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INTENSITY AND EFFECT OF DAILY MORBIDITY DURING HEAT AND HEAT WAVES IN AN URBAN ENVIRONMENT
The case of SKOPJE 2016-2020

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Abstract

The aim of this paper was to determine the relationship between extreme heat, heat waves and hospitalization for non-accidental reasons among the population of the city of Skopje, Republic of North Macedonia.

A total of 295 patients who were hospitalized during heat waves from May 1 to September 30 in the five-year period from 2016 to 2020 was includedduration or intensity *versus* daily number of admissionslimited to a heat wave period.

The results obtained and statistical analysis with multiple comparisons with days of hospitalization, age groups, the Kruskal-Wallis statistical test showed a statistically significant difference in hospitalizations between the age group of 18-44 years compared to the age groups of 45-64 and over 65 years where longer hospitalizations were observed in the examined period.

Timely coordination of available measures and resources, increasing the awareness of the public and health professionals about the impact of heat waves on health are needed. Additional research is necessary regarding regulatory, financial, procedural, knowledge, and other barriers that can prevent effective heat and health action.

Keywords: heat, heat wave, hospitalization, morbidity, action plan

Introduction

The public health outcomes of hot weather and heat waves depend on the degree of exposure (duration, intensity, frequency of the heat wave), the size and demographic profile of the exposed population, the sensitivity of the population (chronic diseases, pharmacological treatment, etc.) and preventive measures[1]. The impact of climate change is a challenge in the modern world. The climate is changing, the risks are increasing, and urgent solutions should be taken to reduce the possible repercussions in the future.

Climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as changes in the state of the climate associated with changes in the average and/or variability of its properties[1].

Warm Spell Duration Index (WSDI) is defined as the annual or seasonal number of days with at least 6 consecutive warm days[2]. Heat waves were defined as ≥2 consecutive days exceeding the 99th percentile of daily county temperatures and were matched to non-heat wave periods by county and week[3].

Four meteorological quantities significantly influence physical processes related to thermal homeostasis; they are air temperature, humidity, air movement (wind speed), and thermal energy from solar radiation.

Desired air temperature in the environment where a person is during conducting usual activities (lightly dressed and performing light physical activities) is from 17 to 22°C, that is, it is the so-called "comfort zone". The regulation of body temperature is in the range of 36.1 to 37.4°C and takes place through complex thermoregulatory mechanisms. The largest amount of excess heat is released through physical methods of thermoregulation. All these physical methods of thermoregulation significantly influence the microclimatic elements of the environment. If the external temperature reaches or exceeds the body temperature, then the body becomes dependent only on the evaporation of sweat. High humidity limits body cooling through the evaporation of sweat and secretions and leads to an increased heat stress. Increased air movement aids heat transfer and sweat evaporation. Radiant heat energy increases heat stress regardless of other quantities. Excessive heat causes a well-known medical cascade of consequences, from relatively mild and self-limited heat rash and heat cramps to more severe heat exhaustion and potentially fatal heat stroke. An increase in temperature by 1^0C is immediately detected through the thermoreceptors of the skin, deep tissues, and organs. Thermoreceptors relay the information to the thermoregulatory center in the hypothalamus, which triggers two powerful responses to heat loss: an active increase in blood flow to the skin and the initiation of sweating (via cholinergic pathways). Vasodilatation of peripheral capillaries increases skin blood flow and cardiac output. When the temperature of the external environment is higher than the temperature of the skin, the only mechanism for heat loss is evaporation (sweating). Thus, any factor that interferes with sweating such as air humidity, reduced airflow, or drugs with anticholinergic mechanisms will increase body temperature which can be a serious life-threatening heat stroke[1].

The most common physical difficulties caused by meteorological factors are the appearance of fatigue, laziness, impaired concentration, collapse, heart palpitations, problems arising from underweight, etc. At an air temperature above 25°C, the oxidation processes in the body decrease as well as the generation of heat through vasodilation. Acclimatization lowers the sweating threshold, which is the most effective natural mechanism in preventing heat stress and can result with or without changes in body surface temperature. As long as the sweating mechanism is active and water and sodium chloride are provided, i.e., the most important constituents of sweat, a person can still withstand a high temperature. Vulnerable populations including children, pregnant women, the elderly, chronically ill, and socially marginalized groups, are more sensitive to climate change and its resulting health impacts. The mentally ill are particularly vulnerable: they are less resistant and take psychotropic drugs that prevent the possibility of sweating - which makes them more prone to overheating. The poor and rural populations are faced with falling incomes, food shortages, and rising prices[5].

The aim of this study was to determine the association between extreme heat, heat waves, and admission to hospital due to non-accidental causes in the population of the city of Skopje, Republic of North Macedonia. Understanding the associations between heat waves and hospital admissions is important to predict how climate change may increase the future burden of heat-related morbidity; identify vulnerable subpopulations for potential interventions, and to refine activation thresholds for heat health warning systems.

Material and methods

The study took data on the ambient air temperature from the Administration of Hydrometeorological Service, for the period of hot weather from May 1 to September 30 from 2016 to 2020 in Skopje, as well as data on the number of hospitalizations from all public health institutions - hospitals in Skopje, obtained through the electronic health system 'Moj termin'(My Appointment).

According to National Hydrometeorological Service (HMRC), the following heat waves were registered:

- **First wave 29-30.06.2017**
- **Second wave 04-06.08.2019**
- **Third wave 11-13.08.2019**
- **Fourth wave 15.06.2020**

No heat waves were registered in 2016 and 2018, hence hospitalizations for that period are not shown.

For the calculation of the number of hospitalizations, the days of the occurrence of the heat wave and the following days in correlation with the length of the heat wave were considered. In 2017, the heat wave lasted 2 days; for calculation, we took 4 days starting from the first. In 2019, two heat waves were registered that lasted three days each, that is, we took into account 6 days. In 2020, one day was taken for the heat wave period, that is, 2 days for hospitalizations. In 2016 and 2018, no heat waves were registered and therefore no data on hospital admissions for those years were analyzed.

According to the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification[6] the following diseases of interest were considered:

- **I00–I99 - Diseases of the circulatory system**.
- **I20–I25 - Ischemic heart diseases** (angina pectoris, acute myocardial infarction, subsequent myocardial infarction, certain ongoing complications after acute myocardial infarction, another acute ischemic heart disease, chronic ischemic heart disease).
- **I60–I69 - Cerebrovascular diseases** (intracerebral hemorrhage, cerebral infarction, stroke, not designated as hemorrhage or infarction, occlusion and stenosis of precerebral arteries not resulting in cerebral infarction, cerebrovascular diseases in diseases classified elsewhere, consequences of cerebrovascular disease).
- **R00–R99 - Symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified** (fever of unknown origin, headache, malaise and fatigue, syncope and collapse, convulsions, not elsewhere classified, shock, not elsewhere classified, bleeding, not elsewhere classified, edema, not elsewhere classified).
- **Other and unspecified effects from external causes (T66–T78).**

A total of 295 patients were included in the study who had been hospitalized during heat waves from May 1 to September 30 in a five-year period (2016 to 2020). The obtained results showed that the longer the heat wave lasted, the more the increase in the number of hospitalizations was delayed. In the first and fourth waves with a length of 2 and 1 day, the increased number of hospitalizations occurred on the first day, while in the second and third waves, which were longer (3 days), the increased number of hospitalizations in both waves occurred on the fifth day, but during the third wave, an increased number of hospitalizations were registered on the second day as well. Hospitalizations were directly proportional to the length of the heat wave.

The Ministry of Health in cooperation with the World Health Organization prepared the Action Plan for preventing the consequences of heat waves on the population's health in the Republic of Macedonia[7-9], adopted by the Government of the Republic of Macedonia in

2011, including an early warning system for heat waves. The Action Plan, appendix 6, shows the distribution by zones in terms of the highest daily temperature recorded in °C by cities and months of the HMRC weather alert. For this analysis, only the Skopje region, that is SKOPJE-PETROVEC ZONE, was taken into account (Table 1).

Table 1. The highest daily recorded temperature expressed in °C by month of the HMRC weather alert

Region I		May	June	July	August	September
Skopje	There is no danger	30	34	37	36	32
Petrovec	Extraordinary	32	36	39	38	34
	Dangerous	35	38	42	41	37
	Catastrophic	37	41	44	43	39

Source: Action plan for preventing the consequences of heat waves on the health of the population in the Republic of Macedonia, appendix 6

The statistical analysis of the data was done with the statistical package SPSS for Windows 26.0. Categorical variables were presented as absolute numbers and percentages. Fisher exact test was used to compare gender and age groups concerning ICD10. The Mann-Whitney U test was used to compare gender in terms of days of hospitalization, and the Kruskal-Wallis test was used to compare age groups in terms of days of hospitalization. Values of $p<0.05$ were taken as statistically significant. The Mann-Whitney U test was used to compare gender in terms of days of hospitalization.

Results

Graph 1 shows a wave trend of temperature differences. During 2016, no deviations from the limit value were registered; in 2017 in the months of June (38.8^{0}C - maximum monthly air temperature) and August (40^{0}C - maximum monthly air temperature) air temperatures above the limit values were measured; in 2018, there were no registered deviations from the limit value; in 2019, higher temperatures above the limit humidity were recorded in August (40^{0}C - maximum monthly air temperature) and in 2020 in May (36.4^{0}C - maximum monthly air temperature).

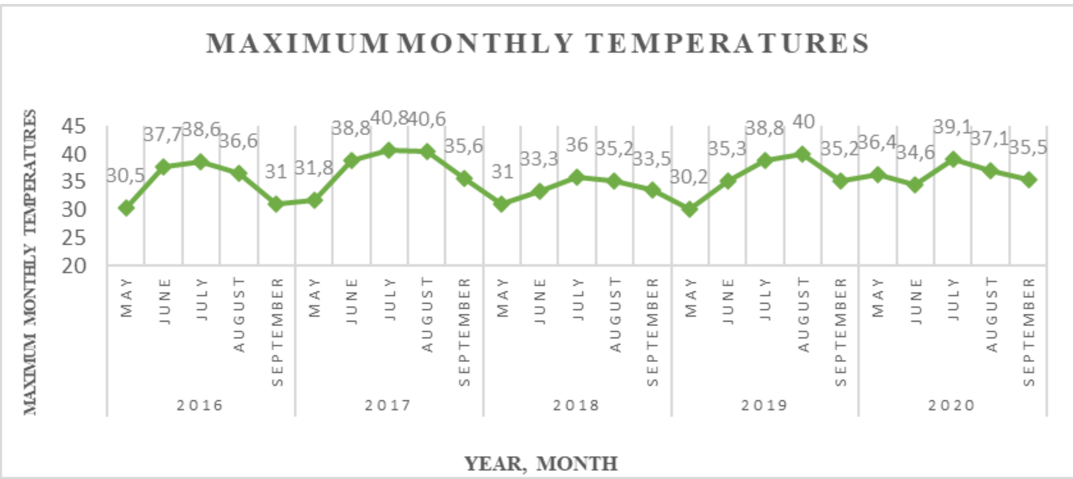

Fig 1. Display of the registered maximum monthly temperatures expressed in ^{0}C in the period from May 1 to September 30 for the five-year period (2016-2020)

A wave trend of changing temperatures of the ambient air was noticed (Figure 1). However, it cannot be concluded that there was an upward/downward trend of the registered temperatures in the examined period.

The duration of the heat wave, not just the intensity of the ambient air temperature, increased the risk of hospitalization for ischemic heart disease (IHD) for 80.34% of 295 hospitalized patients, compared to those hospitalized with general symptoms and signs and cerebrovascular diseases.

Table 2. Number of hospitalizations in relation to gender and age

	Hospitalizations		**Gender**			**Age**	
	Number	**Percent**	**Men**	**Women**	**18-44**	**45-64**	**65**
First wave							
29.06.2017	35	11.86%	11.34%	12.87%	13.04%	11.32%	12.05%
30.06.2017	23	7.79%	7.73%	7.92%	0.00%	5.66%	10.24%
01.07.2017	11	3.72%	5.15%	0.99%	0.00%	2.83%	4.82%
02.07.2017	12	4.06%	4.64%	2.97%	0.00%	2.83%	5.42%
Second wave							
04.08.2019	18	6.10%	8.25%	1.98%	4.35%	3.77%	7.83%
05.08.2019	6	2.03%	2.06%	1.98%	0.00%	1.89%	2.41%
06.08.2019	10	3.38%	3.61%	2.97%	4.35%	2.83%	3.61%
07.08.2019	23	7.79%	6.19%	10.89%	4.35%	8.49%	7.83%
08.08.2019	25	8.47%	9.79%	5.94%	4.35%	13.21%	6.02%
09.08.2019	22	7.45%	5.67%	10.89%	4.35%	5.66%	9.04%
Third wave							
11.08.2019	6	2.03%	1.03%	3.96%	8.70%	2.83%	0.60%
12.08.2019	19	6.44%	6.70%	5.94%	8.70%	7.55%	5.42%
13.08.2019	14	4.74%	5.67%	2.97%	4.35%	3.77%	5.42%
14.08.2019	18	6.10%	7.22%	3.96%	8.70%	10.38%	3.01%
15.08.2019	19	6.44%	5.15%	8.91%	13.04%	8.49%	4.22%
16.08.2019	18	6.10%	4.12%	9.90%	8.70%	2.83%	7.83%
Forth wave							
15.06.2020	13	4.40%	5.15%	2.97%	13.04%	5.66%	2.41%
16.06.2020	3	1.01%	0.52%	1.98%	0.00%	0.00%	1.81%

Table 2 shows the number of hospitalizations in relation to gender and age. During the first wave, a larger number of men were hospitalized (7.12%), in terms of age, in the first age group of 18-44 (13.04%). During the second wave, the number of admissions of women increased compared to men, while in terms of age, the third group, which included 65-year-olds on average, was predominant.With reference to gender in the third wave that was the same as the second one, the female gender was prevalent, but in terms of age groups, the first group of 18-44 years was the most represented. There were no changes in the fourth wave in terms of age groups, but in terms of gender, men dominated.

Table 3. Number of hospitalizations in relation to gender - Mann-Whitney U Test

Variables	**Gender**	
	Z	**p-value**
Days of hospitalization	1.233438	0.217413

*no significance; Marked tests are significant at p <.05000

The Mann-Whitney U test showed that there was no significant gender difference in terms of days of hospitalization. As shown in Table 2, both genders were equally represented.

Table 4. Number of hospitalizations by diagnosis compared to gender and age

MKB10		**Gender**		**Age**			**Total**
		Men	**Women**	**18-44**	**45-64**	**65 и**	
I20-I25	I20	102	56	10	66	82	158
	I21	28	9	2	15	20	37
	I24	13	2	1	6	8	15
	I25	19	8	0	10	17	27
R00-R99	R50	6	2	4	1	3	8
	R51	1	1	1	1	0	2
	R55	2	3	1	0	4	5
I60-I69	I61	4	1	0	1	4	5
	I63	11	12	3	3	17	23
	I64	4	7	1	2	8	11
	I65	2	0	0	0	2	2
	I68	1	0	0	0	1	1
	I69	1	0	0	1	0	1
Total		194	101	23	106	166	

Table 4 illustrates that the largest number of hospitalizations were related to angina pectoris (I20); there was male predominance regarding hospitalizations, and in terms of age, the third group (from 65 years and <) was the most represented, but in relation to the rest of the diagnoses, the third group was the most represented.

Table 5. Days of hospitalizations by age groups using Kruskal-Wallis ANOVA by Ranks

1 group 18-44 years	2 group 45-64 years	3 group <65 years
	0.303129	0.022692
0.303129		0.242528
0.022692	0.242528	

*Multiple Comparisons p values (2-tailed); Days of hospitalization, Independent (grouping) variable: age, Kruskal-Wallis test: H (2, N=295) =8,601497 p=,0136
*The difference between the first and third age group was significant

The results obtained and the statistical analysis with Multiple Comparisons p values (2-tailed); Days of hospitalization, Independent (grouping) variable: age groups, Kruskal-Wallis test: H (2, N= 295) =8.601497 p =.0136 showed a statistically significant difference in hospitalizations between the age group of 18-44 years compared to the age groups of 45-64 and over 65 years where longer hospitalizations were observed in the examined period.

Discussion

Our study revealed an increased number of hospitalized people in June during the heat wave, which was due to the fact that people who were exposed to high ambient temperatures did not have enough time to adapt to them. In July and August, due to the already acquired acclimatization (adaptation) of the body to high ambient temperatures, a delay in admission to the hospital was registered as many days as the heat wave lasted.

Epidemiological studies in 15 European cities show that high temperatures are associated with mortality, but little is known about the exposure-response function and the delayed effect of heat.. This indicates an excess risk of exposure to an apparent temperature above a threshold that varies between cities. There is an important mortality effect of heat across Europe. The effect is evident from June to August; it is limited to the first week after the temperature excess, with evidence of a shift in mortality[11].

Another study found that increases mortality rates appear to be associated with high temperature, especially when these occurring over consecutive days. [12,.

The majority of studies have linked heat waves to mortality, unlike this study which analyzed morbidity.

The studi in Flanders, Belgium, between 2000 and 2015 show that, within primary care settings, heatwaves were associated with an increased incidence of selected morbidities, similarly as in this study[13].

Conclusion

In the future, it is necessary to use data from primary health care, together with data from emergency care, to assess the full impact of heat waves on the general population, and thereby improve the effectiveness of preventive measures.Health services need robust plans to deal with potential disruptions and increased demand during and after temperature extremes; their ability to respond affects the vulnerability of the population. It is crucial to address the thermal comfort needs of vulnerable individuals, and the effect of housing and built environment intervention in reducing hazardous heat exposure at the individual level. Finally, there is a need for more applied research on the regulatory, financial, procedural, knowledge, and other barriers that can prevent effective heat and health action.

Conflict of interest statement. None declared.

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