Seasonal effect of physiological equivalent temperature on cardiovascular and respiratory hospital admissions in Novi Sad (Serbia)

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Extended Abstract

Introduction

Climate change has been recognized as an important concern in public health. The impact of heat and cold extremes, as well as seasonal changes over year are associated with increased mortality, particularly due to cardiovascular and respiratory diseases (Eurowinter group 1997; Analitis et al. 2008; Michelozzi et al. 2009; Guo et al. 2012; Kouis et al. 2019; Arsenović 2019). Exposure to ambient temperature, both heat and cold, could stress cardiovascular system due to fluctuation in blood pressure and lead to adverse cardiovascular conditions (Eurowinter group 1997; Wolf et al. 2009; Xu et al. 2019). Extreme temperature events are recognized as factors that could influence respiratory disease too (D'Amato et al. 2018; Da Silva Viana Jacobson et al 2021). Diseases as asthma, rhinosinusitis, chronic obstructive pulmonary disease and respiratory tract infections are the main respiratory disease of concern (Ayres et al. 2009).
Previous studies about health effects of climate change regarding on morbidity and mortality have largely used average, maximum, minimum and diurnal temperature (Analitis et al. 2008; Michelozzi et al. 2009; Gasparrini et al. 2015; Lee et al. 2018; Arsenović 2019a). Some studies used biometeorological indices, i. e. physiological equivalent temperature and universal thermal climate index to assess the relationship between the outdoor thermal conditions and mortality (Muthers et al. 2010; Matzarakis et al. 2011; Nastos & Matzarakis 2012; Urban & Kysely 2014; Burkart et al. 2013; Sharafkhani et al. 2020), while only few studies investigated it in relation to morbidity and hospital admission (Nastos & Matzarakis 2006; Romaszko-Wojtowicz et al. 2020; Borsi et al. 2021).
This paper aimed to examine relationship between physiological equivalent temperature (PET) and hospital admissions due to cardiovascular and respiratory diseases in Novi Sad, Serbia, in order to assess the effects of PET changes on hospital admissions. Novi Sad is second largest city in Serbia and it is located in northern part of the country. According to the population register in 2016, urban area of Novi Sad had slightly more than 300,000 inhabitants.

Data and methods

Data on daily hospital admissions for Novi Sad was obtained from the database of the Institute for Public Health of the Vojvodina Province from the January 1, 2016 to December 31, 2017. The data provided information about date of admission and discharge, date of birth, gender and primary causes of admission according to the International Classification of Diseases (ICD-10). The analysis were performed for total cardiovacsular (I00-I99) and respiratory (J00-J99) diseases. To examine subroup effects of PET, daily number of cardiovacular and respiratory hospital admissions were stratified according to the age (old population and non-old population). The old population were defined as people aged 65 and over, while non-old were persons younger than 65. PET is one of the most widely used biometeorological indices and it can be „defined as the air temperature at which, in a typical indoor setting (without wind and solar radiation), the heat budget of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions to be assessed“ (Höppe, 1999). PET considers the impact of air temperature (Ta), relative humidity (RH), wind speed (v) and global radiation fluxes (g) on a standard human body. Therefore, the meteorological data used for PET calculation was obtained from two fixed-site weather monitoring stations located in the urban area of Novi Sad. The calculation of PET was conducted using the application of the RayMan microclimate model developed by Matzarakis et al. (2007, 2010).

The asssociation between PET and hospital admissions due to cardiovascular and respiratory disease, in this study, was examined using a generalized additive model (GAM) combined with a distributed lag non-linear model (DLNM), (Gasparrini et al. 2010). The DLNM was used to quantify the lagged and possible non-linear effects of PET on hospital admission. The model used for analysis was given as follow:

$$\log(E(Y_t)) = \alpha + cb\left(\beta PET_{t,l}\right) + ns(humidity_t, 5) + \gamma \cdot wind_t + \lambda \cdot year_t + \nu \cdot month_t + \gamma \cdot DOW_t$$

where, t denotes the observation date, $E(Y_t)$ denotes the expected value of hospital admissions at day t and Y_t follows Quasi-Poisson distribution, cb denotes the "cross-bases" of daily mean PET, l is the maximum lag days, $ns(humidity, 5)$ is the natural cubic spline for relative humidity with five *dfs*. Wind was controlled as linear effect in the model. Seasonality and long-term trend were controlled for by including $year_t$ and $month_t$ as dummy variables in the model (Wei et al. 2020; Xu et al. 2019a). DOW_t stands for day of the week on day t.

Considering that the lagged effect of temperature and PET on hospital admissions could be extended more than 10 days (Borsi et al. 2021; Wang et al. 2021), and to avoid underestimating cumulative effects, we used a natural cubic spline with 3 dfs for PET and the third degree polynomial was used for lags.

To assess the risk related with daily PET, we used median of PET as refence value (11.5 ^{0}C) for modeling of respiratory hospital admission, and found the minimum relative risk corresponded to a PET equals 6 ^{0}C. Therefore, PET=6 was the final refence point for both models, i.e. for cardiovascular model and respiratory model.

The maximum lag for cumulative effect of PET on hospital admissions was examined up to 14 days. In addition, to determinated impact of PET on hospital admissions due to cardiovascular and respiratory diseases, cumulative effects was observed at 1st, 5th, 95th and 99th percentile of the PET, respectively extremely low, moderate low, moderate high and extremely high PET. All analyses were conducted in R statistical environment (version 4.0.3) and “dlnm” (Gasparrini et at. 2010).

Selected findings

A total of 7,517 cardiovascular and 5,551 respiratory admissions were registered during the study period, with daily average about 10 cases for cardiovascular and about 8 cases for respiratory diseases (Table 1). Figure 1 and Table 2 shows cumulative effects of the low and high PET on the cardiovascular and respiratory hospital admissions at different lag structure using PET 6 ^{0}C as referent point. Results confirms non-linear relation between cardiovascular and respiratory hospital admissions and PET, respectively for cardiovascular disease RR decrease under lower PET and increased with higher PET, while for respiratory disease was observed adverse effect i.e low PET caused increase in respiratory admission and higher PET caused decrease of hospitalisation risk due to respiratory disease. Low PET at lag 0 and 0-3 days caused decrease in cardiovascular admission with cumulative RR (95% CI) 0.823 (0.713-0.950) and 0.786 (0.621-0.994) during extremely low PET, i.e 0.890 (0.824-0.961) and 0.852 (0.751-0.966) for moderate low PET. In hospitalisation due to respiratory disease the highest cumulative RR (95% CI) was observed for extremely low and moderate low PET with largest impact at lag 0-14 days with 2.231 (1.539-3.232) and 1.414 (1.163-1.719).
In age subroup (Fig 2; Table 3) low PET at lag 0 and 0-3 days caused a decrease in cardiovascular admission for old population (aged 65 and over) with minimum risk at lag 0-3 days. In all lag structure, extremely low and moderate low PET increase risk of respiratory admission for old population, with highest risk at lag 0-14 days and cumulative RR 2.617 (1.331-5.143) and 1.602 (1.123-2.287). Population below 65 years relative to the respiratory admission was also vulnerable at extremely low and moderate low PET with significant impact at lag 0-14 days and cumulative RR 2.053 (1.319-3.198) and 1.333 (1.055-1.683).
Old population was most vulnerable under low PET and respiratory admission with significante increase of cumulative RR at all lag days.Since that large number of studies already reported old population (aged 65 and over) as one of the most vulnerable group under temperature-related mortality and morbidity (Schwartz 2005; Michelozzi et al. 2009; Romaszko-Wojtowicz et al. 2020) results regarding to old population and respiratory admission were expected. As unexpected was that under low PET, in old population risk of hospitalisation due to cardiovascular disease decreased.

Concluding remarks and outlook

This is first population-based study to examine PET impact on hospital admissions due to cardiovascular and respiratory diseases in Central Europe. This study has found that the relationship between PET and cardiovascular and respiratory hosital admissions was non-linear with greather impact during the cold period of the year, whereas due to high PET the cumulative risk of admissions for cardiovascular and respiratory diseases increased but not statistically significant. According to the lag structure, under the extremely low and moderate low PET, persons with preexisting respiratory disease are more vulnerable, with greater effect at lag 0-14 days. Simultaneously, low PET caused decrease of cardiovascular hospital admisssion with minimum risk at lag 0 and 0-3 days. Subgroup analysis by age shows limited differences with slightly higher risk among old population.

Since that study strengthen the evidence about expositure-response of climate-related health, future investigation should be proceeded and expanded with research that include more environemntal as well as socio-demographic indicators.

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Table 1 Daily number of hospital admissions for cardiovascular and respiratory diseases by age in Novi Sad, Serbia (2016-2017)

Variables	Total admission	Mean	SD	Min	Max
Cardiovascular disease (I00-I99)	7517	10.28	4.90	1	30
Age					
(<65 years)	3047	4.19	2.60	0	15
(≥65 years)	4470	6.11	3.27	0	21
Respiratory disease (J00-J99)	5551	7.59	4.01	0	22
Age					
(<65 years)	4121	5.64	3.30	0	19
(≥65 years)	1430	1.95	1.62	0	9

Note: SD=Standard Deviation; Min=minimum; Max=Maximum.

Table 2 Cumulative effect of low and high PET on cardiovascular and respiratory hospital admissions in various lag structure in Novi Sad, Serbia (2016-2017).[a, b]

	Lag	Extremely low PET RR (95% CI)	Moderate low PET RR (95% CI)	Moderate high PET RR (95% CI)	Extremely high PET RR (95% CI)
	Cardiovascular admission				
	Lag 0	**0.823 (0.713,0.950)**	**0.890 (0.824,0.961)**	1.041 (0.936,1.158)	1.023 (0.897,1.167)
	Lag 0-3	**0.786 (0.621,0.994)**	**0.852 (0.751,0.966)**	1.104 (0.910,1.339)	1.046 (0.820,1.333)
	Lag 0-7	0.948 (0.728,1.234)	0.928 (0.806,1.068)	1.119 (0.892,1.402)	1.009 (0.754,1.350)
	Lag 0-14	0.928 (0.658,1.309)	0.915 (0.763,1.096)	0.935 (0.677,1.289)	0.771 (0.510,1.164)
	Respiratory admission				
	Lag 0	1.058 (0.913,1.225)	1.017 (0.940,1.102)	1.012 (0.888,1.153)	0.973 (0.825,1.148)
	Lag 0-3	1.186 (0.931,1.510)	1.053 (0.924,1.200)	1.168 (0.924,1.478)	1.092 (0.806,1.478)
	Lag 0-7	1.399 (1.058,1.850)	1.131 (0.973,1.313)	1.24 (0.943,1.631)	1.117 (0.778,1.603)
	Lag 0-14	**2.231 (1.539,3.232)**	**1.414 (1.163,1.719)**	0.976 (0.66,1.444)	0.714 (0.428,1.191)

[a]Extremly low (PET=-11 ^{0}C): 1th percentile of PET
Moderate low (PET=-5 ^{0}C): 5tht percentile of PET
Moderate high (PET=28 ^{0}C): 95th percentile of PET
Extremely high (PET=32 ^{0}C): 99th percentile of PET
[b]the bolding values represent the significance level <0.05, the Bolding values was considered as statistically significant.

Table 3 Cumulative effect of low and high PET on cardiovascular and respiratory hospital admissions by age in various lag structure in Novi Sad, Serbia (2016-2017)[a,b]

Age	Lag	Extremely low PET RR (95% CI)	Moderate low PET RR (95% CI)	Moderate high PET RR (95% CI)	Extremely high PET RR (95% CI)
	Cardiovascular admission				
<65	Lag 0	0.953 (0.766,1.186)	0.970 (0.862,1.091)	0.952 (0.810,1.119)	0.919 (0.753,1.121)
	Lag 0-3	0.971 (0.681,1.384)	0.959 (0.792,1.159)	1.078 (0.805,1.445)	1.022 (0.707,1.476)
	Lag 0-7	1.037 (0.693,1.551)	0.965 (0.778,1.197)	1.316 (0.934,1.854)	1.236 (0.796,1.918)
	Lag 0-14	0.927 (0.547,1.571)	0.906 (0.686,1.196)	1.034 (0.633,1.687)	0.867 (0.463,1.621)
≥65	Lag 0	**0.747 (0.622,0.898)**	**0.840 (0.761,0.928)**	1.107 (0.965,1.271)	1.102 (0.930,1.305)
	Lag 0-3	**0.681 (0.502,0.923)**	**0.786 (0.668,0.925)**	1.120 (0.874,1.437)	1.061 (0.776,1.452)
	Lag 0-7	0.884 (0.630,1.239)	0.899 (0.751,1.077)	0.998 (0.746,1.335)	0.875 (0.601,1.276)
	Lag 0-14	0.916 (0.590,1.421)	0.914 (0.725,1.152)	0.871 (0.576,1.316)	0.711 (0.418,1.209)
	Respiratory admission				
<65	Lag 0	0.950 (0.792,1.139)	0.953 (0.864,1.051)	1.034 (0.887,1.205)	0.981 (0.808,1.192)
	Lag 0-3	0.962 (0.713,1.296)	0.931 (0.793,1.093)	1.139 (0.865,1.500)	1.022 (0.715,1.459)
	Lag 0-7	1.173 (0.835,1.648)	1.024 (0.854,1.228)	1.108 (0.804,1.526)	0.940 (0.614,1.440)
	Lag 0-14	**2.053 (1.319,3.198)**	**1.333 (1.055,1.683)**	1.086 (0.688,1.713)	0.794 (0.436,1.447)
≥65	Lag 0	**1.343 (1.053,1.714)**	**1.185 (1.036,1.355)**	0.944 (0.737,1.208)	0.947 (0.695,1.291)
	Lag 0-3	**1.886 (1.253,2.837)**	**1.395 (1.116,1.744)**	1.233 (0.787,1.931)	1.298 (0.733,2.301)
	Lag 0-7	**2.060 (1.264,3.359)**	**1.406 (1.079,1.831)**	1.678 (0.991,2.843)	1.772 (0.898,3.496)
	Lag 0-14	**2.617 (1.331,5.143)**	**1.602 (1.123,2.287)**	0.705 (0.330,1.506)	0.507 (0.191,1.347)

[a]Extremly low (PET=-11 ^{0}C): 1th percentile of PET
Moderate low (PET=-5 ^{0}C): 5tht percentile of PET
Moderate high (PET=28 ^{0}C): 95th percentile of PET
Extremely high (PET=32 ^{0}C): 99th percentile of PET
[b]the bolding values represent the significance level <0.05, the Bolding values was considered as statistically significant.

Fig. 1. Relative risk of hospital admissions for cardiovascular and respiratory diseases with PET and lag (0-14 days) using 6 ^{o}C PET as reference point

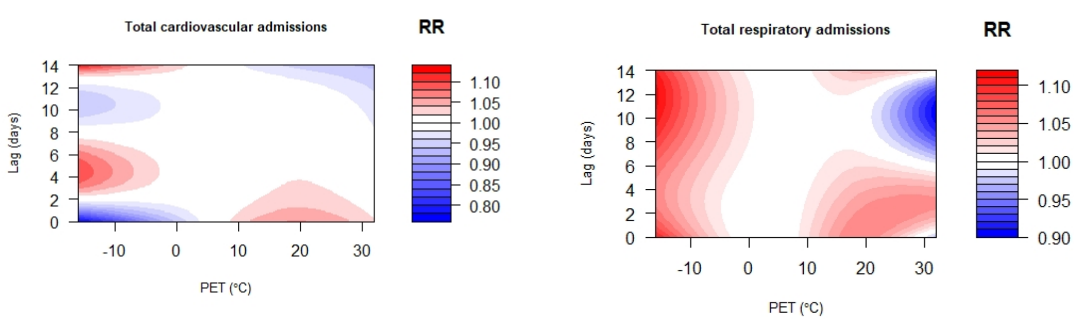

Fig. 2 Relative risk of hospital admissions for cardiovascular and respiratory diseases by age with PET and lag (0-14 days) using 6 ºC PET as reference point