ORIGINAL ARTICLE

Mortality associated with seasonal changes in ambient temperature and humidity in Zenica-Doboj Canton

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ABSTRACT

Aim To determine the relationship between seasonal changes in ambient temperature, humidity and general and specific mortality rates in the area of Zenica-Doboj Canton.

Methods Changes in the average monthly mortality in the period from 2008 to 2019 were analysed (linear regression) in relation to the average temperatures and humidity in those months in the same time period in Zenica-Doboj Canton.

Results Overall mortality increased from 7.9 ‰ in 2008 to 10.2 ‰ in 2019. Overall and specific mortality rates for cardiovascular, malignant, respiratory and metabolic diseases followed seasonal change of ambient temperature and humidity. The monitoring trend showed strong determination degree for overall mortality and mortality for cardiovascular, malignant and respiratory diseases, while for metabolic diseases it was somewhat lower. The highest mortality rates were found in January (cold month), and in August (warm month); the lowest one was in May, September and October. There was a strong significant negative correlation between temperature and mortality rates, while the correlation between humidity and mortality rates was not significant.

Conclusion As we have proven that mortality rates followed seasonal changes in ambient temperature and determined months with the least mortality rate, the community must take measures to ensure microclimatic conditions for the survival of patients with cardiovascular, malignant, respiratory and metabolic diseases.

Key words: air temperature, humidity, mortality rate

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Original submission:
25 December 2020;
Revised submission:
02 March 2021;
Accepted:
24 March 2021
doi: 10.17392/1337-21

Med Glas (Zenica) 2021; 18(2):516-521

INTRODUCTION

The human body is under a constant influence of environmental factors. These factors are numerous and affect the quality of life, age of healthy life and health conditions. Among environmental factors are also climatic ones, and their impact on human health can occur in different ways. These can be indirect effects such as the spread of vector-borne diseases, or direct effects of extreme weather events such as flood, drought or heat. Numerous studies indicate the impact of climate change on health of the population (1,2). Global impacts of climate change on population health are studied in large multicentre studies, and possible outcomes of change are predicted (3,4).

Among the factors that significantly affect human health and whose changes are constantly present are seasonal climate environmental factors such as temperature and humidity. The physiological consequences of human exposure to temperature changes and its ability to adapt are well known (5). Research also provides data on the short-term and long-term cumulative impact of exposure to changes in ambient temperature. It has been proven that short-term as well as longer exposure leads to an increased risk of death from cardiovascular and respiratory diseases (6). It has also been shown that low temperatures during the winter months lead to increased mortality from cardiovascular disease (7,8).

In addition to the change in temperature during the change of seasons, relative humidity also changes. Increased humidity in the warm months contributes to heat stress due to the difficult exchange of heat in the human body, which is also a factor that increases mortality. Sweating is the main process by which the body dissipates metabolic heat into the environment and becomes significantly less efficient if relative humidity of the environment is high, resulting in the accumulation of heat in the body (9).

How much the impact of changes in heat and humidity will affect human health depends on the intensity of the change and adaptive capabilities of a person. According to data from meteorological stations around the world and according to projections of experimental models, the frequency and intensity of extreme hot waves have increased. Sharper changes are also noticeable without slight transitions suitable for adaptation (10,11). Man's adaptive capacities depend on technologies that can improve the living and working environment, as well as internal adaptive capabilities that largely depend on a person's age.

There is no information of the impact on the mortality in the temperate continental and mountain climate regions, which is characteristic of Zenica-Doboj Canton.

The aim of this research was to determine how seasonal climate changes in the area of Zenica-Doboj Canton affect general and specific mortality of the population.

MATERIALS AND METHODS

Materials and study design

Zenica-Doboj Canton is located in the central part of Bosnia and Herzegovina and has a temperate continental and mountain climate. The temperate continental climate is characterized by harsh winters, short springs and warm and humid summers. The mountain climate is characterized by low fluctuation of air temperature with a fluctuation average of about 20 °C (12).

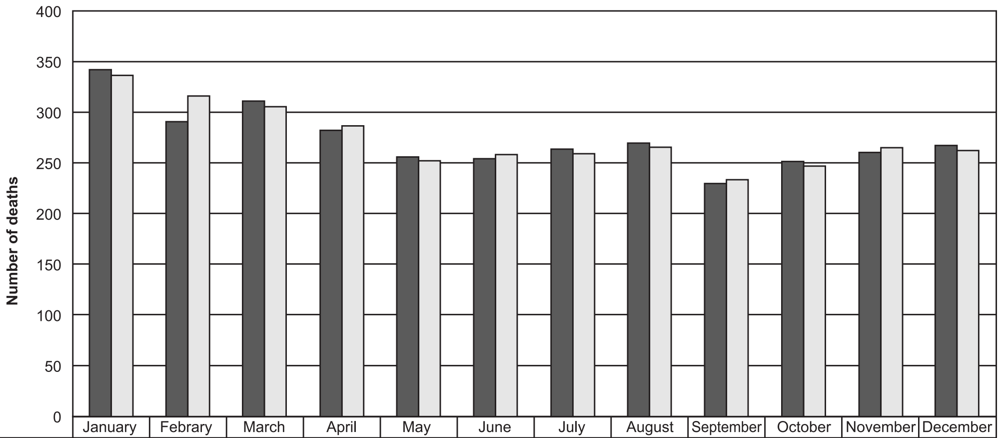
Data on mortality, population and meteorological conditions in Zenica-Doboj Canton were collected from the Federal Statistical Office (13), the Federal Hydrometeorological Institute (14) of the Federation of Bosnia and Herzegovina, as well as at the Institute for Health and Food Safety Zenica. The impact of annual climate changes on mortality (for general, cardiovascular, malignant, metabolic and respiratory diseases) in Zenica-Doboj Canton for the period 2008-2019 was analysed.

Methods

After data collection and extraction, average monthly values for both temperature and humidity and overall and specific mortality were calculated, and obtained values were presented by months of the year. Values for air temperature and humidity were used from meteorological automatic measuring station in Zenica city.

Statistical analysis

A settlement of average deaths is required due to the unequal number of days for each month. In the observed period, each month had an ave-



	January	Febrary	March	April	May	June	July	August	September	October	November	December
Average number	342	291	311	282	256	254	264	270	230	251	261	267
Settled number	336	316	306	287	251	258	259	265	233	247	265	262

Months

Figure 1. Overall average monthly values of deaths

rage of 30.44 days, and this value was calculated using an equation with one unknown for the monthly average of deaths (Figure 1).

Statistical calculations determined the differences between general and specific mortality rates in each month, on the basis of which it was concluded how climate change affected mortality rates. To determine the interdependence of general and specific mortality rates and humidity and air temperature, statistical methods for determining the regression (R^2) and correlation coefficients (r) were used. Regression trends are shown by a parabolic trend of the second degree. The level of statistical significance of $p<0.05$ was used.

For an estimation of the significance of the strength of regression coefficient (R), the Chaddock scale (15) was used, where the strengths were arranged as follows: 0<R<0.1- none, 0.1<R<0.3 – weak, 0.3<R<0.5 – moderate, 0.5<R<0.7 – noticeable, 0.7<R<0.9 – close, 0.9<R<0.99 – strong, 0.99<R<1 – functional.

RESULTS

According to the Federal Bureau of Statistics, a total of 40,641 people died in Zenica-Doboj Canton between 2008 and 2019 (13). Due to incomplete data required for the analysis, 1,284 deaths were not included in the study. Of 39,357 analysed deaths, 20,694 (52.6%) were males and 18,663 (47.4%) females. The average age of deceased people was 70.51 years, and most of them were in the age group of 71-80 years (13,614; 34.6%).

The overall mortality rate in the observed period showed an increasing trend from 7.9‰ in 2008 to 10.2‰ in 2019.

The average of overall total mortality by months ranged from 233 in September to 336 in January. These values were within the parabolic trend of the second degree (Figure 1). The highest mortality was noticed in January (when the average air temperature was the lowest), then mortality decreased in parallel with an increase of the temperature to an average of 16 °C in May; when the average temperature exceeded 20 °C (from June to August) mortality was again increased. In September (average temperatures falling to around 16 °C), the lowest mortality rate was noticed. Further drop in average temperatures resulted in a rise of mortality rate in December. A correlation of humidity and overall mortality rates was not significant. The coefficient of determination of the quadratic polynomial regression for overall mortality (R^2) was 0.902, indicating a strong relationship between months in the year and deaths.

Correlating the variables of average mortality and average temperatures by months of the years, a statistically significant negative correlation was found, with the correlation coefficient of -0.604 (p=0.037). The correlation between overall mortality and humidity was positive but insignificant (p=0.47; r=0.23).

Annual trends for both temperature and humidity followed the curve of the parabolic trend of the second degree, where the coefficients of determi-

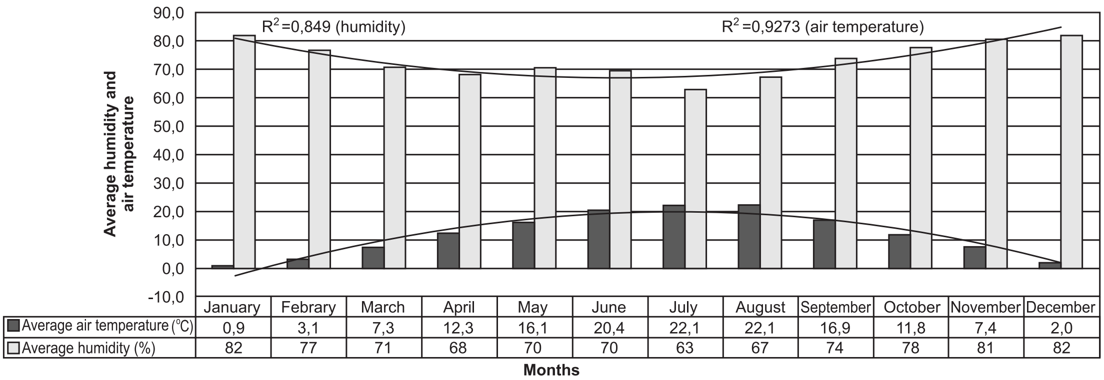


Figure 2. Average monthly values of air temperature

nation showed high values, i.e. a strong correlation between the numerical values of temperature (R^2=9.927) and humidity (R^2=0.849) and the month of the year (Figure 2).

Similar trends were found for specific mortality of cardiovascular, malignant, metabolic and respiratory diseases; Pearson correlation coefficient was negative and significant. The coefficient of determination for regression analysis was also significant and high. The regression curve was specific and characteristic with two peaks of increased morbidity in January and August.

Diabetes mellitus was a cause of death in 94.4% of metabolic diseases cases. The correlation coefficient showed a strong significant inverse association of deaths caused by metabolic diseases and air temperature. Following the trend of mortality by months of the year, the coefficient of determination of medium strength was noticed (Table 1 and Figure 3).

DISCUSSION

The results of this study showed the cyclic rise and fall in the rate of deaths associated with the seasons. These cycles in the twelve-year period were repeated in the same way each year, so that the highest total mortality rate was determined in January, and the lowest one in September.

A large number of environmental factors can affect mortality rates (16), but the characteristic cyclical changes in the intensity of factor action associated with seasonal climate changes only for temperature and humidity was found in our study. Therefore, we hypothesized that seasonal cyclical changes in temperature and humidity were probably the cause of cyclical changes in the number of deaths.

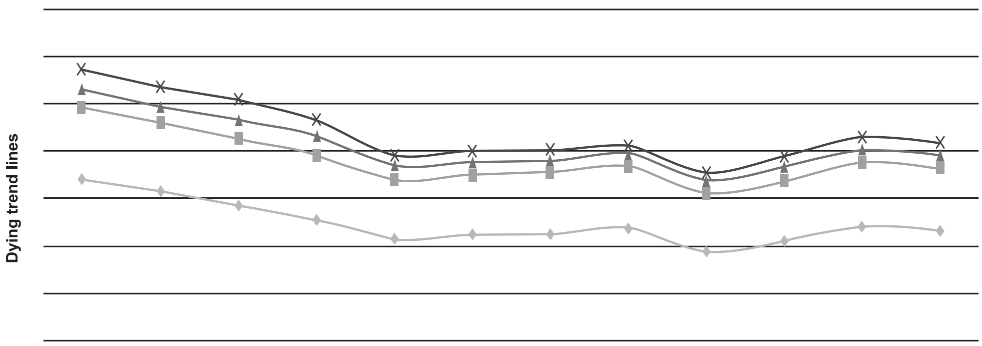
There is ample evidence that air temperature may affect morbidity and mortality rates (17). An increase in ambient temperature by 1 °C increases cardiovascular mortality by 3.44%, respiratory mortality by 3.60% and cerebrovascular mortality by 1.40% in the population older than 65 years of age, according to a meta-analysis of a systematic review of epidemiological evidence in 2016 (17). Our research has shown a strong dependence of mortality on the year's month and the strong correlation with the air temperature.

We also found a strong association between ambient temperature and humidity with specific mortality from cardiovascular disease, respiratory and malignant diseases. Seasonal variations in cardiovascular diseases were identified in study by Stewart et al. in Australia; the variations had a similar pattern of occurrence as in our study with peaks in the coldest and warmest months (18). A study done in Taiwan found an inverse correlation between temperature rise and mortality from cardiovascular and respiratory diseases (19). Unlike our study, a study conducted in Kuwait did not establish an associa-

Table 1. Association of general and specific mortality with monthly temperature and humidity

Mortality category	Percentage of overall mortality (%)	Air temperature*	p	Air humidity*	p	Determination coefficient of the quadratic polynomial regression (R2)
Overall	100.0	-0.60	0.04	0.23	0.47	0.90
Cardiovascular disease	53.0	-0.66	0.01	0.31	0.32	0.89
Malignant neoplasms	20.4	-0.70	0.01	0.38	0.23	0.84
Metabolic diseases	4.7	-0.60	0.04	0.20	0.54	0.65
Respiratory diseases	4.1	-0.73	0.01	0.29	0.37	0.81

*Pearson's correlation coefficient, r;



	January	Febrary	March	April	May	June	July	August	September	October	November	December
Respiratory diseases	200	198	210	167	101	115	108	82	73	109	123	130
Metabolic diseases	197	174	198	199	149	129	123	129	138	158	134	139
Malignant neoplasms	759	720	701	679	631	629	653	659	622	627	682	658
Cardiovascular diseases	2200	2083	1931	1785	1577	1632	1630	1688	1441	1554	1708	1659

Deaths by months

Figure 3. Trendline of specific mortality data by months

tion between deaths from malignant diseases and seasonal changes in temperature (20).

Following the trend of mortality by months of the year for metabolic diseases, the coefficient of determination of medium strength was found in our study. Similar results were obtained in a 2004 study conducted in Japan (21).

Humidity as a single factor did not show a significant effect in all examined causes of death in our study.

In conclusion, the most favourable average ambient temperatures in Zenica-Doboj Canton for the survival of patients with cardiovascular, malignant, respiratory and even metabolic diseases are around 16 °C, which occur in May and September. This research can be of great practical importance in advising patients with chronic diseases to avoid exposure to extremely high or low temperatures. The community can also be encouraged to provide favourable microclimatic conditions for the chronically ill. Future research should answer the question of how to provide a favourable environment to reduce mortality associated with seasonal temperature changes.

FUNDING

No specific funding was received for this study.

TRANSPARENCY DECLARATION

Conflict of interest: None to declare.

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