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ORIGINAL PAPER

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IMPACT OF CLIMATE CONDITIONS ON HOSPITAL ADMISSIONS FOR SUBCATEGORIES OF CARDIOVASCULAR DISEASES

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Abstract

Background: The aim of this study has been to examine the association between climate conditions (CC) and hospital admissions for the subcategories of cardiovascular diseases (CVD), according to patients' age. **Material and Methods:** From January 2010 through December 2011, the daily number of hospital admissions for angina pectoris (AP), essential hypertension (EH), acute myocardial infarction (AMI) and ischemic heart diseases (IHD) for adults (19–64 years old) and the elderly (≥ 65 years old), as well as for the CC (N = 728 days) was collected for multivariate Poisson regression analysis, confounding with season and weekends. The results were expressed by using the relative risk with the corresponding 95% confidence interval. **Results:** The risk for the AMI among the adults and the elderly is significantly higher for 41.8% and 38.9%, respectively on the days with lower ambient temperature and lesser for 32.7% and 29.8%, respectively on the days with lower air pressure values. The risk for the IHD among the elderly is significantly higher on the days with lower ambient temperature and lower relative humidity for 50.6% and 37.4%, respectively. **Conclusions:** Our findings explain how the CC and subcategories of CVD are associated, which could be used for adequate public awareness of the risk for hospitalization due to climate conditions. Med Pr 2017;68(2):189–197

Key words: risk, hospitalization, public health, association, climate, heart diseases

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INTRODUCTION

Owing to scientific investigation [1], there is no doubt that the change of climate conditions has a significant effect on many health outcomes. A huge amount of evidence has pointed to the relationship between daily variations in meteorological parameters and mortality [2]. The research conducted in Serbia has also shown heat-related mortality, especially among elderly females and Roma population [3,4]. On the other hand, the study which investigated the short-term effects of air pollution on cardiovascular mortality in the elderly in Nis, Serbia, did not show the association with the effects of the time trend, seasonal variations, a day of the week, temperature, relative humidity and barometric pressure [5]. Even though the most of published literature

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is related to mortality, in the recent decade research has been followed by cardiovascular morbidity – temperature association [6]. For example, the increase in hospital admissions, due to total cardiovascular diseases (CVD) among the elderly in New York City, USA, was reported by Lin et al. [7]. As well as the mentioned research, most of other morbidity studies used large aggregated disease groups, such as respiratory diseases or the CVD as a health outcome [8].

There are very few studies focused only on one [9] or several specific cardiovascular health outcomes [10]. According to this type of research, some authors found that while few categories of the CVD, like acute myocardial infarction (AMI) and congestive heart failure, increased with maximum temperature, the other CVD (coronary atherosclerosis and pulmonary heart diseases) significantly decreased with temperature [11]. On the other hand, one European study did not find a significant association between temperature and the whole group of the CVD and cerebrovascular admissions [8]. These disease-specific subcategories are not affected solely by the change of weather but are also age dependent, as indicated by the studies conducted in Slovenia and Australia [12,13].

However, there has been very little research concerning specific disease subcategories of the CVD and other meteorological parameters, like relative humidity and air pressure.

The aim of this study has been to analyze the association between the specific disease subcategories of CVD (angina pectoris (AP), essential hypertension (EH), AMI and ischemic heart diseases (IHD)) and meteorological parameters (ambient temperature, relative humidity and air pressure), according to patients' age.

MATERIAL AND METHODS

The daily number of hospital admissions of the AP, according to the International Statistical Classification of Diseases and Related Health Problems, 10th Revision Version for 2007 (ICD-10), coding I20, EH coding I10, AMI coding I21 and IHD coding I25 over a period of 2 years (2010–2011) was related to meteorological parameters (ambient temperature, relative humidity and air pressure) on a day-to-day basis. Health data of hospital admissions was obtained by the Center for the Informatics and Biostatics in the Health Care, Institute of Public Health of Vojvodina, which is registered and authorized for evaluating health data. The data that was used for the purpose of this study was: available data on discharge diagnose, patients' home addresses (only the ones who were residents of the City of Novi Sad) and the patients' age, without any other personal data.

Data on average daily ambient temperatures, relative humidity and air pressure for the observed period (728 days of valid data) was obtained from the National Reference Institution – the Republic Hydrometeorological Service of Serbia.

Statistics

Continuous variables were presented as the mean ± standard deviation (M±SD) and categorical variables as frequencies. The pearson coefficient was applied to evaluate the correlation between average temperature, relative humidity and air pressure.

To link data on the incidence of heart diseases and meteorological parameters, we followed the well-established approach of a multivariate analysis based on the main effect of the generalized linear model, assuming a loglink function with a Poisson distribution [14]. All the analyses were performed for the adults (aged 19–64 years old) and the elderly (aged ≥ 65 years old), considering the hypothesis that older people may be more vulnerable to the effects of various meteorological parameters.

Throughout the investigation of the association between the ambient temperature and daily number of hospital admissions, none of the used transformations of independent variables (logarithm and square root) showed significant β coefficient. Because of the previously established U-shaped relations between the ambient temperature and hospital admissions proven in the other study [15], we decided to observe the temperature in the form of categorical variables, coding as dummy. Based on the annual average value of ambient temperature for the whole examined period and SD (±1 SD), we coded 3 dummy variables. A similar approach was used for the relative humidity and air pressure. Accordingly, throughout the observed period we defined lower, moderate and higher values or levels for observed meteorological parameters (Table 1).

In all statistical analyses, we used moderate values of meteorological parameters as a reference category for each one. This was based on the hypothesis that people acclimate better to moderate values of meteorological parameters in their environment, rather than to those that are lower or higher in value, which could be stressful for their CVD health.

All the statistical models include the categorical variables for the season and weekend days. The sea-

Table 1. Frequencies of the created dummy variables for meteorological parameters in the study of association between climate conditions and hospital admissions for the cardiovascular diseases (CVD) in Novi Sad, the Republic of Serbia, 2010–2011

Value or level	Ambient temperature		Relative humidity		Air pressure	
	°C	days (N = 728) [n]	%*	days (N = 728) [n]	hPa	days (N = 728) [n]
Lower	≤ 2.7	136	≤ 57.7	119	≤ 1 009.2	96
Moderate	2.8–20.5	446	57.8–85.8	468	1 009.3–1 024.1	525
Higher	≥ 20.6	146	≥ 85.9	141	≥ 1 024.2	107

* Classification was done according to established levels, not values.

son 1 was defined as the period from April to September, while the season 2 was calculated from October to March. Days from Monday to Friday were coded as 1, while Saturday and Sunday were coded as 2.

For all examined models, tests of over-dispersion confirmed the Poisson model assumptions. Namely, the mean deviance (the ratio of deviance to degrees of freedom) did not surpass 1.18 [16] as well as the Pearson Chi^2 to degrees of the freedom ratio. The p-value of the Omnibus test was also below 0.05 in all the examined models. The results of the examined association between meteorological parameters and health data were expressed throughout the values of beta regression coefficient (β), relative risk (RR) and corresponding 95% confidence interval (CI) at significance level of p-value < 0.05. The RR was calculated as:

$$RR = \exp(\beta) \quad (1)$$

where:
RR – relative risk,
β – regression coefficient.

The corresponded percent increases in the number of hospital admissions on days with different weather conditions were calculated as:

$$\% = (RR-1)\times 100 \quad (2)$$

The statistical analyses were performed using the SPSS statistical software version 21.0.

RESULTS

Descriptive data and correlation between examined variables

For adults the average daily number of hospital admissions for the AP was 0.28±0.55, for the EH – 0.27±0.51, for the AMI – 0.58±0.82 and for the IHD – 0.52±0.78, while for the elderly the average daily number of hospital admissions was 0.35±0.64 for the AP, 0.36±0.65 for the EH, 0.54±0.80 for the AMI, and 0.45±0.76 for the IHD. The average daily values of ambient temperature, relative humidity and air pressure was 11.64±8.94°C, 71.8±14.04% and 1016.72±7.43 hPa, respectively (Table 2).

The pearson correlation coefficients were calculated between meteorological parameters (Table 3). The ambient temperature showed a highly significantly negative correlation with the relative humidity ($r = -0.58$, $p < 0.001$) as well as with the air pressure ($r = -0.36$, $p < 0.001$). However, no significant correlations were found between the relative humidity and air pressure ($r = 0.07$, $p > 0.05$).

Regression and RR for the CVD subcategories and meteorological parameters

Through the multivariate Poisson regression model (Table 4), the daily number of hospital admissions for the AMI among adults and the elderly was found to be significantly associated with the ambient temperature and air pressure.

Among adults (Table 4), the average daily number of hospital admissions for the AMI on the days with the lower ambient temperature increased by 41.8% (95% CI: 1.027–1.959) as compared to days with the moderate ambient temperature, adjusted for the season, weekend days, relative humidity and air pressure. In the same group (adults), the average daily number of hospital admissions on the days with the lower air pressure decreased by 32.7% (95% CI: 0.473–0.957), as compared to days with the moderate air pressure and adjusted for the ambient temperature, season, weekend days and relative humidity.

For the daily incidence of the AMI among the elderly (Table 4), the results of the adjusted regression mo-

Table 2. Daily number of hospital admissions for the cardiovascular diseases (CVD) and the meteorological parameters in Novi Sad, the Republic of Serbia, 2010–2011

Variable	M	SD	Min.	Max	P25	P50	P75	Me
Dependent variable								
adults								
angina pectoris (N = 252)	0.28	0.55	0.00	3.00	0.00	0.00	0.00	0.00
essential hypertension (N = 264)	0.27	0.51	0.00	3.00	0.00	0.00	0.00	0.00
acute myocardial infarction (N = 392)	0.58	0.82	0.00	4.00	0.00	0.00	1.00	0.00
ischemic heart diseases (N = 329)	0.52	0.78	0.00	4.00	0.00	0.00	1.00	0.00
elderly								
angina pectoris (N = 206)	0.35	0.64	0.00	3.00	0.00	0.00	1.00	0.00
essential hypertension (N = 200)	0.36	0.65	0.00	3.00	0.00	0.00	1.00	0.00
acute myocardial infarction (N = 424)	0.54	0.80	0.00	4.00	0.00	0.00	1.00	0.00
ischemic heart diseases (N = 380)	0.45	0.76	0.00	4.00	0.00	0.00	1.00	0.00
Independent variable								
ambient temperature [°C]	11.64	8.94	–9.00	28.00	4.00	12.00	19.00	12.00
relative humidity [%]	71.80	14.04	23.00	98.00	62.00	73.00	83.00	71.80
air pressure [hPa]	1 016.72	7.43	990.00	1 040.00	1 011.94	1 016.33	1 021.10	1 016.72

N – daily number of hospital admissions.
M – mean, SD – standard deviation, Min. – minimal values, Max – maximal values, P25, P50 and P75 – quartiles, Me – median.

Table 3. Pearson's correlation coefficients between meteorological parameters in Novi Sad, the Republic of Serbia, 2010–2011

Meteorological parameter	Pearson's correlation coefficients		
	ambient temperature	air pressure	relative humidity
Ambient temperature	1		
Air pressure	–0.357**	1	
Relative humidity	–0.589**	0.070	1

** Correlation is significant at the 0.01 level.

Table 4. Relative risk for the acute myocardial infarction (AMI) hospital admissions in Novi Sad, the Republic of Serbia, 2010–2011

Days	Daily AMI hospital admissions							
	adults				elderly			
	β	RR	95% CI		β	RR	95% CI	
			lower	upper			lower	upper
Ambient temperature								
lower*	**0.349**	**1.418**	**1.027**	**1.959**	**0.328**	**1.389**	**1.010**	**1.908**
higher	–0.070	0.932	0.709	1.226	0.067	1.069	0.829	1.379
Relative humidity								
lower	–0.011	0.990	0.751	1.303	0.170	1.185	0.923	1.520
higher	0.022	1.022	0.763	1.369	–0.230	0.794	0.587	1.075
Air pressure								
lower*	**–0.396**	**0.673**	**0.473**	**0.957**	**–0.354**	**0.702**	**0.497**	**0.992**
higher	–0.233	0.792	0.565	1.111	–0.079	0.924	0.672	1.272

* p value < 0.05. Bolded values are statistically significant.
β – regression coefficient, RR – relative risk, CI – confidence interval.

del showed that the average daily number of the AMI arises on days with the lower ambient temperature by 38.9% (95% CI: 1.010–1.908) as compared to days with the moderate ambient temperature. In the same group (the elderly), the daily number of hospital admissions for the AMI decreased by 29.8% on days with the lower air pressure (95% CI: 0.497–0.992) as compared to days with the moderate air pressure.

In the adjusted model which analyzed the IHD, the daily number of hospital admissions among the elderly as a dependent variable, significant association with the ambient temperature and relative humidity was found (Table 5).

Among the elderly, the average daily number of hospital admissions for the IHD (adjusted for the season, weekend days, relative humidity and air pressure) increased by 50.6% (95% CI: 1.090–2.082) on days with the lower ambient temperature and decreased by 25.9% (95% CI: 0.554–0.993) on days with the higher ambient temperature, as compared to the days with the moderate ambient temperature. Daily average admissions for the IHD (adjusted for the season, weekend days, ambient temperature and air pressure) among the elderly increased by 37.4% on days with the lower relative humidity (95% CI: 1.054–1.792) and decreased by 28.0% (95% CI: 0.528–0.981) on days with the higher relative humidity.

The results of the regression models for the daily number of hospital admissions for the AP and EH among the adults and the elderly, as well as for the IHD among the adults were not statistically significant.

DISCUSSION

To our knowledge this is the first undertaken quantitative study that investigates the associations between meteorological parameters (the ambient temperature, relative humidity and air pressure) and the daily number of hospital admissions for several subcategories of heart disease among the adults and vulnerable subpopulations (the elderly) in the City of Novi Sad.

The obtained results suggest a significant association of lower temperatures and the AMI hospital admissions among the adults and the elderly, adjusted for the relative humidity and air pressure. Similarly, several authors from Slovenia [12] have also confirmed a negative correlation between the average daily temperature and the incidence of the AMI in the context of the acute coronary syndrome among the entire population as well as among the elderly. Considering the seasonality and AMI morbidity, some studies published in Korea, Spain and the U.S. have reported an increased morbidity from the AMI during the winter among adults [17–19]. However, only the study from Korea [17] investigated association adjusted for the relative humidity, wind speed, sunshine duration and a thermohydrological index. On the other hand, the study done in Copenhagen also reported statistically significant short-term increased risk of the AMI at lower temperatures among adults but adjusted this association for the air pollution [20]. The results from that study and the Australian study [21] showed that it was reasonable to think that common acute respiratory infections

Table 5. Relative risk for the ischemic heart diseases (IHD) hospital admissions in Novi Sad, the Republic of Serbia, 2010–2011

Days	Daily IHD hospital admissions among the elderly			
	β	RR	95% CI	
			lower	upper
Ambient temperature				
lower*	**0.410**	**1.506**	**1.090**	**2.082**
higher*	**–0.299**	**0.741**	**0.554**	**0.993**
Relative humidity				
lower*	**0.318**	**1.374**	**1.054**	**1.792**
higher*	**–0.329**	**0.720**	**0.528**	**0.981**
Air pressure				
lower	0.145	1.156	0.844	1.585
higher	0.158	1.171	0.858	1.600

* p value < 0.05. Bolded values are statistically significant.
Abbreviations as in Table 4.

on days with lower temperatures may contribute to the increased AMI.

However, in addition to the fact that temperature has a major role in the AMI incidence, our results have also showed that lower air pressure (< 1009 hPa) adjusted for the temperature and relative humidity are good predictors of the lower AMI incidence among the examined population (the adults and the elderly). Yet, according to the available literature [22,23], consequences of air pressure on the AMI have not been studied very often on a daily level. One of the studies that examined daily effects of air pressure on the AMI events has reported that a higher occurrence of the AMI is related to atmospheric pressure below 1000 hPa [24]. Data from a study conducted in Texas showed a significant relation between air pressure and the occurrence of the AMI, where the decrease in air pressure for 1.0 IH/h increased the odds of having the AMI on the next day by 10% [25]. However, a V-shaped relationship with a minimum at 1016 mbar was reported by Danet et al. [26]. They found an increase in the AMI both with the decrease and increase in air pressure. As a possible reason for the U-shaped curve, Houck et al. [25] have explained the fact that distribution of air pressure changes consecutively on a daily level (the decrease in air pressure on one day is often associated with the increase in air pressure on the next), known as a low-pressure weather front passing through the area that might contribute to the plaque rupture.

Regarding this, our results related to the protective effect of lower air pressure on the occurrence of the AMI admissions, could have been anticipated considering the weather conditions in our city and the exemption of very high and strong changes of air pressure throughout the observed period. That is probably one of the reasons why we did not confirm the U-shaped association between the air pressure and AMI. Similarly to air pressure, a possible reason for the lack of U-shaped temperature – the AMI association in our research, is the fact that ranges of temperatures between 20.7–28°C, coded as days with higher temperature, are not sufficient to cause an adverse effect regarding AMI. On the other hand, the report from Copenhagen showed insignificant association of 3-h maximum apparent temperature (Tappmax) (16±6°C) with AMI admissions in the warm period [20].

Cold weather conditions have been shown to have a stronger influence on increasing morbidity associated with heart failure, as compared to the morbidity associated with the IHD [13]. However, our results confirmed the strongly significant association between the IHD admissions and lower temperature among the elderly, adjusted to the relative humidity and air pressure. Similar results are supported by the study from Scotland [27], with regard to the seasonality and annual rhythm of the IHD admissions. Another interesting result of this study is that the number of the IHD admissions is reduced on days with higher temperature. Similarly, an increased rate of all the CVD admissions as a response to cold weather conditions was reported among the elderly as well as the reduction in admissions on very hot days [13]. The association of the CVD admissions with temperature supports the hypothesis that it is likely, that the elderly were more exposed to outside activities on days with lower temperature than on warmer days. However, the results of our study also show that increases and decreases in the IHD admissions are significantly associated with days with lower and higher humidity values throughout the observed period. These results are in line with studies that also reported [28] the increased IHD admissions in the cool and dry season and reduced admissions in the warm and humid season, adjusted with air pollution.

It could be assumed that the elderly reduce their activities in the environment characterized by a high percentage of relative humidity and high temperatures, probably due to the lack of the body's ability to perspire [29]. That conclusion may be used for interpreting our results, which showed no association of warm and humid weather conditions with the IHD admissions among the elderly. On the other hand, these findings may amplify the fact that the relative humidity alone did not show as a major risk factor for temperature-related diseases but combined with temperature, it could increase the number of admissions [30].

All of the results among the studies regarding the temperature, air pressure, relative humidity and heart disease could be contemplated not only as a consequence of a differential methodology approach [31] but also as an impact of different climate areas, the ability of the human body to acclimate and its adaptive behavior patterns [32]. This could be one of the reasons why our results did not confirm the association between the examined meteorological parameters and AP or EH morbidity.

Still, different results could also be due to several limitations of our study. Because of the computer databases used for the health data, we were not able to consider all of the risk factors for the CVD, like smoking status, alcohol consumption, obesity, physical activity and socioeconomic status. Because of the age specific results in this study, with the vision of defining the most vulnerable population, it might have been advisable to define more than 2 age groups (e.g., 25–35 years old, 36–55 years old, or > 80 years old) as well as gender specific groups according to the results of some other authors [33]. The use of the hospital admissions as health data does not represent the real state of morbidity, too because some cases were linked only to medical examination, without admission. Similarly, we did not have the opportunity to distinguish the cases arising from emergency hospitalization. One of the recognized limitations could also be the lack of adjustment of weather conditions for ambient air pollution. On the other hand, in the association between meteorological parameters and health outcome, we used only lag 0 (current effects). The results of many studies [34,35] report that delayed effects (i.e., lag 3, lag 4, lag 7, lag 14 etc.) of meteorological parameters, especially temperature, could be very important for the observed health outcome. However, our results could be the introduction for similar research where we can examine the lag effects, too.

In spite of mentioned limitations, this study could be useful for healthcare and individual protection planning. Namely, we confirmed that sensitivity of the CVD to temperature varies by subcategories of the CVD as well as by age of the exposed population. Although we found more vulnerability among the elderly related to the lower temperature, relative humidity and air pressure, special attention should be paid to adults aged 18–64 years old, according to our results and results from other studies [12].

CONCLUSIONS

The results of this study explain the climate conditions and heart morbidity association in the City of Novi Sad. They suggest that the AMI and IHD hospital admissions among the adults and the elderly are associated with meteorological parameters, contrary to the AP and EH. The days with lower temperature and lower relative humidity are the riskiest days for the AMI and IHD hospitalization, for adults as well as for the elderly, and only for the elderly, respectively, while the days with the lower air pressure carry the smallest risk for the AMI hospitalization, both for adults and the elderly. These findings could be used for raising public awareness of the risk of hospitalization from the CVD subcategories due to weather conditions.

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