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RESEARCH ARTICLE

Association between Extreme Cold Weather Temperatures and Mortality in Greece

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Abstract

Background: Little is known about cold-related mortality in south Europe. The aim of this study was to investigate the association between extreme cold weather and mortality in Greece.

Methods: Daily mortality data covering the period 1999-2012 were retrieved through the Hellenic Statistical Authority Archive. 24-hour mean temperature was collected from 16 weather stations spread throughout the country. Analyses were focused on days with extremely low temperatures (5^{th} percentile) as well as on the following seven days.

Results: The two leading death causes during extreme cold weather were diseases of the nervous system (36.5%) and diseases of the respiratory system (26.8%). The prevalence of deaths due the aforementioned causes was significantly increased on extreme cold weather (and following seven days) when compared to warm temperature days (temperatures ranging between 15-20 °C; $p < 0.001$). In addition, temperature during extreme cold weather was significantly associated with increased mortality; a decrease of 1 °C in mean temperature significantly increased mortality by 2.8% ($p < 0.001$). On the first and second day following extreme cold weather, mortality increased by 0.6% ($p < 0.001$) and 0.8% ($p < 0.01$), respectively.

Conclusion: Extreme cold weather is associated with all-cause mortality and also with cause-specific mortality. During extreme cold days, the diseases of the nervous and respiratory systems rise the most in Greece.

Keywords

Extreme weather events, Climate changes, Total deaths, Cause-specific death

Introduction

Climate change is estimated to affect global temperature, leading to an increased number of extreme weather events across the globe [1]. Mortality during these extreme events has been shown to be increased [2]. Indeed, the association between extremely low or high ambient temperatures and daily deaths across several regions of the world has been extensively reported [3]. It seems that this association is cause-specific and age-specific; i.e., the adverse effects of extreme temperatures are more pronounced in elderly populations, where in cardiovascular diseases and respiratory diseases have been ranking as the top death causes due to climate changes [3,4]. Given that episodes of extreme weather temperature have a serious impact on human health [2], research on the topic is crucial for effective prevention programmes in high-risk countries.

Developed countries with warm climates characterized by frequent extreme heat events (e.g. south Europe countries) are usually investigated on whether isolated episodes of heat waves affect human health outcomes [5]. In Greece, for instance, a Mediterranean country with a generally warm climate, a major heat wave hit Athens in 1987; more than 2000 deaths were associated with temperature during this extreme weather event [6]. However, less in known on the associations between extreme cold weather temperatures with mortality in these warm south European countries. The aim of this study was to investigate the association between extreme cold weather with mortality in Greece.

Methods

Mortality data in Greece covering the period 1999-2012 were obtained from the Hellenic Statistical Au-

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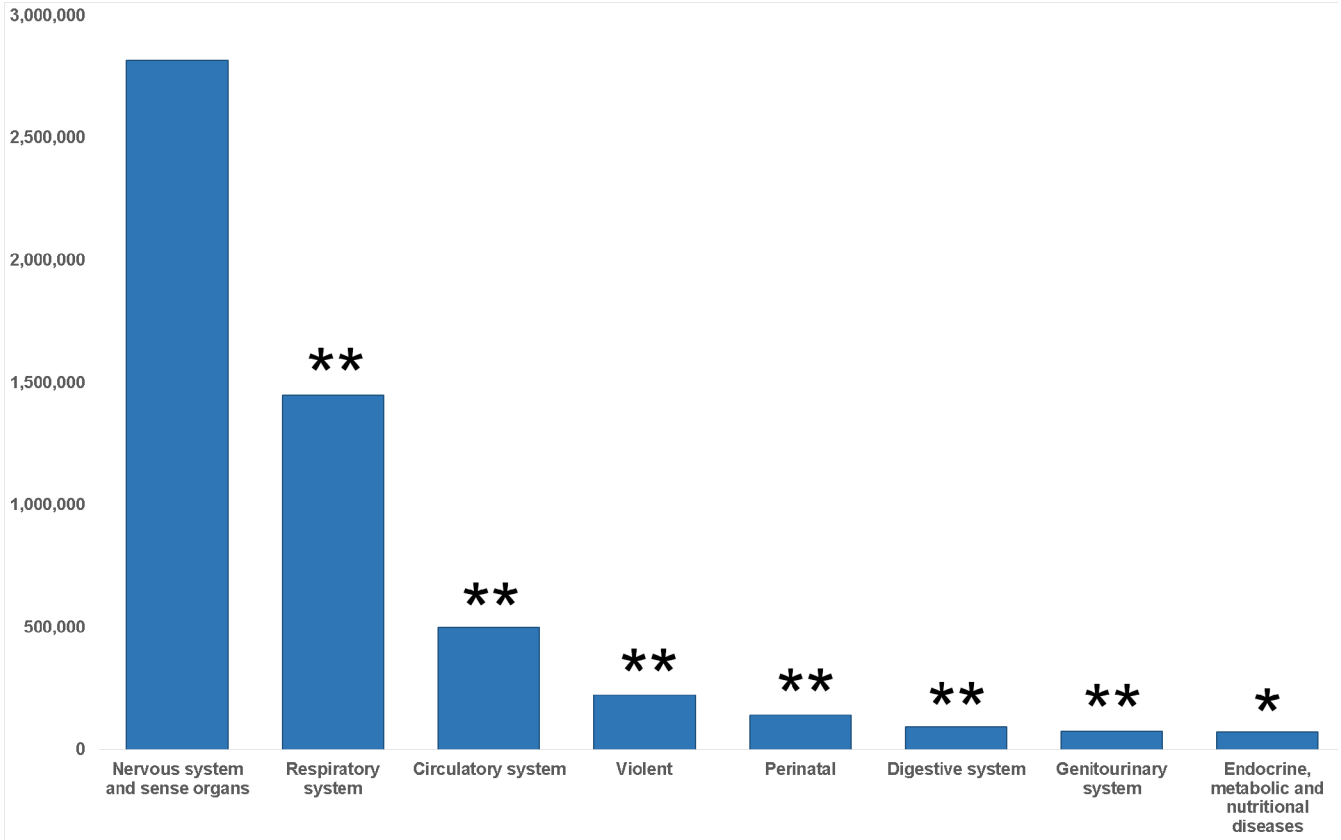

Figure 1: Mortality according to cause-specific death in Greece from 1999-2012. Note: Cause-specific mortality statistically different at *p < 0.01 and **p < 0.001 when compared to cause on the left-hand side.

thority Archive. Meteorological data covering the same time frame were supplied by the Greek Meteorological Service. For the aforementioned period, 24-hour mean temperature was collected from 16 weather stations spread throughout the mainland and islands, covering the entire country. Specifically, temperature information covered the following regions of Greece: Thrace, Macedonia, Thessaly, Epirus, Central Greece, Peloponnese, around Athens, Aegean Islands, Ionian Islands, Crete. The two databases were merged so that each meteorological data was associated with the closest possible weather station within the same region of death. Extreme cold weather temperature was defined as those days with a mean temperature at or less than the 5th percentile of the mean temperature distribution at a national level; < 3 °C. Furthermore, given the well documented lagged effects of temperature on mortality [7], weather data were analysed considering not only days with extreme cold weather events, but also the seven consecutive days that followed.

Statistical analyses were conducted using the software SPSS-version 20.0 (IBM SPSS, Chicago, IL). Chi-square analyses were performed to examine prevalence differences in mortality (considering the two leading death causes in Greece over the selected period) between extreme cold weather temperature days and warm days (defined as those days with a mean temperature between the 50th and 75th percentile of the mean temperature distribution; 15-20 °C). The relationship between mortality and mean temperature was investigated using generalized linear Poisson regression models; the regression was performed on extreme cold weather temperature days and seven consecutive days that followed. Daily death counts were used as a dependent variable, and 24-hour mean temperature, sex and age as independent predictor variables. An offset was added in the model to account and control for potential changes over time (the dimensions year, region and season were considered; region-by-year-by-month). The level of statistical significance was set at $p < 0.05$.

Results

Cause-specific mortality during the period 1999-2012 in Greece is shown in Figure 1. Diseases of the nervous system and sense organs had the highest number of deaths over the examined 13 years (2,818,948), followed by diseases of the respiratory system (1,448,788) and diseases of the circulatory system (501,280) ($p < 0.05$). Endocrine, metabolic and nutritional diseases had the lowest number of deaths 74,540 ($p < 0.05$).

The two leading death causes in Greece over 1999-2012 during extreme cold weather were diseases of the nervous system and diseases of the respiratory system ($p < 0.05$). The number of the deaths due to these causes was significantly increased in extreme cold weather temperature (and following days) in comparison with warm days (temperatures ranging between 15-20 °C) (Table 1); 292,811 deaths on extreme cold weather

Table 1: Mortality of the two leading death cause in Greece during 1999-2012 in extreme cold days (and following seven consecutive days) in comparison with warm days (temperatures ranging between 15-20 °C).

Death cause	Cold days (< 3 °C)	Warm days (15-20 °C)	P
Diseases of the nervous system and sense organs	292,811	212,345	< 0.001
Diseases of the respiratory system	150,089	110,648	0.001

Table 2: Percentage increase (95% CI) in mortality for 1 °C decrease in mean temperature on extreme cold days (and following seven consecutive days) and its association with sex and age.

	% Increase	95% CI	P
All-cause death	8.6	1.074-1.097	< 0.001
Sex	8	0.860-0.982	0.012
Age (> 70 yrs)	2.3	1.136-1.321	< 0.001

Regression analyses were conducted on extreme cold day's temperature and following days; an offset was added in the model to mould mortality rates per year-by-season-by-month.

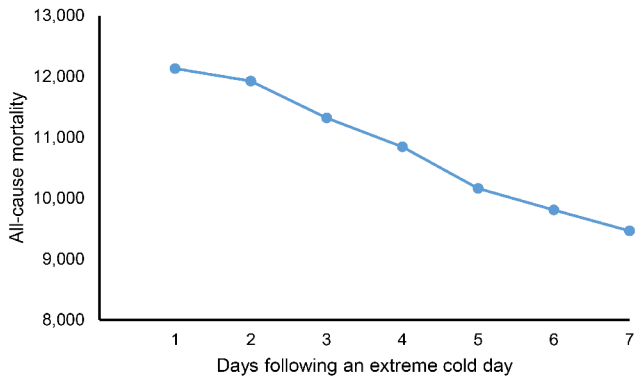

Figure 2: Mortality on the seven consecutive days that followed extreme cold weather temperature.

temperature were due to diseases of the nervous system (vs. 212,345 on warm temperature days, $p < 0.001$) and 150,089 due to diseases of the respiratory system (vs. 110,648 on warm temperature days, $p < 0.001$).

The association between cold weather temperature and total number of deaths was further investigated (Table 2). A decrease of 1 °C in mean temperature significantly increased mortality by 8.6% ($p < 0.001$). On the first and second day following extreme cold temperature, all-cause mortality increased by 0.6% ($p < 0.001$) and 0.8% ($p < 0.01$), respectively (Figure 2). Considering a sex effect, men had 2.3% less probability of dying in extreme cold weather compared to women ($p < 0.05$). Cold weather seems to be associated with all-causes mortality in elderly individuals; individuals with more than 70-years-old seem to be more affected by extreme cold weather temperatures (individuals within this age group had 2.3% more probability of dying during cold temperature days).

Discussion

The relationship between extreme hot weather temperatures with mortality in south European countries during the summer is well documented, but less is known regarding cold-related mortality in these countries. The present study focused on extreme cold weather temperatures in Greece, aiming at investigating the association between cold temperatures with mortality. The main finding was the significantly increased number of deaths in extreme cold weather temperature (and following days) in compassion with warm days. Further, the relationship between cold ambient temperature and mortality in Greece appears to be affected by sex and age; deaths occurring in elderly individuals and women exhibit stronger low-temperature dependence than the ones occurring in younger adults and men. These findings were not surprising, as it has been reported that elderly populations are challenged in adjusting to extreme environmental conditions due to an impaired thermoregulatory capacity and reduced ability to adapt to temperature changes [8,9].

Overall, our findings are consistent with previous studies in central and north European countries. For instance, a study conducted in England and Wales found an association between cold temperature and mortality [10]. Also, in central Europe, it was observed an increased mortality with temperature at low average daily temperatures [11]. Ireland also experiences increased cold-related mortality [12]. Our study shows that the adverse effects of cold temperature in health are not exclusive of north or central European countries (traditionally known for their cold temperature during winter); southern European countries may also be at risk for mortality due to cold ambient temperatures at a same extend than north and central Europe.

Our study further suggests that the relationship between cold ambient temperatures with mortality in Greece is cause-specific. According to our findings, it seems that extreme cold weather events affect more diseases of the nervous system and sense organs, followed by diseases of the respiratory system. These results contradict previous studies showing that respiratory diseases register the greatest cause-specific mortality due to cold ambient temperatures (it has been hypothesized that cold weather directly induces indirectly effects such as pneumonia and influenza) [3]. The present study cannot provide the reasons for these findings. However, to our knowledge, the cold-related mortality data published so far come from northern countries, whereas our data come from a southern Mediterranean country. Results from north regions may not be applicable to populations living in the south as geography, weather-related parameters, latitude and adaptive abilities may further interfere with cause-specific mortality [13]. Vulnerable groups according to country-specific geography need to be further identified.

Future studies in South Europe should further investigate the effects of extreme cold weather temperatures in cause-specific mortality. Indeed, one limitation of the present study is the lack of specificity on the location and conditions of each death. It has been suggested that extreme cold events could only change the timing of death (i.e. anticipated it), not affecting necessarily lifetime expectancy [14]. Therefore, to validate the findings of the present study, future studies should consider the health condition of each citizen to assess whether the cold extreme temperature anticipated death or induce it. Moreover, the exact location of death should also be considered in future research, as well as the specific age groups, sex differences, and region-specific mortality in Greece. Alternative weather-related parameters and the effects of some risk factors as socioeconomic status and urban vs. countryside should also be investigated. Finally, future analysis should also investigate the association between daily hospital admissions (stratified by cause) with cold ambient temperatures.

Conclusion

Warm southern European countries may also be at risk for mortality due to cold ambient temperatures. In Greece, extreme cold weather temperatures not only are associated with mortality in general, but also with cause-specific mortality. Diseases of the nervous and respiratory systems seem to be the most affected by extreme cold weather temperatures. Future research is needed to explore these associations in order to develop strategies for preventing temperature cold-related deaths in Greece.

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