Regional Living Conditions and the Prevalence, Awareness, Treatment, Control of Hypertension at the Individual Level in Russia

Sergey Alekseevich Maksimov (m1979sa@yandex.ru)
National Medical Research Center for Therapy and Preventive Medicine

Yulia A. Balanova
National Medical Research Center for Therapy and Preventive Medicine

Svetlana A. Shalnova
National Medical Research Center for Therapy and Preventive Medicine

Galina A. Muromtseva
National Medical Research Center for Therapy and Preventive Medicine

Anna V. Kapustina
National Medical Research Center for Therapy and Preventive Medicine

Oksana M. Drapkina
National Medical Research Center for Therapy and Preventive Medicine

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Abstract

Background. The objective of this study was to analyze the influence of the living characteristics of large regions on the possible presence, awareness, management and control of hypertension at the individual level in the Russian population.

Methods. Regional characteristics were obtained from the official website of the Federal State Statistics Service of Russia. Principal component analysis was used to reduce the dimensionality of data; it allowed defining 5 integral regional indices: Socio-Geographical, Demographic, Industrial, Mixed, Economic. Presence, awareness, management and control of hypertension were assessed according to the data of the cross-sectional stage of ESSE-RF study that was conducted in 2013-2014. The final sample included 19,791 patients from 12 regions of Russia. Generalized estimation equations were used to determine associations between regional indices and presence, awareness, management and control of hypertension at the individual level taking into consideration nested data structures (individuals in regions).

Results. The Socio-Geographic Index demonstrated the positive impact on hypertension among male (OR = 1.18; 95% CI: 1.05-1.32), undereducated individuals (OR = 1.14; 95% CI: 1.02-1.27) and elderly people (OR = 1.16; 95% CI: 1.02-1.32). Awareness of hypertension is positively associated with Demographic (OR = 1.13; 95% CI: 1.02-1.25) and Industrial Indices (OR = 1.15; 95% CI: 1.01-1.33). Worsening of social environment (Socio-Geographic Index) reduces adherence to management (OR = 0.76; 95% CI: 0.64-0.90) and control of hypertension (OR = 0.79; 95% CI: 0.69-0.90). Impact of regional living conditions on the prevalence of hypertension is not high, compared to the individual predictors, but for the awareness, treatment and control of hypertension, this influence is important.

Conclusions: The study performed allowed assessing the influence of living characteristics of the population in the large regions of Russia on the prevalence of hypertension and on the awareness, management and control of this disease. The data obtained provide new knowledge not only in terms of epidemiology of cardiovascular diseases in Russia but also in general, that is, in the context of studying the influence of living conditions on the health of population.

Introduction

Arterial hypertension is the most important modifiable risk factor for cardiovascular diseases [1]; impact on it can reduce cardiovascular and overall mortality [2, 3]. Kearney P.M. et al. in their systematic review demonstrated that the prevalence of hypertension in population 20 + in the world ranges from 28.5% in the countries with a high level of economic development to 31.5% in countries with a low level of development [4]. The authors mentioned significantly increased incidence of hypertension in the world over the period from 2000 to 2010 (from 25.9–31.1%). In addition, increased awareness of this disease (from 41.4–46.5%), treatment coverage (from 31.8–36.9%) and its effectiveness (from 33.9–37.1%) were also observed during this period.

In general, global studies demonstrate significant differences in the prevalence of hypertension in the countries of the world [5, 6, 7]. For example, an analysis of global trends in blood pressure from 1975 to 2015 that included 1,479 studies with a total population of 19.1 million revealed that over the past four decades high blood pressure levels have shifted from high-income countries to low-income countries in South Asia and sub-Saharan Africa; moreover, blood pressure was consistently high in the regions of central and eastern Europe [8]. The prevalence of hypertension within these global regions varies significantly across different countries. For example, the prevalence of hypertension in sub-Saharan Africa in 2008 was estimated at 16.2% ranging from 10.6% in Ethiopia to 26.9% in Ghana [9]. In the countries of Eastern Europe the value of this parameter was higher – in Serbia 46.8% and 46.2% for men and women, respectively [10]; in Romania – 50.2% and 41.1%, respectively [11]; in Poland – 42.1% and 32.9%, respectively [12], in Lithuania – 44.4% and 49.0%, respectively [13]; the population parameter in the Czech Republic was 43.6% [14], and in Belarus – 36.4% [15].

In addition to interstate differences, many sources describe territorial differences in the prevalence of hypertension within specific countries [16, 17, 18, 19]. At the same time, we surely should mention that individual characteristics have a significant impact on the prevalence, awareness, management and control of hypertension [7, 20], and differences in the structure of population based on the individual characteristics of living areas can, to a certain extent, also cause geographical differences. However, results of studies revealed that there are territorial differences in the prevalence of this disease – additionally to the considered individual features. Even the results of the MONItoring of trends and determinants in CArdiovascular disease (MONICA) project of the World Health Organization revealed that population factors in territorial units explain up to 7–8% of all differences in systolic blood pressure [21]. A particularly strong (up to 20%of the contribution) population effect was found among individuals who took antihypertensive treatment and among women with overweight.

The PURE global study has demonstrated differences in the prevalence, awareness, management and control of hypertension depending on the level of gross national income (according to the World Bank) in several countries of the world [22]. In addition the groups of countries stratified by income (high-, middle-, and low-income countries), within these groups, there are also differences between countries in the prevalence, awareness, management and control of hypertension. This indicates that the level of gross national income is only one of the state factors that have an effect on the prevalence of hypertension. In terms of ecoepidemiology, fundamental factors of different nature, mainly of social one, have an effect on intermediate factors, and these, in turn, influence either behavioral factors, or indirectly – direct factors of cardiovascular risk [23, 24, 25]. Intermediate factors include specific relationships at the local level, public investment and municipal support, legislative and political competence of authorities, physical environment, including artificial one.

Several world-leading epidemiologists Chow C.K., Teo K., Subramanian S.V., McKee M., Yusuf S. mentioned that [26]: «…Historical research demonstrates the impact on health of change in social and physical environments… These observations have highlighted the influential role of population level determinants of health… They are sometimes expressed as ‘upstream’ determinants, such as social

norms, culture and geography, which shape behaviour, as well as the political, economic and legal factors that encourage or constrain the choices that individuals make. There is a now a growing body of research addressing these issues, from a range of disciplinary perspectives… The evidence reviewed above shows that the environments that individuals inhabit influence their risk of CVD, and there are a growing number of methods by which these environments can be assessed. Yet, while population level interventions offer considerable promise for prevention of CVD, they have received much less attention than individual determinants of disease…».

Place of living and its characteristics at different levels have an effect on cardiovascular diseases (CVD): the possibility of developing coronary heart disease [27, 28, 29, 30], myocardial infarction [31], ischemic stroke [29, 32], mortality from CVD [30, 33, 34], hospitalization for CVD [35]. Several publications have demonstrated that territorial features of the place of living have an effect on the prevalence, awareness, management and control of hypertension [36, 37, 38]. Moreover, there are many articles that address the issue of the influence of individual living environment [39, 40]. However, it should be mentioned that almost all found sources on hypertension describe small areas; there are just sporadic studies of associations at the level of states or large regions. Such papers include a population study of large regions in Columbia [41], as well as a study performed in the United States where the impact of socioeconomic characteristics of states at an early age on the possibility of hypertension development was analyzed using the example of Alcoa employees [42].

It should be emphasized that in the large majority of studies, territorial features were considered as 1–2 independent socio-economic parameters: Gini index, crime, average annual income, etc [41, 43, 44, 45], or economic parameters: indices of poverty, deprivation, etc [46, 47, 48]. Only one study was found with an empirical approach and 4 latent factors out of 20 territorial parameters including racial/ ethnic composition, socioeconomic status, age composition, family structure, owner-occupied housing, and housing stability [37]. It is just such empirical studies that allow assessing the whole variety of factors (in addition to socio-economic ones) that have an impact on the state of health.

Epidemiology of hypertension in Russia was studied nationwide in recent years in Epidemiology of Cardiovascular Diseases and Risk Factors in the Regions of the Russian Federation study in 2012–2013 (ESSE-RF-1) and in 2017 (ESSE-RF-2), and similar results were obtained [18, 49]. According to the results of ESSE-RF-2, the prevalence of hypertension was 44.2%; the awareness of this disease was higher among women – 76.8% compared to 69.4% among men; treatment coverage was 53%; half of patients taking antihypertensive drugs (49.7%) control their blood pressure, but if we speak about all subjects with hypertension – only less than a third (24.9%) did the same [18]. ESSE-RF-1 study, with 13 regions of the country involved, revealed regional differences in the prevalence, awareness, management and control of hypertension [49]. However, we don’t know whether it is also influenced by the territorial characteristics of the living conditions of population, in addition to the individual characteristics of the structure of regional samples. No such multilevel analysis has been carried out. The objective of this study was to study the influence of regional characteristics on the possibility of the presence, awareness, management and control of hypertension at the individual level in a cross-sectional study of the Russian population.

Methods

Sample characteristics

Data for analysis were obtained from the cross-sectional stage of Epidemiology of Cardiovascular Diseases and Risk Factors in the Regions of the Russian Federation study (ESSE-RF) that was conducted in 2013–2014 in 13 regions of Russia. More details on the sampling and protocol of ESSE-RF study were presented in the earlier paper [50]. Sampling was performed with the help of Kish method that provided for a systematic, multi-stage, random selection on a territorial basis based on medical institutions. The study was carried out in accordance with the Good Clinical Practice standards and the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment. Percentage of examined subjects was about 80%, with some variations across the study regions.

The primary sample included 21,923 individuals aged 25–64. A subgroup from St. Petersburg (1,588 subjects, 7.2%) was removed from this sample due to the fact that this territory differs significantly in its regional characteristics from the other 12 regions included in the study. The city of St. Petersburg is classified as a separate administrative unit of the Russian Federation, while the other 12 regions represent large territories with both urban and rural areas. Then, participants with incomplete data or with no information about hypertension were also removed from the sample (535 subjects, 2.6%). Then we removed from the sample individuals who did not answer the question: “Have a physician or another medical professional ever told you that you have high blood pressure?” (9 subjects, 0.04%). The final sample amounted to 19,791 subjects.

The final sample included no data on income (248 subjects, 1.2%), obesity (211 subjects, 1.1%), marital status (150 subjects, 0.8%), educational level (16 subjects, 0, 08%), smoking status (14 subjects, 0.07%). Since there are few missing data, no analysis of the possible bias due to missing data was carried out. Missing data imputation was carried out using the k-nearest neighbor algorithm according to the input values of gender, age, region of living and place of living. General characteristics of the sample are presented in Table 1.

Table 1
Individual-level summary statistics, n = 19791.

Characteristics		Number	Percent
Hypertension outcomes	Prevalence (n = 19791)	9569	48.4
	Awareness (n = 9569)	7607	79.5
	Treatment (n = 7607)	5832	76.7
	Control (n = 5832)	2157	37.0
Male		7599	38.4
Rural location		4069	20.6
High education		8352	42.2
Family Yes		12783	64.6
Obesity		6429	32.5
Smoking		4306	21.8
Age	25–34 years	4165	21.0
	35 44 years	6940	19.9
	45–54 years	5528	28.0
	55–64 years	6158	31.1
Income	Low	3348	16.9
	Median	13074	66.1
	High	3369	17.0
Region	Krasnoyarsk	1478	7.5
	Vladivostok	2058	10.4
	Volgograd	1414	7.1
	Vologda	1583	8.0
	Voronezh	1576	8.0
	Ivanovo	1780	9.0
	Kemerovo	1550	7.8
	Samara	1561	7.9
	Orenburg	1544	7.8
	Tomsk	1548	7.8

Characteristics		Number	Percent
	Tyumen	1609	8.1
	Vladikavkaz	2090	10.6

Blood pressure measurement and definitions

Blood pressure was measured in a sitting position, on the subject's right shoulder with an automatic tonometer after a 5-minute rest, twice with an interval of about 2–3 minutes. Obtained values of systolic and diastolic pressure were carefully checked and cleared of values outside the acceptable range, as well as according to the comments of the interviewer about any problems that arose when measuring the blood pressure of respondents. Then, the average of the two blood pressure values was calculated. Cases with only one blood pressure measurement were excluded from the study. Binary parameters of hypertension, awareness, management and control of hypertension were analyzed.

By hypertension is meant the following: (a) mean systolic blood pressure 140 mm Hg or higher, and/or mean diastolic blood pressure was 90 mm Hg or higher, and/or (b) report about taking antihypertensive agents within the past 2 weeks.

Subjects were considered to be aware of their hypertension if they: (a) were identified as hypertensive patients and (b) answered "Yes" to the question: "Have a physician or another healthcare professional ever told you that you have high blood pressure?"

Respondents were considered to receive treatment if they: (a) were aware of hypertension and (b) reported about taking antihypertensive agents within the past 2 weeks.

Respondents were considered to control their hypertension if they: (a) took antihypertensive agents and (b) mean systolic pressure was less than 140 mm Hg. and mean diastolic pressure was less than 90 mm Hg.

In general, analytical sampling is shown in Fig. 1.

Other individual variables

Individual variables included socioeconomic and demographic characteristics, i.e. gender, age, educational level (not higher/ higher education), marital status (with/ without family), place of living (urban or rural area), smoking (smoker/ non-smoker) and income level. Income level was assessed indirectly with the help of three questions characterizing the share of income spent on food, the respondents' opinion about the financial capabilities of the family and about the prosperity in comparison with other families. Each question had 5 answer options that were ranked in points from 1 (the "poorest" answer) to 5 (the "richest" answer). According to the sum of points, the thirds were calculated; in accordance with this parameter income level was grouped into 3 categories: "Low" – from

3 to 7.2 points, “Medium” – from 8 to 10.3 points, “High” – from 11 to 15 points. All these variables are obtained through face to face interviewing.

Obesity was diagnosed by the body mass index – values of 30.0 kg/m2 and above were classified as obesity.

Characteristics of regional indices

Method of obtaining and detailed description of regional indices were presented in the earlier paper [51]. Briefly, regional indices were calculated on the basis of 64 parameters taken from the official website of the Federal State Statistics Service of Russia that characterized 12 regions of the Russian Federation under study from different aspects. Principal component analysis was used as a dimensionality-reduction method. In total, 5 composite indices were identified (Table 2) that explained a total of 77.6% of the total variance. Increase in Socio-Geographical Index is characterized by increased alcohol sales in the northern regions of Russia accompanied by increased crime and worsening of some social living conditions (quality of housing, learning environment for children). High Demographic Index means living in depressed regions with negative rate of natural increase, as well as a high proportion of elderly people in the general structure of the population. Industrial Index means living in regions with high level of mining, electricity production, unfavorable working conditions for a significant part of workers, and high levels of industrial emissions into the air from stationary sources. Mixed Index describes the geographical location of the region (east longitude) along with the development of fishing and fish farms, high amount of paid services in the region, a large number of private cars, as well as increased proportion of women in the general structure of the population. Finally, increased Economic Index highlights increased retail trade, per capita income and household consumption in the region, as well as increased manufacturing (factories, plants) and increased inequality in income distribution (Gini index).

Table 2
Factor loadings of the principal regional indices identified

Characteristic	Factors (Indices)				
	1	2	3	4	5
% from total variance	28.0	16.9	12.5	10.4	9.8
Sales of vodka	0.95				
Average annual temperature	-0.88				
Timberland area	0.82				
Sales of wine-making products	0.80				
Number of recorded crimes	0.76				
Location of the regional center, north latitude	0.71				
Decrepit and dilapidated housing	0.69				
Portion of students second and third shifts	0.69				
Sales of low-alcohol beverages	0.67				
Sales of brandy and brandy spirits	0.66				
Natural increase rate		-0.99			
Crude birth rate		-0.94			
Population of unemployable age		0.92			
Crude mortality rate		0.91			
Mortality rate from diseases of the respiratory system		0.70			
Mineral extraction			0.90		
Mortality rate from tuberculosis			0.80		
Electric power production			0.79		
Mortality rate from infections			0.79		
Portion of people employed at toxic and (or) hazardous jobs			0.78		
Mortality rate from external causes			0.73		
Population size			0.71		
Emissions of pollutants into the atmosphere			0.67		
Number of employees of fisheries				0.95	
Per capita amount of paid services				0.95	

Characteristic	Factors (Indices)				
	1	2	3	4	5
Number of private passenger cars				0.78	
Male/female ratio				-0.77	
Location of the regional center, east longitude				0.69	
Per capita retail turnover					0.92
Per capita actual final consumption of households					0.91
Gini Index					0.88
Per capita income per month					0.84
Manufacturing					0.76

Statistical methods

Analyzed data are presented as a two-level sample with individual and regional characteristics what requires appropriate statistical methods. In this regard, generalized estimating equations [52, 53] with robust standard errors were used to define associations between regional indices and individual presence, awareness, management and control of hypertension taking into consideration nested data structure (individuals in regions). Several sets of logistic models were performed with the calculation of odds ratio and Wald statistic. The null model included only individual variables. Model 1 included all regional indices along with individual variables. Since significant interactions of gender, age and educational level of respondents with regional indices were revealed, the analysis of Model 1 was also carried out separately for these parameters. Descriptive statistics and generalized estimating equations were performed using SPSS version 22 (IBM Corp. USA).

Results

Individual variables that have a statistically significant effect on the prevalence of hypertension included gender, education, marital status, obesity, and age (Table 3). In general sample, regional indices showed no significant impact. At the same time, the Socio-Geographic Index was directly associated with the prevalence of hypertension in male individuals (1.18; 1.05–1.32), people without higher education (1.14; 1.02–1.27), and in subjects 50+ (1.16; 1.02–1.32). In addition, individuals with higher education have an inverse association with the Mixed Index (0.94; 0.89–0.99).

Table 3
Multivariate association of individual and regional variables with hypertension

Predictor		OR	95% CI	OR	95% CI
		All sample			
		Model 0[1]		**Model 1[2]**	
Sex (ref. Women)	Men	1.49	1.24–1.78	1.48	1.26–1.75
Location (ref. Urban)	Rural	1.14	0.93–1.40	1.14	0.93–1.41
Income (ref. Low)	Median	0.93	0.82–1.06	0.91	0.80–1.03
	High	0.88	0.77-1.00	0.83	0.73–0.95
Education (ref. Low)	High	0.76	0.68–0.86	0.77	0.69–0.87
Family (ref. No)	Yes	0.91	0.86–0.96	0.91	0.86–0.96
Obesity (ref. No)	Yes	2.95	2.56–3.40	2.95	2.58–3.37
Smoking (ref. No)	Yes	0.95	0.84–1.08	0.95	0.85–1.07
Age		1.09	1.08–1.10	1.09	1.08–1.10
Socio-geographical index				1.11	0.99–1.25
Demographic index				1.08	0.93–1.25
Industrial index				0.94	0.83–1.07
Mixed index				0.98	0.93–1.03
Economic index				1.00	0.80–1.25
		Stratification by Sex			
		Women[3]		**Men[3]**	
Socio-geographical index		1.07	0.95–1.21	1.18	1.05–1.32
Demographic index		1.07	0.95–1.21	1.09	0.91–1.30
Industrial index		0.90	0.79–1.02	1.01	0.88–1.15
Mixed index		0.98	0.93–1.03	0.99	0.94–1.06
Economic index		1.04	0.85–1.28	0.94	0.73–1.21
		Stratification by Education			
		Low[3]		**High[3]**	

Note: 1 – Model 0 – only individual variable; 2 – Модель 1 – individual variable and regional indices; 3 – adjustment for all individual variables.

Predictor	OR	95% CI	OR	95% CI
	All sample			
	Model 0[1]		**Model 1[2]**	
Socio-geographical index	1.14	1.02–1.27	1.09	0.96–1.24
Demographic index	1.08	0.93–1.26	1.09	0.94–1.26
Industrial index	0.97	0.85–1.10	0.92	0.90–1.05
Mixed index	1.02	0.97–1.08	0.94	0.89–0.99
Economic index	1.04	0.82–1.31	0.93	0.75–1.16
	Stratification by Age			
	< 51 years[3]		**≥ 51 years[3]**	
Socio-geographical index	1.06	0.94–1.20	1.16	1.02–1.32
Demographic index	1.04	0.89–1.22	1.12	0.98–1.28
Industrial index	0.94	0.82–1.08	0.93	0.82–1.06
Mixed index	0.99	0.94–1.05	0.97	0.92–1.02
Economic index	1.00	0.80–1.24	0.99	0.79–1.24

Note: 1 – Model 0 – only individual variable; 2 – Модель 1 – individual variable and regional indices; 3 – adjustment for all individual variables.

Statistically significant associations with awareness were found for the following individual variables: gender, income, obesity, and age (Table 4). Regarding territorial characteristics, in general sample, the Demographic Index (1.13; 1.02–1.25) and the Industrial Index (1.15; 1.01–1.33) are directly associated with awareness, and the Mixed Index has negative association (0.93; 0.88–0.99). Similar associations remain for stratification, with some subgroup differences. So, the associations found are more typical for women, and in men such relationships only approach to be statistically significant, although they are of the same direction. The influence of the Demographic Index is more pronounced in persons with no higher education and 50+. Industrial and Mixed Indices are equally related to awareness regardless of education level and age. At the same time, a slight decrease in the strength of associations for the Industrial Index is most likely due to a decreased sample size in stratification subgroups.

Table 4
Multivariate association of individual and regional variables with awareness

Predictor		OR	95% CI	OR	95% CI
		All sample			
		Model 0[1]		**Model 1[2]**	
Sex (ref. Women)	Men	0.65	0.56–0.75	0.64	0.56–0.72
Location (ref. Urban)	Rural	0.93	0.74–1.19	0.98	0.75–1.27
Income (ref. Low)	Median	0.79	0.64–0.96	0.80	0.69–0.92
	High	0.73	0.54–0.98	0.74	0.57–0.97
Education (ref. Low)	High	1.07	0.94–1.22	1.08	0.95–1.24
Family (ref. No)	Yes	0.96	0.86–1.07	0.97	0.88–1.08
Obesity (ref. No)	Yes	1.63	1.44–1.85	1.62	1.43–1.83
Smoking (ref. No)	Yes	1.00	0.84–1.19	0.98	0.84–1.15
Age		1.04	1.03–1.05	1.04	1.03–1.05
Socio-geographical index				0.94	0.80–1.09
Demographic index				1.13	1.02–1.25
Industrial index				1.15	1.01–1.33
Mixed index				0.93	0.88–0.99
Economic index				0.99	0.77–1.27
		Stratification by Sex			
		Women[3]		**Men[3]**	
Socio-geographical index		0.86	0.73-1.00	1.01	0.87–1.18
Demographic index		1.11	1.01–1.22	1.12	0.99–1.28
Industrial index		1.21	1.04–1.40	1.11	0.96–1.28
Mixed index		0.88	0.82–0.95	0.95	0.89–1.01
Economic index		0.96	0.78–1.18	1.05	0.77–1.44
		Stratification by Education			
		Low[3]		**High[3]**	

Note: 1 – Model 0 – only individual variable; 2 – Модель 1 – individual variable and regional indices; 3 – adjustment for all individual variables.

Predictor	OR	95% CI	OR	95% CI
	All sample			
	Model 0[1]		**Model 1[2]**	
Socio-geographical index	0.93	0.79–1.09	0.91	0.76–1.10
Demographic index	1.16	1.06–1.28	1.06	0.93–1.21
Industrial index	1.13	0.99–1.28	1.23	1.02–1.48
Mixed index	0.92	0.86–0.99	0.92	0.86–0.99
Economic index	1.00	0.79–1.28	0.94	0.70–1.27
	Stratification by Age			
	< 51 years[3]		**≥ 51 years[3]**	
Socio-geographical index	0.97	0.78–1.21	0.88	0.76–1.02
Demographic index	1.04	0.87–1.26	1.19	1.10–1.29
Industrial index	1.16	0.97–1.39	1.14	0.99–1.33
Mixed index	0.91	0.83–0.99	0.95	0.90–0.99
Economic index	0.95	0.67–1.37	1.01	0.83–1.23

Note: 1 – Model 0 – only individual variable; 2 – Модель 1 – individual variable and regional indices; 3 – adjustment for all individual variables.

Regarding individual characteristics, taking antihypertensive agents is associated with gender, education (in Model 1), obesity, smoking, age (Table 5). In general sample, management of hypertension is inversely associated with the Socio-Geographic Index (0.76; 0.64–0.90) and the Mixed Index (0.91; 0.86–0.97). These associations are observed in all stratification subgroups, although they are more pronounced in women, persons with higher education and under 51 years of age. In addition, women demonstrated an inverse association of hypertension management with the Demographic Index (0.84; 0.75–0.95).

Table 5
Multivariate association of individual and regional variables with treatment

Predictor		OR	95% CI	OR	95% CI
		All sample			
		Model 0[1]		Model 1[2]	
Sex (ref. Women)	Men	0.51	0.42–0.62	0.53	0.45–0.63
Location (ref. Urban)	Rural	0.96	0.74–1.24	1.03	0.85–1.26
Income (ref. Low)	Median	0.88	0.73–1.06	0.95	0.81–1.11
	High	0.82	0.63–1.60	0.96	0.78–1.20
Education (ref. Low)	High	0.93	0.83–1.04	0.91	0.84–0.99
Family (ref. No)	Yes	1.02	0.94–1.11	1.01	0.93–1.09
Obesity (ref. No)	Yes	1.15	1.02–1.30	1.16	1.03–1.31
Smoking (ref. No)	Yes	0.82	0.71–0.94	0.83	0.73–0.95
Age		1.04	1.03–1.05	1.04	1.03–1.05
Socio-geographical index				0.76	0.64–0.90
Demographic index				0.91	0.77–1.08
Industrial index				0.99	0.88–1.12
Mixed index				0.91	0.86–0.97
Economic index				1.11	0.86–1.44
		Stratification by Sex			
		Women[3]		Men[3]	
Socio-geographical index		0.71	0.60–0.82	0.83	0.68-1.00
Demographic index		0.84	0.75–0.95	1.01	0.79–1.29
Industrial index		0.98	0.89–1.09	1.00	0.85–1.17
Mixed index		0.89	0.85–0.93	0.92	0.85-1.00
Economic index		1.04	0.85–1.27	1.23	0.89–1.69
		Stratification by Education			
		Low[3]		High[3]	

Note: 1 – Model 0 – only individual variable; 2 – Модель 1 – individual variable and regional indices; 3 – adjustment for all individual variables.

Predictor	OR	95% CI	OR	95% CI
	All sample			
	Model 0[1]		**Model 1[2]**	
Socio-geographical index	0.78	0.64–0.99	0.73	0.62–0.86
Demographic index	0.91	0.77–1.07	0.93	0.77–1.12
Industrial index	1.02	0.90–1.15	0.96	0.85–1.08
Mixed index	0.92	0.86–0.99	0.89	0.84–0.95
Economic index	1.12	0.88–1.42	1.12	0.83–1.51
	Stratification by Age			
	< 51 years[3]		**≥ 51 years[3]**	
Socio-geographical index	0.71	0.59–0.85	0.79	0.67–0.94
Demographic index	0.97	0.81–1.16	0.89	0.75–1.05
Industrial index	0.97	0.86–1.08	1.01	0.86–1.18
Mixed index	0.89	0.84–0.93	0.93	0.86-1.00
Economic index	1.14	0.84–1.54	1.10	0.86–1.40

Note: 1 – Model 0 – only individual variable; 2 – Модель 1 – individual variable and regional indices; 3 – adjustment for all individual variables.

Control of hypertension is associated with the following individual variables: gender, education, obesity, and age (Table 6). In general sample, an inverse association of the Socio-Geographical Index with the control of hypertension (0.79; 0.69–0.90) was revealed; similar associations were observed in all stratification subgroups. No significant associations were found in general sample for other territorial indices, however, interesting relations are observed in stratification subgroups. Demographic Index is inversely associated with the control of hypertension in women and in people under 51 years. Industrial Index is directly associated with the control of hypertension in women, persons with higher education, and subjects 50+. Mixed Index demonstrates multidirectional relationships depending on education level: direct association for people with no higher education (1.06; 1.01–1.11) and inverse association for people with higher education (0.88; 0.82–0.94). In addition, persons under 51 years demonstrated a direct association of the Mixed Factor with the control of hypertension (0.95; 0.90–0.99).

Table 6
Multivariate association of individual and regional variables with control

Predictor		OR	95% CI	OR	95% CI
		All sample			
		Model 0[1]		**Model 1[2]**	
Sex (ref. Women)	Men	0.62	0.51–0.76	0.64	0.53–0.75
Location (ref. Urban)	Rural	0.88	0.75–1.03	0.91	0.74–1.13
Income (ref. Low)	Median	0.91	0.79–1.05	0.98	0.81–1.19
	High	0.97	0.78–1.21	1.11	0.89–1.40
Education (ref. Low)	High	1.41	1.21–1.63	1.33	1.14–1.55
Family (ref. No)	Yes	0.92	0.80–1.06	0.92	0.79–1.06
Obesity (ref. No)	Yes	0.60	0.54–0.67	0.61	0.54–0.68
Smoking (ref. No)	Yes	1.03	0.88–1.19	1.04	0.90–1.20
Age		0.95	0.94–0.96	0.95	0.94–0.96
Socio-geographical index				0.79	0.69–0.90
Demographic index				0.90	0.78–1.04
Industrial index				1.11	1.00-1.23
Mixed index				1.00	0.94–1.06
Economic index				0.88	0.73–1.07
		Stratification by Sex			
		Women[3]		**Men[3]**	
Socio-geographical index		0.83	0.72–0.95	0.73	0.63–0.84
Demographic index		0.86	0.77–0.97	1.03	0.85–1.25
Industrial index		1.13	1.02–1.26	1.06	0.94–1.19
Mixed index		0.99	0.94–1.04	1.00	0.94–1.06
Economic index		0.84	0.70–1.01	0.97	0.80–1.17
		Stratification by Education			
		Low[3]		**High[3]**	

Note: 1 – Model 0 – only individual variable; 2 – Модель 1 – individual variable and regional indices; 3 – adjustment for all individual variables.

Predictor	OR	95% CI	OR	95% CI
	All sample			
	Model 0[1]		**Model 1[2]**	
Socio-geographical index	0.78	0.68–0.91	0.81	0.70–0.93
Demographic index	0.89	0.79–1.01	0.92	0.78–1.10
Industrial index	1.09	0.98–1.22	1.16	1.02–1.31
Mixed index	1.06	1.01–1.11	0.88	0.82–0.94
Economic index	0.87	0.72–1.05	0.91	0.73–1.12
	Stratification by Age			
	< 51 years[3]		**≥ 51 years[3]**	
Socio-geographical index	0.73	0.64–0.84	0.83	0.72–0.94
Demographic index	0.83	0.71–0.97	0.94	0.82–1.07
Industrial index	1.03	0.91 – 0.17	1.14	1.03–1.27
Mixed index	0.95	0.90–0.99	1.00	0.95–1.07
Economic index	0.96	0.77–1.20	0.85	0.71–1.02

Note: 1 – Model 0 – only individual variable; 2 – Модель 1 – individual variable and regional indices; 3 – adjustment for all individual variables.

The values of the parameters for the effects in Wald Chi-squared models (Table 7) indicate that the individual characteristics of population, first of all, gender, age, as well as concomitant diseases (obesity) have the strongest impact on the prevalence, awareness, management and control of hypertension. At the same time, territorial living conditions have much less effect on the prevalence of hypertension; however, the importance of this parameter is similar to individual variables for the awareness, management and control of hypertension.

Table 7
The meaning of the model effect criteria (Likelihood Type III test, Chi-Square Wald)

Predictor	Prevalence	Awareness	Treatment	Control
Sex	19.0	32.8	47.0	21.8
Location	1.7	0.3	0.1	2.5
Income	3.8	6.0	2.2	2.6
Education	21.3	1.1	1.7	20.3
Family	10.2	0.6	0.3	1.2
Obesity	227.4	58.6	5.3	78.7
Smoking	0.6	0.1	8.1	0.1
Age	1212.5	64.2	87.2	71.4
Socio-geographical index	7.9	3.7	19.3	19.2
Demographic index	2.6	19.5	7.4	5.9
Industrial index	2.5	6.4	0.5	6.5
Mixed index	4.7	10.6	24.8	13.9
Economic index	0.4	0.2	1.6	3.3

Note: For individual variables (sex, location, income, education, family, obesity, smoking, age), the Chi-Square Wald values are taken from Model 0. For all indices, the maximum possible Chi-Square Wald values from among the models of the general sample (Model 1) are taken and stratification groups by sex, age and education.

Discussion

Results of this study revealed that, after adjusting for individual characteristics, there is an undeniable effect of regional living characteristics on the prevalence, awareness, management and control of hypertension. The Socio-Geographic Index has the most stable effect, and it is also the only index that demonstrated a stable effect on the prevalence of hypertension. Demographic, Industrial, and Mixed Indices demonstrated stable impact on awareness, management and control of hypertension, predominantly in women and/or in certain age and educational groups.

Mixed Index is hardly understandable, both in its interpretation and in the associations found. The most stable effect of the Mixed Index is its inverse association with awareness and management of hypertension what characterizes its impact as negative. In addition, we could observe not entirely clear associations of the Mixed Index with the prevalence and control of hypertension depending on the level of education. For example, in individuals with higher education, increased Mixed Index is associated, on the one hand, with a decreased prevalence of hypertension, and, on the other, with its decreased control.

The first association describes the Mixed Index as a negative factor, and the second one – as a positive factor. We find it difficult to evaluate and interpret these associations; and we should say “unfortunately” since the influence of the Mixed Index is the most pronounced and stable, second to the Socio-Geographical Index.

Due to significant differences in the analyzed territorial characteristics, it is hard to compare the results obtained with the results of other studies. Moreover, different scales of the analyzed territorial characteristics should be taken into consideration. As mentioned above, the most part of studies deal with small territorial units – neighborhoods, districts within one postal code, etc. Nevertheless, when discussing our results, we will try to compare them with the available data from other studies – but will once again emphasize rather conditional nature of such a comparison.

Prevalence of hypertension

Our data revealed that the Socio-Geographic Index has a direct impact on the prevalence of hypertension among male individuals, subjects with low level of education and elderly people. In our opinion, in accordance with the functional description of the Socio-Geographical Index, it describes the potentiating influence of the worsening of social living conditions and society marginalization on the formation of a high allostatic load [36, 54] that leads to the increased probability of high blood pressure and, as a result, to the development of hypertension. At the same time, our results demonstrated no associations with the prevalence of hypertension in general population what indicates that this effect is selective. The results of other studies do not always confirm the negative impact of unfavorable social conditions of the population on blood pressure and the prevalence of hypertension in general population [45, 47, 55]. On the other hand, several researches revealed increased average levels of blood pressure and increased prevalence of hypertension in general population along with increased unemployment [43] and integral indices of socially unfavorable characteristics of living areas [48, 56, 57], as well as with decreased “average” level of education [58].

According to our data, the influence of social living conditions on the prevalence of hypertension is typical for men but not for women. This is in contradiction with other studies that demonstrated the opposite results [44], including these based on the analysis of only women population [59, 60]. On the other hand, we have interesting results of an American longitudinal study that demonstrated a hard to explain positive effect of the number of reported crimes in a living area on the reduction of systolic and diastolic blood pressure in women, but not in men [40].

The associations found between the increased prevalence of hypertension and worsening of social living characteristics in persons with low level of education and in elderly people are confirmed by other studies. A number of hypotheses (“double danger model”, “collective resource model”, “fundamental cause theory”) explain that the characteristics of living area are especially important for people with a low individual socio-economic level [61]. In our study, these are persons with low and average level of education. Also in some studies, there is a discussion about the possibility that the influence of

unfavorable territorial living characteristics may be more pronounced for elderly population but not for general sample [46, 62].

In our study, the Economic Index showed no significant effect on the prevalence of hypertension, although some studies demonstrated a direct effect of poverty rate on blood pressure and the prevalence of hypertension [63, 64]. In an American longitudinal study, the possibility of hypertension development was 52% higher in those who lived in “poor” neighborhoods compared to those who lived in “non-poor” ones [65]. In addition, study participants who moved from “poor” neighborhoods had significantly higher diastolic blood pressure than those who have never lived in “poor” neighborhoods.

The only large-area study we have found analyzes the impact of income inequality according to Gini index (in our study, Gini index was included in the Economic Index) at the departmental level on hypertension in Colombia [41]. In the adjusted models, women (but not men) living in areas with high income inequality were most likely to have hypertension.

At the same time, a number of studies confirm our results regarding the absence of associations of hypertension with the economic characteristics of living conditions. Thus, a Chinese study of rural areas revealed that the economic characteristics of living area were not associated with the prevalence of hypertension, while the worsening of social parameter (decreased level of education of the population) increased the possibility of disease development [66]. The Chicago study, as well as our research, used principal component analysis to identify territorial characteristics [37]. Four factors were defined that characterize the economic, social, ethnic and demographic parameters of living areas, respectively. However, economic and demographic characteristics demonstrated no associations with the prevalence of hypertension, in contrast to social characteristics – what is fully consistent with our results.

Awareness, management and control of hypertension

Our results demonstrated that unfavorable social environment (Socio-Geographic Index) reduces the possibility of taking antihypertensive agents and of proper hypertension control in general sample. Demographic and Industrial Indices have the most direct and most pronounced impact on the awareness of hypertension. To a greater extent, this is observed in women, as well as in certain educational and age groups. In addition, different gender, age and educational groups demonstrated increased control of hypertension with a decrease in Demographic Index and, conversely, with increased Industrial Index. This positive effect of the industrial development of the region on the awareness and control of hypertension may be due to the increased attention of large public and private industrial corporations to the health of workers that in general may apply to the whole population.

There are few studies on the influence of territorial characteristics of living conditions on awareness, management and control of hypertension. In a general manner, these studies demonstrate trends in reduced awareness, management and control of hypertension in poor living conditions, albeit with some details. For example, in a Singaporean study, territorial living conditions of general sample (rented/ own housing) influenced the awareness, management and control of hypertension but had no effect on its

prevalence [45]. In a study of elderly people, the “poverty” of living area influenced only the control of hypertension but not the awareness and intake of antihypertensive agents [46]. In a Chicago study [37], awareness was positively influenced by the worsening social factor out of four defined territorial characteristics (economic, social, ethnic, and demographic), while all these factors had no effect on management and control. In the ALLHAT (Antihypertensive and Lipid-Lowering Treatment to Prevent Heart Attack Trial) study, participants in the areas with the lowest income had poorer blood pressure control despite standardized treatment protocols [67]. Finally, a study of the control of hypertension using electronic health records in African Americans demonstrated that low socioeconomic status of a living area was associated with the poor control of hypertension [68].

Consequently, the most often analyzed effect is the impact of social and economic characteristics of the population on the awareness, management and control of hypertension. These results are partly confirmed by our findings. At the same time, the Economic Index revealed no associations with awareness, management and control of this disease.

Advantages and limitations of the study

The advantages of our study can be regarded as three following aspects. Firstly, our study is the only one, with the exception of the aforementioned Colombian research [41], that analyzes the effect of the specific features of the population living in large territorial units on the prevalence of hypertension. Moreover, we have found no available literature sources with the similar analysis of awareness, management and control of hypertension. This is despite the fact that there are studies concerning other diseases, mortality or behavioral risk factors in large areas (states or provinces).

Secondly, we performed assessment of territorial characteristics with the help of empirical approach that is rarely used in similar studies. In particular, we found only one such study on the prevalence of hypertension, that is, the aforementioned Chicago study [37].

Thirdly, our results are based on a large sample with data processing by up-to-date statistical approaches that allow adequate analysis of hierarchical samples.

Finally, the results of our study are the first attempt in the history of Russian research to understand why there are such significant differences in the prevalence, awareness, management and control of hypertension between the Russian regions.

Regarding the shortcomings, we would like to highlight the difficulties in interpreting several obtained results. This is the case for the Mixed Index that demonstrated fairly stable associations that are difficult to interpret. We hope that further research will help to resolve this misunderstanding.

Another limitation arises from one of the advantages: a very small number of studies similar to ours determines the difficulty of interpreting the obtained associations as a whole. So, for example, no one considered the social well-being of a living territory in terms of sales or consumption of alcoholic beverages by its population. However, these parameters are among the most important ones in our Socio-

Geographical Index. On the other hand, the ethnic composition of living area, in particular, the proportion of African Americans [68, 69] and Hispanics [70], significantly influenced awareness, management and control of disease in a number of American studies. But these are probably national characteristics that determine the health status of the population at the level of countries and parts of the world.

Conclusion

Thus, the analysis performed allowed assessing the influence of specific features of the population living in large areas on the prevalence of hypertension and on the awareness, management and control of this disease. These patterns describe an empirical, that is, a posteriori approach to the analyzed territorial characteristics. There are few available literature sources on the geography of hypertension using the example of large areas and/or using a posteriori approaches similar to ours. Therefore, the data obtained provide new knowledge not only in terms of epidemiology of cardiovascular diseases in Russia but also in general, that is, in the context of studying the influence of living conditions on the health of population.

Abbreviations

CVD – cardiovascular diseases

ESSE-RF – Epidemiology of Cardiovascular Diseases and Risk Factors in the Regions of the Russian Federation study

OR – odds ratio

CI – confidence interval

Declarations

Ethics approval and consent to participate

The study protocols were approved by the Ethics Committee of National Medical Research Center for Preventive Medicine (Moscow) All methods were performed in accordance with the relevant guidelines and regulations. Informed consent was obtained from all the participants.

Consent for publication

Not applicable.

Availability of data and material

The datasets analysed during the current study are not publicly available due to the privacy of individuals that participated in the study but are available from the corresponding author on reasonable request.

Competing interest

All authors declared no conflicts of interest.

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Authors' contributions

SAM contributed to the conception and design of the work. YAB, SAS, GAM, AVK and OMD conducted the data collection. SAM performed data analysis and prepared the first draft of the manuscript together with YAD. All authors critically revised the manuscript and gave the final approval.

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Figures

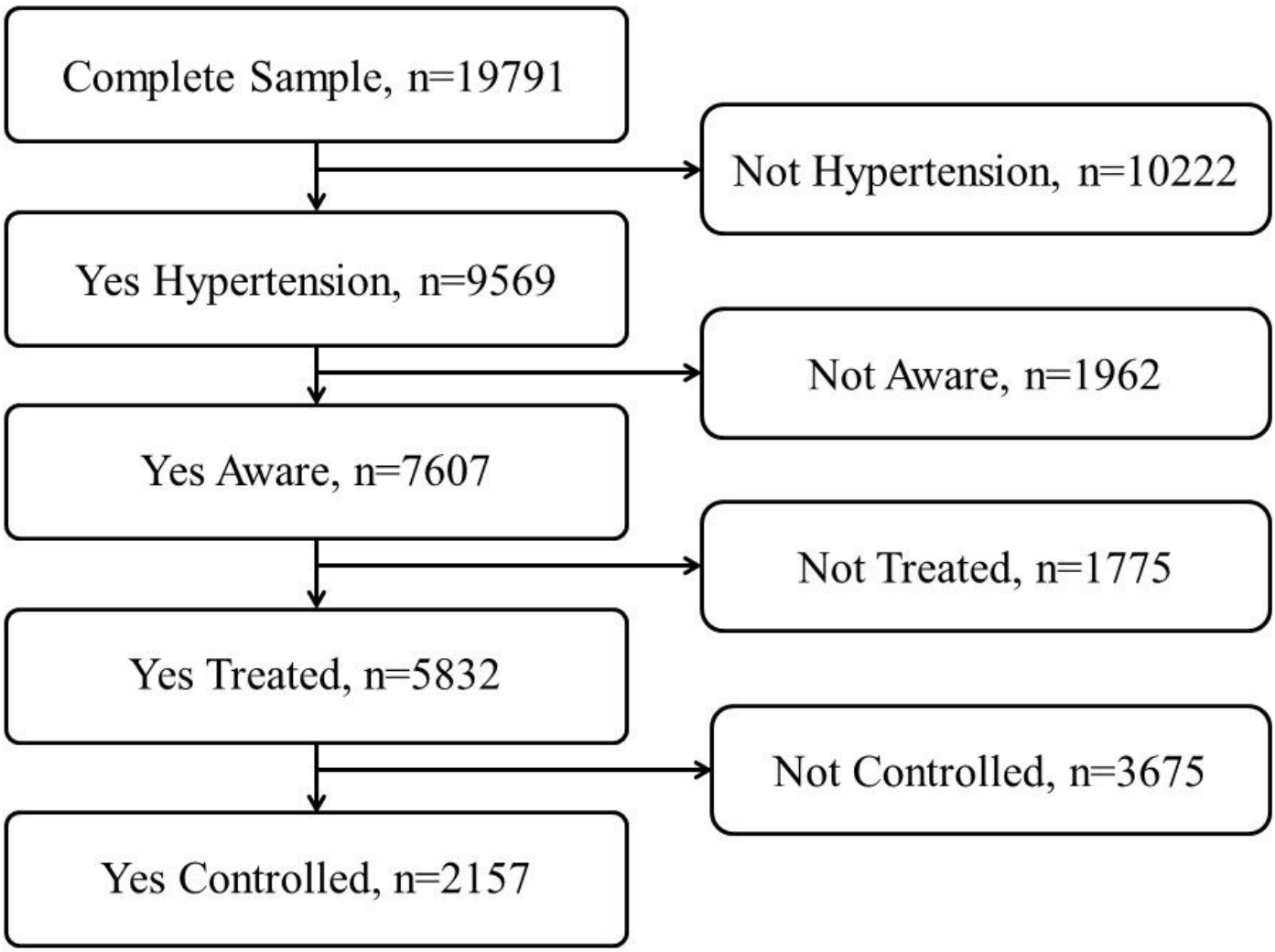

Figure 1

Sampling by prevalence, awareness, treatment and control of hypertension.