Maturitas 69 (2011) 99–105

Contents lists available at ScienceDirect

Maturitas

journal homepage: www.elsevier.com/locate/maturitas

Review

Heat wave impact on morbidity and mortality in the elderly population: A review of recent studies

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ARTICLE INFO

Article history:
Received 4 February 2011
Received in revised form 2 March 2011
Accepted 2 March 2011

Keywords:
Heat wave
Mortality
Morbidity
Elderly
Temperature

ABSTRACT

Background: The on-going climate change is predicted to yield a growing number of extreme climate events which will increase in both intensity and frequency. Increased longevity is changing society's demographics. It is very likely this will have a direct impact on population health. Many studies have previously shown that the elderly in a society are among the most vulnerable to heat waves.
Objectives: With a rapidly growing number of publications on this subject the objective was to review the recent literature for research regarding the impact of heat waves and elevated temperature on the elderly with regards to mortality and morbidity.
Methods: PubMed was searched to identify studies published in English between 1st of January 2008 and 31st of December 2010 using the following key words: heat wave, mortality, morbidity, elderly and temperature. The relationship between high temperature and mortality and/or morbidity had to be studied. Results for the elderly had to be provided.
Results: Six studies of temperature–morbidity-relationship were found and 24 studies of temperature–mortality-relationship. Studies consistently reported increases in cardiovascular and respiratory mortality, as appeared also respiratory admissions to do during hot days and heat waves. However, the number of studies on morbidity published was much fewer. Few studies reported social, medical and environmental susceptibility factors.
Conclusions: Future research should focus on studying susceptibilities and to non-fatal events which are not as studied as mortality. Studies on the modification of type of urban environment, housing and mortality and morbidity in the elderly population are also needed.

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doi:10.1016/j.maturitas.2011.03.008

1. Background

Extreme climate events are predicted to increase in number, duration and frequency with on-going climate change. It is likely that these extreme events will have a greater direct impact on population health than seen previously [1]. In recent decades, several devastating heat waves have caused large health consequences across the globe. For example, the 1987 heat wave in Athens caused around 2000 deaths; the 1995 Chicago heat wave caused around 700 deaths; and the 2003 heat wave in Europe is estimated to have caused 70,000 deaths [2–4].

Within societies today the population structure is changing as the proportion of elderly increases due to increased longevity, resulting in higher prevalence of chronic and degenerative diseases. Studies have shown that elderly populations are among the most vulnerable to heat waves and elevated temperatures. The underlying factors characterising this susceptibility are both social and medical. Physiological responses to environment deteriorate with ageing and some medication interacts with thermoregulation and risk perception. Mental disorders, such as dementia, also alter risk perception and protective behaviours. Living alone contributes to the heat susceptibility of the elderly, as do factors related to increased dependency, such as living in nursing homes or being confined to bed [5–8].

Fortunately, the potential negative health impacts of heat waves are preventable through: heat avoidance, cooling and hydration. Prevention and adaption strategies to reduce heat wave related deaths are through specific outreach targeting vulnerable groups including heat wave early warning systems, emergency plans, and cooling [9]. Adaptation of buildings and cities to reduce heat stress by mitigating the effects of urban heat islands can additionally help prevent heat wave mortality and morbidity.

The impacts of heat waves on populations have been reviewed in the past but publications on this topic have increased rapidly in recent years. Therefore, the aim of this paper was to review the recent literature addressing the morbidity and mortality impacts of heat waves on the elderly.

2. Materials and methods

This review focused on relevant studies published in English between 1st of January 2008 and 31st of December 2010 identified using PubMed.

The following key words were used in the search: heat wave; mortality; morbidity; elderly; temperature.

Publications with the following criteria were considered for inclusion:

1. Examined the relationship between high temperature and mortality and/or morbidity.
2. Presented results specific for the elderly, or
3. Presented results for the elderly analysed as a sub population, in which case only the results corresponding to the elderly were included.

To focus on high quality research, the included studies were limited to those that conducted time series analysis and presented the results as a relative increase in deaths or hospitalisations or emergency visits per degree Celsius above a pre-determined threshold, or as the relative excess (relative risk) in mortality or morbidity corresponding to heat waves as compared to a non-heat wave days.

We did not narrow the review to a specific heat wave definition, since studies reporting excess risks resulting from heat waves often used local definitions. A typical characteristic of a heat wave was daily temperatures over several consecutive days above an extreme temperature percentile (threshold) which may vary for particular regions.

3. Results

The studies focusing on morbidity were outnumbered by the studies focusing on mortality. Studies of temperature-related mortality generally followed standard time series methodology and were more homogenous in design and results than the morbidity studies. Methodological issues in defining heat related morbidity might limit the availability of data for morbidity studies and may help explain why they are comparatively rare and heterogeneous. Differences in conclusions between studies regarding effects of heat might also be due to a ceiling effect on hospital admissions which can only increase to the maximum number of beds available and data from emergency departments may be truncated due to capacity reasons. Additionally difficulties separating the planned hospital admissions from those admitted for acute conditions during periods of elevated temperature may explain apparently inconsistent results. Given the heterogeneity, confidence in the association between high temperatures and morbidity is not as high as that for temperature and mortality. Therefore the results of the morbidity studies will be commented more in detail.

3.1. Morbidity studies

The morbidity studies typically focused on hospitalisations, and were conducted in Australia, US and Europe. [See Table 1]. The majority reported relative risk changes for cardiovascular and respiratory diseases, a minority reported hospitalisation for other causes. The morbidity effects of heat waves were observed immediately, or lagging slightly behind an increase in temperature. For some conditions, there was evidence of higher morbidity with increasing duration of heat waves.

Pooled effect estimates of maximum apparent temperature for 12 European cities, categorised as either Mediterranean or North-Continental cities, showed that increases in temperature above the 90th percentile of maximum temperature increase respiratory admissions for the75 plus age group. This effect was not observed among 65–74 year olds in Mediterranean countries, but a slight effect was observed in the North-Continental cities for the same age group. Cardiovascular and cerebrovascular admissions showed no or a slightly negative association with high temperatures in the European cities studied [10]. Similarly, no association between high temperatures and myocardial infarction hospitalisations was observed among the elderly in UK [11]. However, when temperatures exceeded a threshold, the 50–74 and 75 and over populations, in New York, were found to have increasing rates of respiratory and cardiovascular morbidity compared to the younger population

Table 1
Studies of the relationship between heat waves/high temperature and morbidity published between 2008 and 2010.

Morbidity studies where the elderly were analysed as a sub population				
Reference	Region and population	Exposure and threshold	Outcome variable	% change in outcome variable per 1 °C increase in temperature above threshold
Bhaskaran [11]	15 conurbations in England and Wales 2003–2006	Daily max. and min. temp.	Hospital admissions for myocardial Infarction	No increase in risk regarding heat
Knowlton [13]	California heat wave 2006	Heat wave 15th July–1st August. Reference period 8–14 July and 12–22 August	Hospital admissions and emergency department visits	65+:increased rate ratio for heat related illnesses: emergency department: RR = 10.87 (8.39–14.31) hospitalisations:RR = 14.23 (9.56–22.08)
Lin [12]	New York City residents. June–August 1991–2004	Daily mean and mean app. temperature thresholds: 28.9–29.4 °C (T) 31.7–35.6 °C (AT)	Hospital admissions for respiratory or cardiovascular disease	75+: hospital admissions increase by 4.7% for respiratory causes and by 3.5% for cardiovascular causes above threshold
Hansen [14]	Adelaide, Australia 1st January 1995–31st December 2006	Heat waves versus non-heat wave periods	Hospital admissions for renal disease	Increased risk among elderly during heat waves, higher for females than males IRR: 65+: all: 1.086 males: 1.051 females: 1.085 85+: All: 1.196 males: 1.046, females: 1.218
Hansen [15]	Adelaide, Australia 1st July 1993–31st December 2006	Heat waves versus non-heat wave periods	Hospital admissions for mental and behavioural disorders	Increased risk for 75+ by 17.1% (males) and 19.0% (females) for hospital admissions for mental and behavioural disorders during heat waves compared with non-heat wave periods
Michelozzi [10]	12 European cities 1990–2001	Maximum app. temperature city specific thresholds ranging from 14.7 °C to 29.5 °C	Daily hospital admissions for cardiovascular, cerebrovascular, and respiratory causes	75 +: respiratory admissions increased by 4.5% (1.9–7.3) and 3.1% (0.8–5.5) Mediterranean and North-Continental cities respectively (pooled estimates) cardiovascular and cerebrovascular causes did not show statistically significant differences

[12]. In a study comparing the 2006 Californian heat wave days to non-heat wave days, the elderly had a higher relative risk of hospitalisations and emergency department visits [13].

An Australian study found hospital admissions, both for those aged 65–74 and 75 or above, increased for renal disease and acute renal failure on heat wave days compared to non-heat wave [14]. In addition, hospital admissions for patients aged 65–74 suffering from mental and behavioural disorders increased during heat wave days compared to non-heat wave days [15].

3.2. Mortality studies

The majority of studies examined the relationship between temperature and all cause mortality, with the remaining studies reporting excess mortality rates in relation to specific heat wave events. As heat-related deaths may be attributed to many different causes many studies used all-cause mortality (non-accidental or non-violent deaths) as a measure for this outcome. [See Table 2].

3.2.1. Result by region

In the United States an increase in mortality risk for heat wave days was found for those aged 65–74 years and those 75 or over compared to non-heat wave days. Heat effects were higher for respiratory than cardiovascular mortality in both age groups [16]. In California an increase in the daily mean apparent temperature of 10 °F yielded an increase in non-accidental mortality among the elderly [17].

In Latin America, when comparing the 95th and 75th percentiles of daily mean apparent temperature, an increase in mortality for the population above 65 was observed [18]. Further, evidence from both South America (Santiago, Chile) and southern Europe (Palermo, Italy) suggests an increase in all-cause mortality (cumulative effect) among the population aged 65 and over, with the effects of heat larger in Palermo than in Santiago [19].

In Italy the relative risk of dying on a hot day compared to non-heat wave day was elevated for all-cause, respiratory and cardiovascular mortality [20]. This was also observed in the elderly in Portugal [21]. Heat waves in London, Budapest and Milan were associated with increases in all-cause, respiratory and cardiovascular mortality for those aged over 75 [22]. The results from 15 European cities showed, that even though Mediterranean and North-Continental countries use different empiric thresholds to define a heat wave, they observe similar results for the 65–74 year old populations across countries, and strong and consistent temperature–mortality associations for those above 75 [23].

Another European multicity study of the elderly compared the percentage increase in mortality per day during a heat wave to non-heat wave days and found increases for all-cause mortality as well as for respiratory, cardiovascular and cerebrovascular mortality. Longer lasting heat waves were reported to have larger impacts than shorter. The heat wave effect in Mediterranean region was larger compared to the North-Continental cities [24].

Among the 70 or over population in thirteen cities in Spain a positive percentage increase was associated with a one degree Celsius (1 °C) increase above the temperature of minimum mortality (daily mean temperatures ranging from 14 °C to 23 °C) for all cities [25]. A study of the north of Spain found increasing mortality for the elderly when both maximum and minimum temperatures increased by 1 °C during the summer [26]. Heat related mortality in the elderly increased substantially and consistently when temperatures increased above the 90th percentile of summer temperatures in different regions of Sweden [27].

Table 2
Studies of the relationship between heat waves/high temperature and mortality published between 2008 and 2010.

Reference	Region and population	Exposure and threshold	Outcome variable	% change in outcome variable per 1 °C increase in temperature above threshold
Mortality studies where the elderly was analysed as a sub population				
D'Ippoliti [24]	Population 65+ in 9 cities 1990–2004 and 2003 analysed separately	Heat wave days vs. non heat wave days	Daily all natural-cause, card., cerebrovascular and resp. mortality	Effect of heat waves on daily mortality, % increase for all natural deaths ranging from 7.6% for Munich to 33.6% for Milan
Iniguez [25]	13 Spanish cities 1990–1996	Daily mean temperature MMT = minimum mortality temperature, 14–23 °C	Daily all natural-cause mortality	70+: %increase in all-cause mortality ranging from 0.47 to 4.83%. Statistical significant increases were found in nine out of 13 cities
Klenk [36]	95,808 nursing home residents Germany 2001–2005	Daily ambient maximum temperature threshold of 26 °C	Daily mortality	Above threshold increasing ambient temperatures were associated with increasing mortality risk
Rocklöv [27]	Population 65+ 1998–2005 in three Swedish regions	Daily mean temperature	Daily all-cause (excluding external) mortality	Cumulative combined relative risk of about 5.1% (CI = 0.3, 10.1) per °C above the 90th percentile of summer temperature at lag 0–1.
Vaneckova [30]	65+ population between 1st October and 31st March 1993–2004	Mean of daily average temperature	Daily non-external mortality	Per 10 °C increase in average temperature mortality increased by 13.5–21.8% and 5.7–8.9% (depending on adjustment) two regions of Sydney
Nordon [38]	Population 70–100 in France who died before and during heat wave of 2003 was compared to those who survived	Heat wave 5–13 August. Reference period 1–4 August	Deaths related to use of psychotropic drugs	During heat wave anxiolytic decreased risk of death by 15% (OR = 0.85, 0.79–0.91). Before: 20% (OR = 0.8, 0.70–0.93). During heat wave anti-depressant/psychotic increased risk of death by 70% (OR = 1.71, 1.57–1.86) and 110% (OR = 2.09, 1.89–2.35). Before: 20% (OR = 1.23, 1.02–1.49) and 40% (OR = 1.45, 1.14–1.85)
Rey [39]	Population 55+ in France	Heat wave 3rd to 15th August 2003.Non-heat-wave June–August 2000–2002	Daily mortality	Excess mortality rate of heat wave was two-fold higher in most deprived vs. least deprived cantons.
Stafoggia [20]	Population 65+ in Rome 1987–2005	Daily mean temperature	Daily all-cause, cardiovascular and respiratory mortality	RR of dying on a summer day with an apparent temperature of 30 °C (lag 0–1) compared with a 20 °C day. All natural causes: 1.39 (1.32–1.47). Cardiovascular: 1.44 (1.34–1.55). Respiratory: 1.70 (1.39–2.08)
Stafoggia [37]	Population 65+ in four Italian cities 1997–2004	Daily apparent temperature	Daily non-injury mortality	OR of dying on a day with an apparent temperature of 30 °C (lag 0–1) compared with a 20 °C day, 1.32 (1.25–1.39). Patients hospitalised for heart failure, stroke and chronic pulmonary diseases had higher mortality than others
Mortality studies where the elderly was analysed as a sub population				
Almeida [21]	Portugal, Lisbon and Oporto	Mean apparent temperature	Daily all-cause, cardiovascular and respiratory mortality	Increases in the 65+ population were: Lisbon: AC: 2.7% (1.6–2.5), CVD: 2.8% (2.1–3.6) Resp: 2.3% (0.5–4.1 Oporto: AC: 1.8% (1.2–2.3), CVD: 2.2% (1.3–3.0) Resp.: 3.0% (1.4–4.7)
Huang [34]	Shanghai, China 15th June to 15th September 2003	Heat wave days vs. non heat wave days	Daily total mortality	65+ most vulnerable to the heat wave, RR = 1.13 (1.06–1.21)
Gomez-Acebo [26]	Cantabria, Spain 1st January 2003 to 31st December 2006	Daily maximum and minimum temperature	Daily mortality	Increase risk for increase in both max and min temperature for the population 65–89. No increase in risk for the 90+ regarding max temperature
Rocklöv [28]	Stockholm County, Sweden 1990–2002	Daily minimum apparent temperature	Daily all-cause (excluding external) mortality	The RR corresponding to a 1 °C increase in summertime minimum apparent temperature was significant in the 80+ age group 1.011 (1.005–1.017)
Yu [32]	Brisbane, Australia 1st January 1996 to 17th December 2004	Daily mean temperature Threshold of 24 °C	Daily all-cause mortality	Increase among the age group of over 85 was statistically significant with 13.81% (4.62%, 21.74%)
Anderson [16]	107 US communities 1987–2000	Daily mean, min, max and apparent temperature	Daily mortality	% increase in mortality risk for heat wave days vs. non heat wave days: 65–74: 5.0% (2.0–8.4)and 75+: 8.2% (5.3–11.3)
Muggeo [19]	Palermo, Italy: 1997–2001 Santiago, Chile: 1989–1991	Daily mean temperature	Daily all-cause mortality	Increase among all-cause mortality (cumulative effect) among the 65+ in Palermo 17.6% and in Santiago 5.48%

Table 2 (*Continued*)

Reference	Region and population	Exposure and threshold	Outcome variable	% change in outcome variable per 1 °C increase in temperature above threshold
Mortality studies where the elderly was analysed as a sub population				
Baccini [23]	15 cities 1990–2000 Mediterranean and North-Continental pooled estimates	Apparent temperature different thresholds	All-cause (natural), cardiovascular and respiratory mortality	Mediterranean: 65–74: AC: 2.13%, CVD: 1.92%, Resp.: 3.37% 75+: AC: 4.22%, CVD: 4.66%, Resp.: 8.10% North-Continental: 65–74: AC: 1.65%, CVD: 1.50% Resp: 3.9% 75+: AC: 2.07%, CVD: 2.55% Resp.: 6.62%
Basu [17]	9 counties in California 1st May 1999–30th September 2003	Mean daily apparent temperature	Daily mortality data	% change per 10 °F increase in mean daily apparent temperature for the 65+: 2.3% (1.0–3.6)
Bell [18]	Santiago, Chile, Sao Paulo, Brazil and Mexico City, Mexico 1998–2002	Daily mean apparent temperature	All-cause, cardiovascular and respiratory mortality	% increase in mortality risk at the 95th percentile of mean app. temperature vs. the 75th for the 65+ population: Santiago:2.69% (−2.06 to 7.88), Sao Paolo:6.51% (3.57–9.52) and Mexico City:3.22% (0.93–5.57)
Bi [33]	Monthly deaths 1986–1995, Brisbane	Monthly mean maximum temperature	All-cause, cardiovascular and respiratory mortality	1 °C increase in monthly mean maximum summer temperatures yields ≈7% more total deaths among people 65 +
Hashizume [35]	Matlab, Bangladesh January 1994–December 2002	Daily mean temperature heat threshold 31 °C for the elderly	Daily mortality	Per 1 °C increase in daily mean temperature above heat threshold mortality increased by 108.1% (32.3%, 227.1%) among the 65+
Ishigami [22]	Budapest: 1993–2001 London: 1993–2003 Milan: 1999–2004	Daily mean temperature thresholds: Budapest >24 °C London >20 °C Milan >26 °C	All-cause, cardiovascular and respiratory mortality	Population (75+) increased mortality (by city and cause) Budapest: AC: 1.06% CVD: 1.08% Resp.: 1.08% London: AC: 1.06% CVD: 1.06% Resp.: 1.08% Milan: AC: 1.17% CVD: 1.20% Resp.: 1.22%
Revich [29]	Moscow, Russia 1st January 2000–27th February 2006	Maximum and average daily temperatures MMT: 18 °C	All-cause, cardiovascular and respiratory mortality	Increase in risk (at lag 1) for the population 75+: A–C: 3.3%(2.1, 4.5), CVD: 5.3% (3.7, 6.9), Resp. N/A
Vaneckova [31]	Sydney, Australia October–March 1993–2001	Daily max and min temperature	All-cause, cardiovascular and respiratory mortality	% change in mortality per 10 °C change in the maximum temperature for the population 65+: AC:6.1% (4.1–8.1) CVD: 4.6% (1.6–7.6) Resp.: N/A

In a Swedish population study, an increase in temperature was significant for the 80 and above age group for non-cardiovascular causes only. However, deaths also increased additionally with the duration of heat waves for those aged between 65 and74 years and for cardiovascular causes [28]. Temperatures above a heat threshold were associated with an increase in all-cause and cardiovascular mortality in the 75 and above population in Russia [29].

In Sydney, Australia, a significant increase in mortality on extremely hot days for populations aged above 65 years was observed [30]. Another study of those aged above 65in Sydney found increasing all-cause mortality with increasing maximum temperatures [31]. In Brisbane increased mortality with heat was found for the elderly population, particularly for those aged 75 and older [32]. Another Brisbane study showed the number of total deaths increased with increasing monthly mean maximum summer temperature for the population aged above 65 [33]. Increased mortality, for elderly suffering from mental and behavioural disorders during a heat wave, was also detected in Adelaide [15].

In Shanghai, China, for the above 65 population, the number of deaths among both males and females increased as the average temperature increased above a threshold [34]. Mortality in the elderly in Bangladesh reportedly increased by a staggering 108% as the temperature increased above a heat threshold [35].

3.2.2. Medication and state of health

Increased mortality during heat waves for nursing home patients in Germany was associated with an increase in the daily ambient maximum temperature above a threshold of 26 °C [36]. In Italy, elderly hospitalised patients were at increased risk of dying on days with a mean temperature of 30 °C compared to a mean of 20 °C [37]. A study of the 2003 heat wave in France found an increased risk of death compared to baseline, for those aged above 70 prescribed anti-depressants or anti-psychotic drugs. The effect of anxiolytic drugs was reduced during heat waves compared to baseline [38].

3.2.3. Lag effects

Increases in mortality occurred within a short time frame after the onset of elevated temperatures. Mortality increased the same day or the day after an extreme hot day [10,17,18]. This short lag time was confirmed in other studies [20–23,27]. However, several studies also reported increased mortality with the duration of the heat episode [16,24,28].

3.2.4. Confounders

No confounding effect of air pollution was found in [17,21,27,28] whereas slight changes of estimated risk after adjustment for air pollutants were reported in two studies [10,16].

3.2.5. Gender effect

Females aged 75–84 in Mediterranean cities were significantly worse off during a heat wave than the males [24]. In Australia, females aged75 and over had significantly higher risks when compared to males [31]. In Shanghai, elderly females were more susceptible to heat than elderly males [34]. However no gender differences were observed for mortality and morbidity in the elderly in the United States or Italy [17,37].

3.2.6. Socio-economy

There was no evidence of socio-economic factors modifying morality risk for elderly populations studied in the United States, Europe or Australia [17,22,32]. However, among those aged 55 and above, living in Paris, the excess mortality rate was twice as high during heat waves for the most deprived Cantons versus the least deprived Cantons [39].

4. Discussion

We found that recent studies report a strong relationship between heat and heat waves and increasing death rates among the elderly, particularly for respiratory and cardiovascular mortality. The relationship appeared consistent globally. Few recent studies reported susceptibility factors, although, women appear to have a higher relative risk. The gender effect is somewhat inconsistent, which may, possibly indicate that the social context (such as living alone) is more important than gender in itself.

Although the relationship between hospitalizations heat and heat waves was scattered and weak, increases in respiratory deaths with heat or heat waves were reported in most studies. However, many studies did not consider the effect of heat waves on other potential cause-specific or heat exacerbated illness groups. The decomposition of health effects from heat waves into accidental and non-accidental causes has been questioned before [40]. Interestingly indices show renal, mental and behavioural hospitalizations increase with heat waves [41] and this could be explored in future studies.

Future studies could evaluate any potential differences relating to study design as recent studies have shown that heat wave effects are not adequately captured in temperature-related mortality models [9,29,42]. This may explain some inconsistencies in the results (e.g. heat wave duration contrasted to the effect of temperature in both age and cause specific groups) [29]. An increase in mortality as heat waves progressed was found in Spain [43]. Similar patterns were indicated by hospital admissions. Initially heat waves had a minor effect on hospital admissions however, after three to four days duration, hospital admissions rapidly increased [44].

Recent studies also confirm that more intensive (higher temperature) heat waves are more severe, and as are heat waves in the beginning of the season [25,29,42]. However it was indicated that the time of the year may be less important for effects related to heat waves compared to heat effect. For morbidity, there were no differences in hospital admissions for time of year the heat wave occurred [44].

Although substantial evidence focussed on heat wave related mortality among the elderly, less literature focussed on heat related morbidity. This may be due to publication bias as negative results from morbidity studies may be harder to publish, or perhaps due to methodological issues in defining excess morbidity associated with heat waves. However, the lack of observed increase in morbidity may be that the rapid progression from exacerbation to mortality in elderly heat affected individuals for some diseases obscures the morbidity outcome [45]. In Madrid, Spain, the patterns of hospitalisations were compared with the patterns of mortality. Although the emergency hospital admissions increased for both all-cause and respiratory causes during a heat wave, the effect of the heat wave was far more pronounced for all-cause and respiratory mortality. For circulatory diseases, no increase in hospitalisations was found, despite increased mortality, again likely reflecting the rapid progression of circulatory diseases to death [46]. Also no overall increase in hospital admissions due to cardiovascular diseases in the elderly was found in European study [10].

4.1. Harvesting

Mortality displacement in the elderly was noted in a small number of studies, also referred to as "harvesting" [47,48]. It can be observed as a reduction of mortality below normal levels following a heat wave. The elderly and those with chronic diseases are more vulnerable population groups and show the largest short-term mortality displacement. However, most studies did not report this harvesting effect, indicating this occurs infrequently or that it was overlooked.

One study observed excess mortality was only apparent for a few days after the onset of a heat wave. This suggest that vulnerable elderly individuals who survive the first few days of a heat wave are either better able to adapt to the heat (either through acclimatisation or behaviour adaptations), are inherently less susceptible to heat waves [23], or that the effect of the heat wave prolongation was outweighed by harvesting.

4.2. Death rates previous winter

The death rates in the previous winter modified the effect of heat waves during the following summer (i.e. if the winter was particularly cold, mortality in vulnerable elderly was high, conversely if the winter was mild, more vulnerable elderly survived). There is some evidence that the first heat wave of the season is the deadliest, particularly following a mild winter, due to a larger fragile population [48]. In Europe a higher rate of heat related mortality was observed if the previous winter mortality rate was lower [23,49]. This is consistent with research showing that larger numbers of cardiovascular patients within a population increase the relative risk of mortality associated with elevated temperature [50].

4.3. Awareness

Interestingly when interviewed, the majority of elderly responded that they did not feel the effects of a heat wave and perceived they had taken appropriate actions to reduce any effect of heat. Many interviewed elderly had existing medical conditions that might increase the effect of heat, yet most perceived that they themselves were neither elderly or at risk. However they recognized increased risk in other vulnerable elderly [8]. This suggests pre-existing beliefs need to be explicitly addressed, and that information alone is insufficient to bridge the gap between knowledge and individual heat adaptation behaviour or action to counter heat risk.

Further, we found a lack of epidemiological studies on the effects of urban heat islands and housing density. Increased urbanisation has been associated with increasing heat vulnerability for the elderly as dense cities and cities with larger populations, appear to increase heat related risks [16], as does living on the top floor of a building [6].

5. Conclusion

The elderly appear to be at higher risk than younger populations during hot days and heat waves. However, there is a need to further investigate, quantify and explain the excess deaths related to elevated temperature in an increasingly elderly population. Future research should focus on identifying predictive factors of heat related illnesses and to more extensively describe non-fatal effects of heat, which are currently under-represented in the literature. Studies examining modifications to urban environments and housing, and their effect on mortality and morbidity in elderly populations are also needed.

Contributors

Daniel Oudin Åström performed the literature search and was responsible for writing the manuscript. Bertil Forsberg and Joacim Rocklöv contributed to the study selection procedure and helped write the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare they have no conflicts of interest.

Provenance and peer review

Commissioned and externally peer reviewed.

Acknowledgements

Daniel Oudin Åström received financial support from the Swedish Council for Working Life and Social Research (2009-0454).

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