

Monitoring the cardiorespiratory system of military personnel at risk of developing cardiovascular diseases

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Abstract

Warfare in modern conditions requires soldiers to have a high level of physical and mental readiness, particularly in terms of their respiratory and cardiovascular systems. Early detection of disorders in a soldier's cardiorespiratory system is particularly important, as it enables the timely development of individualized physical training programs to prevent cardiovascular diseases. Therefore, monitoring the functional state of the cardiovascular and respiratory systems is a crucial aspect of ensuring the combat readiness of troops. The study presents results from monitoring the cardiorespiratory system in 139 male soldiers of the Ukrainian Armed Forces, aged 36÷55, who have cardiovascular disease risk factor(s). **Research aimed** to assess the functional state of the cardiorespiratory system and autonomic heart rate regulation in mature servicemen within this risk group, and to identify the structure of relationships among the measured indicators. The research methods included theoretical analysis of scientific literature, physiological research methods, the heart rate variability method, and methods of mathematical statistics. **The results of the research.** The median heart rate of mature soldiers from the risk group (cardiovascular diseases in a relative rest state) is 81.0 bpm, which indicates a tendency to tachycardia in a significant part of the sample. The median systolic and diastolic blood pressure results are 135/85 mm Hg, corresponding to an elevated normal level. In comparison, the 75th percentile systolic pressure result is 147.0 mm Hg, and the diastolic result is 99.0 mm Hg, which indicates the presence of arterial hypertension in a significant part of experimental group. Some servicemen had reduced respiratory system functionality. So, the 25th percentile of their forced vital capacity is 3.6 l, which is lower than the normative values of 4.0÷6.0 l. The forced expiratory volume in the first second is 3.0 l, below the norm of 3.5÷5.0 l. At the same time, the variability of the indicators reaches 23.9% and 30.2%, which indicates the heterogeneity of the sample. The functional test results with local isometric activity made it possible to identify 48.2% of soldiers with a predictor of the development of arterial hypertension, and 31.7% of soldiers had signs of latent hypertension. Analysis of the results of the hypoxic test showed that a normotonic reaction was observed in 27.3% of the military, while their signs of latent hypertension were recorded in 43.2%. Analysis of the orthostatic test results showed a typical activation of the sympathoadrenal system when the initial body position changed from horizontal to vertical, which was indicated by an increase in systolic and diastolic blood pressure and heart rate. The generalized integral index of the orthostatic reaction had a median value of 16 bpm, indicating a decrease in orthostasis's adaptive tone. During the correlation analysis, inverse correlations were observed between heart rate and duration of cardio intervals ($r = -0.374$; $p < 0.001$), as well as with the modal value ($r = -0.386$; $p < 0.001$), which indicates the dominance of sympathetic influences during heart rate acceleration. Conclusion. The research results indicate the presence of signs of latent arterial hypertension, which were detected by functional tests and were accompanied by characteristic changes in autonomic regulation of cardiac activity. The established dependence of functional indicators of the cardiorespiratory system on the level of autonomic regulation indicates the need to develop a holistic system for monitoring physical fitness for this category of soldiers, since traditional approaches do not take into account individual characteristics of the vegetative status and the risks of developing hypertensive conditions.

Keywords: risk indicators; arterial hypertension; adaptive potential; heart rate variability; officers

Introduction

Contemporary conditions of military missions are characterized by high complexity and intensity, which require significant physical and psycho-emotional stress from soldiers. In this context, maintaining the proper functional state of the cardiovascular and respiratory systems is of particular importance, since these systems ensure the soldiers' body adaptation to extreme factors of military service.

The functional capabilities of the cardiorespiratory system of soldiers are an essential indicator of their holistic health and physical fitness. Also, the disturbances in the functioning of the cardiovascular or respiratory systems can negatively affect the effectiveness of performing official duties, especially in combat conditions.

Analysis of scientific sources indicates a strong correlation between the state of the cardiorespiratory system and the risk of developing cardiovascular diseases, particularly among mature and elderly people (Schilling et al., 2019; Taylor et al., 2019; Bustamante-Sanchez et al., 2020; Lin et al., 2020; Dawood et al., 2025; Petrachkov et al., 2022-2024; Strauss et al., 2025). The simplest and, at the same time, most informative indicators of the state of the cardiovascular system remain heart rate (HR) and systolic and diastolic blood pressure. The results of recent studies conducted among operational-level officers demonstrate the preservation of the cardiorespiratory system's ability to function under various physical exertion conditions, regardless of soldiers' age. At the same time, scientists identify several factors contributing to the functional state deterioration of the cardiovascular system, such as adverse socio-economic living conditions, bad habits, physical inactivity, unbalanced nutrition, and even ionizing radiation. That's why the monitoring of the functional state of soldiers and the implementation of adequate preventive measures are becoming more urgent. These include: regular physical activity; weight control; healthy eating habits; and minimizing the impact of risk factors, including smoking and alcohol abuse (Sammuto et al., 2013; Sammuto et al., 2014; Looney et al., 2018; Lavie et al., 2019; LaFountain et al., 2019; Strauss et al., 2020; Larsson et al., 2023; Yarmak et al., 2024; Dawood et al., 2025).

Thus, numerous studies from different countries confirm that the functional state of the cardiovascular and respiratory systems of military specialists significantly depends on their physical fitness level, as well as their psycho-emotional state (Zimmerman et al., 2012; Suspo et al., 2023; Rudenko et al., 2023; Yarmak et al., 2024-2025; Strauss et al., 2025). The comparative relationship between psychological stress and physical fitness of military personnel was investigated by scientists from Taiwan, who suggested that the presence of high psychological stress in military personnel may reduce their cardiorespiratory fitness. Evidence from multiple studies highlighting the link between physical activity and psychological stress supports the notion that aerobic exercise positively affects physical well-being and mental health. (Schilling et al., 2019; Taylor et al., 2019; Bustamante-Sanchez et al., 2020; Lin et al., 2020; Gancitano et al., 2021). Thus, experts from the American College of Sports Medicine have proven that regular physical exercise improves mental symptoms associated with depression, anxiety, and stress, and aerobic training improves the state of the cardiovascular and autonomic nervous systems, and also modulates the reduction in heart rate through physical exercise and motor activity (Lin et al., 2020).

The prevalence of risk factors such as overweight, physical inactivity, smoking, and occupational stress requires systematic monitoring and implementation of specially directed physical activity programs. Optimizing the physical fitness process, particularly by developing aerobic endurance, is an essential direction in preventing cardiovascular diseases and maintaining the combat readiness of personnel in the face of growing professional challenges. The correlation between the risk of developing of cardiovascular diseases (CVD) and the cardiorespiratory fitness level was analyzed in a sample of police officers with an average age of 38.6 years. In the study, CVD risk factors were as follows: high blood pressure, lipids, blood glucose, and unfavorable body composition (Strauss et al., 2021; 2025). The bicycle ergometric test 'Submaximal' assessed soldiers' cardiorespiratory fitness level. The results of this study revealed that police officers with a high level of cardiorespiratory fitness were characterized by a significantly lower cardiometabolic risk. Participants with higher indicators of general physical fitness had a reduced risk of developing CVD compared to those with unsatisfactory physical condition (Zimmerman et al., 2012; Schilling et al., 2019; Ras et al., 2023).

Thus, early detection of abnormalities in the functional state of the cardiorespiratory system of military personnel is an essential factor in preventing chronic non-communicable diseases. One of the leading causes of such disorders is a decrease in the level of physical activity, which causes a reduction in vascular wall tone, an increase in peripheral resistance, and an additional load on the myocardium (Kruk et al., 2020; Dawood et al., 2025). According to the data of the State Statistics Service of Ukraine, the leading cause of mortality among the population remains non-communicable chronic diseases, among which cardiovascular diseases dominate. Thus, about 256 thousand people died of CVD in Ukraine in 2020 (Azhippo et al., 2019).

Early detection of disorders in the functioning of the cardiorespiratory system is of particular relevance, which allows not only to reduce the risks of CVD, but also to develop effective individualized strategies for physical training and prevention of these disorders. In this context, monitoring the functional state of the cardiovascular and respiratory systems is an essential component of medical and pedagogical support for military activities.

Therefore, the research topic is highly relevant, meets modern challenges in the theory and methodology of physical training of military personnel, physical rehabilitation, and its results may have practical significance for optimizing physical training programs and reducing cardiometabolic risk among soldiers.

Materials and methods

Study participants. The study involved 139 male soldiers aged 36 to 55 years serving in the Land Forces of Ukraine. All of them have the risk for cardiovascular disease because of prior medical assessments and the detection of relevant risk factors. The study's inclusion criteria: male gender, age 36-55 years, service in the Land Forces of Ukraine, and the presence of at least one cardiovascular risk factor (high blood pressure, overweight or obesity); absence of acute diseases at the time of examination; provision of written informed

consent to participate in the study. All participants signed written informed consent before enrollment. Exclusion criteria comprised decompensated chronic diseases, verified severe neurological or psychiatric disorders, and refusal to provide consent. Data was collected at the National Defense University of Ukraine between January and February 2024. The research protocol was developed per the ethical standards outlined in the WHO Declaration of Helsinki (2013 revision). Before participation, individuals received detailed information about the aims and procedures of the study and subsequently confirmed their willingness in written form. Heart rate evaluation was performed under standardized resting conditions, with recordings taken in the morning following at least five minutes of seated rest.

To minimize the influence of external factors, the study participants were advised to refrain from physical exertion, caffeine consumption, eating, and smoking for at least 2 hours before the examination. The heart rate was recorded three times with an interval of 1–2 minutes, after which the average HR value was calculated to increase the accuracy and reliability of the results. The obtained data were used to assess the general functional state of the cardiovascular system and for statistical analysis.

Blood pressure was measured using an automatic oscillometric tonometer Omron M2 Basic (Omron Healthcare Co., Ltd., Japan), which simultaneously calculates systolic and diastolic pressure. Measurements were performed on the brachial artery of the left arm in a sitting position after 5 minutes of rest in the absence of external stimuli.

To assess the functional state of the respiratory system of military personnel, a spirometric study was conducted using an electronic spirometer SP 10, which provides automatic recording and processing of pulmonary ventilation parameters. The examination was performed according to the European Respiratory Society (ERS) and the American Thoracic Society (ATS) recommendations. Before the study, each person was informed about the procedure, the correct body position (sitting with a straight back), the proper fixation of the mouthpiece without air leaks and a nasal clip, and compliance with sanitary and hygienic standards. Instructions were given on deep inhalation and maximum sharp exhalation for at least 6 seconds. At least three satisfactory attempts were recorded for each respondent according to the reproducibility and acceptability criteria.

Approximate physiological norms for men of this age category:

FVC norm value (forced vital capacity of the lungs) is $4.0 \div 6.0$ l; below the norm $FVC < 4.0$ l; above the norm $FVC > 6.0$ l.

FEV1 norm value (forced expiratory volume in the 1st second) is $3.5 \div 5.0$ l; below the FEV1 norm < 3.5 l; above the FEV1 norm > 5.0 l.

FTV 1% norm value (ratio of FEV1 to FVC) is $70.0 \div 85.0$ %; below the FTV 1% norm < 70.0 %; above the FTV 1% norm > 85.0 %.

PEF norm value (peak expiratory volume flow) is $8.0 \div 10.0$ l/s⁻¹; below the PEF norm < 8.0 l/s⁻¹; above the PEF norm > 10.0 l/s⁻¹.

Figure 1 shows the research protocol.

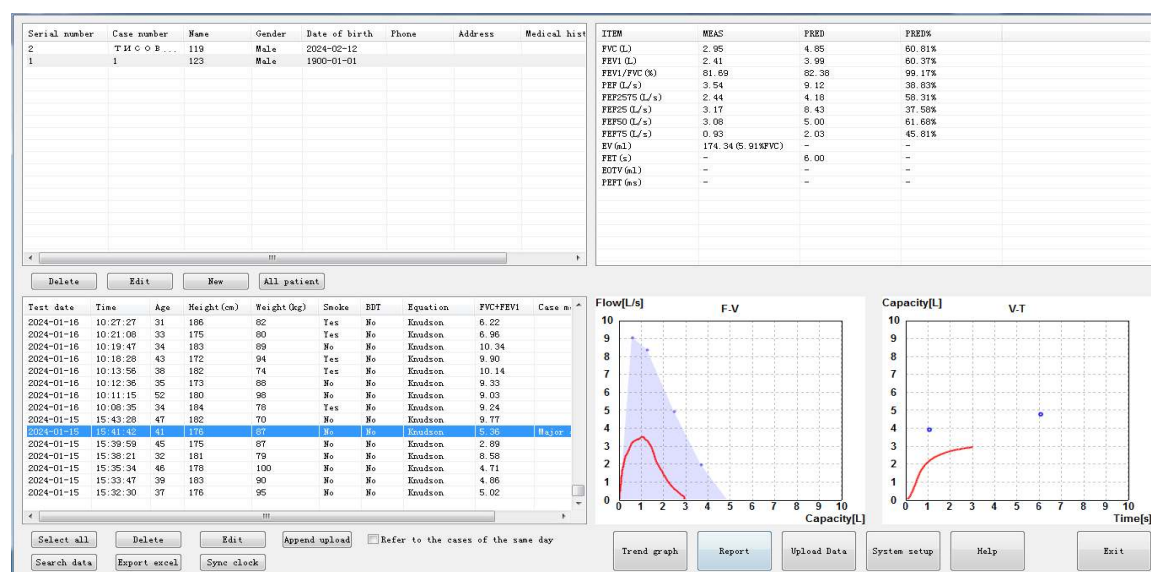


Figure 1. The protocol of the spirometric study results from the SP 10 electronic spirometer. Numerical values of the basic indicators of external respiratory function, and graphic interpretations in the form of 'Volume_Time' (V_T) and 'Flow_Volume' (F_V) curves are presented.

The isometric test with local load was used to assess the cardiovascular system's response to isometric activity, which consisted of squeezing the hand at 50% of maximum force for one minute. Blood pressure was measured before and after the activity. The response was considered normal if the mean arterial pressure (MAP) after the activity was less than 126.4 mm Hg. Values from 126.4 to 139.9 mm Hg indicated a potential risk of arterial hypertension, and exceeding 140 mm Hg could indicate latent arterial hypertension.

The Stange test assessed the response to hypoxic stress – breath holding during inspiration. First, blood pressure was determined at rest, then after holding the breath for 50÷55 seconds, the change in MAP was analyzed. An increase in MAP to 13 mm Hg was regarded as a normotensive reaction, from 13 to 21 mm Hg - a tendency to arterial hypertension, and more than 21 mm Hg a - sign of latent arterial hypertension.

The Hicken formula was used to calculate MAP, which considers the cardiac cycle's systolic and diastolic duration phases.

The orthostatic test assessed the functional state of vegetative regulation of the cardiovascular system by analyzing the body's response to a rapid change in body position from horizontal to vertical. The assessment was carried out on the heart rate. An increase in heart rate of less than 11 bpm is considered an excellent response; an increase from 12 to 18 bpm is considered satisfactory; an increase of 19 or more bpm or a decrease in heart rate of 1 or more bpm indicates an unsatisfactory response.

To assess the autonomous regulation of cardiac activity in mature male military personnel at risk of developing cardiovascular diseases, the method of heart rate variability (HRV) analysis was used. Electrocardiogram (ECG) signals were recorded at rest under standard psychophysiological load conditions: morning hours, lying down after a 10-minute rest. The duration of the protocol recording was 5 minutes.

The recording was carried out using the 'MPFI' rhythmograph computer complex and EasyHRV software, which allows for both temporal and spectral analysis of HRV. In the time domain, the following indicators were determined: SDNN (standard deviation of normal RR intervals); RMSSD (root mean square of differences between adjacent RR intervals); pNN50 (percentage of pairs of consecutive RR intervals that differ by more than 50 ms); Mo, AMO, and dX are statistical indicators of modal analysis.

In spectral analysis, the following were evaluated: TP (total spectral power); VLF (very low frequency component); LF (low frequency component - sympathetic tone); HF (high frequency component – parasympathetic tone); LF/HF (sympathovagal balance index). Spectral analysis data were presented in absolute values (ms^2) and relative units (%), which allowed assessing the predominance of a particular autonomic nervous system department. The index of tension of regulatory systems (IT) and variational pulsometry were also calculated.

The evaluation and interpretation of the results were carried out by the current recommendations of the EU Society of Cardiology and the Nth American Society of Pacing and Electrophysiology (1996), as well as taking into account the normative indicators for the age and professional category of study participants. Figures 2-3 present the HRV protocols.

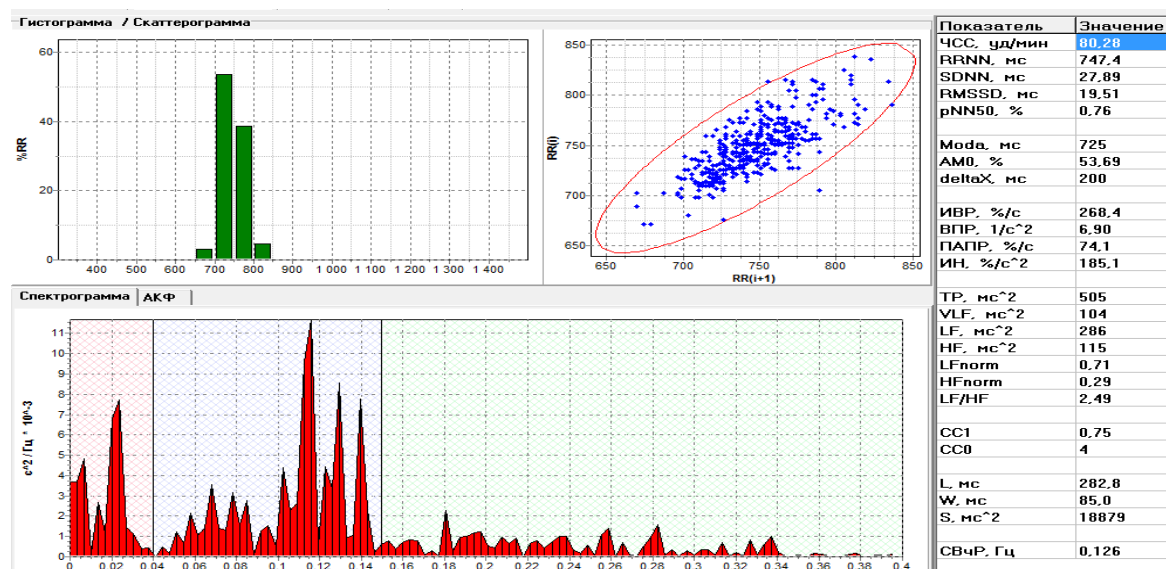


Figure 2. An extended protocol of HRV of soldiers with the risk of cardiovascular disease (histogram, scattergram, and spectrogram)

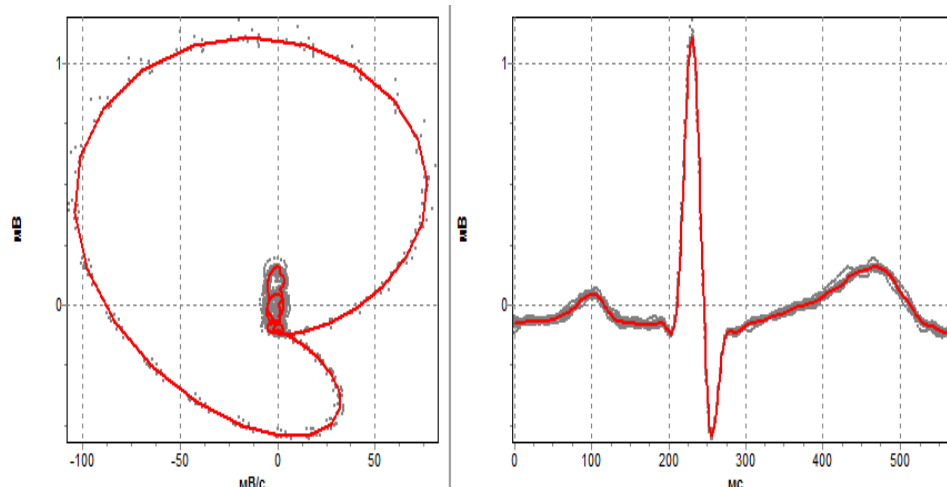


Figure 3. The QRS trajectory loop (left) alongside the electrocardiographic signal of the QRS complex (right) of a soldier with the risk of cardiovascular disease

Data Analysis. The dataset was processed and statistically evaluated using Statistica 10.0 and Microsoft Excel programmes. The analysed variables are presented through median values, interquartile range (25th and 75th percentiles), extreme values (minimum and maximum), and coefficient of variation, allowing an assessment of the overall distribution pattern and variability of the data. The non-parametric Spearman rank correlation criterion was used to establish correlations between the studied variables, which is appropriate when analyzing data that do not correspond to a normal distribution.

Results

The study's results reflect the functional state of the cardiorespiratory system of mature military personnel from the risk group for the development of cardiovascular diseases (Table 1).

According to the median, the result of the heart rate in a state of relative rest is 81.0 bpm, which exceeds the upper limit of the norm for mature men (60÷80 bpm) and indicates a tendency in some individuals to tachycardia. The result at the 75th percentile is 92.0 bpm, and indicates tachycardia in a significant part of the examined individuals. The minimum value of the heart rate is 57.0 bpm, and the maximum is 155.0 bpm, which indicates a significant spread of values and the presence of both bradycardia and pronounced tachycardia in some cases. Increased heart rate is an independent risk factor for cardiovascular complications, as it increases the load on the heart muscle and can contribute to the development of arrhythmias.

Table 1. Cardiorespiratory system indicators of military personnel at risk of developing cardiovascular diseases

N	Parameter	Percentile		Me	V (%)	Max	Min
		25 th	75 th				
1.	HR in rest, bpm	74.0	92.0	81.0	17.7	155.0	57.0
2.	BP systolic, mmHg	130.0	147.0	138.5	11.5	185.0	83.0
3.	BP diastolic, mmHg	83.0	99.0	90.0	14.9	127.0	42.0
4.	FVC (forced vital capacity), l	3.6	4.7	4.2	23.9	6.1	1.9
5.	FEV1 (forced expiratory volume in the 1 st s), l	3.0	4.2	3.7	30.2	5.6	1.3
6.	PEF (peak expiratory flow), l/s ⁻¹	4.2	8.1	6.2	47.1	12.6	1.3
7.	FTV 1% (FEV1 to FVC ratio), %	84.0	98.0	91.0	20.6	100.0	26.0
8.	Stange test, s	40.0	60.0	50.0	28.6	97.0	18.0
9.	Hench test, s	17.0	28.0	22.0	37.0	49.0	11.0

The median systolic pressure is 137.0 mmHg, and the median diastolic pressure is 89.0 mmHg, values corresponding to the upper limit of the normal range and approaching the criteria for arterial hypertension. The results at the 75th percentile are 147.0 mmHg, indicating the presence of hypertension in a significant part of the sample. The minimum and maximum values of systolic (83.0 mmHg and 185.0 mmHg) and diastolic (42.0 mmHg and 127.0 mmHg) pressures emphasize the significant variability of the studied indicators. High blood pressure is a primary risk factor for stroke, myocardial infarction, heart failure, and other cardiovascular diseases.

A significant part of the sample of officers shows a decrease in indicators characterizing the respiratory system function. In particular, the 25th percentile for forced vital capacity (FVC) is 3.6 l, below the norm's lower limit (4.0÷6.0 l). In comparison, the 25th percentile for forced expiratory volume in the 1st second (FEV1) is 3.0 l, which is also below the lower limit of the norm (3.5÷5.0 l). The median forced expiratory volume in the 1st

second was 3.7 l, which generally corresponds to the normative values. However, the variability of the indicator is 30.2%, which may indicate an uneven degree of preservation of bronchial patency in the subjects and heterogeneity of the sample. The median peak expiratory volume flow rate was 6.2 liters per second, with significant fluctuations in values; the coefficient of variation is 47.1%, which may be a sign of functional limitations in the drainage capacity of the respiratory tract in some officers and the heterogeneity of the sample. The ratio of FEV1 to FVC, which characterizes the efficiency and speed of exhalation, is 91.0% by median, and is within normal limits. However, the minimum recorded value is 26.0%, and indicates the possible presence of individuals with severe airway obstruction or chronic diseases of the bronchopulmonary system.

Regarding respiratory tests, the median Stange test is 48.0 s, and the Hench test is 21.0 s, indicating a decrease in the functional reserves of the respiratory system compared to the expected values for this age group. The results for the 25th percentile for both samples are 40.0 s and 17.0 s, respectively, emphasizing that the decrease in these reserves is a common phenomenon in the sample.

Therefore, the overall results indicate the presence of individual signs of a decrease in the functional reserves of the respiratory system, which requires further targeted physical impact to prevent the development of respiratory failure, increase the adaptive potential of the body and reduce the risk of professionally related complications during the performance of official duties in conditions of increased physiological stress.

Several functional tests were used in the study to comprehensively assess the functional state of the cardiovascular system of mature military personnel and identify the features of its reactivity to various types of physical exertion. In particular, the local isometric load test, a test with breath holding (Stange), and an orthostatic test were used. These tests allow assessing the cardiovascular system's adaptive capabilities in stressful conditions. In each of the above samples, heart rate and blood pressure were recorded, which made it possible to determine the nature of the vegetative support of the functional response of the body. The obtained research results are presented in Table 2.

Table 2. Results of functional tests performed by military personnel at risk of developing cardiovascular diseases

N	Parameter	Percentile		Me	V (%)	Max	Min
		25 th	75 th				
Local isometric load test							
1.	BP systolic, mmHg	144.0	171.0	159.0	14.3	218.0	109.0
2.	BP diastolic, mmHg	95.0	117.0	107.0	12.9	132.0	81.0
3.	HR, bpm	85.0	101.0	92.0	25.0	203.0	62.0
4.	BPmean, mmHg	111.3	134.0	124.7	12.8	160.0	92.3
Hypoxic Test (Stange test)							
5.	BP systolic, mmHg	135.0	160.5	146.0	14.8	219.0	104.0
6.	BP diastolic, mmHg	89.5	114.5	103.5	16.8	143.0	65.0
7.	HR, bpm	67.0	83.0	73.0	24.6	173.0	58.0
8.	BPmean, mmHg	103.5	127.2	119.5	14.9	166.3	83.3
Orthostatic test							
9.	BP systolic in a horizontal position, mmHg	117.0	133.0	124.0	10.8	158.0	96.0
10.	BP diastolic in a horizontal position, mmHg	73.0	87.0	80.0	13.4	111.0	57.0
11.	BP systolic in a vertical position, mmHg	129.0	158.0	142.0	15.6	192.0	76.0
12.	BP diastolic in a vertical position, mmHg	87.0	105.0	93.0	17.8	136.0	54.0
13.	HR in a horizontal position, bpm	63.5	78.0	70.0	13.7	93.0	55.0
14.	HR in a vertical position, bpm	76.0	101.5	85.5	17.7	113.0	57.0
15.	Orthostatic test. bpm	-24.0	-8.5	-16.0	-71.6	6.0	-44.0

The local isometric load test allowed for assessing the sympatho-adrenal response and reserve capabilities of the myocardium during static muscle tension. Changes in heart rate and blood pressure after loading reflected the degree of mobilization of the cardiovascular system to maintain homeostasis. The Stange test, which involves holding the breath while inhaling, allowed us to assess tolerance to hypoxia and the sensitivity of chemoreceptors that affect cardiac activity.

The primary hemodynamic parameters were increased in response to local isometric loading. The median value of BP systolic was 159.0 mm Hg, the median value of BP diastolic was 107.0 mm Hg, the mean blood pressure was 124.7 mm Hg, and the heart rate was 92.0 bpm. A wide range of heart rate values from 62 to 203 bpm and a high coefficient of variation of 25.0% indicate significant individual variability in the response of the cardiovascular system to physical activity, which may be associated with different fitness levels or body functional reserves. Blood pressure indicators had a relatively lower degree of variation of 12.8% and 14.3%, which may indicate the homogeneity of the sample. During breath-holding on inspiration (the Stange test), most of the examined individuals had a moderate increase in blood pressure and mild tachycardia. The median heart rate during the test was 73.0 bpm, and the maximum value reached 173.0 bpm, which indicates the presence of individuals with excessive cardiovascular response to hypoxia. The coefficient of variation of this indicator was 24.6%, which means a high level of variability and heterogeneity of the group. The median systolic pressure in

hypoxic conditions was 146.0 mm Hg, and the median diastolic pressure was 103.5 mm Hg. In comparison, the mean blood pressure was 119.5 mm Hg, which, according to the gradation scale, corresponds to a normotensive reaction to this type of physical activity.

Due to the importance of the functional test results, we consider it appropriate to conduct an individual analysis of the mean blood pressure results of servicemen, with the determination of the types of reactions (Figure 4).

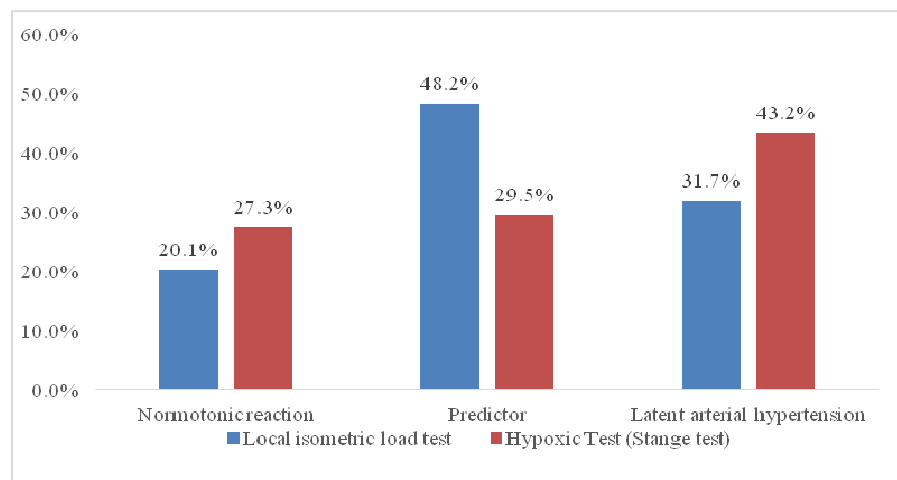


Figure 4. Distribution of cardiovascular reaction types of military personnel with the risk of developing cardiovascular diseases based on the functional test results with local isometric load and the Stange test.

Analysis of individual results of a functional test with local isometric load and a hypoxic test (Stange) allowed identifying different types of reactions. Particular attention was paid to the identification of individuals with latent forms of arterial hypertension.

According to the results obtained, a functional test with local isometric load revealed a reaction classified as a predictor of the development of arterial hypertension in 48.2% of military personnel, and signs of latent arterial hypertension in 31.7%. Only 20.1% of those examined had a normotensive reaction, which indicates a relatively stable state of regulation of the cardiovascular system.

According to the analysis of the results of the hypoxic test (the Stange test), we found a slightly different distribution, in particular, a normotonic reaction was established in 27.3% of soldiers, a predictor in 29.5%, and signs of latent arterial hypertension in 43.2% of the examined persons. Such a percentage of persons with an unfavourable cardiovascular response to hypoxic stress indicates a high prevalence of functional disorders that may have clinical significance in the future.

Thus, the results of both tests allow us to conclude that a significant proportion of service members are at risk of developing arterial hypertension, emphasizing the advisability of including regular functional screening of the cardiovascular system during military service.

Analysis of the orthostatic test results showed that when moving from horizontal body position into vertical, a typical physiological increase in BP systolic from 124.0 to 142.0 mm Hg was found, and BP diastolic from 80.0 to 93.0 mm Hg, as well as an increase in heart rate from 70.0 to 85.5 bpm, which indicates the activation of soldiers' sympathoadrenal system. The variation coefficients of the heart rate in the horizontal and vertical positions were 13.7% and 17.7%. The generalized index of the orthostatic test, which was calculated as an integral response, deserves special attention. The median of this indicator was – 16.0 bpm with a significant range from –44.0 bpm to 6.0 bpm. The negative value indicates a corresponding decrease in adaptive tone in orthostasis, and the high coefficient of variation (71.6%) indicates the heterogeneity of the sample.

As a result of the analysis of HRV indicators in a sample of 139 mature soldiers with risk factors of cardiovascular diseases, several characteristic changes in cardiac regulation parameters were revealed. These changes indicated reduced adaptive potential, increased autonomic regulation, and a predominance of sympathetic influence on heart function. The results of the time characteristics of the HRV state are presented in Table 3. The median HRV value was 76.8 bpm, which is at the upper limit of the norm, and the distribution of values between the 25th and 75th percentiles was insignificant and fluctuated within 68.7 and 81.8 bpm, which indicates a stably increased tone of the sympathoadrenal system.

As a result of the obtained data analysis, the decrease in the RRNN, SDNN, RMSSD, and pNN50 indicators (780.9 ms, 37.3 ms, 22.1 ms, 2.7%) was found, which indicates a decrease in the HRV overall level, impaired parasympathetic regulation and limited ability of the cardiovascular system to adapt under conditions of varying degrees of load.

All the studied indicators have a high variation coefficient, which fluctuates within limits that significantly exceed 14.6%. Also, the highest values were recorded for the pNN50 indicator ($V=160.1\%$), indicating high individual variability of the autonomic nervous system reactivity, which may be associated with hidden dysfunctions of autonomic regulation and physical fitness level.

Table 3. Indicators of heart rate variability of soldiers with the risk of cardiovascular diseases, $n=139$

Parameter	Statistics					
	Me	Percentile		Min	Max	V (%)
		25 th	75 th			
Heart rate (bpm)	76.8	68.7	81.8	52.2	146.0	19.4
RRNN (ms)	780.9	733.9	873.7	411.0	1149.8	16.5
SDNN (ms)	37.3	28.0	49.2	11.4	87.9	41.4
RMSSD (ms)	22.1	15.8	33.5	5.7	109.8	71.6
pNN50 (%)	2.7	0.5	8.7	0.0	53.7	160.1
Moda (ms)	775.0	725.0	875.0	425.0	1175.0	17.1
AMo (%)	49.6	39.8	57.2	21.1	93.7	28.4
deltaX (ms)	250.0	200.0	300.0	100.0	500.0	33.4
ABI (%)	214.9	141.9	286.1	42.2	937.0	69.6
ARI (s^{-2})	6.4	4.3	7.4	2.1	17.4	49.3
IARP (%)	62.0	48.6	76.5	24.1	163.0	43.1
SI (arb.un.)	147.7	87.3	192.0	24.1	814.8	85.3

The low median values of the ABI index, with a result of 214.9%, ARI result of $6.4 s^{-2}$, and IARP result of 62.0%, which characterize the reactivity of the heart rate, further confirm the decrease in the adaptive capabilities of the cardiovascular system and the increased risk of homeostasis disorders when changing environmental conditions or loads.

Analysis of the time indices of HRV at the 25th and 75th percentiles allows us to indicate that the majority of the examined individuals showed a decrease in the overall variability of the heart rate, the predominance of the sympathetic division of the ANS, and a pronounced suppression of parasympathetic regulation.

Analysis of the spectral indices presented in Table 4 showed the predominance of sympathetic activity in the vast majority of military personnel. It should also be noted that the TR indicator, which characterizes the total power of the spectrum, was $889.0 ms^2$, with a variation coefficient of 78.1%, which indicates a pronounced individual variability of the general autonomic activity level of soldiers' cardiovascular system. The VLF indicator (VLF median = $283.0 ms^2$) was also moderately elevated, which may indicate the influence of thermoregulatory processes and humoral mechanisms.

Table 4. Spectral indicators results of heart rate variability of soldiers with the risk of cardiovascular diseases, $n=139$, $n=139$

Parameter	Statistics					
	Me	Percentile		Min	Max	V (%)
		25 th	75 th			
TP (ms^{-2})	889.0	505.0	1328.0	104.0	4236.0	78.1
VLF (ms^{-2})	283.0	134.0	435.0	29.0	1694.0	90.0
LF (ms^{-2})	381.0	254.0	527.0	55.0	1269.0	65.6
HF (ms^{-2})	115.0	71.0	308.0	9.0	1951.0	148.3
LFnorm (arb.un.)	0.73	0.53	0.83	0.35	0.92	23.66
HFnorm (arb.un.)	0.27	0.17	0.47	0.08	0.65	53.48
LF/HF	2.8	1.1	4.7	0.5	11.8	76.1

The low median value of the HF indicator was $115.0 ms^2$; this indicator reflects parasympathetic activity, and its significant variability ($V=148.3\%$) indicates a weakening of the vagal influence on the heart rate in a significant part of the examined individuals. Such a condition is characteristic of chronic stress, fatigue, or pre-pathological changes in soldiers' cardiovascular system functioning. Analysis of normalized units by the LFnorm and HFnorm indicators confirms the dominance of the sympathetic division of the autonomic nervous system. The median value of LFnorm was 0.73 (73%) in the structure of the total power spectrum, while HFnorm was only 0.27 (27%). Such an imbalance in the vegetative provision of heart rate regulation is a characteristic sign of increased cardiovascular risk.

The LF/HF indicator, as an integral marker of sympathovagal balance, was increased to 2.8, corresponding to the low parasympathetic activity and the predominance of sympathetic influence. The obtained results confirm the increased psychophysiological stress and possible maladaptation of the regulatory mechanisms of the cardiovascular system in soldiers with CVD risk factors.

Thus, the spectral analysis results of the HRV state indicate the presence of the autonomous regulation imbalance of cardiac activity, with the dominance of the sympathetic link, which means an increased load on the body, and requires a comprehensive approach to correcting the functional state of the cardiovascular system, in particular, the implementation of health-improving physical training, control of the psycho-emotional state and constant medical monitoring.

In order to achieve the set goal of the study, we conducted a correlation analysis to clarify the structure of the relationships between the studied parameters. The results obtained are presented in Table 5.

Table 5. Matrix of correlations between HRV, hemodynamics, and respiratory system functional status indicators

Indicators	SBP, mmHg	DBP, mmHg	HR, bpm	FVC, l	FEV1, l/s	
Heart rate (bpm)	0.225	0.274	0.374	-0.140	-0.120	-0.4
RRNN (ms)	-0.225	-0.274	-0.374	0.140	0.120	
SDNN (ms)	-0.264	-0.156	-0.046	0.312	0.215	0.3
RMSSD (ms)	-0.218	-0.159	-0.018	0.294	0.214	
pNN50 (%)	-0.276	-0.163	-0.027	0.331	0.233	0.2
Moda (ms)	-0.234	-0.308	-0.386	0.134	0.078	
AMo (%)	0.289	0.177	0.125	-0.149	-0.028	0.1
deltaX (ms)	-0.320	-0.209	0.075	0.273	0.167	
ABI (%)	0.275	0.152	0.009	-0.239	-0.103	0
ARI (s ⁻²)	0.254	0.179	0.050	-0.205	-0.092	
IARP (%)	0.314	0.250	0.184	-0.148	-0.076	-0.1
SI (arb.un.)	0.332	0.254	0.138	-0.172	-0.069	
TP (ms ²)	-0.332	-0.206	0.011	0.269	0.166	-0.2
VLF (ms ²)	-0.461	-0.315	-0.041	0.058	-0.049	
LF (ms ²)	-0.239	-0.188	0.147	0.303	0.154	-0.3
HF (ms ²)	-0.291	-0.165	0.150	0.329	0.292	
LFnorm (arb.un.)	0.168	0.101	-0.099	-0.155	-0.214	-0.4
HFnorm (arb.un.)	-0.168	-0.101	0.099	0.155	0.214	
LF/HF	0.150	0.089	-0.080	-0.147	-0.216	-0.5

Note. The matrix shows the values of pairwise correlation coefficients (r) between HRV and cardiovascular and respiratory system indicators according to the nonparametric Spearman test. The colour of the cells corresponds to the direction and strength of the relationships: red – direct correlation relationship, blue – inverse relationship. Darker shades indicate a higher strength of the relationship. Spearman's correlation coefficients: $r=0.168$, $p < 0.05^*$; $r=0.232$, $p < 0.01^{**}$; $r=0.294$, $p < 0.001^{***}$; $r_{cr}=\pm 0.166$ ($n=139$ critical value).

The presented correlation matrix reflects the results of non-parametric Spearman correlation analysis between HRV and cardiovascular and respiratory function indicators. The analysis revealed several statistically significant correlation relationships. Thus, the HR indicator demonstrates significant inverse correlations with time-dependent HRV indicators, particularly the SDNN and the pNN50 ($r = -0.264$, $r = -0.276$; $p < 0.01$). This fact confirms the expected decrease in HRV with increasing HR.

Also, temporal HRV indices, specifically the SDNN and Moda ($r = -0.264$, $r = -0.308$; $p < 0.001$), showed significant inverse correlations with BP systolic, and the RRNN and Moda ($r = -0.274$, $r = -0.308$; $p < 0.01$) with BP diastolic, indicating an inverse relationship between total HRV and BP. Also, significant direct correlations were found between FVC with the SDNN, the pNN50 and the RMSSD ($r < 0.350$; $p < 0.001$), and the RMSSD and the pNN50 with FEV1 ($r < 0.300$; $p < 0.01$), which indicates a direct relationship between some indicators of short-term HRV and external respiratory function (see Table 5).

Among the spectral indices of the HRV frequency domain, the VLF index shows a significant inverse correlation with SBP ($r = -0.461$; $p < 0.001$) and DBP ($r = -0.315$; $p < 0.001$), indicating a significant relationship of the very low frequency component of HRV with blood pressure levels. The LF also has a significant inverse correlation with SBP ($r = -0.239$; $p < 0.01$) and a direct correlation with FVC ($r = 0.303$; $p < 0.001$). The significant direct correlations of HF indicators with FVC and FEV1 are particularly important ($r = 0.329$, $r = 0.292$; $p < 0.01$), which emphasize the connection of parasympathetic activity with the functional state of the respiratory system.

Significant direct correlations were found between AMo and SBP ($r=0.289$; $p < 0.01$) and DBP ($r = 0.177$; $p < 0.05$) and inverse correlations between deltaX and SBP ($r = -0.320$; $p < 0.001$) and DBP ($r = -0.209$; $p < 0.05$) among the nonlinear HRV indicators.

The inverse correlations between the HR and the SDNN and pNN50 indices, which are markers of vagal modulation of the heart rate, require an additional explanation. These relationships may indicate a decrease in parasympathetic control over cardiac activity in this group of soldiers. Therefore, the imbalance of the autonomic nervous system of soldiers, with the dominance of sympathetic influence and suppression of parasympathetic tone, is an established pathophysiological mechanism associated with an increased risk of cardiovascular diseases. The logical explanation for the detected dependency may be the influence of risk factors such as chronic stress, a sedentary lifestyle, and potential metabolic disorders that often accompany this category of individuals. Such factors may lead to chronic activation of the sympathoadrenal system and inhibition of vagus nerve activity, which is manifested in increased heart rate and reduced heart rate variability, particularly its parasympathetic components. In addition, the direct correlations between RMSSD and pNN50 and FVC and FEV1 indicators of external respiratory indicate an integrated regulation of the functions of the cardiovascular and respiratory systems, where significant influence plays a positive role in maintaining respiratory efficiency. Disruption of the interplay between heart rate variability and cardiorespiratory parameters in military personnel at risk of cardiovascular disease may hold significant clinical relevance.

The present findings demonstrate statistically meaningful correlations between selected HRV indices and cardiovascular and respiratory function measures in the studied cohort, suggesting their potential utility for comprehensive assessment of functional status and early identification of individuals at elevated cardiovascular risk.

Discussion

The findings of this investigation underscore the importance of evaluating the functional status of the cardiorespiratory system and autonomic heart rate regulation in military personnel who are at elevated risk for cardiovascular disease. The median heart rate and blood pressure indicators indicate the relatively satisfactory functional state of the studied individuals. In addition, the studied sample revealed a decrease in HRV indicators SDNN, RMSSD, and pNN50 in some participants, which is a marker of a decrease in parasympathetic influence and dominance of sympathetic activation. Such changes can be considered as an adaptive and compensatory response of the body to the effects of psychoemotional or physical stress, which is characteristic of the professional activities of military personnel, especially in martial law conditions. Similar results are consistent with previous studies indicating a decrease in HRV as an early marker of cardiovascular dysfunction (Taylor et al., 2019; Lin et al., 2020).

Also, some of the examined soldiers had an increase in the Stress Index, which may indicate excessive vegetative support of the cardiovascular system at rest. According to Sammito et al. (2013, 2014), chronic stress in regulatory systems can lead to a decrease in heart adaptive potential, coronary heart disease, and an increase in the risk of arterial hypertension.

Analysis of the relationships between functional indicators of heart rate, blood pressure, and indices of autonomic regulation revealed the presence of statistically significant correlations, which indicates the systemic nature of changes in the body of military personnel at risk of CVD. In particular, the inverse relationship between RMSSD and systolic BP may indicate decreased parasympathetic activity in individuals with higher blood pressure. Similar trends were described in Bustamante-Sanchez et al. (2020) and Yarmak et al. (2024), where HRV decrease was accompanied by cardiometabolic risk increase.

The obtained results are consistent with the data of Strauss et al. (2021, 2025), who showed that law enforcement officers with low cardiorespiratory fitness levels have higher blood pressure, glucose, and blood lipids. The authors emphasize the importance of systematic monitoring of physical activity and the application of aerobic training to maintain the functional capacity of the cardiorespiratory system. Our results also confirm the feasibility of such an approach to prevent CVD among military personnel.

The identified changes in heart rate variability, decrease in reserve capabilities of autonomic regulation, and relationships between BP, HR, and vegetative indices can be considered grounds for improving the Ukrainian military physical fitness assessment system. The need for such changes is because a significant percentage of soldiers with adverse reactions of the cardiovascular system to various types of physical exertion was recorded, particularly in the local isometric load test and the hypoxic test. The obtained results indicate the presence of specific functional limitations that are not considered during the standard approach to physical fitness assessment.

Conclusions

A risk group with latent signs of cardiovascular dysregulation was identified as a result of a comprehensive examination of military personnel, which is characterized by an adverse reaction to local isometric load with an intensity of 50% of the individual's maximum. The vast majority of soldiers also recorded similar changes when performing a hypoxic test, which indicates the presence of early predictors of arterial

hypertension development. It was set that the studied category of soldiers has decreased their adaptive reserves, vegetative support dysfunction of their cardiac activity, and insufficiency of compensation mechanisms during functional load. As a result, the orthostatic test showed an increase in soldiers' systolic pressure, a predominance of sympathetic activation, and an increase in their heart rate. Moreover, soldiers' heart rate variability decrease was recorded, which can be considered an indirect prognostic criterion for the presence of latent disorders in their cardiovascular system functioning. The study results show that the traditional military physical fitness assessment does not consider the individual reactivity of the cardiovascular system to different physical exertion types and does not allow timely identification of soldiers with hidden dysfunctions. The negative reaction recorded in such individuals may indicate the initial manifestations of hemodynamic destabilization and requires the introduction of adaptive approaches to assessing and correcting the physical fitness process.

The study's theoretical significance lies in clarifying the mechanisms of early disruption of the regulation of the cardiovascular system of military personnel with a high level of functional load.

The practical significance lies in revising existing physical fitness standards and developing a physical fitness assessment system, considering the identified risk indicators.

Conflict of Interest. The authors state there is no conflict of interest.

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