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Connection of Holiday Climate Index with Public Health (on Example of Tbilisi and Kakheti Region, Georgia)

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ABSTRACT

Study on connection of Holiday Climate Index (HCI) and its components and components ratings with public health (on Example of Tbilisi - mortality by cardiovascular deseases and Kakheti Region of Georgia - ambulance calls, hospitalization, total mortality are presented).
It is shown that, in general, all indicators adequately correspond to the degree of bioclimatic comfort of the living environment for people. In particular, the relationship between HCI and mortality in Tbilisi has the form of a second-degree polynomial, and in Kakheti - a third-degree polynomial. At the same time, with an increase in the degree of bioclimatic comfort to the category "Very good", there is a tendency for a decrease in mortality. With the transition to the "Excellent" category, there is a slight increase in mortality. A similar result for some components of the HCI and the ratings of these components was obtained.
It is proposed to make adjustments in determining the degree of comfort of bioclimatic index scales for the population, taking into account local social and climatic conditions.

Key words: *Holiday Climate Index (HCI), public health, ambulance calls, hospitalization, mortality*.

Introduction

Studies of weather conditions, climate change, atmospheric air quality, and also of different heliogeophysical and space factors for the human organism, are conducted in many countries of the world [1-8].

A significant number of works are devoted to the study of the impact on human health of individual meteorological and heliogeophysical elements, space weather parameters, etc. In particular, these elements include: air temperature [5, 8-11], wind speed [11], humidity [12], atmospheric pressure [13], solar activity (Wolf's number) [12-15], the geomagnetic fields [16-18], solar radiation [9], the cosmic rays [9, 19], light ions [9, 20,21], aerosols [9, 22], ozone [9, 23], other air toxic admixtures and etc. [9, 24].

It is well known that the effects of a significant increase in the mortality of population with the strong cold and the extreme heat [25-31]. For determining the extent of comfort or discomfort of the human living environment for her health (so-called "average person") frequently are used different simple and complex thermal indices [32-36].

Simple thermal indices involve more than one meteorological parameter and consider the combined effects on human organism (air equivalent- effective temperature - EET, Wet-bulb-globe temperature - derived from energy budget models. Such indices are popular in recent years, for example: Physiologically Equivalent Temperature (PET), Standard Effective Temperature (SET), Physiological Subjective Temperature and Subjective Temperature (MENEX), the Universal Thermal Climate Index (UTCI) etc. [37-41]).

Action on the human organism by the higher indicated factors have different scales - from minute, hour, day, decade and month to the seasonal and annual [5,7,9,14,17,19,23,30,31,33,36,42-44]. For example, in the works [43,44] is obtained that the dependence of mortality on EET takes the classical form - the decrease of mortality from the gradation "Sharply Coldly" to "Comfortably" with further increase to the gradation "Warmly". It is found in the works [30,31] that the relationship between the average monthly air temperature in Kutaisi and Kakheti region and such indices of the health of population as the total number of emergency medical calls, cases of hospitalizations and deaths has the form of a third power polynomial. In general, in the warm months there is a decrease of the total number of emergency medical calls, cases of hospitalizations and deaths. In the hot months, there is a worsening in these indicators of health, comparable to the cold months of the year (increase of the emergency medical calls, cases of hospitalizations and deaths).

For the bioclimatic zoning of territories (including for evaluating the bioclimatic potential of health resort- tourist industry) frequently is used the mean monthly values of simple thermal indices [33,42,45,46].

The standard scale and categories of the majority of these indices is usually used in this case for describing the real (hour or day) bioclimatic situation. In the latter case, as a rule, with the monthly averaging of meteorological data occurs range reduction of the scale of thermal indices and decrease of its sensitivity for evaluating the degree of the bioclimatic comfort of environment for the people. Therefore, the numerical values of the standard scale of thermal indices always cannot coincide with the verbal description of the categories of these indices. The results of investigating the connection of eight simple thermal indices and Tourism Climate Index with the monthly mortality of the population of Tbilisi city apropos of the cardiovascular diseases, which made it possible to estimate the representativeness of the standard scales and categories of the indicated indices as the bioclimatic indicator in monthly time scale, were represented in [36].

In this work, comparative analysis of the connection of eight simple thermal indices and Tourism Climate Index (TCI) [47] with the monthly mortality of the population of Tbilisi city apropos of cardiovascular diseases is represented. The values of simple thermal indices were calculated with the use of mean monthly and mean monthly for 13 hours data of meteorological elements. Between all studied simple thermal indices practically direct functional connection with the coefficient of linear correlation not lower than 0.86 is observed. The connection of simple thermal indices with the TCI is nonlinear and takes the form of third power polynomial. The possibility of using the standard scales and categories of the indicated indices as the bioclimatic indicator in monthly time scale is studied. As a whole, all indices adequately correspond to the degree of the bioclimatic comfort of environment for the people - with an increase in the level of comfort the mortality diminishes. Most representative for this purpose is Missenard air effective temperature in 13 hours.

This work is a continuation of the study [36]. Results of investigation on connection of Holiday Climate Index (HCI) and its components and components ratings [48-51] with public health (on Example of Tbilisi - mortality by cardiovascular deseases and Kakheti Region of Georgia - ambulance calls, hospitalization, total mortality) are presented below.

Study Area, Material and Methods

Study area – Tbilisi and Kakheti region of Georgia (below - Kakheti).

In this work the Holiday Climate Index (HCI) is used. The HCI uses five climatic variables related to the three facets essential to tourism (table 2): thermal comfort (TC), aesthetic (A), and physical (P) facet. The five climatic variables used for the HCI input are maximum air temperature and relative humidity (TC), cloud cover (A), precipitation and wind (P) [48].

The HCI score is calculated according to the following formula [48]:

$$\mathbf{HCI = 4 \cdot T + 2 \cdot A + 3 \cdot R_d + 1 \cdot W.}$$

This formula uses the following bioclimatic indicators and ratings of these indicators. Thermal Comfort (TC) - effective temperature (°C) [47] – combination of maximum dry-bulb temperature and mean values of relative humidity (%), rating of TC is T; CC - daily cloud cover (%), rating of CC is A; DP - daily precipitation (mm), rating of DP is R_d; WS - wind speed (m/sec or km/hour), rating of WS is W. Values of all HCI components rating change from 0 to 10 [48-51]. Note that below the physical dimensions of the studied parameters are omitted.

In this work the data of HCI for Tbilisi is used [49]. For Kakheti, these data were averaged over six locations of this region (Dedoplistskaro, Gurjaani, Kvareli, Lagodekhi, Sagarejo and Telavi) [51].

The population health indicators are as follows. Mean monthly decade mortality by cardiovascular deseases – M; mean monthly decade values of ambulance colls - AC, hospitalization – H; total mortality – TM.

In the work analysis of data is carried out with the use of the standard statistical analysis methods. The following designations will be used below: Mean – average values; Min – minimal values; Max - maximal values; Range: Max – Min; St Dev – standard deviation; C_v, % - coefficient of variation: $C_v = 100 \cdot$ St Dev/Mean; R^2 - coefficient of determination; R - coefficient of linear correlation; α - level of significance.

R(M), … etc. - coefficient of linear correlation between mortality, … etc. with mean monthly values of HCI componets and these ration respectivelly; α (R(M)), … etc. - the corresponding values of the significance level of the linear correlation coefficient.

Results

Results in Table 1-6 and Fig. 1-13 are presented.

Table 1. Statistical characteristics of mean monthly values of HCI and mean monthly decade mortality by cardiovascular deseases in Tbilisi in 1980-1990.

Variable	**HCI**	**HCI Category**	**Mortality**
Mean	73	Very Good	105
Min	53	Acceptable	70
Max	89	Excellent	168
Range	36		98
St Dev	8.7		17.3
Cv, %	11.9		24.7

In Table 1 statistical characteristics of mean monthly values of HCI and mean monthly decade mortality by cardiovascular deseases in Tbilisi in 1980-1990 is presented. As follows from this Table values of HCI change from 53 (category - Acceptable) to 89 (category - Excellent). Values of M change from 70 to 168.

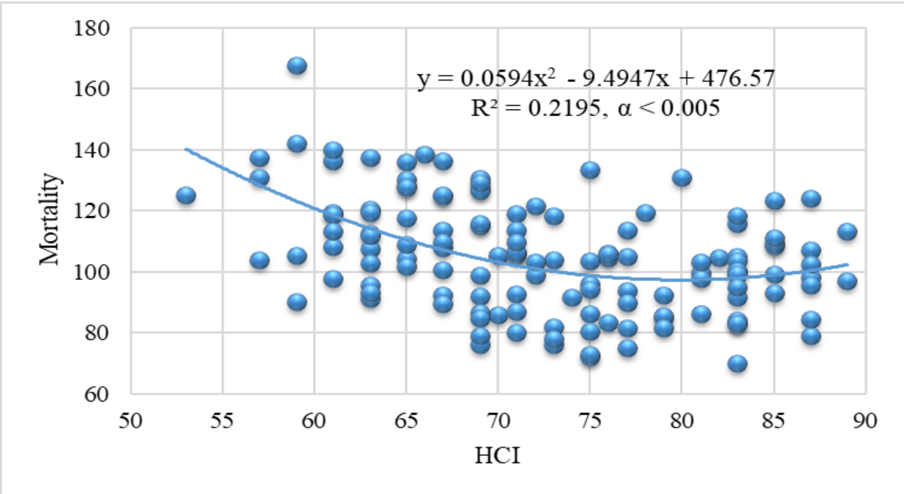

Fig.1. Connection between mean monthly values of HCI with mean monthly decade mortality by cardiovascular deseases in Tbilisi in 1980-1990.

Connection between mean monthly values of HCI with mean monthly decade mortality by cardiovascular deseases in Tbilisi (Fig. 1) has the form of a second degree polynomial. It should be noted that with an increase of the HCI values, in general, a decrease of mortality is observed. At the same time, at high values of HCI, mortality tends to increase.

This fact is also clearly demonstrated in Fig. 2. As follows from Fig. 2 in the range of HCI categories Acceptable – Very Good, mortality by cardiovascular deseases in Tbilisi decreases. With the transition of HCI categories from Very Good to Excellent - mortality increases. And although this growth is statistically insignificant, the some trend is still observed.

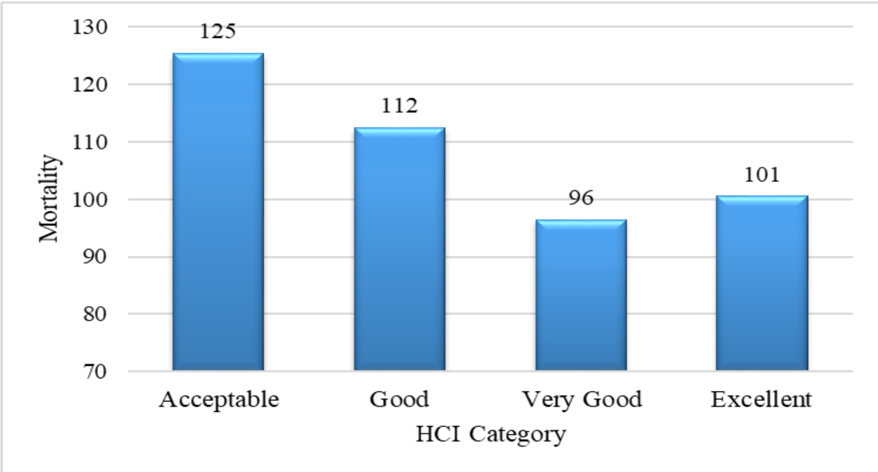

Fig.2. Mean monthly decade mortality by cardiovascular deseases at different HCI categories in Tbilisi in 1980-1990.

It should be noted that in our early studies [36, 42] it was found that the relationship between the Tourism Climate Index (TCI) and mortality by cardiovascular deseases in Tbilisi has an inverse linear relationship. At the same time, for both TCI categories Very good and Excellent, the mortality rate in Tbilisi was the same.

Table 2. Statistical characteristics of HCI components and ratings of these components in Tbilisi in 1980-1990.

Variable	TC	T	CC	A	DP	R_d	WS	W
Mean	19.2	6.2	5.9	5.6	40.1	8.9	0.9	10.0
Min	1.6	3	2.8	3	0.0	8	0.1	8
Max	34.1	10	9.0	9	158.7	10	1.9	10
Range	32.5	7.0	6.2	6.0	158.7	2	1.8	2
St Dev	9.4	2.1	1.2	1.2	33.4	0.3	0.4	0.2
Cv, %	48.8	33.3	19.5	21.8	83.4	3.6	44.2	2.5

In Table 2 statistical characteristics of HCI components and ratings of these components in Tbilisi in 1980-1990 are presented. As follows from this Table the variability of the investigated parameters is as follows. TC: – mean – 19.2, range of change – 1.6÷34.1; T: mean – 6.2, range of change – 3÷10; CC: mean – 5.9, range of change – 2.8÷9.0; A: mean – 5.6, range of change – 3÷9; DP: mean – 40.1, range of change – 0.0÷158.7; R_d: mean – 8.9, range of change – 8÷10; WS: mean – 0.9, range of change – 0.1÷1.9; W: mean – 10.0, range of change – 8÷10.

Table 3. Linear correlation coefficient between HCI components and ratings of these components with mean monthly decade mortality by cardiovascular deseases in Tbilisi in 1980-1990.

Variable	TC	T	CC	A	DP	R_d	WS	W
R(M)	-0.65	-0.36	0.25	-0.23	-0.14	0.09	-0.18	0.00
α (R(M))	<0.005	<0.005	0.005	0.01	0.10	no sign	0.05	no sign

In Table 3 information about linear correlation coefficient between HCI components and ratings of these components with mean monthly decade mortality by cardiovascular deseases in Tbilisi is presented. The largest value of the linear correlation coefficient between the values of M and the HCI components is -

0.65 (with TC), the smallest is -0.14 (with DP). The largest value of the linear correlation coefficient between the M values and the ratings of the HCI components is -0.36 (with T), the smallest is 0.0 (with W). Thus, the TC and T parameters make the main contribution to the mortality by cardiovascular deseases variability.

For example, in Fig. 3 shows a graph of the linear correlation between the values of TC and M.

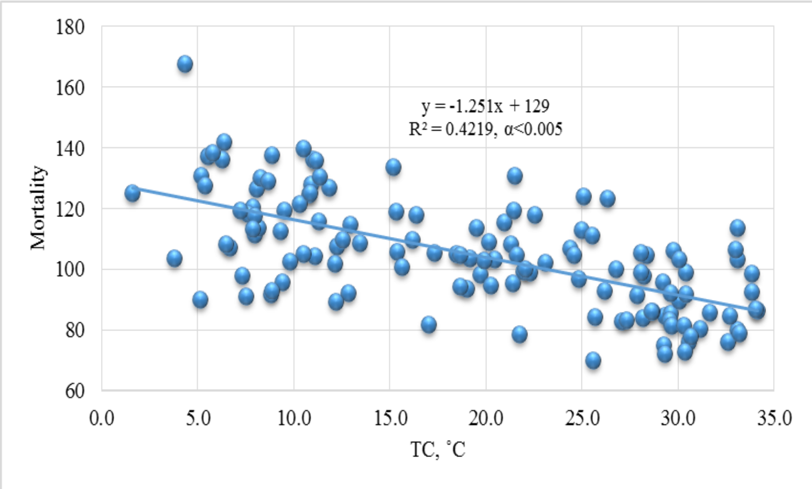

Fig.3. Connection between mean monthly values of TC with mean monthly decade mortality by cardiovascular deseases in Tbilisi in 1980-1990.

Connection between mean monthly values of T with mean monthly decade mortality by cardiovascular deseases in Tbilisi in Fig. 4 is presented. As follows from this Fig. coonection between indicated parameters has the form of a second degree polynomial (R^2 = 0.3078, $\alpha<0.005$).

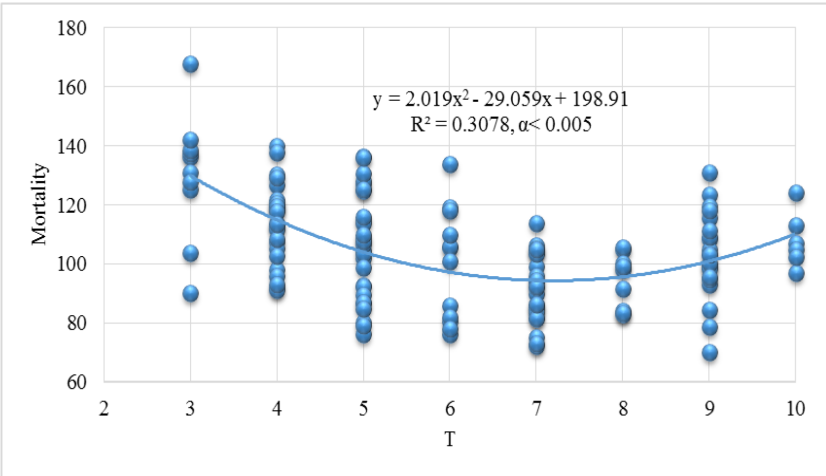

Fig.4. Connection between mean monthly values of T with mean monthly decade mortality by cardiovascular deseases in Tbilisi in 1980-1990.

Note that the second degree polynomial describes the relationship between M and T better than linear regression (R = -0.36, or R^2 = 0.1239, $\alpha<0.005$, Table 3). Fig. 4 also implies that, in general, with an increase in the values of T, mortality decreases, with the exception of values of T> 9 (some increase in mortality). This fact determines the connection between HCI and M in the case of the HCI category "Excellent" (some increase in mortality, Fig.2).

The statistical characteristics of mean monthly values of HCI and mean monthly decade values of ambulance calls, hospitalization and total mortality in Kakheti in 2013 and 2015 in Table 4 are presented.

Table 4. Statistical characteristics of mean monthly values of HCI and mean monthly decade values of ambulance calls, hospitalization and total mortality in Kakheti in 2013 and 2015.

Variable	HCI	Ambulance Calls	Hospitalization	Total mortality
Mean	71	1753	435	15
Min	62	1184	296	8
Max	84	2265	623	26
Range	22	1081	326	18
St Dev	6.8	335.8	79.0	4.2
Cv, %	9.6	19.1	18.2	28.0

As follows from this Table values of HCI change from 62 (category Good) to 84 (category Excellent). Values of ambulance calls change from 1184 to 2265, hospitalization - from 296 to 623, total mortality - from 8 to 26.

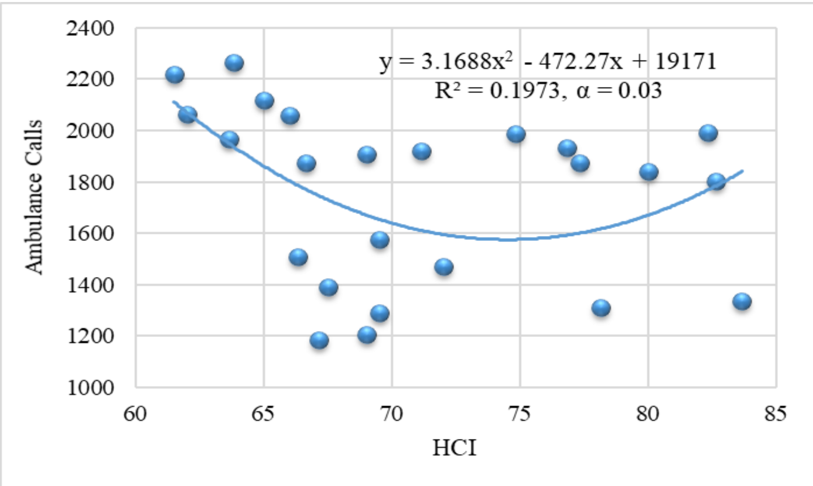

Fig.5. Connection between mean monthly values of HCI with mean monthly decade value of ambulance calls in Kakheti in 2013 and 2015.

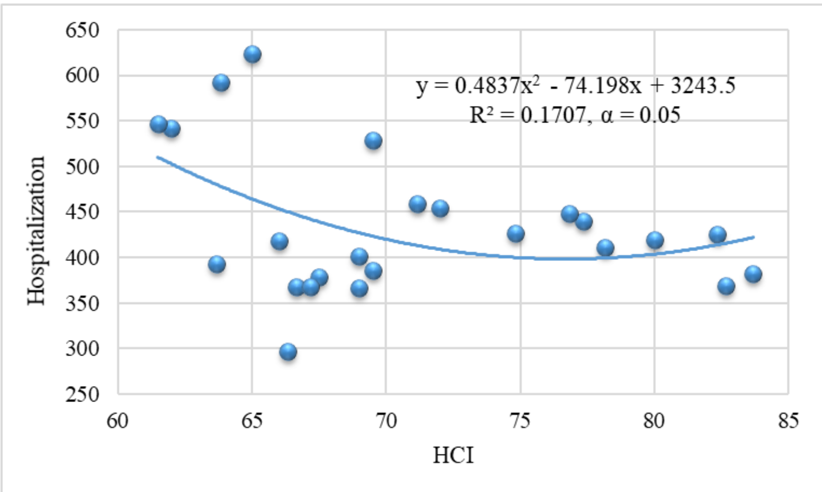

Fig.6. Connection between mean monthly values of HCI with mean monthly decade value of hospitalization in Kakheti in 2013 and 2015.

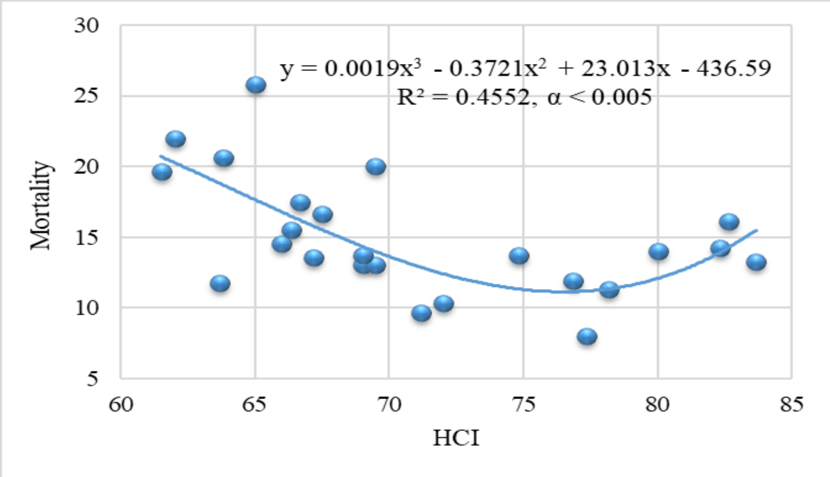

Fig.7. Connection between mean monthly values of HCI with mean monthly decade value of total mortality in Kakheti in 2013 and 2015.

In Fig. 5-7 connection between mean monthly values of HCI with mean monthly decade value of ambulance calls, hospitalization and total mortality in Kakheti are presented. As follows from these Fig. all the indicated connections have the form of a second degree polynomial (as in the case of Tbilisi, Fig.1). That is, in general with an increase of HCI values, there is a decrease of the values of AC, H and TM, and with the HCI category Excellent), their slight increase.

Table 5. Statistical characteristics of HCI components and ratings of these components in Kakheti in 2013 and 2015.

Variable	TC	T	CC	A	DP	R_d	WS	W
Mean	19.8	6.0	5.8	5.8	73.6	8.5	1.0	10
Min	6.3	3.3	3.8	3.8	17.0	6.5	0.8	10
Max	33.8	9.8	8.0	8.0	202.1	9.0	1.3	10
Range	27.5	6.5	4.2	4.2	185.1	2.5	0.5	0
St Dev	9.4	1.8	1.2	1.2	48.8	0.6	0.1	0
Cv, %	47.3	30.3	20.7	20.7	66.3	7.6	11.7	0.0

In Table 5. statistical characteristics of HCI components and ratings of these components in Kakheti in 2013 and 2015 are presented. As follows from this Table the variability of the investigated parameters is as follows. TC: – mean – 19.8, range of change – 6.3÷33.8; T: mean – 6.0, range of change – 3.3÷9.8; CC: mean – 5.8, range of change – 3.8÷8.0; A: mean – 5.8, range of change – 3.8÷8.0; DP: mean – 73.6, range of change – 17.0÷202.1; R_d: mean – 8.5, range of change – 6.5÷9.0; WS: mean – 1.0, range of change – 0.8÷1.3; W: mean – 10, range of change – 10÷10.

Table 6. Linear correlation coefficient between HCI components and ratings of these components with mean monthly decade values of ambulance colls, hospitalization and total mortality in Kakheti in 2013 and 2015.

Variable	TC	T	CC	A	DP	R_d	WS	W
R(AC)	-0.37	-0.20	-0.30	-0.30	-0.28	0.28	0.05	0.00
α (R(AC))	0.075	0.35	0.15	0.15	0.2	0.2	no sigh	no sigh
R(H)	-0.06	-0.29	-0.24	-0.24	-0.17	0.22	-0.22	0.00
α (R(H))	no sign	0.15	0.26	0.26	no sign	0.30	0.30	no sign
R(TM)	-0.57	-0.46	-0.22	-0.22	-0.25	0.26	0.35	0.00
α (R(TM))	0.005	0.02	0.30	0.30	0.24	0.22	0.1	no sigh

In Table 6 data about linear correlation coefficient between HCI components and ratings of these components with mean monthly decade values of ambulance colls, hospitalization and total mortality in Kakheti are presented.

The largest value of the linear correlation coefficient between the values of AC and the HCI components is -0.37 (with TC), the smallest is 0.05 (with WS). The largest value of the linear correlation coefficient between the AC values and the ratings of the HCI components is -0.30 (with A), the smallest is 0.0 (with W).

The largest value of the linear correlation coefficient between the values of H and the HCI components is -0.24 (with CC), the smallest is -0.06 (with TC). The largest value of the linear correlation coefficient between the H values and the ratings of the HCI components is -0.29 (with T), the smallest is 0.0 (with W).

The largest value of the linear correlation coefficient between the values of TM and the HCI components is -0.57 (with TC), the smallest is -0.22 (with CC). The largest value of the linear correlation coefficient between the TM values and the ratings of the HCI components is -0.46 (with T), the smallest is 0.0 (with W).

For example, in Fig. 8-13 shows a graphs of the connections between the values of TC and T with values of ambulance calls, hospitalization and total mortality in Kakheti.

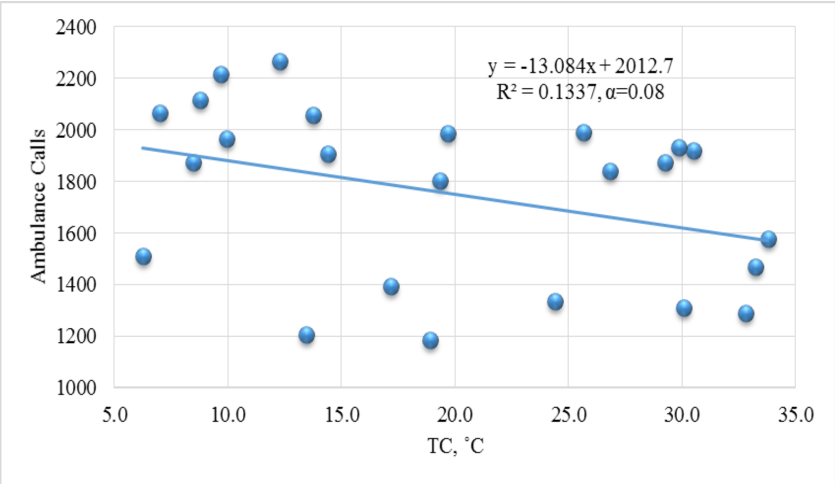

Fig.8. Connection between mean monthly values of TC with mean monthly decade value of ambulance calls in Kakheti in 2013 and 2015

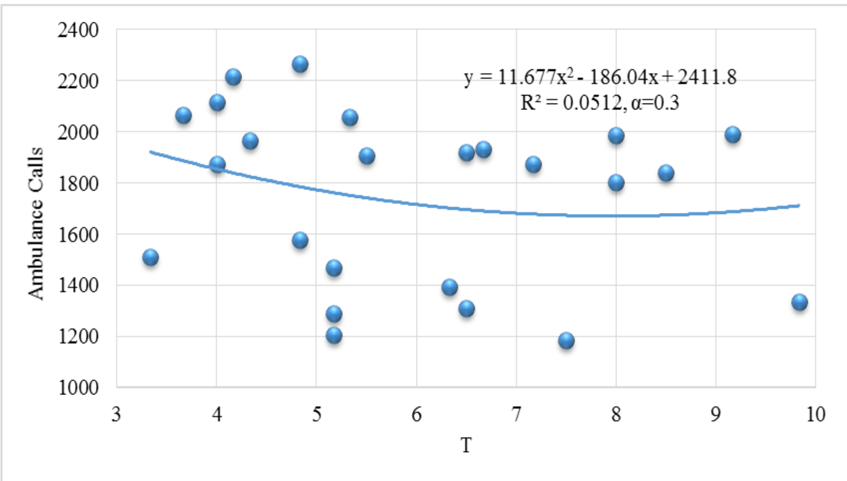

Fig.9. Connection between mean monthly values of T with mean monthly decade value of ambulance calls in Kakheti in 2013 and 2015.

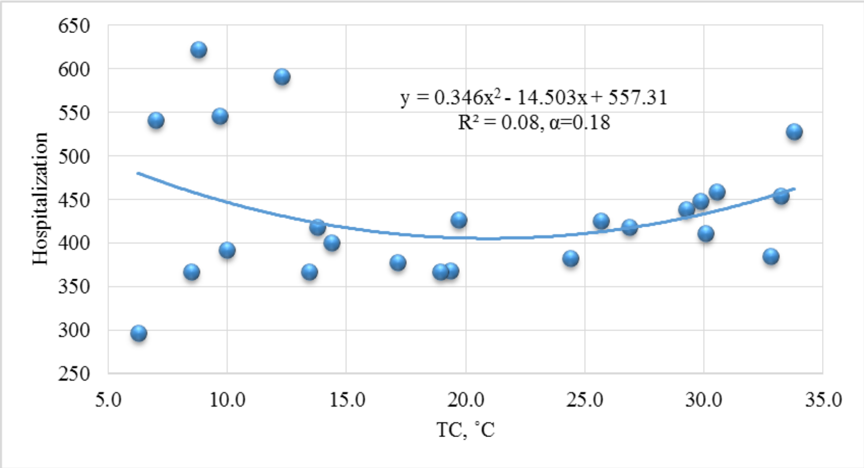

Fig.10. Connection between mean monthly values of TC with mean monthly decade value of hospitalization in Kakheti in 2013 and 2015.

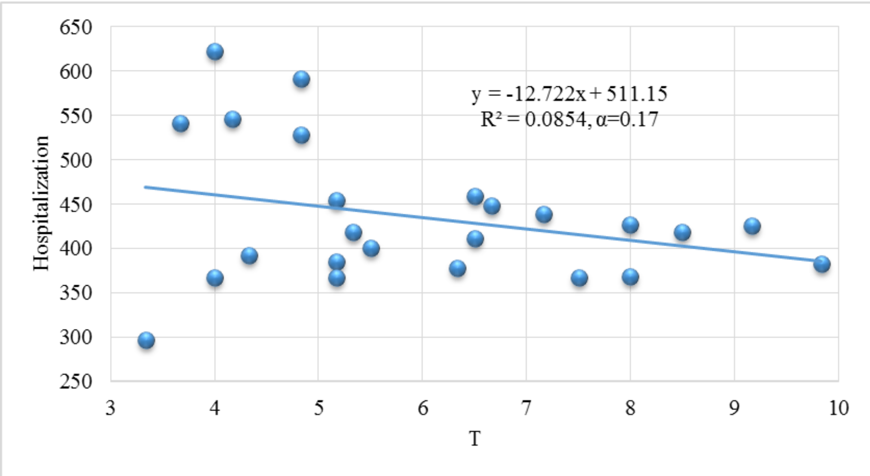

Fig.11. Connection between mean monthly values of T with mean monthly decade value of hospitalization in Kakheti in 2013 and 2015.

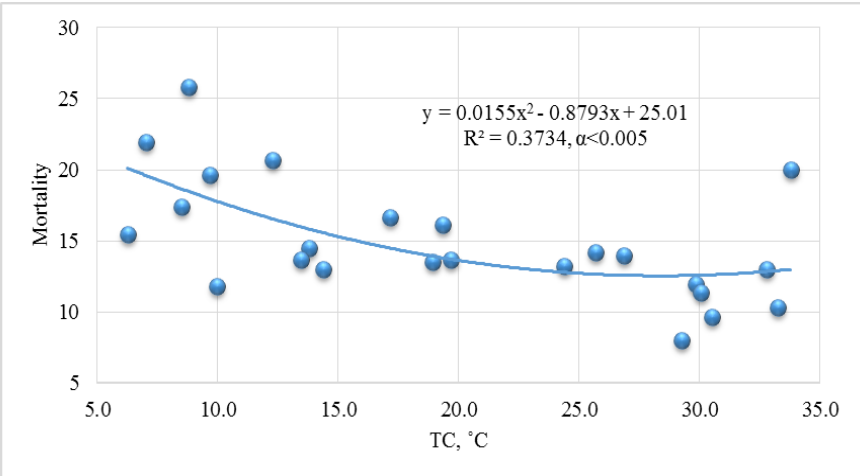

Fig.12. Connection between mean monthly values of TC with mean monthly decade value of total mortality in Kakheti in 2013 and 2015.

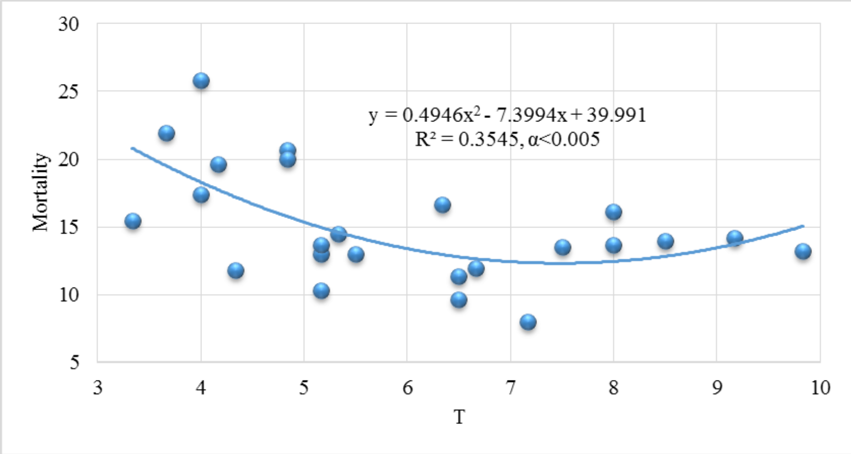

Fig.13. Connection between mean monthly values of T with mean monthly decade value of total mortality in Kakheti in 2013 and 2015.

So, the relationship between the values of TC and AC is inverse linear, and between T and AC - a polynomial of the second degree (Fig. 8 and 9); the relationship between the values of TC and H is a polynomial of the second degree, and between T and H - inverse linear (Fig. 10 and 11); the relationship between the values of TC and TM and T and TM are a polynomial of the second degree (Fig. 11 and 13).

Thus, the relationship between the HCI and the health indicators of the population in Tbilisi and Kakheti is in general similar to the classical form of mortality distribution according to the scale of thermal indices (a decrease in mortality from gradations with low uncomfortable values of the scale to comfortable ones, and then there is an increase in mortality in gradations with high uncomfortable values scale) [36].

Therefore, in our opinion, it is desirable to make adjustments in determining the degree of comfort of the HCI scale (as well as scales of other bioclimatic indices), taking into account local social and climatic conditions.

Conclusion.

In the future, we are planning to envisage conducting similar studies for other regions of Georgia.

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დასვენების კლიმატური ინდექსის კავშირი ადამიანის ჯანმრთელობასთან (თბილისის და კახეთის რეგიონის მაგალითზე)

ა. ამირანაშვილი, ა.რევიშვილი, ქ. ხაზარაძე, ნ. ჯაფარიძე

რეზიუმე

წარმოდგენილია დასვენების კლიმატური ინდექსის (დკი), მისი კომპონენტებისა და ამ კომპონენტების რეიტინგების ადამიანის ჯანმრთელობასთან კავშირის გამოკვლევა (თბილისის მაგალითზე - სიკვდილიანობა გულსისხლძარღვთა დაავადებების გამო და კახეთის რეგიონში - სასწრაფო სამედიცინო დახმარების გამოძახების, ჰოსპიტალიზაციის, საერთო სიკვდილიანობის რაოდენობა).

ნაჩვენებია, რომ მთლიანობაში ყველა მაჩვენებელი ადეკვატურად შეესაბამება ადამიანების საარსებო გარემოს კომფორტულობის ხარისხს. კერძოდ, დკი-ს კავშირს სიკვდილიანობასთან თბილისში აქვს მეორე ხარისხის პოლინომის, ხოლო კახეთში- მესამე ხარისხის პოლინომის სახე. ამავე დროს, ბიოკლიმატური კომფორტულობის ხარისხის ზრდისას დონემდე "ძალიან კარგი" დაიკვირვება სიკვდილიანობის შემცირების ტენდენცია. კომფორტულობის დონეზე "შესანიშნავი" გადასვლისას აღინიშნება სიკვდილიანობის გარკვეული მატება. ანალოგიური შედეგია მიღებული დკი-ს ზოგიერთი კომპონენტისა და მათი რეიტინგებისათვის.
შემოთავაზებულია მოსახლეობის ბიოკლიმატური კომფორტულობის ხარისხის სკალის განსაზღვრის კორექტირების ჩატარება ადგილობრივი სოციალური და კლიმატური პირობების გათვალისწინებით.

Связь климатического индекса отдыха со здоровьем людей (на примере Тбилиси и Кахетинского региона, Грузия)

А.Г. Амиранашвили, А. А. Ревишвили, К. Р. Хазарадзе, Н. Д. Джапаридзе

Резюме

Представлено исследование связи Климатического Индекса Отдыха (КИО), его компонент и рейтингов этих компонент на здоровье людей (на примере Тбилиси - смертность от сердечно-сосудистых заболеваний и Кахетинского региона Грузии – количество вызовов скорой медицинской помощи, госпитализаций, общей смертности).
Показано, что в целом все показатели адекватно соответствуют степени биоклиматической комфортности среды обитания для людей. В частности, связь КИО со смертностью в Тбилиси имеет вид полинома второй степени, а в Кахетии – полинома третьей степени. При этом, с повышением степени биоклиматической комфортности до категории "Очень хорошая" наблюдается тенденция уменьшения смертности. С переходом на уровень комфортности с категорией "Превосходная" отмечается некоторый рост смертности. Аналогичный результат получен для некоторых компонент КИО и рейтингов этих компонент.
Предлагается внести корректировки в определение степени комфортности шкал биоклиматических индексов для населения с учетом местных социальных и климатических условий.