

Assessing the impact of socio-economic factors on public health in Russia

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Abstract

Negative demographic processes in Russia and its regions substantiate the relevance of exploring the impact of socio-economic factors on public health in Russia. A dynamic nature of economic and social changes in the conditions and lifestyle contribute to both changes in reproductive behaviour of the population and attitude to health. Despite the development of medical technologies in Russia, the health of the Russian population remains a constant government and public concern. Death rates, despite a downward trend, remain rather high compared to other countries. This situation calls for a higher effectiveness of the adopted national projects and programs on demographic development and health protection of the Russian population, which is largely dependable upon the level of understanding of the mechanisms of influence by decision-makers, necessitating monitoring over the impact of socio-economic factors on demographic processes.

The purpose of the study is to develop methodological tools to determine the impact of socio-economic factors on the dynamics in crude death rate as one of the most important indicators characterizing public health.

The study novelty is the proposed methodological approach to modeling the impact of socio-economic factors on mortality dynamics based on panel data for 2005-2021 using machine learning tools and methods, in particular the decision tree method.

The information base of the study includes panel data of the Federal State Statistics Service (Rosstat) on demographic processes in the Russian Federation and its regions. Five intervals characterizing peculiar features of socio-economic processes in each time period have been singled out from the overall period under study. The study results can be used to adjust measures aimed at implementing national projects and regional health protection programs with due regard to the impact of the factor groups on the required indicator.

Keywords

population, public health, mortality, assessment, quality of life, socio-economic factors, partial contribution

JEL codes: J11; C13, C45

Introduction

Qualitative aspects of the demographic development are directly related to such concepts as health protection and social sector development, which are becoming increasingly important in the demographic and socio-economic policy of the state.

However, the macroeconomic reforms in Russia made the social interests mainly drop off the radar resulting in numerous socio-demographic consequences coming into a full force, intensified by a general crisis of the system of values and motivations. The coronavirus pandemic has become a significant test for society, dividing demographic processes in the country into pre-and post-pandemic periods.

Over the period from 2005 to 2021, dynamics in the Russian demographic indicators was rather uneven, responding to many different factors. In the pre-pandemic period, crude birth rate increased from 10.2‰ in 2005 to 13.3‰ in 2015. The trend was largely due to the increase in the number of women of fertile age during this period because of the baby boom of the 80s of the 20th century and to some extent to a positive effect of the state demographic policy stimulus (primarily, measures of financial support to families with children and maternity capital granted for the birth of a second child, introduced in 2007). However, by 2019, the crude birth rate had decreased to 10.1‰. In 2020 it was even smaller, amounting to 9.8‰, which was mainly due to a sharp decline in fertility in the 1990s.

Before the pandemic, the crude death rate tended to decrease (from 16.1‰ in 2005 to 12.3‰ in 2019). (Fig. 1)

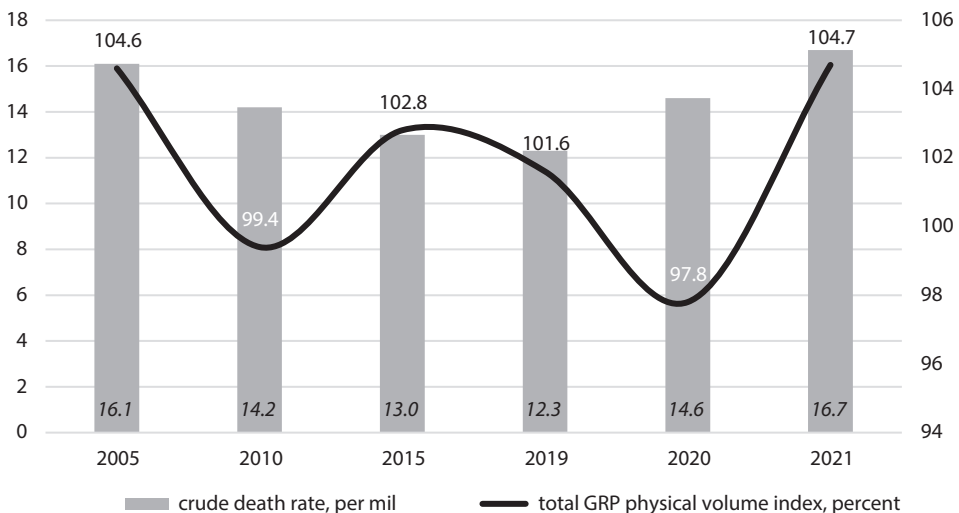


Figure 1. Dynamics in death rates and total GRP in Russia in 2005-2021. *Source:* (Rosstat 2022)

Figure 1 shows that mortality in 2005-2021 is somehow dependable upon the dynamics in total GRP with a time lag of 2-3 years however, since 2015 improvements in the overall socio-economic situation in the country are characterized by a decrease in mortality, while deterioration of the economic development indicators is characterized by its growth. 2021 is the exception, by this year the economic consequences of the pandemic of a new coronavirus infection had already been managed, while the demographic ones (in the form of deteriorated public health and increased mortality) were yet to be coped with. Infant mortality significantly decreased during the analyzed period (from 11.0‰ in 2005 to 4.5‰ in 2019). These indicators for Russia as a whole suggested positive processes in health protection because of the increased effectiveness of the state policy aimed at increasing life expectancy and reducing avoidable mortality, including infant mortality. However, 2020 was characterized by a sharp increase in crude mortality rate - up to 14.6‰; while in 2021, it already increased to 16.7‰, and infant mortality added up to 4.6‰.

If we are to analyze demographic development in the regional context, the picture turns out to be very heterogeneous. With an average all-Russia birth rate of 9.6‰ in 2021, the highest birth rates were registered in the Republic of Tyva and the Chechen Republic (19.9‰ and 19.4%, respectively). The highest infant mortality, compared with the average Russian, was registered in the Jewish Autonomous Region and the Chukotka Autonomous Area (11.7‰ and 15.8‰, respectively). The lowest crude death rate was registered in the Republic of Ingushetia (4.2‰), and the highest one - in the Novgorod region (22.3‰).

Among the main classes and causes of death, socially significant diseases were on the rise in the period from 2005 to 2021. Compared to 2005, the number of diseases associated with neoplasms increased by 7.4%, diseases of the respiratory system - by 38.4% and diseases of the circulatory system - by 32.6%.

In 2021, the structure of death causes was dominated by diseases of the circulatory system (38.3%) and consequences of the Covid-19 coronavirus infection (19.1%). It should be noted that mortality from coronavirus infection in 2021 increased more than 3-fold compared to 2020, when the federal government imposed strict mobility restrictions due to the pandemic (from 0.98‰ to 3.19‰) (Rosstat 2021).

Thus, identification and evaluation of the relationship between socio-economic factors, health and mortality is an urgent research problem. The research objective of the study was to measure the size of the impact of socio-economic factors on mortality in certain time intervals and population size without any additional linkage to other demographic indicators that determine the accuracy of the death rate measurement. Therefore, in view of the set research objective, we believe that crude death rate can serve as an important specific indicator of mortality, which comprises mortality from all causes within the analyzed time period for a given population, as well as “evenly depends upon the age profile of mortality and age composition of the population” (Andreev 2021).

Theoretical background

The World Health Organization (WHO) defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease and infirmity” (WHO 1946). As a result, the economic, social, and demographic problems related to public health are not limited to the field of medicine alone, they are the consequence of the profound changes in the life quality and system of values, and self-protective behaviour of all members of society.

The concept of health as a set of multiple qualitative and quantitative characteristics contains two major aspects such as individual and social (Fokin & Efimov 2010). In the most general terms, public health reflects the ability of society to follow an active lifestyle and create material and spiritual benefits (Dantsiger et al. 2022), while individual health has mainly medical characteristics, the analysis of public health as a social phenomenon is based on dynamics in statistical indicators (Migunova 2015) and, above all, demographic indicators, such as fertility, mortality, morbidity, and life expectancy (Perkhov & Korkhmazov 2022)

Foreign health researchers note that population health is determined by its socio-demographic characteristics (Firza & Monaco 2022; Xu et al. 2022; Shafran et al. 2023), and also it largely depends on those diseases associated with a certain socio-demographic group of the population (Nephew et al. 2023; Alzahrani et al. 2023). In addition, the researchers focus on self-protective behaviour of the population in relation to their health (Chenet et al. 1998; Olišarová et al. 2021; Tong et al. 2022; Petrova et al. 2022) as well as the impact of various geographical (Baljepally & Metheny 2022; Masselot et al. 2023) and socio-economic factors (Ivankova et al. 2022; Odabasi & Hartarska 2021), including working conditions (Nurhayati et al. 2022). A number of research is devoted to the relationship between public health and health care effectiveness (Jakovljevic et al. 2020; Ranabhat et al. 2020), including achievement of the health-related sustainable development goals (GBD 2019 Under-5... 2021).

According to Russian scientists, the socio-economic factors play a significant role in population health and its individual age groups, since they have different sensitivity to the effects of adverse factors. The ethnographers (Zubov & Kozlov 1982) proved that the chronological boundary of life depends on the natural, ethnic, socio-cultural, psychological and other conditions in which specific populations live.

Domestic researchers consider the problems of factor influence on health, fertility and mortality rates (Baevsky & Berseneva 1997); peculiarities of self-rated health and its perception by gender (Pautova & Pautov 2015; Lebedeva-Nesevrya & Zinker 2018); morbidity with temporary disability of the working population depending on age, financial status and sectoral employment, as well as professional affiliation and behavioral factors characterized by high premature mortality (Suslin & Nikolskaya 2015); evaluation of a general impact of socio-economic factors on health based on sociological surveys (Malysheva et al. 2016). On a separate note we'd like to highlight studies related to the development of methodological tools for assessing the economic damage associated with complete or partial loss of health based on measuring the impact of socio-economic and environmental factors using regression analysis of panel data both in Russia and its regions (Zubarev 2020; Derstuganova et al. 2013; May & Zaitseva 2022; Chashchin et al. 2020).

Based on the results of research available in scientific literature, we came to the decision to use crude death rate as one of the most important indicators characterizing the level of public health in order to develop methodological tools for assessing the contribution of socio-economic factors to public health.

Data

The unit of analysis is a Russian region. According to the 2021 administrative-territorial division of the Russian Federation, it consisted of 85 constituent entities. To calculate a partial contribution of socio-economic factors to mortality, 57 indicators were initially selected and presented in dynamics for the period from 2005 to 2021 by region. A correlation analysis

made it possible to narrow this list down to 17 key indicators with the strongest relationship with crude death rate, which was selected as a required indicator (Table 1). Thus, the sample consisted of 23120 observations (85 regions, 16 years, 17 indicators).

Table 1. Factor blocks of socio-economic indicators to evaluate partial contribution to mortality

Factor block	Indicators
Employment and labour market	<ul style="list-style-type: none"> • share of people employed in jobs with hazardous and (or) dangerous working conditions, % • share of the employed with higher education, % • unemployment rate, % • share of industry in the gross value added of the Russian regions, %
Healthcare	<ul style="list-style-type: none"> • capacity of outpatient facilities, visits per shift per 10,000 population • prevalence per 1,000 population • nursing staff per 10,000 population • doctors per 10,000 population • hospital beds per 10,000 population
Life safety	<ul style="list-style-type: none"> • registered crimes per 10,000 population • paved road density, km per 1000 km² • share of household spending on alcohol, % • share of budget spending on health, physical education and sports, %
Standard of living	<ul style="list-style-type: none"> • budget expenditures per capita, thousand rubles • share of budget expenditures on social support, % • purchasing power of wages (average wage to subsistence minimum working population), times • number of own cars per 1000 population

Source: compiled by the authors.

The mortality rate is most closely associated with the indicators characterizing the standard of living, general level of security in society and healthcare performance, and this impact can be either direct, increasing mortality, or reverse, reducing it. After performing the analysis calculations, a number of indicators for which a statistically significant correlation was obtained, but the sign of the correlation coefficient could not be logically explained were excluded.

The indicators selected based on the results of the correlation analysis were grouped into four factor blocks (employment and labour market, health care, life safety, and standard of living, Table 1). Selection of indicators and their grouping by factor blocks made it possible to formulate a research hypothesis about a complex influence of socio-economic factors on mortality dynamics with due regard to both positive and negative effects of external causes on public health.

Methods

To calculate the partial contribution of factors to the dynamics in mortality, the authors use the methods of machine-learning. In our particular case, we solve the problem of regression recovery. The tree algorithms allow calculation of informative features, making it possible

to determine the impact strength of different factors. One of such iteration algorithms is the Recursive Feature Elimination algorithm, available in the Scikit-Learn library for Python.

To ensure successful application of the machine learning methods, we have brought data to a comparable form. To select the model, we used the following methods: least squares method; random forest; logistic regression; support vector machine method; nearest neighbor method. We split the initial sample of data for 2005-2021 into test and training sets, predict the output variable Y using the models and compare it with the already known data. We obtained the following determination coefficients (Table 2), based on which the optimal model was selected.

Table 2. Determination coefficients for the methods of modeling a partial contribution of socio-economic factors to mortality in the Russian regions in 2005-2021

Model	R2_Y
Linear Regression	0.582636
Random Forest Regressor	0.902035
K-Neighbors Regressor	0.876758
SVR	0.523440
Logistic Regression	0.75409

Source: calculated by the authors based on the modeling results.

The data suggest that the “Random Forest” method was the best to model the partial contribution, since its coefficient of determination is higher compared to others.

Further, in order to study the influence of socio-economic factors on mortality, we have identified time intervals in the general period that were characterized by certain features of socio-economic and demographic trends in the development of Russia:

- 2005-2008 (pre-crisis period and global financial crisis);
- 2009-2011 (consequences of the global financial crisis);
- 2012-2014 (recovery period after the global financial crisis);
- 2015-2018 (period of sanctions);
- 2019-2021 (period of tougher sanctions and the Covid-19 pandemic).

A similar procedure for choosing the optimal model was carried out on the selected time intervals. For all periods, the “Random Forest” algorithm showed the best predictive ability compared with others. The partial contribution is a result of constructing a regression model for the selected 17 indicators. Each individual decision tree is generated using metrics for selecting indicators according to the MDI (mean decrease in impurity) criterion to calculate the importance of each feature, that is, the contribution of each indicator to the forecast of the impact on the required indicator. The Scikit-learn library automatically calculates the relevance of each feature at the training stage. Then the partial results of the factor influence were summed up taking into account the belonging of the indicators to the corresponding block of factors.

Since out of all multiple factors that affect public health, we have selected only the main socio-economic indicators characterizing their impact, to simplify the result visualization, we proceeded from the assumption that the total contribution of socio-economic factors to mortality equaled to 100%.

Results

Each of the selected time intervals has its own specific factor impact on the dynamics in mortality in the Russian population affecting the contribution of each factor to crude death rate at each of the time intervals under study and for the entire period (Table 3).

Table 3. Partial contribution of socio-economic development factors to mortality in Russia in 2005-2021

Factor blocks	Indicators	Partial contribution, %					
		2005-2008	2009-2011	2012-2014	2015-2018	2019-2021	2005-2021
Employment and labour market	share of people employed in jobs with hazardous and (or) dangerous working conditions, %	0.9	4.3	2.7	16.3	7.7	7.7
	share of the employed with higher education, %	2.0	5.8	4.2	2.1	5.9	4.9
	share of industry in the gross value added of the Russian regions, %	1.7	2.2	1.2	1.5	3.5	1.4
	unemployment rate, %	4.5	1.0	7.4	20.7	17.5	2.3
	Block total	9.1	13.3	15.5	40.6	34.6	16.3
Healthcare	capacity of outpatient facilities, visits per shift per 10,000 population	1.8	11.9	18.6	4.8	3.3	2.5
	total morbidity per 1,000 people of the population	13.7	1.5	1.6	1.7	2.6	1.6
	nursing personnel per 10,000 population	1.7	1.7	1.5	2.7	4.2	5.7
	doctors per 10,000 population	3.3	1.2	1.7	1.1	2.0	2.2
	hospital beds per 10,000 population	25.3	2.5	2.1	2.1	2.5	4.2
	Block total	45.8	18.8	25.5	12.4	14.6	16.2
Life safety	registered crimes per 10,000 population	19.6	38.4	31.8	7.6	4.0	38.9
	Paved road density, km per 1000 km ²	7.7	14.2	7.6	12.0	9.9	13.7
	share of household spending on alcohol, %	1.8	1.8	0.5	1.4	1.2	0.8
	share of budget spending on health, physical education and sports, %	1.7	1.1	1.0	0.4	13.9	1.9
	Block total	30.8	55.5	40.9	21.4	29.0	55.3
Standard of living	state budget expenditures per capita, thousand rubles	9.0	2.5	10.8	15.7	6.9	4.8
	share of budget expenditures on social support, %	1.7	1.4	2.8	0.4	2.6	2.3
	number of own cars per 1000 population	1.2	1.2	1.1	2.1	10.2	1.6
	purchasing power of wages (average wage to subsistence minimum among working population), times	2.4	7.3	3.4	7.4	2.1	3.5
	Block total	14.3	12.4	18.1	25.6	21.8	12.2
	Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: compiled by the authors.

Table 3 shows that each time interval within the entire period of 16 years is characterized by a different impact strength of the factors on crude death rate. Partial contribution of each factor expressed as a percentage can be regarded as an objective situation characterizing the level of health protection.

Below, we will analyze peculiar features of each of the time intervals selected, based on the modeling results summarized in Table 3.

In the period from **2005 to 2008**, Russia was characterized by economic and social stability, supported by a favorable foreign economic and political environment. There was an increase in the total GRP compared to previous years. The share of the population with income below the subsistence minimum decreased from 17.7% in 2005 to 13.1% in 2008, while the unemployment rate went down from 7.2% to 6.3%, respectively. In general, favorable trends in the socio-economic development contributed to a decrease in mortality from 16.1‰ in 2005 to 14.2‰ in 2008.

Despite certain problems in healthcare during this period, it was this factor that had a significant impact on public health. First, a negative impact on mortality is associated with the reduced number of hospital beds (25.3%) and increased prevalence (13.7%). In addition, important indicators characterizing factor impact on health during this period included the number of registered crimes (19.6%), budget expenditures per capita (9.0%), as well as road density (7.7%). The growth of economic activity contributed to a higher employment, including jobs with hazardous and dangerous working conditions. In production, transport and communication, the share of those employed in jobs with unhealthy and dangerous working conditions increased from 27% in 2005 to 34% in 2008 (Rosstat Share...), however, this factor did not have any significant impact on mortality during the analyzed period (with a contribution of only 0.9%).

The period from **2009 to 2011** is characterized by a crisis and post-crisis economy, accompanied by increased social tension. In 2009, there was a decline in real incomes and employment, the unemployment rate rose up to 8.4%. The share of jobs with hazardous and dangerous working conditions in the economy remained high with a tendency towards rising (from 37.9% in 2009 to 40.7% in 2011). By the end of the analyzed period, however, the socio-economic situation had somehow improved. The state anti-crisis business and population supportive measures had a significant positive impact resulting in stabilized employment and consumer demand by 2011. Largely due to the focused policy, the unemployment rate fell to 6.6% by the end of the period.

In general, the socio-economic instability of this period, declining incomes and confidence in the future had a negative impact on the level of security in society, so that this factor became key in defining mortality (55.5%), primarily, the crime rate (38.4%).

During this period, the healthcare reforming was initiated to optimize costs resulting in further reduction in the number of beds and increase in the number of outpatient visits per shift. The reduced availability of state medical care was associated with a significant decrease in the contribution of the healthcare factor to public health (down to 18.8%). Such factors as employment and labour market, standard of living in general had significantly less influence on the dynamics in mortality (13.3% and 12.4%, respectively).

The next period from **2012 to 2014** is associated with complications in the foreign policy situation. At the same time, socio-economic processes within the country have a positive trend, the total GRP is growing, while unemployment continues to decline (from 5.5% in 2012 to 5.2% in 2014). However, there are certain negative trends including a further deterioration of working conditions (the share of those employed in jobs with unhealthy,

hazardous and(or) dangerous working conditions reached 53% by 2014), as well as deterioration of the healthcare performance associated with further reduction in the number of beds and stagnated outpatient capacity resulting in a lower access to health care in reality. During this period, the major factors of public health are the factors of life safety (40.9%) and healthcare (25.5%), while the leading indicators included the crime rate (31.8%) and outpatient capacity (18.6%), however, their influence decreased compared with the previous period. At the same time, the importance of employment and labour market and living standards increased (15.5% and 18.1%, respectively) as well as budget expenditures per capita (10.8%).

During the period from **2015 to 2018**, on the one hand, the Russian economy has already recovered from the crisis and showed a growth; on the other hand, the foreign sanctions were imposed to ban the access to foreign markets initiating negative processes in the economy. At that time, the volume index of the total GRP was 100-103% and tended to decrease. Mortality during this period continued to decline from 13.0‰ in 2015 to 12.5‰ in 2018. At the same time, the average morbidity remained stable at about 78.1 thousand newly diagnosed cases per 100000 population. The share of those employed in jobs with hazardous and dangerous working conditions in industry and transport remained high, equaling to 52.7% in 2018, resulting in a negative contribution of working conditions to the required indicator. Healthcare remained a tendency towards changing priority forms of interaction with the population: the availability of inpatient medical care was reducing while the access to outpatient care was expanding.

This period was characterized by a lower negative impact on health of such factors as life safety and healthcare – a decrease to 21.4% and 12.4%, respectively. Employment factors topped the list with a contribution of 40.6%, including 20.7% associated with unemployment and 16.3% related to employment in jobs with hazardous and dangerous working conditions. The standard of living also becomes an important factor of public health (25.6%), primarily budget expenditures per capita (15.7%).

The socio-economic development of Russia in **2019-2021** was characterized by the increasing impact of the sanctions, severe consequences of the lockdown during the pandemic of a new coronavirus infection and, accordingly, a decrease in the volume index of the total GRP to negative values. The exception is 2021 with the rise in GRP marking the beginning of the economic recovery. It is obvious that during this period, the excess mortality from Covid-19 was growing, as well as mortality associated with strong restrictions on receiving medical care during the pandemic such as quarantine or repurposing to treat Covid-patients. Thus, the crude death rate increased from 12.3‰ in 2019 to 16.7‰ in 2021. Morbidity also significantly increased from 78 thousand newly diagnosed cases per 100000 population in 2019 to 85,7 thousand in 2021.

The healthcare was struggling through a crisis. On the one hand, the pandemic of a new coronavirus infection has introduced serious changes such as deployment of additional beds in hospitals, expanding the number of doctors and nursing personnel to combat the new coronavirus infection. On the other hand, optimization of health care delivery continued, and following the decline in the Covid-19 incidence, the dynamics in health indicators returned to the previous trajectory.

At the same time, the quality of employment somehow improved during this period. The share of those employed in jobs with hazardous and dangerous working conditions decreased from 53.8% in 2019 to 52.6% in 2021, while the unemployment rate remained stable equaling to 4.6-4.8%, with individual spikes in the lockdown months.

Thus, it is the pandemic and its medico-demographic and socio-economic consequences that determined the mortality dynamics in 2019-2021. A partial contribution of individual socio-economic factors reflects this impact. Employment factors (34.6%) including unemployment (17.5%) play a leading role in shaping public health as key sources of social stress. Safety factors rank second (29.0%), budget expenditures on healthcare, physical education and sports (13.9%) have a defining role as a factor of higher state financing of healthcare during the pandemic. It should be noted that, despite significant public spending to support the healthcare system during the pandemic, the development of the healthcare itself had a little effect on reducing mortality (14.6%). Among factors of living standards, one should note an increasing role of budget expenditures on social support of the population and business in the conditions of the coronavirus-associated restrictions, however, the targeting of such support has decreased its contribution to mortality comparing to the previous period, and the role of such a factor as budget expenditures per capita in the partial contribution went down to 6.9%.

Summarizing data for the entire period from 2005 to 2021, we should note that life safety (55.3%) and healthcare (16.2%) as well as employment and the labour market (16.3%) had the greatest contribution to dynamics in death rate as the most important indicator of public health. The impact of standard of living equaled to 12.2%.

The leading indicators contributing to dynamics in death rate included the factors of avoidable mortality such as the number of registered crimes (38.9%) and paved road density (13.7%), as well as the share of people employed in jobs with hazardous and dangerous working conditions (7.7%). Such factors determine security in society and self-protective behaviour.

Conclusions

The research has corroborated the hypothesis that factors defining the socio-economic situation in the country have a considerable impact on public health, while the strength of the impact varies depending on their peculiar features in each specific period. The hypothesis was tested by analyzing dynamics in crude death rate as an important demographic indicator of public health. Using the machine learning and data mining methods we have established that in each time period under study the impact of socio-economic factors on mortality differed in strength and direction. A significant impact on the increase in mortality is associated with life safety factors, primarily crime rates, as well as factors characterizing effectiveness of the healthcare system, which during the study period underwent reforming and significant resource mobilization in the context of the Covid-19 pandemic. Working conditions and unemployment, as well as the standard of living, had a lesser impact on public health, however, such impact must be taken into account in the context of lifestyle and the level of self-protective behaviour of the population.

The results of the proposed methodological approach should be taken into account to predict the level of impact of the socio-economic factors on demographic processes in order to develop and adjust directions of the state policy aimed at improving public health and self-protective behaviour of the population, and reducing mortality from a complex of external causes of social and economic nature.

In general, assessing partial contribution of the socio-economic factors to the dynamics in demographic indicators of public health, such as fertility, mortality, and life expectancy can be an important supplementary to research in this field.

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