

## Prediction of temporary disability due to of circulatory system diseases in housing and communal services employees

G.Ya. Bendyuk<sup>1</sup>, N.K. Grishina<sup>2</sup>, M.A. Dokhov<sup>1,3\*</sup>, A.A. Sidorov<sup>1</sup>

<sup>1</sup>Medical and Sanitary Unit of State Unitary Enterprise “Vodokanal of St. Petersburg”, Saint Petersburg, Russia;

<sup>2</sup>N.A. Semashko National Research Institute of Public Health, Moscow, Russia;

<sup>3</sup>Saint Petersburg State Pediatric Medical University, Saint Petersburg, Russia

### Abstract

**Aim.** To develop a prognostic model of incidence of temporary (short-term) disability due to cardiovascular diseases in a housing and communal services employees using the example of the State Unitary Enterprise (SUE) “Vodokanal of St. Petersburg”.

**Methods.** The study included 4634 people, observed in the departmental outpatient clinic of SUE “Vodokanal of St. Petersburg”, between 2015 and 2017 years. We calculated extensive indicators determining the disease patterns and intensive indicators characterizing the prevalence of the pathological process in the study of morbidity by the findings of periodic health examinations and incidence of short-term disability. The incidence of short-term disability was predicted by using the method of sequential analysis A. Wald modified by E.V. Gubler and the neural network.

**Results.** We found that based on the operational and statistical data of the medical and sanitary unit, using a neural network, relying on linear and nonlinear dependence of comorbidity, in particular, respiratory diseases, it is possible to predict (in 92.4% of cases) the incidence of temporary disability due to cardiovascular diseases in employees of the housing and communal services SUE “Vodokanal of St. Petersburg”. The high sensitivity (97.7%) and specificity (90.7%) of the method allows it to predict the need for treatment and prophylaxis measures in the contingent attached to the medical and sanitary unit.

**Conclusion.** The developed model allows to determine the main directions of preventive work to reduce the incidence of circulatory system diseases with temporary disability: prevention of high blood pressure and respiratory diseases.

**Keywords:** disease prediction, neural network, temporary (short-term) disability, cardiovascular system.

**For citation:** Bendyuk G.Ya., Grishina N.K., Dokhov M.A., Sidorov A.A. Prediction of temporary disability due to of circulatory system diseases in housing and communal services employees. *Kazan Medical Journal*. 2020; 101 (5): 734–739. DOI: 10.17816/KMJ2020-734.

**Background.** Nowadays, cardiovascular diseases (CVD) remain the leading cause of disability and mortality. Recent studies have shown that the combination of DCS and other organ and system diseases often leads to socioeconomic losses [1–5]. More and more researchers believe that the greatest effect of preventive measures can be achieved among organized groups: employees of institutions and industrial enterprises [6, 7].

Indicators of morbidity with a temporary disability (TD) reflect the impact of the entire complex of adverse factors on the health of workers, which

can be used in the evaluation of the effectiveness of the applied and treatment technologies [8–10]. In addition, the forecast of the disease development assessment allows a more effective use of health-care resources by specifying the necessary amount of treatment and prevention measures [11, 12].

**Aim.** This study aims to develop a predictive model on the occurrence of TD associated with cardiovascular system diseases of employees of housing and utility service plants, for example, state unitary enterprise (SUP) Vodokanal of St. Petersburg.

**Table 1.** Concomitant diseases and pathological conditions discovered during periodic medical examinations and associated with the incidence of a temporary disability by cardiovascular diseases

Diseases and pathological conditions discovered during periodic medical examinations	Cardiovascular diseases				RR	EF, %
	Availability ITD, persons		The lack ITD, persons			
	n	%	n	%		
Pathological conditions characterized by a high blood pressure	16*	10.7	53	1.2	9.1 (5.3–15.5)	89.0
Coronary heart disease	5*	3.4	19	0.4	7.9 (3–20.9)	87.4
Respiratory system diseases	41*	27.5	662	14.7	1.9 (1.4–2.4)	46.3
Diseases of the choroid and retina	6*	4.0	37	0.8	4.9 (2.1–11.4)	79.5
Cerebrovascular disease	28*	18.8	304	6.8	2.8 (2.0–3.9)	63.9
Diseases characterized by a high blood pressure	106*	71.1	1239	27.6	2.6 (2.3–2.9)	61.2

Note: \*The significance level of the  $\chi^2$  criterion is less than 0.05; ITD, incidence with a temporary disability.

**Materials and methods.** Based on the departmental outpatient clinic, the medical and sanitary aspects of SUP Vodokanal of St. Petersburg, a continuous retrospective monitoring of diseases and pathological lesions registered in 2015–2017 for 4,634 people (57.5%, men; 42.5%, women) who were employees of the enterprise, were performed. The average age was  $42.1 \pm 5.0$  years (men,  $43.1 \pm 3.3$  years; women,  $40.8 \pm 4.2$  years;  $p = 0.39$ ). In the study of morbidity based on the data of periodic medical examinations and morbidity with TD, extensive indicators were calculated, indicating the structure of morbidity and intensive indicators that characterize the prevalence of the pathological process (the number of diagnoses per 100 examined).

The statistical estimation of differences for absolute values and fractions was made using criterion  $\chi^2$  and Fisher's angular transformation, respectively.  $p < 0.05$  rejects the null hypothesis. The confidence interval with 95% reliability was calculated by approximating the Poisson distribution in  $\chi^2$  [13].

To predict the incidence of TD, we used the sequential analysis by A. Wald modified by E.V. Gubler, according to which two groups were distinguished: training (65.6%, 3040 people) and testing (34.4%, 1594 people) [14]. Nonlinear links were accounted for using a neural network model, forming three groups, two of them directly involved in the training (the training group, 50.6% (2345 people), and the control group, 24.0% (1112 people)), and the testing group, 25.4% (1177 people) [15]. We used a combined global optimization method to create a neural network, which consisted in applying conjugate gradient methods, a random search, and inertial and genetic algorithms at various iterations.

**Results and discussion.** In the structure of pathological lesions discovered according to peri-

odic medical examinations, cardiovascular diseases, as indicated in our earlier work [16], are in the second rank, 25.7% (25.3–26.1%), following the diseases of the eye and its appendage, 27.1% (26.7–27.5%). Among men, pathological conditions of the circulatory system were registered almost twice more often than among women: 75.0 (73.6–76.4) per 100 examined men versus 45.4 (44.0–46.9) per 100 examined women ( $p = 0.003$ ). The first place was diseases characterized by a high blood pressure (69.9%); second (15.0%), cerebrovascular diseases; and third (6.9%), coronary heart disease.

In the structure of morbidity with TD, the proportion of morbidity caused by a circulatory pathology is not dependent on gender ( $p = 0.3$ ), amounting to 9.8% (10.9% among men and 8.1% among women). The first place (43.6%; 42.8% for men and 45.1% for women) was diseases characterized by a high blood pressure; second (17.8%; 14.7% for men and 24.1% for women), cerebrovascular diseases; and third (17.3%; 19.5% for men and 12.8% for women), coronary heart disease.

The indicators of morbidity with TD and pathological lesions established in the course of the study qualitatively corresponded to the estimates of the health status of employees identified by researchers in other sectors of the national economy [17, 18].

When predicting the occurrence of a case of DEN in connection with CVD, at the first stage, those of concomitant diseases and pathological conditions were identified, the presence of which was statistically significant in cardiovascular system diseases. Table 1 shows the frequency of concomitant CVD with TD and pathological conditions.

The most common concomitant pathology of CVD with TD was the presence of a high blood pressure (71.1% among patients with CVD versus 27.6% among well patients). The etiology that cha-

**Table 2.** Diagnostic coefficients for predicting the occurrence of a case of circulatory disease with a TD (the fragment of the diagnostic table)

Kullback coefficient R	Questionnaire questions	Diagnostic coefficients
0,9	Whether pathological conditions of the circulatory system were established based on the medical examination results in 2017: (1) yes; (2) no	(1) 1.8; (2) -2.3
0,9	Whether pathological conditions characterized by a high blood pressure were established based on the medical examination results in 2017: (1) yes; (2) no	(1) 2.1; (2) -2.0
0,6	Whether pathological conditions were established based on the medical examination results in 2017: (1) yes; (2) no	(1) 0.8; (2) -3.0
0,5	Age, years: (1) up to 25; (2) 25-29; (3) 30-34; (4) 35-39; (5) 40-44; (6) 45-49; (7) 50-54; (8) $\geq 55$	(1) 4.7; (2) -1.5; (3) 0.7; (4) -0.6; (5) 1.0; (6) -0.5; (7) 1.6; (8) -0.8

racterizes the contribution of a high blood pressure (if it is presented) in the occurrence of cases with TD was 61.2%. Among the diseases leading to TD, the most common were respiratory diseases (27.5% among patients with TD versus 14.7% among well patients), the etiology of which was 46.3%.

In predicting CVD with TD, the entire study population (4,634 people) was divided into two groups: training, 65.6% (3,040 people), and testing, 34.6% (1,594 people). The informative value of the features was evaluated using the Kullback coefficient, with their significance being evaluated using the  $\chi^2$  criterion (those with  $p < 0.05$  were chosen).

Table 2 presents the diagnostic coefficients for the prediction of the occurrence of a case of circulatory disease with TD (at R not less than 0.3), which form the basis of the diagnostic table.

The most informative signs that allow the prediction of CVD with TD cases in 2017 were the following: established pathological conditions of the circulatory system during the periodic medical examination and pathological conditions characterized by a high blood pressure ( $R = 0.9$ ), the presence of pathological conditions discovered during the periodic medical examination ( $R = 0.6$ ), and the age group ( $R = 0.5$ ).

Summing up the diagnostic coefficients, the resulting diagnostic coefficient was obtained. A positive value predicts the presence of CVD with TD, while a negative value predicts the absence. The resulting decision rule was applied to the test group, showing the correct result in 74.6% of cases (sensitivity, 77.6%; specificity, 74.5%).

The peculiarity of the constructed model of A. Wald in the modification of E.V. Gubler is, first, the assumption of the linearity of the interaction of factors within the model and, secondly, the loss of some information due to the transformation of the data included in the model into a nominative scale,

which could reduce the accuracy of the forecast. Thus, to eliminate these shortcomings, a neural network model was chosen, and the input parameters used earlier in the A. Wald model were used for its construction and training.

The neural network structure included an input layer of 18 neurons, a hidden layer of 23 neurons, and an output layer of 1 neuron. The neural network was trained using the methods of an error back propagation and conjugate gradients, forming three groups from the total population, two of which directly participated in the training: the training group was 50.6% (2345 people), the control group 24.0% (1112 people), and the testing group 25.4% (1177 people). The correct result in the training group was 90.4%, control 92.4%, and testing 94.2%.

The results of testing the neural network in the testing group showed a sensitivity of 97.7% and a specificity of 90.7%. That is, when predicting the occurrence of cardiovascular system diseases with TD during the year for 1177 people, the cases were correctly predicted for 42 people, with a false-negative prognosis for 1 person. Moreover, a false-positive prognosis was made for 106 patients.

The sensitivity of a variable was defined as the ratio of neural network errors in a test group without a factorial feature of the interest to network errors and with a factorial feature of the interest: the greater the sensitivity, the greater the value of the predictor under the study and the smaller the prediction error of the neural network.

The most informative factor (sensitivity, 24.6) was diseases with a respiratory TD that occurred in the year preceding the registration of diseases with circulatory TD, predicting TD using a neural network. The second (sensitivity, 6,8) was determinate  $\beta$  during the periodic medical examination of the pathological lesions of the circulatory sys-

tem and pathological conditions characterized by a high blood pressure. The nonlinear link between respiratory diseases and the cardiovascular system revealed using a neural network corresponds to modern concepts of comorbidity as a systemic lesion that requires large health resources for treatment and prevention measures [19,20].

As a result of the study, the linear model of sequential analysis of Wald in the modification of E.V. Gubler based on the data of operational statistical accounting of the medical and sanitary aspects was found to allow the correct prediction of cases with TD CVD in 74.6% of cases. At the same time, taking into account nonlinear dependencies of a comorbid incidence, in particular respiratory diseases, using neural networks increases the accuracy of the forecast to 92.4%. A high sensitivity (97.7%) and specificity (90.7%) make it possible to use the resulting neural network to predict the need for medical and preventive measures of CVD attached to the medical and sanitary aspects of the contingent. In the future, the use of the obtained model will allow us to reveal quantitative patterns and conduct a cost-effect analysis when choosing a model for TD prevention.

### CONCLUSION

The developed model allowed us to determine the main directions of a preventive work to reduce the incidence of cardiovascular diseases with a temporary disability: the prevention of a high blood pressure and respiratory diseases.

**Author contributions.** G.Y.B. и M.A.D. were responsible for the research concept and design and A.A.S. for collecting and analyzing the results; N.K.G. was the head of the study.

**Funding.** The study had no external funding.

**Conflict of interest.** The authors declare no conflict of interest.

### REFERENCES

- Belyalov F.I. Internal diseases and comorbidity. *Vestnik sovremennoi klinicheskoi mediciny*. 2010; 3 (2): 44–47. (In Russ.)
- Samorodskaya I.V., Nikiforova M.A. Terminology and methods of assessment of influence of comorbidity on prognosis and outcomes of treatment. *The bulletin of Bakoulev center cardiovascular diseases*. 2013; 14 (4): 18–26. (In Russ.)
- Efros L.A., Naumova O.A., Zhdanova E.A., Andrienko S.V. Clinical aspects and approaches to expressiveness assessment of comorbidity of patients with acute coronary syndrome. *Ural Medical Journal*. 2018; (10): 81–89. (In Russ.) DOI: 10.25694/URMJ.2018.10.26.
- Boytsov S.A., Deev A.D., Shalnova S.A. Mortality and risk factors for non-communicable diseases in Russia: Specific features, trends, and prognosis. *Therapeutic archive*. 2017; (1): 5–14. (In Russ.) DOI: 10.17116/terarkh20178915-13.
- Boytsov S.A., Shalnova S.A., Deev A.D. The epidemiological situation as a factor determining the strategy for reducing mortality in the Russian Federation. *Therapeutic archive*. 2020; (1): 4–9. (In Russ.) DOI: 10.26442/00403660.2020.01.000510.
- Rakitsky V.N., Lipatova L.V., Izmaylova O.A. The prevention of cardio-vascular diseases in workers of enterprises of mining industry. *Zdravookhraneniye Rossiyskoy Federatsii*. 2016; (1): 10–12. (In Russ.) DOI: 10.18821/0044-197X-2016-60-1-10-12.
- Karimova L.K., Gimaeva Z.F., Galimova R.R. Assessment of cardiovascular risk in workers in petrochemical industries and development of a cardiovascular disease prevention program. *Hygiene and sanitation*. 2019; 98 (9): 978–983. (In Russ.) DOI: 10.18821/0016-9900-2019-98-9-978-983.
- Averyanova T.A., Trufanova N.L., Poteryaeva E.L. Estimation of efficiency of technologies for prophylaxis and sanitation of medical workers in large medical organization. *Journal of Siberian Medical Sciences*. 2012; 5: 75–79. (In Russ.)
- Pyrikova N.V., Osipova I.V., Kontsevaya A.V. et al. Clinical and economic efficacy of primary prediction organizational model for cardiovascular diseases in railway system workers. *Russian Journal of Cardiology*. 2014; (6): 12–18. (In Russ.) DOI: 10.15829/1560-4071-2014-6-12-18.
- Suvorova E.I., Shalnova S.A., Kontsevaya A.V. et al. Association of risk factors for non-communicable diseases with health care resources utilization and temporary disability according to data of population study in Russian Federation. *Rational Pharmacotherapy in Cardiology*. 2018; 14: 70–76. (In Russ.) DOI: 10.20996/1819-6446-2018-14-1-70-76.
- Pyrikova N.V., Kontsevaya A.V., Osipova I.V. Clinical and economic analysis of the implementation of primary prevention of cardiovascular disease in an organized team. *Bulletin of medical science*. 2018; (4): 60–66. (In Russ.)
- Belyalov F.I. Prediction of diseases using scales. *Kompleksnyye problemy serdechno-sosudistyyh zabolevaniy*. 2018; 7 (1): 84–93. (In Russ.) DOI: 10.17802/2306-1278-2018-7-1-84-93.
- Petri A., Sabin K. *Naglyadnaya meditsinskaya statistika*. (Visual medical statistics.) M.: GEOTAR-Media. 2015; 216 p. (In Russ.)
- Gubler E.V. *Informatika v patologii, klinicheskoy meditsine i pediatrii*. (Computer science in pathology, clinical medicine and pediatrics.) Leningrad: Medicine. 1990; 176 p. (In Russ.)
- Galushkin A.I. *Neyronnye seti: osnovy teorii*. (Neural networks: the basics of theory.) M.: Hotline — Telecom. 2017; 496 p. (In Russ.)
- Bendyuk G.Ya., Dohov M.A., Sidorov A.A. Analysis of pathologies among workers of a large enterprise of housing and communal services based on the results of periodic medical examinations. *Kazan Medical Journal*. 2019; (4): 695–700. (In Russ.) DOI: 10.17816/KMJ2019-695.
- Zakharova R.R., Kalimullina G.N., Romanov V.S. Working conditions and health status of oil refining workers. *Occupational medicine and human ecology*. 2015; (4): 120–122. (In Russ.)
- Bespalova A.V., Kononenko T.V. Trends in morbidity with temporary disability of railway workers working at the st. Fevral'sk. *Vestnik obshchestvennogo zdravookhraneniya Dal'nego Vostoka Rossii*. 2017; (4): 5–14. (In Russ.)
- Vretkin A.L., Skotnikov A.S. Comorbidity. *Lechatschiy vrach*. 2013; (8): 78–81. (In Russ.)
- Naumova L.A., Osipova O.N. Comorbidity: mechanisms of pathogenesis, clinical significance. *Modern problems of science and education*. 2016; (5): 105–119. (In Russ.)