SA Health

The unfolding story of heat waves in metropolitan Adelaide

Monika Nitschke and Graeme Tucker
Department of Health, South Australia

Government of South Australia
SA Health

Executive summary

Two extreme heat waves occurred in South Australia recently, in March 2008 (15 days of ≥ 35ºC) and late January to early February 2009 (12 days of ≥ 35ºC, interspersed by one day of 33ºC). This report explores both events by comparing average daily morbidity and mortality rates during the respective heat wave periods to daily rates during non-heat wave periods within the respective years and restricted to the warm season (October to March).

Health outcomes examined were total and age group-specific hospital admissions, emergency presentations, ambulance call-outs and mortality. With the exception of mortality (data not available at this time), relevant disease-specific subgroups were also explored.

The number of cases with adverse health outcomes which were in excess of what is normally expected was calculated for the 2009 heat wave.

Summary of results

Ambulance call-outs

Ambulance call-outs increased by 10 per cent during the March 2008 heat wave and by 16 per cent during the 2009 event. It was estimated that an extra 519 call-outs occurred during the 2009 heat wave.

Total cardiac-related ambulance call-outs were increased by 9.8 per cent in 2008 and 12.7 per cent in 2009 respectively. Neurological call-outs were increased in the 65-74 year age group in 2008 by 39.3 per cent and in 2009 by 35.3 per cent respectively.

Hospital admissions

Small increases in total admissions occurred during both heat waves; 5.9 per cent in 2008 and 8.2 per cent in 2009 (both were statistically not significant).

During the 2009 heat wave ischaemic heart disease hospital admissions increased by 33 per cent in the 15–64 year age group and renal admissions by 47.5 per cent in the 75+ age group.

Direct heat-related admissions (ICD codes for volume depletion, effects of heat and light, and exposure to excessive heat) increased almost three-fold in 2008 and 14-fold in 2009. It was estimated that an extra 213.6 heat-related hospital admissions occurred during the 2009 heat wave with the majority of cases (136.5) affecting the 75+ age group.

Emergency departments

Total emergency presentations were increased by 5.5 per cent during the 2008 heat wave; the 15–64 and 65–74+ age group were mainly affected. During the 2009 heat wave, total emergency presentations were increased by 2.4 per cent (not statistically significant), but an impact was seen in the 15–64 and 75+ age group. Younger age groups were not affected; their emergency presentations were in fact reduced.

Renal disease-related emergency presentations were increased by 10.5 per cent (statistically not significant; $p=0.06$) in 2008 and by 39.3 per cent in 2009.

Direct heat-related total emergency presentations increased three-fold in 2008 and 12-fold in 2009. It was estimated that an extra 304.4 heat-related presentations occurred during the 2009 heat wave, mainly affecting the 15–64 year (123.2) and the 75+ age group (140.5).

Mortality

In 2008, total mortality increased by 4.8 per cent (not statistically significant). In 2009, total mortality increased by 9.5 per cent (marginally statistically significant). In 2009, the major impact was seen in the 15–64 year age group with a statistically significant increase in mortality of 36.7 per cent. Mortality was not significantly increased in the older age groups. Estimation of excess mortality for 2009 indicated 32 extra cases. Age-specific estimation indicated 23 extra deaths in the15–64 year age group.

These findings indicate an increased severity in health risks during the 2008 and 2009 heat waves in Adelaide compared to previous heat waves. In comparison to other national and international extreme heat events, Adelaide's health outcomes were relatively well-contained; in particular, the relatively moderate increase in excess mortality. This may reflect the positive impact of prevention measures directed to the vulnerable population during the 2009 heat wave.

Table of contents

Executive summary	**2**
Summary of results	**2**
Introduction	**5**
Methods	
Health data	**6**
Heat wave definition	**6**
Statistics	**6**
Results	
Temperatures during the 2008 and 2009 extreme heat waves	**7**
Morbidity and mortality during heat waves	**9**
Ambulance call-outs	**11**
Hospital admissions	**14**
Emergency department presentations	**17**
Mortality	**20**
Discussion	**22**
References	**24**

Introduction

Over the past 15 years, there have been a number of heat waves around the world that were severe enough to initiate efforts for preventive actions in the affected cities and at an international level supported by the WHO (1) (2). At least 700 extra deaths were reported during the 1995 Chicago heat wave and this was the first event that was intensively investigated in terms of identifying risk factors for those who died (3) (4). In the same year, a heat event occurred in London during which an estimated 619 extra people (8.9 per cent extra deaths) died (5). Increased mortality was most obvious as a result of cerebrovascular-related and respiratory diseases. The second deadliest heat wave in Chicago, during the summer of 1999, resulted in at least 80 extra deaths (6). Case-control investigations of the two Chicago heat events identified important social factors that increased the risk of dying; such as, living alone, social isolation, no working air-conditioner and living in top-floor apartments (7). The record-breaking European heat wave in 2003 estimated 14 802 heat-related deaths in France (a 60 per cent increase above expected numbers (8) (9). Excess mortality was also observed in other European countries. A retrospective estimation for this heat wave resulted in an unprecedented 45 000 extra deaths for August 2003 in the affected countries (10) (11) (12) (13).

There have been numerous investigations into excess mortality during heat waves, but cause-specific mortality has been investigated to a lesser degree. The few studies that have explored causes of heat-related mortality agree that the prominent causes of excess deaths were related to circulatory, respiratory, renal and nervous systems (11) (14). Information from a small number of cause-specific hospital admission investigations during heat waves provides evidence of increases in admissions due to acute renal disease, respiratory-related disorders, mental health-related illnesses and direct heat-related admissions. However, the increases are less for cardiovascular- or stroke-related disorders (6) (7) (15).

Recently, emergency presentations and ambulance call-outs have also been investigated, indicating excessive caseloads during heat waves and supporting the involvement of the above-mentioned disease groups (16) (17) (18). Investigations into heat waves in Adelaide substantiate overseas findings, indicating that the risk of getting admitted to hospital or presenting to the emergency department with renal- or mental health-related diseases is increased during hot weather (19) (20) (21).

There are a number of approaches that can be taken to study heat-related health effects. Time-series or case cross-over analysis is used for calculating increased adverse health effects in association with temperatures above certain thresholds using population-based data (22) (23). Results from these types of studies provide information regarding the impact of specified temperature increases on health rather than examining health impacts during specific heat waves.

For single extreme events, excess morbidity and mortality have been calculated by comparing average counts of health outcomes during heat waves with those from previous years during similar time periods. However, this methodology does not necessarily take into account the trends in health-care usage and population increases over years (8) (18).

The study presented here used a case-series approach to examine the health impacts of two recent extreme heat waves in Adelaide which occurred in 2008 and 2009. Daily ambulance call-outs, hospital admissions, emergency presentations and mortality during heat wave episodes were compared with non-heat wave periods during the concurrent warm season (October–March).

Methods

Health data

Daily hospital, mortality, emergency and ambulance data were used to examine relevant health outcomes retrospectively over 13 years during heat waves and during the two recent extreme heat waves in Adelaide. Categories of adverse health effects were defined using international classifications of diseases (ICD revisions 9 and 10 were relevant for the time period of the study). The broad disease categories were selected on the basis of information canvassed from previously published heat wave investigations.

With the exclusion of transfers between hospitals, the ambulance data categories utilised in this study were call-outs related to assault, work, road or sport accidents, falls, blunt traumas, and cardiac, respiratory and neurological conditions.

Total mortality data was obtained from the Register of Birth Deaths and Marriages (BDM); cause specific mortality data was obtained from the Australian Bureau of Statistics (ABS); hospital data was obtained from the Integrated South Australian Activity Collection (ISAAC); emergency data was obtained from the Emergency Department Data Collection (EDDC); and ambulance data was sourced from the South Australian Ambulance Service (SAAS).

Metropolitan Adelaide health data was obtained retrospectively from 1993 to 30 March 2009. For mortality data, ICD subcategories were only available up to December 2006; therefore disease specific subcategories were not available for the 2008 and 2009 heat waves. Emergency data was available from July 2003 onwards.

For mortality, hospital admissions and emergency department presentations data, the following ICD categories of diseases were selected: total cardiovascular (ICD-9, 390-4599; ICD-10, I00-99), ischaemic (ICD-9, 410-4149; ICD-10, I20-I25), cerebrovascular (ICD-9, 430-4489; ICD-10, I60-I699), respiratory (ICD-9, 460-5199; ICD-10, J00-J99), asthma (ICD-9, 493; ICD-10, J45-J469), mental (ICD-9, 290-294-9; ICD-10, F00-F999), renal (ICD-9, 580-599; ICD-10 N00-N399), food-borne (ICD-9, 0030-0039, 0050-0059; ICD-10, A02-A059), and direct heat-related (ICD-9, 2765, 992, E900; ICD-10, E86, T67, X30). The ICD categories relating to direct heat-related diseases include health effects resulting from: volume depletion, effects of heat and light, and exposure to excessive heat.

Heat wave definition

The general definition used for a heat wave in metropolitan Adelaide has been 35ºC or above for three days or more. The March 2008 heat wave covered a 15-day period (from 3 to17 March 2008). The January/February 2009 heat wave was counted as a 13-day episode including 4 February (from 26 January to 7 February 2009). On this day, the maximum temperature was 33ºC, but after this, temperatures soared well above 35ºC for another three days.

Statistics

Case-series analysis was used to compare average daily rates of adverse health effects in metropolitan Adelaide during heat waves (from July 1993 to 30 March 2009) with non-heat wave periods during the warm season (from October to March) (24) (25). Exposure to high temperatures during heat waves is considered to be common for the metropolitan population of Adelaide; hence the case-series design has been modified to apply at the population level using aggregated daily health outcomes in relation to acute risk and control periods. In essence, the case-series approach produces the same result as a case-crossover analysis where all non-heat wave periods in the observation period is used as control time (26) (27;28).

Acute risk periods refer to defined heat wave episodes that were compared to non-heat wave periods (control periods) during the warm season. These comparisons were expressed as incidence rate ratios (IRRs). The analysis was conducted within years; therefore it implicitly adjusts for long-term trends (24). Seasonality was non-parametrically controlled for by excluding the cold period (from April–September). Poisson regression models were fitted in Stata version 10 (29). Each model was tested for fit, and negative binomial regression models were used to allow for over-dispersion where it occurred.

To calculate the adverse health effects during the recent extreme heat waves, the 2008 and 2009 heat wave days were excluded from the general heat wave indicators. These heat wave days were included in the models as two separate (dummy) variables in addition to the general heat wave indicator variable. The models estimate the risk for the average daily health outcome data over the past 16 years for all non-heat wave days during the warm season. This data was analysed within years and compared to the 2008 and 2009 heat waves. Separate IRRs for the two heat wave episodes under specific consideration were provided and adjusted for the effects of other heat waves if they occurred during that season.

Expected cases were calculated as observed cases divided by the IRR. Excess cases were then calculated by subtracting expected from observed cases. For the purpose of this report, the excess cases were only calculated for the 2009 heat wave.

Results

Temperatures during the 2008 and 2009 extreme heat waves

Daily maximum and minimum temperatures during the two recent extreme heat waves are provided in table 1 and depicted in figure 1 as a time-series graph.

The 2008 heat wave covered 15 days (3 March–17 March 2008) and was by far the longest period with maximum daily temperatures of 35ºC and above on record for any capital city (30). Previously the longest previous period was 8 days in 2004. Temperatures only exceeded 40ºC twice, with the highest maximum daily temperature of 40.5 ºC recorded on the last day of the heat wave. Minimum daily temperatures stayed below 30ºC, with an average of 23 ºC, with the exception of 14 March, where the minimum temperature reached 30.2ºC. The Bureau of Meteorology (BOM) reported that the specific weather pattern was due to a very slow-moving high pressure system in the southern Tasman Sea, which directed north-to north-easterly winds across southern Australia (31). This weather pattern lasted for more than two weeks which is considered unusual for this part of the year.

In early 2009 an extreme heat wave affected south-eastern Australia, characterised by exceptionally high daily temperatures for a long period (26 January–7 February 2009). These conditions were facilitated by hot air originating in tropical regions that was able to move south due to a high pressure system in the Tasman Sea which combined with a tropical low off the northwest of Western Australia and an active monsoon trough. The 13-day hot weather period was briefly interrupted on day 10 when the maximum temperature stayed below 35ºC. The maximum temperature soared to 45.7ºC on 28 January, representing the third highest temperature in Adelaide since 1939 (when readings reached 46.1ºC and 45.9ºC followed by high night minimum temperatures). On 29 January 2009, the Kent Town monitoring station recorded 33.9ºC, while the Edinburgh

RAAF station recorded 41.7 ºC at 3.04 am (BOM, 2009).

The NASA weather map (figure 2) captures the land surface temperature anomalies during the 2009 heat wave. The reddish-brown areas indicate land surface temperatures during the period from January 25 to1 February 2009 which were 10ºC higher than average mid-summer temperatures from 2000 to 2008. The blue areas indicate colder than usual temperatures in the north and the white areas show regions where no change occurred.

Table 1 Daily maximum and minimum temperature during the 2008 and 2009 heat waves.

Heat wave 2008			**Heat wave 2009**		
Date	**Min T**	**Max T**	**Date**	**Min T**	**Max T**
3-Mar-08	15.6	35.4	26-Jan-09	16.9	36.6
4-Mar-08	23.5	35.7	27-Jan-09	21.2	43.2
5-Mar-08	24.4	37.9	28-Jan-09	30.7	45.7
6-Mar-08	19.6	38.5	29-Jan-09	33.9	43.4
7-Mar-08	19.9	39	30-Jan-09	29.4	43.1
8-Mar-08	21.1	39.8	31-Jan-09	27.5	41.1
9-Mar-08	25.4	40.2	01-Feb-09	25.9	40.6
10-Mar-08	22.4	40	02-Feb-09	28.3	38.8
11-Mar-08	22	38.4	03-Feb-09	21.5	36.3
12-Mar-08	22.4	39.2	04-Feb-09	19.3	33
13-Mar-08	25	39.7	05-Feb-09	19.1	35.6
14-Mar-08	30.2	38.6	06-Feb-09	21	43.9
15-Mar-08	23.6	38.3	07-Feb-09	25.8	41.5
16-Mar-08	22.5	39.9			
Average T	**22.9**	**38.5**		**26.1**	**41.0**
Min T	**15.6**	**35.4**		**16.9**	**36.3**
Max T	**30.2**	**40.5**		**33.9**	**45.7**

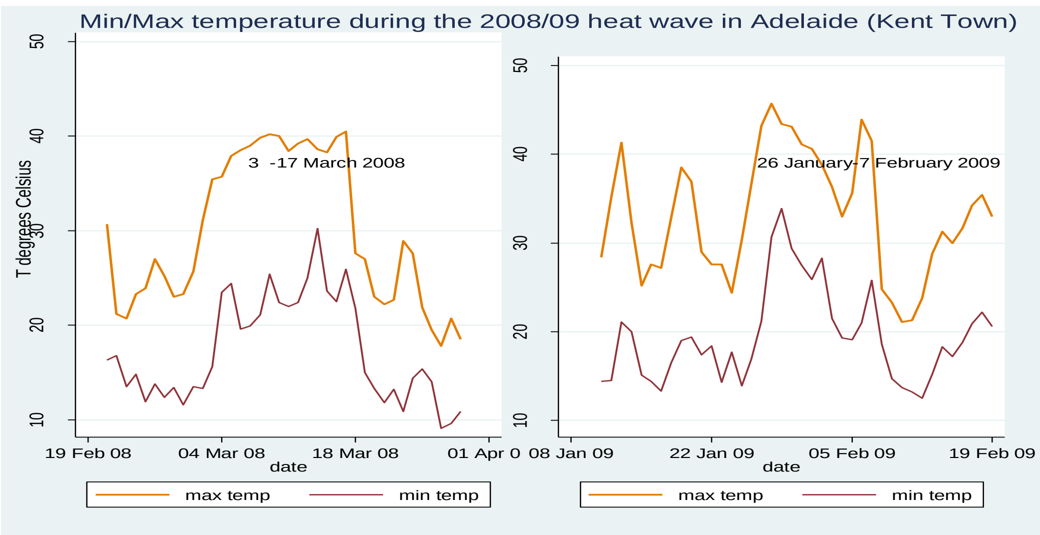


Figure 1 Temperature time series during the 2008 and 2009 Adelaide heat waves.

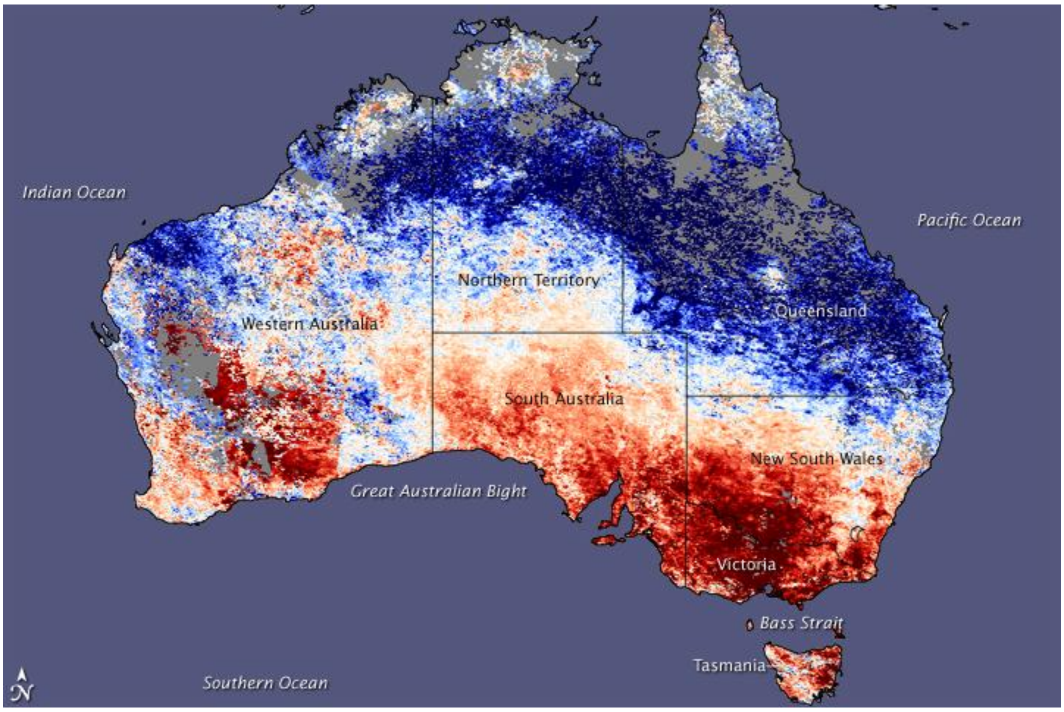
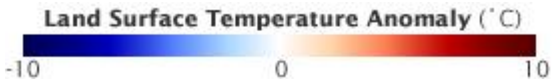


Figure 2 Exceptional Australian heat wave: The NASA map shows land surface temperature anomalies for the period 25 January – 1 February 2009. (http://earthobservatory.nasa.gov/IOTD/view.php?id=36900; accessed 10 July 2009)



Morbidity and mortality during heat waves

This section provides summary statistics for daily health outcomes and a summary of previous findings of heat wave research in Adelaide.

Specifically, table 2 provides summary statistics for the average daily rates of ambulance call-outs, hospital admissions, emergency presentations and mortality during heat waves and non-heat wave periods over the past 17 years (not including the 2008 and 2009 extreme heat waves). It also presents rates during the 2008 and 2009 extreme heat waves and, for comparison, the rates for 2008 and 2009 during non-heat wave periods occurring in the warm season.

The IRRs occurring during heat waves in Adelaide from 1993 to 2006 have been previously published (19). The following points summarise the findings of the 2007 study relating to the daily average increases in adverse health effects measured during heat waves in previous years:

- total ambulance call-outs: 4 per cent (6 extra cases daily)
- total daily hospital admissions: 7 per cent (86 extra admissions daily)
- total mental health hospital admissions: 7 per cent
- total renal hospital admissions: 13 per cent
- ischaemic heart disease hospital admissions: 8 per cent (in 65–74 year age group)
- total emergency presentations: 4 per cent (38 extra presentations daily)
- emergency presentations for mental health disorders: 6 per cent
- no overall increase in total mortality

> mental health-related mortality: 2.6 times (in 65–74 year age group)

Table 2 Descriptive statistics for total and disease-specific categories for daily incidences of ambulance transports, hospital admissions (July 1993–March 2009), emergency department presentations (July 2003–March 2009) and mortality (total: 1993–2009; ICD specific: 1993–2006) for metropolitan Adelaide. Descriptive statistics are also presented by season and specific heat waves.

Description	Min.	Max.	Mean	SD
Daily ambulance use: 5753	**84**	**361**	**182.2**	**51.1**
non-heat wave periods (cold seasons): 2837 days	**89**	**331**	**183.9**	**50.6**
non-heat wave periods (warm seasons): 2748 days	**84**	**336**	**179.4**	**50.8**
Heat wave periods (excluding 08/09 heat wave) : 141 days	**110**	**331**	**184.6**	**52**
Heat wave period 08: 15 days:	**248**	**303**	**270.9**	**17.6**
non-heat wave periods (October 07–March 08): 159 days	**180**	**305**	**246.1**	**21.6**
Heat wave period 09: 13 days	**243**	**361**	**291.1**	**36.1**
non-heat wave periods (October 08–March 09):169 days	**187**	**301**	**249.5**	**20.1**
Assault	0	35	6.1	3.7
Work related	0	7	1.3	1.3
Road motor vehicle accident	0	33	7.1	3.7
Other road accidents	0	7	0.9	1.0
Sport related	0	18	2.9	2.2
Falls	0	43	15.7	6.3
Blunt injury	0	37	11.0	4.7
Cardiac	1	66	27.1	8.0
Respiratory	0	48	16.0	6.7
Neurological	1	48	18.9	8.8
Daily hospital separation: 5753	**202**	**1811**	**1086.5**	**465.2**
non-heat wave periods (cold seasons): 2837 days	**263**	**1811**	**1103.0**	**461.7**
non-heat wave periods (warm seasons): 2748 days	**202**	**1800**	**1066.3**	**469.3**
Heat wave periods (excluding 08/09) : 141 days	**342**	**1693**	**1109.1**	**428.7**
Heat wave period 08: 15 days:	**385**	**1676**	**1248.6**	**508.8**
non-heat wave periods (October 07–March 08): 159 days	**297**	**1756**	**1208.4**	**492.8**
Heat wave period 09: 13 days	**460**	**1742**	**1322.9**	**506.4**
non-heat wave periods (October 08–March 09):169 days	**271**	**1798**	**1231.5**	**523.4**
Ischaemic heart disease	3	60	24.8	8.6
Stroke	0	20	6.7	2.9
Other	4	89	41.5	17.1
Cardio-vascular	17	137	73.0	24.6
Respiratory	13	138	58.7	20.8
Mental health	5	214	35.6	13.5
Epilepsy	0	9	2.0	1.5
Renal	1	60	21.1	9.9
Heat	0	55	1.1	1.7
Asthma	0	32	9.0	4.7

Description	Min.	Max.	Mean	SD
Daily Emergency Department: 2101 days (total)	**653**	**1263**	**880.3**	**98.4**
non-heat wave periods (cold seasons): 1007 days	**658**	**1263**	**879.0**	**102.4**
non-heat wave periods (warm seasons): 1020 days	**653**	**1138**	**878.3**	**92.2**
Heat wave periods (excluding 08/09) : 46 days	**714**	**1198**	**874.2**	**110.8**
Heat wave period 08: 15 days:	**889**	**1129**	**1025.4**	**63.3**
non-heat wave periods (October 07-March 08): 159 days	**864**	**1124**	**969.2**	**55.3**
Heat wave period 09: 13 days	**905**	**1065**	**994.5**	**54.3**
non-heat wave periods (October 08-March 09):169 days	**802**	**1122**	**971.5**	**59.0**
Ischaemic heart disease	0	22	9.6	3.3
Stroke	0	19	5.0	2.5
Other	5	45	20.7	6.0
Cardio-vascular	13	63	34.8	7.7
Respiratory	23	175	70.1	24.0
Mental health	0	61	22.7	16.2
Epilepsy	0	16	4.0	2.4
Renal	5	46	19.0	5.8
Food	0	4	0.3	0.6
Heat	0	63	2.2	3.0
Asthma	0	39	14.2	5.6
Daily mortality: 5753 (total)	**2**	**44**	**23.7**	**5.4**
non-heat wave periods (cold seasons): 2837 days	**7**	**43**	**25.3**	**5.4**
non-heat wave periods (warm seasons): 2747 days	**6**	**44**	**22.4**	**5.2**
Heat wave periods (excluding 08/09) : 141 days	**2**	**35**	**21.8**	**5.7**
Heat wave period 08: 15 days:	**19**	**31**	**23.2**	**4.2**
non-heat wave periods (October 07-March 08): 159 days	**10**	**33**	**22.1**	**4.9**
Heat wave period 09: 13 days	**15**	**44**	**28.6**	**9.4**
non-heat wave periods (October 08-March 09):169 days	**14**	**41**	**26.1**	**5.6**
Ischaemic heart disease	0	15	5.1	2.4
Stroke	0	10	2.6	1.7
Other	0	9	2.0	1.4
Cardio-vascular	0	25	9.4	3.4
Respiratory	0	11	2.3	1.6
Mental health	0	5	0.6	0.8
Epilepsy	0	2	0.0	0.2
Renal	0	5	0.5	0.7
Heat	0	2	0.1	0.2
Asthma	0	2	0.1	0.3

Ambulance call-outs

Total ambulance call-outs

The frequency distributions of daily ambulance call-outs during the 2008 and 2009 extreme heat waves are presented in figure 3. Several peak call-out numbers can be observed during heat wave days. In 2009, following the very hot day and night (28 January and 29 January), the number of ambulance call-outs peaked at 361 call-outs on 30 January.

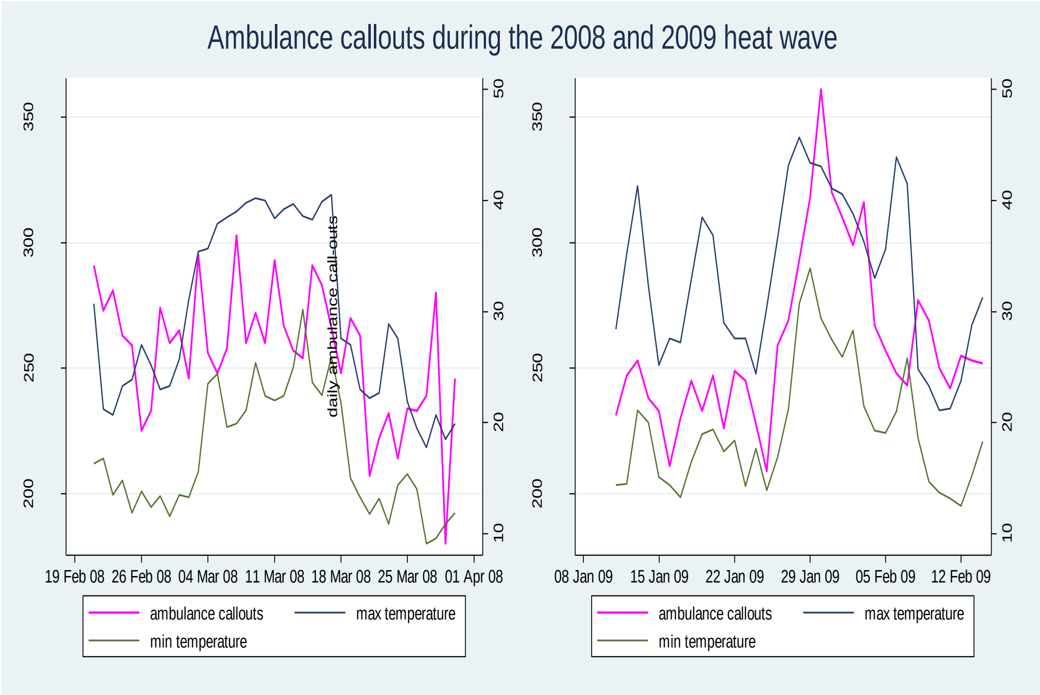


Figure 3 Daily ambulance call-outs and min/max temperature progression during the 2008 and 2009 heat waves

During the 2008 and 2009 heat waves, total ambulance call-outs increased by 9.7 per cent and 16 per cent respectively (table 3). These increases were generally consistent across all age groups for both heat wave periods with the exception of the 5–14 year age group in 2009, which experienced reduced ambulance call-outs.

Health-related subcategories of ambulance call-outs

Health-related IRRs for ambulance call-outs and their 95 per cent confidence intervals are presented in table 3.

During both recent heat waves, total cardiac-related call-outs increased by 9.8 per cent and 12.7 per cent respectively. Cardiac-related ambulance call-outs during the 13-day heat wave in 2009 averaged 39.8 per day. In comparison, during 2008 and 2009 non-heat wave days in the warm season the average was 35.3 call-outs per day. This increase was relevant for the 15–64, 65–74, and 75+ age groups. Neurological-related call-outs also increased during the two extreme heat waves, but this was restricted to the 65–74 year age group. Increased call-outs were also seen for blunt injuries in the 0–4 year age group in 2008 and the 15–64 year age group in 2009 and for respiratory-related call-outs in the 15–64 year age group only in 2008. Ambulance call-outs for sport-related injuries were reduced.

Table 3 Ambulance call-outs IRRs and 95% confidence intervals (95%CI): IRRs are based on the daily mean incidence of ambulance call-outs during the 2008 (15 days) and 2009 (13 days) heat waves divided by incidence during non-heat wave periods in metropolitan Adelaide, controlled within years and adjusted for seasonality using conditional fixed-effects Poisson regression. To avoid over-dispersion, negative binomial regression analysis was used. Empty cells indicate insufficient data to produce reliable estimates. Dark-grey shaded cells indicate significance at P<0.05; light-grey shaded cells indicate borderline significance at P<0.1.

	All ages		0–4		5–14		15–64		65–74		75+	
Ambulance categories	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**
Heat wave 2008												
Total ambulance	1.097 1.027-1.17	**0.006**	1.085 0.87-1.35	0.462	1.125 0.922-1.37	0.245	1.120 1.03-1.21	**0.006**	1.130 1.03-1.24	**0.008**	1.044 0.97-1.13	0.260
assault	0.937 0.63-1.40	0.753	0.942 0.122-7.27	0.955			0.975 0.66-1.44	0.901				
work	1.197 0.83-1.73	0.342					1.245 0.85-1.83	0.263				
road motor vehicle accidents	1.006 0.80-1.26	0.958			0.721 0.26-1.98	0.527	1.015 0.80-1.28	0.888	1.323 0.66-2.64	0.427	0.835 0.36-1.91	0.670
other road-related accidents	1.246 0.75-2.06	0.389			2.008 0.44-9.06	0.365	1.082 0.58-2.01	0.803			2.606 0.83-8.22	0.102
sport	0.731 0.47-1.13	0.161			0.560 0.30-1.06	0.074	0.798 0.45-1.43	0.448	1.099 0.34-3.60	0.877	0.853 0.31-2.36	0.759
fall	1.087 0.98-1.21	0.130	0.649 0.28-1.48	0.303	0.825 0.46-1.46	0.527	1.110 0.91-1.36	0.315	1.117 0.81-1.54	0.499	1.108 0.96-1.28	0.169
blunt	0.990 0.84-1.16	0.894	2.883 1.4-5.78	**0.003**	0.801 0.42-1.52	0.498	1.009 0.84-1.21	0.918	0.476 0.17-1.29	0.146	0.830 0.47-1.46	0.518
cardiac	1.098 1.01-1.20	**0.033**					1.163 1.01-1.34	**0.040**	1.184 0.98-1.43	0.082	1.015 0.89-1.16	0.822
respiratory	1.055 0.94-1.19	0.385	1.184 0.76-1.86	0.462	0.779 0.40-1.50	0.607	1.317 1.08-1.61	**0.008**	0.866 0.63-1.18	0.362	0.971 0.80-1.17	0.762
neurological	1.084 0.99-1.19	0.092	1.047 0.68-1.61	0.833	0.608 0.28-1.30	0.200	1.061 0.94-1.20	0.330	1.393 1.01-1.91	0.040	1.106 0.90-1.36	0.335
Heat wave 2009												
Total ambulance	1.160 1.08-1.24	**<0.001**	1.078 0.86-1.36	0.520	0.856 0.68-1.08	0.192	1.137 1.04-1.24	**0.003**	1.113 1.01-1.23	**0.031**	1.243 1.15-1.34	**<0.001**
assault	1.243 0.84-1.83	0.270	1.857 0.42-8.18	0.413			1.277 0.88-1.86	0.203				
work	0.736 0.83-1.73	0.248					0.765 0.45-1.31	0.329				
road motor vehicle	1.008 0.79-1.29	0.946			0.448 0.11-1.84	0.265	1.122 0.91-1.34	0.284	0.788 0.29-2.16	0.643	0.302 0.74-1.23	0.094
other road-related accidents	0.658 0.32-1.34	0.248			1.625 0.20-12.99	0.647	0.805 0.38-1.73	0.578				
sport	0.848 0.54-1.32	0.465			0.400 0.18-0.90	**0.027**	1.134 0.67-1.93	0.644	2.294 0.67-7.82	0.185	0.531 0.13-2.18	0.380
fall	0.967 0.86-1.09	0.590	1.226 0.64-2.35	0.537	0.675 0.37-1.19	0.260	0.858 0.68-1.09	0.208	1.018 0.71-1.47	0.925	1.043 0.89-1.22	0.608
blunt	1.068 0.9-1.27	0.407	0.289 0.04-2.10	0.219	0.477 0.18-1.29	0.146	1.188 1.01-1.40	**0.041**	0.443 0.14-1.40	0.166	0.807 0.43-1.53	0.512
cardiac	1.127 1.03-1.23	**0.009**					1.156 0.99-1.35	0.069	1.062 0.86-1.31	0.575	1.133 0.10-1.29	0.059
respiratory	0.881 0.77-1.01	0.063	1.050 0.67-1.64	0.830	0.641 0.22-1.90	0.423	1.158 0.93-1.45	0.194	0.782 0.55-1.10	0.164	0.734 0.59-0.92	**0.006**
neurological	1.017 0.92-1.12	0.748	0.936 0.59-1.49	0.779	0.977 0.56-1.72	0.935	1.002 0.88-1.14	0.978	1.353 0.97-1.89	0.076	0.984 0.78-1.24	0.887

Excess ambulance call-outs during the 2009 heat wave

There were a total of 3760 call-outs observed during the 13 days of the 2009 heat event. This observed number was 16% higher than the expected number (The observed number is 116% of the expected number, so there are 3241.4 call-outs expected). The excess number of call-outs (observed minus expected) was 517.6 with a 95% confidence interval (CI) of 402.9–626.7 call-outs. Table 4 presents the excess ambulance call-outs by age group.

*Table 4 Total number of ambulance call-outs, IRRs and excess call-outs during the 2009 heat wave by age groups. * significant at P<0.05; bl significant <0.1*

Age-group	Observed ambulance call-outs	IRR	Excess ambulance call-outs
0–4	126	1.08	+9.1 ns
5–14	75	0.86	-12.6 ns
15–64	1666	1.14*	+200.9*
65–74	442	1.11*	+44.9*
75+	1446	1.24*	+282.7*
total	3760*+	1.16*	+517.7*

+ Total observed ambulance call-outs include observations from individuals without age details.

Hospital admissions

Total hospital admissions

Daily temperatures and daily hospital admissions during the 2008 and 2009 heat waves are illustrated in figure 4. No visibly obvious peaks in hospital admissions can be observed during the respective heat wave periods.

Small but statistically insignificant increases in total hospital admissions were observed during both heat waves (table 5). These small increases were also apparent in the 15-64 and 75+ age groups.

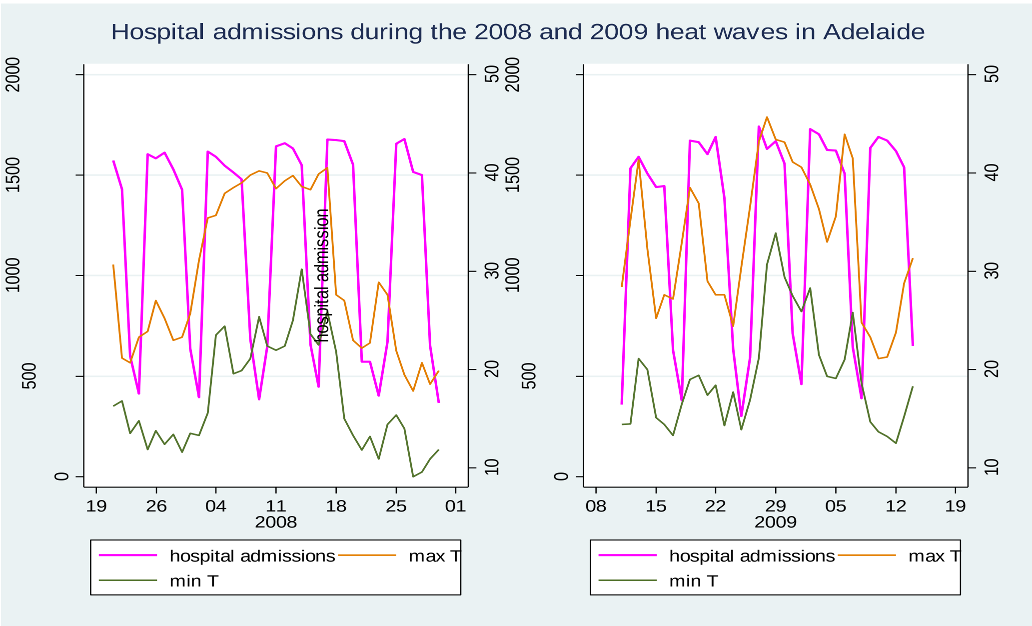


Figure 4 Daily hospital admissions and min/max temperature during the 2008/09 heat waves.

ICD categories of hospital admissions

Health-related IRRs for hospital admissions and their 95 per cent confidence intervals are presented in table 5. Total renal admissions increased during both extreme heat waves, but the increase was not statistically significant. Renal admissions almost tripled (2.6-fold increase) in the 5–14 year age group and increased by 23.3 per cent in the 75+ age group during the 2008 heat wave. In 2009, only the 75+ age group experienced statistically significant increases.

During the 2009 heat wave, an increase of 33 per cent in admissions for ischaemic heart disease occurred in the 15–64 year age group only. Increases were also observed in admissions for renal disease, with an increase of 47.5 per cent in the 75+ age group that was statistically significant.

In 2008 and 2009, the increase in direct heat-related hospital admissions was pronounced. In 2008, total admissions were 2.6-fold higher during heat wave days compared to non-heat wave days in the relevant summer season. This increase was similar in the 15–64 year age group (2.5-fold increase) while the risk tripled (3.1-fold increase) in the 75+ age group. Non-significant changes were seen in the 65–74 year age group. Case numbers in the youngest age group were insufficient for estimation.

Direct heat-related hospital admissions observed during the 2009 heat wave exceeded 2008 rates. Overall, there was an almost 14-fold increase in heat admissions; 12-fold in the 15–64 year age group; 7-fold in the 65–74 year age group; and 20-fold in the 75+ age group.

In both extreme heat waves, there was no clear trend in relation to respiratory- or asthma-related hospital admissions.

Excess hospital admissions in 2009

Differences in total hospital admissions were not statistically significant. This also applied to any of the age range-specific total hospital admissions parameters (table 5). Excess hospital admissions were based on the IRR of 1.082. For the point estimate, an excess of 1310.4 admissions was calculated with a very wide 95 per cent CI of -3248 to +4853. Table 2 shows the average hospital admissions during the 13-day 2009 heat wave was 1322.9 per day and the average admissions during the non-heat wave period (October–March in 2008 and 2009) was 1231.5 per day. This comparison indicates a numerical difference of 91.5 hospital admissions per day between the 2009 heat wave and the respective comparison period.

Table 5 Hospital admissions IRRs and 95 per cent confidence intervals (95%CI). The IRRs are based on daily mean incidence of admission to hospitals during the 2008 (15 days) and the 2009 (13 days) heat waves divided by incidence during non-heat wave periods in metropolitan Adelaide, controlled within years and adjusted for seasonality using conditional fixed-effects Poisson regression; in case of over-dispersion, negative binomial regression analysis was used. Empty cells indicate insufficient data to produce reliable estimates. Dark-grey shaded cells indicate significance at P<0.05; light-grey shaded cells indicate borderline significance at P<0.1.

	All ages		0–4		5–14		15–64		65–74		75+	
Hospital Categories	**IRR** (95% CI)	**p**	**IRR** (95%CI)		**IRR** **p**(95%CI)	**p**	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**
						Heat wave 2008						
Total admissions	1.059 0.84-1.34	0.64	0.986 0.83-1.18	0.88	0.979 0.73-1.32	0.89	1.046 0.80-1.36	0.74	1.060 0.82-1.36	0.65	1.110 0.90-1.37	0.33
Ischaemic	1.027 0.84-1.25	0.79					0.970 0.71-1.33	0.85	1.166 0.91-1.49	0.21	0.985 0.82-1.19	0.88
Stroke	1.027 0.83-1.28	0.81					1.088 0.72-0.98	0.69	0.841 0.47-1.51	0.56	1.054 0.79-1.40	0.72
Other cardio-vascular	1.001 0.78-1.28	0.99	1.725 0.51-5.83	0.38	1.805 0.70-4.64	0.22	0.957 0.67-1.37	0.81	1.065 0.80-1.41	0.66	1.006 0.82-1.23	0.95
All cardio-vascular	1.011 0.83-1.26	0.92	1.581 0.47-5.30	0.46	1.804 0.70-4.64	0.22	0.967 0.72-1.30	0.82	1.090 0.87-1.36	0.45	1.005 0.88-1.15	0.94
Respiratory	0.978 0.77-1.24	0.85	0.829 0.59-1.2	0.29	1.021 0.71-1.47	0.91	1.058 0.77-1.45	0.73	0.906 0.72-1.13	0.39	0.962 0.80-1.15	0.68
Mental health	0.979 0.84-1.14	0.78			1.642 0.70-3.87	0.26	0.966 0.83-1.12	0.65	0.869 0.62-1.22	0.42	1.103 0.85-1.41	0.44
Renal	1.109 0.85-1.45	0.45	1.121 0.60-2.08	0.72	2.638 1.47-4.73	**0.001**	1.003 0.73-1.38	0.99	1.071 0.68-1.69	0.77	1.233 1.03-1.47	0.096
Direct heat	2.617 1.32-5.20	**0.006**					2.533 1.22-5.25	**0.01**	1.991 0.53-7.48	0.31	3.054 1.54-6.06	**0.001**
Asthma	1.018 0.63-1.65	0.94	0.876 0.47-1.65	0.68	1.105 0.52-2.32	0.79	1.157 0.78-1.72	0.47	1.048 0.32-3.42	0.94	0.964 0.30-3.13	0.95
						Heatwave 2009						
Total admissions	1.082 0.84-1.39	0.54	1.05 0.82-1.26	0.62	0.796 0.56-1.13	0.20	1.077 0.82-1.42	0.60	1.078 0.83-1.40	0.58	1.137 0.91-1.42	0.26
Ischaemic	1.086 0.88-1.33	0.44					1.33 0.99-1.80	0.06	0.910 0.91-1.49	0.53	0.977 0.79-1.20	0.83
Stroke	1.177 0.95-1.47	0.15					1.27 0.84-1.91	0.26	1.195 0.72-1.99	0.49	1.130 0.84-1.53	0.43
Other cardio-vascular	0.966 0.74-1.26	0.80	0.929 0.12-7.06	0.94	0.361 0.50-2.63	0.32	1.03 0.89-1.16	0.87	0.832 0.60-1.16	0.28	0.979 0.79-1.22	0.85
All cardio-vascular	1.017 0.82-1.26	0.88	0.867 0.11-6.56	0.89	0.351 0.048-2.56	0.30	1.13 0.84-1.51	0.43	0.884 0.68-1.14	0.35	0.995 0.86-1.15	0.95
Respiratory	0.946 0.73-1.22	0.67	1.026 0.74-1.42	0.88	0.649 0.41-1.04	0.07	0.10 0.71-1.41	0.99	0.820 0.64-1.05	0.11	0.982 0.84-1.14	0.85
Mental health	1.031 0.88-1.20	0.70			0.844 0.34-2.09	0.71	1.03 0.89-1.21	0.67	1.028 0.74-1.42	0.87	1.045 0.80-1.36	0.75
Renal	1.238 0.95-1.62	0.12	1.159 0.67-2.00	0.60	0.707 0.29-1.74	0.45	1.093 0.79-1.51	0.59	1.383 0.89-2.14	0.15	1.475 1.15-1.88	**0.002**
Direct heat	13.66 8.89-20.98	**<0.001**					11.53 7.18-18.53	**<0.001**	7.064 3.05-16.3	**<0.001**	19.23 12.44-29.7	**<0.001**
Asthma	0.825 0.47-1.44	0.50	1.114 0.63-1.98	0.71	0.621 0.23-1.65	0.34	0.554 0.303-1.01	0.06	0.333 0.46-2.43	0.28	0.684 0.17-2.84	0.60

Emergency department presentations

Total emergency presentations

Following the progress of daily emergency presentations during the 2008 and 2009 heat waves, several peaks and troughs in presentations can be observed over several days (figure 5).

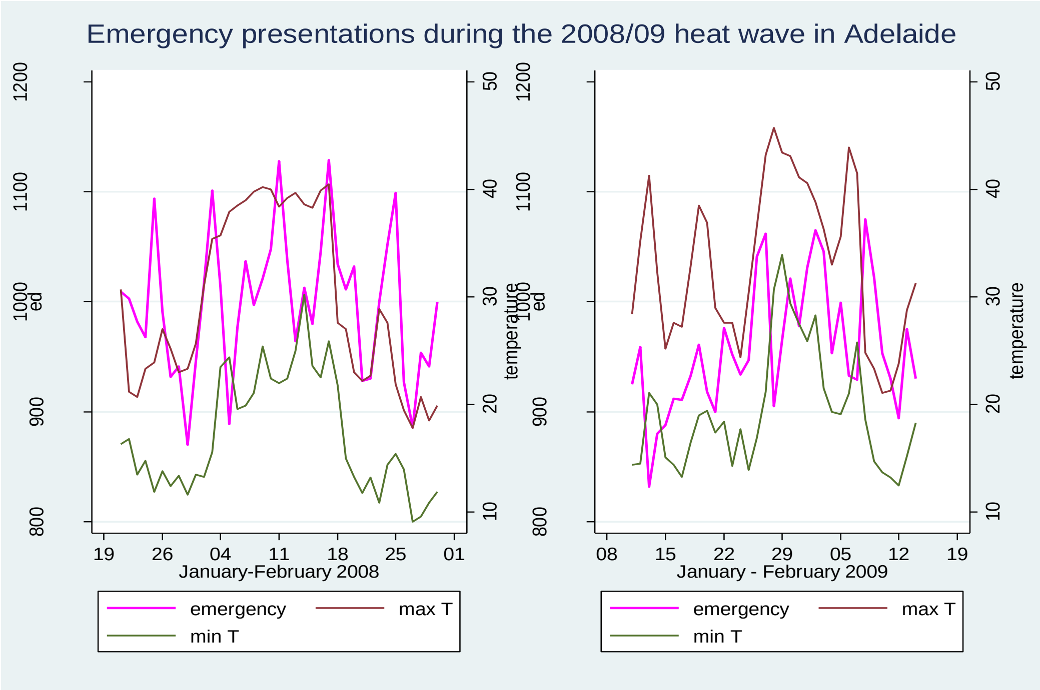


Figure 5 Emergency presentations during the 2008/09 heat of peaks and troughs waves in Adelaide.

ICD categories of emergency presentations

The analysis of the IRRs in relation to emergency presentations shows some consistent patterns for both heat waves (table 6). Total emergency presentations increased on both occasions, by 5.5 per cent in 2008 and by 2.5 per cent in 2009; albeit, the increase was statistically significant only in 2008. There were some inconsistencies between the two heat waves in relation to the age groups affected. In 2008, it appears that emergency cases increased across all age groups, whereas, in 2009, significant decreases were observed in the younger age groups. In 2008, the 65–74 year age group experienced statistically significant increases; whereas, in 2009, the 75+ age group was more clearly affected.

Renal disease-related presentations increased by 10.5 per cent in 2008 and by 39.3 per cent in 2009.

The greatest increase was in direct heat-related emergency presentations. These presentations more than tripled in 2008 and rose to twelve times the normal summer rates in 2009. Once again, the risk increase was observed across all age groups in 2009.

The only subcategory of cardiovascular disease presenting in excess during heat waves was ischaemic heart disease. The excess was restricted to the 2009 heat wave and the 15–64 year age group. Overall, cardiovascular disease was not increased, if anything, in some age groups including the elderly, it was decreased. Other obvious decreases were observed in respiratory disease presentations, particularly for asthma in 2009. None of the minor increases in respiratory presentations in 2008 reached statistical significance.

Table 6 Emergency department presentations IRRs and 95 per cent confidence intervals (95%CI). The IRRs are based on daily mean incidence of presentations during the 2008 (15 days) and the 2009 (13 days) heat waves divided by incidence during non-heat wave periods in metropolitan Adelaide, controlled within years and adjusted for seasonality using conditional fixed-effects Poisson regression; in case of over-dispersion, negative binomial regression analysis was used. Empty cells indicate insufficient data to produce reliable estimates. Dark-grey shaded cells indicate significance at P<0.05; light-grey shaded cells indicate borderline significance at P<0.1.

Age range	All ages		0–4		5–14		15–64		65–74		75+	
Emergency presentation	**IRR** (95% CI)	**p**	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**	**IRR** (95%CI)	**p**
						2008						
Total emergency	1.055 1.014-1.10	**0.01**	1.022 0.92-1.13	0.68	1.038 0.95-1.14	0.42	1.066 1.02-1.12	**0.01**	1.085 1.02-1.15	**0.01**	1.029 0.97-1.08	0.23
Ischaemic	0.957 0.81-1.13	0.60					0.946 1.08-1.78	0.68	1.071 0.77-1.48	0.68	0.900 0.69-1.18	0.44
Stroke	1.015 0.78-1.32	0.91					1.141 0.77-1.80	0.56	1.020 0.55-1.89	0.95	0.939 0.65-1.36	0.74
Other cardio-vascular	0.942 0.84-1.05	0.30	2.346 0.80-6.90	0.12	1.192 0.51-2.77	0.68	0.826 0.69-0.99	**0.045**	0.953 0.73-1.25	0.73	1.029 0.87-1.22	0.74
All cardio-vascular	0.954 0.87-1.04	0.29	2.341 0.80-6.89	0.12	1.189 0.51-2.76	0.69	0.886 0.78-1.02	0.10	1.001 0.82-1.22	0.99	0.981 0.86-1.12	0.79
Respiratory	1.031 0.93-1.14	0.58	1.049 0.93-1.19	0.43	1.076 0.70-1.66	0.74	0.967 0.75-0.98	0.67	1.209 0.96-1.53	0.11	1.018 0.85-1.22	0.85
Mental health	1.045 0.96-1.14	0.30	0.561 0.75-4.18	0.57	0.957 0.53-1.73	0.89	1.037 0.95-1.13	0.43	1.241 0.85-1.82	0.27	1.150 0.78-1.51	0.63
Renal	1.105 0.99-1.23	0.06	0.795 0.48-1.32	0.38	1.735 1.06-2.85	**0.03**	1.057 0.92-1.22	0.44	1.298 0.94-1.79	0.10	1.144 0.86-1.53	0.37
Food	0.303 0.07-1.23	0.10					0.291 0.34-2.12	0.22				
Direct heat	3.327 2.40-4.62	**<0.001**	0.922 0.21-4.27	0.91	2.113 0.62-7.23	0.23	4.768 3.11-7.30	**<0.001**	1.586 6.13-14.65	0.29	2.946 2.07-4.18	**<0.001**
Asthma	1.128 0.77-1.64	0.53	1.077 0.74-1.56	0.70	1.146 0.57-2.29	0.70	1.236 0.92-1.66	0.16	0.604 0.16-2.24	0.45	0.958 0.38-2.39	0.93
						2009						
Total emergency	1.024 0.98-1.07	0.28	0.899 0.85-0.95	0.08	0.826 0.74-0.92	**<0.001**	1.049 0.99-1.10	0.06	1.003 0.94-1.07	0.92	1.165 1.11-1.22	0.00
Ischaemic	1.033 0.86-1.23	0.72					1.386 1.08-1.78	0.01	0.757 0.49-1.16	0.20	0.843 0.61-1.16	0.29
Stroke	1.059 0.83-1.36	0.65					1.173 0.77-1.80	0.47	0.897 0.50-1.61	0.71	1.065 0.75-1.52	0.73
Other cardio-vascular	0.964 0.86-1.08	0.53	0.963 0.23-4.05	0.96	0.867 0.27-2.79	0.81	0.968 0.81-1.16	0.72	0.873 0.65-1.17	0.36	1.003 0.84-1.13	0.97
All cardio-vascular	0.993 0.91-1.09	0.88	0.897 0.21-3.76	0.88	0.848 0.26-2.73	0.78	1.092 0.95-1.25	0.22	0.842 0.67-1.05	0.13	0.974 0.84-1.13	0.72
Respiratory	0.774 0.68-0.88	**<0.001**	0.720 0.63-0.82	**<0.001**	0.642 0.36-1.14	0.13	0.861 0.73-1.02	0.08	0.802 0.61-1.05	0.11	0.825 0.68-0.99	0.05
Mental health	1.039 0.95-1.13	0.38	0.619	0.64	0.959 0.58-1.59	0.87	1.052 0.96-1.15	0.27	0.658 0.40-1.09	0.10	1.179 0.85-1.64	0.33
Renal	1.393 1.26-1.54	**<0.001**	1.510 1.02-2.23	0.04	1.252 0.71-2.21	0.43	1.318 1.16-1.50	**<0.001**	1.214 0.87-1.71	0.24	1.676 1.29-2.17	**<0.001**
Food	0.907 0.28-2.92	0.87					1.625 0.49-5.40	0.43				
Direct heat	12.014 9.55-15.12	**<0.001**	3.355 1.54-7.30	0.01	3.824 1.4-10.4	0.01	12.404 8.8-17.4	**<0.001**	9.479 6.1-14.7	**<0.001**	15.854 12.49-20.12	**<0.001**
Asthma	0.772 0.48-1.24	0.28	0.896 0.74-1.56	0.60	0.601 0.23-1.57	0.30	0.798 0.55-1.15	0.23	0.595 0.16-2.26	0.45	0.578 0.14-2.38	0.45

Excess emergency presentations

In 2009, total presentations increased by 2.4 per cent (not statistically significant). Based on a total of 12 928 cases presenting over 13 days, the point estimate for excess presentations was 301 with a 95 per cent CI of -254.3 to +832.6. Comparison of average daily presentations during the 2009 heat wave (994.5) to average daily cases during 2008 and 2009 non heat wave days (971.5) (table 2) suggests a numerical difference of 23 extra presentations per heat wave day.

Direct heat-related hospital and emergency cases during the 2008 and 2009 heat waves

Figure 6 shows increases in direct heat-related hospital and emergency cases during the two extreme heat waves. The sharp rise in direct heat-related cases in 2009 was particularly pronounced on 29 January and 30 January (with maximum hospital admissions = 39 and maximum emergency presentations = 63). Table 7 shows the excess number of heat-related cases by age-groups during the 2009 heat wave.

It was estimated that an extra 213.6 (95% CI 205.9-220.9) excess hospital admissions occurred with only two cases in the <15 year age group and the majority of 136.5 cases estimated to have occurred in the 75+ age group.

Total emergency excess cases were estimated to be 304 cases (95% CI 297.2-309.0). Extra cases were evident throughout the age groups, but the majority of cases were seen in the 15–64 year age groups (123.2) and in the 75+ age group (140.5).

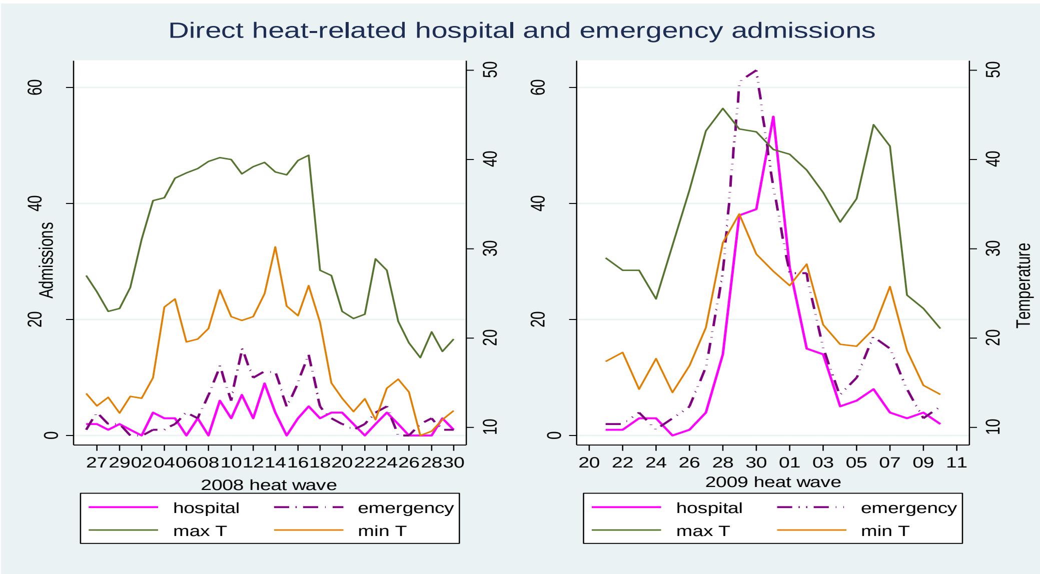


Figure 6 Direct heat-related hospital and emergency admissions during the 2008 and 2009 heat waves.

*Table 7 Total number of heat-related hospital and emergency cases, IRRs and excess call-outs during the 2009 heat wave by age-groups. *significant at p<0.05*

Age-group	Observed heat-related cases	IRR	Excess heat-related cases
Hospital admissions			
0–4	2		
5–14	0		
15–64	59	11.53*	53.9*
65–74	27	7.06*	23.2*
75+	144	19.23*	136.5*
Total	**232**	**13.66***	**213.6***
Emergency presentations			
0–4	8	3.36*	5.6*
5–14	5	3.82*	2.5*
15–64	134	12.40*	123.2*
65–74	35	9.48*	31.3*
75+	150	15.85*	140.54*
Total	**332**	**12.01***	**304.4**

Mortality

Total mortality

Figure 7 illustrates daily mortality rates during the 2008 and 2009 heat waves. It can be seen that considerable increases in mortality occurred during the 2009 heat wave.

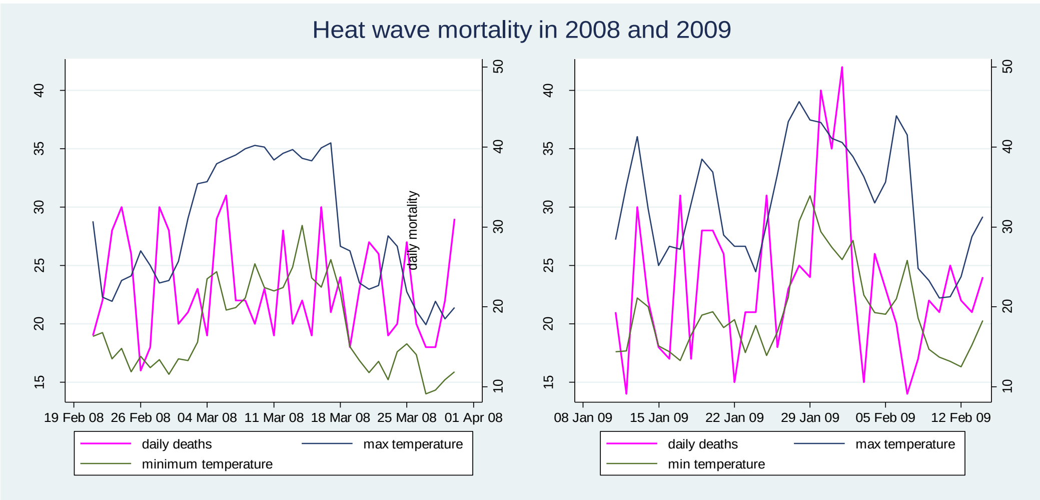


Figure 7 Time-series of mortality and temperatures during the 2008 and 2009 heat waves

Figure 8 depicts the 2009 heat wave only and includes daily number of deaths on the mortality graph. Daily deaths peaked on the 30 January 2009 (44 deaths), 31 January 2009 (38 deaths), and 1 February 2009 (44 deaths). The average rate of daily deaths during non-heat wave days in summer (from October to March 2008 and 2009) was 26 for the 2008 heat wave and 29 for the 2009 heat wave (see also table 2).

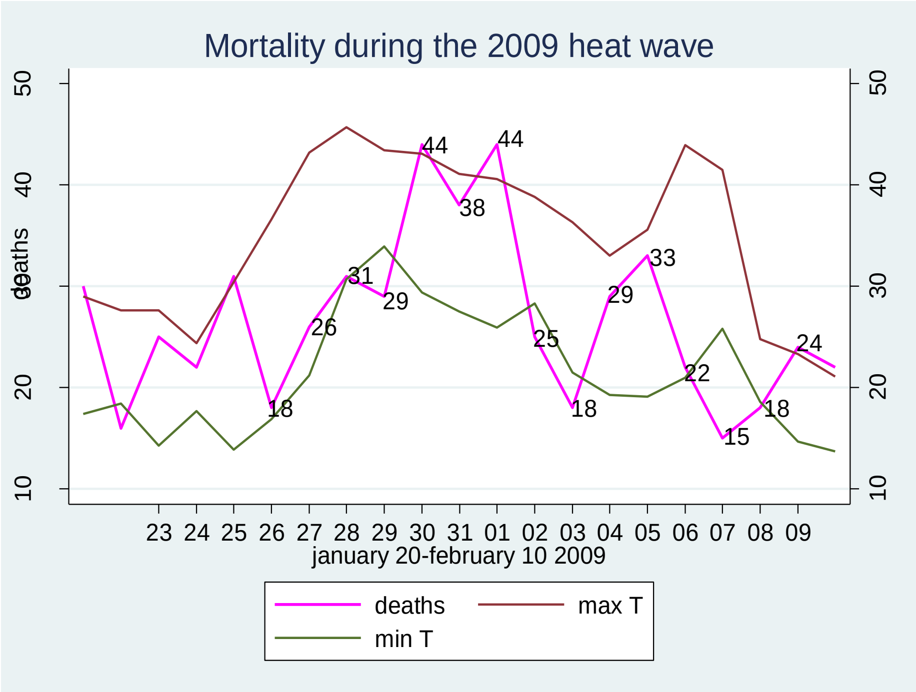


Figure 8 Progression of daily rates of mortality and temperatures during the 2009 heat wave

During the 2008 heat wave, total mortality was increased but the increase was not statistically significant. Non-significant increases also applied to all age groups except for the 0–4 year age group where a significant increase occurred (table 8).

In 2009, the total daily mortality IRR indicated a marginally significant increase of 9.5 per cent (table 8). A significant increase of 36.7 per cent was noted in the 15–64 year age group.

Excess mortality

Table 9 sets out the total excess mortality by age group for the 2009 heat wave. The total number of deaths during the 13-day event was 372. This represented an increase of 9.5 per cent above the expected number (339.7). Total number of excess deaths was therefore calculated to be 32.4 (95% CI of -5.5–67). In the 15–64 year age group, the point estimate was 23.1 extra deaths with a 95 per cent CI of 7.4–35.7 deaths.

Table 8 Mortality IRRs and 95% confidence intervals (95%CI). The IRRs are based on daily mean incidence of mortality during the 2008 (15 days) and the 2009 (13 days) heat waves divided by incidence during non-heat wave periods in metropolitan Adelaide, controlled within years and adjusted for seasonality using conditional fixed-effects Poisson regression; in case of over-dispersion, negative binomial regression analysis was used. Empty cells indicate insufficient data to produce reliable estimates. Dark-grey shaded cells indicate significance at P<0.05; light-grey shaded cells indicate borderline significance at P<0.1.

Age groups	All ages		0–4		5–14		15–64		65–74		75+	
Heat wave 2008												
	IRR (95%CI)	p	IRR (95%CI)	p	IRR (95%CI)	p	IRR (95%CI)	p	IRR (95%CI)	p	IRR (95%CI)	p
Total mortality	1.048 0.94-1.22	0.40	3.226 1.30-7.99	**0.01**	3.771 0,39-36.27	0.25	1.005 0.57-2.29	0.97	1.026 0.76-1.38	0.87	1.043 0.91-1.19	0.54
Heat wave 2009												
Total mortality	1.095 0.99-1.22	0.09	1.529 0.54-5.31	0.42	4.333 0.45-41.66	0.20	1.367 1.09-1.71	**0.01**	1.145 0.86-1.52	0.35	1.003 0.88-1.15	0.97

*Table 9 Total mortality: IRRs and excess mortality during the 2009 heat wave by age group. *significant at P<0.05; bl significant <0.1*

Age-group	Total number	IRR	Excess mortality
0–4	4	1.5	1.4
5–14	1	4.3	0.8
15–64	86	1.37*	23.1*
65–74	51	1.15	6.5
75+	230	1.00	0.7
total	372	1.095 bl	32 bl

Discussion

The main objective of this study was to assess the potential health effects that occurred during the 2008 and 2009 extreme heat waves in the Adelaide metropolitan area. In the main, the results of this study compare well with the findings of the 2007 study (19). Increased IRRs in the ambulance, hospital, and emergency settings were observed during the two recent extreme heat waves; identifying the same health-specific categories that were prominently increased in the previous study. In particular, renal disease-related IRRs were substantially increased for hospital admissions and emergency presentations. In-depth analysis of renal hospital admissions during heat waves in Adelaide has previously indicated that acute renal failure and co-morbid effects of direct heat are the greatest contributors to increased renal admissions (20).

Unlike the 2007 study, a clear picture has not emerged for mental health-related morbidity during the recent extreme heat waves, with the exception of neurological-related ambulance call-outs. However, this may due to the small sample size available when comparing single heat wave episodes.

Unlike the 2007 study, where IRRs of cardiac-related ambulance call-outs were not increased during non-heat wave periods, increases in cardiac-related call-outs were observed during both recent heat waves. In contrast, increased total cardiac hospital admissions were not observed. This is consistent with overseas findings which show high risks of circulatory-related mortality during extreme heat waves, but not necessarily hospital admissions (15). It is hypothesised that this discrepancy is due to the short interval that is usually seen between a rapid decline in health and death during high temperature events, which makes it difficult to access preventive health care in time (32). Due to the delay in disease-specific mortality data availability, the hypothesis of increased cardiac-related mortality associated with recent heat waves cannot be tested at this time. During the 2009 heat wave, ischaemic heart disease-related hospital admissions and emergency presentations were increased in the 15–64 year age group. This suggests that circulatory disturbances associated with heat occurred. This observation is also evident in the previous heat wave study.

Direct heat-related cases were particularly increased during the 2009 heat wave. IRRs for direct heat-related average daily total hospital admissions generally tripled during heat waves in Adelaide but during the 2009 heat wave, admissions showed an almost 14-fold increase. Emergency presentations generally increased 2.7-fold, but were 12-fold higher in 2009. It is possible that, ICD codes for direct heat-related diseases were not routinely utilised for diagnosis during previous heat waves but were used more rigorously during the extreme heat wave in 2009. This change in use may have inflated the ICD coding for direct heat-related cases on this occasion.

Evidence from previous heat wave investigations in Adelaide indicated that mortality was generally not impacted by heat waves, in fact, mortality even decreased in the two elderly age groups (65–74 year and 75+ age groups). This changed during the 2008 and 2009 heat waves, where statistically significant increases in mortality were observed in the 0–4 year age group in 2008 and in the 15–65 year age group in 2009. Total excess mortality was more pronounced in 2009. Contrary to the experience in other countries, excess mortality was not seen in Adelaide's elderly population (65–74 year and 75+ age groups) (28). Studies in Europe and the USA identified the following vulnerabilities in elderly populations that contributed to deaths during extreme heat: pre-existing illnesses, socioeconomic factors, institutional living without air-conditioning, and housing characteristics that enhance thermal heat (28). It could be argued that the absence of increased elderly deaths in Adelaide may be due to generally high standards of care provided to elderly people during heat waves. The extra interventions apportioned to the elderly population at risk during the 2009 heat wave may have largely prevented excess deaths.

The 2009 heat wave occurred simultaneously in Victoria and Adelaide. The observed mortality rate in Victoria increased by 62 per cent above the expected rate (http://www.health.vic.gov.au/chiefhealthofficer/downloads/heat_impact_rpt.pdf). The Victorian study used a different statistical approach to the Adelaide investigation, but the obvious difference in mortality risk during the heat wave cannot be attributed solely to the different approach in calculating expected number of deaths. The reasons for the marked differences are more likely to be location specific, such as differences in population and weather-related parameters. Similar differences in mortality risks between cities have been observed in the 2003 heat wave in France, and the importance of location-specific investigations are strongly supported in heat wave literature (8) (33) (28).

Further studies are recommended to assess in detail the progression of disease processes and risk factors during heat waves in South Australia including:

> case-control studies to examine individual risk factors (reported in either patient case-notes or gathered by asking next of kin) that are evident in cases (deaths) compared to controls.

> survey of the elderly and their perceptions of risk during recent heat waves

> time-series studies to examine the modifying effect of air quality during heat waves on health outcomes (e.g. ozone and dust-PM10).

> geo-spatial studies of health outcomes during heat waves

References

(1) Heat Health Action Plans. Copenhagen: WHO Regional Office for Europe; 2008.

(2) Kovats SR, Ebi KL. Heatwaves and public health in Europe. Eur J Public Health 2006;16:592-9.

(3) Semenza JC, Rubin CH, Falter KH, Selanikio JD, Flanders WD, Howe HL, et al. Heat-Related Deaths during the July 1995 Heat Wave in Chicago. The New England Journal of Medicine 1996 Jul 11;335(2):84-90.

(4) Kaiser R, Le TA, Schwartz J, Gotway CA, Daley WR, Rubin CH. The effect of the 1995 heat wave in Chicago on all-cause and cause-specific mortality. American Journal of Public Health 2007 Apr;97:Suppl-62.

(5) Johnson H, Kovats RS, McGregor G, Stedman J, Gibbs M, Walton H. The impact of the 2003 heat wave on mortality and hospital admission in England. Health Stat Q 2005;25:6-11.

(6) Semenza JC, McCullough JE, Flanders WD, McGeehin MA, Lumpkin JR. Excess hospital admissions during the July 1995 heat wave in Chicago.[see comment]. American Journal of Preventive Medicine 16(4):269-77, 1999 May.

(7) Naughton MP, Henderson A, Mirabelli MC, Kaiser R, Wilhelm JL, Kieszak SM. Heat related mortality during a 1995 heatwave in Chicago. Am J Prev Med 2002;22:221-7.

(8) Vandentorren S, Suzan F, Medina S, Pascal M, Maulpoix A, Cohen JC. Mortality in 13 French cities during the August 2003 heat wave. Am J Public Health 2004;94:1518-20.

(9) Fouillet A, Rey G, Laurent F, Pavillon G, Bellec S, Guihenneuc-Jouyaux C. Excess mortality related to the August 2003 heat wave in France. Int Arch Occup Environ Health 2006;80:16-24.

(10) Conti S, Meli P, Minelli G, Solimini R, Toccaceli V, Vichi M, et al. Epidemiologic study of mortality during the Summer 2003 heat wave in Italy. Environmental Research 98(3):390-9, 2005 Jul.

(11) Conti S, Masocco M, Meli P, Minelli G, Palummeri E, Solimini R, et al. General and specific mortality among the elderly during the 2003 heat wave in Genoa (Italy). Environmental Research 2007 Feb;103(2):267-74.

(12) Kosatsky T. The 2003 European heat waves. Euro Surveill 2005;10(7):148-9.

(13) Johnson H, Kovats RS, McGregor G, Stedman J, Gibbs M, Walton H, et al. The impact of the 2003 heat wave on mortality and hospital admissions in England. Health Statistics Quarterly (25):6-11, 2005.

(14) Michelozzi P, de DF, Bisanti L, Russo A, Cadum E, DeMaria M, et al. The impact of the summer 2003 heat waves on mortality in four Italian cities. Euro Surveillance: Bulletin Europeen sur les Maladies Transmissibles = European Communicable Disease Bulletin 2005 Jul;10(7):161-5.

(15) Kovats RS, Hajat S, Wilkinson P. Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in Greater London, UK. Occup Environ Med 2004;61:893-8.

(16) Dhainaut JF, Claessens YE, Ginsburg C, Riou B. Unprecedented heat-related deaths during the 2003 heat wave in Paris: consequences on emergency departments. Critical Care 2004;8:1-2.

(17) Dolney J, Sheridan SC. The relationship between extreme heat and ambulance response calls for the city of Toronto, Ontario, Canada. Environmental Research 2006;101:94-103.

(18) Knowlton K, Rotkin-Ellman M, King G, Margolis HG, Smith D, Solomon G, et al. The 2006 California heat wave: impacts on hospitalizations and emergency department visits. Environmental Health Perspectives 2009 Jan;117(1):61-7.

(19) Nitschke M, Tucker G, Bi P. Morbidity and mortality during heatwaves in metropolitan Adelaide. Medical Journal of Australia 187[11/12], 662-665. 2007.

(20) Hansen AL, Bi P, Ryan P, Nitschke M, Pisaniello D, Tucker G. The effect of heat waves on hospital admissions for renal disease in a temperate city of Australia. Int J Epidemiol 2008 Aug 18;dyn165.

(21) Hansen A, Bi P, Nitschke M, Ryan P, Pisaniello D, Tucker G. The effect of heat waves on mental health in a temperate Australian city. Environmental Health Perspectives 2008 Oct;116(10):1369-75.

(22) Stafoggia M, Forastiere F, Agostini D, Biggeri A, Bisanti L, Cadum E, et al. Vulnerability to heat-related mortality: a multicity, population-based, case-crossover analysis. Epidemiology 17(3):315-23, 2006 May.

(23) Hajat S, Kovats RS, Lachowycz K. Heat-related abd cold-related deaths in England and Wales: who is at risk? Occup Environ Med 2007;64:93-100.

(24) Whitaker HJ, Farrington CP, Spiessens B, Musonda P. Tutorial in biostatistics: the self-controlled case series method. Statistics in Medicine 25(10):1768-97, 2006 May 30.

(25) Whitaker HJ, Hocine MN, Farrington CP. The methodology of self-controlled case series studies. Statistical Methods in Medical Research 2009 Feb 1;18(1):7-26.

(26) Navidi W. Bidirectional case-crossover designs for exposures with time trends. Biometrics 1998;54(2):596-605.

(27) Farrington CP, Whitaker HJ. Semi-parametric analysis of case series data. The Open University Milton Keynes MK7 6AA, UK; 2004.

(28) Kovats RS, Hajat S. Heat stress and public health: a critical review. Annu Rev Public Health 2008;29:41-55.

(29) Stata Statistical Software [computer program]. Version Release 10. College Station: TX: StataCorp; 2007.

(30) National Climate Centre. An Exceptional and Prolonged Heatwave in Southern Australia. Melbourne: Bureau of Meteorology; 20098.

(31) National Climate Centre. The exceptional January-February 2009 heatwave in south-eastern Australia. Melbourne: Bureau of Meteorology; 2009.

(32) Mastrangelo G, Hajat S, Fadda E, Buja A, Fedeli U, Spolaore P. Contrasting patterns of hospital admissions and mortality during heat waves: are deaths from circulatory disease a real excess or an artefact? Medical hypotheses 2006;66:1025-8.

(33) Sheridan SC, Kalkstein LS. Progress in heat watch-warning system technology. American Meteorological Society 2004;1931-41.