MULTIFACTORIAL REGRESSION MODEL FOR PREDICTING THE LEVEL OF HEAT SENSITIVITY IN HEALTHY YOUNG PEOPLE IN THE CONTEXT OF GLOBAL WARMING

Article *in* Wiadomośći Lekarskie · September 2023

DOI: 10.36740/WLek202309104

9 authors, including:

Viktoria Huk
I. Horbachevsky Ternopil National Medical University

Andriy Sverstyuk
I. Horbachevsky Ternopil National Medical University

Volodymyr Dzhyvak
I. Horbachevsky Ternopil National Medical University

ORIGINAL ARTICLE

MULTIFACTORIAL REGRESSION MODEL FOR PREDICTING THE LEVEL OF HEAT SENSITIVITY IN HEALTHY YOUNG PEOPLE IN THE CONTEXT OF GLOBAL WARMING

DOI: 10.36740/WLek202309104

Stepan N. Vadzyuk[1], Viktoria O. Huk[1], Tetiana V. Dzhyvak[1], Andriy S. Sverstiuk[1], Volodymyr H. Dzhyvak[1], Valentyna I. Bondarchuk[1], Uliana P. Hevko[1], Iryna M. Nikitina[2], Nadiia V. Herevych[3]

[1]I. YA. HORBACHEVSKY TERNOPIL NATIONAL MEDICAL UNIVERSITY, TERNOPIL, UKRAINE

[2]SUMY STATE UNIVERSITY, SUMY, UKRAINE

[3]DEPARTMENT OF OBSTETRICS, GYNAECOLOGY AND NEONATOLOGY OF POSTGRADUATE EDUCATION, BOGOMOLETS NATIONAL MEDICAL UNIVERSITY, KYIV, UKRAINE

ABSTRACT

The aim: To create a mathematical model for predicting the level of heat sensitivity in healthy young people based on multivariate regression analysis.

Materials and methods: 150 healthy young people aged 17-20 years answered the questionnaire "Levels of heat sensitivity", underwent a heat test and mathematical analysis of the heart rate, after which the results were used to build a regression model of heat sensitivity.

Results: The model of mathematical prediction of heat sensitivity (CHSL1/CHSL2), which we proposed for the first time, takes into account the most significant factors that influence the determination of higher and lower sensitivity to heat (Q1-Q6, %LF2, %HF1, %HF2, HR1, HR2), so its use will allow timely identification of individuals who are particularly susceptible to the effects of elevated ambient temperature and prevent the development of potential negative consequences of this exposure.

Conclusions: Based on the results obtained, it is possible to use this prognostic model in the future to develop a diagnostic system for determining the level of heat sensitivity.

KEY WORDS: global warming, heat sensitivity, cardiovascular system, multivariate regression analysis, individual sensitivity, climate change

Wiad Lek. 2023;76(9):1922-1929

INTRODUCTION

The World Health Organisation (WHO) has identified modern climate change as one of the greatest threats to human health in the 21st century [1]. The average annual temperature in Ukraine and Europe has increased by almost 1.5 °C over the past 30 years [2]. Global warming poses a great danger to life on planet Earth, and if this problem is neglected and the necessary measures are not taken, society will face catastrophic consequences [3, 4].

It is known that the negative impact on human life and health is caused not by the increase in air temperature, but by the resulting increase in the load on the cardiovascular system, which causes disorders of its activity and functioning of the body as a whole, and limits the adaptive potential of the human body and thermoregulatory mechanisms [5 - 7].

Scientific studies have shown that people have individual sensitivity to various environmental factors [8]. The degree of vulnerability to climate change is modulated by the age of the individual, the environmental conditions in which he or she lives, the activity of the cardiovascular system, the presence or absence of chronic diseases, mental disorders, and access to healthcare [9, 10].

Given the above, it is important to predict heat sensitivity to identify people with a higher sensitivity to elevated ambient temperatures, i.e. those most vulnerable to climate change, and to actively monitor their health status, increase their adaptive potential and stress resistance [11 - 14].

Today, multivariate regression analysis is one of the most common and accurate methods for predicting the occurrence of any disease or pathological condition, which can be used as secondary prevention and facilitate the work of practitioners [15]. In our work, we propose to use a similar approach to determine the individual response of the human body to thermal changes in the environment, as well as to build an appropriate mathematical model for prediction. This will allow timely identification of individuals with higher heat sensitivity in order to prevent or minimise the negative impact of global warming on their bodies.

THE AIM

To create a mathematical model for predicting the level of heat sensitivity in healthy young people based on multivariate regression analysis.

MATERIALS AND METHODS

To develop a mathematical model for predicting the level of heat sensitivity, 150 healthy young people aged 17-20 years were examined. The study was conducted on the basis of the laboratory of psychophysiological research certified by the Ministry of Health of Ukraine at the Department of Physiology with the basics of bioethics and biosafety of the I.Y. Gorbachevsky Ternopil National Medical University of the Ministry of Health of Ukraine (Certificate No. 003/18). The study was conducted in compliance with bioethical standards (Minutes of the meeting of the Bioethics Commission of I. Gorbachevsky Ternopil National Medical University No. 73 of 03 April 2023). All subjects signed an informed consent to the study.

The level of heat sensitivity was determined by the following algorithm [16]:

1. At the first stage, the subjects were asked to answer the questions of the questionnaire «Levels of heat sensitivity» (copyright certificate No. 115529 of 01.11.2022) issued by State Enterprise "Ukrainian Intellectual Property Institute" (UIPI) [17]. The number of points obtained was used to evaluate the result: 0-6 - lower heat sensitivity, 7-16 - higher.
2. The next step in the study was a heat test. Before it began, the temperature in the room was measured using an electronic thermometer «Omron Gentle Temp 720 (MS-720-E)». The subjects' pulse rate and blood pressure were palpated using the auscultatory method using the MMP-60 device, after which the hands of both hands

Table I. Potential factors that may influence the level of heat sensitivity (CHSL1/CHSL2) and their indexation in young healthy people.

№	Names of the CHSL1/CHSL2 heat sensitivity level predictors	Symbols in the model
1.	Question in questionnaire №1.	Q1
2.	Question in questionnaire №2.	Q2
3.	Question in questionnaire №3.	Q3
4.	Question in questionnaire №4.	Q4
5.	Question in questionnaire №5.	Q5
6.	Question in questionnaire №6.	Q6
7.	Question in questionnaire №7.	Q7
8.	Question in questionnaire №8.	Q8
9.	The autonomous balance coefficient is the ratio of the power of low-frequency and high-frequency waves in the heart rhythm to the heat test.	LF\HF1
10.	Autonomous balance coefficient - the ratio of low-frequency to high-frequency wave power in the heart rhythm after a heat test.	LF\HF2
11.	The relative value of low-frequency wave power in % in the heart rhythm before the heat test.	%LF1
12.	The relative value of low-frequency wave power in % in the heart rate after the heat test.	%LF2
13.	Power of the spectrum of the high-frequency component of variability in % of the total power of oscillations before the heat test.	%HF1
14.	Power of the spectrum of the high-frequency component of variability in % of the total power of oscillations after the heat test.	%HF2
15.	Stress index (mode amplitude/(2 × mode × variation range)) to the heat test, units.	SI1
16.	Stress index after heat test, unit.	SI2
17.	Heart rate, beats per minute, before the heat test.	HR1
18.	Heart rate, beats per minute, after the heat test.	HR2
19.	Systolic blood pressure, mm Hg, before the heat test.	SBP1
20.	Systolic blood pressure, mm Hg, after the heat test.	SBP2
21.	Diastolic blood pressure, mm Hg, before heat test	DBP1
22.	Diastolic blood pressure, mm Hg, after heat test	DBP2

were immersed in a container of warm water (45 °C) for 3 minutes. During this, at the 2nd minute, the pulse rate and blood pressure were determined. The same procedure was repeated after the hands were removed from the water and every 2 minutes until the pulse rate and blood pressure were restored and the time was recorded. According to the results of the heat test, it was found that in people with higher heat sensitivity, after the test, the pulse rate and blood pressure increased, while in people with lower heat sensitivity, the pulse rate decreased or did not change.

3. All subjects underwent mathematical analysis of the heart rhythm using the computer software complex «Spectrum+» (Kharkiv, Ukraine). 5-minute segments of rhythmograms were recorded. Statistical and spectral methods, as well as cardiac intervalography according to R.M. Baevsky were used. The results of heart rate variability showed that parasympathetic influences prevail in individuals with lower heat sensitivity, and in subjects with higher heat sensitivity, the activity of the sympathetic division of the autonomic nervous system prevails.

To build a mathematical model for predicting the level of heat sensitivity, 150 subjects were included in the study with different levels of sensitivity to the thermal factor: lower (n=94) and higher (n=56). After that, we analysed 22 possible probable factors (Table I) that may affect the level of heat sensitivity (CHSL). In the prognostic model, the higher heat sensitivity is designated as CHSL1, and the lower - CHSL2, and, accordingly, the dependence of the heat sensitivity coefficient (CHSL1/ CHSL2) on the studied factors was established.

The statistical processing of the data and the construction of a regression model of the level of heat sensitivity were carried out using the programs «Microsoft Excel 2016» and «Statistica 10.0» (StatSoft. Inc.). The model for predicting the value of the heat sensitivity coefficient included 11 factors with correlation coefficients ranging from 0.3 to 0.7. The total initial number of predictors was 22. The factors of CHSL1/CHSL2 occurrence with a significance level of $p>0.05$ were excluded from the regression analysis. To check the quality of the prognostic model, the Neigelkerk criterion (R2) was used, and to assess the model's acceptability, ANOVA was performed.

RESULTS AND DISCUSSION

To assess the significance of the influence of the above factors (Table I) on the occurrence of heat sensitivity (CHSL1/ CHSL2), a stepwise multivariate regression analysis was performed.

At the initial stage, a correlation matrix was constructed, which confirms the absence of pairwise correlation coefficients greater than 0.7, i.e. multicollinear factors.

Then, to build a regression model, we included 22 potential triggers of CHSL1/CHSL2. The regression coefficients «b» (Beta) were calculated, which show for each individual predictor the ratio of influence on the degree of CHSL1/ CHSL2 in the subjects (Fig. 1).

Factors Q7, Q8, LF/HF1, LF/HF2, %LF1, SI1, SI2, DBP1, SBP2, DBP2, with a significance level of $p>0.05$, were excluded from further analysis. Since the significance levels of the remaining 12 risk factors were $p<0.05$, they were included in the mathematical model for predicting the occurrence of CHSL1/CHSL2.

After processing the potential 22 factors using multivariate regression analysis, the following predictors with a p value of 0.05 were included in the mathematical prediction model (Q1-6, %LF2, %HF1, %HF2, HR1, HR2). It was found that the significance level of SBP1 was $p>0.05$, so this factor was also not included in the construction of the prognostic model of heat sensitivity (CHSL1/CHSL2) (Fig. 2).

Fig. 3 shows the result of obtaining the 11 studied factors, which were found to be the most significant for predicting the level of heat sensitivity (CHSL1/CHSL2) and were used to build a multivariate regression model: Q1-6: questions 1-6 of the questionnaire; %LF2 - relative value of low-frequency wave power in % in the heart rate after the heat test; %HF1 - power of the spectrum of the high-frequency component of variability in % of the total power of oscillations before the heat test; %HF2 - power of the spectrum of the high-frequency component of variability in % of the total power of oscillations after the heat test; HR1 - heart rate, bpm, before the heat test; HR2 - heart rate, bpm, after the heat test (Table I).

Based on the results shown in Fig. 3, we build a mathematical model to determine the coefficient of occurrence of the heat sensitivity level (CHSL1/CHSL2):

CHSL1/CHSL2=-0,259210*Q1-0,147279*Q2-0,229916*Q3-0,082847*Q4-0,071384*Q5-0,072407*Q6-0,002567*(%LF2)-0,008002*(%HF1)+0,008610*(%HF2)+0,004509*HR1-0,005476*HR2

To assess the quality of the regression model, it was necessary to analyse the residual deviations, in particular, to obtain their histogram (Fig. 4). As can be seen from the histogram, the residual deviations are distributed symmetrically, approaching the curve of the normal distribution of residuals, so the statistical hypothesis about their distribution in accordance with the normal distribution law is not rejected.

In order to further confirm the residual deviations from the normal distribution law, a normal-probability graph was constructed (Fig. 5). Analysing its data, we note the absence

	Regression Summary for Dependent Variable: CHSL1/CHSL2 (1 in 11) R= ,98824191 R?= ,97662208 Adjusted R?= ,97257236 F(22,127)=241,16 p<0,0000 Std.Error of estimate: ,08037					
N=150	b*	Std.Err. of b*	b	Std.Err. of b	t(127)	p-value
Intercept			2,270676	0,140634	16,14599	0,000000
Q1	-0,231246	0,028058	-0,231246	0,028058	-8,24171	0,000000
Q2	-0,148823	0,019697	-0,125317	0,016586	-7,55576	0,000000
Q3	-0,210996	0,022136	-0,204185	0,021421	-9,53182	0,000000
Q4	-0,119503	0,024364	-0,070803	0,014435	-4,90489	0,000003
Q5	-0,092464	0,022897	-0,059137	0,014644	-4,03818	0,000093
Q6	-0,053025	0,018572	-0,064945	0,022747	-2,85515	0,005026
Q7	0,001749	0,014939	0,003563	0,030427	0,11708	0,906978
Q8	-0,025346	0,020156	-0,018867	0,015004	-1,25748	0,210886
LF\HF1	-0,039649	0,042568	-0,008128	0,008726	-0,93142	0,353404
LF\HF2	0,021628	0,042878	0,006395	0,012677	0,50441	0,614845
%LF1	0,066043	0,036993	0,003639	0,002038	1,78532	0,076596
%LF2	-0,113734	0,039094	-0,005360	0,001842	-2,90922	0,004279
%HF1	-0,232299	0,065753	-0,007147	0,002023	-3,53292	0,000574
%HF2	0,262540	0,066915	0,007998	0,002039	3,92346	0,000142
SI1	0,032920	0,039988	0,000230	0,000279	0,82324	0,411915
SI2	-0,059743	0,042595	-0,000342	0,000244	-1,40258	0,163183
HR1	0,090679	0,023288	0,004907	0,001260	3,89375	0,000159
SBP1	0,133403	0,042190	0,005477	0,001732	3,16199	0,001960
DBP1	-0,064162	0,037164	-0,003730	0,002161	-1,72645	0,086699
HR2	-0,099331	0,024049	-0,005688	0,001377	-4,13041	0,000065
SBP2	-0,068058	0,034968	-0,003085	0,001585	-1,94629	0,053828
DBP2	-0,022418	0,033364	-0,001333	0,001984	-0,67194	0,502841

Fig. 1. The result of obtaining significant factors for predicting the occurrence of CHSL1/CHSL2 in multivariate regression analysis in Statistica 10.0.

	Regression Summary for Dependent Variable: CHSL1/CHSL2 (1 in 11) R= ,98566232 R?= ,97153021 Adjusted R?= ,96903650 F(12,137)=389,59 p<0,0000 Std.Error of estimate: ,08540					
N=150	b*	Std.Err. of b*	b	Std.Err. of b	t(137)	p-value
Intercept			2,282238	0,139345	16,3783	0,000000
Q1	-0,259337	0,028260	-0,259337	0,028260	-9,1768	0,000000
Q2	-0,175130	0,019105	-0,147468	0,016087	-9,1668	0,000000
Q3	-0,237588	0,021360	-0,229919	0,020671	-11,1228	0,000000
Q4	-0,139799	0,023810	-0,082827	0,014107	-5,8715	0,000000
Q5	-0,111302	0,023069	-0,071185	0,014754	-4,8247	0,000004
Q6	-0,059041	0,018370	-0,072313	0,022500	-3,2140	0,001633
%LF2	-0,054182	0,020241	-0,002553	0,000954	-2,6769	0,008339
%HF1	-0,259747	0,053471	-0,007992	0,001645	-4,8577	0,000003
%HF2	0,282164	0,059033	0,008596	0,001798	4,7798	0,000004
HR1	0,083751	0,022194	0,004532	0,001201	3,7736	0,000239
SBP1	-0,001395	0,016155	-0,000057	0,000663	-0,0863	0,931334
HR2	-0,096291	0,023245	-0,005514	0,001331	-4,1425	0,000060

Fig. 2. The result of obtaining significant factors for predicting the occurrence of CHSL1/ CHSL2 in multivariate regression analysis in Statistica 10.0 without factors Q7, Q8, LF/HF1, LF/HF2, %LF1, SI1, SI2, DBP1, SBP2, DBP2.

N=150	Regression Summary for Dependent Variable: CHSL1/CHSL2 (1 in 11) R= ,98566153 R?= ,97152866 Adjusted R?= ,96925920 F(11,138)=428,09 p<0,0000 Std.Error of estimate: ,08509					
	b*	Std.Err. of b*	b	Std.Err. of b	t(138)	p-value
Intercept			2,274752	0,108682	20,9304	0,000000
Q1	-0,259210	0,028120	-0,259210	0,028120	-9,2181	0,000000
Q2	-0,174905	0,018858	-0,147279	0,015880	-9,2748	0,000000
Q3	-0,237585	0,021283	-0,229916	0,020597	-11,1629	0,000000
Q4	-0,139832	0,023721	-0,082847	0,014054	-5,8949	0,000000
Q5	-0,111614	0,022703	-0,071384	0,014520	-4,9163	0,000002
Q6	-0,059117	0,018283	-0,072407	0,022393	-3,2335	0,001530
%LF2	-0,054466	0,019900	-0,002567	0,000938	-2,7370	0,007018
%HF1	-0,260067	0,053151	-0,008002	0,001635	-4,8930	0,000003
%HF2	0,282628	0,058577	0,008610	0,001785	4,8249	0,000004
HR1	0,083308	0,021515	0,004509	0,001164	3,8720	0,000166
HR2	-0,095633	0,021880	-0,005476	0,001253	-4,3707	0,000024

Fig. 3. The result of obtaining significant factors for predicting the occurrence of CHSL1/CHSL2 in multivariate regression analysis in Statistica 10.0 without the SBP1 factor.

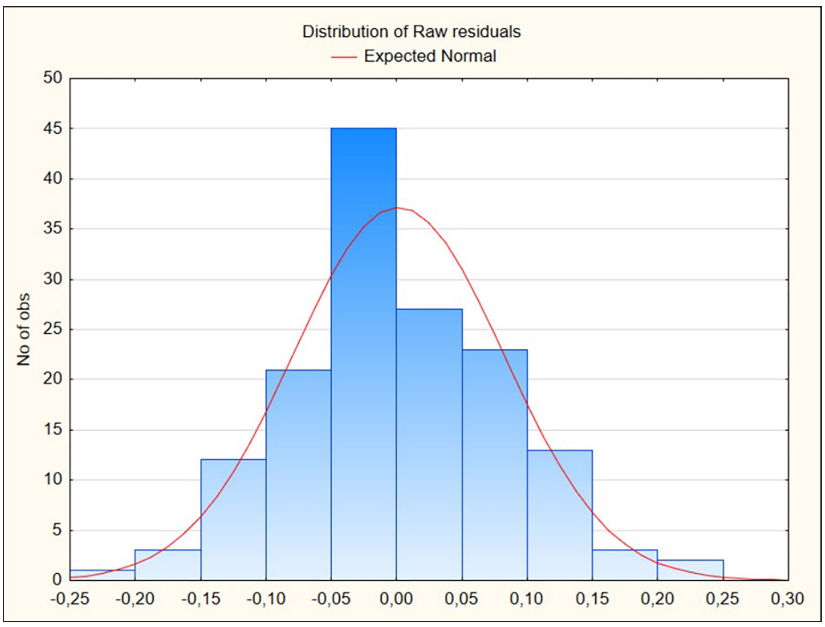

Fig. 4. Histogram of residual deviations of the multivariate regression model for predicting the occurrence of CHSL1/CHSL2.

of systematic deviations from the normal probability line. This allows us to conclude that the residual deviations are distributed according to the normal distribution law.

The next step was to assess the acceptability of the model as a whole, for which we performed an ANOVA analysis (Fig. 6). Analysing the data obtained, we can conclude that the model for predicting the level of heat sensitivity (CHSL1/CHSL2) is highly acceptable in general using ANOVA analysis, since the significance level is $p<0.001$, and the model itself will work better than a simple prediction using average values.

To further evaluate the quality of the mathematical model of heat sensitivity level (CHSL1/CHSL2), we analysed the coefficient of determination of the Neijelkerk (R2), which shows how much of the factors are taken into account in the prediction. It is considered a universal measure of the relationship between one random variable and others. The coefficient of determination varies from 0 to 1. The closer its value approaches «1», the better the multivariate regression model is. In the proposed CHSL1/CHSL2 mathematical model, the coefficient of determination is R2=0.9715 (in Statistica 10.0, R2= .97152866 (Fig. 4)). Thus, in our case, 97.15 % of the factors are taken into account in the model for predicting the level of heat sensitivity (CHSL1/CHSL2). The coefficient of determination indicates the

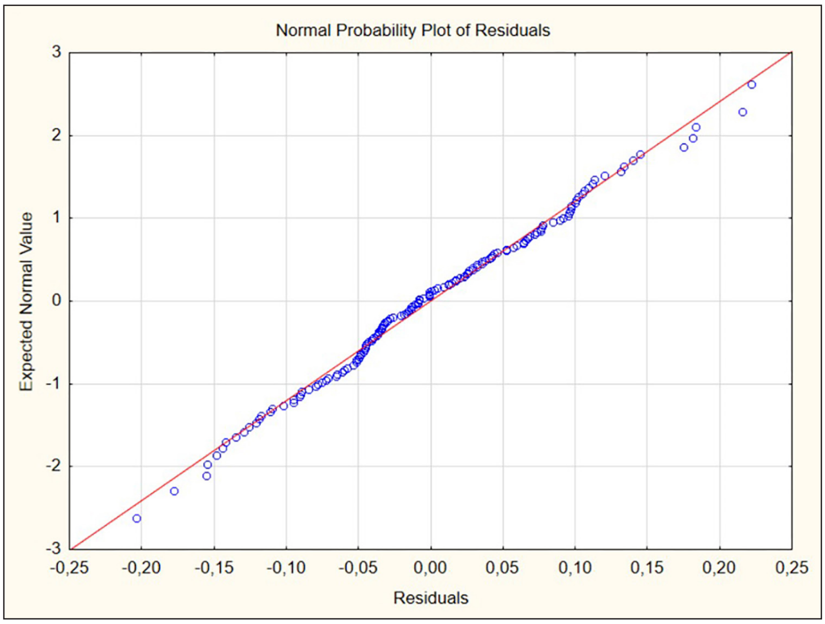

Fig. 5. Normal probability plot of residual deviations of the multivariate regression model for predicting the level of heat sensitivity (CHSL1/CHSL2).

Analysis of Variance; DV: CHSL1/CHSL2 (1 in 11)

Effect	Sums of Squares	df	Mean Squares	F	p-value
Regress.	34,09418	11	3,099471	428,0890	0,00
Residual	0,99915	138	0,007240		
Total	35,09333				

Fig. 6. Analysis of the coefficient of determination of the multivariate regression model for predicting CHSL1/CHSL2.

extent to which the experimental results confirm the mathematical model.

Thus, the prognostically significant factors affecting the level of heat sensitivity obtained by mathematical modelling (Q1-Q6, %LF2, %HF1, %HF2, HR1, HR2) confirmed that, first of all, to determine heat sensitivity, it is necessary to test according to the questionnaire «Levels of heat sensitivity», and then to conduct a heat test, In particular, a significant diagnostic criterion here is the heart rate before and after heat exposure, and the final stage, to confirm higher and lower heat sensitivity, is to assess the tone of the autonomic nervous system using mathematical analysis of the heart rate, where the power of the spectrum of high-frequency and low-frequency components of variability as a % of the total power of oscillations is important.

The model of mathematical prediction of heat sensitivity (CHSL1/CHSL2), which we have proposed for the first time, takes into account the most significant factors that influence the determination of higher and lower heat sensitivity, so its use will allow us to identify people who are particularly susceptible to high ambient temperatures and prevent the development of potential negative consequences of this exposure in time. This could become one of the stages of primary and secondary prevention of cardiovascular diseases in the future, reducing morbidity and mortality from circulatory system diseases, respectively.

Based on the results obtained, it is possible to use this prognostic model to develop a diagnostic system for determining the level of heat sensitivity in the future.

In future studies, it is also possible to conduct a ROC analysis to determine the sensitivity, specificity and accuracy of the proposed mathematical model for predicting the level of heat sensitivity (CHSL1/CHSL2).

CONCLUSIONS

1. The model of mathematical prediction of heat sensitivity (CHSL1/CHSL2), which we have proposed for the first time, takes into account the most significant factors that influence the occurrence of higher and lower heat sensitivity in healthy young people, so its use will allow timely identification of individuals susceptible to high ambient temperatures to prevent the development of potential negative effects of global warming.
2. Based on the results obtained, it is possible to use the mathematical prognostic model presented by us in the future to develop a diagnostic system for determining the level of heat sensitivity.

REFERENCES

1. Kotcher J, Maibach E, Miller J, et al. Views of health professionals on climate change and health: a multinational survey study. Lancet Planet Health. 2021;5(5):e316-e323. doi:10.1016/S2542-5196(21)00053-X.
2. European State of the Climate 2019 summary, Copernicus Climate Change Service, https://climate.copernicus.eu/sites/default/files/2020-04/ESOTC2019_summary.pdf, doi:10.24381/zw9t-hx58.
3. Sandra Bhatasara. Debating sociology and climate change. Journal of Integrative Environmental Sciences. 2015;12:3:217-233, doi: 10.1080/1943815X.2015.1108342.
4. Sun Q, Miao C, Hanel M, et al. Global heat stress on health, wildfires, and agricultural crops under different levels of climate warming. Environ Int. 2019;128:125-136. doi:10.1016/j.envint.2019.04.025.
5. Bein T, Karagiannidis C, Quintel M. Climate change, global warming, and intensive care. Intensive Care Med. 2020;46(3):485-487. doi:10.1007/s00134-019-05888-4.
6. Chenqiu Du, Baizhan Li, Yong Cheng, Chao Li, Hong Liu, Runming Yao. Influence of human thermal adaptation and its development on human thermal responses to warm environments. Building and Environment. 2018;139:134-145. doi:10.1016/j.buildenv.2018.05.025.
7. Périard JD, Travers GJS, Racinais S, Sawka MN. Cardiovascular adaptations supporting human exercise-heat acclimation. Auton Neurosci. 2016;196:52-62. doi:10.1016/j.autneu.2016.02.002.
8. Pluess M. Individual Differences in Environmental Sensitivity. Child Development Perspectives. 2015;9(3):138-143. doi:10.1111/cdep.12120
9. Hajat S, O'Connor M, Kosatsky T. Health effects of hot weather: from awareness of risk factors to effective health protection. Lancet. 2010;375(9717):856-863. doi:10.1016/S0140-6736(09)61711-6
10. Christogianni A, O'Garro J, Bibb R, Filtness A, Filingeri D. Heat and cold sensitivity in multiple sclerosis: A patient-centred perspective on triggers, symptoms, and thermal resilience practices. Mult Scler Relat Disord. 2022;67:104075. doi:10.1016/j.msard.2022.104075
11. Tiantian Xu, Runming Yao, Chenqiu Du, Xizhen Huang. A method of predicting the dynamic thermal sensation under varying outdoor heat stress conditions in summer. Building and Environment. 2022;223:109454. doi:10.1016/j.buildenv.2022.109454.
12. Weiwei Liu, Yingxia Zhang, Qihong Deng. The effects of urban microclimate on outdoor thermal sensation and neutral temperature in hot-summer and cold-winter climate. Energy and Buildings. 2016;128:190-197. doi:10.1016/j.enbuild.2016.06.086.
13. Potchter O, Cohen P, Lin TP, Matzarakis A. Outdoor human thermal perception in various climates: A comprehensive review of approaches, methods and quantification. Sci Total Environ. 2018;631-632:390-406. doi:10.1016/j.scitotenv.2018.02.276.
14. Satoru Takada, Sho Matsumoto, Takayuki Matsushita. Prediction of whole-body thermal sensation in the non-steady state based on skin temperature. Building and Environment. 2013;68:123-133. doi:10.1016/j.buildenv.2013.06.004.
15. Musiienko V, Marushchak M, Sverstuik A et al. Prediction Factors For The Risk Of Hypothyroidism Development In Type 2 Diabetic Patients. PharmacologyOnLine. 2021; 3: 585-594.
16. Vadzyuk SN, Kharkovska TV, Huk VO, Dzhyvak VH, Papinko IY, Nikitina IM. Prognostic criteria for the selection of individuals with different heat sensitivity. Wiad Lek. 2022; 75(5 pt 2):1370-1375. doi:10.36740/WLek202205225
17. Vadzyuk SN, Dzhyvak TV, Huk VO. Literary and written work of scientific nature "Questionnaire: Levels of heat sensitivity". UANIPIO Special Informational System. 01 March 2023, bul. №74. https://sis.ukrpatent.org/en/search/detail/1730421/

The study was performed in the framework of research work of the Department of Physiology, Bioethics and Biosafety of Ivan Horbachevsky Ternopil National Medical University of the Ministry of Health of Ukraine "Psychophysiological mechanisms of adaptation of young people in the context of global warming." № state registration 0121U100134 (2021 -2025 years).

ORCID and contributionship:

Stepan N. Vadzyuk: 0000-0001-9105-8205 [A,E,F]
Viktoria O. Huk: 0000-0001-9210-4859 [A,B,D]
Tetiana V. Dzhyvak: 0000-0001-9367-9742 [A,B,D]
Andriy S. Sverstiuk: 0000-0001-8644-0776 [C]
Volodymyr H. Dzhyvak : 0000-0002-4885-7586 [C,D]
Valentyna I. Bondarchuk: 0000-0001-6906-2494 [E]
Uliana P. Hevko: 0000-0001-5265-2842 [B]
Iryna M. Nikitina: 0000- 0001-6595-2502 [F]
Nadiia V. Herevych 0000-0002-1750-135X [E]