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Research article

LIFE EXPECTANCY AT BIRTH FOR THE RF POPULATION: PREDICTION BASED ON MODELING INFLUENCE EXERTED BY A SET OF SOCIO-HYGIENIC DETERMINANTS ON AGE-SPECIFIC MORTALITY RATES EXEMPLIFIED BY DISEASES OF THE CIRCULATORY SYSTEM

M.V. Glukhikh, S.V. Kleyn, D.A. Kiryanov, M.R. Kamaltdinov

Federal Scientific Center for Medical and Preventive Health Risk Management Technologies, 82 Monastyrskaya Str., Perm, 614045, Russian Federation

The article dwells on cause-effect relations between certain socio-hygienic factors and age-specific mortality rates due to cardiovascular diseases. New research trends in hygiene, a multidisciplinary approach to studies in the field and the current state policy make the present work topical.

Our methodical approach to predicting probable age-specific mortality rates due to cardiovascular diseases relied on applying artificial neural networks. We analyzed a set of indicators that described the public healthcare system, sanitary-epidemiological welfare on a given territory, lifestyle, economic conditions, sociodemographic conditions, and primary incidence.

Overall, we obtained 18 models (as per 5-year age-specific periods) of a relationship between socio-hygienic determinants and mortality rates due to cardiovascular diseases. The determination coefficients fell within 0.01–0.75 range and the greatest explanatory power occurred when the age period "30 years and older" was analyzed. We detected comparability of variational series obtained for mortality due to cardiovascular diseases among the whole population and the determination coefficients of the created models. We established predictive estimates of life expectancy at birth (LEB) in case there were changes in the analyzed socio-hygienic determinants by 2024 set within a certain scenario. Thus, changes in the whole set of determinants would result in 514 days added to LEB; lifestyle-related indicators, 205 days; indicators describing sanitary-epidemiological welfare, 126 days; economic indicators, 102 days; sociodemographic indicators, 101 days; primary incidence rates, 40 days; indicators describing the public healthcare system, 19 days. Several determinants were shown to be the most significant for reducing mortality due to cardiovascular diseases among working age population and older age groups. They are indicators describing people's physical and motor activity, income levels, consumption of vegetables, education, and working conditions. Our research results are consistent with those obtained by other studies with their focus on establishing cause-effect relations between environmental factors and public health.

Keywords: *life expectancy at birth, mortality, cardiovascular diseases, socio-hygienic determinants, environmental factors, lifestyle factors, artificial neural networks, factor analysis, prediction of medical-demographic situation.*

The new profile of the academic specialty 3.2.1 "Hygiene" clarifies several research trends[1] in the sphere that concentrate on life expectancy and quality of life. They correspond to the national goals outlined in the strategy for the RF development for the period

Maxim V. Glukhikh – Junior Researcher at the Department for Systemic Procedures of Sanitary-Hygienic Analysis and Monitoring (e-mail: gluhih@fcrisk.ru; tel.: +7 (342) 237-18-04; ORCID: https://orcid.org/0000-0002-4755-8306).

Svetlana V. Kleyn – Professor of the Russian Academy of Sciences, Doctor of Medical Sciences, Associate Professor, Head of the Department for Systemic Procedures of Sanitary-Hygienic Analysis and Monitoring (e-mail: kleyn@fcrisk.ru; tel.: +7 (342) 237-18-04; ORCID: https://orcid.org/0000-0002-2534-5713).

Dmitrii A. Kiryanov – Candidate of Technical Sciences, Head of the Department for Mathematical Modeling of Systems and Processes; Associate Professor at the Department of Human Ecology and Life Safety (e-mail: kda@fcrisk.ru; tel.: +7 (342) 237-18-04; ORCID: https://orcid.org/0000-0002-5406-4961).

Marat R. Kamaltdinov – Candidate of Physical and Mathematical Sciences, Senior Researcher acting as the Head of the Situation Modeling and Expert and Analytical Management Techniques Laboratory (e-mail: kmr@fcrisk.ru; tel.: +7 (342) 237-18-04; ORCID: http://orcid.org/0000-0003-0969-9252).

[1] The Profiles of academic specialties within which academic degrees are granted, approved by the Order of the RF Ministry for Science and Higher Education; Nomenklatura nauchnykh spetsial'nostei, po kotorym prisuzhdayutsya uchenye stepeni (s izmeneniyami na 11 maya 2022 goda) (utv. prikazom Ministerstva nauki i vysshego obrazovaniya Rossiiskoi Federatsii ot 24 fevralya 2021 g. № 118) [The Nomenclature of academic specialties within which academic degrees are granted (last edited on May 11, 2022), approved by the Order of the RF Ministry for Science and Higher Education on February 24, 2021 No. 118]. *KODEKS: electronic fund for legal and reference documentation.* Available at: https://docs.cntd.ru/document/573956750 (August 15, 2022) (in Russian).

up to 2030, which is "preservation of population, people's health and wellbeing" [2]. A key component in many of them is identifying priority socio-hygienic factors that determine current mortality rates and life expectancy at birth (hereinafter LEB).

These trends can provide a certain ground for preventive medicine (hygiene) to be able to form a unified complex with such fields of knowledge as sociology, demography, informatics (mathematics) and some others. They can expand analytical potential of hygiene but still preserve its traditional connections with physiology, toxicology, and clinical medicine and its capacity to find solutions to purely hygienic tasks. Besides, these trends are extremely topical now [1, 2], given the current project activities[3] accomplished by the state and concerning multiple spheres in people's lives. The document[4] has initiated changes in the nomenclature of academic specialties. It highlights the necessity to make appropriate effort to perform research studies on the interdisciplinary basis since it corresponds to the context (essence) of contemporary science accepting the complexity of this world, its objects, phenomena and processes and relying on a complex interdisciplinary approach [3].

Over the last decades and at present as well, mortality due to cardiovascular diseases (CVD for short) has been and still is the basic reason for population decline. This mortality, together with that caused by malignant neoplasms, produces substantial effects on public health losses in most countries worldwide [4]. Elevated blood pressure is the leading risk factor[5] that causes CVD and diseases with elevated blood pressure being their typical clinical sign are considered socially significant in Russia[6].

Contemporary concepts regarding these diseases consider them multi-factorial ones with additive-polygenic inheritance with a threshold effect [5]. With this in mind, we face a rather difficult task, which is to establish exact contributions (the size of an effect) made by each component (genetic or environmental one) to CVD development. Still, it is a very promising research trend. Any results achieved within it will make it possible to develop the most effective strategies to minimize harm (risk) to public health caused by priority socially significant diseases[5].

LEB as an integral indicator of public health is relatively easy to calculate and use in assessments, including those of an existing medical and demographic situation within a specific population cohort at a fixed moment. Still, it has certain drawbacks that arise from its origin [6].

Artificial neural networks (hereinafter ANN) are quite an effective and precise analytical procedure that is applied to predict LEB levels and to analyze associations between this

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[2] O natsional'nykh tselyakh razvitiya Rossiiskoi Federatsii na period do 2030 goda: Ukaz Prezidenta ot 21.07.2020 № 474 [On the national goals of the Russian federation development for the period up to 2030: the Order by the RF President issued on July 21, 2020 No. 474]. *The official Internet portal for legal information*. Available at: http://publication.pravo.gov.ru/Document/View/0001202007210012 (August 15, 2022) (in Russian).

[3] Edinyi plan po dostizheniyu natsional'nykh tselei razvitiya Rossiiskoi Federatsii na period do 2024 goda i na planovyi period do 2030 goda; utv. rasporyazheniem Pravitel'stva RF ot 01.10.2021 № 2765-r (s izm. ot 24.12.2021) [The unified action plan on achieving national goals of the Russian Federation development for the period up to 2024 and plans for the period up to 2030; approved by the RF Government Order dated October 01, 2021 No. 2765-r (with alterations made on December 24, 2021)]. *KonsultantPlus*. Available at: http://www.consultant.ru/document/cons_doc_LAW_398015/ (August 15, 2022) (in Russian).

[4] Perechen' poruchenii po itogam sovmestnogo rasshirennogo zasedaniya prezidiuma Gossoveta i Soveta po nauke i obrazovaniyu. Pr-589, p.1zh-2 [The list of order following the joint extended meeting of the Presidium of the State Council and the Council on Science and Education. Pr-589, p.1zh-2]. *Prezident Rossii*. Available at: http://www.kremlin.ru/acts/assignments/orders/63083 (August 15, 2022) (in Russian).

[5] GBD cause and risk summaries. *The Lancet*. Available at: https://www.thelancet.com/gbd/summaries (August 15, 2022).

[6] Ob utverzhdenii perechnya sotsial'no znachimykh zabolevanii i perechnya zabolevanii, predstavlyayushchikh opasnost' dlya okruzhayushchikh: Postanovlenie Pravitel'stva RF ot 01.12.2004 № 715 (red. ot 31.01.2020) [On approval of the list of socially significant diseases and the list of diseases that pose hazard for people: The RF Government Order issued on December 01, 2004 No. 715 (last edited on January 31, 2020)]. *KonsultantPlus*. Available at: http://www.consultant.ru/document/cons_doc_LAW_50559/49feaa28d1c4631a481c33187e7a693e879fb051/ (August 15, 2022) (in Russian).

indicator and environmental and lifestyle-related factors [7–9].

Latest works that concentrate on identifying reasons for incidence and mortality among population, CVD-related included, rely on the concept of social determinants of health[7]. These determinants are multiple factors variable in their origin including education; food quality; quality of ambient air and drinking water; socioeconomic status; etc. [10–13].

The project activities that are being accomplished by the state now are aimed at reducing mortality, including that caused by CVD; achieving growth in LEB; mitigating negative effects produced by health risk factors (creating favorable conditions for people to improve their lifestyle); improving socioeconomic conditions. Many studies address risk factors for specific population groups; however, a population as a whole is extremely heterogeneous and exposed to multiple heterogeneous factors with different compatibility and influence. Therefore, it is quite relevant to make an effort to identify cause-effect relations between influence exerted by environmental factors and public health indicators, including those determined for age-specific groups, and to predict a future medical and demographic situation.

Our research goal was to estimate a potential growth in LEB for the RF population by 2024 based on modeling cause-effect relations between environmental and lifestyle-related factors (socio-hygienic determinants) and age-specific mortality rates due to cardiovascular diseases.

Materials and methods. The task was to examine common regularities of cause-effect relations between the analyzed socio-hygienic determinants and LEB in detail and to predict effects on the indicator considering managerial decisions being implemented at present. To achieve this, we modeled relationships between a set of socio-hygienic determinants and age-specific mortality rates due to cardiovascular diseases as a priority cause of death.

The present study relies on principles and methodical approaches to predicting LEB that were described in our previous article [14] and stipulated in the Methodical guidelines MR 2.1.10.0269–21[8]. In accordance with the MR 2.1.10.0269–21, we took a dataset that consisted of 148 indicators based on official state statistical data collected in 2010-2018 in all the RF regions. These data were taken from statistical reports and collections issued by Rospotrebnadzor, the RF Public Healthcare Ministry, and the Federal Statistic Service. The dataset covered the following: sanitary-epidemiological welfare (53 indicators), lifestyle (30 indicators), economy (14 indicators), public healthcare (9 indicators), a social and demographic situation (34 indicators), weather and climate (8 indicators). Besides, to solve tasks outlined within the present study, we added data collected in 2019. We also introduced ten new indicators describing a sanitary-epidemiological profile and 48 indicators describing primary incidence of basic nosologic categories as per age groups (children, working age population, and people older than working age). The ultimate dataset was made of 206 indicators that described the environment, lifestyle and incidence among the RF population over 2010–2019.

We applied an artificial neural network (ANN) to create models of the analyzed cause-effect relations. The ANN structure was based on a four-layer perceptron with two internal layers. A process for accomplishing predictive estimates of changes in mortality rates due to CVD was iterative in its essence since we examined 5-year intervals in age-specific mortality. Values of the analyzed indicators first un-

[7] According to the WHO, Social Determinants of Health (SDoH) are non-medical factors that influence health status.

[8] MR 2.1.10.0269-21. Opredelenie sotsial'no-gigienicheskikh determinant i prognoz potentsiala rosta ozhidaemoi prodolzhitel'nosti zhizni naseleniya Rossiiskoi Federatsii s uchetom regional'noi differentsiatsii (utv. Glavnym gosudarstvennym sanitarnym vrachom RF A.Yu. Popovoi 14 dekabrya 2021 g.) [MR 2.1.10.0269-21. Identification of socio-hygienic determinants and prediction of a potential growth in life expectancy at birth for the RF population, regional differentiation taken into account (approved by A.Yu Popova, the RF Chief Sanitary Inspector on December 14, 2021)]. Moscow, 2021, 113 p. (in Russian).

derwent factor transformation and then were fed into the ANN input layer; age-specific mortality rates were the ANN output layer. The ultimate predictive LEB level was calculated by using tables with ages of survival based on predicted and actual mortality rates. The calculations were based on scenario changes in socio-hygienic determinants. Therefore, predictive LEB levels were determined by effects produced by the analyzed socio-hygienic determinants on age-specific mortality rates due to CVD.

To obtain predictive estimates of age-specific mortality rates due to CVD, we applied an approach similar to that described in our previous work [14] and the Methodical guidelines MR 2.1.10.0269-21[8]. It involves accomplishing several consequent stages: creating a baseline and a target scenario of changes in 206 analyzed indicators; calculating model age-specific mortality rates due to CVD according to both scenarios; calculating predictive mortality rates as a difference between model mortality rates within the baseline and target scenario. Values of socio-hygienic indicators obtained for the last year (2019) in the analyzed period (2010–2019) were taken as a baseline scenario. The target scenario included indicator and target values of indicators fixed in the National and Federal projects ("Clean Air", "Clean Water", "Sport is the standard of living", "Public health improvement", etc.) as well as registered tendencies of changes in other indicators as per a logarithmic or a linear trend by 2024 depending on the determination coefficient (R^2). We applied the same scenario conditions to predict all age-specific mortality rates in this study. We used standard software packages for statistical analysis (Statistica 10, RStudio, MS Excel 2010) to create a data matrix, to perform statistical analysis of the data and to visualize the results.

Results and discussion. Having modeled effects produced by the analyzed socio-hygienic determinants on age-specific mortality rates due to CVD, we obtained 18 neural network models with the determination coefficient (R^2) falling within the range from 0.01 to 0.75 (Table 1).

Table 1

Determination coefficients (R^2) and correlation coefficients (r) of ANN models within the "socio-hygienic indicators – age-specific mortality rates due to CVD" system

Model No.	Age group of mortality due to CVD, years	Determination coefficient (R^2)	Pearson correlation coefficient (r)	Qualitative evaluation of correlation intensity *
15	70–74	0.75	0.87	High
11	50–54	0.71	0.84	High
13	60–64	0.70	0.84	High
14	65–69	0.69	0.83	High
12	55–59	0.69	0.83	High
17	80–84	0.69	0.83	High
16	75–79	0.60	0.77	High
7	30–34	0.60	0.77	High
10	45–49	0.56	0.75	High
18	85 and older	0.55	0.74	High
8	35–39	0.49	0.70	Notable
9	40–44	0.46	0.68	Notable
6	25–29	0.44	0.66	Notable
2	5–9	0.22	0.47	Moderate
5	20–24	0.20	0.45	Moderate
1	0–4	0.16	0.41	Moderate
4	15–19	0.03	0.18	Low
3	10–14	0.01	0.12	Low

N o t e : * qualitative evaluations of correlation intensity are given as per the Chaddock scale. Further analysis concentrates on age groups 30 years and older.

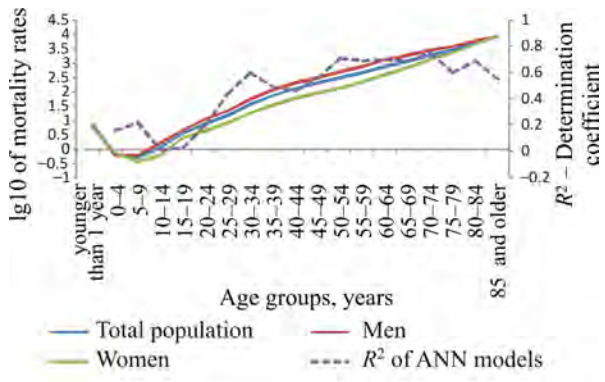

Figure 1. Age-specific mortality rates due to CVD in 2019 (per 100 thousand people in the relevant age group) with the model determination coefficients

We established that the determination coefficient had low values in models that described relations between the analyzed determinants and age-specific mortality rates within the range from 0 to 29 years ($R < 0.5$). The coefficient exceeded 0.5 starting from the age group "30 years and older", except the age groups 35–39 years and 40–44 years. At the next stages, the analysis covered only models created for age groups 30 years and older considering the determination coefficient values and qualitative evaluations of correlation intensities. They meant that the applied dataset had rather weak explanatory force in the models created for age groups younger than 30 years.

We analyzed how mortality rates due to CVD were distributed as per age groups. The analysis revealed that mortality due to this cause grew exponentially with age; this trend was more apparent for men than for women but sex-related differences smoothed over with age (Figure 1).

We comparatively analyzed the model determination coefficients and mortality rates. The analysis revealed that the determination coefficients in the models that described relations between socio-hygienic indicators and primary incidence rates and age-specific mortality rates due to CVD among the RF population were similar to actual distribution of mortality rates due to this cause as per age groups.

According to the target scenario of changes in the analyzed socio-hygienic determinants and without considering impacts exerted by COVID-related processes and the current socioeconomic conditions (economic sanctions), the ultimate LEB level should increase by 1.41 years (514 days) by 2024 solely due to changes in modified age-specific mortality rates due to CVD (Table 2).

Table 2

Comparative assessments of the results obtained by modeling a potential change in LEB (years / days) within scenarios of modifying influence exerted by the whole set of socio-hygienic determinants / specific groups of such determinants

A group of socio-economic determinants	"SHD – LEB" model*		18 "SHD – CVD – LEB" models**		A share of predictive values as per "SHD – CVD – LEB" models relative to "SHD – LEB", %
	Years	Days	Years	Days	
The whole set of determinants (all the analyzed SHD together with primary incidence rates)	–	–	1.41	514	–
The whole set of determinants (without primary incidence rates)	3.0	1095	1.3	473	43.3
Lifestyle-related indicators	1.26	461	0.56	205	44.4
Sanitary-epidemiological welfare on a given territory	0.58	212	0.34	126	58.6
Economic indicators	0.36	131	0.28	102	77.8
Socio-demographic indicators	0.54	196	0.28	101	51.8
Public healthcare system	0.19	70	0.05	19	26.3
Primary incidence	–	–	0.11	40	–

Note: * is the model showing LEB dependence on socio-hygienic determinants (SHD), which we described in our previous study [11]; ** is the set of models showing dependence of age-specific mortality rates on socio-hygienic determinants, which is analyzed in the present work with the following LEB calculation.

If we use scenarios without primary incidence in the models showing a relation between the analyzed factors and age-specific mortality rates due to CVD, then the ultimate potential growth in LEB amounts to 1.3 years (473 days). This equals 43.3 % of the effect on LEB obtained due to modeling a direct relation between socio-hygienic factors and LEB (Table 2). An actual contribution made by mortality due to CVD to the total mortality is comparable and amounts to approximately 47.7 %[9]. This means our estimates are quite correct.

Scenario modeling of changes in socio-hygienic factors that included age-specific mortality rates due to CVD discovered several most significant areas with substantial reserves for LEB growth that were not used properly. They were lifestyle-related indicators (205 days) and sanitary-epidemiological indicators (126 days).

We estimated a decline in age-specific mortality rates due to CVD within the analyzed scenarios and established that all the groups of the analyzed determinants had their peculiar effects regarding larger age groups, such as "from 30 to 59 years" and "60 years and older" (Figures 2 and 3).

We analyzed the results obtained for the larger age groups. The analysis showed that the aggregated modifying influence exerted by the analyzed determinants on mortality due to CVD was more apparent among middle-aged and older people of working age (30–59 years) than among those who were older than working age (60 years and older). A predicted decline in age-specific mortality rates would be equal to 24.8 % (within the range from 17.6 to 34.1 %) and 22.3 % (within the range from 12.8 to 30.2 %) accordingly (Figures 2 and 3). The

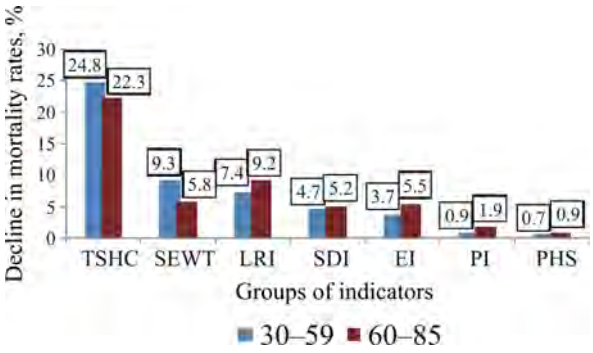

Figure 2. A percent of decline in age-specific mortality rates due to CVD among the whole RF population (average rates as per the age groups 30–59 years, 60 years and older) under scenario changes in the analyzed socio-hygienic determinants as per their conventional groups by 2024, (%): TSHC is the whole set of the determinants; SEWT is sanitary-epidemiological welfare of a given territory; LRI is lifestyle-related indicators; SDI is sociodemographic indicators; EI is economic indicators; PI is primary incidence; PHS is public healthcare system

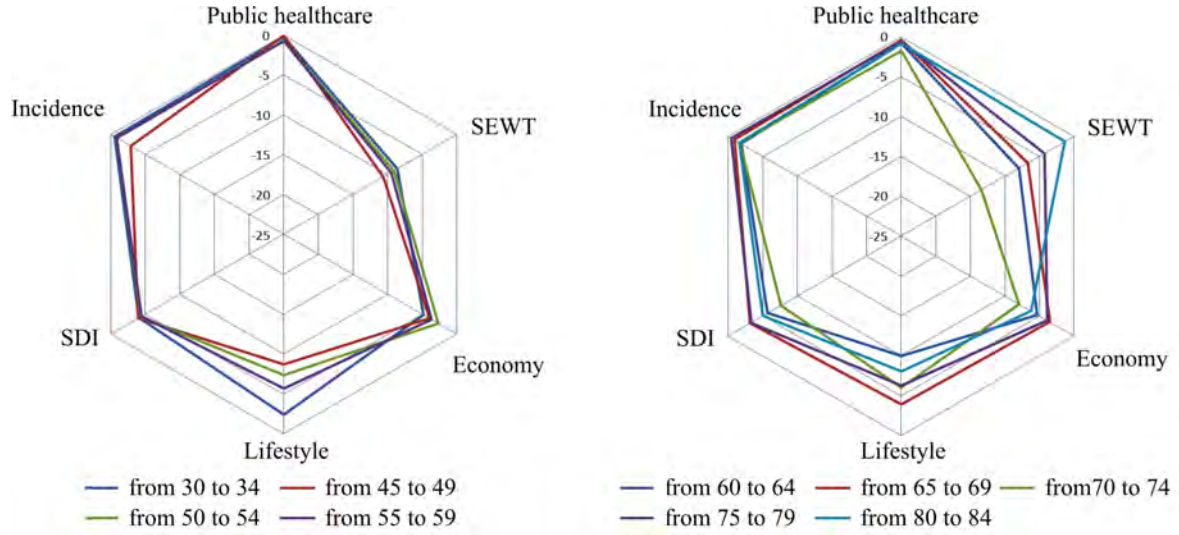

Figure 3. A decline in age-specific mortality rates due to CVD among the RF population as per groups of the determinants given their scenario changes by 2024, (%): SEWT is sanitary-epidemiological welfare on a given territory; SDI is socio-demographic indicators

[9] Actual mortality rates due to CVD accounted for 47.0 % in the total mortality in 2019.

discovered differences between the analyzed age groups were largely due to influence exerted by indicators of sanitary-epidemiological welfare on the age group "30–59 years". It was by 1.6 times higher in this age group than among older people (a decline in mortality rates equaled 9.3 and 5.8 % accordingly).

The group of indicators that characterized lifestyle also turned out to be significant for a predicted decline in mortality rates due to CVD. An averaged decline in the analyzed mortality rates amounted to 9.2 % in the age group "60 years and older" within the set scenario. It was by 1.24 times higher than in the age group "30–59 years". Changes in socio-demographic indicators and indicators of the public healthcare system had comparable capacities to facilitate a potential decline in age-specific mortality rates due to CVD under the set scenarios. This decline would reach 4.7 % and 0.7 % accordingly in the age group "30–59 years" and 5.2 % and 0.9 % in the age group "60 years and older". Primary incidence rates are both factors that result from impacts exerted by all the analyzed socio-hygienic determinants and the initial basis under modifying influence by the analyzed SHD (they describe the initial health status). Their role in a decline in age-specific mortality rates due to CVD was more apparent in the age group "60 years and older" (by 2.1 times higher) than among people aged 30–59 years under the set scenarios (Figure 2).

We analyzed isolated effects produced by specific socio-hygienic factors on age-specific mortality rates due to CVD and calculated potential LEB levels. This enabled us to determine priority determinants for the analyzed age groups (Table 3).

Physical activity is the most significant factor in the analyzed larger age groups (30–59 years and 60 years and older). In case the indicator reaches its target value 55.0 %[10], LEB grows by 21 and 106 days accordingly. We detected a significant effect produced by growing economic welfare of households in the analyzed age groups (growing consumer expenses provided additional 9 and 41 days; growing average incomes per capita, 4 and 22 days accordingly). We also established another significant factor with comparable priority. It characterized diets, namely, consumption of vegetables and melons growing by 34.0 % against the current levels up to the recommended standards[11]. This target achieved, effects produced on LEB would be positive in both larger age groups, resulting in its growth by 6 and 25 days accordingly. "A share of employed people with higher education" was important for both analyzed groups as it would facilitate LEB growth by 5 and 17 days accordingly if it increased by 11.9 % against its current level.

A decrease (from 34.0 to 83.0 %) in a share of workers exposed to harmful occupational factors was a priority in the age group "30–59 years". This concerns a decline in such exposures as work intensity (5 days), harmful microclimate at a workplace (3 days), dust and aerosols in workplace air (3 days), and electromagnetic fields at workplaces (3 days).

Several factors were established to have high priority in the age group "60 years and older". They include a rise by 11 % in shares of expenses on social policies within consolidated budgets (11 days); a decline by 23 % in ethanol consumption per capita (adult population) (8 days); a growth by 46.0 % in gross regional product (6 days); a decline by 7.0 % in primary incidence of diseases of the musculoskeletal system and connective tissue among people older than working age (4 days).

[10] A share of people who do sports or physical exercises. Federal'nyi proekt «Sport – norma zhizni» ["Sport is the standard of living" Federal project]; Pasport natsional'nogo proekta «Demografiya» (utv. prezidiumom Soveta pri Prezidente RF po strategicheskomu razvitiyu i natsional'nym proektam, protokol ot 24.12.2018 № 16) [The profile of the "Demography" National project (approved by the Presidium of the RF Presidential Council on strategic development and national projects, the meeting report issued on December 24, 2018 No. 16)]. *KonsultantPlus*. Available at: http://www.consultant.ru/document/cons_doc_LAW_317388/4e8c28415c3cabb0f45fa6ed843c85bd7dbee4b9/ (August 15, 2022) (in Russian).

[11] Ob utverzhdenii Rekomendatsii po ratsional'nym normam potrebleniya pishchevykh produktov, otvechayushchikh sovremennym trebovaniyam zdorovogo pitaniya: Prikaz Ministerstva zdravookhraneniya RF ot 19 avgusta 2016 g. № 614 [On approval of the Recommendations on rational consumption of foods that correspond to up-to-date standards of a healthy diet: The Order by the RF Public Healthcare Ministry dated August 19, 2016 No. 614]. *GARANT: information and legal portal*. Available at: https://www.garant.ru/products/ipo/prime/doc/71385784/ (August 15, 2022) (in Russian).

Table 3

Priority socio-hygienic factors that separately modify age-specific mortality rates due to CVD with calculated LEB levels as per larger age groups, days

30–59 years		60 and more years	
Socio-hygienic factor	Effect on LEB, days	Socio-hygienic factor	Effect on LEB, days
A share of people who do sports or physical exercises, %	21	A share of people who do sports or physical exercises, %	106
Consumer expenses per capita, rubles per month	9	Consumer expenses per capita, rubles per month	43
Consumption of basic foods in households (vegetables and melons), kg/year/consumer	6	Consumption of basic foods in households (vegetables and melons), kg/year/consumer	25
A share of employed people with higher education aged 15–72 years, %	5	Average incomes per capita, rubles per month	22
A specific weight of workers with working conditions at their workplaces not conforming to hygienic standards (work intensity), %	5	A share of employed people with higher education aged 15–72 years, %	17
Average incomes per capita, rubles per month	4	A share of expenses on social policies within consolidated budgets, %	11
A percent of soil samples not conforming to sanitary-hygienic requirements (microbiological indicators), %	3	Ethanol per capita (adult population)*, liters per capita	8
A share of workplaces at industrial enterprises not conforming to sanitary-hygienic requirements (microclimate at a workplace), %	3	A percent of soil samples not conforming to sanitary-hygienic requirements (microbiological indicators), %	6
A share of air samples with admixtures exceeding MPC at industrial enterprises (dust and aerosols at workplaces), %	3	Gross regional product per capita, rubles	6
A share of workplaces at industrial enterprises not conforming to sanitary-hygienic requirements (EMF at a workplace), %	3	Primary incidence of diseases of the musculoskeletal system and connective tissue among people older than working age, ‰	4

Note: * means the calculation was based on retail sales of alcohols. A share of ethanol was taken according to the values stated in the State Standards (GOST) for relevant types of alcohol products.

Discussion. As we were modeling relations between the analyzed socio-hygienic determinants and age-specific mortality rates due to CVD, we established low explained variance of the analyzed factors in age groups younger than 30 years and, in addition, declining values of the determination coefficient in age groups 70 years and older although it still remained higher than 0.55. This may indicate some additional effects produced by other factors on mortality rates due to CVD in these age groups that were not included in the analyzed set of socio-hygienic determinants. Children mortality due to CVD most often occurs in case there are congenital malformations and cardiomyopathy that are largely caused by genetic factors or improper healthcare (poor prenatal diagnostics, surgical treatment or pediatric care not being effective) [15, 16]. Meanwhile, adverse effects produced by socio-hygienic factors on children due to allostatic loads or chronic stress may create elevated risks of cardiovascular diseases developing at adulthood [17, 18].

We established that the models of relations between the analyzed socio-hygienic determinants and age-specific mortality rates due to CVD predicted 43.3 % of the effects on LEB obtained by direct modeling of relations between socio-hygienic factors and LEB [14]. Actual contribution made by mortality due to CVD to the total population mortality equals 47.0 % and this indicates that the created models allow quite precise predictions.

In addition, we compared the results of modeling accomplished in the present research

work with those obtained in our previous work [14] and found out they were quite consistent as regards identified priority determinants or their groups. This may indicate the perceptron truly has an optimal structure and there is continuity of the modeling results.

The authors of the work [19] applied hierarchical linear regression to examine 35 indicators. They established that modifiable health determinates accounted for 54.0 % of explained variance of public health at the national level in the USA. Relative contributions made by each groups of determinants were as follows: socioeconomic factors, 47.0 %; behavioral factors, 34.0 %; factors related to public healthcare, 16.0 %; environmental factors, 3.0 %. In this study, lifestyle-related indicators and sanitary-epidemiological welfare on a given territory were established to be the most significant groups of determinants that produced the greatest effects on LEB through age-specific mortality rates due to CVD.

Certain socio-hygienic determinants, such as people's physical activity, incomes, education, and consumption of vegetables, had more apparent effects on LEB. It was shown in multiple relevant studies that aimed to determine cause-effect relations between environmental factors and lifestyle-related ones and incidence of / mortality due to cardiovascular diseases [20–22].

Our estimates of priority regarding influence of the analyzed factors on LEB in older age groups are similar to the results obtained in the study [23]. The authors examined remaining life expectancy[12] in various administrative districts in Germany by using two-dimensional analysis. They showed that "a share of employees with academic degrees" was the most reliable predictor of this indicator; RLE was also influenced significantly by "a share of elderly people provided with financial support", "household incomes", and "unemployment". In addition, the authors of the work [23] showed that factors related to public healthcare had only insignificant influence and this is well in line with our results, which, as we'd like to point out, were obtained by using multi-dimensional analysis (factor analysis, ANN) of heterogeneous factors.

The study [24] showed that life expectancy at birth could be determined by socio-economic differences between population groups. Thus, 13.0 % of women and 27.0 % of men with low incomes were established to die before they reach 65 years; differences in LEB between people with low and high incomes amounted to 4.4 years for women and 8.6 years for men. In this study, we revealed that "consumer expenses" and "incomes per capita" were also significant factors able to modify LEB levels as it was shown in other relevant studies [25–27]. In addition, such factors as "expenses on social policies" and "gross regional product" turned out to be significant for the age group "60 years and older". This might be due to compensatory influence exerted by these factors on retired people who have to face a substantial decline in incomes (loss of their major source).

Overall, we can conclude that studies with their aim to examine influence exerted by a multi-component environment on public health are a promising trend in preventive medicine (hygiene). However, finding solutions to tasks set within such studies and achieving their goals should rely on multi-level and interdisciplinary approaches [28].

This study has certain limitations. First, only a limited list of indicators has been examined (206 overall) that characterize a multi-component complex environment in the RF; second, a time range is rather short (2010–2019); and finally, a research territory (the Russian Federation). The study results are largely able to give an insight into cause-effect relations between environmental and lifestyle-related factors and age-specific mortality rates due to CVD in the age group "30 years and older" together with providing a predictive estimate of potential changes in LEB. If we want to establish such relations in age groups younger than 30, we will

[12] Remaining life expectancy (RLE) is applied since the study focuses on calculating LEB for people aged 60 years (e_{60}).

need to adjust our initial datasets and, probably, to develop our mathematical approach.

Conclusions:

1. Our examination of cause-effect relations between socio-hygienic factors and age-specific mortality rates due to CVD revealed that the greatest share of explained variance ($R^2 > 0.5$) is in the age groups "30 years and older".

2. A predicted growth in LEB determined by using scenario modeling of relations between the analyzed socio-hygienic factors and age-specific mortality rates due to CVD amounted to 514 days (1.3 years). The greatest aggregated effect on a potential growth in LEB would be produced by lifestyle-related factors (0.56 years or 205 days) and sanitary-epidemiological welfare on a given territory (0.34 years or 126 days). We established that a probable decline in mortality due to CVD within the analyzed models amounted to 24.8 % in the age group "30–59 years" and 22.3 % in the age group "60 years and older".

3. "A share of population doing sports or physical exercises", "Consumer expenses per capita", "Average incomes per capita", "Consumption of vegetables and melons", "A share of population with higher education" and some other determinants are priority ones as regards a decline in mortality rates due to CVD in the age groups "30 years and older".

4. Indicators that described working conditions also had quite a high priority among influencing socio-hygienic determinants in the age group "30–59 years". These indicators included work intensity (5 days), microclimate at workplaces (3 days), dust and aerosols in workplace air (3 days), electromagnetic fields at workplaces (3 days) etc.

5. Age-specific mortality rates due to CVD in the age group "60 years and older" were mostly determined by such indicators as a share of expenses on social policies within consolidated budgets (11 days); ethanol consumption per capita (adult population) (8 days); gross regional product (6 days); primary incidence of diseases of the musculoskeletal system and connective tissue among people older than working age (4 days).

6. The suggested methodical approach to predicting a potential growth in LEB is based on modeling cause-effect relations between environmental factors and age-specific mortality rates due to CVD. It can be helpful for making relevant managerial decisions regarding prevention of cardiovascular diseases among population as well as within examining influence exerted by environmental factors and lifestyle-related ones on other priority reasons for population mortality.

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