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D O C T O R A L T H E S I S

Study of human bioclimatology in the large urban areas of Romania

- s u m m a r y -

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CONTENT

KEYWORDS: Extreme temperature; Bioclimatic stress; thermal stress; bioclimatic indices; Natural mortality; Relative risk; Rheumatic pathology; Meteotropism.

INTRODUCTION

It has been proven that weather and climate influence people's health and wellbeing (Michelozzi et al., 2009; Nastos and Matzarakis, 2012; Kuchcik, 2020).

The main aim of the paper is to analyze the influence of various climatic conditions on the human body, in the most populated urban areas of Romania.

More specifically, we aimed to identify:

- the main bioclimatic conditions in the urban areas under study;
- the periods with heat and/or cold thermal stress that can negatively affect the human body, the daily activities and also the tourist activities in the analyzed cities;
- the influence of thermal stress on the natural mortality recorded in the cities investigated;
- the perception of patients with chronic rheumatic diseases of the weather conditions that mostly influence their pain and contribute to the intensification of symptoms and pathological conditions.

The results of our research are useful for informing the urban population about the negative effects that some extreme climate events can have on their health and wellbeing. The information is also important to the medical staff for setting up intervention plans to prioritize care provision to people with various medical conditions, when unfavorable climatic conditions are forecast. Much more, local governments can take measures to improve living conditions in residential neighborhoods. Our findings are also of interest for development of tourism sector (planning for vacations, sports and recreational activities, outdoor cultural events), or for taking preventive measures for staff carrying out professional outdoor activities in various other economic fields. In addition, the obtained results bring novelty to the scientific research at the national level and can represent an important tool for the local and national authorities in the implementation of an effective warning system of extreme meteorological phenomena with an impact on human health.

1. LITERATURE REVIEW

Literature review was performed considering only the studies that totally or partially overlap with the subtopics debated in this research.

At the international level, the bioclimatic indices used in research are quite numerous: over 160 climate stress indices (Freitas and Grigorieva, 2014; Havenith and Fiala, 2015), more than 100 of them synthesizing thermal stress conditions (Belding, 1970; Goldman, 1988; Havenith and Fiala, 2015). The most recent studies are based on the analysis of the Universal Thermal Climate Index (UTCI) (Jendritzky et al., 2012; Havenith and Fiala, 2015; Kolendowicz et al., 2018; Di Napoli et al., 2019; Rozbicka and Rozbicki, 2021).

Many of the studies carried out in recent years have investigated the relation between air temperature (maximum and/or minimum) and mortality (Barnett et al., 2010; D'Ippoliti et al., 2010; Iñiguez et al., 2010; Basagaña et al., 2011; Gasparrini et al., 2011; Åström et al., 2013; de' Donato et al., 2015; Gasparrini et al., 2015a; 2015b; Guo et al., 2016, 2017; Åström et al., 2018; Mitchell et al., 2018). During periods of thermal extremes (heat or cold) an increase in mortality and morbidity has been detected (Laschewski and Jendritzky 2002; Díaz et al., 2006; 2015; Fouillet et al., 2006; Rocklöv et al., 2014; Goldberg et al., 2011; Green et al., 2016; Guo et al., 2017; Royé et al., 2020). Heat waves are considered extreme weather events with a major negative impact on human health (Peterson et al., 2013).

Compared to the effects of cold or other weather conditions, the stress caused by excessive heat has been approached in more studies (Pat, 2007). Overall, research has shown that the population of cities with a warmer climate tends to show greater sensitivity to cold thermal extremes, whereas population of cities with colder climate is more vulnerable to heat thermal extremes (Curriero et al., 2002; Analitis et al., 2008; Anderson and Bell, 2009; Ng et al., 2014).

Another topic of interest in bioclimatology is the relation between changes in weather conditions and pain fluctuations, yet, the changes occurring in the structure of joints not being fully clarified (Strusberg et al., 2002; Bossema et al., 2013; Azzouzi and Ichchou, 2020). The studies on patients' perception of weather's influence on pain have mainly considered patients with degenerative pathology (Shutty et al., 1992; Jamison et al., 1995; Hendler et al., 1995; Dixon et al., 2019). Most of the studies are retrospective, and many of them conclude that the intensity of rheumatic pain is influenced by the weather changes (Aikman, 1997; Gorin et al., 1999; Ng et al., 2004; Dorleijn et al., 2014; Timmermans et al., 2014; Dixon et al., 2019; Azzouzi and Ichchou, 2020).

Compared to the international human bioclimatology research, there are fewer studies in the national literature. Most of them focus on bioclimatic and balneoclimatic analyses (Bistricean et al., 2017; Maftei and Buta, 2017; Bistricean, 2018; Scripcă and Croitoru, 2018a; 2018b; 2019; Sfîcă et al., 2018; Croitoru et al., 2019b; Velea et al., 2019; Banc et al., 2020;

Grigore et al., 2020a; Ichim and Sfîcă, 2020; Roșu et al., 2022) and on theoretical analyses (Croitoru and Sorocovschi, 2012; Teodoreanu and Gaceu, 2013; Enache, 2016). Little research has been carried out to illustrate the direct influence of the weather on people with different pathologies, or on mortality values (Teodoreanu, 1988; Teodoreanu and Rădulescu, 2001; McMichael et al., 2008; Velea et al., 2017; Croitoru et al., 2018; Croitoru et al., 2019a; Scripcă et al., 2021).

2. DATA AND RESEARCH METHODOLOGY

2.1. Data

The *meteorological parameters* used are: minimum air temperature (TN), average air temperature (T), maximum air temperature (TX), relative air humidity (RH), wind speed at 10 m above the ground (v10), atmospheric precipitation (PP) and cloudiness (N). Data was available for the period 1961-2016 and was recorded at the main weather stations in the analyzed areas: Bucharest-Băneasa, Cluj-Napoca, Constanța, Iași, and Timișoara. A significant part of data was provided by the National Meteorological Administration (NMA), or was extracted from the following databases: https://www.ecad.eu/, http://meteomanz.com/, https://rp5.ru/, and ROCADA archive (Dumitrescu and Birsan, 2015).

The *geodemographic data* covers the period 1999-2016, for every year and urban area selected for study. We used the free information available in the database of the National Institute of Statistics (NIS) (http://www.insse.ro) and from the Territorial Observatory (TO) (https://ot.mdrap.ro). For the population analysis we used the data available in the archives: POP108D - Population by domicile on July 1 by age group and age, gender, counties and localities, and POP201D - Live births by counties and localities. Mortality daily data was available for the period 1999-2016 and was provided free of charge by the NIS, for research purposes.

The data from the sociological survey were collected by applying a questionnaire, specially designed for this type of research.

Other types of data refer to: labor force (average number of employees), medical information (health infrastructure, medical staff), education (graduates by education level). Data was downloaded from the NIS archive, free of charge.

2.2. Methods

The geodemographic features of the studied cities were illustrated by calculating several demographic indicators: population density, population growth rate, general birth rate, general mortality rate, rate of natural increase.

The general weather conditions were described by calculating: the minimum value, the lower quartile, the mean, the median, the upper quartile and the maximum value, for each meteorological parameter. For N, RH and v10, monthly averages were calculated. To illustrate the thermal and precipitation features, the Péguy climatogram, the De Martonne Index and the Walter-Lieth climatogram were employed.

Bioclimatic indices

Simple bioclimatic indices - a single meteorological parameter (air temperature) was used for their calculation: TX and TN values. In this category, we included the following:

- *the bioclimatic indices calculated based on relative thresholds*: percentage of very hot days (TX90p), percentage of cold days (TX10p), percentage of warm nights (TN90p), percentage of cold nights (TN10p). Indices were calculated at annual level, using the ClimPACT2 software (Alexander and Herold, 2016), and the reference period was established between 1961 and 1990. To explain the results, the analysis of climate variability was performed and the extreme values were identified (minimum, maximum, average); trends were also presented.
- *the heat waves/warm periods and cold waves/cold periods*: heat waves/warm periods were identified when TX was equal to or greater than the moving average value (calculated over five days) of the 90th percentile. Cold waves/cold periods were identified when TN was equal to or below the moving average value (calculated over five days) of the 10th percentile. The results were explained considering: the annual and seasonal (cold, warm) number of events; the identification of trends in the number of events (annual, seasonal).

Complex bioclimatic indices – several meteorological and climatic parameters were used for their calculation. The following were identified: the Universal Thermal Climate Index (UTCI), the Cooling Power index (H), Effective Temperature (TE) and Equivalent Temperature (TEK). The indicators were calculated at daily level, for the period 1961-2016, for each weather station under study, using the BioKlima software, version 2.6 (Błażejczyk and Błażejczyk, 1997). For each indicator, the following was calculated: the frequency of days by thermal comfort class per month and for the entire analyzed period; the average duration of the occurrence period; trend detection for the frequency and duration of the occurrence period.

Correlations between the complex bioclimatic indices and the heat waves and cold waves were identified aiming to illustrate: the distribution of days with heat waves/warm periods, respectively cold waves/cold periods in each bioclimatic class, for each complex index;

the calculation of the frequency of days with and without conditions of heat waves/warm periods, respectively cold waves/cold periods in each bioclimatic class of a complex index.

Mortality and its dependence on the heat stress was investigated using data on deaths that occurred from natural causes/ non-accidental deaths. Daily mortality data was classified by diagnosis, in accordance with the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (ICD-10-AM) (https://www.drg.ro/DocDRG/ListaTabelara_Boli_ICD_10_AM.pdf).

The analysis of mortality and its dependence on the heat stress, included the following:

- description of mortality data - average, relative frequency by year, season, month and day;
- identification of relations between deaths and the simple bioclimatic indices calculated based on relative thresholds and the UTCI index;
- establishing the relation between mortality and TN and TX. The R software (version 3.5.1) and the information available in the dlnm package (The distributed lag non-linear model) were used (Gasparrini et al., 2010; Gasparrini, 2011; https://cran.r-project.org/web/packages/dlnm/index.html). The effects of TX and TN on mortality are expressed by the relative risk value (RR).

The perception of meteorological conditions by patients with degenerative rheumatic pathology was investigated by conducting a survey based on a questionnaire especially created to answer the research objectives. In order to illustrate a clear picture of all the patients' answers, we decided to calculate their frequencies for every question in the questionnaire. To identify the existing correlations between patient's responses and the meteorological variables, Pearson correlation coefficient was calculated, using the SPSS software (version 22). The level of statistical significance was established at $\alpha = 0.01$. The Shapiro-Wilk normality test was also applied to verify data distribution.

For the *trend detection* of the bioclimatic indices The Mann-Kendall test was selected, using the XLSTAT ProPlus software, and the magnitude of the trend was calculated by employing the Sen's slope method.

For the *graphical representation of the results*, RStudio, Microsoft Excel 2016, and ArcMap10.2 software were used.

3. MAIN RESULTS AND DISCUSSION

3.1. Analysis of bioclimatic conditions in the selected urban areas

The results obtained from the *analysis of simple bioclimatic indices calculated based on the relative thresholds* show an increase in the warm thermal extremes (TX90p, TN90p), for which statistically significant growth trends were detected. For the indices that show discomfort in relation to cold thermal stress (TX10p and TN10p) we found a decrease in the number of days with these features in the last decades analyzed, the decrease being more evident after the year 2000. Their decrease trends are dominantly statistically significant.

For the extreme events identified considering *heat waves/warm periods, cold waves/cold periods*, the results show a clear increase in the thermal extremes calculated based on TX. For the last interval of the reference period, an increase in the number of heat waves was observed. All their trends show statistically significant growth. Conversely, there is a decrease in the number of cold waves/cold periods, in the last part of the reference period. In most cases, statistically significant downward trends or stationary trends were calculated.

By analyzing *the complex bioclimatic indices*, we were able to identify the months in a year when stressful bioclimatic conditions dominate (for heat and cold thermal stress). Also, for every bioclimatic class, the frequency of occurrence of each type of bioclimatic conditions was calculated at the city level. The analysis was carried out for each index; afterwards, the results obtained for every weather station were compared.

The analysis of *UTCI* by bioclimatic classes at monthly level shows that, regardless of the analyzed city, during winter months (December, January, February) the classes of discomfort due to cold thermal stress predominate; in opposition, during summer months (June - August) we mostly found classes of discomfort due to warm thermal stress. In the months of transition seasons (especially from April to May and from September to October), thermal comfort conditions prevail. For the cold thermal stress, in almost all locations, the most severe bioclimatic conditions are generally associated with the extreme cold stress class, yet these days occurring relatively rare and isolated, with a maximum frequency in the first month of the year. The classes that illustrate the most severe conditions, strong heat stress and very strong heat stress, occur only during the summer months. The strong heat stress class was recorded in all locations, most of the days with these features being recorded in July. The very strong heat stress class was reported only for the weather stations of Bucharest (days in July) and Constanța (days in August and July). For this indicator, the statistically significant decrease trends are specific to 27% of the data sets related to frequency, attributed to the classes showing the bioclimatic conditions for cold thermal stress.

The distribution of bioclimatic classes for the *H index* reveals that, for all weather stations, especially during winter months, the most severe conditions were not met, because the extreme classes (very cold and windy, and very cold) were recorded in very few days. The most severe bioclimatic conditions associated with heat stress are specific to the sultry class: during the year, they are recorded mainly in the summer months, the highest share occurring in July in Bucharest, Iași and Timișoara and in August in Cluj-Napoca and Constanța. For the thermal comfort classes, most of the conditions of the cool, very hot, and sultry classes recorded a statistically significant increase (over 60%). For a significant share (over 30% of the total of each class showing thermal sensations of very cold and windy, very cold, cold, and cool) the trends showed a statistically significant decrease.

The *TE* indicator reveals that for all urban areas, the bioclimatic classes related to cold stress (very cold, cold and cool) were recorded in most of the days. The conditions associated with heat thermal stress are given by the warm bioclimatic class, for which a small number of days was identified. During winter months, the most severe bioclimatic conditions are recorded, regardless of the analyzed area, the highest share of the conditions felt during these months being associated with the very cold class (over 80% per month). The most severe conditions for the heat stress, associated with the very hot class, have a frequency of only two days at the Bucharest and Constanța stations. Regardless of the type of thermal stress, about 56% of all frequency data series show increasing trends and 46% of them are also statistically significant. Statistically significant increasing trends are specific to the cold, cool, comfortable, warm classes (more than 40% of the total of each class). The decreasing trends represent 34% of the total, of which 17% are also statistically significant, and their distribution by classes of thermal sensations is associated with very cold and cold bioclimatic classes.

Regarding the average frequency of occurrence calculated for *the TEK indicator*, the highest values were obtained for the cold class. For the winter season, the largest share of days (over 70%) is associated with the cold class, for all locations. For the summer season, there were high frequency values associated with the days belonging to the very hot and sultry classes. For all stations, the month of July stands out as being favorable for the occurrence of heat thermal stress. The frequency of bioclimatic classes at the annual level highlights the predominance of cold thermal stress conditions for all weather stations. The most important changes are attributed to the classes of extreme thermal conditions: the very hot and sultry classes show increasing trends in 80% of the data sets, a significant share of which are also statistically significant (40% for the very hot class and 60% for the sultry class), while the cold class only registers decreasing trends, of which 20% are also statistically significant.

Since the frequency of certain categories of stress is quite important in bioclimatic studies, this research focused on this type of analysis, as well. In winter, the bioclimatic conditions are specific to several classes of thermal sensations associated with cold stress, however the most severe cold thermal stress having a low frequency. In the summer season, extreme conditions related to heat thermal stress predominate, regardless of the analyzed bioclimatic index. At the monthly level, July is the most vulnerable for the occurrence of heat stress. This was found especially particular to the south-east part of the country (Constanța), where, no matter the analyzed index, the most severe conditions associated with warm bioclimatic stress recorded the highest percentage.

Relations between complex bioclimatic indices (UTCI, H, TE, TEK) and heat waves/warm periods and cold waves/cold periods

Following this analysis, it can be concluded that:

- for all four bioclimatic indices analyzed, heat waves significantly correspond to the periods with critical conditions for the human body (heat thermal stress), but the closest relation was detected for H, TE and UTCI;
- cold waves generally correspond to the most severe bioclimatic classes of all analyzed indicators (for cold stress); most of the cold waves occurred when the most severe bioclimatic classes for the cold thermal stress were calculated for the UTCI and H indices;
- the relations between heat waves and warm thermal stress classes of the complex bioclimatic indices are stronger compared to those between cold waves and cold thermal stress classes;
- the cold periods during the warm semester and the warm periods during the cold semester mostly correspond to the thermal comfort conditions identified based on the bioclimatic indices, which leads to an alleviation of the thermal stress felt by the human body during these seasons.

3.2. Analysis on the relation between extreme thermal conditions and natural mortality

At first, the statistical analysis and the quality control of mortality data were performed. We checked the data series for any annual, monthly, multiannual discrepancies that could influence the analyses of correlation with air temperature. The analysis on the number of deaths for the entire period, showed no important quantitative changes from one year to another (Figure 1, Table 1).

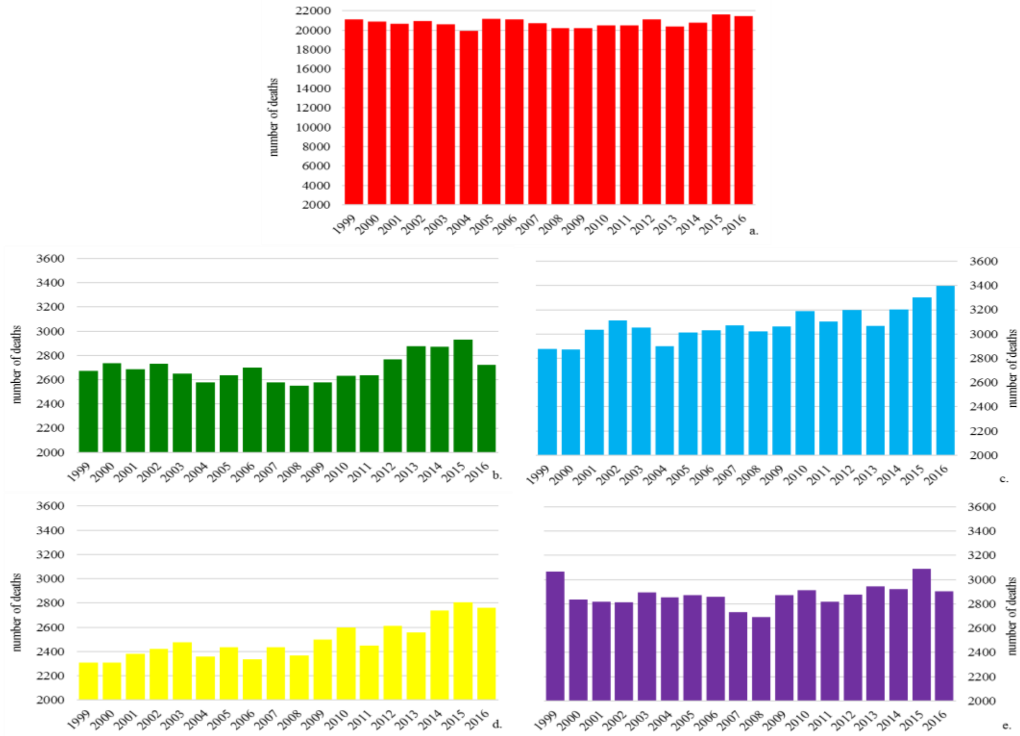

Figure 1. Variations in the annual number of deaths, in: a - Bucharest, b - Cluj-Napoca, c - Constanța, d - Iași, e - Timișoara, in the period 1999-2016 (data processed based on NIS archive)

Table 1. Annual number and multi-annual average value of recorded deaths, in the period 1999-2016 (data processed based on the NIS archive) (Scripcă et al., 2021, with modifications)

Year	*Bucharest*	*Cluj-Napoca*	*Constanța*	*Iași*	*Timișoara*
1999	21113	2673	2877	2309	3066
2000	20883	2735	2872	2308	2838
2001	20659	2684	3033	2380	2816
2002	20929	2730	3110	2420	2815
2003	20577	2652	3051	2476	2895
2004	19950	2577	2900	2358	2856
2005	21179	2636	3012	2435	2873
2006	21101	2700	3032	2334	2859
2007	20737	2578	3070	2436	2732
2008	20218	2550	3022	2368	2689
2009	20185	2578	3061	2498	2870
2010	20468	2633	3190	2596	2912
2011	20467	2635	3102	2451	2816
2012	21101	2769	3198	2611	2877
2013	20382	2875	3068	2558	2945
2014	20801	2870	3203	2737	2924
2015	21619	2930	3301	2805	3090
2016	21462	2721	3398	2759	2904
multianual mean	20768.4	2695.9	3083.3	2491.1	2876.5
annual death rate *	987.7	837.3	973.3	681.4	865.9

* calculated as the number of deaths per 100,000 inhabitants

It is important to mention that the highest mortality values were recorded in the winter, and the lowest number of deaths in the summer (Figure 2). This seasonal distribution of mortality is significant for the correlations with climate data. This trend has also been noted in other human bioclimatology studies (Muthers et al., 2010; Scortichini et al., 2018; Rodrigues et al., 2019).

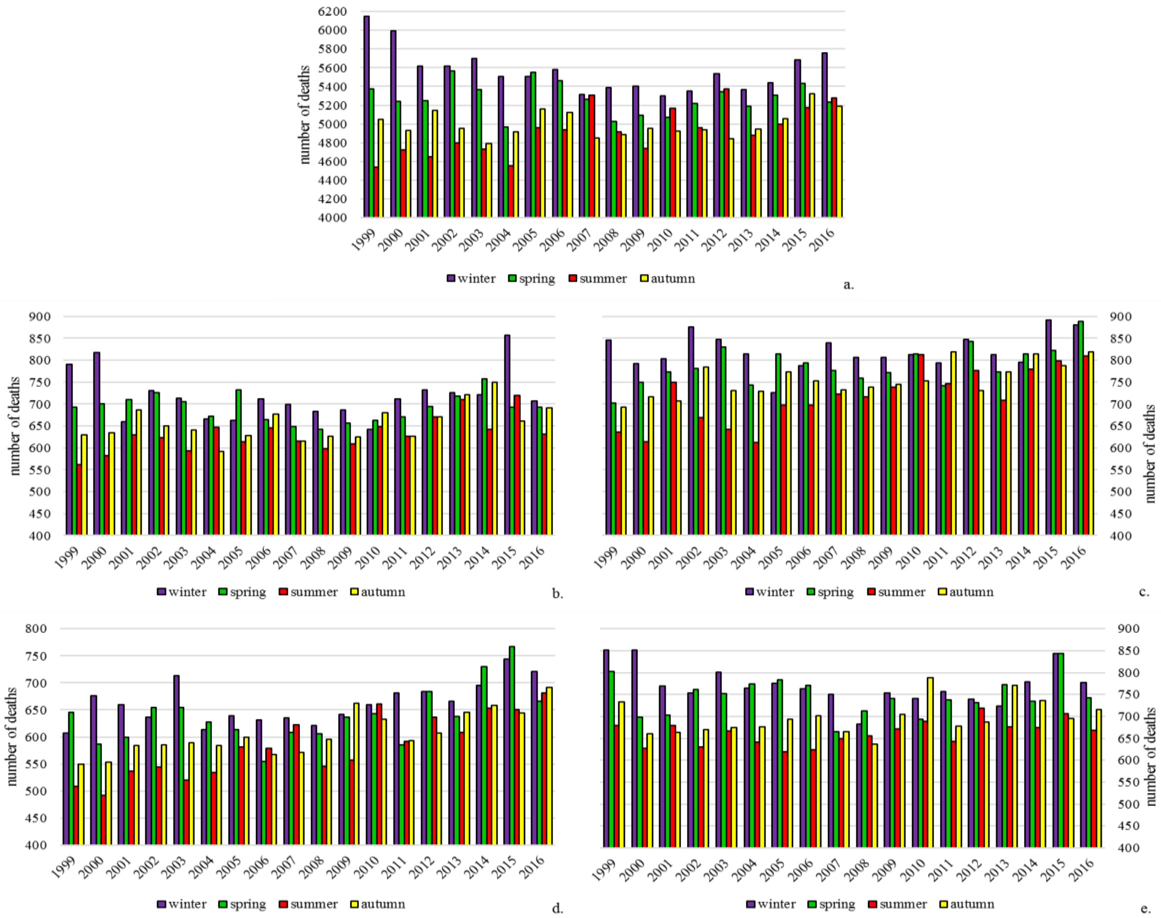

Figure 2. Seasonal number of deaths, in: a - Bucharest, b - Cluj-Napoca, c - Constanța, d - Iași, e - Timișoara, in the period 1999-2016 (data processed based on NIS archive)

The analysis on the relation between *the simple bioclimatic indices calculated based on relative thresholds* and *the mortality* recorded in the analyzed cities reveals a more visible connection with the indices for warm extremes (TX90p and TN90p) compared to the indices for negative thermal extremes (TX10p, TN10p). This indicates that the urban population is more vulnerable to positive thermal extremes, compared to negative ones (Figure 3).

For the existing correlations between *mortality* and *the UTCI index*, we chose to describe the extreme seasons, because the harshest bioclimatic conditions are recorded in the summer and winter. For the summer, the higher daily mortality value than the average is associated with a high frequency of heat stress conditions, especially hot, but also slightly cold. Thus, the number of days with above-average mortality value decreases from the classes with intensive heat stress to the class with thermal comfort conditions, and then suddenly increases with the occurrence of mild cold stress. These results prove a greater sensitivity of the population to the stressful conditions generated by high temperatures (Table 2).

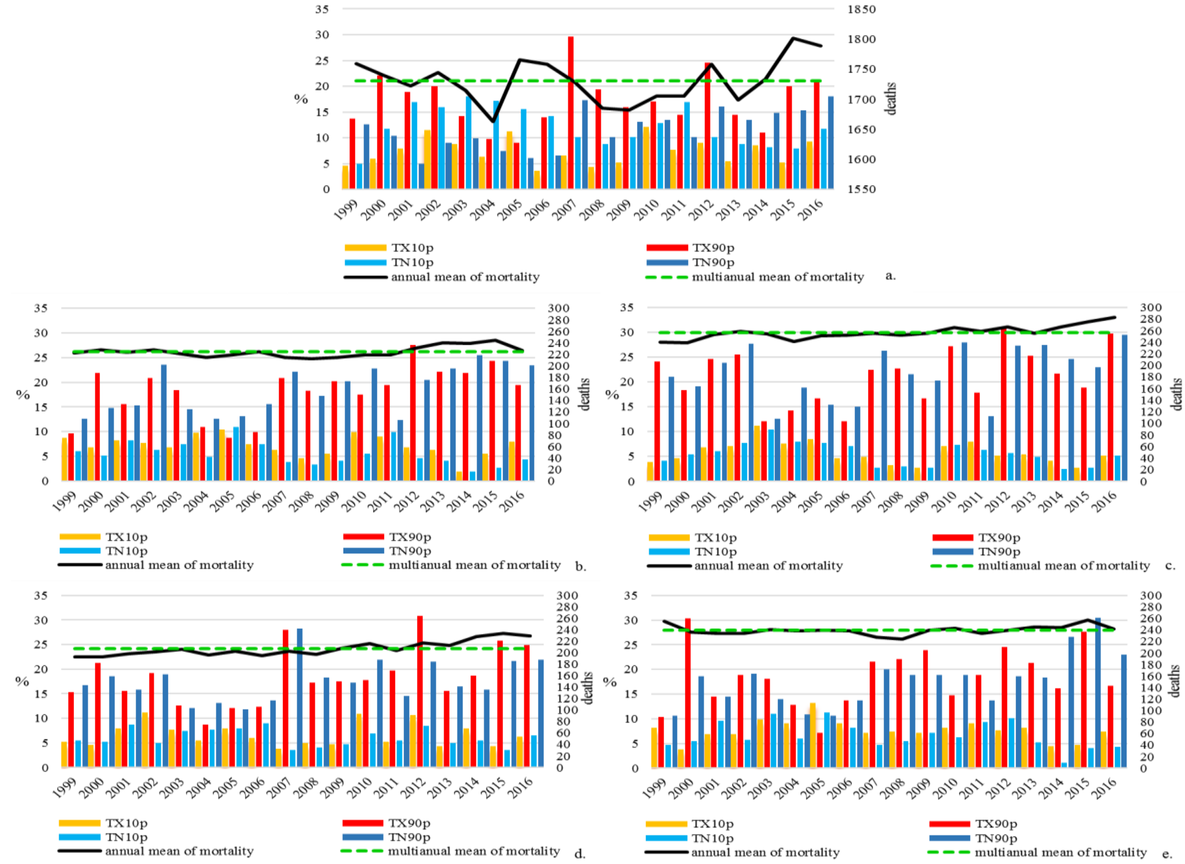

Figure 3. Relations between simple bioclimatic indices and mortality, in Bucharest (a), Cluj-Napoca (b), Constanța (c), Iași (d), Timișoara (e), in the period 1999-2016

Table 2. Mortality frequency for each bioclimatic class of the UTCI index, during summer (%)

Bioclimatic class	Bucharest		Cluj-Napoca		Constanța		Iași		Timișoara	
	Mz ≥ Med.A	Mz < Med. A	Mz ≥ Med.A	Mz < Med. A	Mz ≥ Med.A	Mz < Med. A	Mz ≥ Med.A	Mz < Med. A	Mz ≥ Med.A	Mz < Med. A
Extreme cold stress	/	/	/	/	/	/	/	/	/	/
Very strong cold stress	/	/	/	/	/	/	/	/	/	/
Strong cold stress	/	/	/	/	/	/	/	/	/	/
Moderate cold stress	/	/	0.0	100.0	0.0	100.0	100.0	0.0	/	/
Slight cold stress	100.0	0.0	75.0	25.0	25.0	75.0	27.3	72.7	66.7	33.3
No thermal stress	30.9	69.1	50.5	49.5	46.8	53.2	55.2	44.8	50.0	50.0
Moderate heat stress	46.5	53.5	54.7	45.3	47.9	52.1	59.8	40.2	60.8	39.2
Strong heat stress	79.6	20.4	73.8	26.2	61.5	38.5	70.9	29.1	68.6	31.4
Very strong heat stress	100.0	0.0	/	/	50.0	50.0	/	/	/	/

Where: Mz - daily mortality; Med.A = seasonal mean of mortality; / no days with those bioclimatic conditions were recorded

Overall, in winter, the bioclimatic classes that show the harshest conditions of cold stress greatly overlap the days that recorded a mortality increase. Thus, 50% of the days with above-average mortality values in Constanța and 100% of the days with above-average mortality values in Iași and Timișoara were identified as associated with the extreme cold stress class. Also, the lower the cold thermal stress, the lower the frequency of days with above-average mortality values and the higher the number of days with below-average mortality values. Therefore, we emphasize that the population is more vulnerable when significant changes in the weather occur (Table 3).

Table 3. Mortality frequency for each bioclimatic class of the UTCI index, during winter (%)

Bioclimatic class	Bucharest		Cluj-Napoca		Constanța		Iași		Timișoara	
	Mz≥ Med.A	Mz< Med. A	Mz≥ Med.A	Mz< Med. A	Mz≥ Med.A	Mz< Med. A	Mz≥ Med.A	Mz< Med. A	Mz≥ Med.A	Mz< Med. A
Extreme cold stress	/	/	/	/	50.0	50.0	100.0	0.0	100.0	0.0
Very strong cold stress	44.4	55.6	/	/	55.8	44.2	53.1	46.9	100.0	0.0
Strong cold stress	55.6	44.4	51.5	48.5	63.9	36.1	61.6	38.4	71.4	28.6
Moderate cold stress	49.1	50.9	51.5	49.1	57.4	42.6	57.9	42.1	45.7	54.3
Slight cold stress	47.1	52.9	54.0	46.0	53.7	46.3	59.4	40.6	46.3	53.7
No thermal stress	39.4	60.6	61.5	38.5	51.3	48.7	57.1	42.9	50.0	50.0
Moderate heat stress	/	/	/	/	/	/	/	/	/	/
Strong heat stress	/	/	/	/	/	/	/	/	/	/
Very strong heat stress	/	/	/	/	/	/	/	/	/	/

Where: Mz - daily mortality; Med.A = seasonal mean of mortality; / no days with those bioclimatic conditions were recorded

We believe that the previously mentioned differences are in accordance with the local climatic conditions, along with the demographic and urban peculiarities of the studied cities. In all cities, the lower-level adaptation of urban population during the warm season is demonstrated by the increased mortality in the periods for which the UTCI indicated a heightened discomfort for extreme heat stress (classes of severe heat stress and very severe heat stress). This is highly visible in Bucharest.

The results of the *relative risk* (RR) of mortality determined by positive and negative temperature extremes are illustrated with a strong emphasis on the effect of temperature on the human body over time. The effect of TX on mortality appears more evident in the first days after the extreme temperature is recorded. For the reference period, the maximum calculated

RR value corresponds to the moment the highest TX value was recorded. In all analyzed locations, the RR value decreases as the TX value decreases (Figure 4).

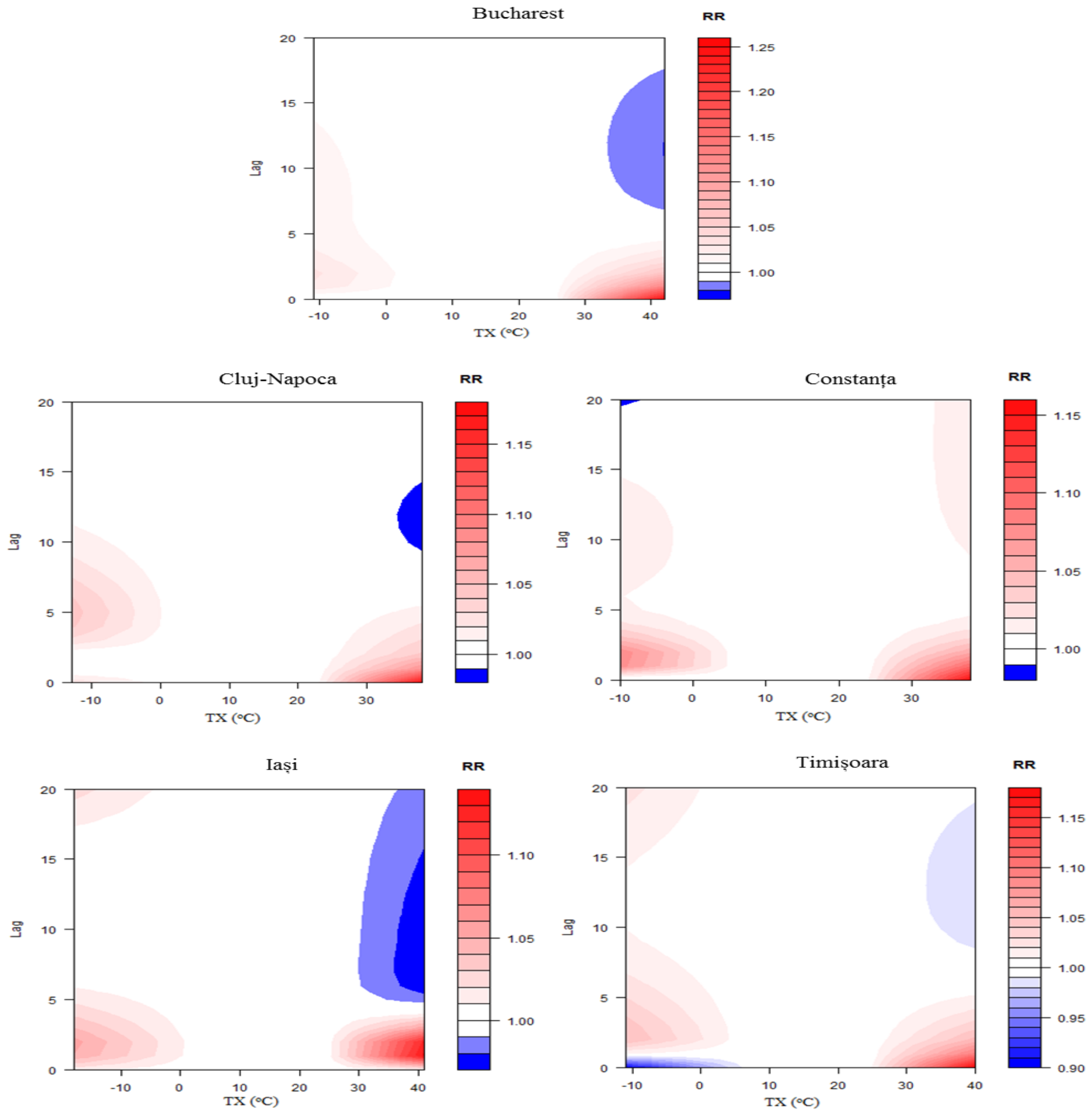

Figure 4. RR of natural mortality due to TX (°C) – the right column indicates the RR value (after Scripcă et al., 2021)

The effects of TN on natural mortality are different from one city to another. For all the urban areas analyzed, the effects of TN are felt over a much longer period of time, lasting from a few days (Cluj-Napoca and Iași), to approximately two weeks for the other three cities (more evident for the cities of Constanța and Timișoara). In Constanța, the effect of TN is felt sooner, the RR being recorded from the very first day when the negative thermal extreme is recorded. A possible explanation for this fact is given by its geographical location on the Black Sea shore and the possible discomfort caused by the higher relative humidity in the area. The RR values of natural mortality associated with TN are much lower compared to those associated with TX, underlining once again the greater vulnerability of the urban population to positive thermal extremes (Figure 5).

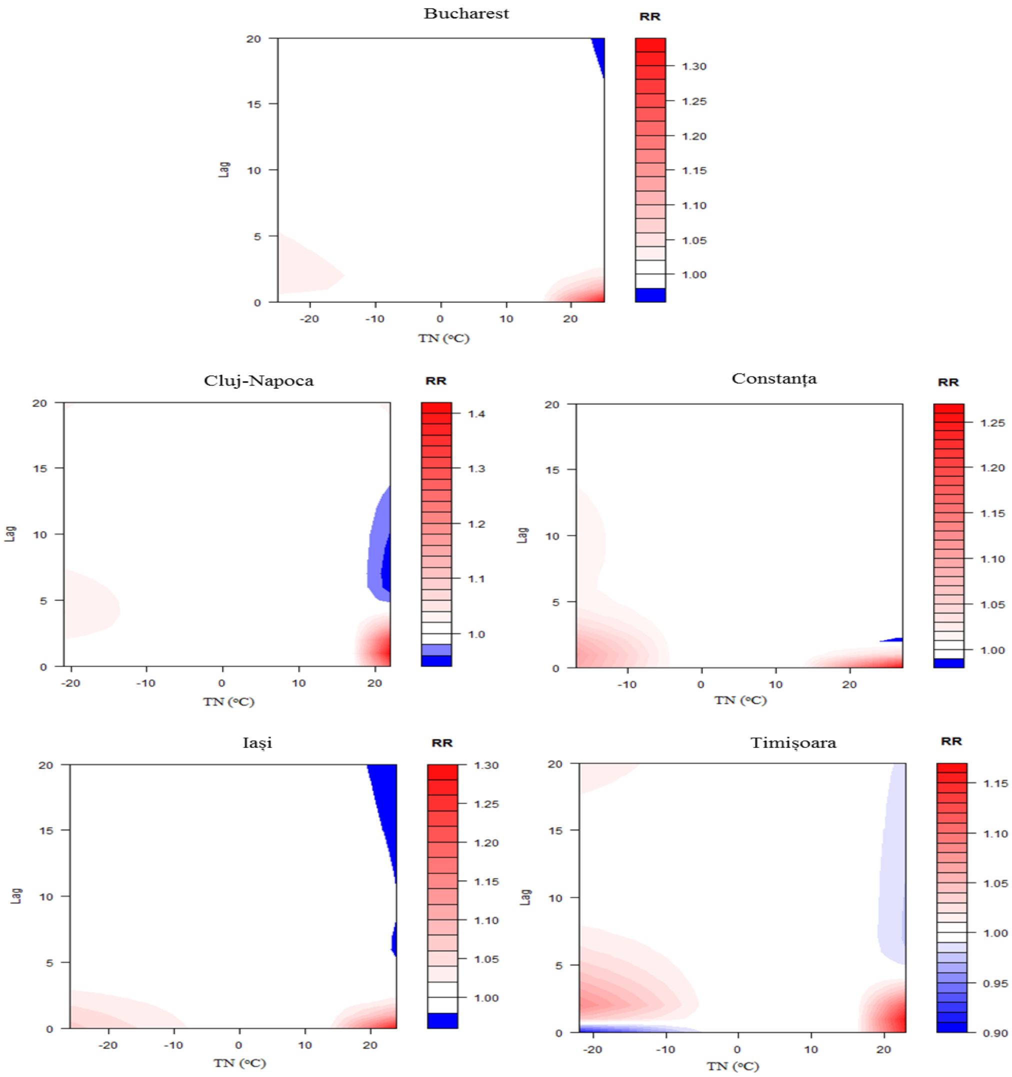

Figure 5. The RR of natural mortality due to TN (°C) – the left column indicates the RR value (after Scripcă et al., 2021)

The perception of patients with chronic rheumatic diseases of the impact of climatic conditions on the intensity of rheumatic pain

For this chapter, we selected and analyzed 105 participants residing in the cities studied throughout the entire research period. All individuals participating in the study had already been diagnosed with degenerative rheumatic pathology for over 18 years on average (18.8 years).

Regarding the frequency of pain occurrence, most of them (67.6%) reported that they feel pain daily, or almost daily. When analyzing the rheumatic pain that the patients felt in the days before admission/interview, and the pain felt frequently, it was found that there were no significant differences between the two reports, which proves once again that the selected patiens had a chronic pathology, with major changes in their joints (Figure 6b).

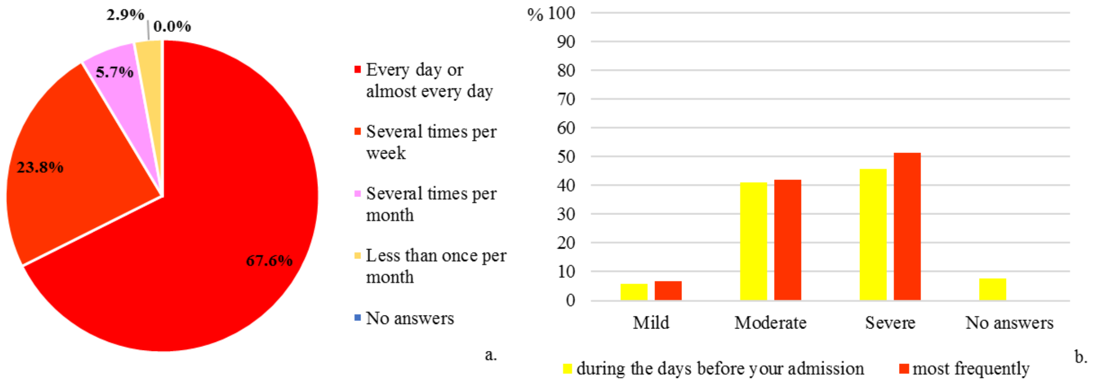

Figure 6. a - Frequency of rheumatic pain during the last year; b - intensity of patients' pain frequently felt

Regarding the sensitivity to weather changes, measured by clinical rheumatic pain, most of the patients declared themselves as weather sensitive. More than 80% of the patients stated that the weather influences the onset and/or intensification of their pain (Figure 7a). About 51.5% of women and 51.4% of men declared that the weather definitely influences them (Figure 7b). Most of the patients who answered that the weather definitely influences them are over the age of 80 (Figure 7c).

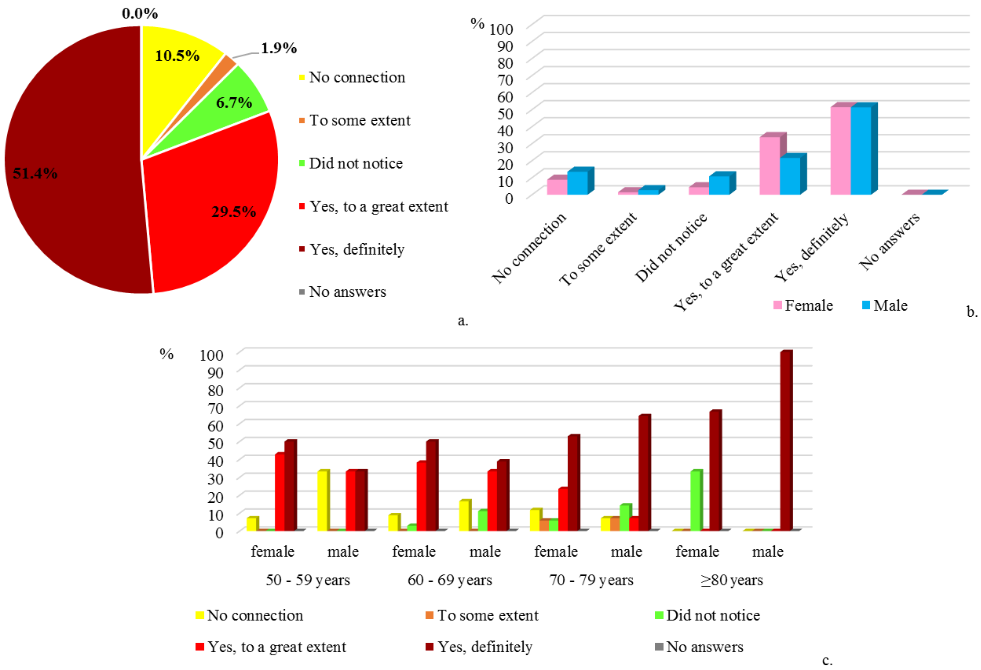

Figure 7. The influence of weather on rheumatic pain: a - for all patients; b - by social gender; c- by age group and social gender

For most of the respondents, the pain is severe when the following weather conditions occur: air temperature suddenly drops (for 85.1% of the subjects), relative humidity suddenly increases (92.6%), there is fog/hazy air (92.2 %), cloudiness suddenly increases (92.6 %) (Figure 8).

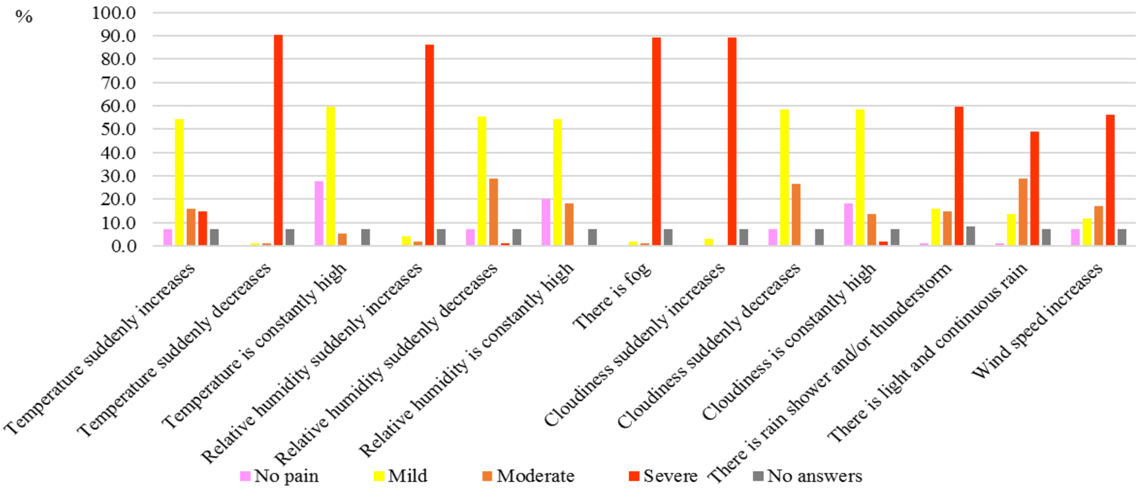

Figure 8. Pain fluctuations when different meteorological parameters are recorded

About 80.1% of the patients stated that the most intense pain due to weather changes is felt during transition seasons, when most of the meteorological fluctuations are recorded: 47.9% reported the worst pain in spring and autumn, and 32.9% reported pain intensification in spring or autumn.

The analysis of meteotropism for rheumatic patients reveals that more than 70.0% of the respondents stated that they can predict weather changes by the changes in their pain intensity. Meteotropism is more evident for women and people over 70 years of age (Figure 9).

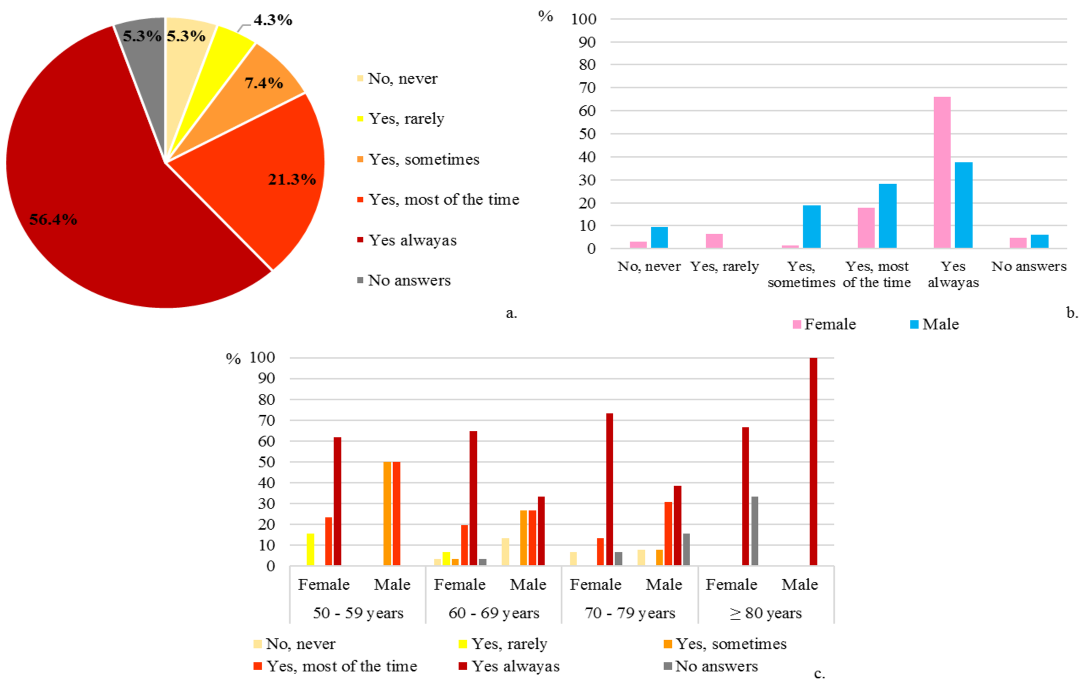

Figure 9. Meteotropism triggered by rheumatic pain: a - for all patients; b - by social gender; c - by age group and social gender

The Pearson's correlation matrix was established between all items of the questionnaire. Participants who believe that the weather influences their pain (Q7) also reported that they feel more intense pain when the weather worsens (Q9) (0.403) or when the air temperature suddenly increases (0.444) (related to Q10). The change in pain (intensity increase) during weather worsening (Q9) correlated significantly with the following weather conditions (Q10): when the temperature suddenly drops, when the humidity suddenly increases, when there is fog/hazy air, when cloudiness sharply increases, when there is light and continuous rain (with correlation values between 0.289 and 0.379). Conversely, when the weather was presented as fine (clear sky, no wind, no precipitation) and most of the participants stated that the weather does not aggravate their pain, direct correlations were identified with the sudden increase in air temperature (0.287) and with the sudden decrease in cloudiness (0.355). When rheumatic pain intensifies, significant correlations are identified for several situations (Q10): when the temperature suddenly rises, it directly correlates with the intensity of the pain that patients frequently feel (Q5) (0.404); when the pain increases while cloudiness suddenly decreases, it correlates directly with the frequency of the pain reported by patients with rheumatic pathology (0.405).

CONCLUSIONS

The aim of the present study was to analyze the influence of extreme weather conditions on the human body. More precisely, the analysis focused on identifying the periods of thermal stress (cold and/or heat) and the periods of thermal comfort in five urban areas. After identifying the periods that can negatively affect human health (periods with thermal discomfort), we verified whether they overlap the most severe weather conditions, heat and cold waves, which are currently widely publicized as periods with potential danger for the population. Since the adverse effects caused by extremely hot or cold periods are widely studied at international level, an important part of the research focused on this type of analysis and also on identifying the perception of patients with chronic rheumatic diseases of the weather conditions that influence pain the most and contribute to the intensification of symptoms and pathological problems.

In most cases, the simple biometeorological indices (TX90p, TN90p, number of heat wave events) showed an increase in warm thermal extremes.

However, the complex biometeorological indicators do not consistently present the same periods indicating cold or heat thermal discomfort. Still, we can broadly state that, during winter, the recorded bioclimatic conditions are not quite homogeneous; thermal conditions specific to several comfort classes in the cold thermal range occur, but the most severe classes are less often found (very low frequency). In the summer season, it was found that extreme conditions specific to heat thermal stress predominate, regardless of the analyzed bioclimatic index. For most of the indicators, there were also cases when the heat thermal stress had values specific to the maximum intensity class. In terms of frequency, July is the month when the most intense heat stress occurs.

It was found that, for all four bioclimatic indices analyzed, heat waves highly correspond to periods with critical conditions for the human body (heat thermal stress). The strongest relation was detected between heat waves and the UTCI index. On the other hand, cold waves generally correspond to the most severe bioclimatic classes of all analyzed indicators (for cold stress). The highest correlations were obtained between cold waves and the maximum cold stress intensity classes of the UTCI and H indices.

The analysis on the relation between simple bioclimatic indices and mortality reveals a stronger relation with indicators for warm extremes (TX90p, TN90p). Also, for all the studied cities, the results on the relation between the UTCI values and mortality show an increased mortality in the intervals for which the indicator revealed a heightened discomfort for the extreme heat stress (strong heat stress and very strong heat stress).

The effect of TX on mortality is more intense in the day or in the first days after the temperature increases. The highest RR values were calculated for Bucharest, as the urban area where the highest TX values are also recorded. In opposition, the lowest RR value was calculated for Constanța. Here, the effect of TN on mortality is felt over a much longer period of time, and the RR values calculated for this parameter are much lower than those associated with TX.

The analysis on the perception of weather conditions in relation with the intensity of rheumatic pain showed that most of the respondents, as patients with rheumatic conditions, confirmed that a change in pain occurs simultaneously with changes in the weather.

These results demonstrate that the Romanian population is more vulnerable to positive thermal extremes compared to negative thermal extremes.

Overall, according to all analyses, it was found that the inhabitants of the analyzed cities show a better adaptation to cold thermal stress conditions and a greater vulnerability in conditions of intense heat thermal stress and high atmospheric instability.

Although research in the field of human bioclimatology at the international level is extensive and covers a wide range of sub-topics of this field, this topic is quite rarely approached in Romania. We believe that our findings bring novelty to the specialist national literature. Also, the presented results can be a useful tool for authorities and decision-makers at the local, regional and national level to implement effective measures to reduce the effects generated by the extreme weather phenomena.

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