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FUNCTIONAL DISORDERS AND THE RISK OF AGRICULTURAL MACHINE OPERATORS' CARDIOVASCULAR DISEASES

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Abstract

Prevention of diseases associated with exposure to harmful factors in working conditions is relevant in the light of strategic objectives in the field of public health. Identification of functional disorders and prenosological conditions of the cardiovascular system is an important link in the prevention of diseases of the circulatory system. A study was made of the functional state of the cardiovascular system in agricultural machine operators working under conditions of exposure to a complex of harmful factors in the work environment and the labor process, which have a hypertensive effect. Functional disorders of the cardiovascular system are identified, showing the operation of reducing the circulatory system, the voltage regulator systems until exhaustion functional reserves, which can be regarded as a manifestation prenosological states. Screening ECG dispersion charting showed signs of borderline states, evidence of violation of the autonomic regulation of the heart, myocardial hypoxia and violation of cardiometabolic processes it in people older than 40 years with experience of 20 years or more. The positive statistically significant correlation between the basic hemodynamics, level of functioning of the cardiovascular system, the prevalence of diseases of the circulatory system and work experience in the profession. Production due to the conditionality of diseases of the circulatory system indicates the need for the development and implementation of health and hygiene programs for the prevention of functional disorders of the cardiovascular system in the course of employment and the risk of health problems in mechanization of agriculture.

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Keywords: Agricultural machine operators, cardiovascular system, functional disorders, disease risk.



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1. Introduction

Cardiovascular pathology is one of the reasons for the decline in the working capacity of the population and mortality, both throughout the world and in our country (Ivanov et al., 2019). Among the causes of its occurrence, one of the leading places is occupied by the stressful effects of harmful production factors - chronic psycho-emotional stress, industrial noise, general and local vibration, heating and cooling microclimate, exposure to various chemical agents, physical and functional overstrain (Bykov et al., 2017; Tsutsumi et al., 2009; Theorell et al., 1998). All these factors are exposed to professional tractor drivers, agricultural machine operators, agricultural machine operators (Danilov et al., 2019; Novikova et al., 2018; Galyanov et al., 2007).

The cardiovascular system (CVS) experiences a greater damaging effect of stress factors than other body systems, playing a leading role in providing adaptive responses and maintaining its functioning as a whole. With prolonged stress exposure, overstrain of regulatory systems can lead to a breakdown of adaptation and the development of pathological conditions. According to the data available in the literature (Babanov & Baraeva, 2015; Kontsevaya et al., 2016), the spread of hypertension in the workplace is from 15 to 20%, manifesting itself in the development of cardiovascular complications (Babanov & Baraeva, 2015; Kontsevaya et al., 2016).

Violations of the regulatory mechanisms of CVS are the earliest signs of prenosological conditions (Baevsky & Bersneva, 2008; Gromova, 2012; Shlyakhto, 2002) and their timely detection is relevant both for assessing the circulatory system, physiological and adaptive status of workers, and for developing preventive measures to preserving their health.

2. Problem Statement

According to our previous studies (Danilov et al., 2019) and published data (Galyanov et al., 2007; Omland, 2002), agricultural machine operators working on mobile agricultural machinery are exposed to a complex of adverse factors that form harmful working conditions (classes 3.2-3.4). In the warm season, the air temperature in the cabins can increase to 44.2 °C, the cab air is polluted with exhaust gases containing carbon monoxide, hydrocarbons, acrolein, nitrogen oxides, dust, pesticides and mineral fertilizers in concentrations exceeding the maximum permissible (MPC) in 1-29.75 times. The noise in the cabs exceeds the maximum permissible levels (MPC) by 4-105 dBA, general and local vibration - by 6 dB, - 4 dB, respectively. Constructive and ergonomic imperfection of cabins and workplaces form an uncomfortable working posture and excessive static-dynamic physical loads leading to functional overstrain (Novikova et al., 2018).

During the winter repair work, machine operators carry out all the main types of equipment repair operations (disassembly, washing of components and parts, repair of electric and fuel equipment, testing and adjustment of engines, etc.), mechanical and other work, accompanied by noise (81- 89 dBA), the emission of harmful substances (exhaust gases, hydrocarbons, alkalis, solvents, etc.) and dust in air in concentrations exceeding the MPC by 1-3 times. Dismantling and washing operations are carried out in conditions of elevated temperatures (more than 28°), humidity and air mobility (more than 75% and 0.5 m/s, respectively). Excessive physical exertion, maintaining uncomfortable and forced work postures, body

tilts of more than 30 ° and a long (80% shift) stay in a standing position (Danilov et al., 2019). Harmful production factors, acting alternately and in combination, including at levels not exceeding hygienic standards, can participate in the pathogenetic mechanisms of development and progression of common non-occupational diseases, including circulatory system pathologies. It is known that the effect of a heating microclimate in combination with high air humidity is a factor contributing to the development of arterial hypertension. Closed space and a small amount of air with high humidity and low mobility lead to disruption of heat transfer processes and the accumulation of heat in the body, manifesting itself in an increase in body temperature, increased heart rate, and decreased blood pressure. Intense sweating leads to dehydration and loss of salts, accompanied by an increase in blood viscosity, worsening microcirculation, and can lead to the development of acute heart failure (Babanov & Baraeva, 2015; Izmerov, 2011). A pro-hypertensive effect is exerted by carbon monoxide constantly present in the breathing zone of machine operators, which is formed during incomplete combustion of fuel. It has been proven that its effect is enhanced under the influence of high air temperature, which is associated with a violation of thermoregulation and an increase in the sensitivity of the body (Babanov & Baraeva, 2015).

Under the stressful effects of local vibration, increased noise, combined with static-dynamic physical activity, uncomfortable and forced body position, changes in central hemodynamics and myocardial contractility are observed (Buyanov, 2003). Under the influence of industrial noise, changes in the circulatory system occur, characterized by the development of neurocirculatory syndrome, which occurs with hypertensive reactions, indicating the development of arterial hypertension (Brook & Julius, 2000; Izmerov, 2011). One of the leading roles in the development of circulatory system diseases belongs to psychoemotional stress (Kontsevaya et al., 2016; Shlyakhto, 2002). Chronic psycho-emotional loads on machine operators are associated with a high amount and density of incoming information, the need for its quick processing and response, risk to one's own life, responsibility for the safety of others and material values, and an irrational mode of work and rest. The tension of the attention functions, visual and auditory analyzers is due to the need for accurate driving of the unit and the perception of differentiated signals against pronounced noise interference (Novikova et al., 2018).

3. Research Questions

The functional state and the risk of developing diseases of the cardiovascular system in men - agricultural machine operators (85 people) of working age (30-59 years old) who did not complain at the time of the study were studied. The average length of service in the profession was 19.61 ± 1.26 years. All machine operators were previously informed about the contents of the study and, in accordance with the requirements of biomedical ethics, they received voluntary consent to the examination.

4. Purpose of the Study

The purpose of this study was to assess the functional disorders of the cardiovascular system and the risk of developing circulatory system diseases in agricultural machinery.

5. Research Methods

To assess the functional state of CVS of the examined, systolic (SBP), diastolic (DBP) blood pressure (BP) of the blood and heart rate (HR) were recorded. In the study of systemic hemodynamics, integrated calculated indicators were used - pulse pressure (PD), mean hemodynamic pressure (RAF), stroke (systolic) volume of blood circulation (CI), minute volume of blood circulation (IOC), total peripheral vascular resistance (OPS) (Makarova, 2002).

Assessment of blood pressure levels was carried out in accordance with the clinical recommendations of the Ministry of Health of the Russian Federation in 2013 (Chazova & Zhernakova, 2019) and the clinical recommendations of the EOC / EAG (2018) for the treatment of patients with arterial hypertension. The normative values of the calculated hemodynamic parameters were taken as the WHO standards for adults when determining blood pressure by the sound method (Shushkova et al., 2013). Assessment of the functional reserves of CVS was carried out by the endurance coefficient (CE) and the coefficient of efficiency of blood circulation (BCE). An assessment of the level of functioning of the circulatory system was carried out using the calculated index of the adaptive potential (API) of the CVS according to Baevsky and Bersneva (2008).

To identify functional cardiac abnormalities, we used a computer screening analyzer for rapid assessment of the state of the heart by ECG signals from the patient's limbs "Cardiovisor-06c", designed for preclinical diagnosis of conditions bordering between normal and pathology based on the method of dispersive ECG mapping. The integrated indicators "Myocardium", "Rhythm" and "Pulse" were used (Katelnitskaya et al., 2008).

Statistical processing of the results was carried out using the Microsoft and Statistica10 applications. The mean values of the indicators (M), the standard error of the mean ($\pm m$), and the standard deviation (σ) were calculated. The statistical significance of the differences was evaluated by the Mann-Whitney U-test, the differences were considered statistically significant at $p < 0.05$. To identify the relationship between the studied indicators, we used the methods of correlation analysis for parametric and nonparametric types of distribution - the Pearson and Spearman criteria, respectively.

6. Findings

Analysis of systemic hemodynamics showed that the average group values of SBP, DBP, PD, and MHP exceeded the physiological limits in all age groups of the examined, indicating arterial hypertension. The highest values of these indicators were recorded in people of the older age group (50-59 years old) with a work experience of 30 years or more, the least in the group of 20-29 years old, but their levels also exceeded the age norms (Table 01).

Table 01. Hemodynamic parameters in agricultural machine operators at rest

Name of indicator	All Examined (n = 85)	The value of the indicator (M ± m)			
		1st group (n = 14)	2nd group (n=24)	3rd group (n=19)	4th group (n=28)
Age (years)	42.36±1.2	26.07±0.74	35.35±0.45	44.21±0.58	55.36±0.66
Work experience in the profession (years)	19.606±1.26	5.67±1.05	13.83±1.08	19.05±51.40	31.89±1.65
SBP mm. Hg. Art.	148.03±2.19	136.50±3.66	142.17±2.99	146.16±4.03	159.96±4.44*
DBP mm. Hg. Art.	85.01±1.29	75.35±4.06	81.58±1.89	87.73±2.29	90.93±1.80*
Heart rate, beats in minutes	76.30±1,9	76.86±2,32	77.25±2,41	74.42±1,95	76,50±2,48
Pulse pressure mm. Hg. Art	63.02±1.87	61.43±5.15	60.58±2.81	58.42±2.75	69.03±3.92*
RAF, mm. Hg. Art.	106.02±1.39	95.83±3.09	101.78±1.90	107.21±2.69	113.94±2.31
IOC, ml / min	3851.05 ±128.40	4962.68 ±342.22	4300.24 ±207.36	3409.51 ±174.69	3209.84 ±181.38
OPSS din-s-cm ⁵	2215.23 ±103.52	1692.77 ±185.73	2022 ±135.77	2665.36 ±186.79	3062.75 ±179.37*
CE, mustache units	13.88±0.34	12.67±0.23	12.89±0.36	14.29±0.21	14.0±0.45
BCE, mustache units	4307.67 ±22.23	4262.21 ±20.12	3941.06 ±19.76	4227.50 ±21.23	4616.65 ±23.46
API, mustache units	3.04±0.005	2.53±0,008	2.84±0,007	3.016±0.008*	3.48±0.007*

Notes: * Statistical significance of differences compared with the group 1 (p <0,05 level of significance Mann-Whitney U-criterion on).

Individual hemodynamic levels have differences - the SBP corresponding to the norm is registered in 44.2%, DBP - 59.7% of the examined. Moreover, the largest number of people with blood pressure, according to the norms (69.2% and 88.5%, respectively), were identified in the 1st age group. At the same time, the levels of SBP and DBP of the machine operators of the 3rd and 4th groups were significantly different compared with those in the 1st group (p = 0.000464, p = 0.000008, respectively). Elevated levels of SBP and PD, which is directly correlated with it, at rest can indicate functional disorders of CVS in all examined. The highest levels of SBP and PD were recorded in the 4th group, which is possibly associated with age-related changes in the arteries, causing an increase in peripheral vascular resistance and, as a consequence, an increase in SBP (Baevsky & Bersneva, 2008).

The average group levels of diabetes in machine operators of all age groups significantly exceeded the physiological norm, indicating a lack of adaptation of the circulatory apparatus (Omland, 2002). Moreover, the levels of diabetes in the 3rd and 4th groups were higher than in the 1st group, which indicated a more pronounced violation of blood circulation regulation. Reduced IOC levels in the 3rd and 4th groups indicated a decrease in myocardial contractile function. Reliable positive correlation was established

between different strengths of the main hemodynamic parameters (SBP, DBP, RAF, OPSS) with professional experience ($r = 0.29$; $r = 0.36$; $r = 0.38$; $r = 0.57$, respectively), which confirms its influence on the development of functional disorders of CVS.

The results of the study of hemodynamic parameters are confirmed by the assessment of the functional reserves of CVS according to the calculated coefficients. 27.8% of the examined showed increased values of endurance coefficient (CE), indicating a weakening of the circulatory system, although the average values of the indicator were within normal limits.

Almost all of the examined (97.6%) showed higher than normal levels of the coefficient of efficiency of blood circulation, which indicated fatigue and a decrease in the functional activity of the circulatory system. It is believed that BCE characterizes the body's expenditures for the movement of blood in the vascular bed, the higher it is, the less economical is the expenditure of reserves of the cardiovascular system (Makarova, 2002).

Adaptation potential is a comprehensive, integral indicator characterizing the level of functioning of the CVS, since it is determined by the basic parameters of hemodynamics - CR, IOC, RAF, OPSS. In the 1st group, the state of satisfactory adaptation was revealed (sufficient functionality), in the 2nd group, the state of the functional tension of adaptation mechanisms, and in the 3rd group, the borderline state. The average group API values in the 4th age group corresponded to unsatisfactory adaptation, 42.85% of the machine operators of this group were in a state of disruption of adaptive capabilities. Statistically significant differences in API levels were found in the 3rd and 4th groups compared with the 1st ($p = 0.004361$, $p = 0.000003$, respectively). A direct correlation correlation ($r = 0.53$) between the length of service in the profession and the level of functioning of the CVS was found. The results of API assessment allow us to talk about overstrain and depletion of regulation mechanisms in people of the 4th group with professional experience of more than 30 years, manifested by a sharp drop in the reserve capacity of the heart.

According to the dispersion ECG mapping, the average group value of the Myocard index was $14.8 \pm 0.8\%$, which indicated the absence of pathologies. The analysis took into account the appearance of a red color on the portrait of the left ventricle. The individual values of this indicator in 13.3-14.3% of the examined in each group ranged from 16% to 19% with a yellow color of the "portrait of the heart", which was regarded as a borderline state (a passing episode of a short-term increase in dispersion characteristics) or the initial stage probable pathology (Katelnitskaya et al., 2008).

The most altered "portraits of the heart" with a predominance of red flowers, which indicated myocardial hypoxia and impaired cardiometabolic processes in it, were noted among mechanists of the 3rd and 4th age groups with a professional experience of 19.05 ± 1.47 years and 31.18 ± 1.65 years, respectively. The predominance of green in the "portrait of the heart" was recorded mainly in the 1st age group, indicating the absence of pathology.

The indicator "Rhythm" (IR) can vary from 0 to 100%. IR = 100% corresponds to the most pronounced changes in the characteristics of the variability of the R-R intervals. In healthy people with an optimal balance of sympathetic and parasympathetic influences, this indicator is steadily in the range from 0% to 20%, indicating a vegetative dysfunction accompanying the tension of adaptation. The average values of the IR index in all groups examined were within the range of $20.13 \pm 2.9\%$ - $34.3 \pm 3.1\%$, which indicated an increased voltage of regulatory systems. At the same time, increased indicators were more often recorded

in the 4th group (in 12.2%), less often in the first (2.1%). Heart rate variability (HRV) in the majority (61.5%) of the examined was defined as “without disturbance”. In 19% it was reduced, which indicated a violation of the autonomic regulation of the heart. A decrease in HRV was more often detected in the 4th group (in 17.9%). The color change of the Pulse indicator, which corresponds to the norm, was detected in 57% of machine operators, in 8.9% bradycardia was noted, in 34.1% of tachycardia.

Based on the results of periodic medical examinations, the prevalence of circulatory system diseases was studied. 208 male machine operators with an average age of 48.84 ± 0.56 years were examined. To assess the connection of diseases with the profession, the examined were divided into 4 groups: 1st — with a professional experience of 6.00 ± 0.46 years (20 people); 2nd - 14.69 ± 0.39 years (54 people); 3rd - 23.91 ± 0.35 years (81 people); 4th - 33.75 ± 0.8 years (53 people). It was found that the prevalence of people with a detected chronic pathology among the observation group was 88.1% of the number examined. Circulatory system diseases were detected in 20.19% and are mainly represented by diseases characterized by high blood pressure (I10-I15 according to ICD-10). Heart rhythm disturbances (1.44%), angina pectoris (0.96%), varicose veins of the lower extremities (0.48%), hemorrhoids (0.48%) were also detected. At the same time, the largest number of cases of diseases of the circulatory system was diagnosed among machine operators of the 4th group. A statistically significant positive correlation was established ($r = 0.24$) between professional work experience and the prevalence of circulatory system diseases.

7. Conclusion

Thus, the results obtained indicate violations of the functional state of the CVS of agricultural machine operators, indicating tension in regulatory systems, exacerbated by an increase in the length of service in the profession, up to the depletion of functional reserves, which can be regarded as a manifestation of prenosological conditions. According to the data available in the literature (Buyanov, 2003), impaired functioning of the heart of machine operators under intense and prolonged exposure to harmful factors in working conditions can contribute to the accumulation of under-oxidized products in myocardiocytes and increase myocardial rigidity, which ultimately leads to a breakdown in the adaptive capabilities of the heart (Buyanov, 2003). This information is consistent with the pre-pathological disturbances in the state of the heart of machine operators with experience in the profession of 20 years or more that we identified according to the data of dispersive ECG mapping. A statistically significant positive relationship between professional work experience and the prevalence of diseases of the circulatory system also indicates a certain contribution to the development of harmful working conditions.

The research results allow us to draw the following conclusions:

1. Agricultural machine operators in the process of professional activity are subject to the influence of a complex of factors of the industrial environment and the labor process, which have a hypertensive effect.
2. Functional disorders of the cardiovascular system have been identified, indicating regulatory tension up to the depletion of functional reserves, which can be regarded as a manifestation of prenosological conditions.

3. Work experience in the profession is a risk factor for functional disorders and the development of diseases of the circulatory system in agricultural machine operators.

The research results indicate the need for the development and implementation of measures to prevent the development of functional disorders and risk-associated diseases of the cardiovascular system in agricultural machinery.

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