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PERSONAL FACTORS OF HUMAN THERMAL PERCEPTION: LONG-LASTING CLIMATE EXPERIENCE

Percepcja warunków termicznych przez osoby zaaklimatyzowane do badanej strefy klimatycznej

Streszczenie. W ciągu ostatnich kilkudziesięciu lat nastąpił intensywny rozwój obiektywnych metod oceny warunków termicznych, w których przebywa człowiek. Nadal jednak brak jest szczegółowych informacji na temat naszej subiektywnej percepcji tych warunków. Długotrwałe procesy aklimatyzacyjne mogą powodować u tych osób inny sposób odczuwania warunków termicznych niż u osób niezaaklimatyzowanych.
W opracowaniu przedstawiono wyniki pilotażowych badań indywidualnej percepcji panujących warunków pogodowych u osób na stałe mieszkających w trzech wybranych miastach Bułgarii: Sofii, Koprivshtits'y i Sandanski (tab. 1), różniących się cechami klimatu. Badania eksperymentalne składały się z dwóch elementów: oceny panujących w dniu badania warunków biotermicznych (za pomocą trzech wskaźników opartych na analizie bilansu cieplnego człowieka: temperatury odczuwanej fizjologicznie PST, obciążenia cieplnego HL i stresu cieplnego UTCI). Jednocześnie prowadzono badania ankietowe percepcji warunków termicznych na grupie osób w wieku 16–18 lat, zaaklimatyzowanych, ubranych stosownie do panującej pogody.
Stwierdzono, że obiektywne miary warunków termicznych nie zawsze są w ten sam sposób oceniane przez badane osoby. Najbardziej zbliżone subiektywne oceny odnosiły się do obiektywnych miar wskaźników PST i UTCI. Wyniki badań wskazują jednak na potrzebę pogłębionych analiz na szerszym materiale obserwacyjnym, przy uwzględnieniu zróżnicowanych warunków pogodowych.

Key words: human heat balance, questionnaire approach, long-lasting acclimatization, physiological subjective temperature, heat load, UTCI, subjective thermal perception
Słowa kluczowe: bilans cieplny człowieka, badania ankietowe, aklimatyzacja długookresowa, temperatura odczuwana fizjologicznie, obciążenie cieplne, UTCI, subiektywne odczucia cieplne

INTRODUCTION

During the last decades the investigation of the factors of human thermal comfort has deepened considerably but the role of some personal factors has not been still elucidated sufficiently. The durable sojourn in a certain climatic environment and the respective climate experience may influence the thermal perception in man. It may be expected that people with long-lasting adaptation to hot climates have lower sensitivity to them and higher sensitivity to cold climates, and vice versa – people durably adapted to cold climates have lower sensitivity to them and higher sensitivity to warm climatic conditions.

The study and substantiation of such hypothesis may open a new area in scientific investigations towards determining the bioclimatic "distances" between different climatic zones and defining correction coefficients for the thermal comfort depending on the long-lasting climate experience accumulated by the individual under certain climatic conditions.

OBJECTIVE AND METHODOLOGICAL APPROACH

The objective of the present work is to investigate the interrelations between two parameters: (1) the actual thermal perception of weather by people living in places with a specific climate, and (2) the values of thermal perception indices calculated for the same places. It will lead to establish the respective shift between these two parameters along the scale of human thermal perception. To achieve this objective, it is necessary to carry out in a synchronous regime an inquiry studies on thermal status on the one hand, and to obtain the parameters of this status in a computation manner on the other hand. The results from solving such a problem would represent the base for further more detailed investigations for establishing an exact quantitative expression of the corresponding differences between both parameters as a function of the continuous adaptation of an organism to the local climatic conditions.

The research were carried out in three experimental localities in Bulgaria, represented various climates. In spite of small territory Bulgaria has very diverse climates, changing significantly at short distances both along north-south and east-west transects. It is caused by location of Bulgaria's territory within the border between the moderate and subtropical climates. This determines the presence of three climatic zones: moderate-continental, continental-Mediterranean and transitional between the first two types. The another important factor of climatic differences is great hypsometric variability, encompassing a range of almost 3000 m above sea level. To illustrate diversity of climate in the country three experimental localities were chosen: Sandanski, Sofia and

Koprivshtitsa. Their basic climatic parameters being shown in table 1 and figure 1. The climate of Sandanski is distinguished by very hot summer and mild winter, of Koprivshtitsa – by very cold winter and moderately warm summer, and Sofia is characterized by intermediate parameters between the upper two stations. The selection of stations with such specific climatic features will provide the possibility of verifying the formulated hypothesis – whether the sensitivity of people towards weather undergoes changes under the effect of adaptation to the specific climate conditions.

The computational approach refers to indices derived from human heat balance model (Physiological Subjective Temperature – PST and Heat Load – HL) which has been applied for estimating the thermal status of human organism in experimental localities. The calculations are made for the moments, coinciding with the performance of an inquiry study about the subjective thermal perception of people. The model MENEX_2005 (Błażejczyk 1994, 2008), its option SolAlt in particular, was used for the computation. For this purpose, input meteorological data were ensured for air temperature and humidity, wind velocity and cloudiness. The calculations were made for physical activity of 100 $W \cdot m^{-2}$ and clothing, equal to 0.9 clo for Sandanski, 1.0 clo for Koprivshtitsa and 1.2 clo for Sofia. These are the parameters of the physical activity and clothing of the persons, subjected to the inquiry.

In order to shed additional light on the study, the algorithmic mechanism of Universal Thermal Climate Index UTCI (Błażejczyk et al. 2010; Bröde et al. 2009; Jendritzky 2000; Jendritzky et al. 2002) was applied as well.

Table 1. Basic geographical information and annual climatic characteristics of experimental localities
Tabela 1. Podstawowe informacje geograficzne oraz średnie roczne charakterystyki klimatu badanych obszarów

Station	Altitude above sea level (m)	Relief form	Climate type	Air temperature (°C)	Precipitation totals (mm)	Cloudiness (%)	Number of clear days	Number of cloudy days
Sandanski	191	mountain valley	continental-mediteranean	13.9	533	50	84	85
Sofia	600	wide plain	moderate-continental	10.0	636	55	59	119
Koprivshtitsa	945	mountain plain	mountain	6.8	737	56	67	106

The inquiry approach was used for collecting information about the subjective thermal perception of people living in the experimental localities. For this purpose, a special questionnaire with two groups of questions was applied. The first group deals with general information about the examined persons: gender, age, permanent and temporal place of residence, permanent and temporal health status, clothing and physical activity at the moment of inquiry. The second group of questions refers to personal thermal sensation and the thermal perception of the questioned persons at the moment of inquiry. The questionnaire study was carried out outdoor. Simultaneously, the meteorological parameter necessary for the calculations of specific indices were measured.

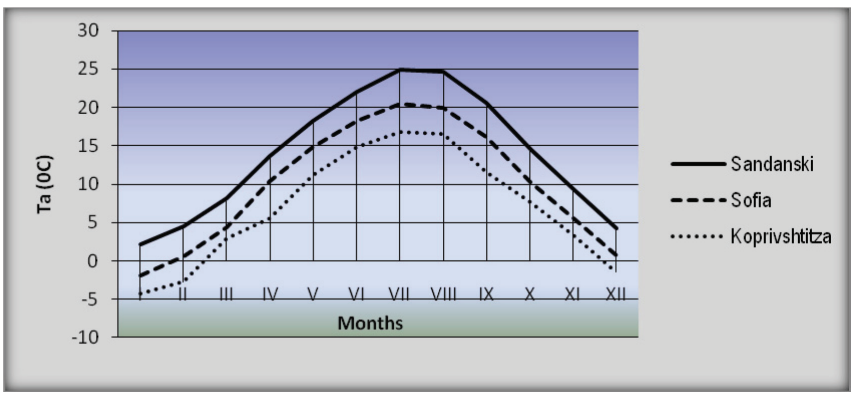

Fig. 1. Mean monthly air temperature (Ta) in studied cities (1931–1970)
Ryc. 1. Średnia miesięczna temperatura powietrza (Ta) w badanych stacjach (1931–1970)

The total number of the examined persons in studied localities is 170. All of them were within the age category of 16–18 years. They have lived at last one year in the place of inquiry and they have normal health status – both in principle, and during the time of holding the questionnaire. The examined persons started filling in the questionnaires after 20-minute adaptation. The responses of the questioned people were subjected to standard primary statistical processing.

The meteorological measurement was aimed at ensuring input data for air temperature and humidity, wind velocity and cloudiness for computing the thermal perception parameters of MENEX model and UTCI. The measurements were made simultaneously with filling in the inquiry forms of the examined people. For every locality experiment (inquiry & calculation) was carried out independently on different dates and under different weather conditions. It was the cause that only same of PST, HL and UTCI categories were represented during the experiment (Tab. 2).

RESULTS

In Sandanski the Physiological Subjective Temperature (PST) reached 58.7°C, which corresponds to the highest degree of thermal sensation – "sweltering". The Heat Load of an organism has the value of 1.367, which corresponds to "great hot stress". In Sofia the PST was 21.4°C, which denotes the thermal sensation as "comfortable". The Heat Load of an organism has the value of 1.083, which corresponds to "moderate hot stress". However in Koprivshtitsa the PST reached 43.5°C, which determines the thermal sensation as "very hot". The HL value was 1.214, which corresponds to "great hot stress".

Table 2. Classes of examined indices and their ranges (in bold) reported by subjects during questionnaire collection in studied sites: Sandanski – 1; Sofia – 2; Koprivshtitsa – 3

Tabela 2. Kategorie badanych wskaźników z zaznaczniem (boldem) klas podawanych przez osoby ankietowane w poszczególnych lokalizacjach: Sandanski – 1; Sofia – 2; Koprivshtitsa – 3

HL	PST	UTCI
	sweltering – 1	extreme heat stress
extreme hot load	**very hot – 3**	very strong heat stress
great hot load – 1; 3	hot	**strong heat stress – 1**
moderate hot load – 2	warm	**moderate heat stress – 3**
thermoneutral	**comfortable – 2**	**no thermal stress – 2**
moderate cold stress	cool	slight cold stress
great cold stresss	cold	moderate cold stress
extreme cold stress	very cold	strong cold stress
	frosty	very strong cold stress
		extreme cold stress

The processing of the same output data by means of the instruments of UTCI shows "no thermal stress" for Sofia, "strong heat stress" for Sandanski and "moderate heat stress" for Koprivshtitsa (Tab. 2).

When analyzing the results of the inquiry studies of the subjective thermal perception preliminary relations to objective assessment made by bioclimatic indices were found. According to the PST scale, the predominating part of the examined people in Sandanski determine their thermal sensation as "very hot", in Sofia – as "cool", and in Koprivshtitsa – as "hot" (Fig. 2, 3 and 4).

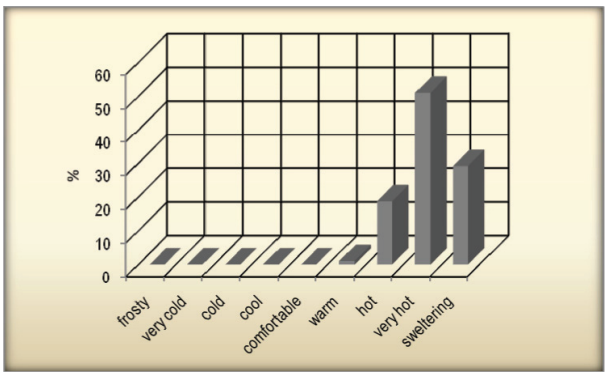

Fig. 2. Percentage of persons reported various thermal sensations in Sandanski at PST category of sweltering
Ryc. 2. Odsetek osób podających różne rodzaje odczuć cieplnych w miejscowości Sandanski w warunkach termicznych określonych za pomocą wskaźnika PST jako upalnie

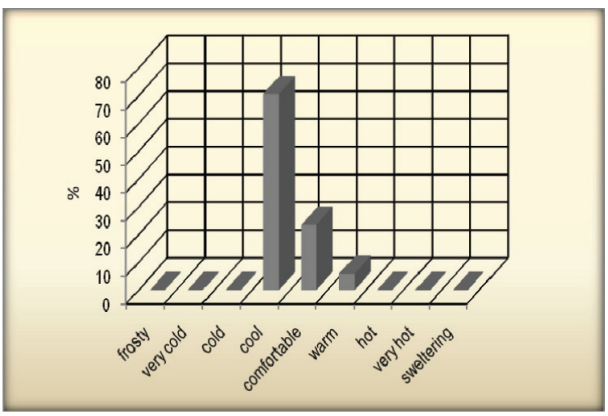

Fig. 3. Percentage of persons reported various thermal sensations in Sofia at PST category of comfortable
Ryc. 3. Odsetek osób podających różne rodzaje odczuć cieplnych w Sofii w warunkach termicznych określonych za pomocą wskaźnika PST jako komfortowo

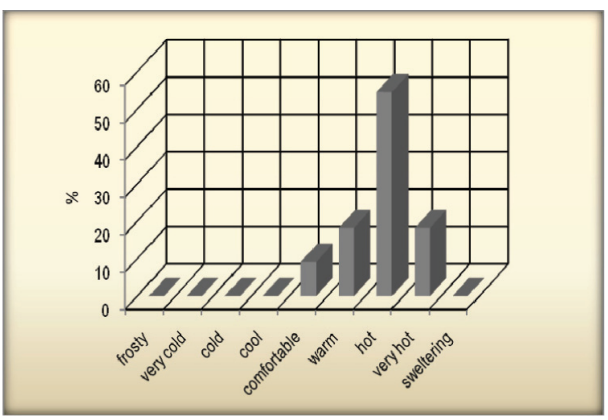

Fig. 4. Percentage of persons reported various thermal sensations in Koprivshtitsa at PST category of very hot
Ryc. 4. Odsetek osób podających różne rodzaje odczuć cieplnych w miejscowości Koprivshtitsa w warunkach termicznych określonych za pomocą wskaźnika PST jako bardzo gorąco

According to the HL scale, the predominating part of the examined people determine their heat load in the following manner: in Sandanski – "great hot load", in Sofia – "thermoneutral", in Koprivshtitsa – "great hot load" (Fig. 5, 6 and 7).

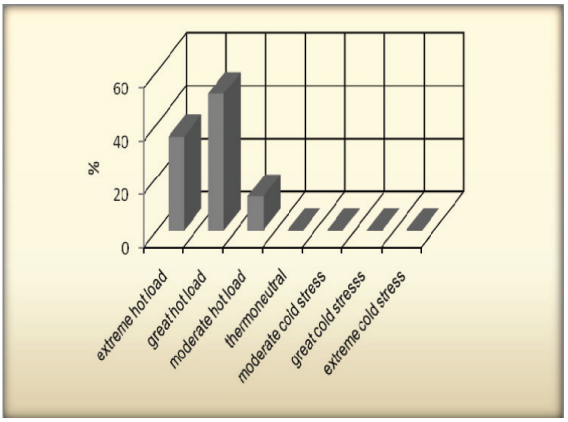

Fig. 5. Percentage of persons reported various heat load in Sandanski at HL category of great heat load
Ryc. 5. Odsetek osób podających różne rodzaje obciążenia cieplnego w miejscowości Sandanski w warunkach termicznych określonych za pomocą wskaźnika HL jako duże obciążenie cieplne

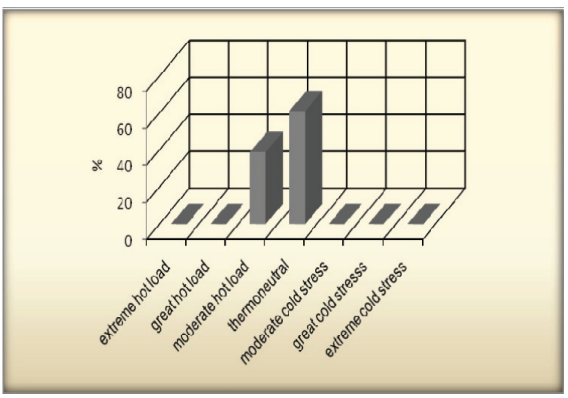

Fig. 6. Percentage of persons reported various heat load in Sofia at HL category of moderate heat load
Ryc. 6. Odsetek osób podających różne rodzaje obciążenia cieplnego w Sofii w warunkach termicznych określonych za pomocą wskaźnika HL jako umiarkowane obciążenie cieplne

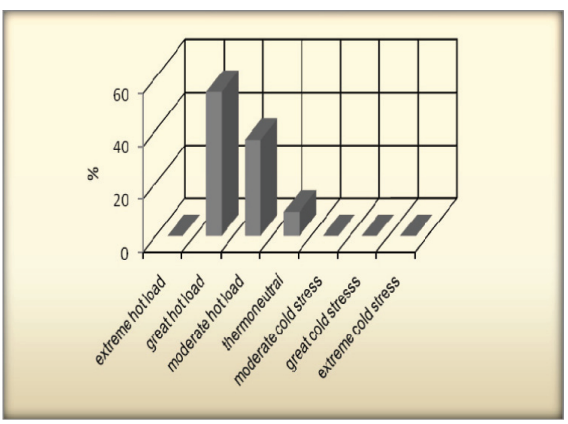

Fig. 7. Percentage of persons reported various heat load in Koprivshtitsa at HL category of great hot load
Ryc. 7. Odsetek osób podających różne rodzaje obciążenia cieplnego w miejscowości Koprivshtitsa w warunkach termicznych określonych za pomocą wskaźnika HL jako duże obciążenie gorącem

According to the UTCI scale, the thermal stress, reported by the inquired people in Sandanski is "strong heat stress", in Sofia – "no thermal stress", in Koprivshtitsa – "moderate heat stress" (Fig. 8, 9 and 10).

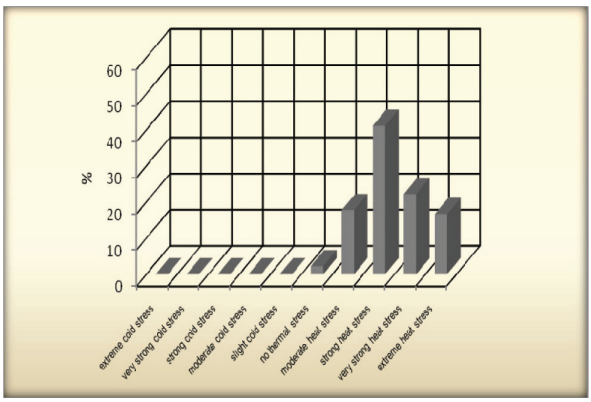

Fig. 8. Percentage of persons reported various heat stress in Sandanski at UTCI category of strong heat stress
Ryc. 8. Odsetek osób podających różne rodzaje stresu cieplnego w miejscowości Sandanski w warunkach termicznych określonych za pomocą wskaźnika UTCI jako silny stres ciepła

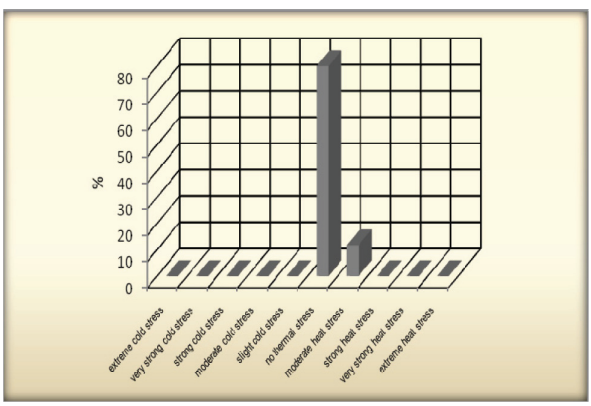

Fig. 9. Percentage of persons reported various heat stress in Sofia at UTCI category of no thermal stress
Ryc. 9. Odsetek osób podających różne rodzaje stresu cieplnego w Sofii w warunkach termicznych określonych za pomocą wskaźnika UTCI jako brak obciążeń cieplnych

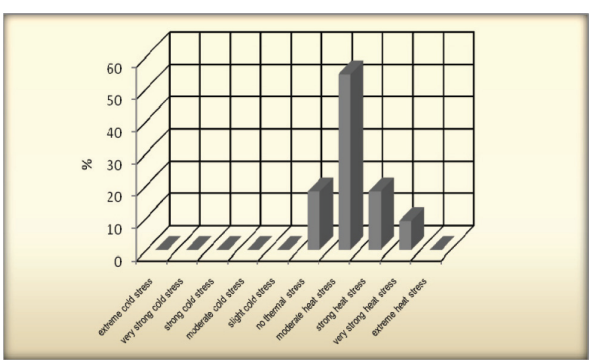

Fig. 10. Percentage of persons reported various heat stress in Koprivshtitsa at UTCI category of moderate heat stress
Ryc. 10. Odsetek osób podających różne rodzaje stresu cieplnego w miejscowości Koprivshtitsa w warunkach termicznych określonych za pomocą wskaźnika UTCI jako umiarkowany stres ciepła

The inquiry study in Sandanski was carried out in summer, during weather evaluated according to the PST calculations as "sweltering". At the same time the majority of the questioned persons determine their thermal perception at that moment with one degree lower – as "very hot". In principle, in multiannual plan the locality of Sandanski is characterized by very hot summer. This

presumes decreased sensitivity to warm weather and increased sensitivity to cold weather. The results confirm the formulated hypothesis that the continuous sojourn under conditions of hot weather decreases the sensitivity towards it.

The inquiry study in Sofia was carried out in late spring, during weather evaluated according to the PST calculations as "comfortable". At the same time the majority of the questioned persons determined their thermal perception at that moment with one degree lower – as "cool". In principle, the locality of Sofia is characterized by moderately hot summer and moderately cold winter. We could expect coincidence between the thermal perception of the examined persons and its calculated parameters. The lack of such coincidence provides evidence that another reason should be found to explain this.

The inquiry study in Koprivshtitsa was carried out in summer, during weather evaluated according to the PST calculations as "very hot". At the same time the majority of the questioned persons determined their thermal perception at that moment with one degree lower – as "hot". In principle, in multiannual perspective the locality of Koprivshtitsa is characterized by cool summer and cold winter. This presumes decreased sensitivity to cold weather and increased sensitivity to warm weather. The results do not confirm the formulated hypothesis that the continuous sojourn under conditions of cool weather increases the sensitivity towards warm weather. It is possible that there might be a psychological reasons here, which opens a new questions for investigation.

With respect to the heat load of the organism (HL), as well as to the thermal stress (UTCI), both the results from the calculations and from the inquiry study exhibit almost complete coincidence. This means that the reasons for shifting of the subjective and objective thermal estimates are not unidirectional and should be sought not only in the multiannual adaptation climate experience but also in the scaling of the different models of the spectrum of thermal perceptions.

CONCLUSION

The following inferences and recommendations could be made on the basis of the obtained results:

1. There are some indications for transformation of the thermal perception of man under the effect of durable climate experience accumulated under specific climate conditions. In order to substantiate this thesis, it is necessary to perform further large scale experiments, broadening the precision of the study with respect to: number of inquired persons, representativeness of the meteorological conditions and of the geographic localities, the influence of psychological factor on the heat perception of man, etc. It is necessary

to engage much more examined people, to compare predicted and felt thermal perceptions in all weather spectra – from hot to frosty, and for all climatic varieties – from the equator to the poles and from the continents to the oceans.

2. The shifting between the subjective and objective thermal estimates might be due to the specifics in the scaling of the applied evaluation scales. Further investigations are necessary for verifying and conforming the evaluation scales of the different heat balance approaches.

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