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Original communication

Using the Excess Heat Factor (EHF) to predict the risk of heat related deaths

Neil Langlois MD, Forensic Pathologist [a,b,*], Jonathon Herbst MD, Pathologist [c], Kerryn Mason BAppSc., Grad Dip, Forensic Scientist – Toxicologist [a], John Nairn Bsc. Hon. Dip. Met., Supervising Meteorologist [d], Roger W. Byard MBBS, MD, Professor [a,b]

[a] Forensic Science South Australia, Australia
[b] Discipline of Pathology, University of Adelaide, South Australia, Australia
[c] Department of Pathology, WellStar Cobb Hospital, Georgia, United States
[d] Bureau of Meteorology, South Australian Regional Office, Australia

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ABSTRACT

Extremes of climate are not uncommon in Australia and heatwaves are not infrequent. Periods of high ambient temperature may result in clusters of heat related deaths, which may place strain on forensic facilities. This paper describes the formulation of the Excess Heat Factor using meteorological data to provide a means of predicting death resulting from periods of extreme heat stress. The 2009 South Australian heatwave had the highest ranked Excess Heat Factor in Adelaide's records. There were 58 heat related deaths, with the bulk of the heat related deaths following the peak Excess Heat Factor value (144 °C^2). The 2008 heatwave had a lower peak Excess Heat Factor value (36 °C^2); there was only one heat related death, which followed the peak in the Excess Heat Factor. It is proposed that calculation of the Excess Heat Factor from meteorological data could provide a means to predict and identify heat related deaths resulting from extreme weather conditions.

1. Introduction

Heat related deaths may occur in isolation related to individual circumstances (for example, resulting from exertion)[1,2] or in clusters associated with unusually high and persistent environmental temperatures, commonly known as "heatwaves". Heatwaves are declared when temperatures exceed a predetermined level over a set number of days. However, there is no 'gold standard' to predict or define a heatwave. In Adelaide, South Australia consists of five consecutive days with temperatures of 35 °C or more, or three consecutive days with temperatures of 40 °C or more.[3]

Heat related fatality clusters can cause considerable strain on the resources of medical facilities, including forensic mortuaries, in terms of having to provide adequate staffing levels and resources to deal with markedly increased workloads. Heat related deaths would be expected when daily average and maximum temperatures remain elevated for protracted periods. However, there is not a simple relationship between temperatures and mortality.[4] Exposure to heat can result in acclimatisation and adaptation,[5] but sudden and sustained substantial elevations of ambient temperature above baseline levels have the potential to result in clusters of heat related deaths. The authors propose the use of the Excess Heat Factor, which can be calculated from meteorological data, to predict when there is a high risk of heat related mortality and morbidity.

2. Materials and methods

The means for calculating The Excess Heat Factor, which provides a numeric value for the environmental temperature load, is described below.[6] Analysis of meteorological data for South Australia for the 30-year period 1971–2000 provided the 95th percentile of the upper limit of the average daily temperature (DT_{95}) as a climate reference value. The Significance Excess Heat Index (EHI_{sig}) is defined as unusually high heat that is not sufficiently discharged overnight due to high overnight temperature. Maximum and

* Corresponding author. Forensic Science SA, 21 Divett Place, Adelaide, SA 5000, Australia. Tel.: +61 8 8226 7700; fax: +61 8 8226 7777.
E-mail address: Neil.Langlois@sa.gov.au (N. Langlois).

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subsequent minimum temperatures averaged over a three-day period (DT_{3days}) are compared against the climate reference value (DT_{95}).

$$EHI_{sig} = \text{Average}\left(DT_{3days}\right) - DT_{95}$$

Thus the Significance Excess Heat Index provides a measure of how much the average daily temperature over three days exceeds the 95th percentile of the average daily temperature over the reference 30-year period.

The Acclimatisation Excess Heat Index (EHI_{accl}) is defined as a period of heat that is warmer, on average, than the recent past. Maximum and subsequent minimum temperatures averaged over a three-day period (DT_{3days}) are compared to the average temperature over the preceding 30 days (DT_{30days}):

$$EHI_{accl} = \text{Average}\left(DT_{3days}\right) - \text{Average}\left(DT_{30days}\right)$$

Thus, the Acclimatisation Excess Heat Index makes an allowance for expected acclimatization to the variation in temperature.

The Excess Heat Factor (EHF) is calculated by multiplying the Significance Excess Heat Index by the absolute value of the Acclimatisation Excess Heat Index:

$$EHF = \left(EHI_{sig}\right) \times \left|\left(EHI_{accl}\right)\right|$$

Thus the Excess Heat Factor is an expression of the long term temperature anomaly, amplified by the short term temperature anomaly.[6] Any Excess Heat Factor value above zero indicates heatwave conditions and the higher the value the more extreme the conditions. A severe heatwave is an event where the Excess Heat Factor values exceed a threshold for severity that is specific to the climatology of each location. A severity threshold for Excess Heat Factor has been proposed utilising Probability of Exceedance theory. Rare and relatively common heatwave events are separated by sampling the 85th percentile of a site's positive Excess Heat Factor cumulative distribution function.

A review of all deaths reported to the South Australian State Coroner's office from 23rd January to 10th February 2009 incorporated the period of 13 days from 26th January to 7th February where

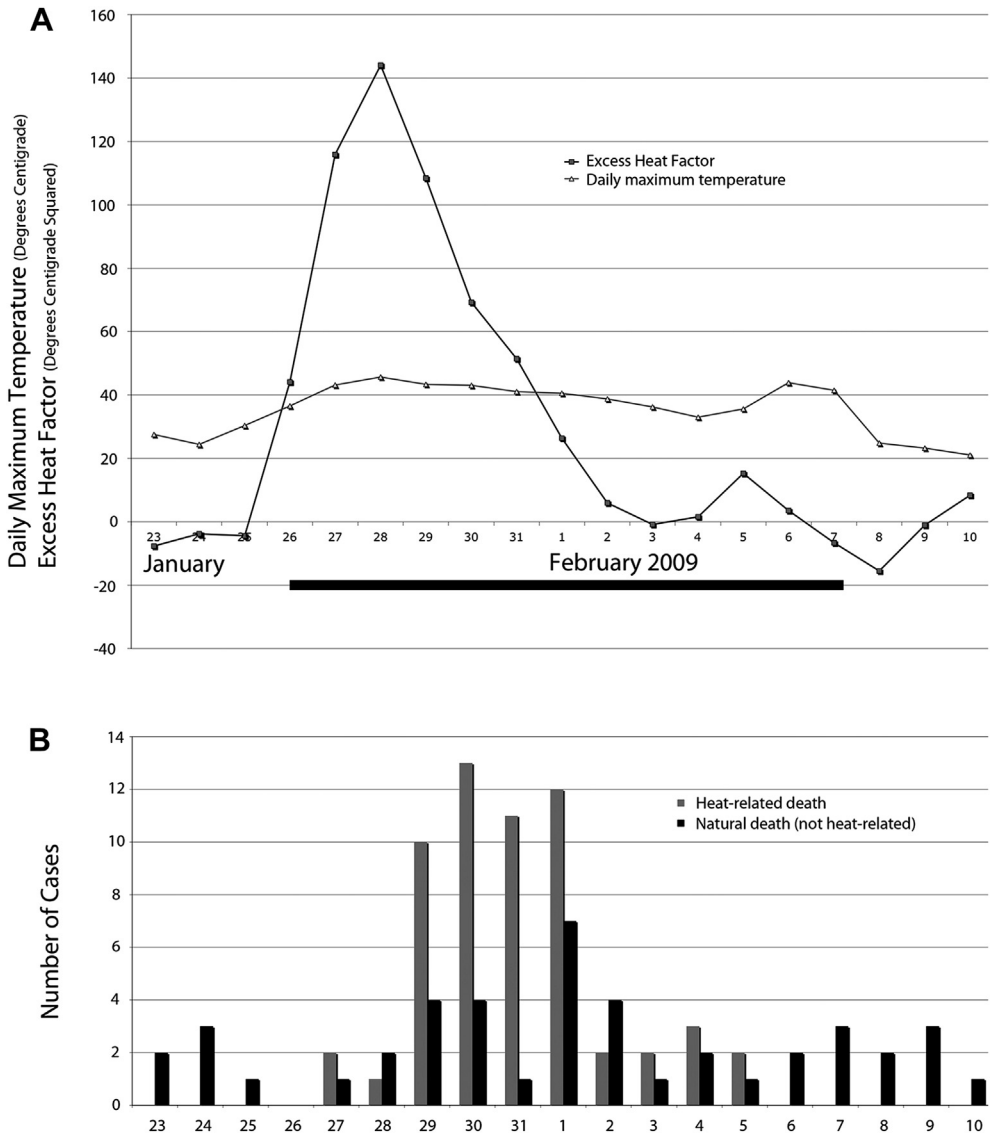

Fig. 1. 2009 Heatwave. A (top): Excess Heat Factor and maximum temperatures plotted on a daily basis. The black bar indicates the designated period of the heatwave from January 26th to February 7th 2009. B (bottom): Numbers of heat related and non-heat related natural deaths plotted against the date of death.