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MEDICAL AND CLIMATIC STUDIES OF LIVING CONDITIONS AND THEIR IMPACT ON HUMAN HEALTH

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In recent years, living conditions of people and potential of their health are increasingly dependent on changes in climatic factors. Therefore, studies in the field of medical and climatic research are becoming more relevant. This paper presents the results of medical and climatic study of living conditions in the territorial boundaries of Poltava for the period of 2006–2019, which were carried out on the basis of bioclimatic characteristics by determining the people's thermal sensitivity degree of the environment. To concretize the obtained results, we carried out a sociological survey of a control group of Poltava residents on the thermal sensitivity of the environment in different seasons of the year. A comparative evaluation of the obtained calculation data with the survey data was performed, which allowed us to carry out a deeper analysis of the causal relationships between the thermal sensitivity of the human body and climatic indices and to draw appropriate conclusions.

Key words: medical and climatic studies, bioclimatology, human health, thermal comfort.

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МЕДИКО-КЛІМАТИЧНІ ДОСЛІДЖЕННЯ УМОВ ПРОЖИВАННЯ ТА ЇХ ВПЛИВУ НА СТАН ЗДОРОВ'Я ЛЮДЕЙ

В останні роки умови проживання людей, потенціал їх здоров'я все більше залежать від зміни кліматичних факторів, тому роботи в сфері медико-кліматичних досліджень стають все більше актуальними. У даній роботі представлені результати медико-кліматичного дослідження умов проживання людей в територіальних межах міста Полтави за період 2006–2019 роки, які були проведені на основі біокліматичних характеристик шляхом визначення ступеня тепловідчуття людьми навколишнього середовища. Для конкретизації отриманих результатів було проведено соціологічне опитування контрольної групи мешканців міста Полтави щодо теплового сприйняття оточуючого середовища у різні сезони року. Було здійснено порівняльну оцінку одержаних розрахункових даних з даними опитування, що дозволило більш глибоко проаналізувати причинно-наслідкові зв'язки між тепловідчуттям організму людини та кліматичними показниками і сформулювати відповідні висновки.

Ключові слова: медико-кліматичні дослідження, біокліматологія, здоров'я людей, тепловий комфорт.

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Medical and climatic methods of studying the state of human health are among the most well-known, widely used to determine the status of a territory both in terms of its recreational value and comfort of living, the degree of performance efficiency and projected health potential. Given the process of rapid climate change, the bioclimatic resources of a given area are important parameters to consider. Therefore, studies aimed at determining the positive and negative effects of various climatic factors on the human body, allow us to establish the medical and climatic potential of a particular area in order to efficiently use its landscape and climatic conditions in health care and recreation.

Modern medical and climatic (bioclimatic) researches has several directions. Studies using bioclimatic indices, which characterize the features of the thermal structure of the environment in physical terms and are indirect indices of the thermal state and one of the criteria for assessing the potential of human health, are widely developed [2, 4, 9, 10, 12, 13].

Another area is the study of climate changes impact on human mental health. In particular, the report of the American Psychological Association "ZIK" and the environmental group ecoAmerica entitled "Mental health and our changing climate: impacts, implications, and guidance" are well known. This report emphasizes that people living in certain regions may become more sensitive to post-traumatic stress disorder, anxiety, depression, suicide, and other mental health problems as a result of climate change [5].

Another well-known area is the study of methods for assessing the bioclimatic living conditions of people, which is based on an integrated approach and, accordingly, can be applied to any study area. These studies are based on the characteristics of climatic comfort, such as comfort, discomfort and sub-comfort conditions. These characteristics are directly combined with the mechanisms of adaptation of the human body and the psychophysiological state [1, 7].

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Research is actively developing to study the impact of meteorological factors on the human body by determining equivalent-effective temperatures, using methods to assess hot and stuffy weather, assessing severe weather, as well as determining comfort and discomfort indices separately for healthy and sick people [6, 11].

Thus, today, the study of changes in environmental factors that affect human health, and the study of causal relationships between them and the biological functions of the human body, including the mechanisms of thermoregulation, is becoming increasingly important. The climatic parameters of the environment are among the most variable, which requires constant observations, analysis and updating of approaches in this scientific field.

The purpose of the study was to carry out an assessment based on bioclimatic characteristics by determining the degree of thermal sensitivity of the environment in people living within the territorial boundaries of Poltava.

Materials and methods. This study was carried out on the basis of empirical analysis, namely indicative assessment using well-known bioclimatic (biometeorological) indices, most of which are complex ones and take into account two or more climatic factors [10, 13]. The basic approach in our study was to assess the thermal state of the human body and the degree of its discomfort, based on the concept of effective temperature (ET). The concept of ET was introduced by Houghton, F.C. and Yaglou, C.P. (1923) as thermal sensitivity index of the organism, taking into account the influence of temperature, humidity and wind speed, determined by A. Missenard's formula [10, 13]:

$$ET = 37 - \frac{37 - t}{0.68 - 0.0014 \times f + \frac{1}{1.76 + 1.4 \times v^{0.75}}} - 0.29 \times t \times (1 - \frac{f}{100}) \text{ , (1)}$$

where *ET* is the equivalent-effective Missenard's temperature (EET), t – air temperature, ºC; f – relative humidity, %; v – wind velocity, m/sec.

However, today it is increasingly important to take into account such a climatic factor as the intensity of solar radiation. Therefore, in this work we used an approach to estimate the radiation-equivalent-effective temperature (REET), which takes into account the impact on human thermal sensitivity of four meteorological elements: temperature and humidity, wind velocity and solar radiation (by Ye.G. Golovina and V.I. Rusanov, 1993) [13].

However, due to the complexity of obtaining data on the solar radiation absorbed by the surface of the human body (kW/m^2), the REET value was determined by the approximate ratio of I.V. Butieva [4, 13]:

$$REET=NEET+6.2^oC, (2)$$

where NEET is the normal equivalent-effective temperature, which is body's thermal sensitivity index, considering the influence of wind for a clothed person, and was defined as [4, 13]:

$$NEET=0.8\ EET+7^oC, (3)$$

To perform a bioclimatic assessment, we formed a database of climatic indices, which were observed in the period from 01.01.2006 to 31.12.2019 in Poltava. The following mean monthly values were selected for calculations: air temperature (in degrees Celsius) at a height of 2 meters above the ground; relative humidity at a height of 2 meters above the ground; wind velocity at a height of 10-12 meters above the Earth's surface, averaged over a 10-minute period (in meters per second). A sample of air temperature values during the observation time ($14^{\underline{00}}$) was formed separately for the summer period. One of the most detailed Internet sites http://rp5.ua was chosen as the source of the initial information database.

Additionally, this study used the method of a sociological survey of respondents' sample to determine a person's subjective perception of the thermal conditions of the environment under various weather conditions. The sample of respondents consisted of 14 people of different sexes and different age categories: adolescents under 18 years; boys and girls from 18 to 29 years old; women and men aged 30–45 and 46–60, as well as the elderly people over the age of 60. The survey was performed monthly within November 2017 – September 2018.

Results of the study and their discussion. At present, existing medical and climatic studies, in particular on bioclimatology, are still far from generalizing the relationship between changes in the response of the human body and the action of the adaptation mechanism in adapting to different climatic conditions. The definition and analysis of existing bioclimatic characteristics allow us to identify only the climatic conditions that are optimal for human habitation within a particular area in a given period of time, but they do not make it possible to take into account the sharp daily changes in climatic conditions, and as a result do not fully reflect the impact of these characteristics on the formation of human health potential. Therefore, the most pressing issues are the establishment of causal links between natural factors, including climate, and mechanisms of thermoregulation, ensuring the thermal stability of the human body, its resistance and, accordingly, the risk of developing various pathologies.

The medical and climatic study, the results of which are presented in this paper, was performed on the basis of the above dependencies (1)–(3). As a result, the REET value for each month of the year within the 14-year period from 2006 to 2019 was determined and, accordingly, the level of thermal comfort of human perception of environmental conditions in Poltava was established (the results are presented in table 1).

Table 1

Estimated REET values for the period 2006–2019

REET	January	February	March	April	May	June	July	August	September	October	November	December
2006	-6.2	-3.6	2.6	14.4	19.5	24.0	24.6	25.9	20.2	14.0	6.7	4.7
2007	3.6	-0.4	9.7	13.7	22.5	24.8	26.3	26.7	19.7	14.4	3.6	2.3
2008	-1.2	2.3	9.4	15.3	18.7	23.5	25.4	26.3	18.8	16.1	8.1	1.5
2009	-1.0	2.2	5.8	15.2	19.5	25.4	26.3	23.3	21.4	13.8	8.3	-1.4
2010	-6.9	-2.1	4.8	15.6	22.3	26.1	28.9	28.5	19.9	10.1	12.2	0.8
2011	-1.0	-6.0	5.0	13.6	22.1	24.8	27.4	24.4	20.5	12.4	5.5	5.3
2012	-2.0	-6.3	3.0	18.2	23.3	25.2	27.6	24.9	21.6	15.4	8.0	-2.6
2013	0.4	2.5	1.8	15.1	24.4	25.5	25.0	24.9	16.5	12.6	9.3	1.6
2014	-3.6	3.0	9.8	14.0	22.7	22.3	26.1	26.3	19.5	11.9	4.7	0.4
2015	0.5	1.8	7.6	13.6	20.7	24.8	25.2	25.3	22.8	12.04	8.1	2.7
2016	-4.0	4.5	7.3	17.02	20.3	24.9	26.8	25.6	20.0	10.8	3.8	-0.6
2017	-2.9	-0.1	9.5	13.9	19.3	24.0	25.4	26.7	21.3	12.5	9.4	6.0
2018	-0.4	-1	1.1	17.1	23.2	24.6	27.0	27.1	20.9	17.0	4.8	1.3
2019	-0.6	4.0	9.0	16.3	22.7	27.2	25.7	25.9	21.7	17.2	8.6	7.2

In the process of this study and adaptation of existing approaches to the climatic specifics of Poltava, adjustments were made to the well-known V.I. Rusanov's method, namely the classification of thermal comfort levels, determined by the REET index. The adjusted version of the classification used in these studies is shown in table 2.

Table 2

Classification for determining the thermal comfort level of human perception of the city's climatic conditions by the REET index

Color	Standard REET interval	Comfort level
	=+32…+37	Hot (intense heat load)
	=+27…+32	Heat (moderate heat load)
	=+21…+27	Comfort
	=+17…+21	Moderately cool
	=+12…+17	Cool
	=+7…+12	Very cool
	=+2…+7	Moderately cold
	=-3…+2	Cold
	=-8…-3	Very cold

To further concretize the results, a sociological survey of a control group of 14 Poltava residents on the thermal perception of the environment in different seasons of the year and evaluation of the relationship of the obtained calculation data with the survey data were performed.

After the calculation phase of the research and the sociological survey, a comparative evaluation of their results was carried out, which allowed to perform a deeper analysis of the causal relationships between the thermal sensitivity of the human body and climatic indices. Using the mean values of the sample of standard intervals of REET indices corresponding to the comfort levels according to the legend, the arithmetic mean values between the answers of all respondents for each day of the experimental study were calculated. In parallel, we calculated the radiation-equivalent-effective temperatures indices for the days of the sociological study. Thus, we were able to compare the calculated results of the study with the subjective thermal feelings of the respondents. Table 3 was formed for visual analysis. It showed the study results together with recorded weather conditions and mean indices of daily temperature, humidity and wind speed on the survey days, and in the summer (June 3, 2018 – August 21, 2018) in terms of temperature, humidity and wind velocity indices as of $14^{\underline{00}}$.

Table 3

Comparative analysis of the results of the sociological survey and the calculated REET values in the days of the sociological survey

Date	Subjective thermal sensitivity	Estimated REET	Description of weather conditions	Temperature, ^{0}C	Humidity, %	Wind velocity, m/sec
1	2	3	4	5	6	7
16.11.2017	22.91	7.6	Clear, without precipitation	2.3	84	2.3
17.11.2017	25.09	11.0	Clear, without precipitation	2.1	82	1
20.11.2017	8.58	8.5	Overcast, rainy	2.8	97	1.8
22.11.2017	8.17	2.2	Overcast, without precipitation	-0.4	86	3.9
02.12.2017	17.46	9.5	Overcast, rainy	6.8	95	3.8
11.12.2017	21.00	2.5	Clear, without precipitation	1.1	84	5.3
22.12.2017	16.21	2.5	Clear, snowy	-2.3	92	2.3
30.12.2017	20.33	6.0	Overcast, rainy	1.5	97	2.3
10.01.2018	17.33	3.9	Clear, without precipitation	-2	87	2
17.01.2018	11.00	-1.6	Overcast, snowy	-3.5	93	3.8
23.01.2018	3.00	-6.1	Clear, snowy	-5.6	86	6.4
12.02.2018	10.00	-2.8	Clear, snowy	-4	83	5.1
22.02.2018	16.86	-0.9	Clear, without precipitation	-6.5	81	2.4
24.02.2018	5.79	-7.7	Clear, without precipitation	-10.5	77	4.1
06.03.2018	14.00	-1.7	Clear, without precipitation	-7	79	2.6
13.03.2018	21.92	2.7	Clear, without precipitation	-0.5	84	3.6
26.03.2018	22.29	7.3	Clear, without precipitation	0.5	68	2.1
27.03.2018	17.64	6.5	Overcast, rainy	1.2	91	2.1
14.05.2018	23.64	18.94	Overcast, without precipitation	13.9	82	2.3
23.05.2018	26.64	23.54	Overcast, without precipitation	17.3	74	1.3
03.06.2018	21.14	21.99	Overcast, without precipitation	16.8	61	2
18.06.2018	32.00	29.29	Clear, without precipitation	27.2	26	2
27.06.2018	30.46	30.36	Overcast, without precipitation	28.8	43	6
12.07.2018	33.36	30.75	Clear, without precipitation	27.8	46	2
23.07.2018	33.14	30.80	Overcast, without precipitation	27.8	47	2
12.08.2018	32.91	29.79	Overcast, without precipitation	28.4	26	3
17.08.2018	33.71	31.88	Overcast, without precipitation	30.4	35	3
21.08.2018	34.00	31.15	Clear, without precipitation	30.0	23	2
09.09.2018	19.71	19.70	Overcast, rainy	16.4	67	4.3
23.09.2018	15.36	19.70	Overcast, rainy	14.3	68	3.3
05.10.2018	28.91	11.71	Overcast, without precipitation	7.7	64	3.8
15.10.2018	20.00	23.71	Clear, without precipitation	15.7	63	0.6
25.10.2018	15.36	8.71	Overcast, rainy	4.5	88	2.8
07.11.2018	16.50	13.81	Clear, without precipitation	2.9	87	0.5
17.11.2018	14.00	5.31	Overcast, snowy	-0.1	58	3.3
19.11.2018	14.00	4.40	Clear, without precipitation	-2	65	2.5

The analysis of the sociological survey results shows the most acute reaction of people to changes in climatic characteristics of the environment in the summer period. They manifested primarily not in changes in the absolute average daily climatic indices, but in increasing the daily amplitude of their fluctuations. That is, sharp daily fluctuations in all the major climate parameters cause the most noticeable uncomfortable perception of the environment by people. Taking this into account, we performed REET calculations for the summer months based not on the average daily indices values, but on their fixed values at $14^{\underline{00}}$, which is shown in the resulting table 3.

Comparison of the results of the study for the summer period (from 18.06.2018 to 21.08.2018) revealed almost complete convergence between the calculated and experimental results, which proves the feasibility of calculating REET for the summer months not by the average daily values of indicators, but by the values at $14^{\underline{00}}$.

The results of the study make it possible to highlight the following most important points:

complete convergence or proximity of the calculated results and subjective feelings of the respondents was observed in 16 days of observations from their total number of 36 days (20.11.2017, 23.05.2018, 03.06.2018, 27.06.2018, 18.06.2018, 12.07.2018, 23.07.2018, 12.08.2018, 17.08.2018, 21.08.2018, 09.09.2018, 23.09.2018, 15.10.2018, 25.10.2018, 07.11.2018, 22.11.2018), when the temperature factor was accompanied by only one of the concomitant "synergetic" factors (high humidity or increased wind velocity), which are moderate. Thus, the synergistic effect of the negative effect of low or high air temperature was not actively expressed;

on the contrary, for 13 days of the study (16.11.2017, 17.11.2017, 02.12.2017, 11.12.2017, 30.12.2017, 10.01.2018, 22.02.2018, 06.03.2018, 13.03.2018, 26.03.2018, 27.03.2018, 23.09.2018, 05.10.2018), there was a cardinal discrepancy between the calculated results of the study and the subjective thermal sensations of the respondents, one of the reasons for which may be the accompanying negative impact of the temperature factor by the action of both synergistic factors at the same time (high humidity and increased wind velocity). It should be noted that all these days belong to the cold or transitional spring-autumn period, in which thermoregulation mechanisms of the human body has the greatest burden, and therefore becomes the most sensitive to the impact of any negative external factors; the greatest deviations from the "comfortable" state according to a person's subjective perception of the environment occur mainly due to the impact of such climatic factors: high humidity in the transitional and winter periods; increased wind velocity and low humidity in the warm period.

These results make it possible to express the following: changes in air temperature are not always the main factor in a person's thermal perception of the environment. Deviation from comfortable conditions occurs in most cases when a person is exposed to concomitant factors (high humidity and increased air mobility), which create a synergistic effect with the temperature factor. The effect of the importance of the action of concomitant synergistic factors on human heat perception increases significantly in the cold and transitional spring-autumn periods of the year, which in recent years are most subject to changes in terms of climatic and seasonal instability.

Accordingly, this effect of enhancing the action of concomitant climatic factors-synergetics and increasing climatic instability, especially in periods with average daily air temperatures below $+10^0$C, create conditions for a significant burden on the thermoregulatory system of the human body, which leads to the manifestations of painful conditions of the body and, as a consequence, to the risk of pathology and reduced resistance to infectious diseases. That is why such periods of the year are already today and will be in the future the periods of increased risk of pathologies that directly depend on the resistance of the human body to external factors.

In the discussion of existing scientific research in the medical and climatic (bioclimatic) direction, it was taken into account that these studies have a pronounced territorial and temporal specificity. This gave grounds to perform a comparative analysis, firstly, only of the results of research for regions with similar or analogical climatic characteristics (mostly regions of Ukraine), and secondly, the analysis of the results obtained in the last decade.

Studies performed to assess the level of sensitivity of the population to the new climatic conditions of the Kyiv region, found trends in the distribution of comfortable and uncomfortable periods based on EETs calculations [3, 14]. The research of [7] focuses on the prospects of using empirical indices for bioclimatic assessments, on the basis of which it is possible to identify areas with the most comfortable/uncomfortable conditions for humans. The results of the assessment of the bioclimate of Ukraine, published in [13], indicate a sufficient objectivity of application of the REET index for any region of Ukraine.

Thus, the results and conclusions of the above studies are fully correlated with the chosen approaches in this work, and directly with the conclusions about the greatest impact of sharp daily fluctuations of all major climate parameters on the uncomfortable perception of the environment, which is widely studied in Medical Climatology and Disaster Medicine [9]. In addition, the results of this study are unique to the Poltava region and are a continuation of well-known research in Ukraine, focusing on the medical and climatic aspects of this scientific field.

Conclusion

The results of this study emphasize the relevance and practical significance of medical and climatic assessments, which not only allow to determine the level of adaptability of the human body to climate changes in certain areas, but also to assess the risk of disease and timely predict the occurrence of those pathologies that directly depend on the action of external factors, in particular climatic, or are actively spread at certain times of the year (especially infectious diseases).

In addition, the results of this study can be used in the activities of sanitary, epidemiological and environmental services at the stage of developing a plan for adaptation to climate changes in urban settlements.

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