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Contrasting patterns of hospital admissions and mortality during heat waves: Are deaths from circulatory disease a real excess or an artifact?

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Summary In old subjects exposed to extreme high temperature during a heat wave, studies have consistently reported an excess of death from cardio- or cerebro-vascular disease. By contrast, dehydration, heat stroke, acute renal insufficiency, and respiratory disease were the main causes of hospital admission in the two studies carried out in elderly during short spells of hot weather. The excess of circulatory disease reported by mortality studies, but not by morbidity studies, could be explained by the hypothesis that deaths from circulatory disease occur rapidly in isolated people before they reach a hospital. Since the contrasting patterns of hospital admission and mortality during heat waves could also be due to chance (random variation over time and space in the spectrum of diseases induced by extreme heat), and bias (poor quality of diagnosis on death certificate and other artifacts), it should be confirmed by a concurrent study of mortality and morbidity. Many heat-related diseases may be preventable with adequate warning and an appropriate response to heat emergencies, but preventive efforts are complicated by the short time interval that may elapse between high temperatures and death. Therefore, prevention programs must be based around rapid identification of high-risk conditions and persons. The effectiveness of the intervention measures must be formally evaluated. If cardio- and cerebro-vascular diseases are rapidly fatal health outcomes with a short time interval between exposure to high temperature and death, deaths from circulatory disease might be an useful indicator in evaluating the effectiveness of a heat watch/warning system.

Introduction

Heatwaves are periods where temperature is unusually high, relative to the usual climate for a

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particular place. According to Bouchama and Knochel [1], a heat wave is an isolated episode of hot weather, consisting of three or more consecutive days during which the air temperature is above 32 °C. However, it is difficult to have a standard definition because the threshold may vary depending on which temperature each population is acclimatised. These episodes have been explored to identify both heat-related mortality and morbidity (e.g., changes in hospital admissions). Numerous studies have investigated mortality during a heat wave, while there have been comparatively few studies that have quantified heat associated morbidity; the latter studies have been published only recently. Studies reporting cause specific deaths and hospital admissions during heat waves provided conflicting results. The present paper first reviews the epidemiologic evidence, then illustrates a key hypothesis and the design of a confirming study, and lastly discusses the consequences if the hypothesis were demonstrated.

Evidence for the hypothesis

The relevant literature was identified through *PubMed* and *Current Contents* databases, using ''elevated temperature'', ''heat wave'', ''mortality'', ''hospital admissions'' as keywords. The search was limited to studies of humans in biomedical research. Then, we visited the web sites of World Health Organization, Regional Office for Europe (at: www.euro.who.int), Centers for Disease Control (at: www.bt.cdc.gov/disasters/extremeheat/), and Sistema Epidemiologico Regionale — Veneto (at: http://www.ser-veneto.it). We focused our literature search on studies published until June 2005, reporting population-based data on the impact of heat waves on morbidity and mortality, broken down by cause. We review below only studies on short-term heat-wave related mortality/morbidity, while excluding papers on long-term effects of weather on mortality or hospitalization.

In New York City, during the heat waves in 1972, 1973 [2], and 1975 [3] death counts (lag: few days), mostly from ischemic heart disease, increased in $\geqslant$65 years old subjects. Short spells of hot weather during summer in Greater London, from 1965 to 1972, were associated with a peak in deaths from respiratory disease (1968), cardio-vascular disease (1969, 1969, 1970), and cerebro-vascular disease (1970) in persons aged $\geqslant$60 years [4]. Mortality increased by 20%, mainly from cardio- or cerebro-vascular disease, in subjects aged 70—79 years in Birmingham, UK, during a heat wave in 1976 [5]. During a severe heat wave in several US cities in 1980, increased risk of total and cardio-vascular mortality was reported in elderly (aged $\geqslant$60 years), poor, black people, inner-city residents in Memphis [6]. Extremely hot weather during summer 1993 in Philadelphia increased total mortality by 26% and cardio-vascular mortality by 98% [7]. Four hundred and fifty-six heat-related deaths (core body temperature $\geqslant$105 °F), and excess of cardio-vascular deaths occurred (lag: 2 days) in 1995 during a 1-week heat wave in Chicago, the risk being greatest in males, black people, elderly [8]; similar results were reported by Whitman et al. [9]. A 5-day heat wave during summer 1995 entailed extra deaths in England and Wales (9%) and Greater London (16%) mostly from respiratory and cerebro-vascular diseases, among women [10] (notice that sex difference shows an inconsistent pattern across studies and might be attributed to age since women tend to live longer than men). Lastly, during July 1999, a heat wave occurred over south-central Winsconsin resulting in 21 deaths; cardio-vascular conditions contributed to 71% (15/21) of heat-related deaths [11].

A detailed analysis of all inpatients hospital admissions during a heat wave was reported in only two studies. Considering retrospectively the number of hospital admissions for medical conditions treated in 47 hospitals in Chicago, Semenza et al. [12] calculated the difference between admissions recorded on each day during July 1995 heat wave and those recorded in the appropriate days of July 1994 (comparison year because of absence of heat waves). In a 1-week heat wave, 838 (35%) more hospital admissions than in reference weeks were found among patients >65 years, mainly due to dehydration, heat stroke, heat exhaustion, acute renal failure. Like other countries in Europe, Veneto region (North-Eastern Italy) experienced an atypically hot summer in the 2003. Among people aged $\geqslant$75 years, it was reported that a region-wide increase in hospital admissions for all causes (+2%), respiratory disease (+13%), degenerative nervous system disorders (+23%), acute renal failure (+31%), and electrolyte disorders (+75%) occurred in summer 2003 compared to summer 2004 (comparison year because of absence of heat waves); interestingly, hospitalizations for cardio-vascular disease decreased by 3% [13].

The hypothesis

During the Chicago heat waves many deaths occurred in people living alone or who had limited

social contact [14,15]. The excess of circulatory disease reported by mortality studies, but not by morbidity studies, could therefore be explained by the hypothesis that deaths from circulatory disease occur rapidly in isolated people before they reach a hospital [16]. The conflicting findings could however result from many factors, including variation across the populations, different analytic methods (e.g., source of data), issues related to data quality and measurement error, and chance. In the papers reviewed, there are three sources of variation (country, data source, and data quality), and the random error. In order to disentangle the separate effects of each source of variation, we suggest investigating concurrently mortality and hospital admissions during heat waves in two or more countries, and to achieve best evidence of circulatory disease through clinical (hospital and/or family physicians) records, and interview of relatives shedding light on the circumstance of the death.

Consequences of the hypothesis

Observational data are essential for developing models of the relation between temperature and morbidity/mortality in order to predict the consequences of global warming, particularly for those most vulnerable and least able to adapt, so that preventive steps can be taken [17]. An increasing number of cities worldwide have started to issue heat warnings and develop and implement heat-wave response plans. The initial step and most important input is accurate weather forecast data, because the effects of heat waves are immediate. Other components include educating the public about the hazards of heat, communicating with agencies that work with vulnerable populations during heat alerts, establishing cooling centres at libraries and community centres and providing water and transportation when needed. Thus, another specific question is how well the health services and policy makers respond during heat waves. Many heat-related diseases may be preventable with adequate warning and an appropriate response to heat emergences, but preventive efforts are complicated by the short time interval that may elapse between high temperatures and death. Therefore, prevention programs must be based around rapid identification of high-risk conditions and persons [18]. The effectiveness of the intervention measures must be formally evaluated. If cardio- and cerebro-vascular diseases were rapidly fatal health outcomes with a short time interval between exposure to high temperature and death, deaths from circulatory disease might be the best indicator in testing how effective the protective efforts can be.

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