

## Heat Waves' Influence on Health: Some Uncertainties about Their Impact

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There are two preliminary issues that arise on addressing the above-referenced study. On the one hand, there is the matter of the independent meteorological variable which is to be used to define a heat wave; and, on the other, there is the matter of the health variable which is to be used as the basis for ascertaining the influence of the extreme atmospheric phenomenon.

With respect to the first of these, it would seem clear that the meteorological variable that should define a heat wave is air temperature: yet the question that then arises is which temperature? i.e. maximum daily, minimum daily or mean daily temperature? Alternatively, should a heat wave rather be defined on the basis of other semi-empirical equations that link temperature to other atmospheric variables, such as relative humidity, known as apparent temperature [1], or the so-called wind chill factor [2] which couples air temperature with wind speed?

The answers to these questions still lack scientific consensus, in view of the fact that there are many studies which use the different variables mentioned above to define what is known as a heat wave from a public health standpoint [3]. Although maximum daily temperature appears to be the most widely used of these, the EUROHEAT project [4] has resulted in the so-called "apparent temperature" being employed in Europe in recent years as a meteorological indicator of the combined effect of temperature and humidity. However, the use of this parameter is not free of controversy for various reasons.

In the first place, the use of any given parameter that synthesises diverse variables in a single mathematical algorithm is only advisable if its efficacy has previously been tested under all possible scenarios. Reliance on apparent temperature implies assuming that, during any heat wave, there is a positive quadratic relationship between relative humidity (as measured by a wet-bulb temperature) and mortality, namely, that an increase in humidity is always associated with an increase in mortality. Nevertheless, a number of papers report exceptions to this: in the USA, for instance, the above relationship varies among the different cities analysed [5]; and in Spain, studies which have examined humidity independently show that the highest mortality is associated with low humidities [6,7]. Failure to taken into account the direction of the association may give rise to erroneous interpretation of results. There can be no doubt that the extent to which air temperature influences the definition of apparent temperature makes for this strong association between apparent temperature and mortality, regardless of any possible impact of relative humidity.

Not only is there no scientific unanimity surrounding the choice of the independent atmospheric variable, but it is equally unclear which health indicator is most appropriate for quantifying the impact of a heat wave. In the latter case, daily mortality is by far the most widely used indicator [8], yet there are other health indicators which are also affected by extremely high temperatures, such as hospital admissions [9] or use of emergency services [10]. Although it might seem, *a priori*, that these indicators must be interrelated, what happens in reality is that this does not occur. Hence, if a heat wave has its maximum impact on, say, circulatory-cause mortality, what in fact happens is that this may never be reflected in the emergency admissions due to these causes, since the diseases implicated can be fulminant and persons may die without ever reaching the hospital emergency ward [11].

In addition to the strictly meteorological variables, there are others that also influence the possible impact of heat waves on health, namely: heat-wave duration, in that the longer a heat wave's duration, the greater its impact on mortality [12]; the chronological number of a wave in any given year, inasmuch as the first heat waves have a greater impact on mortality because there are more susceptible persons [6]; or even other atmospheric factors, such as air pollution, whose detrimental effects on health are reinforced by high temperatures, as in the case of ozone [13] or particulate matter [14].

Notwithstanding the above, even if maximum daily temperature were to be accepted as an independent variable to define a heat wave and as a health variable to measure the impact on daily mortality, there is still no consensus when it comes to defining from which temperature a heat wave would be deemed to exist. In this regard, there are two clearly marked trends: on the one hand, there are those who use strictly climatological criteria to define a heat wave, i.e., a heat wave exists in any case where the maximum daily temperature exceeds the 95th percentile of the maximum daily temperature series of the summer months [15]; and, on the other hand, there are those who contend that a multitude of parameters intervene, such as socio-economic and demographic factors that cause mortality to rise at temperatures which, in some cases, may be above or below the 95th percentile of the above-mentioned maximum temperature series. In other words, epidemiological (mortality-temperature) studies would have to be undertaken in each place in order to detect at which precise temperature mortality began to rise sharply in response to temperature [6]. It is evident that the definition of heat-wave temperature is an essential pre-requisite for establishing heat-wave impact [16].

If the panorama described thus far for ascertaining the health impact of heat waves which have already taken place appears complex, then the problem becomes that much more complicated and the uncertainties increase even further when one wishes to forecast what impact such heat waves are going to have within a given time horizon. In this connection, a study has recently been published [17] which concludes that, "the major sources of uncertainty were the relative risks estimates for mortality on heat wave versus non-heat wave days, the RCP scenarios and the heat wave definition." One conclusion to be drawn from reading this manuscript would seem to be that a good heat-wave definition based on epidemiological studies and accurate determination of the risk associated with such temperatures would greatly reduce these uncertainties. Although the authors make some

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allusion to the possible geographical variability of these risks, there is nevertheless no mention of the possible evolution over time that can take place both in heat-wave definition temperatures and in the modifications of these possible impacts, beyond those stemming from the use of air-conditioning equipment and the implementation of heat-wave prevention plans.

Along these lines, it should be noted that recent studies have found that demographic and socio-economic factors may be behind the trend in minimum mortality temperatures [18]. Hence, in Castile-La Mancha (Spain) the minimum mortality temperature went from 32°C in the decade 1975-1985 to 28°C in the period 1995-2003 as a consequence of population ageing, and the same may thus be deduced from heat-wave definition temperatures which are very closely linked to the over-65 age group [8].

Added to this uncertainty are the shifts over time observed in the impact of heat waves. Studies conducted in different parts of the world show that, far from remaining constant, these impacts are changing over time, with a trend towards the minimisation of such effects [19], i.e., while the effect is most pronounced in cardiovascular-cause mortality [20], it has remained practically constant in the case of respiratory-cause mortality [21]. These results, obtained from a time series covering a time span of over 30 years, show that the increase in risk of heat-related mortality for each degree centigrade that the threshold temperature is exceeded, went from 13.7% in the decade 1975-1985 to 7.4 % in the decade 1997-2008, and specifically, that this decline was due to circulatory causes, going from 18.2% in the period 1975-1985 to 5.8% in the period 1997-2008; in the case of respiratory causes, however, no such decline was in evidence, with the respective figures remaining practically constant, i.e., 11.8% in 1975-1985 versus 13.5% in 1997-2008. This pattern would seem to be linked to improvements in health-care services -particularly in the case of patients with cardiovascular diseases- socio-economic improvements and the provision of infrastructures for better living conditions; it therefore follows that any changes in the trend of these parameters could reverse the situation and increase the effects of temperature extremes on mortality. This decline in heat-wave-related mortality does not appear to be connected with the implementation of prevention plans, in Spain at least [22].

Since the factors that appear to influence the shifts in the relationship between temperature and mortality are not local and are thus extrapolatable to a large proportion of developed countries, their relevance is self-evident.

These above uncertainties go to add to those already cited in the paper by Wu et al., and serve to highlight the need for more in-depth knowledge, not only of temperature forecasts at the different time horizons, but also of the behaviour pattern over time of the temperature-mortality relationship which, far from being constant, displays a time trend that is seldom taken into account in the models used to predict the impact of climate change on human health.

Lastly, it should be made clear that, despite the above-mentioned uncertainties, it is obvious that extremely high temperatures have an impact on population health, as is borne out by the 70,000 deaths caused by the 2003 heat wave in Europe [23] and the 55,000 deaths caused by the 2010 heat wave in Russia [24]. One cannot cling to these uncertainties in order to avoid implementing the sort of public health prevention measures that are required to minimise the undeniable effects which heat waves have on population health.

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