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The effect of high indoor temperatures on self-perceived health of elderly persons

J.A.F. van Loenhout [a,b,*], A. le Grand [c], F. Duijm [c], F. Greven [c], N.M. Vink [c], G. Hoek [d], M. Zuurbier [a]

[a] Public Health Services Gelderland-Midden, Arnhem, The Netherlands
[b] Centre for Research on the Epidemiology of Disasters (CRED), Université Catholique de Louvain, Brussels, Belgium
[c] Municipal Health Services Groningen, Groningen, The Netherlands
[d] Division of Environmental Epidemiology, Institute for Risk Assessment Sciences, Utrecht University, Utrecht, The Netherlands

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ABSTRACT

Introduction: Exposure to high ambient temperatures leads to an increase in mortality and morbidity, especially in the elderly. This relationship is usually assessed with outdoor temperature, even though the elderly spend most of their time indoors. Our study investigated the relationship between indoor temperature and heat-related health problems of elderly individuals.
Material and methods: The study was conducted in the Netherlands between April and August 2012. Temperature and relative humidity were measured continuously in the living rooms and bedrooms of 113 elderly individuals. Respondents were asked to fill out an hourly diary during three weeks with high temperature and one cold reference week, and a questionnaire at the end of these weeks, on health problems that they experienced due to heat.
Results: During the warmest week of the study period (14–20 August), average living room and bedroom temperatures were approximately 5 °C higher than during the reference week. More than half of the respondents perceived their indoor climate as too warm during this week. The most reported symptoms were thirst (42.7%), sleep disturbance (40.6%) and excessive sweating (39.6%). There was a significant relationship between both indoor and outdoor temperatures with the number of hours that heat-related health problems were reported per day. For an increase of 1 °C of indoor temperature, annoyance due to heat and sleep disturbance increased with 33% and 24% respectively. Outdoor temperature was associated with smaller increases: 13% and 11% for annoyance due to heat and sleep disturbance, respectively. The relationship between outdoor temperature and heat-related health problems disappeared when indoor and outdoor temperatures were included in one model.
Conclusions: The relationship with heat-related health problems in the elderly is stronger with indoor (living room and bedroom) temperature than with outdoor temperature. This should be taken into account when looking for measures to reduce heat exposure in this vulnerable group.

1. Introduction

Exposure to high ambient temperatures leads to an increase in mortality, as was seen by the heat wave that affected Europe in 2003 and caused more than 15,000 excess deaths in France alone (CRED, 2015; Fouillet et al., 2006). Less than one-third of this figure could be attributed to mortality displacement (harvesting) (Toulemon and Barbieri, 2008). A study that reviewed the relationship between outdoor temperature and mortality in 15 European cities found that for a 1 °C increase in temperature above a city-specific threshold, there is a significant increase in mortality of almost 2% in the north-continental region of Europe, especially among the elderly (Baccini et al., 2008). Other studies have also shown that the elderly (≥65 years of age) are more at risk for detrimental effects of heat and heat waves, including an increase in mortality (D'Ippoliti et al., 2010; Garssen et al., 2005; Hajat et al., 2007; Hajat and Kosatky, 2010) and an increase in the number of hospital admissions (Gronlund et al., 2014; Li et al., 2015),

* Corresponding author at: Centre for Research on the Epidemiology of Disasters, Université Catholique de Louvain, School of Public Health, Clos Chapelle-aux-Champs 30, 1200 Woluwé-Saint-Lambert, Brussels, Belgium.
E-mail addresses: joris.vanloenhout@uclouvain.be (J.A.F. van Loenhout), amanda.legrand@ggd.groningen.nl (A. le Grand), frans.duijm@ggd.groningen.nl (F. Duijm), frans.greven@ggd.groningen.nl (F. Greven), nienke.vink@ggd.groningen.nl (N.M. Vink), g.hoek@uu.nl (G. Hoek), moniek.zuurbier@vggm.nl (M. Zuurbier).

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specifically for respiratory admissions (Kovats et al., 2004; Mastrangelo et al., 2007; Michelozzi et al., 2009) and admissions for heart diseases (Schwartz et al., 2004). Other adverse health conditions that occur more frequently during a hot period are dehydration, hyperthermia, malaise, hyponatremia, renal colic and renal failure (Josseran et al., 2009). The elderly are more sensitive for heat-related mortality and morbidity since they have a lower threshold for the development of renal failure, and they are often unable to obtain sufficient volumes of water for themselves due to infirmity or impaired thirst, all of which may be exacerbated by both concomitant cardiorenal disease and various commonly used medications (Flynn et al., 2005). Studies on self-reported symptoms due to heat are scarce: a Finnish study showed that the most prevalent heat-related symptoms in a population aged 25–74 were thirst (68%), a dry mouth (43%), impaired endurance (43%) and sleep disturbance (32%) (Nayha et al., 2014). In a Dutch study, the most reported heat-related symptoms among the elderly were sleep disturbance (62%), fatigue (61%) and breathing discomfort (29%) (van Daalen and van Riet, 2010). Since mortality and hospitalisation present only the tip of the iceberg with respect to the impact of heat, it is important to gain insight on self-reported symptoms by these types of studies.

The Netherlands experiences a moderate maritime climate, with mild winters and cool summers. Heat waves are relatively uncommon: it is defined by the Royal Netherlands Meteorological Institute (KNMI) as a period of five consecutive days with maximum temperatures of 25.0 °C or higher, including at least three day with temperatures of 30.0 °C or higher. Only eight heat waves have been registered by the KNMI in the 21st century so far (KNMI, 2015). However, a study has shown that mortality in the Netherlands already increases when daily average temperatures exceed the optimum of 16.5 °C (Huynen et al., 2001). An increase in mortality due to heat was also shown in a study by Gasparrini et al. (2015). In addition, there is a trend that extreme climate events, including heat waves, will increase in duration and frequency in Western Europe in the coming years due to climate change, as postulated by the Intergovernmental Panel on Climate Change (IPCC) (Parry et al., 2007). These effects are stronger in cities compared to rural areas due to the urban heat island effect, which can lead to heat accumulation and temperature differences up to 12 °C in the evening (USEPA, 2013). Within cities, temperature differences between areas are caused by to differences in building density and levels of vegetation. Areas that are the most sensitive to heat accumulation are called micro urban heat islands (Smargiassi et al., 2009).

Studies on the relationship between temperature and mortality or morbidity of the elderly are usually based on outdoor temperature, even though elderly persons spend approximately 90% of their time indoors (EPA, 2009). We identified only few studies that measured indoor temperature in dwellings of the elderly, and these studies did not describe the impact on health (Nguyen et al., 2014; White-Newsome et al., 2012). The aim of our study was to investigate the relationship between indoor and outdoor temperature and heat-related health problems of elderly individuals during the summer months in the Netherlands.

2. Material and methods

The design used was a prospective observational study, carried out from April until August 2012 among a group of elderly individuals.

2.1. Study population

The study was carried out in Arnhem and Groningen, two medium-sized cities in the Netherlands (population 150,000–200,000). Within both cities, four areas were identified with a high level of building density and a low level of vegetation. This identification was based on climate maps that were available for both cities (ERDF, 2009; Klok, 2012). Home addresses of elderly individuals ($\geq$65 years of age) within these areas were obtained through the registers of the municipalities of Arnhem and Groningen, and 500 and 572 individuals were invited randomly to participate in both cities, respectively. The response was 70 (14%) for Arnhem and 100 (17%) for Groningen. Out of the responders, we randomly selected 56 persons in Arnhem and 57 in Groningen to participate, suited to the availability of measuring equipment. All participants provided written informed consent.

2.2. Temperature and relative humidity measurements

Each study participant received a home visit in April 2012. Measuring equipment was placed in the living room and bedroom that were most often used by the occupants. Indoor air temperature and relative humidity were measured and logged using iButton Hygrochron temperature/humidity loggers, (type DS1923; Maxim Integrated, San Jose, CA, USA). All iButtons were placed on a small standard, at living height (for the living room) or sleeping height (for the bedroom), away from any heat and ventilation sources to decrease the risk of other factors influencing temperature readings. iButtons do not have a display, so participants could not observe real-time temperatures based on our equipment. Outdoor air temperature and relative humidity were measured using the same devices within radiation shields (Davis Instruments Corp., Hayward, CA, USA). The radiation shields were attached to traffic signs or balconies close to each dwelling, at a height of at least 2.5 m (to minimise the risk of vandalism). Since some dwellings were at a close distance from each other, the number of outdoor temperature measurements was smaller than the number of dwellings. Temperature and relative humidity were measured every 30 min, with an accuracy of 0.5 °C and 0.4%, respectively.

Before the start of the study, the temperatures of all iButtons were simultaneously tested for deviations from the average. The maximum deviation of any iButton was 0.6 °C. Half-term readouts of the equipment were performed in July 2012, and non-functioning equipment was replaced. All equipment was collected and the final readouts were performed in September 2012.

2.3. Heat Index

Apart from temperature, relative humidity can also have an influence on heat perception. Combining values for temperature and relative humidity according to a set algorithm leads to the Heat Index. Various algorithms are available, although the results are relatively similar (Anderson et al., 2013). In this study, we used the algorithm also used by Blazejczyk et al. (2012), to assess whether the Heat Index is a more exact measure to explain heat-related health problems than temperature. This algorithm is:

$$HI = -8.784695 + (1.61139411{*}T) + (2.338549{*}H) - (0.14611605{*}T{*}H) - (0.012308094{*}T^2) - (0.016424828{*}H^2) + (0.002211732{*}T^2{*}H) + (0.00072546{*}T{*}H^2) - (0.000003582{*}T^2{*}H^2).$$

Where HI = Heat Index in °C, T = air temperature in °C, and H = relative humidity in percent. HI = T when $T \leq 20$ °C.

2.4. Questionnaires and hourly diary

All participants filled out a baseline questionnaire in April, which included questions on participants' health status and sensitivity to heat (Supplementary material 1). We used a checklist to collect characteristics of the dwelling, living room and bedroom.