PROBLEMS OF MORTALITY ANALYSIS IN TOWNS OF THE RUSSIAN FEDERATION

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Mortality rate is one of the main indicators of how healthy a population is, and planning and implementing measures aimed at reducing morbidity and increasing life expectancy in the population is impossible without an adequate analysis and interpretation of mortality data. At the same time, as pointed out by many researchers, there are factors external to a human body being that can have a significant effect on the mortality rate in a population. This study aimed to assess the impact of one of these factors, the number of beds in hospitals (per 10,000 people) of cities with population exceeding 100,000 people. The analysis included data from Rosstat (Russian statistics service) on the population size, mortality, number of hospital beds, average monthly wages in 12 cities within the period from 2017 through 2019. Five cities from these 12 were selected as a more homogeneous subgroup in terms of socio-economic conditions. We found a positive correlation between mortality rate per 1000 inhabitants ($R > 0.7$; $p < 0.009$) and the number of hospital beds per 10,000 people in the sample of 12 cities. This correlation was higher ($R \geq 0.9$; $p < 0.037$) in the more homogeneous subgroup. A factor that may condition this correlation may be that of deaths of people from other regions in hospitals of the cities in question, which are counted when estimating the mortality rate and have a significant effect on that estimation. The results of the study point to the need to differentiate between people registered in a city and those living there permanently when assessing mortality rate therein.

Keywords: mortality, access to medical care

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ПРОБЛЕМЫ АНАЛИЗА СМЕРТНОСТИ В ГОРОДАХ РОССИЙСКОЙ ФЕДЕРАЦИИ

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Уровень смертности является одним из основных индикаторов здоровья населения, поэтому планирование и проведение мероприятий, направленных на снижение заболеваемости и увеличение продолжительности жизни населения, невозможны без адекватного анализа и интерпретации данных о смертности. Вместе с тем, как отмечают многие исследователи, существуют внешние для организма человека факторы, которые могут существенно влиять на показатели смертности населения. Целью работы было оценить значимость влияния одного из таких факторов — размера коечного фонда больничных организаций (на 10 тыс. населения) — в городах с населением более 100 тыс. человек на показатели смертности населения в этих городах. В анализ были включены данные Росстата за 2017–2019 гг. о количестве населения, смертности, количестве больничных коек, среднемесячной заработной плате в 12 городах. Из этих городов была сформирована более однородная по социально-экономическим условиям подгруппа, включающая 5 городов. Выявлено, что показатель смертности населения на 1000 жителей положительно коррелировал ($R > 0,7$; $p < 0,009$) с числом больничных коек на 10 тыс. населения в группе из 12 городов и корреляция была выше ($R \geq 0,9$; $p < 0,037$) в более однородной подгруппе. Указанная закономерность может быть обусловлена тем, что при оценке показателей смертности населения значимым оказывается вклад количества умерших в городских стационарах жителей других регионов. Полученные результаты указывают на необходимость при изучении смертности населения в городах анализировать число смертей, не только зарегистрированных в городе, но и постоянно проживающих в нем жителей.

Ключевые слова: смертность, доступность медицинской помощи

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Since mortality rate is one of the main indicators of how healthy a population is, adequate analysis and interpretation of the data on mortality are mandatory prerequisites for measures aimed at reducing morbidity and increasing life expectancy in a population.

As of 2019, there were over 1100 cities in Russia. Most of them (about 1000) are cities with a population of less than 100,000 people, i.e. medium and small towns [1]. Most of the restricted administrative-territorial entities and territories serviced by the Federal Medical Biological Agency (FMBA) of Russia also fall into this category [2]. Relatively small population in such localities considerably impedes statistical analysis of data on mortality of the population stratified by sex, age and cause of death [3].

In addition, it should be noted that such factors as the rules of death registration and indication of the cause thereof, which are essentially external to the human body, have an effect on the mortality data [4, 5]. Throughout the world, it is common practice to keep track of morbidity and causes of death relying on the 10th revision of the International Classification of Diseases (ICD 10). Many researchers note that in the Russian Federation there is a relatively high percentage of fatalities the conditions of which are recorded in an obscure way: "injuries with uncertain intentions", "ill-defined and unspecified causes of

death", "unspecified cardiomyopathy", "old age" [6–10]. These causes of death can be used to underrate contribution of the so-called "socially significant causes of death" (alcohol and drug poisoning, murder and suicide) and causes that were targeted with a mitigation and reduction plan (diseases of the circulatory system) [7]. Some causes of death that were registered as belonging to the circulatory system diseases category before 2013 have been attributed to other categories thereafter, which significantly distorts the real structure of mortality in a population [6]. High losses from ill-defined conditions disallow adequate assessment of the potential for reducing mortality and development of the effective prevention measures.

Another factor that significantly distorts mortality statistics is the following one. Currently, in addition to the deaths of city residents, indicators of mortality in a given city incorporate deaths of persons who permanently lived in another place but died and were registered dead (Civil Registry Office) in that given city [7, 11]. This problem has been analyzed in greatest detail for Moscow [11, 12]. The large population of the metropolis allows obtaining the most reliable and reproducible results; they clearly show the significance of this problem. In addition, at any given moment there is a significant population of migrants in Moscow that includes both citizens of other countries and Russian nationals from other regions of the country. In 2003, migrants that died from neoplasms in Moscow made up 5.3% (men) and 6.3% (women) of the respective mortality rate for the entire population of the city, and the shares of migrants in the category of deaths from circulatory system diseases were 8.4% (for men) and 6.0% (for women) [11]. At the same time, the contribution of this population group to mortality from infections, injuries and poisoning, as well as inaccurately described conditions, was over 33% for men and more than 25% for women; from a quarter to a third of all deaths from all major causes at a young working age also happened in this group. The revealed patterns persisted through 2013. The authors of this study conclude that if only the residents of Moscow were factored in, the mortality rate there would have been lower than what is recorded by the statistics currently, and the structure of causes of death would be closer to that seen in European countries due to lower mortality from external causes. Similar patterns were also registered in other regions of the Russian Federation [13].

In addition, city hospitals throughout the Russian Federation set up primary vascular departments, and there are also dedicated regional vascular centers established. In a centralized manner, these medical facilities receive patients with the most severe cardiovascular pathologies, and these patients come not only from the city where such center/hospital department operates but also from other cities, towns and villages. On the one hand, the said centers/hospital departments improve accessibility of qualified medical care for the population, and on the other hand, they contribute to the city's mortality rates because deaths of patients from outside the city are factored in when calculating the respective indicators. This factor has the greatest impact on mortality rates in cities with relatively small populations. Another factor that significantly affects a small town's mortality rates but bears no relation to the state of health of its population is the presence of penitentiary facilities therein, which show high mortality from socially significant diseases [14].

It should be noted that a complete and detailed analysis of the death rate of residents of a given city is required in order to implement targeted measures that account for the specifics of that city, such analysis factoring in all possible statistical artifacts. Small sample size makes conducting such an analysis in small towns most difficult. It seems appropriate to target larger cities with analytical studies in order to identify the possible statistical artifacts. Such studies should include cities with similar natural-climatic and socio-economic conditions, since this approach allows excluding the impact of factors of natural conditions (how favorable they are) and living standards, which are significant for public health. As noted above, one of the possible statistical artifacts that can affect the mortality rates in a city is the presence of a large hospital therein, including a dedicated regional vascular center, since this would mean that the overall number of the deceased recorded in the that city will include deaths of people from other cities and regions [7, 11]. This allows hypothesizing that the number of hospital beds (per 10,000 people of population) can affect the mortality rate (the number of deaths per 100,000 residents) in cities with a population of up to 500,000 people. It is obvious that this factor will be of smaller significance in the largest cities and cities with over a million residents.

The purpose of this study was to assess the significance of impact of the number of hospital beds (per 10,000 people of population) on the mortality rates in the cities of the Moscow region with a population ranging from 100,000 to 500,000 people.

METHODS

The study included 2017–2019 Rosstat [15] data on the number of deaths per 1000 people, the average monthly nominal accrued salaries, the number of hospital beds in round-the-clock hospitals (per 10,000 people), as well as the population of 12 cities of the Moscow region (range from 100,000 to 500,000 people). The study included: 1) only the cities that have the all the indicators considered in the study published in freely available press; 2) only the cities of the Moscow region, which nullifies the effect differences in natural and climatic conditions have on mortality rates (the entire Moscow region is in the same climatic zone) and reduces the impact of socio-economic conditions. To improve accuracy of the assessment of possible impact of living standard on the mortality in a population, the analysis included data on the average monthly nominal accrued wages.

Table 1 presents data on the main group (12 cities, G_12) population in 2017 and shows the proportion of people outside the working age.

Spearman's rank correlation coefficient (*R*) was used to assess the statistical dependence between the studied indicators. Descriptive statistics data are presented in the tables as a median (Med) and an interquartile range (Q_1; Q_3). To assess reproducibility of the identified patterns, we analyzed the statistical relationship separately for each year (2017, 2018, 2019). The study analyzed statistical relationship between the mortality rate (the number of deaths from all causes per 1000 people), the average monthly nominal accrued wages of employees and the number of hospital beds in round-the-clock hospitals (per 10,000 people of population). Additionally, we analyzed such indicators as the share of residents over the working age (according to Rosstat [15]) and distance from the considered city to the center of Moscow. These indicators were included in the analysis to form a more homogeneous subgroup and thus eliminate the influence of the following factors: transport accessibility of medical institutions located in the regional center and share of older age people.

Since a relatively small sample size disallowed multivariate analysis, we formed a relatively homogeneous group of cities (G_5) lying within 30 kilometers from the center of Moscow (Balashikha, Khimki, Reutov, Mytishchi, Korolev) where the average monthly nominal accrued wages of exceeded 50,000 RUB in 2017.

Table 1. Population in the studied cities in 2017

	Population at the end of 2017, thousand human	Share of residents over the working age, %
Domodedovo	127.9	20
Balashikha	468.2	20
Reutov	103.8	23
Khimki	250.7	23
Mytishchi	211.6	22
Elektrostal	158.2	28
Korolev	223	27
Serpukhov	125.8	27
Zhukovsky	108.2	29
Podolsk	302.8	24
Kolomna	142.7	29
Orekhovo-Zuevo	118.8	27

Table 2. Statistical characteristics (median, lower and upper quartiles) of the studied indicators in the G_12 group

	Med (Q_1;Q_3)		
	2017	2018	2019
Mortality (per 1000 people)	12.25 (10.8; 13.7)	12.1 (10.6; 14.1)	11.65 (10.2; 13.7)
Number of hospital beds (per 10,000 people)	48.2 (35.0; 58.7)	47.4 (33.0; 55.8)	47.45 (32.6; 54.3)
Average salary	52,133 (44,795; 58,443)	57,551 (48,286; 65,401)	62,727 (51,390; 69,294)

RESULTS

Table 2 presents the statistical characteristics of such studied indicators as the population mortality rate (per 1000 people), the number of hospital beds in round-the-clock hospitals (per 10,000 people) and the average monthly salary in 12 cities (G_12) in 2017–2019.

At the first stage, we analyzed the dependence of population mortality rates on the number of hospital beds and the level of wages, as well as on such factors as the share of people above working age (in 2017) and distance to the center of Moscow.

Table 3 presents Spearman's correlation coefficients between population mortality rates, number of hospital beds and the level of salary in the G_12 group.

The mortality rates per 1000 residents correlated ($R > 0.7$) with the number of hospital beds per 10,000 people. This dependence is highly significant; it was registered every year. The correlation coefficient between wage and mortality rates was negative, smaller in absolute value and also differing significantly from 0 every year.

We have analyzed the values of Spearman's correlation coefficients between the mortality rates and the share of population over working age in 2017, as well as between the mortality rates and the distance to the center of Moscow. The former was 0.675 ($p < 0.016$) and the latter 0.904 ($p < 0.0001$).

Thus, there is a strong statistical relationship between mortality rates in the population, number of hospital beds and distance from the considered city to the center of Moscow (positive relationship). The relationships with wages (negative) and the share of population over the working age (positive relationship) are not as strong.

Having identified these patterns, we additionally analyzed the values of Spearman's rank correlation coefficients between the distance to the center of Moscow and wages, as well as the distance to the center of Moscow and the share of population over the working age. All the correlation coefficient values differed from 0 significantly ($p < 0.04$) and amounted to –0.601, –0.629, –0.625 for wages in 2017, 2018 and 2019, respectively, and 0.615 for the share of population over the working age in 2017. To a large extent, the identified dependencies on the distance to the center of Moscow are conditioned by the specifics of the cities of Orekhovo-Zuevo, Kolomna, Serpukhov, Elektrostal, which are 60–115 km away from Moscow. There, the wages were lowest (in 2017 — 42,000–45,000 RUB), the proportion of residents over the working age was 27–29% and the number of hospital beds per 10,000 people was largest (from 13 to 16.7).

The identified significant patterns, on the one hand, and the small sample size, on the other hand, necessitated formation of a more homogeneous group of cities. This group consisted of five cities (G_5) located within a 30-kilometer radius from the center of Moscow: Balashikha, Khimki, Reutov, Mytishchi, Korolev. The average monthly nominal accrued wages therein exceeded 50,000 RUB in 2017. Table 4 presents the statistical features of the studied indicators in this group, which show that on average, both the mortality rate and the number of hospital beds are smaller in this subgroup.

Table 5 shows the G_5 Spearman's rank correlation coefficient values of the population mortality rates, wages and the number of hospital beds in 2017, 2018 and 2019. In a subgroup of cities relatively homogeneous in terms of socio-economic conditions, an even stronger positive statistical relationship was registered between the population mortality

Table 3. Spearman's correlation coefficients (*R*) between population mortality rates, salary and the number of hospital beds in 2017, 2018 and 2019, group G_12

	2017		2018		2019	
	R	*p*	*R*	*p*	*R*	*p*
Number of hospital beds (per 10,000 people)	0.828	0.001	0.727	0.007	0.709	0.009
Average salary	–0.585	0.046	–0.594	0.042	–0.628	0.029

Table 4. Statistical characteristics (median, lower and upper quartiles) of the studied indicators in the G_5 group

	Med (Q1;Q3)		
	2017	2018	2019
Mortality (per 1000 people)	9.5 (8.7; 11.2)	9.4 (8.4; 11)	9.3 (8.0; 10.5)
Number of hospital beds (per 10,000 people)	35.8 (32.4; 42.0)	34.3 (29.2; 39.8)	33.3 (30.5; 37.7)
Average salary	52,602 (51,664; 60,621)	60,349 (58,106; 66,172)	65,233 (63,066; 69,031)

Table 5. Spearman's correlation coefficients (*R*) between population mortality rates, salary and the number of hospital beds in 2017, 2018 and 2019, group G_5

	2017 г.		2018 г.		2019 г.	
	R	*p*	*R*	*p*	*R*	*p*
Number of hospital beds (per 10,000 people)	0.975	0.005	0.9	0.037	0.975	0.005
Average salary	0.5	0.391	0.7	0.188	0.668	0.219

rate and the number of hospital beds ($R \geq 0.9$), while there was no significant dependence on salary recorded.

We identified no significant dependence of the G_5 population mortality rate on the distance to the center of Moscow and the share of people over the working age in 2017. The respective correlation coefficients amounted to 0.4 ($p = 0.505$) and 0.7 ($p = 0.188$).

DISCUSSION

The results of this study, which considered 12 cities of the Moscow region, confirmed the well-known negative correlation between population mortality rate and standard of living [8, 12, 16, 17] (in this study — between mortality and the average monthly nominal accrued salary).

This study has also revealed a positive correlation between the number of deaths per 1000 people of population, a widely used indicator in healthcare, and the number of hospital beds in round-the-clock hospitals (per 10,000 people of population), another widely used indicator. The latter indicator (number of beds) also characterizes availability of medical care [18]. The apparent contradiction — mortality is higher with greater availability of medical care in a hospital setting - has the following reasons behind it. Hospitals, especially in regional centers, admit not only residents of the city where they are located but also residents of the neighboring towns and villages, as well as people from other regions. When a patient dies, the death can be registered in the city of the hospital [7, 11]. This applies, first of all, to the residents of other subjects of the Russian Federation and foreign countries. It should be noted that in the largest cities and cities with over a million residents there is no effect from large medical institutions on the overall death rate assessment, since residents of these cities constitute the majority in the number of deaths per 1000 people of population in these cities. In small towns, on the contrary, deaths of non-residents in hospitals have had a greater distorting effect on mortality rates therein. This is of particular importance in cities located in the territories served by the FMBA of Russia. A significant part of the nuclear industry workers are exposed to low doses of ionizing radiation throughout their professional life, which potentially contributes to the development of malignant neoplasms and diseases of the circulatory system, the two main causes of death of the population [19–21]. At the same time, as shown by this study, presence of a regional vascular center, for example, in the city of Severodvinsk (population 180000 people, there are shipyards repairing nuclear submarines therein), can, to some extent, condition the increased mortality from the circulatory system diseases in this city [22].

The results of this study are consistent with the results of other researchers who have identified statistical artifacts in assessing a city's mortality rates, such artifacts resulting from the presence of a significant number of labor migrants therein, which translates into the increased number of deaths from infectious diseases and external causes [11–13].

The results published in this article indicate that studying population mortality rates of relatively small cities it is necessary to analyze not only the number of deaths registered in the city but also the number of deaths of permanent residents of this city.

CONCLUSIONS

Medical care availability indicators have an ambiguous association with health status indicators in cities. An adequate assessment of the mortality rate in small towns requires accounting for the possible contribution of deaths of residents of other regions to the overall number number of deaths therein. This contribution is directly related to the number of hospital beds in round-the-clock hospitals.

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