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Cold-related mortality vs heat-related mortality in a changing climate: A case study in Vilnius (Lithuania)

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Direct health effects of extreme temperatures are a significant environmental health problem in Lithuania, and could worsen further under climate change. This paper attempts to describe the change in environmental temperature conditions that the urban population of Vilnius could experience under climate change, and the effects such change could have on excess heat-related and cold-related mortality in two future periods within the 21st century.
Methods: We modelled the urban climate of Vilnius for the summer and winter seasons during a sample period (2009–2015) and projected summertime and wintertime daily temperatures for two prospective periods, one in the near (2030–2045) and one in the far future (2085–2100), under the Representative Concentration Pathway (RCP) 8.5. We then analysed the historical relationship between temperature and mortality for the period 2009–2015, and estimated the projected mortality in the near future and far future periods under a changing climate and population, assuming alternatively no acclimatisation and acclimatisation to heat and cold based on a constant-percentile threshold temperature.
Results: During the sample period 2009–2015 in summertime we observed an increase in daily mortality from a maximum daily temperature of 30 °C (the 96th percentile of the series), with an average of around 7 deaths per year. Under a no acclimatisation scenario, annual average heat-related mortality would rise to 24 deaths/year (95% CI: 8.4–38.4) in the near future and to 46 deaths/year (95% CI: 16.4–74.4) in the far future. Under a heat acclimatisation scenario, mortality would not increase significantly in the near or in the far future. Regarding wintertime cold-related mortality in the sample period 2009–2015, we observed increased mortality on days on which the minimum daily temperature fell below − 12 °C (the 7th percentile of the series), with an average of around 10 deaths a year. Keeping the threshold temperature constant, annual average cold-related mortality would decrease markedly in the near future, to 5 deaths/year (95% CI: 0.8–7.9) and even more in the far future, down to 0.44 deaths/year (95% C: 0.1–0.8). Assuming a "middle ground" between the acclimatisation and non-acclimatisation scenarios, the decrease in cold-related mortality will not compensate the increase in heat-related mortality.
Conclusion: Thermal extremes, both heat and cold, constitute a serious public health threat in Vilnius, and in a changing climate the decrease in mortality attributable to cold will not compensate for the increase in mortality

Abbreviations: *AD*, attributable deaths; *AF*, attributable fraction; *ARIMA*, autoregressive integrated moving average; *CI*, confidence interval; *CMIP5*, Coupled Model Intercomparison Project 5; DTU, Technical University of Denmark; *GCMs*, global climate models; *ICD*, International Classification of Diseases; *IHD*, ischemic heart disease; *IPCC*, Intergovernmental Panel on Climate Change; ISCIII, Institute of Health Carlos III; *PAF*, Population Attributable Fraction; PM_{10}, particulate matter less than 10 μm in diameter; $PM_{2.5}$, particulate matter less than 2.5 μm in diameter; *RAMSES*, Reconciling Adaptation, Mitigation and Sustainable Development for Cities; *RCP8.5*, Representative Concentration Pathway scenario 8.5; *RR*, relative risks; SMLPC, Centre for Health Education and Diseases Prevention; *VITO*, Flemish Institute for Technological Research; *WHO*, World Health Organization; *WPP*, World Population Prospects

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attributable to heat. Study results reinforce the notion that public health prevention against thermal extremes should be designed as a dynamic, adaptive process from the inception.

1. Background

Fewer studies focus on cold-related mortality than on heat-related mortality. Probable reasons include a longer delay between exposure to cold and effect (Alberdi et al., 1998; Anderson and Bell, 2009; Díaz et al., 2005) as well as an overlap in time of concomitant infectious diseases (Carmona et al., 2016; Rocklov et al., 2014; Ryti et al., 2016). In addition, while heat waves are increasing in frequency, duration and intensity, cold spells are decreasing. This trend is likely to continue (IPCC, 2013; Melillo, 2014), despite some evidence suggesting a prospective increase in cold waves in medium latitudes (Cohen et al., 2014; Zhang et al., 2016). However, a reduction in the frequency, duration or intensity of cold waves may not necessarily translate into a decrease in cold-related mortality. Various studies in multiple locations suggest that while heat-related mortality is in decline due to various adaptative processes (Gasparrini et al., 2015; Miron et al., 2015; Díaz et al., 2015a; Ha and Kim, 2013; Petkova et al., 2014), cold-related mortality has either remained constant or increased (Gasparrini et al., 2015; Díaz et al., 2015a; Linares et al., 2016).

Consistently, studies on future impacts of thermal extremes on health focus mostly on heat and its effects on mortality. Most researchers assume that neither the "heat wave" threshold temperature nor the effect of temperature increase itself will change in time, so projections of mortality attributable to heat in far future horizons tend to be quite high (Peng et al., 2011; Wu et al., 2014; Martinez et al., 2016; Roldán et al., 2016). Others, however, assume a heat acclimatisation process (Martinez et al., 2018). Very few studies analyse projected impacts of cold, and all assume no changes in the impacts of cold on mortality across time (Wang et al., 2016).

The evidence base on health and temperature extremes (particularly heat, as mentioned) is relatively well established in several European countries. However, research in this field is still scarce in Baltic countries. In the context of the technical assistance of the WHO Regional Office for Europe to its Member States in the area of climate change and health, we set out to contribute to addressing this gap in Lithuania, where various studies suggest a significant impact of thermal extremes on health and wellbeing (Liukaitytė, 2011; Styra et al., 2009; Vaičiulis and Radišauskas, 2014). However, no study had comprehensively analysed the impacts of heat and cold on mortality in urban settings in the country.

This study has various objectives: first, to analyse retrospectively the impact of heat and cold on daily short-term mortality in Vilnius, determining threshold temperatures for both. Second, to estimate the projected impact of heat and cold in a near future period (2030–2045) and a far future one (2085–2100), under Representative Concentration Pathway (RCP) 8.5. For the projected impacts, we considered two hypotheses: 1) constant thresholds for heat waves and cold waves, and 2) thresholds for heat waves and cold waves varying over time. In addition, we compare projected heat and cold impacts, to determine whether lower cold-related mortality (Kinney et al., 2015; Staddon et al., 2014) will compensate an increase in heat-related deaths.

The results of this study show the change in environmental temperature conditions that the urban population of Vilnius could experience under climate change, and the effects such change could have on excess heat-related and cold-related mortality in two future periods within the 21st century. These results can inform both current-day prevention efforts and relevant urban health adaptation policies.

2. Methods

2.1. Retrospective study of the impact of thermal extremes on short-term daily mortality

2.1.1. Data sources

2.1.1.1. Environmental variables.

- Air temperature data**:** Air temperature measurements for the years 2009–2015 were obtained from the Lithuanian Hydrometeorological Services under the Ministry of Environment. Only daytime temperatures with a 3 h frequency were made available for the current study. Measurements took place daily at 9 h, 12 h, 15 h and 18 h. We have used the measurement at 9 h as a proxy for the minimum daily temperature, and the measurement at 12 h as proxy for the maximum daily temperature.
- Relative humidity**:** Data were also available on relative humidity (rH) at 9 h, 12 h, 15 h and 18 h for the same period; we worked with mean relative humidity obtained as the average of the relative humidity readings recorded at the above-mentioned times of day.
- Chemical air pollution: daily data were available on μg/m^3 of $PM_{2.5}$, PM_{10}, SO_2, NO_2 and O_3 for the same period, recorded at four monitoring stations, and received from the Environmental Protection Agency in Lithuania. We worked with the daily means obtained based on the values furnished by these four stations.

2.1.1.2. Health variables. We calculated the daily crude mortality rate of Vilnius based on the following two variables:

1. Daily mortality: The geographical area under study comprises the Municipality of Vilnius, for which we collected from the Institute of Hygiene the daily mortality series corresponding to the period 01-01-2009 to 31-12-2015 for all-cause mortality (International Classification of Diseases, 10th Revision (ICD-10:A00-R99).
2. Population: Population data for the city of Vilnius were obtained from Statistical Office of Lithuania (DoS, 2018) for the period 2009–2015.

2.1.2. Statistical methodology

2.1.2.1. Determination of cold wave and heat wave threshold temperatures. Some definitions of heat wave or cold wave require that the threshold temperature is exceeded two or more days for the series to qualify as either (Guo et al., 2017). However, from the health impact standpoint, mortality increases can be observed already when the threshold value is exceeded only by a single day, an observation confirmed in several studies analyzing the impact of heat and cold on mortality (Díaz et al., 2002; Montero et al., 2012; Miron et al., 2015, Díaz et al., 2015b; Carmona et al., 2016; Martinez et al., 2018; Gasparrini et al., 2017; Wang et al., 2016). However, acknowledging that there is no consensus on what constitutes a heat wave or a cold wave, we considered impacts in this study on the basis of an operational definition, following previous studies (see for instance Martinez et al., 2018). Thus, we defined "hot days" as days with mortality attributable to heat, and "cold days" as days with mortality attributable to cold.

The extent of the retrospective analysis was limited by the availability of daily mortality data, corresponding to the period 2009–2015, hereon referred to as the "sample period". Impact of heat was studied for summertime (June-September) and impact of cold for wintertime (November-March). In both cases, we aimed at determining a threshold temperature. For heat, it was defined as the maximum daily