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Predictive Models for Hypertension Incidence in the Population of Western Siberia Under Climate Change Conditions

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ABSTRACT

BACKGROUND: The development of arterial hypertension is a highly relevant issue, especially in high-latitude regions, due to its significant impact on the working population. It often leads to prolonged temporary incapacity to work, increasing the risks of disability and mortality. Climate change, primarily associated with increased temperature variability, has a negative impact on the cardiovascular system.

AIM: The work aimed to develop predictive models for hypertension incidence in Western Siberia (Yamalo-Nenets Autonomous Okrug, YNAO and Tyumen Oblast) under climate change conditions.

METHODS: Monitoring of primary incidence rates of hypertension per 1000 population in YNAO and the Tyumen Oblast for the period 2010–2020 was conducted. The data were obtained from the annual reports on primary morbidity in the working-age adult population from the official website of the Ministry of Health of the Russian Federation, and from the average annual air temperature provided by the Federal Service for Hydrometeorology and Environmental Monitoring. The Dickey–Fuller test was used for time series analysis. Forecasting was performed using the Box–Jenkins method (ARIMA). The forecast was calculated using the Time Series/Forecasting submodule based on the autoregressive integrated moving average (ARIMA) model.

RESULTS: The predictive models confirmed a growing trend the primary of hypertension in the Arctic zone of Western Siberia over the next five years, taking into account climate change.

CONCLUSION: To prevent the increase in hypertension at the regional level, a comprehensive set of preventive measures should be developed to mitigate the impact of climate change and support the sustainable formation of adaptive mechanisms for preserving public health.

Keywords: cardiovascular diseases; physiological adaptation; forecasting; Arctic region; climate change.

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Прогностические модели заболеваемости артериальной гипертензией у населения Западной Сибири в условиях климатических изменений

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АННОТАЦИЯ

Обоснование. Проблема развития артериальной гипертензии очень актуальна, особенно на территориях высоких широт, в плане сохранения трудоспособности населения, так как нередко приводит к длительной временной нетрудоспособности, повышению рисков инвалидизации и смертности. Изменение климата, в первую очередь сопряжённое с повышенной изменчивостью температуры, отрицательно связано с состоянием сердечно-сосудистой системы.

Цель. Построение прогностических моделей заболеваемости артериальной гипертензией на территории Западной Сибири (в Ямало-Ненецком автономном округе — ЯНАО и Тюменской области) в условиях климатических изменений.

Методы. Проведён мониторинг данных по первичной заболеваемости артериальной гипертензией на 1000 населения в ЯНАО и Тюменской области за 2010–2020 гг. Данные получены из ежегодных отчётов по первичной заболеваемости взрослого трудоспособного населения с официального сайта Минздрава России и среднегодовых значений температуры воздуха на основании данных Федеральной службы по гидрометеорологии и мониторингу окружающей среды. Для исследования временно́го ряда использовали критерии Дики–Фуллера. Прогнозирование осуществляли на основе методологии Бокса–Дженкинса (АРПСС). Прогноз рассчитывали в подмодуле «Временны́е ряды/прогнозирование» с использованием модели авторегрессии и скользящего среднего АРПСС.

Результаты. Прогностические модели подтвердили наличие тенденции роста первичной заболеваемости артериальной гипертензией среди населения Арктической зоны Западной Сибири с учётом климатических изменений в течение 5 лет.

Заключение. С целью предотвращения роста артериальной гипертензии на региональном уровне следует разработать комплекс профилактических мероприятий, который позволит компенсировать влияние климатических изменений и обеспечит устойчивое формирование адаптационных механизмов для сохранения здоровья населения.

Ключевые слова: сердечно-сосудистые заболевания; физиологическая адаптация; прогнозирование; Арктический регион; изменение климата.

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气候变化背景下西西伯利亚居民高血压发病率的预测模型

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摘要

论证。高血压发病问题在高纬度地区尤为严峻，对于劳动人口工作能力的维持具有重要意义。高血压常导致长期暂时性丧失劳动能力，并显著增加致残和死亡的风险。气候变化，首要特征为气温变异性增加，其与心血管系统的健康状况呈负相关关系。

目的。在气候变化条件下，建立适用于西西伯利亚地区(Yamalo-Nenets Autonomous Okrug,YNAO 和 Tyumen Oblast) 高血压发病率的预测模型。

材料与方法。对2010—2020年YNAO和Tyumen Oblast每千人口高血压初发病率进行了动态监测。数据来源包括：Ministry of Health of the Russian Federation官方网站发布的劳动年龄人口高血压初发病率年度报告，以及Federal Service for Hydrometeorology and Environmental Monitoring提供的年平均气温数据。时间序列的研究采用了迪基 - 富勒检验。预测是基于Box–Jenkins方法（ARIMA）进行的。预测计算在“时间序列/预测”子模块中，使用自回归整合滑动平均模型（ARIMA）完成。

结果。所构建的预测模型证实，考虑气候变化因素后，西西伯利亚北极地区居民的高血压初发率在未来5年内存在增长趋势。

结论。为在地区层面遏制高血压发病率上升趋势，有必要制定综合性预防策略，以减弱气候变化对人群健康的不利影响，促进适应性机制的稳定建立，从而保障公众健康水平。

关键词：心血管疾病；生理适应；预测；北极地区；气候变化。

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BACKGROUND

According to the Working Group of the World Climate Research Programme (WCRP) on Coupled Modeling, the most significant changes in the Earth's climate are observed in the high latitudes of the Northern Hemisphere. The global linear trend of average annual air temperature in 1976–2019 was +0.16 °C/10 years; whereas the warming rate in the Northern Hemisphere is twice as high (+ 0.32 °C/10 years).[1] The Russian Arctic shows even higher warming rates, where the linear increase in average annual temperature is approximately 2.43 °C over 30 years (or 0.81 °C/10 years) [1]. Significantly accelerated warming of the Arctic has been observed since the 1990s; rapid warming of winters in 1970–1995 and subsequent cooling until 2010 [2].

The ambient environment and natural conditions are major factors of the human ecosystem. According to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), climate risks are growing faster than expected, making it more difficult to adapt to increasing global warming.[2] As early as 2009, the Lancet Health and Climate Change Commission warned that climate change was the greatest threat to global health in the 21st century [3]. One risk group vulnerable to the effects of climate change is individuals with cardiovascular diseases because extreme temperatures increase the risk of adverse cardiovascular outcomes [4, 5].

Current global warming and climate change trends have a profound impact on the epidemiology of hypertension and cardiovascular diseases as they may significantly affect both blood pressure variability and cardiovascular disease, especially in individuals with high cardiovascular risk and the elderly population [6]. However, the World Health Organization underestimates the impact of climate change on arterial hypertension (AH), still noting unhealthy diet, low physical activity, tobacco use and alcohol consumption, overweight, obesity, and air pollution as the key risk factors.[3] Nevertheless, scientific research conducted since the 1990s [7] has confirmed the relationship between the climate-related increase in average annual air temperature and the risk of hypertension in patients at risk [6, 8, 9].

Despite the emerging trend toward a decrease in cardiovascular mortality rate in the Russian Federation, these indicators are still among the highest in the world [10] and the leading cause of mortality (more than 50%). Multiple studies in Russia are focused on identifying the relationship between mortality and air temperature, including heat and cold waves. Some approaches to studying the health risks of temperature waves were proposed by Russian scientists in the early 2010s [11]. They also modeled and predicted the additional mortality with an increase in average annual air temperature both for individual cities [12, 13] and for regions of Russia [14, 15]. However, there is still a few specific publications on the influence of rising air temperatures on the AH based on long-term monitoring of regions with uncomfortable climate [16].

The problem of hypertension and maintaining working ability is especially relevant in high latitudes as it often leads to long-term temporary inability to work and increased disability and mortality risks. Accordingly, observational panel studies of patient sensitivity to such fluctuations will provide a valuable knowledge base required to timely adjust adaptation plans in the Arctic region, which is highly sensitive to climate change.

AIM: To develop predictive models for hypertension incidence in Western Siberia (Yamalo-Nenets Autonomous Okrug (YNAO) and Tyumen Oblast) under climate change conditions.

MATERIALS AND METHODS

We monitored incidence rates of hypertension per 1,000 adult working-age population in YNAO and Tyumen Oblast in 2010–2020 and developed a predictive model of climate-related hypertension incidence. The statistics on primary morbidity in the adult working-age population were obtained from the annual reports of the Ministry of Health of the Russian Federation[4] and the average annual air temperature data in Salekhard and Tyumen provided by the Federal Service for Hydrometeorology and Environmental Monitoring.[5]

The area was selected for the study of hypertension trends based on the fact that Siberia is a modular region for studying climate change. Having experienced catastrophic heat waves in 2010 and 2012, it is one of the regions where the frequency of extreme climate events has increased recently [17]. Predictive models of primary hypertension morbidity in YNAO and Tyumen Oblast allow us to identify trends in adaptation to increased average annual air temperatures in the population of the Arctic zone of Western Siberia (YNAO) as compared to a region located farther south (Tyumen Oblast).

Time series were analyzed by a step-by-step method with five steps [18]:

1) Construction of a time series;

2) Stationarity test of the series to determine the appropriate model (ARMA or ARIMA);

3) Model parametrization;

4) Reliability and adequacy test of the model;

5) Forecasting based on the analyzed time series.

Forecasting was performed using the Box–Jenkins method (ARIMA). For the stationary time series, we used a model

[1] World Climate Research Programme. URL: https://www.wcrp-climate.org. Accessed on August 12, 2024.

[2] Climate change. URL: https://www.who.int/ru/news-room/fact-sheets/detail/climate-change-and-health. Accessed on June 24, 2024.

[3] Hypertension. URL: https://www.who.int/ru/news-room/fact-sheets/detail/hypertension. Accessed on June 24, 2024.

[4] The Ministry of Health of the Russian Federation. URL: https://minzdrav.gov.ru/ru. Accessed on June 24, 2024.

[5] The Federal Service for Hydrometeorology and Environmental Monitoring. URL: https://www.meteorf.gov.ru/. Accessed on June 24, 2024.

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structure with a combination of an autoregressive process of order *p* and a moving average process of order *q*. For non-stationary data, Box and Jenkins proposed the ARIMA (*p, d, q*) model, where *p, d, q* are structural parameters of the order for the corresponding parts of the model (autoregressive, integrated, and moving average) [19].

As a result, we developed medium-term (5 years) predictive models for hypertension. To assess the relationship between temperature time series and hypertension incidence, we used cross-correlations, including distributed lag models [20]. To reduce the multicollinearity, we used the Almon's technique [21].

The Dickey–Fuller test was used for time series analysis. The model's adequacy was tested using the Akaike information criterion (AIC) [23]. The forecast was calculated using the Time Series/Forecasting submodule based on the autoregressive integrated moving average (ARIMA) model.

The obtained data were processed using Statistica for Windows, v. 8.0 (StatSoft Inc., USA) and Microsoft Excel (Microsoft, USA). The significance of differences was considered to be taken at $p < 0.05$.

RESULTS

Fig. 1 shows the time series for the changes in hypertension incidence per 1,000 people and the average annual air temperature in YNAO before the transformation. Fig. 2 shows the time series for the primary hypertension incidence per 1,000 people and the average annual air temperature in Tyumen Oblast before the transformation.

Next, we conducted a cross-correlation analysis of the temperature and hypertension incidence time series for YNAO and Tyumen Oblast; to find a connection, we changed the lag length and the degree of the Almon polynomial. It was found that a model with a polynomial degree of 2 has the best approximation of the coefficient of determination (0.97) to describe the relationship between temperature and morbidity in YNAO. The highest significance corresponds to a lag length of 3 (see Fig. 3).

The obtained statistical estimates will allow us to build an explicit model of the relationship between the primary hypertension incidence and the average annual temperature for YNAO (primary hypertension incidence is calculated as the number of cases per 1,000 people, the temperature is expressed in degrees Celsius):

$$\text{incidence\_AH}(t) = -0.32592 \times \text{Temperature}(t) + 1.162 \times \text{Temperature}(t-1) - 0.434 \times \text{Temperature}(t-2).$$

After the required transformations and their adequacy tests, a forecast was made based on the analyzed time series. The Hypertension in YNAO ARIMA (*p*, *d*, *q*) model may be described as (0, 0, 1) (0, 1, 0), SS Initial = 87.2, SS Final = 43.9, MS Residual = 5.5. The Akaike criterion is 8. Model parameters are $d = 1$; $q = 1$; the model constant is 0.998 ± 1.51; *q* calculated in Statistica is -0.99 ± 0.025 (see Fig. 4).

Thus, the final model was:

$$\Delta X = 0{,}998 - 0{,}99\Delta Xt - 1 + 1\Delta Xt - 2 + \varepsilon t.$$

The final model was used to forecast primary hypertension incidence in YNAO for the next 5 years. The forecast is shown in Table 1.

The reliability and adequacy of the model are verified by comparing actual and predicted parameters and by a high value of the coefficient of determination. Thus, the final forecast show that the 5-year changes in the primary hypertension incidence in YNAO will be positive (see Fig. 4).

We analyzed the cross-correlation between the temperature and hypertension incidence time series for Tyumen Oblast; to find a connection, the lag length and the degree of the Almon polynomial were changed. It was found that a model with a polynomial degree of 0 has the best approximation of the coefficient of determination (0.91) to describe the relationship between temperature and morbidity in Tyumen Oblast. The highest significance corresponds to a lag length of 1 (see Fig. 5).

The obtained statistical estimates will allow us to build an explicit model of the relationship between the primary hypertension incidence and the average annual temperature for

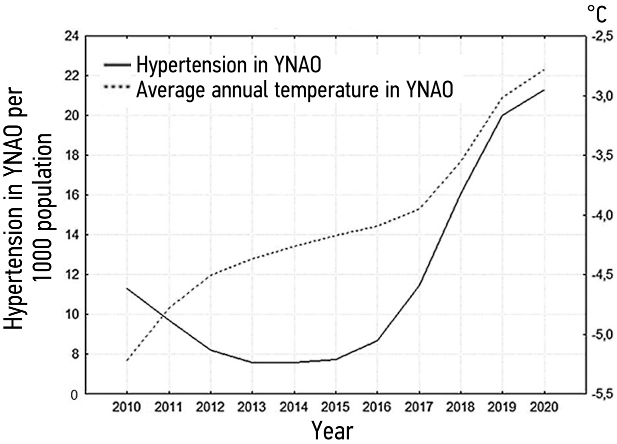

Fig. 1. Time series of primary incidence of hypertension per 1000 population and average annual air temperature (°C) in the Yamalo-Nenets Autonomous Okrug (YNAO) prior to transformation.

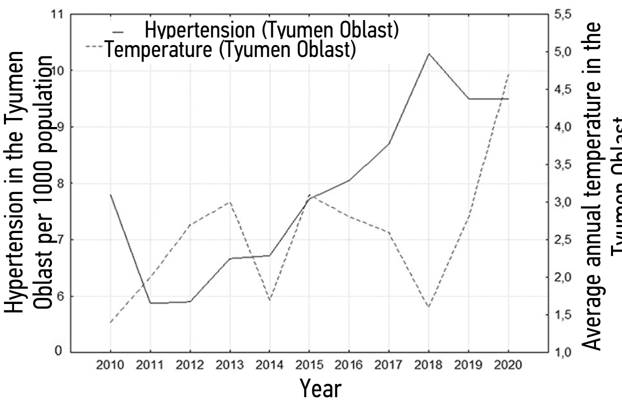

Fig. 2. Time series of primary incidence of hypertension per 1000 population and average annual air temperature(°C) in the Tyumen Oblast before transformation.

Almon Polyn. Distr.Lags; Regression Coefficients (Анализ ЯНАО1.sta)
Indep: АГ в ЯНАО Dep: Среднегодовая температура ЯНАО Салехард
Lag: 3 Polyn. order: 2 R= ,9886 R-square= ,9773 N: 8

Lag	Regressn Coeff.	Standard Error	t(4)	p
0	-0,325919473584	0,094989413173	-3,43111366515	0,026508568726
1	0,401889511736	0,079732124464	5,04049671872	0,007279526161
2	0,262204624396	0,087473805767	2,99752162488	0,040039724917
3	-0,744974135605	0,088968513587	-8,37345826705	0,001112567941

Almon Polyn. Distr.Lags; Analysis of Variance
Indep: АГ в ЯНАО Dep: Среднегодовая темп
Lag: 3 Polyn. order: 2 R= ,9886 R-square= ,97

Effect	Sums of Squares	df	Mean Square	F	p
Regress.	137,3758	4	34,34396	43,14358	0,001516
Residual	3,1842	4	0,79604		
Total	140,5600				

Almon Polyn. Distr.Lags; Alpha Coefficients (Анализ ЯНАО1.sta)
Indep: АГ в ЯНАО Dep: Среднегодовая температура ЯНАО Салехард
Lag: 3 Polyn. order: 2 R= ,9886 R-square= ,9773

poly-nomial	Alpha Coeff.	Standard Error	t(5)	p
0	-0,325919473584	0,094989413173	-3,43111366515	0,018613136327
1	1,161555921651	0,244521724648	4,75031788412	0,005103080977
2	-0,433746936330	0,079002220943	-5,49031319819	0,002736168573

Fig. 3. Estimation statistics of the distributed lag model between temperature and hypertension incidence in the Yamalo-Nenets Autonomous Okrug.

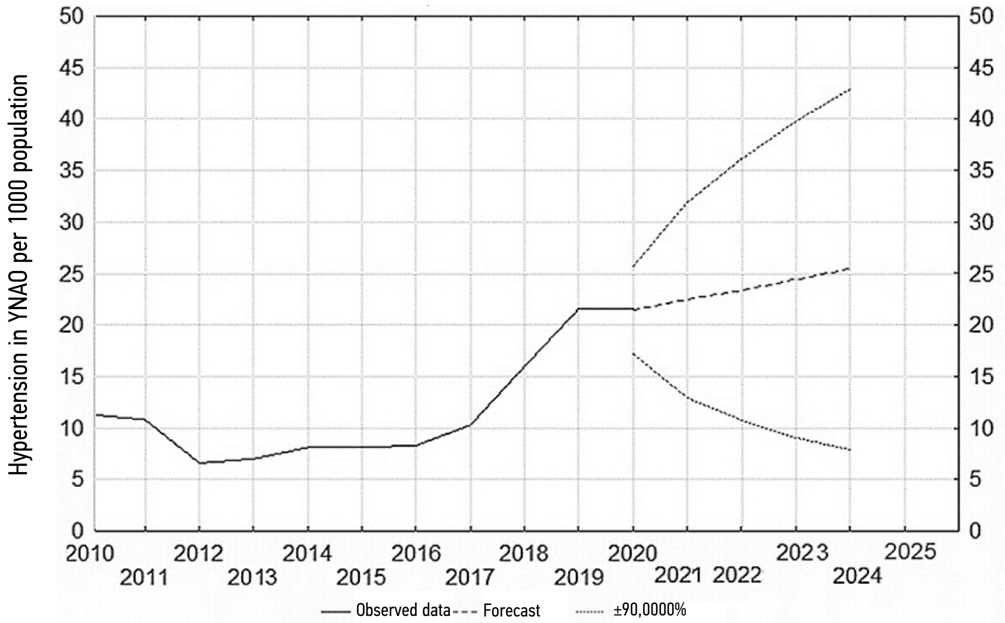

Fig. 4. ARIMA forecast of hypertension incidence in the Yamalo-Nenets Autonomous Okrug (YNAO).

Tyumen Oblast (primary hypertension incidence is calculated as the number of cases per 1,000 people, the temperature is expressed in degrees Celsius):

incidence_AH(t) = 0.1699 × Temperature(t) + 0.1699 × Temperature(t – 1).

After the required transformations and their adequacy tests, a forecast was made based on the analyzed time series. The Hypertension in Tyumen Oblast ARIMA (p, d, q) model may be described as (0, 1, 1) (0, 0, 1), SS Initial = 21.01, SS Final = 9.37, MS Residual = 0.52. The Akaike criterion is 5. Model parameters are d = 1; q = 1; Qs = 1 (seasonal lag 7); the model constant is 0.43 ± 0.14; q is –0.13 ± 0.2; Qs calculated in Statistica is 1.0 ± 0.008 (see Fig. 6).

Thus, the final model was:

Y = 0,43 + (1 + 0.13 × L) (1 – 0,99 × L7) × εt.

The final model was used to forecast primary hypertension incidence in Tyumen Oblast for the next 5 years. The forecast is shown in Table 2. The reliability and adequacy of the model are verified by comparing actual and predicted parameters and by a high value of the coefficient of determination.

According to the Tyumen Oblast Health Department, in 2021–2022, the recorded incidence characterized by high blood pressure increased from 11,000 cases in 2021 to 15,000 in 2022 in Tyumen Oblast, excluding autonomous okrugs.[6]

The reliability and adequacy of the model are verified by comparing actual and predicted parameters and by a high value of the coefficient of determination.

Thus, the forecast estimates show that the changes in primary hypertension morbidity in Tyumen Oblast for 5 years

[6] Federal State Statistics Service of the Russian Federation. URL: https://rosstat.gov.ru. Accessed on June 24, 2024.

Table 1. Predictive values of primary incidence of hypertension (per 1000 working-age population) in the Yamalo-Nenets Autonomous Okrug for a 5-year period

Observation year	Predictive value	−90.0%	+90.0%	Standard error	Observed values	Residuals
2020	21.44	17.2	25.7	2.302	21.6	0.16
2021	22.44	12.9	31.96	5.12	**23.65**	1.2
2022	23.44	10.7	36.2	6.9	**24.5**	1.1
2023	24.44	9.1	39.8	8.25	–	–
2024	25.43	7.9	42.97	9.43	–	–

Note. The converted data according to the resolution and the collection from the website of the Department of Health of the Yamalo-Nenets Autonomous District for 2022 are shown in bold.

Almon Polyn. Distr.Lags; Regression Coefficients (Тюм область.sta)
Indep: АГ Dep: Температура
Lag: 1 Polyn. order: 0 R= ,9532 R-square= ,9086 N: 10

Lag	Regressn Coeff.	Standard Error	t(8)	p
0	0,169906812795	0,017963321029	9,458541242187	0,000012841711
1	0,169906812795	0,017963321029	9,458541242187	0,000012841711

Almon Polyn. Distr.Lags; Analysis of Variance (T
Indep: АГ Dep: Температура
Lag: 1 Polyn. order: 0 R= ,9532 R-square= ,9086

Effect	Sums of Squares	df	Mean Square	F	p
Regress.	72,57865	2	36,28933	39,76178	0,000070
Residual	7,30135	8	0,91267		
Total	79,88000				

Almon Polyn. Distr.Lags; Alpha Coefficients (Тюм область.sta)
Indep: АГ Dep: Температура
Lag: 1 Polyn. order: 0 R= ,9532 R-square= ,9086 N: 10

poly-nomial	Alpha Coeff.	Standard Error	t(9)	p
0	0,169906812795	0,017963321029	9,458541242187	0,00000567

Fig. 5. Estimation statistics of the distributed lag model between temperature and hypertension incidence in the Tyumen Oblast.

Table 2. Predictive values of primary incidence of hypertension in the Tyumen Oblast (per 1000 working-age population) for a 5-year period

Observation year	Predictive value	−90.0%	+90.0%	Standard error	Observed values	Residuals
2020	9.48	8.22	10.74	0.73	9.5	0.024
2021	9.51	7.61	11.41	1.1	–	–
2022	9.54	7.16	11.92	1.37	–	–
2023	9.57	6.8	12.35	1.6	–	–
2024	9.63	6.51	12.75	1.8	–	–

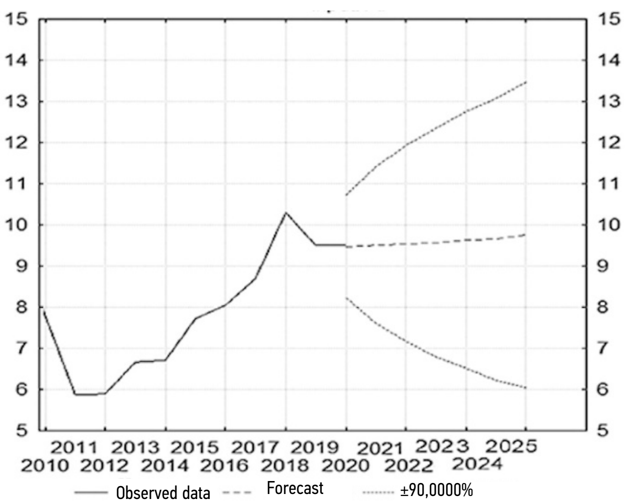

Fig. 6. ARIMA forecast of hypertension incidence in the Tyumen Oblast.

will have a slowly ascending trend. The results largely indicate the potential of the selected forecasting tool based on autoregressive algorithms and integrated moving average.

DISCUSSION

Summary of Primary Results

Predictive models confirmed a trend toward an increase in the primary hypertension incidence in the population of the Arctic zone of Western Siberia in relation to climate change over five years. We assumed that the change in the prevalence of hypertension in the Arctic zone of Western Siberia will correspond to the changes in prevalence in regions located farther south with similar values of average annual temperature. Western Siberia is a convenient region for testing this assumption as the area located in the Arctic (YNAO) and its southern part (Tyumen Oblast) are close in ethnic, social, age, and sex composition and healthcare system performance; they are not separated by mountain ranges and are located in the zone affected by the western disturbance. However, they have different average annual temperatures.

Discussion of Primary Results

Climate change is known to increase heat stress in summer and higher winter temperatures are expected to largely offset these adverse effects in summer. Nevertheless, this study is an important example of how climate-related increased temperature variability affects human health even during colder months. Overall, the study adds to the growing evidence that climate change affects health (including cardiovascular health) through both extreme heat and significant all-season adverse effects on humans [24].

In recent years, more and more studies highlight the adverse weather and climate effects on the incidence of various cardiovascular symptoms [25, 26]; they have identified weather and climate connection with heat stress. Sudden weather changes may influence cardiovascular mortality rates [27]. For example, decreasing temperatures in Norway were associated with a higher coronary heart disease incidence and death rates [28]. In addition, Finnish scientists [29] suggested a relationship between heat waves and certain cardiovascular diseases; they have proven that high air temperatures are related to higher hospitalization rates for cerebrovascular diseases in Helsinki. Another study confirmed that with high greenhouse gas climate change forecast, heat-related mortality would spike in most regions. However, it would not be accompanied by lower cold-related mortality rates and would result in a significant positive increase in mortality [30].

Previous studies have also showed that exposure to extremely high temperatures may increase sweating and blood flow to the skin, cause water loss and dehydration, and increase cardiac output [31]. When thermoregulation is impaired, core body temperature increases, thus leading to systemic inflammation, oxidative stress, endothelial dysfunction, and cytotoxic effects and promoting myocardial ischemia [32].

It is worth noting that the relationship between high ambient temperatures and hospitalization rates for hypertension requires a more detailed study. Today, reduced risk of heat-related hospitalization has been confirmed, but the possible effect of cold exposure was not studied [33–46]. Previous studies have highlighted an increased diastolic and systolic blood pressure in winter [37]. However, some studies deny the obvious relationship between temperature conditions (and its fluctuations) and cardiovascular risk [38], including in relation to high air temperatures (heat) [39, 40].

There are some development mechanisms of cardiovascular diseases. In the winter with low temperatures, systolic and diastolic blood pressure, serum low-density lipoprotein cholesterol, heart rate, plasma fibrinogen, platelet viscosity, and peripheral vasoconstriction increase; whereas high-density lipoprotein cholesterol decrease, increasing the risk of complications in people with cardiovascular diseases [41–44].

Age has been identified as a possible risk factor because individuals over 65 years are more likely to visit physicians or be hospitalized for cardiovascular diseases [40, 45, 46], which is consistent with previous studies [47, 48]. This may be caused by age-related physiological changes as in addition to a decreased ability to thermoregulate and redistribute blood flow, older people experience central stress on the cardiovascular system, thereby increasing their exposure to high temperatures. Thus, the influence of high temperatures on the incidence of specific cardiovascular diseases may vary with age due to factors beyond physiological ones, including sociodemographic conditions and the environment [49].

Contemporary understanding of the relationship between temperature and morbidity and mortality involves a U- or V-shaped relationship between exposure and outcome. It means that morbidity and mortality continue to increase beyond both high and low temperature thresholds [50, 51]. It may be assumed that natural and social environment unique to each region may alter the effects of high temperatures on health in different geographic regions.

The entire territory of YNAO included in this study is located in an absolutely and extremely uncomfortable zone, which affects human health. Climate change is most rapid in the Arctic and affects the prevalence of cardiovascular diseases both directly, due to a higher frequency of extreme weather events, and indirectly, due to changes in reindeer herding and local fishing providing the population with traditional foods that have high preventive activity. Higher average annual temperature can affect the health of the Arctic population both by longer periods of unstable atmospheric pressure; inversion of cold and warm air strata; wind conditions and environmental changes affecting commercial fish species, mammals, and wild plants. Heat waves, dry seasons, and wind-driven estuarine surges may both reduce the productivity of traditional fishing grounds and affect the composition of the caught species and fishing seasons. These changes will inevitably affect the fatty acid and micronutrient content in the diet, cause deficiency of omega-3 fatty acids, magnesium, decrease the proportion of protein and increase the intake of easily digestible carbohydrates. This will naturally lead to higher prevalence of hypertension [52].

Study Limitations

Like other time series analysis, this study has limitations. First, we did not use detailed personal data on patients' socioeconomic conditions, smoking, medications, diet, or comorbidities as the study is based on the analysis of aggregated statistical data. In addition, this limited our ability to exclude some causes of cardiovascular diseases that are not solely related to temperature, which could introduce bias and would likely bias the effect estimates toward zero. Moreover, the study may be influenced by factors modifying the effect of temperature on cardiovascular morbidity (e.g. social factors, demographics, infrastructure, housing, and access to air conditioning) [53].

CONCLUSION

Studying the influence of environmental and climate changes as major risk factors on the development of cardiovascular diseases requires special attention, monitoring, and forecasting. Temperature fluctuations and higher frequency of extreme weather affect human health and, importantly, will have an all-season adverse effect, especially on the cardiovascular system in individuals with high cardiovascular risk. In the Arctic zone, rising air temperatures and heat waves due to climate change are additional stresses for the human body, which has already adapted to low temperatures. Moreover, previous studies have shown that the mechanisms of adaptation to these climate changes are not very effective in one of the key cardiovascular risk groups, i.e. people over 65 years of age.

Given that the frequency of extreme environmental and climate events in the Arctic region has become most obvious over the past 30 years and the global epidemiological picture has changed drastically as compared to the previous century, we assume that potential risk groups will expand. This issue falls beyond the scope of our study, but is of interest for future scientific research. In addition, a promising area will be hypertension forecasting in populations living in different climatic zones and analyzing models of adaptation to climate change.

A predictive model of the relationship between the prevalence of cardiovascular diseases and the higher average annual air temperature showed that the incidence will increase. Comparison of predictive prevalence models of cardiovascular diseases in regions located in the West Siberian Plain with similar ethnic and social characteristics of the population and level of medical care, but different average annual temperature, shows that when the average annual temperature exceeds 1.5 °C, the linear relationship between morbidity and the average annual temperature will weaken; whereas the amplitude of cyclic changes and the influence of non-climatic factors on this process will increase. The positive influence of the average annual temperature can be realized through the new practices of cultivating agricultural plants and animals that are grown farther south and reducing the climate and adaptation stress.

This demonstrates the need for a comprehensive approach to the prevention of cardiovascular diseases (including preventing the higher hypertension rates) and the importance of preventive actions at the regional level that will compensate for the climate change and ensure the sustainable adaptation mechanisms to preserve the health of the population.

ADDITIONAL INFORMATION

Author contributions: S.V. Andronov: sources review, writing—original draft, writing—review & editing; E.N. Bogdanova: sources review, writing—original draft; O.M. Shaduyko: writing—review & editing; A.A. Lobanov: supervision, writing—review & editing. All the authors approved the version of the manuscript to be published and agreed to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. С.В. Андронов — обзор литературы, сбор и анализ литературных источников, написание текста и редактирование статьи; Е.Н. Богданова — обзор литературы, сбор и анализ литературных источников, подготовка и написание текста статьи; О.М. Шадуйко — редактирование статьи; А.А. Лобанов — курация, редактирование статьи. Все авторы одобрили рукопись (версию для публикации), а также согласились нести ответственность за все аспекты работы, гарантируя надлежащее рассмотрение и решение вопросов, связанных с точностью и добросовестностью любой её части.

Этическая экспертиза. Настоящее исследование не требует получения одобрения этического комитета, поскольку данные о случаях заболевания получены из открытых официальных статистических источников, клинические исследования не проводили.

Источники финансирования. Исследования частично финансировались в рамках проекта № НУ 2.2.1.24 ОНГ программы ТГУ «Приоритет-2030».

Раскрытие интересов. Авторы заявляют об отсутствии отношений, деятельности и интересов за последние три года, связанных с третьими лицами (коммерческими и некоммерческими), интересы которых могут быть затронуты содержанием статьи.

Оригинальность. При создании настоящей работы авторы не использовали ранее опубликованные сведения (текст, иллюстрации, данные).

Доступ к данным. Редакционная политика в отношении совместного использования данных к настоящей работе не применима, новые данные не собирали и не создавали.

Генеративный искусственный интеллект. При создании настоящей статьи технологии генеративного искусственного интеллекта не использовали.

Рассмотрение и рецензирование. Настоящая работа подана в журнал в инициативном порядке и рассмотрена по обычной процедуре. В рецензировании участвовали два внешних рецензента, член редакционной коллегии и научный редактор издания.

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