rate over the distance, bpm	159.5	153.0	168.0	150.0	172.0	4.8
Minimum heart rate over the distance, bpm	136.0	120.0	152.0	77.0	167.0	17.7
Maximum heart rate over the distance, bpm	177.5	175.0	183.0	167.0	186.0	3.4
Average pace of running, min. s per km	5.51	5.13	5.59	4.37	6.15	8.2
Basal metabolic rate, kcal	333.5	303.0	375.0	201.0	491.0	20.6
Pace of a 5 km forced march						
1 km, min. s	5.14	5.13	5.20	4.30	5.59	6.2
2 km, min. s	5.51	5.16	5.55	4.37	7.10	9.9
3 km, min. s	6.04	5.09	6.11	4.42	7.33	12.2
4 km, min. s	5.50	5.12	6.08	4.40	7.44	12.2
5 km, min. s	6.05	5.13	6.14	4.39	8.12	14.4

In our study, the running pace was observed for each kilometer. The lowest average pace was shown on the first kilometer while the highest values were observed on the fifth kilometer ($p<0.05$). This may indicate a pacing strategy where cadets try to conserve energy at the start of the run and increase their pace as they approach the finish line. Such a strategy may support optimal levels of running performance. The total difference between the minimum and maximum values at the first kilometer was $1.29 \text{ min}\cdot\text{km}^{-1}$, while at the fifth kilometer, this difference increased to $2.73 \text{ min}\cdot\text{km}^{-1}$. This indicates the presence of fatigue, a low level of physical performance or a limitation in the development of aerobic productivity.

Assessment of basic metabolism showed an average value of 333.5 kcal. This indicates high energy expenditure during physical activity and confirms the significant physiological reaction of the body to a 5-kilometer forced march in the moderate altitude conditions. Large energy costs are needed in order to maintain intensive muscle activity and the functioning of important organs and systems of the body.

Moreover, the main parameters of our analysis were the pulse intensity zones measured in beats per minute (bpm^{-1}), and the time spent in each zone. Figure 2 shows the results in a graphical interpretation. The average duration in the HR zone of $101\text{-}120 \text{ bpm}^{-1}$ was 0.39 min, which may indicate the low activity of the participants during running. Additionally, the median of this zone was about 23 s, and 75% of cadets spent less than 2 min in it. Moderate activity was observed in the HR zone of $121\text{-}140 \text{ bpm}^{-1}$. The average duration in this zone was 0.58 min, but the variation in duration was significant, with a zero value for 25% of the cadets and a maximum time of 4.14 minutes for 75% of the cadets. Moderate activity was in the HR zone of $141\text{-}161 \text{ bpm}^{-1}$. The cadets spent 8.37 minutes in this zone though there was considerable variation between participants, with 25% of cadets spending 5.14 min and 75% of cadets spending 13.43 min. Based on the heart rate variability indicators, we calculated the stress index with the determination of five levels. The obtained results are presented in graphical interpretation in Figure 2.

In the submaximal HR zone of $162\text{-}181 \text{ bpm}^{-1}$, high activity was observed, with an average duration of 12.28 min and a total variation from 6.14 min for the 25% percentile to 18.08 minutes for the 75% percentile. Such a long stay in the submaximal zone of intensity may indicate a high level of physical performance of some cadets and their ability to effectively perform tasks associated with high physical load. In the maximum HR zone of more than 181 bpm^{-1} , zero time period was recorded for all participants. This may indicate that the cadets avoided high HR during the 5-kilometer run, which may be due to energy conservation, insufficient physical activity, or exposure to low air temperature.

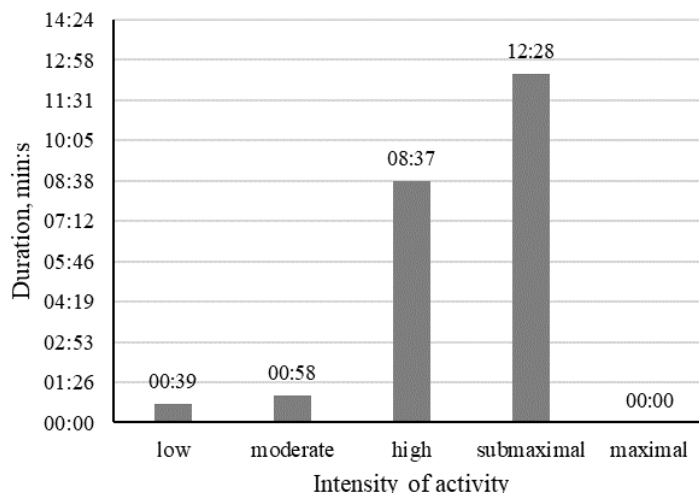


Fig. 2 Duration of activities in different intensity zones during the 5 km forced march of cadets of HMEI in the moderate altitude conditions

Obtaining information about the state of the heart rhythm of cadets of HMEI involves the identification of individuals with violations of the regulatory mechanisms of the autonomic nervous system. Taking into account the group of studied cadets and their professional orientation, the obtained HRV results, which are presented in Tables 2-3, are of applied value and can serve as markers of the adaptation capabilities of the body in stressful conditions, in particular in the moderate altitude conditions.

Table 2. Results of the temporal analysis of HR variability of cadets of HMEI in the moderate altitude conditions, n=26

Indicators	Results in a state of relative rest	Results after the 5 km forced march	Z	p
	Me (25%;75%)			
HR, bpm ⁻¹	80.0 (74.1;89.8)	90.3(83.8;98.0) ^{**}	2.82	0.01
RRNN, ms	750.3(668.1;810.0)	664.5(612.1;715.9) ^{**}	2.72	0.01
SDNN, ms	46.4(37.8;68.2)	37.3(26.1;51.6) ^{**}	2.49	0.01
RMSSD, ms	38.6(27.8;48.4)	21.4(11.8;29.8) ^{**}	2.63	0.01
pNN50, %	16.6(6.3;26.9)	3.1(0.4;6.6) ^{**}	2.67	0.01
Moda, ms	725.0(675.0;825.0)	650.0(625.0;725.0) ^{**}	2.67	0.01
AM0, %	43.3(32.7;52.6)	51.5(37.8;58.9) [*]	2.04	0.04
deltaX, ms	300.0(250.0;400.0)	250.0(150.0;350.0) [*]	2.31	0.02
IRI, %	143.7(86.5;210.5)	222.6(109.6;373.4) ^{**}	2.53	0.01
ICI, s ⁻²	4.6(3.6;5.9)	6.4(4.2;9.2) ^{**}	2.64	0.01
PPA, %	57.2(41.7;75.9)	79.4(56.8;94.2) [*]	2.44	0.02
NI, CU	91.4(55.8;151.9)	171.9(81.2;276.3) ^{**}	2.67	0.01
SFV, Hz	0.13(0.11;0.16)	0.10(0.08;0.12) ^{**}	2.49	0.01

Note: Significant differences according to the non-parametric Wilcoxon test for dependent samples between the results in a state of relative rest and after the 5 km forced march, Z-statistics; p - the level of significance reached * $p<0.05$; ** $p<0.01$

The analysis of these results shows statistically significant differences ($p<0.05$; $p<0.01$) between HR indicators in a state of relative rest and after running the 5-kilometer forced march in military personnel. HRV represented by RRNN, RMSSD, SDNN, and pNN50, also showed statistically significant ($p<0.01$) changes. After the march, reduced HRV was observed which may be associated with the activation of the sympathetic nervous system and the increased impact of stress factors during the physical exercise. RMSSD is a measure of HR variability that reflects the influence of the parasympathetic nervous system on the HR. An increase in the value of RMSSD after the physical exercise may indicate an increased activity of the vagotomy of the nervous system, which controls the slowing of the HR and its recovery after physical exertion. An increase in RMSSD may be the result of the body's compensatory mechanisms to maintain HR stability and optimal functioning of the cardiovascular system after the exercise. Therefore, an increase in RMSSD indicates an improvement in parasympathetic control of HR after the 5-kilometer run. This result can indicate the improvement of the

adaptation capabilities of the cardiovascular system of cadets to physical exercise in the moderate altitude conditions. In short records that do not exceed 5 min, the value of the SDNN indicator is considered normal in the range of 40-80 ms. In a state of relative rest, the median value of SDNN in cadets was 46.4 ms, and after the 5 km run, this value decreased to 37.3 ms ($p<0.01$). Smaller values of SDNN showed after running indicate an increase in autonomic regulation, i.e. an increase in the effects of breathing on heart rhythm. Indices of modality activity (AM0) show an increase after the 5-kilometer run, indicating increased activity of the sympathetic nervous system and response to exercise. Indices of rhythm influence (IRI) and conduction influence (ICI) also showed statistically significant increases after the 5-kilometer run indicating increased activity of the sympathetic nervous system and increased cardiac conduction. PPA (parametric pulse amplitude) and NI (normalization index) indicators showed a statistically significant ($p<0.05$; $p<0.01$) increase after the forced march. This may indicate increased physiological activity of the cardiovascular system and increased adaptation of the body to physical exertion. Normally, NI is 80-150 CU; this indicator is overly sensitive to increased tone of the sympathetic nervous system, and its value after running according to the median is 171.9 CU compared to the value of 91.4 CU in a state of relative rest ($p<0.01$). The analysis of the SFV indicator (spectral frequency variability) showed a statistically significant ($p<0.01$) decrease after the 5-kilometer run. A decrease in SFV values after the exercise indicates a decrease in parasympathetic activity and a possible increase in sympathetic activity of the cardiovascular system. The parasympathetic nervous system usually leads to a decrease in HR and an increase in HRV while the sympathetic nervous system contributes to an increase in heart rate and a decrease in HRV. Taking into account the obtained results of the spectral indicators of the cadets' HR, which are presented in Table 3, some changes can be noted.

Table 3. Results of spectral indicators of the heart rhythm of cadets of HMEI in the moderate altitude conditions, n=26

Indicators	Results in a state of relative rest	Results after the 5 km forced march	Z	p
	Me (25%;75%)			
Spectral indicators of heart rate variability				
TV, ms ⁻²	1313.5(1015.0;1738.0)	1038.5(532.0;1729.0)	1.92	0.06
VLF, ms ⁻²	420.5(295.0;517.0)	374.0(182.0;702.0)	0.07	0.94
LF, ms ⁻²	576.5(425.0;845.0)	459.5(245.0;767.0)	1.59	0.12
HF, ms ⁻²	301.0(165.0;569.0)	154.0(77.0;289.0)**	2.53	0.01
LFnorm, CU	0.63(0.54;0.76)	0.78(0.69;0.83)*	2.37	0.02
HFnorm, CU	0.37(0.24;0.46)	0.22(0.17;0.31)*	2.32	0.02
L, ms	424.2(353.5;565.6)	353.5(212.1;494.9)*	2.41	0.02
W, ms	135.0(95.0;165.0)	90.0(55.0;95.0)*	2.41	0.02

Note: Significant differences according to the non-parametric Wilcoxon test for dependent samples between the results in a state of relative rest and after the 5 km forced march, Z-statistics; p - the level of significance reached * $p < 0.05$; ** $p < 0.01$

Analysis of the results of the TV indicator (total variability) showed a decrease in its median from 1313.5 ms⁻² to 1038.5 ms⁻² after the forced march although this change did not reach statistical significance ($p=0.06$). Such a decrease may indicate a general decrease in the variability of the HR of service personnel after physical exercise. In the case of the VLF (very low frequency) indicator, the median did not change after running the forced march which indicates the stability of the low-frequency variability of the HR. The median LF indicator (low frequency) decreased from 576.5 ms⁻² to 459.5 ms⁻² ($p=0.12$) which may indicate a decrease in HRV in the low-frequency range although this change did not reach statistical significance. In the case of the HF indicator (high frequency), the median significantly decreased from 301.0 ms⁻² to 154.0 ms⁻² ($p<0.01$) which indicates a decrease in HRV in the high-frequency range after the exercise. The median LFnorm indicator (normalized LF value) increased from 0.63 to 0.78 ($p=0.02$) which may indicate a certain dominance of low-frequency variability over high-frequency variability after the exercise. The HFnorm indicator (normalized HF value) showed a decrease in the median from 0.37 to 0.22 ($p=0.02$) indicating a decrease in HRV in the high-frequency range after the forced march.

During the next stage of our scientific research, we determined the effect of physical exertion in the moderate altitude conditions on sensorimotor reactions in the cadets of HMEI. Table 4 presents the obtained results.

The analysis of the results of the sensorimotor reaction to a moving object in cadets of HMEI in medium-mountain conditions after the 5-kilometer forced march, compared to a state of relative rest, was carried out using the non-parametric Wilcoxon test for dependent samples. The studied indicators included the sum of deviations, the average deviation, the number of accurate attempts, the number of anticipation (the sum of deviations, the average deviation), the number of delays (the sum of deviations, the average deviation). Analysis of the results after running showed that the mean deviation was significantly reduced ($p=0.02$). Those results indicate an improvement in the accuracy of the sensorimotor response after the exercise.

Table 4. Results of the sensorimotor reaction to a moving object in cadets of HMEI in the moderate altitude conditions, n=26

Indicators	Results in a state of relative rest	Results after the 5 km forced march	Z	p
	Me (25%;75%)	Me (25%;75%)		
Total amount of deviations, ms	794.3(655.9;1133.1)	626.8(542.7;831.6)	1.53	0.13
Average deviation, ms	29.1(23.2;37.8)	20.9(18.1;27.7)*	2.27	0.02
Accurate attempts, number	7.0(4.0;11.0)	9.0(7.0;10.0)	1.30	0.19
Anticipations, number	17.0(14.0;20.0)	13.0(11.0;16.0)*	2.44	0.02
Sum of deviations, ms	648.0(503.2;855.3)	389.7(310.7;650.7)**	2.78	0.01
Average deviation, ms	43.2(32.5;47.5)	31.6(28.2;43.0)*	2.21	0.03
Delays, number	6.0(4.0;8.0)	8.0(6.0;10.0)*	2.04	0.04
Sum of deviations, ms	180.4(107.6;246.9)	173.7(131.5;256.6)	1.14	0.26
Average deviation, ms	29.8(24.0;33.9)	26.3(21.1;32.0)	0.85	0.39

Note: Significant differences according to the non-parametric Wilcoxon test for dependent samples between the results in a state of relative rest and after the 5 km forced march, Z-statistics; p - the level of significance reached * $p<0.05$; ** $p<0.01$

The number of anticipations decreased significantly ($p=0.02$) which indicates a decrease in the number of false reactions to a moving object after physical exertion. This may be related to the improvement of sensorimotor coordination and increased attention after the physical exercise. A decrease in the sum of deviations and the mean deviation indicates a decrease in the difference between the sensory input and the motor output value after the exercise. A statistically significant difference ($p=0.04$) was found in the number of delayed reactions in the cadets of HMEI in the middle-mountain conditions after the 5-kilometer forced march compared to a state of relative rest. This means that after physical exertion, cadets showed more delays in sensorimotor reactions to a moving object. The delay can be interpreted as the predominance of excitatory processes in response to a stimulus (Makarenko, 2006; Makarenko et al. 2018). This may be the result of physical fatigue after running. Physical activity can affect the speed of transmission of nerve signals and slow down or speed up the processing of information in the brain (Alvarez-Alvarado et al 2021). The obtained results proved the complex interaction of the physical state of the organism, sensorimotor processes and cognitive functions. The study highlights the need to consider physical activity and fatigue when assessing sensorimotor responses.

Discussion

Our previous scientific research on the physical condition of the youth contingent of draft age confirms the relevance of this topic (Yarmak et al. 2018; Andrieieva et al. 2020a,b; Hakman et al. 2021). In our study, we determined the effect of physical exertion on HRV in cadets. The results of our study have confirmed the data (Alalyan et al. 2020; Kashuba et al. 2021; Vondrasek et al. 2022; Petrachkov & Yarmak, 2023) that exercise has an effect on HRV and causes changes in neuromuscular regulation. First, we observed a decrease in the overall variability of the HR after running the 5-kilometer forced march in the moderate altitude conditions. That indicates activation of the sympathetic nervous system and increased tension in the cadets' bodies. Those changes may be related to the increased physical load and effort required to overcome the mountainous terrain. The second important observation was the changes in HRV spectral indices. We found a decrease in variability in the low-frequency (LF) and high-frequency (HF) ranges after the exercise. Those changes indicate the presence of a state of maladaptation during physical activity. A decrease in LF indicates a decrease in the activity of the sympathetic nervous system which is usually responsible for mobilizing the body in response to physical stress. A decrease in the HF indicator means a decrease in the activity of the parasympathetic nervous system which regulates restorative processes associated with stress. Moreover, maladaptation is observed in cadets after physical exertion by decreasing the values of indicators L (average length of the rhythmogram) and W (width of the histogram of HR intervals). A decrease in L indicates a reduction in the time between successive intervals of heart rhythm which may be associated with increased reactivity of the body and a faster response of the cardiovascular system to stimuli after physical exertion. A decrease in W indicates a narrowing of the range of HR intervals which may reflect a reduced variety of responses of the cardiovascular system to stimuli. A decrease in total HRV and changes in spectral indicators indicate increased tension and activity of the sympathetic nervous system, as well as decreased activity of the parasympathetic nervous system.

Our research expands the understanding of the body's adaptation processes to physical stress, in particular in the moderate altitude conditions. The obtained results also confirm the relationship between physical activity and sensorimotor function (Bezokopylna, Lizogub & Palabyiik, 2020). We observed an improvement in accuracy and a decrease in false responses in sensorimotor responses after the exercise. This can be explained by the improvement of sensorimotor coordination and changes in the speed of transmission of nerve signals after physical exertion. However, it is worth noting that an increased number of delays was recorded which may be a

consequence of changes in neuromuscular interaction and general fatigue of the body which leads to maladaptation.

The significance of our results is to confirm the importance of physical load as a means of modulating the neuromuscular system and adapting the body to extreme conditions. Understanding changes in cardiovascular function and neuromuscular regulation after exercise may have practical implications in physical training, rehabilitation, and stress situations. In particular, the use of HRV monitoring methods can help assess the functional state of military personnel and determine the optimal training regimen to achieve maximum performance and reduce the risk of overload.

However, it is important to take into account the limitations of our study; a sample of 26 cadets cannot affect the generalization of the results to the general population. In addition, our study was aimed at analyzing the impact of physical exertion on the cardiovascular system and sensorimotor function, but did not take into account other factors that may influence these parameters, especially the state of emotional well-being and the level of physical preparedness of the participants. Additional studies with larger samples and different factors can complement our results and confirm their significance.

In addition, our study has had a cross-sectional design, meaning that we observed only one point in time after exercise. To obtain more complete information on the body's adaptation processes to physical stress, it would be useful to conduct long-term observations and study the dynamics of changes in the work of the cardiovascular system and sensorimotor functions during a long period after the exercise.

The mechanisms underlying the changes in HRV and sensorimotor functions after exercise may be an additional area for further research. The study of the relationship between changes in neural activation and biochemical indicators can reveal the details of adaptation mechanisms. It is also possible to investigate the role of other factors, such as genetic variations, the effects of which may vary among individuals.

Conclusions.

HR variability has changed after physical exertion which indicates the tension of the sympathetic or parasympathetic nervous system. The study makes it possible to better understand the processes of adaptation of the organism to the moderate altitude conditions. We have found that after the 5-kilometer forced march through mountainous terrain, the cadets had a reduced HRV which indicates activation of the sympathetic nervous system and increased tension. The value of the SDNN indicator decreased which indicates strengthening of autonomic regulation and an increased influence of breathing on the heart rhythm. In addition, a decrease in HRV was found in the LF and HF ranges which indicates the presence of maladaptation. Indicators L (average length of the rhythmogram) and W (width of the histogram of the intervals) also showed statistically significant changes after the forced march. A decrease in the values of L and W indicators shows the presence of a state of maladaptation as they reflect a decrease in the length of the rhythmogram and the histogram of HR intervals. The obtained data has confirmed the effect of physical activity on the cadets' HRV and indicated the presence of a state of maladaptation.

The results of the study have indicated an improvement in accuracy and a reduction in false responses in sensorimotor responses after the exercise. These results can be explained by the improvement of sensorimotor coordination and changes in the speed of transmission of nerve signals after physical exertion.

Conflict of Interest. All the authors declare to have no conflict of interest.

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