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Research article

PREDICTING GROWTH POTENTIAL IN LIFE EXPECTANCY AT BIRTH OF THE POPULATION IN THE RUSSIAN FEDERATION BASED ON SCENARIO CHANGES IN SOCIO-HYGIENIC DETERMINANTS USING AN ARTIFICIAL NEURAL NETWORK

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The article presents the results produced by predicting growth potential in life expectancy at birth (LEB) of the RF population. The predictions are based on scenario changes in social and hygienic determinants (SHD) identified by using an artificial neural network (ANN). This research is vital given the existing social strategies aimed at improving the medical and demographic situation in the Russian Federation. These strategies stipulate achieving targets set within the major national and federal projects. We identified an optimal ANN structure based on a four-layer perceptron with two inner layers containing eight and three neurons accordingly. This structure is able to produce results at the highest determination coefficient (R^2= 0.78). Differences between actual LEB levels and predicted ones obtained by using the suggested model did not exceed 1.1 % (or 0.8 years). We established that average LEB in the RF would reach 75.06 years (by 2024) provided that the demographic situation in the country recovers in the nearest future, LEB level reaches its values detected in 2018–2019, and SHD values grow to their preset levels according to the target scenario. Therefore, the detected growth potential amounts to 3.0 years (1095 days) against 2018. "Lifestyle-related determinants" produce the greatest effects on the growth potential in LEB by 2024 (461 days). We also identified effects produced by such SHD groups as "Sanitary-epidemiological welfare on a given territory" (212 days), "Social and demographic indicators" (196 days), "Economic indicators" (131 days), "Indicators related to public healthcare" (70 days). An indicator that shows "A share of population doing physical exercises or sports" is the most significant determinant producing the greatest effects on potential changes in LEB. If it grows up to 55.0 %, a potential growth in LEB amounts to 243.5 days. If we do not consider COVID-related processes and rely only on the trends that are being observed now when predicting changes in the demographic situation by 2030, we can expect a possible additional growth in LEB that equals 286 days. The developed algorithm for determining growth potential in population LEB can be used as an instrument for determining and ranking priority health risk factors.

Keywords: *life expectancy at birth, socio-hygienic determinants, artificial neural networks, factor analysis, prediction of a medical and demographic situation, growth potential, national projects, lifestyle, sanitary-epidemiological welfare.*

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The basic provisions of "The unified action plan on achieving national goals of the Russian Federation development for the period up to 2024"[1] highlight that these goals can be achieved by implementing "inter-project" activities. Their achievement requires a complex (systemic) approach to implementing all the actions mentioned in the document. An increase in life expectancy at birth (hereinafter LEB) is "the most significant indicator showing people's quality of life". It is declared a most significant condition for providing natural population growth and is considered especially vital in the post-COVID economy in the country that is also facing the most severe economic sanctions. A priority (key) trend in improving the medical and demographic situation in the country involves "… a substantial reduction in mortality rates in several age groups, including working population and people older than employable age …". This reduction can be achieved by developing preventive activities as per basic causes of death for the RF population (circulatory diseases, malignant neoplasms, and external causes). Simultaneously, experts admit "…this issue cannot be resolved solely with medical means …" and, moreover, it requires "…providing sanitary-epidemiological wellbeing of the population …". Given that, it seems only reasonable "… to support activities aimed at increasing a share of citizens who pursue healthy lifestyle …". Key instruments in implementing this trend include "Healthcare", "Demography" and "Ecology" National Projects as well as several state programs such as "Healthcare development", "Development of sports and physical culture", "Environmental protection" and others. It is obvious that the current project activities accomplished by the state authorities are truly complex (systemic); they all are aimed at improving social strategies and the medical and demographic situation in the country.

It seems relevant to choose LEB as an indicator of a predicted medical and demographic situation when we strive to estimate improvements in basic spheres of people's life activities. LEB is relatively simple to calculate, has a direct correlation with sex- and age-specific mortality due to all causes and is comparable between different countries since it is widely used in multiple studies that focus on estimating people's quality of life [1–4]. Besides, challenges related to increasing LEB are often considered in reports made by many international organizations [5–9].

We can find several approaches to estimating influence exerted by environmental factors on LEB, population mortality taken into account, in scientific literature. They include creating conventional mortality tables [10, 11]; estimates of eliminated reserves [12]; component analysis of mortality [13, 14]; assessment of contribution made by mortality to LEB [15]. In addition, it is quite common to use econometric analysis of influence exerted by a limited number of factors (more often economic ones). The method usually involves building correlation-regression models of relationships between LEB and environmental factors together with determining the hierarchy of the RF regions and their clusterization. The procedure is equally suitable for inter-country estimates [16–20].

Since amounts of heterogeneous analyzed data on relevant indicators that characterize a research object (public health) are only growing, some other methods are considered promising alongside the aforementioned ones. These methods include multidimensional statistical analysis procedures (multiple regressions, factor analysis, neural networks, etc.) and their combinations. Thus, Yu.A. Grigor'ev and O.I. Baran applied a set of statistical procedures for data analysis in their work (principal component method, regression analysis, and factor analysis) bearing in mind lag influ-

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[1] 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/ (April 05, 2022) (in Russian).

ences exerted by a factor on population mortality [21].

The Global Burden of Disease is the most remarkable project in this sphere performed by western researchers. This study is accomplished regularly by a consortium that includes researchers from various countries. It concentrates on estimating mortality in dynamics and, above all, aims to determine reasons for negative trends that occur due to effects produced by priority risk factors. The overall data array analyzed so far includes more than 1 billion units of observation. Such a huge volume of statistical data has been analyzed by using innovative technologies of Bayesian statistical modeling and required substantial computational capacities. An analytical instrument called CODEm (the Cause of Death Ensemble model) was applied to solve the task; this ensemble model was created by using several mathematical and statistical procedures with the best predictive validity and biological plausibility of mortality being dependent on analyzed covariates [22].

Some researchers believe that public health should be viewed as a complex adaptive system with multiple dynamic non-linear interactions between its subsystems and determinants of different origin. They also note that interactions between these determinants are contextual during a certain period and they should be analyzed at multiple levels and in large scales. The resulting managerial decisions should only be complex [23, 24].

Yu.P. Lisitsyn, RAS Academician, stated that public (population) health was a complex, developing and dynamic system that required a systemic approach and analysis in any study accomplished in the field[2]. The necessity to apply an interdisciplinary approach to issues of public health (a nation's viability) was also stressed by B.T. Velichkovskiy, RAMS Academician, who stated a need in such an integral science as social human biology [25]. He thought socioeconomic factors creating "a social stress" to be as important as other factors, including hygienic ones. He also pointed out that establishing a relationship between socioeconomic factors and health disorders was among key information and analytical components in the social and hygienic monitoring and believed studies in this field to be vital for hygiene as a science [26, 27].

At present, there are a growing number of studies, biomedical ones included, that are based on using artificial neural networks or ANNs. This method is shown to have greater predictive capacities more often than logistic regression models [28–31]. ANNs are widely used in medicine in multiple spheres including diagnosing, selecting a treatment tactics, patient routing, preparing and accomplishing biomedical research and some others [32–38].

At the same time, we can clearly see that methods for predicting life expectancy at birth that consider multiple and variable impacts exerted on it by environmental factors and lifestyle are not presented sufficiently in domestic and foreign research articles dealing with medical and demographical issues and reasons for them. Verified assessments within "environmental factors – life expectancy at birth", "environmental factors – mortality – life expectancy at birth" systems have not been given much attention in scientific literature either. It is also vital to adjust and supplement well-known risk factors influencing public health and to clarify intensity of their influence.

Therefore, we can state the present research is vital given the current state policy being oriented at improving the medical and demographic situation in the country and aiming to achieve certain levels of relevant indicators (LEB). Another important factor is developing biomedical research with its focus on examining multiple influences exerted by environmental factors on population health that involves using multidimensional statistical procedures, artificial neural networks included.

Our research goal was to make quantitative predictions of influence exerted by a set of social and hygienic determinants on life expec-

[2] Lisitsyn Yu.P. Obshchestvennoe zdorov'e i zdravookhranenie: uchebnik [Public health and healthcare: manual], the 2nd edition. Moscow, GEOTAR-Media, 2010, 512 p. (in Russian).

tancy at birth for the RF population by using a neural network model.

Materials and methods. We analyzed domestic and foreign research works on the subject (influence exerted by environmental factors and lifestyle on public health). As a result, we created a pool of contemporary models that describe cause-effect relationships between multiple environmental factors and public health.

We used relevant scientific data on cause-effect relationships between environmental factors and public health as grounds for creating a list 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[3], the RF Public Healthcare Ministry[4], and the Federal Statistic Service[5]. We created a data matrix as per groups of the analyzed indicators that included 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). These groups were identified conventionally and were applied to estimate effects produced by relevant factor groups with a possibility to make comparisons between them.

The task we set was to predict LEB together with establishing quantitative effects produced by a set of social and hygienic determinants (hereinafter SHD) on LEB and its growth potential. To do that, we created a mathematical model that reflected a system of cause-effect relationships between the analyzed indicators that characterized SHD and LEB. This mathematical model included a sub-model for factor transformation of a system of independent variables into common factors and an artificial neural network (hereinafter ANN).

A factor transformation sub-model was built by using factor analysis and applied to reduce dimensionality of initial data that were fed into an input layer in ANN.

Factor transformation that resulted from examining the system of cause-effect relationships between SHD-characterizing indicators and weather and climate made it possible to switch from the system of interrelated indicators (148 SHD) to pairwise independent common factors (the created model contains 33 such factors).

The factor transformation sub-model is a system of linear algebraic equations that are given as follows in their matrix form (1):

$$Y = A\tilde{X}, \tag{1}$$

Where $\tilde{X} = \{\tilde{x}_1, \tilde{x}_2, ..., \tilde{x}_I\}^T$ is the column-vector of standardized values determined for independent variables, I = 148;

$Y = \{y_1, y_2, ..., y_J\}^T$ is the column-vector of common factors, J = 33;

$A = \begin{bmatrix} a_{11} & a_{12} & ... & a_{1J} \\ a_{21} & a_{22} & ... & a_{2J} \\ ... & ... & ... & ... \\ a_{I1} & a_{I2} & ... & a_{IJ} \end{bmatrix}$ is a matrix of factor marks within factor analysis.

The expression (1) is given as follows in its component form (2):

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[3] Ob utverzhdenii statisticheskogo instrumentariya dlya organizatsii Federal'noi sluzhboi po nadzoru v sfere zashchity prav potrebitelei i blagopoluchiya cheloveka federal'nogo statisticheskogo nablyudeniya za sanitarnym sostoyaniem sub"ekta Rossiiskoi Federatsii: Prikaz Rosstata ot 29.12.2017 № 885 (utratil silu s otcheta za 2019 god na osnovanii prikaza Rosstata ot 24 dekabrya 2019 goda № 800) [On approval of statistical tools to organize federal statistical observation of a sanitary situation in an RF region by the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing: The Order by the Rosstat issued on December 29, 2017 No. 885 (became invalid after the 2019 report was issued according to the Order by Rosstat issued on December 24, 2019 No. 800)]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/556189703 (April 07, 2022) (in Russian).

[4] Mediko-demograficheskie pokazateli Rossiiskoi Federatsii v 2018 godu: stat. spravochnik [Medical and Demographic indicators in the Russian Federation in 2018: statistical reference book]. *The RF Public Healthcare Ministry*. Moscow, 2019, 253 p. (in Russian).

[5] Regiony Rossii. Sotsial'no-ekonomicheskie pokazateli. 2018: stat. sb. [Russian regions. Socioeconomic indicators. 2018: statistical data collection]. *Rosstat*. Moscow, 2018, 1162 p. (in Russian).

$$y_j = \sum_{i=1}^{I} a_{ij}\tilde{x}_i \qquad (2)$$

The system of independent variables was standardized as per the following relationship (3):

$$\tilde{x}_i = \frac{x_i - \bar{x}_i}{\sigma_i}, \qquad (3)$$

where x_i is a value of the *i*-th variable;

$\bar{x}_i$, σ_i are mean and standard deviations of the *i*-th variable as per sampling data.

Our ANN was trained based on using the initial data matrix. When doing it, we determined its optimal structure that was based on a four-layer perceptron with two internal layers containing eight and three neurons accordingly with the determination coefficients being equal to 0.78 (Figure 1).

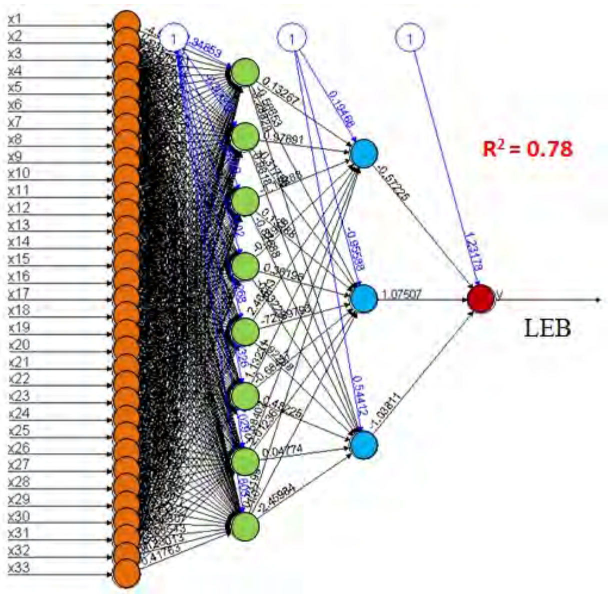

Figure 1. The structure of four-layer perceptron with two internal layers containing eight and three neurons accordingly

Predictive LEB levels were calculated by accomplishing a sequential series of mathematical operations.

Values of common factors that were fed into ANN input layer were standardized as per the formula (4) (after completing factor transformation of values determined for independent variables):

$$\tilde{y}_j = \frac{y_j - y_j^{\min}}{y_j^{\max} - y_j^{\min}}, \qquad (4)$$

where $\tilde{y}_j$ is a standardized value of the *j*-the common factor;

$y_j^{\min}$, $y_j^{\max}$ are minimum and maximum values of the *j*-the common factor obtained as per the results produced by factor transformation of the initial system of indicators.

Calculation of input signals for the first internal neuron layer that consisted of eight neurons was performed as per the formula (5):

$$F_{in1k} = b_{0k} + \sum_{j=1}^{33} b_{jk}\tilde{y}_j, k = \overline{1,8}, \qquad (5)$$

where F_{in1k} is input signals for the *k*-th neuron in the first internal layer;

b_{0k}, b_{jk} are coefficients of the neural network model for the first neuron layer.

Calculation of output signals for the first internal neuron layer was performed as per the formula (6):

$$F_{out1k} = \frac{1}{1+e^{-F_{in1k}}}, k = \overline{1,8}, \qquad (6)$$

where F_{out1k} is output signals for the *k*-th neuron in the first internal layer.

Calculation of input signals for the second internal neuron layer that consisted of three neurons was performed as per the formula (7):

$$F_{in2l} = c_{0l} + \sum_{k=1}^{8} c_{kl}F_{out1k}, l = \overline{1,3}, \qquad (7)$$

where F_{in2l} is input signals for the *l*-th neuron in the second internal layer;

c_{0l}, c_{kl} are coefficients of the neural network model for the second neuron layer.

Calculation of output signals for the second internal neuron layer was performed as per the formula (8):

$$F_{out2l} = \frac{1}{1+e^{-F_{in2l}}}, l = \overline{1,3}, \qquad (8)$$

where F_{out2l} is output signals for the *l*-th neuron in the second internal layer.

Model standardized values of life expectancy at birth were calculated as per the formula (9):

$$\tilde{z} = d_0 + \sum_{l=1}^{3} d_l F_{out2l}, \qquad (9)$$

where $\tilde{z}$ is the model standardized LEB value;

d_0, d_l are coefficients of the neural network model for calculating standardized LEB values (the output layer values).

The model LEB value was calculated as per the formula (10):

$$z = LEB = \tilde{z}(z_{\max} - z_{\min}) + z_{\min}, \quad (10)$$

where $z = LEB$ – model LEB.

To make quantitative predictions of influence exerted by SHD on LEB for the RF population based on the applied ANN, we used a stepwise algorithm that included the following stages.

– Stage 1. Creation of a baseline and target scenario for changes in SHD-characterizing indicators.

– Stage 2. Calculation of predictive LEB values using the ANN according to the baseline and target scenario.

– Stage 3. Calculation of LEB growth potential for the RF population.

SHD values (independent variables) within the baseline scenario were set according to the available data on actual values of the analyzed indicators in 2018 taken from official statistical sources. SHD values within the target scenario were set in accordance with the targets fixed in the national and federal projects and calculated (predictive) values as per linear / logarithmic trends. A target value of an indicator between a linear or logarithmic trend was selected by using the highest value of the determination coefficient (R^2) as a criterion for this selection.

Thus, within the present study, we fixed target SHD values for 10 indicators at the levels outlined for them in the national and federal projects; 103 indicators were changed in accordance with the trends outlined for them by 2024; changes in 21 indicators amounted to 10.0 %[6] against the baseline scenario considering biological sense of their influence on LEB; values of the remaining 14 indicators were set at the baseline scenario levels since any adequate and correct estimates of changes in them were impossible to achieve.

In addition, we estimated whether it was possible to achieve target LEB levels fixed in "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"[1] and obtained trend changes in the analyzed indicators that could be expected by 2030.

Growth potential of LEB for the RF population was calculated as per a difference in predicted LEB estimates within the baseline and target scenarios (11):

$$\Delta LEB = z^{Trg} - z^{Bsl}, \qquad (11)$$

where ΔLEB is LEB growth potential;

z^{Trg} is a predictive LEB value within the target scenario;

z^{Bsl} is a predictive LEB value within the baseline scenario.

To statistically analyze the obtained data and perform necessary computations, we used mathematical computational software for statistical data analysis (Statistica 10, RStudio, MS Excel 2010). The results were visualized using geoinformation systems (ArcGis 9.3.1).

Results and discussion. We comparatively assessed actual and model LEB levels to test whether the data obtained by using the developed methodical approach were correct. Thus, according to the baseline scenario, the LEB level calculated by using the developed mathematical model that employed baseline values of 148 determinants in 2018 equaled 72.1 years whereas the actual LEB level in Russia amounted to 72.9 years in 2018. The difference between the actual and model LEB values amounts to 0.8 years or 1.1 % in 2018. This similarity between the LEB calculated within the baseline scenario and the actual

[6] This approach was used due to structural interrelations between certain indicators.

Table 1

Growth potential for life expectancy at birth as per groups of indicators describing the environment and lifestyle based on the scenario modeling by 2024

SHD group	Target scenario for one group, years	LEB growth potential, years (days)	Rank
Lifestyle	73.32	1.26 (461.2)	1
Sanitary-epidemiological welfare on a given territory	72.64	0.58 (211.9)	2
Sociodemographic indicators	72.6	0.54 (196.3)	3
Economic indicators	72.42	0.36 (131.2)	4
Public healthcare	72.25	0.19 (70.0)	5

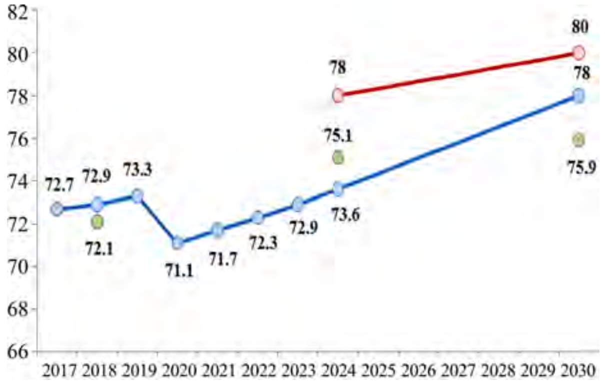

Figure 2. Target and predicted changes in LEB level for the RF population by 2024 and 2030: the red line shows target LEB levels in conformity with the RF President Order No. 204 dated May 07, 2018[7]; the blue line shows target LEB levels according to The unified action plan on achieving national goals of the Russian Federation development for the period up to 2024 and plans for the period up to 2030[8]; green dots show model LEB values according to the ANN

registered LEB level indicates that estimates produced by the developed mathematical model are quite correct.

We estimated scenario changes in the whole set of analyzed SHD values that would occur by 2024 in accordance with the approaches described in "Materials and methods" section of the work. Our estimation revealed that the model LEB value would be equal to 75.1 years; therefore, a predicted LEB growth potential in the RF amounted to 3.0 years (1095 days) over 2018–2024.

Then, we estimated LEB growth potential depending on a change in each conventional group of indicators (when indicators from only one group changed in accordance with the outlined approaches whereas the other determinants retained their baseline values). This estimation revealed that different groups had different predicted values of LEB growth potential by 2024. The highest values were determined for "Lifestyle" indicators (+1.3 years or 461.2 days) (Table 1). They were followed by "Sanitary-epidemiological welfare on a given territory" (+0.58 years or 211.9 days), "Sociodemographic indicators" (+0.54 years or 196.3 days), "Economic indicators" (+0.36 years or 131.2 days), "Public healthcare" (0.19 years or 70.0 days).

Therefore, if the overall demographic situation and LEB recover in the Russian Federation up to their levels detected in 2018–2019, implementation of the National and Federal Projects as well as complex action plans will make it possible to increase LEB by 3 years and its level will reach 75.1 years. At the same time, if we predict changes in the demographic situation by 2030 given the trends detected now and without considering COVID-19-induced processes, we can see a possible additional growth in LEB that is equal to 0.8 years (286 days) (Figure 2).

[7] O natsional'nykh tselyakh i strategicheskikh zadachakh razvitiya Rossiiskoi Federatsii na period do 2024 goda: Ukaz Prezidenta № 204 ot 07.05.2018 [On national goals and strategic tasks in the development of the Russian Federation for the period up to 2024: The RF President Order No. 204 dated May 07, 2018]. Available at: https://digital.tatarstan.ru/rus/file/pub/pub_1960762.pdf (May 11, 2022) (in Russian).

[8] 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/ (April 05, 2022) (in Russian).

The latter means it is necessary to retain the occurring trends by achieving the outlined targets. At the same time, if we want to achieve LEB equal to 78 years by 2030, we have to provide an additional 2.1-year growth in it. It can be comparable with additional implementation of such major projects as "Clean Air", "Clean Water", "Demography" etc. Certain substantial reserves for LEB growth can be found due to target activities aimed at creating stimuli for population to pursue healthy lifestyle. These activities should be structured as per their significance. A growth can also be secured due to changes in some negative trends that are being detected now (working conditions, a number of divorces, demographic load coefficients etc.).

A detailed study with its focus on specific conventional groups of indicators made it possible to estimate influence exerted on LEB by each separate indicator from the whole list of the analyzed determinants. Thus, "A share of population doing sports or physical exercises" produced the most significant effect among all the indicators from the group that described population lifestyles and among all the indicators as well. If this share reaches 55 %, which is its target level according to the "Sport is the standard of living" [9] Federal Project, a growth potential in LEB is equal to 243.5 days. LEB is predicted to grow if there is an increase in "A total number of sport facilities per 100 thousand people"; the effect produced on LEB is +18.9 days. The next important indicator in this group is "Consumption of fruit and vegetables". An increase in this consumption up to its recommended standards[10] can result in a potential growth in LEB by 53 and 39 days accordingly. We also established that LEB would grow by 19.5 days in case ethanol consumption[11] per an adult reduced by 24 % according to data provided by retail outlets dealing with alcohol sales. An isolated 24 % reduction in alcohol retail sales also led to LEB growth, which, if taken as per specific alcohol beverages, would amount to 17 days for beer; 12 days, for vodka; 11 days, for wines; 10 days, for sparkling wines.

Indicators that described working conditions for working population produced the greatest effects on changes in LEB levels in the group of indicators related to sanitary-epidemiological welfare on a given territory. If a specific share of workers who have to work under working conditions deviating from hygienic standards as per certain standardized workplace factors goes down in accordance with the detected trends, we will see the following changes in LEB levels. A 1.8-time decrease in workplaces with working conditions not conforming to the standards as per the biological factor will lead to a growth in LEB that is equal to 37.9 days; a 2.5-time decrease (lighting), a 20.2-day growth in LEB; a 3.3-time decrease (work intensity), a 17.5-day growth in LEB; and a 1.2-time decrease (microclimate), a 8.3-day growth in LEB.

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[9] Pasport federal'nogo proekta «Sozdanie dlya vsekh kategorii grazhdan i grupp naseleniya uslovii dlya zanyatii fizicheskoi kul'turoi i sportom, massovym sportom, v tom chisle povyshenie urovnya obespechennosti naseleniya ob"ektami sporta, a takzhe podgotovka sportivnogo rezerva» – kratkoe naimenovanie: Sport – norma zhizni (utv. proektnym komitetom po natsional'nomu proektu «Demografiya», protokol ot 29.04.2019) [The profile of the Federal Project "Creation of the necessary conditions for doing sports or physical exercises, including an increase in a number of sport objects provided to the population as well as training of sports reserve" the short title being "Sport is the standard of living" (approved by the Project Committee responsible for the "Demography" National project, the meeting report issued on April 29, 2019)]. *Zakony, kodeksy, normativnye i sudebnye akty*. Available at: https://legalacts.ru/doc/pasport-federalnogo-proekta-sozdanie-dlja-vsekh-kategorii-i-grupp_2/ (May 13, 2021) (in Russian).

[10] 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 food products that conform to the up-to-date standards of healthy diet: The Order by the RF Public Healthcare Ministry issued on August 19, 2016 No. 614]. *GARANT: informational and legal portal*. Available at: https://www.garant.ru/products/ipo/prime/doc/71385784/ (May 13, 2021) (in Russian).

[11] Pasport federal'nogo proekta «Formirovanie sistemy motivatsii grazhdan k zdorovomu obrazu zhizni, vklyuchaya zdorovoe pitanie i otkaz ot vrednykh privychek» (utv. Minzdravom Rossii, protokol ot 14.12.2018 № 3) [The profile of the Federal Project "Creation of stimuli for citizens to pursue healthy lifestyle including healthy diets and giving up bad habits" (approved by the RF Public Healthcare Ministry, the meeting report dated December 14, 2018 No. 3)]. *The RF Ministry of Labor*. Available at: https://mintrud.gov.ru/ministry/programms/demography/4 (May 13, 2021) (in Russian).

Quality of soils that conforms to hygienic standards is another sanitary-epidemiological factor associated with changes in LEB. Given the existing descending trends in a share of soil samples deviating from the hygienic standards as per sanitary-chemical indicators, we can predict certain growth in LEB. Thus, if a share of soil samples that deviate from the standards as per sanitary chemical-parameters goes down by 2.7 times by 2024, LEB is expected to grow by 7 days; as per heavy metal contents (by 2.3 times), by 11.6 days; as per microbiological indicators (by 1.8 times), by 5.5 days accordingly. LEB is expected to grow if the total emissions of contaminants into ambient air decrease by 22.0 % (the target set within the "Clean Air" Federal Project)[12] from all sources, stationary ones in particular. The greatest contribution here (3.6 days) is made by a calculated indicator that describes how environmentally friendly (clean) an economy is in a given region, that is, a quantity of emissions per a gross regional product (kg/million rubles). A significant growth in LEB is expected if food products become safer. Should a share of food products that do not conform to the hygienic standards as per microbiological indicators decrease by 1.2 times and reach zero regarding non-conformity as per sanitary-chemical indicators, an expected growth in LEB can be up to 15 days. A 15.6 % reduction in a share of non-centralized water supply sources (wells, catchments and springs) that do not conform to the sanitary-epidemiological requirements will result in LEB growing by 8.9 days.

As for sociodemographic indicators, "A number of registered crimes per 100 thousand people" turned out to be the most significant one. If it went down from 1428.5 to 1074 crimes per 100 thousand people, an expected growth in LEB would amount to 24 days. A growing share of people with higher education regardless of their employment status (employed, up to 35.4 %; unemployed, up to 26.4 %) would lead to a potential growth in LEB by 9.4 and 20.6 days accordingly. An increase in a number of working hours on average per one employed person from 38.1 hours (in 2018) up to the upper limit of a standardized working week (40 hours) that is stipulated by the RF Labor Code[13] would produce a certain effect on LEB, namely, a growth in it by 19 days. Overall improvement of housing that involves equipping it with water supply, sewage and central heating by 2–4 % against its level detected in 2018 can lead to a growth in LEB, by 16.5, 13.1 and 8.6 days accordingly. "A share of expenses on social policy funded from consolidated budgets" is another indicator producing a positive effect on LEB. An expected growth in it from 20.3 % to 21.7 % will increase LEB by 10 days. A reduction in social inequality (Gini coefficient) from 41.3 % to 40.3 % can result in LEB growing by 1.8 days.

When it comes down to economic indicators, incomes per capita and consumer expenses turned out to be the most significant among them. Their increase up to 45 thousand rubles per month and 35.5 thousand rubles per month can lead to a potential growth in LEB by 16.4 and 82.5 days accordingly. Greater incomes are likely to be associated with wider opportunities to improve one's lifestyle, to make it healthier. A growth in consumer expenses can result from not only purely economic reasons (inflation) but also from buying products or services of higher quality that give an opportunity to maintain or even improve one's health. We did not manage to confirm a

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[12] Pasport natsional'nogo proekta «Ekologiya» (utv. prezidiumom Soveta pri Prezidente RF po strategicheskomu razvitiyu i natsional'nym proektam, protokol ot 24.12.2018 № 16) [The profile of the "Ecology" National Project (approved by the RF Presidential Council on the 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_316096/45da8841765f8eb5fccef6cdb801897e354873b/ (May 13, 20211) (in Russian).

[13] Trudovoi kodeks Rossiiskoi Federatsii ot 30.12.2001 № 197-FZ (prinyat Gosdumoi 21.12.2001). Stat'ya 91. Ponyatie rabochego vremeni. Normal'naya prodolzhitel'nost' rabochego vremeni [The Labor Code of the Russian Federation issued on December 30, 2001 No. 197-FZ (passed by the RF State Duma on December 21, 2001). Clause 91. The concept of working time. The standard working week in Russia]. *GARANT: informational and legal portal*. Available at: https://base.garant.ru/12125268/ (May 11, 2022) (in Russian).

relationship between a growth in a gross regional product and an increase in LEB for population that is usually established by many researchers. In most studies, such a relationship is established by using linear models (pair or multiple regressions) that can oversimplify all the obtained dependences and interpret them too mechanistically. In addition, such a relationship is often established by using data collected at a national level or even in various countries and over longer observation periods. The present study relies on using a model based on artificial neural networks and on data collected at a meso-level (regional one) over ten years. This could both influence differences in the results and detect peculiarities and regularities typical for regions or the country as well as for the existing situation as a whole that is changing rather dynamically.

As for indicators describing the public healthcare system in the country, we found out two most significant indicators, "A number of doctors with all specialties" and "Loads on health workers", an indicator that is functionally related to the first one. An increase in the first indicator in accordance with the targets stipulated within the "Public healthcare" National Project[14] will result in LEB growth by 26.2 days and a relevant decrease in the second one will make LEB grow by 21.9 days. Besides, we established that a decrease in "A share of expenses on public healthcare funded from consolidated budgets" would result in a 4.4-day decrease in LEB on average in the RF. An isolated increase in "Capacities of out-patient polyclinics" could lead to a 2.9-day growth in LEB.

We should note that the present study has certain limitations. The mathematical model applied within its framework describes a complex system of non-linear cause-effect relationships between the analyzed determinants and LEB. This results in disrupted additivity of the computation results as per different scenarios; that is, an aggregated value of LEB growth potential calculated separately as per scenario changes in groups of indicators does not coincide with the results produced by the complex scenario changes in all the indicators. Consequently, it becomes difficult to determine a correct structure of contributions made by effects produced on LEB by specific determinants.

The results produced by predictive estimates of LEB growth potential in the RF as a whole are consistent with estimating contributions made by heterogeneous factors into public health supplementing and extending the results produced by previous studies in the sphere. Thus, lifestyle-related determinants as well as indicators of sanitary-epidemiological welfare turned out to be the most significant factors inducing a potential LEB growth. Still, the described model applied to estimate LEB growth potential has certain limitations such as the domain of the model. An adequate predictive estimation of LEB growth potential that is based on the created model is possible only at the macro- and meso-levels (the RF and its regions). The model can be used on data obtained at other levels (administrative districts within a region, or a country level) only after necessary retraining and, possibly, adjusting a list of analyzed SHD.

Conclusions. We created a mathematical model based on artificial neural networks that employed scenarios involving complete achievement of social and hygienic target indicators stipulated in the National and Federal Projects. All this allowed us to predict LEB growth potential by 2024, which amounted to 3.0 years (1095 days). The differences between a LEB level calculated with the baseline scenario and the actual LEB level in 2018 did not exceed 1.1 %. This indicated that our predictive estimates of LEB growth potential were highly precise. We conventionally decomposed the whole set of the analyzed de-

[14] Pasport natsional'nogo proekta «Zdravookhranenie» (utv. prezidiumom Soveta pri Prezidente Rossiiskoi Federatsii po strategicheskomu razvitiyu i natsional'nym proektam, protokol ot 24 dekabrya 2018 g. № 16) [The Profile of the "Public healthcare" National Project (approved by the RF Presidential Council on the strategic development and national projects, the meeting report issued on December 24, 2018 No. 16)]. *GARANT: informational and legal portal*. Available at: https://base.garant.ru/72185920/ (May 13, 2021) (in Russian).

terminants into separate groups and then analyzed them as per individual scenarios describing changes in them by 2024 with subsequent ranking of LEB growth potential values. The results were consistent with the existing paradigm of priority influence exerted by lifestyle-related factors, ecological and sociodemographic factors on public health. The greatest scenario changes in LEB growth potential were detected for "Lifestyle" (+1.26 years or 461.2 days), "Sanitary-epidemiological welfare on a given territory" (+0.58 years or 211.9 days), and "Sociodemographic indicators" (+0.54 years or 196.3 days).

The created algorithm for determining LEB growth potential for population can be used as an instrument for correct determination of priority factors / groups of factors (social and hygienic determinants) that produce their effects on the integral health indicator (LEB) on a given territory. It is advisable to use this instrument when making managerial decisions on how to improve a medical and demographic situation. Besides, the suggested estimation model corresponds to the up-to-date concept of public health as a complex system that requires a multisided approach to studying and analyzing it as well as interpreting research results. The developed model that describes multiple non-linear interrelations between social and hygienic determinants and life expectancy at birth can be used to achieve the following:

– determining manageable (by executive authorities) priority social and hygienic determinants (hereinafter SHD) that produce the greatest effects on LEB;

– making medical and demographic predictions whether it is possible to achieve target LEB levels considering scenario changes in SHD and specific socioeconomic factors, sanitary-epidemiological situation, and weather and climatic conditions on a given territory (in a specific RF region);

– improving the social and hygienic monitoring system and statistical observation at the regional and federal levels by creating optimal lists of monitored indicators, improving procedures for analyzing and assessing data on public health;

– developing preventive activities that make it possible to either decrease or prevent effects produced by a specific SHD of a group of such determinants on public health;

– providing objective data to people participating in developing and making managerial decisions, including those on prevention activities, aimed at preserving and improving public health, LEB growth, providing sanitary-epidemiological welfare and socio-economic wellbeing.

The results produced by the present study are quite suitable for being implemented into practical activities accomplished by experts of the sanitary-epidemiological service and research institutions dealing with public healthcare issues as well as by municipal authorities. To facilitate the process, a PC software package has been developed. It is entitled "Socio-economic and sanitary-hygienic indicators and an associated growth potential of life expectancy at birth for the RF population" (it was registered in the Software Register on March 28, 2022, the registration certificate No. 2022614959). The software gives an opportunity to perform computational experiments with the trained ANN using only numeric values determined within the baseline and target scenarios.

In future, we plan to continue examining aggregated, share and mutual influence exerted by socio-hygienic determinants on public health in the Russian Federation (mortality and morbidity as per specific causes) including analysis of data obtained at micro- (municipal districts) and macro-levels (different countries) as per sex- and age-specific differences.

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