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Research article

WORK ENVIRONMENT OF THE AUTOMOTIVE INDUSTRY AS A RISK FACTOR OF DISEASES OF THE CIRCULATORY SYSTEM AMONG WORKERS

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This study has shown that working conditions of basic occupational groups in the automotive industry involve combined exposure to several harmful occupational factors. Major harmful occupational factors include intense noise, vibration, work hardness and chemical levels; their intensity varies between permissible levels (the hazard category is 2.0) and harmful ones (the hazard category 3.1–3.2, harmful working conditions with hazard levels 1 or 2). This may induce occurrence or exacerbation of basic non-communicable diseases such as diseases of the circulatory system (CSDs), occupational and work-related diseases.

CSDs were diagnosed in 37.7 % of workers employed at automotive productions. The most frequent diseases include hypertension (EH) that accounted for 28.2 %; cerebrovascular diseases (CVDs), 6.5 %; ischemic heart disease (IHD), 3.6 %. CSDs developed at an early age in workers exposed to harmful occupational factors belonging to the hazard category 3.1–3.2; these diseases became more frequent as work records got longer, and were more frequently exacerbated with acute cardiovascular conditions. We assessed the total cardiovascular risk using the SCORE scale and established that shares of people with high and very high cardiovascular risks were higher among painters, laboratory assistants responsible for chemical analysis, and repairmen. The attributive risk of new cardiovascular diseases ranged between 9.6 (turners) and 42.6 (repairmen) cases.

The highest occupational CSDs causation was identified for repairmen and mechanics at mechanical assembly production; average causation was established for stampers, painters, laboratory assistants dealing with chemical analysis, crane operators, and turners.

Keywords: *automotive industry, working conditions, occupational factors, workers, diseases of the circulatory system, risk, occupational causation.*

The automotive industry produces various makes of cars and accounts for 23 % of the total civil engineering output in Russia. Dozens of thousand workers are employed at car-making productions all over the country. Workers from the basic occupational groups have to work under such conditions that can be estimated as harmful, hazard category 1 or 2 (3.1 or 3.2). The priority harmful occupational factors include, first of all, some physical ones

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such as intense occupational noise and vibration; they are followed by chemical pollution in workplace air, predominantly with aerosols, and physical overloads [1–3]. Intensive noise and vibration at production, their quantitative and qualitative features, and duration of exposure to them throughout the entire work process frequently induce various health disorders caused by lower adaptive reserves of the body and weaker protection and compensatory reactions [4–6]. Most workplaces in this branch involve workers' exposure to a whole set of harmful production factors [1, 4]. Increasing production capacities in the automotive industry due to a higher demand on the market make their effects on the body even more significant, create elevated risks of acute and chronic diseases of various organs and systems including life-threatening states caused by cardiovascular pathology [7–10].

Out of more than 200 risk factors (RF) causing occurrence and progression of CSDs (diseases of the circulatory system), only about nine leading ones account for almost 95 % of the population health risk. They are essential hypertension, diabetes mellitus, dyslipidemia, tobacco smoking, strong alcohol abuse, abdominal obesity, depression / stress, low physical activity, and low consumption of vegetables / fruits [11–14]. Some studies reported that occupational risk factors could also make a substantial contribution to growing incidence of CSDs among workers. These factors include noise; toxic chemicals and aerosols in workplace air; harsh climate and microclimate; physical overloads and work intensity caused by the necessity to work in shifts and at night; stress and psychoemotional loads at a workplace due to high responsibility for the work process [9, 15–20].

This study is relevant since very few research works investigate prevalence of CSDs in workers employed in the automotive industry; we should remember that these diseases are a major cause of high mortality and disability among working age people. Given that, conformity to the safety requirements as regards exposure to occupational factors ensures health protections and provides the necessary levels of work capacity. This calls for developing scientifically grounded approaches to preventing diseases of the circulatory system and reducing risks of their development.

The aim of this study was to analyze incidence of CSDs among workers from various occupational groups exposed to a set of harmful occupational factors at workplaces in the automotive industry.

Materials and methods. We performed hygienic examination of working conditions at 250 workplaces at a leading car-making enterprise in Russia; the examination involved assessing quantitative and qualitative parameters of harmful occupational factors according to the Guide R 2.2.2006-05[1] and relied on data obtained by our own research and materials of the special assessment of working conditions (SAWC).

The modern production in the automotive industry involves a lot of processing operations including assembly, mechanical processing and subsequent assembly of components and large-size units as well as non-standard components.

The leading technical processes in car-making production are assembly of components and mechanical processing of pieces and non-standard units as well as large-size components. Mechanics at mechanical assembly production (MAP mechanics) is the leading and the largest occupational group at car-making enterprises; they are followed by stampers who are exposed to occupational noise with its levels higher than maximum permissible ones by 7–16 dBA as per the equivalent level (the hazard category 3.2), local vibration (the hazard category 3.1), physical overloads (lifting and moving heavy weights, local loads on the shoulder girdle) (the hazard category 3.1) (Table 1). Working

[1] Guide R 2.2.2006-05. Guide on Hygienic Assessment of Factors of Working Environment and Work Load. Criteria and Classification of Working Conditions (approved by G.G. Onishcheno, the RF Chief Sanitary Inspector on July 29, 2005; became valid on November 01, 2005). *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200040973 (January 06, 2023) (in Russian).

Table 1

The final assessment of working conditions at workplaces in the automotive industry

Occupation	Harmful occupational factors					The overall assessment of working conditions
	Chemical	Noise (L equiv.)	Micro-climate	Local vibration	Work hardness	
MAP mechanics	2	3.2	-	3.1	3.1	3.2
Stampers	-	3.2	-	3.1	3.1	3.2
Conveyor and crane operators	2	2	2	-	3.1	3.1
Turners; repairmen	2	3.1	-	-	3.1	3.1
Painters	3.1	3.1	-	-	3.1	3.2
Laboratory assistants responsible for chemical analysis	3.1	2.0	2.0	-	3.1	3.2

conditions for other occupational groups involve elevated exposures to the following occupational factors: conveyor operators and crane operators, work hardness; turners and repairmen, work hardness and noise; painters and laboratory assistants responsible for chemical analysis, exposure to such toxicants as phenol, toluene, formaldehyde, white spirit, lead and its compounds, xylene, ammonia, and chromium trioxide (the hazard category 3.2). In addition, painters are exposed to physical overloads (the hazard category 3.1) and noise (the hazard category 3.1).

Therefore, elevated noise and local vibration that are higher than their MPLs, high physical overloads, and elevated levels of highly toxic chemicals in workplace air able to create chemical health risks for workers are the leading adverse factors that make working conditions at the analyzed workplaces harmful for workers' health. Peculiar features of work processes at the analyzed productions create specific working conditions at workplaces of these basic occupational groups. These conditions involve combined exposure to several harmful occupational factors at most analyzed workplaces.

Workers' health was examined in 2018–2019 in conformity with the Order by the RF Ministry of Health and Social Development issued on April 12, 2011 No. 302n[2] by performing a periodical medical examination (PME). We examined 583 workers from the basic occupational groups: MAP mechanics (173 people), repairmen (99 people), turners (130 people), crane operators (67 people), conveyor operators (39 people), painters and laboratory assistants responsible for chemical analysis (75 people). The reference group included 150 production workers who were not exposed to harmful occupational factors at their workspaces. All the examined workers were comparable in terms of work records and age. The examination involved questioning based on a standard questionnaire to estimate a person's health relying on their complaints and to establish non-modifiable and modifiable factors of cardiovascular risks (as per the SCORE scale). In addition, all the workers were examined by a cardiologist.

We did not identify any significant differences as per work records or age between the analyzed occupational groups.

We determined a relative risk (RR) and its 95 % confidence interval (CI). Occupational causation of CSDs was estimated depending on relative risk (RR) levels and the etiological fraction (EF). All the calculations were performed using Microsoft Excel.

[2] Ob utverzhdenii perechnei vrednykh i (ili) opasnykh proizvodstvennykh faktorov i rabot, pri vypolnenii kotorykh provodyatsya obyazatel'nye predvaritel'nye i periodicheskie meditsinskie osmotry (obsledovaniya), i Poryadka provedeniya obyazatel'nykh predvaritel'nykh i periodicheskikh meditsinskikh osmotrov (obsledovanii) rabotnikov, zanyatykh na tyazhelykh rabotakh i na rabotakh s vrednymi i (ili) opasnymi usloviyami truda: prikaz Minzdravsotsrazvitiya RF ot 12.04.2011 № 302n [On Approval of the lists of harmful and (or) hazardous occupational factors or works that require mandatory preliminary and periodical medical examinations (check-ups), and the Order of accomplishing mandatory preliminary and periodical medical examinations (check-ups) of workers performing hard works or working under harmful and (or) hazardous working conditions: the Order by the RF Ministry of Health and Social Development dated April 12, 2011 No. 302n] (became invalid on April 01, 2021 based on the joint Order by the RF Ministry of Labor and RF Ministry of Health issued on December 31, 2020 No. 988n/1420n). *KODEKS: electronic fund for legal and reference documentation.* Available at: https://docs.cntd.ru/document/902275195 (December 24, 2022) (in Russian).

Table 2

CSDs prevalence in workers with basic occupations of the automotive industry (cases/100)

Occupation	EH	CVDs	IHD	Total
Stampers (*n* = 61)	24.6	6.5	6.5	37.7
MPA mechanics (*n* = 173)	33.1	6.4	2.5	41.6
Repairmen (*n* = 99)	43.4	7.0	10.1	60.6
Turners (*n* = 130)	21.5	4.6	1.5	27.6
Crane operators (*n* = 67)	16.4	11.9	0	28.8
Conveyor operators (*n* = 39)	10.3	5.1	0	15.3
Painters, laboratory assistants responsible for chemical analysis (*n* = 75)	31.5	5.3	4.0	41.7
Total (644)	28.2	6.5	3.6	37.7
The reference group (*n* = 150)	13.1	1.3	3.3	18.0

Results and discussion. We analyzed generalized qualitative and quantitative parameters of the examined occupational factors. As a result, we established that, according to the final assessment of working conditions, they corresponded to the hazard category 3.1 or 3.2 for the examined workers employed in the automotive industry. Exposure to occupational risk factors typical for car-making production can promote a growth in incidence of non-communicable, occupational and work-related diseases among workers.

Clinical and laboratory tests performed within the periodical medical examination revealed that diseases of the circulatory system were diagnosed in more than one third of the examined workers (37.7 %), primarily, essential hypertension (EH) (28.2 %), cerebrovascular diseases (CVDs) (6.5 %) and ischemic heart disease (IHD), (3.6 %) (Table 2). Such diseases of the circulatory system as lower limb varicose veins, atherosclerosis of the lower limb arteries or the aorta were diagnosed in singleton cases.

High risks of effects produced by occupational factors on the development of essential hypertension were identified for workers from basically all the analyzed occupational groups: stampers (RR = 1.84; CI: 1.01–3.36), MAP mechanics (RR = 2.47; CI: 1.56–3.90), repairmen (RR = 3.26; CI: 2.04–5.19), turners (RR = 1.23; CI: 0.63–2.43), and painters (RR = 2.40; CI: 1.42–4.06). The highest relative risk was identified for painters and laboratory assistants responsible the chemical analysis; repairmen and MAP mechanics followed. The examination established that, according to medical records, essential hypertension was diagnosed in the workers with the basic analyzed occupations at a considerably younger age (38–49 years) than in the workers from the reference group where the disease was more frequently diagnosed at an age of 50–62 years. We can assume that exposure to such harmful occupational factors as intense noise higher than the MPL and work hardness has its negative influence on EH occurrence and progression. We should mention that the SAWC performed for the analyzed workplaces did not estimate work intensity in any of the analyzed occupational groups and this fact raises certain concerns.

IHD was established in 3.6 % of the examined workers, basically, in the senior age group (50–59 years and older); the disease was diagnosed in singleton cases in the age group of 40–49 years. The analysis of IHD nosologic forms revealed that workers predominantly suffered from angina of effort (87.3 %); ischemic arrhythmia and post-infarction cardiosclerosis were quite rare (3.8 % and 8.9 % accordingly).

Developing IHD against long-term essential hypertension (not shorter than 7–10 years) was established in 17.8 % of all the workers with CSDs, mostly, in people older than 55 years. Complicated IHD was established in 0.7 % of the workers from the basic occupational groups and was represented by acute cardiovascular states (myocardial infarction and acute cerebrovascular accidents in medical case history). This was the reason for un-

scheduled capability assessment and the necessity to move some workers to another workplace without any exposure to harmful and hazardous occupational factors.

Cerebrovascular diseases were mostly diagnosed in workers older than 40 years and were represented by chronic vascular pathologies such as chronic cerebral ischemia at its initial stage. The pathology became more frequent in older workers with longer work records at car-making production.

Our assessment of the total cardiovascular risks using the SCORE system established higher shares of people with high and extremely high risks among painters, laboratory assistants responsible for chemical analysis and repairmen against the reference group ($p < 0.05$) (Table 3).

Work records longer than 8–10 years involve greater frequency of high and extremely high risks and lower frequency of moderate risks of unavoidable cardiovascular disasters. It is noteworthy that it was workers from the aforementioned occupational groups who worked under the most harmful working conditions (the hazard category 3.1–3.2) according to the hygienic criteria.

Assessment of posterior occupational risk should rely on such basic indicators as prevalence of cardiovascular diseases among workers with different occupations typical for the analyzed production as well as the level of their occupational causation identified by assessing relative risks (RR) and the etiological fraction of occupational risks in occurrence of cardiovascular pathology. It is also important to examine an attributive or additional risk (AR) of CSDs development (Table 4).

Table 3

Assessment of the total cardiovascular risk for workers employed in the automotive industry as per the SCORE scale ($p \pm m$)

Occupation	Total cardiovascular risk as per SCORE scale			
	low	moderate	high	extremely high
Stampers ($n = 61$)	11.7	45.7	28.7	13.9
MAP mechanics ($n = 173$)	8.9	50.2	30.2	10.7
Repairmen ($n = 99$)	9.7	44.4	31.8	14.1*
Turners ($n = 130$)	10.7	53.9	22.3	13.1
Crane operators ($n = 67$)	13.9	54.7	21.2	10.2
Conveyor operators ($n = 39$)	12.5	54.2	21.3	12.0
Painters, laboratory assistants responsible for chemical analysis ($n = 75$)	10.0	45.7	34.2*	10.1
The reference group ($n = 150$)	14.2	56.3	22.0	9.5

N o t e: *$p < 0.01$, the difference from the reference group is statistically authentic.

Table 4

Assessment of occupational causation and additional risks of CSDs in workers employed in the automotive industry

Occupation	RR	EF	AR, 100 people	Level of causation
Stamper ($n = 61$)	1.7	41.9	13.3	medium
MAP mechanics ($n = 173$)	2.3	56.5	23.3	high
Repairmen ($n = 99$)	3.4	70.5	42.6	high
Turners ($n = 130$)	1.5	33.3	9.6	medium
Crane operators ($n = 67$)	1.6	37.5	10.8	medium
Conveyor operators ($n = 39$)	0.7	-	-	absent
Painters, laboratory assistants responsible for chemical analysis ($n = 75$)	1.9	47.3	16.9	medium

N o t e: RR is relative risk, EF is etiological fraction, AR is attributive risk.

Additional (attributive) risks (AR) ranged between 9.6 (turners) and 42.6 (repairmen) new cases of cardiovascular diseases per 100 workers against the CSDs prevalence in the reference group.

The highest occupational causation of CSDs was identified for repairmen (the hazard category of working conditions is 3.1) (RR = 3.4; EF = 70.5 %) and MAP mechanics (the hazard category is 3.2) (RR = 2.3; EF = 56.5 %).

Medium occupational causation of CSDs was identified for stampers (the hazard category is 3.2) (RR = 1.7; EF = 41.9 %), painters and laboratory assistants responsible for chemical analysis (the hazard category is 3.2) (RR = 1.9; EF = 47.3 %), crane operators and turners (the hazard category is 3.1) (RR = 1.6; EF = 37.5 % and RR = 1.5; EF = 33.3 % accordingly).

We did not establish any occupational causation of CSDs for conveyor operators.

Diseases of the circulatory system occupy the leading place among reasons for extreme mortality and disability of working age people as per their prevalence and severity of their complications [20, 21]. Such lifestyle factors as consumption of fatty and refined foods, harmful alcohol use, tobacco smoking and use of electronic cigarettes, as well as low physical activity, hypertriglyceridemia and obesity are the major causes of the cardiovascular pandemic [20, 22]. At the same time, a risk of CSDs as an occupational pathology in workers who work under harmful and hazardous conditions occurs not only due to modifiable or non-modifiable lifestyle factors. It is caused by working under exposure to harmful occupational factors that are potentially able to induce the development of cardiovascular pathology and prolong its clinical course, just as we reported in our study [22–24].

Our research at a large car-making production has revealed that harmful working conditions are created by a set of occupational factors and factors related to work process such as noise, vibration, chemicals in workplace air, and physical overloads. Their intensity varies between permissible (the category 2.0) to harmful levels (the hazard category (3.1–3.2). Medical examination revealed CSDs in almost 40 % of the examined production workers; these diseases were detected among repairmen, MAP mechanics, stampers and painters authentically more frequently than in the reference group. Essential hypertension was diagnosed in practically each third worker (29.8 %); cerebrovascular diseases and ischemic heart disease were not so frequent, 5.6 % and 4.9 % accordingly. It is noteworthy that the risk of CSDs development was higher for workers with the analyzed occupations typical for the automotive industry at a younger age than for people who were not exposed to harmful occupational factors at their workplaces. In addition, CSDs often had complications such as acute cardiovascular events in workers with the basic occupations of the automotive industry. The risk assessment as per the SCORE scale identified high and extremely high risks of fatal cardiovascular complications for 32.7 % workers with the basic production occupations and 18.1 % had a medium risk.

Attributive risks of CSDs ranged between 9.6 (turners) and 42.6 (repairmen) new cases per 100 people. Our assessment of CSDs occupational causation established that the level of this causation was high for repairmen and MPA mechanics; it was medium for stampers, painters, laboratory assistants, crane operators and turners.

Therefore, the working environment at enterprises operating in the automotive industry is a significant risk factor able to cause CSDs occurrence and progression in workers. This is in line with findings reported by several authors who examined CSDs prevalence and clinical course in workers employed in various sub-branches of civil engineering. Production conditions create combined exposure to a set of harmful occupational factors, and not to just one isolated occupational factor, for a worker. As work records grow longer, chronic non-communicable pathology, CSDs included, occurs and progresses in workers under exposure to harmful occupational, social and communal factors. This leads to growing

numbers of applications for medical aid [4, 25, 26]. Some authors provide convincing evidence that exposure to intense noise and vibration together with non-occupational risk factors leads to growing incidence of cardiovascular diseases. This requires effective primary prevention aimed at reducing mortality among workers [27–29].

Conclusions. The analyzed set of harmful occupational factors is a risk factor able to promote CSDs development in workers employed in the automotive industry. These harmful occupational factors include intense occupational noise, vibration, and work hardness. The assessment of the total cardiovascular risk as per the SCORE scale revealed that a share of people with high and extremely high risks was higher than in the reference group among painters, laboratory assistants responsible for chemical analysis and repairmen. The attributive risk of new CSDs cases ranged between 9.6 and 42.6. Harmful working conditions in the automotive industry (the hazard category 3.1–3.2) are among reasons for the development of occupational CSDs in workers, the level of occupational causation varying from medium to high. Since the automotive industry is developing quite intensively, this requires solid substantiation provided for organizational and prevention activities aimed at protecting workers' health.

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