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ORIGINAL PAPER

# Risk factors for deaths during the 2009 heat wave in Adelaide, Australia: a matched case-control study

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**Abstract** The extreme heat wave in Australia in 2009 resulted in significantly increased number of daily deaths. The circumstances that lead to deaths during extreme heat have not been explored before in Australia. This study aims to identify the individual and community risk factors for deaths during this extreme heat wave in Adelaide. A matched case-control study was conducted. Cases were those who died in the Adelaide metropolitan area during the heat wave period. For each case, two community controls were randomly selected, matched by age and gender. Face-to-face or telephone interviews were conducted to collect data of demographic information, living environment, social support, health status and behavioural changes during the heat wave. Descriptive analysis, as well as simple and multiple conditional logistic regressions were performed. In total, 82 deaths and 164 matched community controls were included in the analysis, with a median age of 77.5 (range 26.6–100.7). The multiple logistic regression model indicated that, compared with controls, the risk of death during the heat wave was significantly increased for people living alone (AOR = 42.31, 95 % CI 2.3, 792.8) or having existing chronic heart disease (AOR = 22.4, 95 % CI 1.7, 303.0). In addition, having air conditioning in bedrooms (AOR = 0.004, 95 % CI 0.00006, 0.28) and participating in social activities more than once a week (AOR = 0.011, 95 % CI 0.0004, 0.29) indicated significant protective effects. We have identified factors that could significantly impact on the likelihood of deaths during heat waves. Our findings could assist in the development of future intervention programs and policies to reduce mortality associated with a warmer climate.

**Keywords** Heat wave · Risk factors · Mortality · Comorbidity · Case-control

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## Introduction

An increasing number of extreme heat events have been observed globally over the last decades and it is very likely that extreme heat events will occur more often and last longer in the future (IPCC 2013). Australia experienced very hot summers in recent years culminating in the 2009 heat wave, which led to record-breaking prolonged high temperatures (Australian Bureau of Meteorology 2014).

The increased death toll during heat waves has attracted worldwide attention and is described in a number of studies. For example, more than 70,000 excess deaths were attributed to the 2003 heat wave in Europe (Vandentorren et al. 2006). The 2009 Australia heat wave was related to a 62 % increase in mortality in Victoria and a 9.5 % increase in mortality in Adelaide (Nitschke et al. 2011). Our health impact studies in Adelaide show that heat waves can affect various vulnerable populations such as the elderly, culturally and linguistically diverse (CALD) communities, remote communities and outdoor workers (Hansen et al. 2014; Hanson-Easey et al. 2013; Williams et al. 2013; Xiang et al. 2014).

It is acknowledged that many of the excess heat wave-related deaths are preventable with appropriate public health interventions targeting vulnerable populations (Hajat et al. 2010). However, the risk factors for the vulnerability to heat waves at both the individual (e.g. health status and living conditions) and community levels (e.g. social support and health services) have so far not been investigated in depth in Adelaide. The majority of previous studies on heat and deaths have focused on health impact assessment at a population level with aggregated data, using ecological or case-only study designs, with only a few investigating associated risk factors (Knowlton et al. 2009). Little work has been done on case-control studies identifying risk factors for heat wave-related health outcomes. Most of these studies were conducted in Europe and the USA (Foroni et al. 2007; Semenza et al. 1996; Vandentorren et al. 2006).

No appropriately designed epidemiological case-control study has been conducted in Australia to investigate risk factors for heat wave-related deaths. The 2009 heat wave in Adelaide provided an excellent opportunity to implement such a study aiming to examine risk factors for deaths during this exceptional heat wave. Our results provide robust evidence in an Australian context to support further policy and intervention programs, including refining current early heat and health warning systems and providing better individual health services that aim to reduce health impacts during heat waves in Australia and globally.

## Methods

### Exposure and health outcomes

A case-control study was conducted in Adelaide in 2012–2013. Adelaide, capital of South Australia, with a total population of 1.2 million in 2012, has a semi-arid climate with hot daytime temperatures and cool nights in summer. In 2009, Adelaide experienced a severe heat wave from 26 January to 7 February, a 13-day episode, where five consecutive days recorded maximum temperatures over 40 °C. The maximum temperature soared to 45.7 °C on 28 January and was followed by an unusually high minimum temperature of 34 °C the following night. Health impacts of the 2009 Adelaide heat wave included a 9.5 % increase in mortality (Nitschke et al. 2011). Furthermore, our previous report found that mortality and health-specific hospital and emergency admissions peaked during the five hottest days, i.e. 28 January to 1 February (Nitschke and Tucker 2010). The maximum temperatures of these 5 days were 45.7, 43.4, 43.1, 41.1 and 40.6 °C, consecutively. This 5-day period was defined as the heat wave exposure period of our study. Our definition for the heat wave matched with the Australian Bureau of Meteorology method to assess when extreme heat warnings should take place, which does not include humidity (CAWCR 2013). In addition, the definition of exposure was consisted with our previous studies in Adelaide with a typical Mediterranean climate, where humidity was not a problem during heat events.

Deaths from all causes over the study period were included in the analysis. The reasons for selecting all deaths rather than heat-related deaths include (1) the under-diagnosis of ‘heat-related’ deaths is very common. For example, renal disease will not be coded as heat-related in the coding system but renal disease is related to heat waves based on one of our previous studies in Adelaide (Hansen et al. 2008a); and (2) some deaths are potentially related to heat wave so should not be excluded from this study. For example, suicide and car accidents could not be excluded because evidence shows an association of heat wave and increased mental health problems or violence in Australian cities (Hansen et al. 2008b; Loughnan et al. 2010).

### Subjects (cases and controls)

Cases were those who died in Adelaide over the 5-day exposure period. The reference population was those who survived the heat wave period. Controls were sampled from the South Australian State Electoral Roll (SASER) and were matched 1:2 to cases by age (±2 years) and gender. SASER has contact details of all persons for state election purpose. Currently, enrolment is compulsory for the Australian who are 18 years and over and who have lived at their current address for at least 1 month (Electoral Commission SA). The purpose of use of the SASER was to randomly select controls from the same region. More than 98 % of the controls were Australian citizens leading to minimum bias in the selection. It was believed that this population, who were local residents in Adelaide, had the same exposure of the heat wave compared with the cases and a similar risk of having the investigated outcome. We used randomly generated numbers for selection of controls to ensure the controls were representative. The SASER provided an electronic source of people who resided in metropolitan Adelaide (postcodes 5000–5199). Those who were not living in the Adelaide metropolitan area during the 2009 heat wave exposure period, and those who died in private hospitals, were excluded from the analysis due to the inability of contacting next-of-kin to collect information.

### Recruitment

Contact information of next-of-kin was retrieved from public hospitals and the SA Coroner’s Office after appropriate approvals. To recruit people as controls, random numbers were generated using the Stata program. If a potential control declined to participate or was unable to be contacted, a replacement control was randomly selected, until enough controls agreed to participate.

Cases' next-of-kin and controls were initially contacted by the Department for Health and Ageing (DHA) by a letter containing project information. A follow-up letter was sent if no response was received within 2 weeks. If there was still no response after a further week, then potential participants were contacted by telephone. All personal information was removed before data were passed on for analysis.

### Ethical approvals

This project was approved by the Human Research Ethics Committees (HREC) from both the University of Adelaide (H-101-2010) and the South Australian DHA (376/06/2013). Due to the ethical sensitivity of the study, work was carried out within the DHA in SA as required by the ethical approvals. In order to collect deceased patients' data from the hospitals' medical records, ethical approvals were also obtained from each Ethics Committee of relevant hospitals. Consent from subjects participating in the study was received prior to conducting the study.

### Data collection

**Questionnaire** Risk factors were investigated using a specifically designed and developed questionnaire (Appendix A), which was based on a literature review and informed by other studies undertaken by our team (Hansen et al. 2014; Nitschke et al. 2013). The questions were related to factors such as environmental conditions, health status, individual behaviour and demographic information. Physical impairment was measured using the Activities of Daily Living (ADL) scale. Socioeconomic status of participants was indicated by the Socioeconomic Indexes for Areas (SEIFA), a proxy developed by the Australian Bureau of Statistics (ABS). Based on information from the 5-yearly Census, SEIFA ranks areas in Australia according to relative socioeconomic advantage and disadvantage. Postcode-based 2011 SEIFA ranking was used with a higher ranking indicating better socioeconomic status. Consistent face-to-face or telephone interviews of controls and cases were conducted by an experienced interviewer, who was trained specifically for this purpose including skills asking sensitive emotional questions related to deceased cases and responses to potential emotional reactions from participants.

**Environmental data** Mean daily temperature and mean relative humidity between January and February 2009 were obtained from the Australian Bureau of Meteorology (Kent Town location), which is representative of Adelaide metropolitan conditions.

**Hospital records** Mortality data were obtained from the South Australian DHA, including the Integrated South Australian Activity Collection (ISAAC) and the Emergency Department Data Collection (EDDC). Case-note data were also retrieved from relevant hospitals by reviewing patients' medication history, including comorbid conditions and other relevant factors. Australia has a high standard in collecting patients' medical records. Data retrieved from the included hospitals all had an electronic system for data storage with coded variables. During the interview, we cautiously confirmed the veracity of the information, including medication history and comorbidities. Therefore, we believe that the quality of these data is highly reliable.

**Coroner's office records** Information was collected from the South Australian Coroner's Office for cases who died outside of hospitals.

### Statistical power

The power calculation was based on McNemar's Test, the method of Dupont for matched case control studies (Dupont 1988). Assuming that 30 % of the control subjects were exposed to any risk factor, and defining the significance level at 0.05, our sample size could provide a statistical power of more than 80 % to detect a minimum odds ratio of 2.0. The assumptions were made based on our previous studies examining heat-health associations in Adelaide by the same team (Nitschke and Tucker 2010; Nitschke et al. 2011, 2013, Hansen et al. 2014; Xiang et al. 2014; Zhang et al. 2013).

### Statistical analyses

First, a descriptive analysis was performed. Characteristics of the cases and controls and their distribution of potential risk factors were appraised using univariate analyses. The *t* test or $\chi 2$ test was applied to examine the association of any potential risk factor and deaths. The variables significantly associated with the outcomes ($p < 0.2$) were entered into the multivariate logistic regression model. Crude odds ratios (ORs) and adjusted ORs (AORs) were estimated from the regression analyses.

## Results

### Description of the characteristics of participants

In total, there were 237 deaths over the 5 days in Adelaide, of which 172 died outside of hospitals (73 %), 49 (21 %) in public hospitals and 16 (7 %) in private hospitals. Those who died in private hospitals were excluded because the contact details of their next-of-kin were not available. One patient was under 18 years old and following ethical requirements was excluded. The response rate from both next-of-kins of the cases and community controls were approximately 40 %. The main reasons for declining to participate included moved interstate, too ill and not interested for various reasons. Ultimately, we had 82 cases (including 26 hospital cases and 56 coroner cases, accounting for 37 % of the total deaths) and 164 matched community controls interviewed, with a median age of 77.5 (range 26.6–100.7), 72 % retired and 10 % in institutional living. Similarities and differences in the characteristics of the cases and controls and potential risk factors are listed in Table 1, which indicates that cases and controls were similar in many demographic characteristics, including socio-economic status, education, occupation and income, but significantly different in many of the potential risk factors (Table 1).

### Simple regression analysis

The results of the simple regression analysis with a $p$ value less than 0.2 are shown in Table 2. It shows that most factors included in the study describing demographic characteristics, living conditions, health status, available support and behavioural changes have the potential to have contributed to the deaths during the 2009 heat wave, in the absence of controlling for any other factors.

### Multivariate conditional logistic regression analysis

In Table 2, the AORs of these significant risk factors derived in the simple regression analysis are presented for comparison. It shows that after controlling for other potential confounders, only four factors were significant in the multiple regression analysis, including living alone (AOR = 42.31, 95 % CI 2.3, 792.8) and having heart disease (AOR = 22.4, 95 % CI 1.7, 303.0). In addition, having air conditioning in bedrooms (AOR = 0.004, 95 % CI 0.00006, 0.28) and participating in social activities more than once a week (AOR = 0.011, 95 % CI 0.0004, 0.29) indicated significant protective effects.

## Discussion

This is the first case-control study to comprehensively investigate a wide range of potential contributing factors of deaths during a heat wave in Australia. We have identified factors that could significantly increase or reduce the risk of deaths during heat waves in an Australian setting.

Our findings confirm the increased risk of dying during a heat wave among those who had pre-existing heart conditions, which is consistent with the previous study on risk factors of the deaths at home among the elderly in the 2003 heat wave in France (Vandentorren et al. 2006). Adaptation to extreme heat requires extra work from the cardiovascular system to pump extra fluid to the body surface for evaporative cooling in order to maintain a healthy core body temperature. In addition, specific medicines taken for heart conditions may hamper this mechanism of adjusting the core body temperature. Therefore, the extra burden that extreme heat puts on an unhealthy cardiovascular system could lead to lethal outcomes during such extreme heat events. Mobility restriction due to heart disease may be another cause of increased risk. Our study also shows a borderline significance of ADL = 1 (i.e. need assistance for daily activities) in the multiple regression model. However, in the investigation of risk factors of heat-related mortality after the 1995 Chicago heat wave, people with heart disease were not identified as a higher-risk group for deaths (Semenza et al. 1996). The salient increase in the risk of deaths for patients with heart disease in our study (more than 20 times higher compared with those who did not have heart diseases) may be due to different data sources, age of the study population, definitions of exposure to heat and the choice of study designs.

Other pre-existing conditions, including mental illness, did not show up significantly in the multivariate model. However, the simple regression analysis did suggest that dementia, depression and renal disease may have significantly contributed to the risk of deaths during the heat wave. There are some studies that show an impact of temperature or heat waves on mental illness in general and on psychological conditions, such as depression and dementia (Davido et al. 2006; Hansen et al. 2008b; Page et al. 2012a; Williams et al. 2012). One study in England indicated that for every 1 °C increase in temperature (above the 93rd percentile of the annual temperature distribution), the risk of death for patients with mental illness increases by 4.9 % (95 % CI 2.0–7.8) (Page et al. 2012b). Our results may be due to the small sample size or the higher rate of comorbidities among the participants. Moreover, interaction among these comorbidities may contribute to the lack of significance in the multiple regression models due to the complexity of these chronic conditions. However, the high negative odds ratios for dementia, depression and other comorbidities, e.g. renal disease, in the simple regression analysis, together with results from previous studies regarding the negative association between the conditions and exposure to extreme heat, should not preclude the likelihood of increased vulnerability during heat waves among these groups.

**Table 1** Characteristics and the distribution of potential risk factors of cases and controls*

| | Cases (%) | Controls (%) | *P* |
|---|---|---|---|
| Demographic | | | |
| Non-European ethnic | 7 | 1 | <0.05 |
| Married/De facto | 14 | 65 | <0.01 |
| SEIFA ranking ≤3 | 19 | 12 | >0.05 |
| Main language speak at home/English | 94 | 97 | >0.05 |
| Occupation/retired | 70 | 74 | >0.05 |
| Education ≤ year 12 | 71 | 61 | >0.05 |
| Annual household income ≤70,000 | 75 | 69 | >0.05 |
| Living condition | | | |
| Institutional living | 10 | 11 | >0.05 |
| North face building | 56 | 83 | <0.05 |
| Living alone | 68 | 27 | <0.05 |
| Having pet | 30 | 48 | <0.01 |
| Air conditioning in house | 49 | 89 | <0.01 |
| Air conditioning in bedroom | 17 | 54 | <0.01 |
| Easy ventilation | 51 | 80 | <0.01 |
| Support | | | |
| No relative or friend or carer visit | 13 | 8 | >0.05 |
| No home delivery service | 80 | 89 | >0.05 |
| Having private health insurance | 19 | 62 | <0.01 |
| Having emergency button | 13 | 32 | <0.05 |
| Having social activity more than once a week | 40 | 90 | <0.01 |
| Health status | | | |
| Heart diseases | 81 | 20 | <0.01 |
| Asthma | 25 | 11 | <0.05 |
| Respiratory diseases | 33 | 15 | <0.05 |
| High blood pressure | 45 | 43 | >0.05 |
| Kidney diseases | 33 | 5 | <0.05 |
| Diabetes | 35 | 13 | <0.05 |
| Dementia | 37 | 2 | <0.05 |
| Depression | 68 | 13 | <0.01 |
| Confine to bed | 13 | 1 | <0.05 |
| Neurological disease | 6 | 5 | >0.05 |
| Cancer | 27 | 23 | >0.05 |
| Taken more than two medicine | 77 | 70 | >0.05 |
| Need assistance for daily activities ADL = 1 | 89 | 2 | <0.01 |
| Behaviour changes during heat wave | | | |
| Dress lighter than usual | 84 | 95 | >0.05 |
| Stopping usual activities | 59 | 63 | >0.05 |
| Use air conditioning | 27 | 86 | <0.01 |
| Take extra bath | 12 | 13 | >0.05 |
| Open windows | 17 | 17 | >0.05 |
| Use of refreshment | 53 | 83 | <0.05 |

*Variables with $p \geq 0.05$ (no difference between groups) were not included in further regression analysis

The effect of individual living conditions on risk of death during heat waves has so far been insufficiently examined. The benefit of having and/or using air conditioners during heat waves is inconsistent considering a

**Table 2** Crude ORs and adjusted ORs of the risk factors estimated by the conditional logistic regression

| Factors | ORs | SE | *p* | AORs | SE | *p* |
|---|---|---|---|---|---|---|
| Non-European ethnic | 6.00 | 4.90 | *0.028* | 0.02 | 0.06 | 0.276 |
| Married/De facto | 0.08 | 0.03 | *<0.001* | 0.30 | 0.27 | 0.182 |
| North facing building | 3.13 | 1.30 | *0.006* | 2.50 | 2.38 | 0.353 |
| Living alone | 5.81 | 1.92 | *<0.001* | 42.31 | 63.27 | *0.012* |
| Having pets | 0.56 | 0.23 | 0.16 | 0.46 | 0.49 | 0.462 |
| Air conditioning in house | 0.09 | 0.04 | *<0.001* | 0.42 | 0.36 | 0.313 |
| Air conditioning in bedroom | 0.15 | 0.06 | *<0.001* | 0.004 | 0.009 | *0.011* |
| Easy ventilation | 0.21 | 0.08 | *<0.001* | 0.29 | 0.27 | 0.188 |
| Having private health insurance | 0.19 | 0.09 | *<0.001* | 0.12 | 0.14 | 0.076 |
| Having emergency button | 0.27 | 0.14 | *0.010* | 0.09 | 0.13 | 0.083 |
| Having a social activity more than once a week | 0.14 | 0.07 | *<0.001* | 0.011 | 0.019 | *0.007* |
| Heart disease | 26.64 | 15.91 | *<0.001* | 22.420 | 29.785 | *0.019* |
| Asthma | 2.26 | 1.02 | <0.071 | 1.86 | 2.27 | 0.609 |
| Respiratory disease | 5.98 | 2.60 | *<0.001* | 0.75 | 0.94 | 0.821 |
| Kidney disease | 30.52 | 31.50 | *0.001* | 109.89 | 511.73 | 0.313 |
| Diabetes | 2.92 | 1.24 | *0.011* | 1.50 | 1.67 | 0.710 |
| Dementia | 17.27 | 12.89 | *<0.001* | 8.87 | 10.35 | 0.061 |
| Depression | 2.87 | 0.65 | *<0.001* | 5.36 | 5.16 | 0.081 |
| Confined to bed | 10.0 | 7.75 | *0.003* | 2.21 | 3.11 | 0.574 |
| Need of assistance for daily activities (ADL = 1) | 141.5 | 142.5 | *<0.001* | 121.58 | 135.35 | 0.071 |
| Use of air conditioning | 0.04 | 0.24 | *<0.001* | 0.37 | 0.38 | 0.332 |
| Use of refreshment | 0.07 | 0.03 | *<0.001* | 0.11 | 0.14 | 0.091 |

number of studies (Hajat et al. 2010). Having an air conditioner at home in South Australia or France was reported as a protecting factor to adverse health outcomes during heat (Abrahamson et al. 2009; Hansen et al. 2014). Our study showed that having air conditioning in bedrooms could dramatically reduce the risk of death during a heat wave. As climate change will bring more extreme heat events during summer, encouraging people, especially vulnerable older people, to have air conditioning installed in their bedroom or to sleep in an air conditioned part of the house may be beneficial in reducing risk of dying in extreme heat conditions. However, decision-making related to commonly promoted behaviours, such as using air conditioner, "is complex and these resources are often financially not feasible, physically, or culturally" (Sampson et al. 2013)."

There may be some additional risk factors related to living conditions as reported in studies in the USA and Europe, e.g. lack of insulation, north facing building and living on the top floor of a building, although this factor is not an issue in Adelaide because of the low population density with very few apartment buildings (Semenza et al. 1996; Vandentorren et al. 2006). In addition, the socioeconomic context of an individual's living condition is important because residents in many poorer neighbourhoods lack educational opportunities and health care services and have inferior quality housing conditions. This may result in adverse health outcomes during heat waves (Harlan et al. 2013). In our study, socioeconomic deprivation was indicated by a significantly lower percentage of people with private health insurance among the cases in the univariate analysis.

A study in UK also indicated that elderly people in nursing and age-care homes were most vulnerable with a greater risk of heat mortality (Hajat et al. 2007). This factor did not apply in our study in Adelaide. In fact, living alone is another risk factor for heat-related mortality that has been examined in other studies and is particularly relevant for older people. Our study confirms a dramatically increased risk of deaths among those who were living alone during the heat wave. The findings are consistent with the risk investigations in other countries and link well with the reduction in deaths during heat waves because of more social activity participation. Social isolation was also identified as a key risk factor of heat-related deaths during heat waves in earlier studies in the USA (Semenza et al. 1996). The benefit of having more social activities has not been examined in European studies. Our study has revealed great importance of having social activities in preventing and reducing deaths during heat waves. Having social activities may be related to receiving more frequent and timely support through social interaction and therefore being less likely to be isolated and having more opportunities to be looked after before and during extreme heat events. This positive factor, together with the risk factor of living alone, suggests that by regular contact and checking of high-risk groups during heat, or by providing heat-health-related information to the community, and by offering social support interventions during extreme heat, better health outcomes are more likely to be achieved during heat waves, especially for the vulnerable groups.

A clear strength of the study is the matched case-control study design, the first conducted in an Australian setting. We have collected data at the individual level, which allowed for investigation of a range of risk factors and controlling for potential confounders. One of the key limitations was ‘recall bias’ from the next-of-kin, which cannot be avoided in a case-control study. Moreover, potential biases may be generated from data collection, such as self-selection bias from the participants or interviewing bias between cases and controls. Although we have adopted necessary measures to reduce the biases, e.g. using randomization of age and gender matched SASER population in selecting controls and training of the interviewers, these biases might still affect the results in either direction. This is a common challenge for case-control study design which should be acknowledged. The other limitation could be due to the small sample size leading to significant factors shown in the univariate analysis, but which are not significant in the multiple regression model. The limitations of recruiting less than 40 % of the eligible cases were mainly due to our inability to approach next-of-kin (reasons given included too ill, very busy and personal), which should be acknowledged. Due to the lack of studies using individual data to explore risk factors for heat-related deaths in Australia, the assumptions used to calculate the sample size were based on our previously published studies, which might have limitations on investigating the effects of the risk factors.

Findings from our study can assist the improvement of the current ‘extreme heat’ warning systems in South Australia specifically and can influence warnings in other Australian states more generally by providing further evidence about those people at high risk of dying during a heat wave. Following the 2009 heat wave event, the South Australian government now provides comprehensive warnings for the general population and reaches out to potentially vulnerable people by checking on their welfare during extreme heat warning situations. Currently, 12 European countries have heat wave early warning systems for public health prevention purposes. “Better understanding of the particular measures to increase resilience to heatwaves can improve existing and enhance current action plans” (Lowe et al. 2011). Our results are also helpful in contributing to building long-term community resilience to extreme heat events by recognising the importance of social activities and connectedness at a community level, but also to remind next-of-kin, friends and neighbours of their contribution to significantly reducing the chance of deaths during a heat wave. The findings provide a solid base to develop further intervention studies with a focus on vulnerable populations during a heat wave, either at a community or individual level. For example, health education in the community, sending information to people with heart conditions and encouraging the use of air conditioners in bedrooms on days when it is extremely hot.

In conclusion, by analysing individual data, we are able to detect that pre-existing heart disease and living alone could significantly increase the risk of dying during a heat wave and that the presence of an air conditioner in the bedroom and more social activities could reduce the risk. Because deaths during a heat wave are largely avoidable, our findings will benefit policy-making, clinical practice and community resilience capacity building and inform further interventional research in order to reduce mortality in a warming climate.

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**Compliance with ethical standards** This project was approved by the Human Research Ethics Committees (HREC) from both the University of Adelaide (H-101-2010) and the South Australian DHA (376/06/2013). Due to the ethical sensitivity of the study, work was carried out within the DHA in SA as required by the ethical approvals. In order to collect deceased patients’ data from the hospitals’ medical records, ethical approvals were also obtained from each Ethics Committee of relevant hospitals. Consent from subjects participating in the study was received prior to conducting the study.

**Competing interests** The authors declare that they have no competing interests.

**Appendix: The Questionnaire**

# A retrospective study of the 2009 heatwave in Adelaide: Vulnerability to mortality and morbidity

## Questionnaire

**Case** ☐ **Control** ☐ **No.____** **Date:____________**

## 1. Demographic information

1.1. Surname: ______________ Initials:__________

1.2. Suburb:______________ Postcode: _____

1.3. Date of birth: ____________

1.4. Gender: ☐Female ☐ Male

1.5. Ethnical:

☐ European origin

☐ Asian origin

☐ African origin

☐ Middle Eastern origin

☐ Others, ______

1.6. What main language do you speak at home?

☐ English

☐ Non-English, __________

1.7. Marital status:

☐ Married

☐ Never married

☐ Widowed

☐ Divorced

1.8. Occupation:

☐ Manager

☐ Farmer

☐ Clerical or service worker

☐ Labour work

☐ Retired

☐ Others, _____

1.9. Highest level of education obtained:

☐ Postgraduate degree

☐ Undergraduate degree

☐ Year 12

☐ Some secondary education

☐ Primary school
☐ Not finished primary school

1.10. Annual personal income before tax:
☐ >$70,000
☐ 50,000-70,000
☐ 30,000-50,000
☐ 10,000-30,000
☐ <10,000

1.11. Annual household income before tax:
☐ >$70,000
☐ 50,000-70,000
☐ 30,000-50,000
☐ 10,000-30,000
☐ <10,000

## 2. <u>Environmental information</u>

***The following questions refer to summer 2009:***

### 2.1. Living conditions

2.1.1. Institutional living (nursing house or retirement home):
☐ Yes [go to 2.1.8]
☐ No [go to next question]

2.1.2. Type of living:
☐ Independent house – one story
☐ Independent house – two stories
☐ Multiple dwelling unit – top floor
☐ Multiple dwelling unit – non top floor
☐ Others, ________________________

2.1.3. Age of building:
☐ <10 years
☐ 10-30 years
☐ 30-50 years
☐ >50 years

2.1.4. North-face building:
☐ Yes ☐ No

2.1.5. Live alone:
☐ Yes [go to 2.1.8]
☐ No [go to next question]

2.1.6. No. of people living with:

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 or more

2.1.7. Who are you living with:

☐ spouse
☐ children
☐ grandchildren
☐ friend
☐ other ___________

2.1.8. Do you have a pet: ☐ Yes ☐ No

2.1.9. Air-conditioner in house: ☐ Yes ☐ No

2.1.10. Air-conditioner in bedroom: ☐ Yes ☐ No

2.1.11. Structure of house is easy to ventilate: ☐ Yes ☐ No

**2.2. Social support conditions**

2.2.1. Frequency of relatives visit:

☐ Never
☐ Less than once a week
☐ More than once a week

2.2.2. Frequency of neighbours/friends visit:

☐ Never
☐ Less than once a week
☐ More than once a week

2.2.3. Frequency of health carers visits:

☐ Never
☐ Less than once a week
☐ More than once a week

2.2.4. Private health insurance: ☐ Yes ☐ No

2.2.5. If 'emergency button' available: ☐ Yes ☐ No

2.2.6. Home delivery service (e.g. meals on wheels)

☐ Never
☐ Less than once a week
☐ More than once a week

2.2.7. Frequency of social activities:

☐ Never
☐ Less than once a week
☐ More than once a week

2.2.8. Reason of social activities:

☐ Religion ☐ Culture ☐ Leisure ☐ Others____________

2.2.9. Daily access to media, i.e. newspapers and TV:
☐ Yes ☐ No

## 3. Health status

3.1.Did you have the following diseases in summer 2009:

3.1.1. heart diseases ☐ Yes ☐ No ☐ Not sure
3.1.2. asthma ☐ Yes ☐ No ☐ Not sure
3.1.3. respiratory diseases ☐ Yes ☐ No ☐ Not sure
3.1.4. high blood pressure ☐ Yes ☐ No ☐ Not sure
3.1.5. kidney disease ☐ Yes ☐ No ☐ Not sure
3.1.6. diabetes ☐ Yes ☐ No ☐ Not sure
3.1.7. dementia ☐ Yes ☐ No ☐ Not sure
3.1.8. depression ☐ Yes ☐ No ☐ Not sure
3.1.9. liver disease ☐ Yes ☐ No ☐ Not sure
3.1.10. neurological disease ☐ Yes ☐ No ☐ Not sure
3.1.11. cancer
☐ Yes, type __________
☐ No
☐ Not sure
3.1.12. others, please state: _________________

3.2.Medication

3.2.1. Did you take medicines?
☐ Yes [go to next question]
☐ No [go to 3.3]

3.2.2. How many medicines did you take daily in summer 2009?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 or more

3.2.3. What were the medicines for?
_______________________________________
_______________________________________

3.3.Physical impairment

3.3.1. Confined to bed during the 2009 heatwave? ☐ Yes ☐ No

3.3.2. When bathing, did you receive either no assistance or assistance in bathing only one part of the body? ☐ Yes ☐

No

3.3.3. Were you able to get dressed without any assistance except for tying shoes? ☐ Yes ☐ No

3.3.4. Were you able to go to the toilet room, use the toilet, arrange clothes and return without assistance (may use cane or walker for support and may use bedpan/urinal at night)? ☐ Yes ☐ No

3.3.5. Were you able to move in and out of bed and chairs without assistance (may use cane or walker)? ☐ Yes ☐ No

3.3.6. Did you have complete bowel and bladder control (without occasional "accidents")? ☐ Yes ☐ No

3.3.7. Were you able to feed yourself without assistance (except for help with cutting meat or buttering bread)? ☐ Yes ☐ No

## 4. Behaviours during heatwaves

4.1.dress lighter than usual ☐ Yes ☐ No

4.2.stopping usual activities ☐ Yes ☐ No

4.3.take extra bath ☐ Yes ☐ No

4.4.use air conditioner

☐ Yes, at what time ___________________________

☐ No

4.5.time out during heatwaves ☐ Yes ☐ No

4.6.open windows ☐ Yes ☐ No

4.7.use of refreshments as a way to stay cool: ☐ Yes ☐ No

**Do you have any other relevant information to share regarding your health during hot weather?**

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

________________________________________

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