Heat Waves, Human Health, and Climate Change

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Abstract

Health indicators, for both mortality and morbidity, have been frequently associated with extreme hot temperatures. Many studies have found the existence of a minimum temperature of mortality, named comfort temperature. Another temperature from which a sudden increase in mortality is produced, named trigger temperature, has also been described. Both may vary according to geographical location and according to socioeconomic and demographic characteristics of the population. The most common definition for a heat wave is given by exceeding the trigger, or threshold, for maximum and/or minimum temperatures. Future scenarios of climate change state that heat waves will become more intense and frequent.

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Due to this, the implementation of prevention plans to reduce the health effects of heat waves are indispensable in public health policy.

Keywords

Air temperature • Heat temperature • Heat wave • Heat effects • Health effects • Human health • Mortality

Relationship Between Temperature and Health

The influence of air temperature on mortality is generally described as a nonlinear relationship with a U or V shape (Baccini et al. 2008). Usually, mortality increases with the rise or fall of the environmental temperature, from a certain comfort temperature or minimum mortality temperature. According to the climate characteristics of the area studied, the comfort temperature can vary, generally decreasing as the latitude increases or the weather is colder, as a result of an adaptation process of the population to its habitat. It has been observed that in cities with the lowest annual mean temperatures, a lower mortality from cold is done as a result. On the other hand, the more the influence of summer season, the more the mortality due to cold rises. Similarly mortality due to heat is greater in those populations subject to lowest average temperatures.

Delayed Health Effect of Temperature

The health effect of heat is, usually, immediate leading to an increase of the mortality in the population more quickly than cold, which produces a more delayed and sustained health effect. The relationship between heat and mortality is that the association does not usually occur only in the same day, but it also appears during at least the next 3 days. On the other hand, the persistence of high temperatures may produce cumulative effects on the population, increasing the mortality when bad weather conditions are maintained further few more days. The elderly people are more physiologically prone to the negative effects of temperature variations, also being the group of population who bring more deaths (WHO 2003). This does not mean that the temperature does not affect other age groups. However, the health effects of heat can be more immediate or more delayed depending on geographical location and socio-health situation of the studied city.

Threshold Levels for Temperature

Since the relationship between temperature and mortality is not linear, it has been studied the threshold level of air temperature that increases significantly the mortality of the population. In the case of heat, temperature thresholds have been reported around the 95th percentile of daily maximum temperatures in summer,

between June and September (Díaz et al. 2006). However, recent studies indicate that this percentile may not be fixed, and that it is influenced by other variables such as demographic structure of the population or socioeconomic factors (Montero et al. 2012). Thus, different physiological adaptation thresholds produce different mortality trigger temperatures, depending on more or less temperate regions jointly with the confluence of specific factors or local factors such as social, economic, or demographic characteristics that may vary over time.

Economic and Demographic Factors

Several studies have indicated social and economic factors as one of the major determinants of the differences between countries or regions regarding the association of air temperature and mortality. In the United States, poverty level, social isolation, confinement at home, insufficient knowledge of English, low reading level, living in neighborhoods with high rates of crime, and being black have been identified as important risk factors for dying due to heat effects (O'Neill et al. 2005). That is, those characteristics indicative of low social and economic level would impede the access to services and better conditioning of their homes, consigning this population to live in habitats worse located where the heat island effect is more pronounced. Thus, in France it has been reported that the main protective factor against a heat wave is to have adequate cooling in working hours, followed by to have access to a place with an air conditioner for a few hours, and having a house with a good insulation (Vandetorren et al. 2006). For these reasons, it seems likely that changes fast enough in the environment may modify the effect of ambient temperature on the mortality. It has been observed that as we advanced in, the economic development was alleviating the influence of environmental variables on morbidity and mortality, which in Japan has been outlined as *loss of seasonality diseases* (Sakamoto-Momiyama 1978).

Heat Wave Definition

It is well known that high temperatures are related to an increase in mortality, being especially strong during extreme heat temperatures. However, until now, there is no unanimous definition for a heat wave among the scientific community. Maximum, minimum, and mean temperatures have been used for this. Differences also exist defining the number of days, one or more, that the temperature must exceed the threshold to ascertain for a heat wave. Some authors consider two definitions of heat wave with two different temperatures according to the days in which these are exceeded. Air temperature and other meteorological variables (relative humidity, wind speed, atmospheric pressure, etc.) have also been combined into a single index that serve as a measure of heat stress caused by heat. In this sense, the most used index has been the apparent temperature (Steadman 1979), which combines air temperature and relative humidity, due to that a high humidity

prevents the evaporation due to perspiration, preventing the cooling of bodies. However, others consider that the role of perspiration in the reduction of body temperature has been exaggerated; they also found a relationship in dry environments with an increase in the effects of contaminants, mostly ozone. Another approach is studying synoptic situations in each geographic region. Under this methodology weather conditions are analyzed as a whole, identifying those characteristics most often associated with a rise on the mortality.

Impact of Heat Waves on Mortality

It seems to be clear that each geographical location will have a different mortality trigger temperature. Furthermore, daily mortality will be larger the more the maximum daily temperature increases far from the threshold temperature. According to the pathophysiological mechanisms, described above, the effect of heat usually occurs immediately. That is, 1 day after the occurrence of a heat wave, daily mortality begins to increase, and this effect could be maintained over time until 4 days later. It also influences the number of days this threshold is exceeded. One single day of overcoming causes excess mortality, but whether the phenomenon is repeated for several consecutive days, the cumulative effect of heat will be higher. Finally, it also influences when a heat wave occurs. A heat wave in early summer may have a greater effect on daily mortality if it occurs at the end. This is because there are a larger group of susceptible people, mainly elderly, and that this population has not been acclimated to the heat. Thus, the following heat waves will have less effect on daily mortality because susceptible people have already died and the remaining will have acclimatized to heat.

The 2003 Heat Wave

The temperature in the summer of 2003 was a really extreme event because it was probably the hottest summer in Europe since 1500. Heat waves occurred with different intensities and at different periods, in many countries, causing in all of them a strong excess of mortality, estimated at 70,000 deaths (Robine et al. 2008). But this was not an isolated phenomenon. In some provinces of Spain, heat waves between 1991 and 1995 were higher in both, maximum temperature and duration, than in 2003. The really exceptional heat wave in 2003 is that the thermal extremes covering the entire central and western Europe, affecting countries as far north, where although it is described an excess mortality in the summer months, temperatures are not as common as those registered in August 2003. So its effect was greater than in more southern latitudes. The exceptional fact about the heat wave of 2003 is that the maximum daily temperatures covered the entire central and western Europe, affecting countries as far north, where although it is described an excess mortality in the summer months are not as common temperatures such as those that occurred in August 2003.

Future Climate Scenarios due to Climate Change

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPPC 2007) reinforces the evidence that we are in a phase of climate change, largely due to human activity. The projections reflect an increase in air temperature at the surface for the year 2100 between 1.8 °C and 4 °C, representing a rate of change very quickly, and involve a wide range of uncertainties in the relatively near future, with potential environmental, economic, social, and health consequences. The most likely scenarios for the coming years will be characterized by an increase in all types of weather extremes (heat waves, droughts, heavy precipitation, etc.). Furthermore, these will be very different and of diverse intensity depending on the geographic and climatic characteristics of each area. Thus, in the assessment of the impacts of climate change in Spain (Moreno 2005), it is expected that there is a:

- progressive increase in average temperatures over the century
- higher increase in the summer temperatures
- less accumulated annually rainfall
- increased amplitude and frequency of monthly thermal anomalies
- increased frequency of days with extreme temperatures, mainly in summer.

In Spain, projections have been recently made based on different climate change scenarios (AEM 2010). Thus, if we refer to A2 scenario (which is disrespectful to the environment in terms of emissions and that could be called medium-high emissions), for the second quarter of the twenty-first century (2041–2070), it is expected an increase in the maximum temperature between 3 °C and 5 °C, whereas for the period 2070–2100 that increase in the maximum temperature would be between 5 °C and 8 °C. Also, the annual distribution of maximum temperature change is not equal for all months, showing a greater increase in maximum temperatures in summer months and a smaller increase in winter. As for the existence of thermal events with extremely high temperatures, a considerable increase is expected in the days with extreme summer temperatures, rising to 13 days between 2021 and 2050 and to 40 days from 2071 to 2100 (Fischer and Schär 2010).

Expected Impact on Health

Within the framework of the European Project PHEWE, on the possible increase in mortality in the horizon of 2030, under different scenarios of the IPCC, it is concluded that the average attributable fraction of deaths due to heat shall be 2 %, being the greatest impact on the Mediterranean cities (Baccini et al. 2011). This phenomenon will increase in the future according to the expected rise in frequency and intensity of the heat waves. Similarly, a study carried out in 44 US cities calculated increments between 70 % and 100 % in the mortality in summer 2050, depending on the consideration of a more or less conservative model (Kalstein and Greene 1997). The possible effects of acclimation to these new circumstances, such as an increased use of air conditioning, physiological

habituation, or an active health policy against heat waves, could mitigate partially this increase by around 25 %, but never fully compensate. It is difficult to guess what will be the behavior of populations in a future climate change scenario. It is known that the comfort temperature varies with latitude, and there is an adaptation to local weather patterns. However, everything suggests that a rapid increase in temperature will make a prompt change in the habits of the society difficult. Furthermore, it is not just that heat waves will occur more frequently, as indicated by climate models, if the threshold temperatures tend to decrease as a result of aging population, the number of heat waves will increase much faster than expected by climate models that consider fixed threshold temperatures.

Final Remarks

As discussed previously, in a medium-term future, heat waves will become more frequent and intense, because the air temperature will be higher due to the change climate and the trigger threshold for mortality will be lower by the aging of the population. Moreover, the number of people susceptible to the heat effect will become higher as a result of aging, so its effects on human health will become more important. Given this situation, the only option is to mitigate these health effects through the implementation of action plans to minimize impacts on human health. These plans must be designed comprehensively and with as much information about the impact of extreme heat temperatures on human health.

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