Morbidity and mortality during heatwaves in metropolitan Adelaide

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ABSTRACT

Objective: To investigate morbidity and mortality associated with heatwaves in metropolitan Adelaide using ambulance, hospital admission, and mortality data.

Design, participants and setting: Case-series study comparing health risks in the Adelaide metropolitan population during heatwaves and non-heatwave periods.

Main outcome measures: Daily observations for ambulance transports (1993–2006), hospital admissions (1993–2006), and mortality (1993–2004), categorised using International classification of diseases (ninth and tenth revisions) codes for the relevant disease groups.

Results: During heatwaves, total ambulance transport increased by 4% (95% CI, 1%–7%), including significant assault-related increases for people aged 15–64 years. Reductions were observed in relation to cardiac, sports- and falls-related events. Total hospital admissions increased by 7% (95% CI, –1% to 16%). Total mental health admissions increased by 7% (95% CI, 1%–13%), and total renal admissions by 13% (95% CI, 3%–25%). Ischaemic heart disease admissions increased by 8% (95% CI, 1%–15%) among people aged 65–74 years. Total mortality, disease- and age-specific mortality did not increase, apart from a small increase in mental health-related mortality in people aged 65–74 years. Significant decreases were observed in cardiovascular-related mortality.

Conclusion: In contrast to evidence from extreme heatwaves in the northern hemisphere, we found no excess mortality during heatwaves in metropolitan Adelaide, perhaps because of adaptive behaviour to regular hot weather spells. Projected temperature increases and evidence of modest increases in morbidity during heatwaves indicate the need for a heatwave response plan for Adelaide.

MJA 2007; 187: 662–665

Epidemiological investigations following the record-breaking European heatwave in 2003 estimated 14 802 excess deaths in France.[1] Excess mortality was also observed in other European countries, and it has been estimated that overall more than 30 000 people may have died prematurely during this period.[2-4]

Recent weather predictions for Adelaide, the capital of South Australia, suggest average summer temperatures will rise 0.4–1.3° C by 2030 and 0.8–4.0° C by 2070.[5] An increase in average summer temperatures is likely to increase the number of heatwaves. Therefore, it is timely to assess local evidence of acute health effects of heatwaves in Adelaide. We compared daily ambulance use, hospital admissions, and mortality between heatwaves and non-heatwave periods during 13 recent summers.

METHODS

Ambulance data

Daily incidence data of ambulance transports from the South Australian Ambulance Service were available for 13 years from July 1993 to June 2006. Patient transfers between hospitals were excluded. South Australian Ambulance Service categories used in the analysis were ambulance call-outs related to assault; work, road or sport accidents; falls; blunt traumas; and cardiac, respiratory or neurological conditions.

Hospital admission and mortality data

Daily cases of hospital admission from 1993 to 2006 and mortality from 1993 to 2004 were analysed using the International classification of diseases (revisions 9 and 10) categories for total cardiovascular (ICD-9, 390–4599; ICD-10, I00–I99), ischaemic (ICD-9, 410–4149; ICD-10, I20–I25), cerebrovascular (ICD-9, 430–4489; ICD-10, I60–I69), respiratory (ICD-9, 460–5199; ICD-10, J00–J99), mental (ICD-9, 290–294-9, 580–5999; ICD-10, N00–N39) diseases. Selection of the broad disease categories was informed by previously published heatwave investigations.[6-8]

Heatwaves

Daily maximum temperatures for the required periods were obtained from the Bureau of Meteorology Kent Town location, which is representative for Adelaide metropolitan conditions. In the absence of a universal criterion, we defined a heatwave as a period in which the daily maximum temperature was ⩾ 35° C for 3 or more consecutive days, consistent with hotter than usual weather for Adelaide over an extended period.[7,9]

Statistical analysis

Rates of daily events for hospital admissions, mortality and ambulance use were calculated, and the average daily rates during heatwave episodes were compared with average daily rates during non-heatwave periods during spring and summer.

In this study, the risk period refers to defined heatwave episodes.

The data were analysed using a case-series approach. The analysis was conducted within years, and therefore implicitly adjusts for long-term trends.[10] Seasonality was controlled for by excluding autumn and winter. We fitted Poisson regression models using Stata, version 9.2 (StataCorp, College Station, Tex, USA). Each model was tested for fit, and negative binomial models were used to deal with any significant over-dispersion. The models provide estimates of the relative incidence of events, and the results are expressed as incidence rate ratios (IRRs).

RESULTS

Our data included 4748 observation days for ambulance transports and hospital admissions, and 4193 days for mortality. Applying our definition, there were 31 heatwaves, extending over a total of 120 days. The mean length of the heatwaves was 3.9 days, with the longest episode lasting 8 days.

Box 1 provides an overview of daily summary statistics for ambulance call-outs, hospital admissions, and mortality, including

1 Descriptive statistics for total and disease-specific categories of daily incidences of ambulance transports, hospital admissions (1993–2006) and mortality (1993–2004) for metropolitan Adelaide

Description	Minimum	Maximum	Mean	SD	Median
Ambulance transport (4748 observation days)					
Non-heatwaves (autumn/winter) (2391 days)	89	331	169.8	41.7	159
Non-heatwaves (spring/summer) (2237 days)	84	292	163.9	41.6	154
Heatwaves (spring/summer) (120 days)	110	254	170.2	41.2	160
Total ambulance transports	84	331	167.0	41.7	157
Assault	0	25	6.4	3.8	6
Work-related	0	7	1.2	1.2	1
Road-motor vehicle accident	0	23	6.9	3.6	6
Other road accidents	0	7	0.9	1.0	1
Sport-related	0	17	2.7	2.1	2
Falls	0	35	14.2	5.4	14
Blunt injury	0	37	10.5	4.5	10
Cardiac	1	66	25.2	6.9	25
Respiratory	0	48	14.8	6.1	14
Neurological	1	47	16.6	7.6	15
Hospital admissions (4748 observation days)					
Non-heatwaves (autumn/winter) (2391 days)	263	1766	1065.5	442.9	1228
Non-heatwaves (spring/summer) (2237 days)	202	1796	1024.9	446.9	1163
Heatwaves (spring/summer) (120 days)	342	1674	1110.6	408.0	1260
Total hospital admissions	202	1796	1047.5	444.4	1195
Cardiovascular	17	137	72.7	24.6	79
Ischaemic	6	60	25.3	8.7	25
Stroke	0	20	6.8	2.9	7
Other	4	82	40.8	16.8	45
Respiratory	13	138	57.9	20.8	57
Mental	5	213	35.6	13.8	38
Renal	1	49	20.4	9.6	21
Mortality (4193 observation days)					
Non-heatwaves (autumn/winter) (2116 days)	6	57	28.7	7.3	28
Non-heatwaves (spring/summer) (1964 days)	3	50	25.1	6.6	25
Heatwaves (spring/summer) (113 days)	8	40	23.3	6.7	23
Total deaths	3	57	26.8	7.2	26
Cardiovascular	0	31	11.0	4.3	11
Ischaemic	0	20	6.0	2.9	6
Stroke	0	12	3.0	2.0	3
Other	0	10	2.4	1.6	2
Respiratory	0	11	2.6	1.8	2
Mental	0	5	0.6	0.8	0
Renal	0	5	0.3	0.6	0

average daily incidence during heatwaves and non-heatwave periods.

During heatwaves, total ambulance transports increased by 4% (95% CI, 1%–7%) (Box 2). An increase of 13% (95% CI, 3%–24%) was observed in assault-related injuries among people aged 15–64 years, and a non-significant 37% (95% CI, –3% to 93%) increase for respiratory-related ambulance transports in children aged 5–14 years (P = 0.074). Decreases in sports-related transports (36%; 95% CI, 18%–51%), falls (40%; 95% CI, 16%–57%) and blunt trauma (21%; 95% CI, 0–37%) were observed in children aged 5–14 years. Motor vehicle-related ambulance transports fell by 33% (95% CI, 3%–53%) among people aged 75 years and older, and cardiac-related transports in this group fell by 7% (95% CI, 2%–13%). The IRRs for the remaining categories were close to 1.

During heatwaves, an increase in total hospital admissions of 7% (95% CI, –1% to 16%) (P = 0.095) was observed (Box 3), and increases were observed in age groups 15–64 years, 65–74 years, and 75 years and older. Total mental health-related admissions increased by 7% (95% CI, 1%–13%) and total renal disease admissions by 13% (95% CI, 3%–25%). Increases were observed largely in all age groups for mental health admissions, and in the 15–64 years, 65–74 years, and 75 years and older age groups for renal health admissions. Total and age group-specific cardiovascular admissions did not increase, and a significant reduction was seen among people aged 75 years and older. Analysis for temperature-sensitive cardiovascular subcategories such as ischaemic heart disease and stroke showed no major heatwave effects, apart from an increase in admissions for ischaemic heart disease by 8% (95% CI, 1%–15%) among people aged 65–74 years. In contrast, a decrease was seen among people aged 75 years and older. Decreases were also observed for respiratory admissions among people aged 75 years and older, and for children aged 0–4 years.

During heatwaves, all-age mortality was not affected (Box 4), but for people aged 75 years and older, mortality fell by 7% (95% CI, 2%–11%). In the cardiovascular diseases group, reductions were detected for all-age mortality, and in the 65–74 years and 75 years and older age subgroups. The only heatwave-related rise in daily incidence rates was seen in the form of an increase in the incidence of mental disease-related mortality in the 65–74 years age group (IRR, 2.58; 95% CI, 0.96–6.93; P = 0.060).

DISCUSSION

Our investigation of the health effects of heatwaves in Adelaide showed mixed results, with average increases in total ambulance call-outs of 6.3 extra daily cases and a small increase in hospital admissions adding an average of an extra 85.7 daily cases (Box 1). The increases in all-age hospital admissions were significant for the renal and mental diseases groups. On the other hand, there were surprising reductions in hospital admissions, and mortality fell for all

2 Ambulance transport incidence rate ratios (IRRs)*

Ambulance categories	Age groups in years (IRR [95% CI])					
	All ages	0–4	5–14	15–64	65–74	≥ 75
Total ambulance	1.04 (1.01–1.07)	1.00 (0.94–1.08)	0.98 (0.90–1.06)	1.08 (1.04–1.12)	1.02 (0.98–1.06)	1.01 (0.99–1.04)
Assault	1.06 (0.99–1.14)	1.17 (0.84–1.63)	0.89 (0.57–1.39)	1.13 (1.03–1.24)	1.11 (0.88–1.39)	0.96 (0.85–1.08)
Work	1.10 (0.93–1.30)	—	—	1.12 (0.94–1.33)	—	—
Road-motor vehicle accidents	0.98 (0.91–1.06)	0.74 (0.46–1.20)	0.96 (0.73–1.27)	1.01 (0.94–1.10)	0.99 (0.72–1.38)	0.67 (0.47–0.97)
Other road accidents	0.93 (0.76–1.13)	1.51 (0.53–4.29)	0.83 (0.44–1.59)	1.04 (0.81–1.33)	0.95 (0.48–1.89)	0.54 (0.28–1.04)
Sport	0.84 (0.69–1.03)	—	0.64 (0.49–0.82)	0.98 (0.76–1.27)	0.75 (0.36–1.52)	0.77 (0.49–1.23)
Falls	0.94 (0.89–0.99)	1.01 (0.75–1.36)	0.60 (0.43–0.84)	0.97 (0.88–1.08)	0.98 (0.84–1.13)	0.96 (0.89–1.03)
Blunt trauma	1.00 (0.94–1.06)	1.06 (0.78–1.45)	0.79 (0.63–1.00)	1.03 (0.97–1.10)	0.93 (0.70–1.22)	0.89 (0.71–1.12)
Cardiac	0.98 (0.94–1.02)	1.21 (0.85–1.74)	0.69 (0.25–1.90)	1.03 (0.96–1.10)	1.03 (0.95–1.11)	0.93 (0.87–0.98)
Respiratory	0.98 (0.93–1.03)	0.96 (0.78–1.20)	1.37 (0.97–1.93)	1.01 (0.91–1.11)	0.95 (0.84–1.07)	0.93 (0.86–1.02)
Neurological	1.00 (0.95–1.04)	1.15 (0.94–1.41)	0.96 (0.74–1.26)	1.01 (0.95–1.08)	0.95 (0.82–1.09)	0.96 (0.87–1.05)

* The IRRs are based on daily mean incidence of ambulance transport during heatwaves (≥ 35°C over 3 days or more) over incidence during non-heatwave periods in metropolitan Adelaide, controlled for trend over years and adjusted for seasonality using conditional fixed-effects Poisson regression.
— = insufficient data to produce a reliable estimate. Shaded cells are significant at $P < 0.05$. ◆

3 Hospital admission incidence rate ratios (IRRs)*

Hospital admissions categories	Age groups in years (IRR [95% CI])					
	All ages	0–4	5–14	15–64	65–74	≥ 75
Total hospital admissions	1.07 (0.99–1.16)	0.99 (0.94–1.04)	1.03 (0.95–1.12)	1.08 (1.00–1.18)	1.08 (0.99–1.18)	1.06 (0.98–1.15)
Cardiovascular	0.99 (0.92–1.07)	0.82 (0.45–1.52)	1.01 (0.60–1.68)	1.03 (0.93–1.13)	1.00 (0.91–1.08)	0.95 (0.90–1.00)
Ischaemic	1.01 (0.94–1.08)	—	—	1.04 (0.94–1.17)	1.08 (1.01–1.15)	0.91 (0.85–0.97)
Stroke	0.94 (0.87–1.01)	—	—	0.84 (0.70–1.00)	0.89 (0.77–1.04)	0.99 (0.89–1.09)
Other	0.99 (0.90–1.08)	—	—	1.03 (0.91–1.17)	0.95 (0.86–1.06)	0.96 (0.89–1.05)
Respiratory	0.97 (0.88–1.06)	0.86 (0.76–0.97)	1.00 (0.87–1.15)	1.03 (0.93–1.16)	0.97 (0.90–1.05)	0.90 (0.82–0.98)
Mental	1.07 (1.01–1.13)	1.52 (0.99–2.32)	1.09 (0.85–1.39)	1.05 (0.99–1.11)	1.12 (1.00–1.26)	1.17 (1.07–1.28)
Renal	1.13 (1.03–1.25)	0.98 (0.78–1.23)	0.85 (0.63–1.15)	1.16 (1.04–1.30)	1.10 (0.92–1.32)	1.11 (0.99–1.25)

* The IRRs are based on daily mean incidence of hospital admission during heatwaves (≥ 35°C over 3 days or more) over incidence during non-heatwave periods in metropolitan Adelaide, controlled for trend over years and adjusted for seasonality using conditional fixed-effects Poisson regression.
— = insufficient data to produce a reliable estimate. Shaded cells are significant at $P < 0.05$. ◆

disease categories except mental health. The decreases in risks during heatwaves were particularly manifest among people aged 75 years and older.

This study is the first systematic approach to quantifying health effects during heatwaves in an Australian city. Our results have the potential to assist in health services planning and provide baseline information for heatwave-related health effects. We focused on excess health risks during heatwaves, which can be underestimated in the time-series study approach.[11] Our study design has limited resolution in relation to more detailed disease information, and is not able to explore heatwave effects beyond the acute hazard period. Furthermore, we could not address the issue of potential confounding by air pollution because of limited availability of relevant air quality data before 2001.

Only a few studies have explored ambulance use and hospital admissions during heatwaves. Similar to many mortality studies, they have been restricted to single-episode studies during excessive heatwaves in the northern hemisphere. The excess risks observed in these overseas studies (2.6% and 11% for total hospital admissions, and 10% for ambulance call-outs), as well as the relevant disease pattern indicating modest increases in mental and renal disease, compare well with our findings.[6,12,13]

Contrary to the mostly inverse relationship between mortality and heatwaves that we found, high risks of mortality (ranging from 9% to 150%) were observed in other cities, pointing to intense and prolonged heatwaves to which the population had not had the opportunity to adapt.[3,6] The discrepancy in magnitude of risk between hospital admissions and mortality observed in the overseas studies has led to the insight that mortality during intense heatwaves can occur without much warning in the sensitive population.[7,14]

Our results have implications for the future. Reductions of health risks, especially in relation to mortality in the elderly population, indicate that the population is currently well adapted to heatwaves. Post-heatwave risk factors research suggests that the positive outcome could be due to the high prevalence of air-conditioning (82%) in Adelaide; factors such as good care of the elderly and social cohesion could also have contributed.[15-19]

Considering the increased risks observed in this study, it will be necessary to focus on the specific underlying diseases, the circum-

4 Mortality incidence rate ratios (IRRs)*

Mortality categories	Age groups in years (IRR [95% CI])					
	All ages	0–4	5–14	15–64	65–74	⩾ 75
Total mortality	0.95 (0.90–1.01)	1.19 (0.82–1.71)	1.15 (0.58–2.29)	0.98 (0.89–1.07)	0.97 (0.85–1.10)	0.93 (0.89–0.98)
Cardiovascular	0.90 (0.84–0.96)	—	—	1.06 (0.87–1.28)	0.81 (0.69–0.96)	0.90 (0.83–0.97)
Ischaemic	0.91 (0.83–0.99)	—	—	1.13 (0.80–1.60)	0.76 (0.61–0.94)	0.93 (0.83–1.03)
Stroke	0.84 (0.74–0.96)	—	—	0.91 (0.56–1.50)	0.72 (0.50–1.04)	0.86 (0.74–0.99)
Other	0.91 (0.74–1.12)	—	—	0.98 (0.45–2.16)	1.12 (0.80–1.57)	0.86 (0.73–1.01)
Respiratory	0.92 (0.80–1.05)	—	—	1.12 (0.72–1.74)	1.14 (0.85–1.54)	0.84 (0.72–0.99)
Mental	1.04 (0.73–1.47)	—	—	1.24 (0.53–2.91)	2.58 (0.96–6.93)	0.87 (0.64–1.18)
Renal	0.84 (0.59–1.19)	—	—	—	1.06 (0.32–3.48)	0.83 (0.57–1.21)

* The IRRs are based on daily mean incidence of mortality during heatwaves (⩾ 35°C over 3 days or more) over incidence during non-heatwave periods in metropolitan Adelaide, controlled for trend over years and adjusted for seasonality using conditional fixed-effects Poisson regression.
— = insufficient data to produce a reliable estimate. Shaded cells are significant at $P < 0.05$. ◆

stances leading to admissions, comorbidities, and the population affected. Further studies should consider the socioeconomic and infrastructural issues of the heat-sensitive population groups.

CONCLUSION

Our quantitative assessment of 13 years of heatwave-related health data for Adelaide found moderate increases in morbidity (increased rates of ambulance call-outs and hospital admissions), particularly for renal and mental diseases. In contrast to evidence from extreme heatwaves in other countries, we did not observe excess mortality in metropolitan Adelaide. We believe this is due to behavioural adaptation to regular hot weather spells. To prevent possible rapid increases in mortality in future due to changing weather conditions, we recommend development of a heatwave response plan.

COMPETING INTERESTS

None identified.

AUTHOR DETAILS

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REFERENCES

1 Le Tertre A, Lefranc A, Eilstein D, et al. Impact of the 2003 heatwave on all-cause mortality in 9 French cities. *Epidemiology* 2006; 17: 75-79.
2 Conti S, Meli P, Minelli G, et al. Epidemiologic study of mortality during the Summer 2003 heatwave in Italy. *Environ Res* 2005; 98: 390-399.
3 Johnson H, Kovats RS, McGregor G, et al. The impact of the 2003 heatwave on daily mortality in England and Wales and the use of rapid weekly mortality estimates. *Euro Surveill* 2005; 10: 161-165.
4 Kosatsky T. The 2003 European heatwaves. *Euro Surveill* 2005; 10: 148-149.
5 Suppiah R, Preston B, Whetton PH, et al. Climate change under enhanced greenhouse conditions in South Australia. Melbourne: CSIRO Marine and Atmospheric Research, 2006. http://www.cmar.csiro.au/e-print/open/suppiahr_2006a.pdf (accessed July 2007).
6 Kovats RS, Hajat S, Wilkinson P. Contrasting patterns of mortality and hospital admissions during hot weather and heatwaves in Greater London, UK. *Occup Environ Med* 2004; 61: 893-898.
7 Mastrangelo G, Hajat S, Fadda E, et al. Contrasting patterns of hospital admissions and mortality during heatwaves: are deaths from circulatory disease a real excess or an artifact? *Med Hypotheses* 2006; 66: 1025-1028.
8 Hajat S, Kovats RS, Lachowycz K. Heat-related and cold-related deaths in England and Wales: who is at risk? *Occup Environ Med* 2007; 64: 93-100.
9 Bouchama A, Knochel JP. Heat stroke. *N Engl J Med* 2002; 346: 1978-1988.
10 Farrington CP, Whitaker HJ. Semi-parametric analysis of case series data. *J R Stat Soc Ser C Appl Stat* 2006; 55: 553-594.
11 Hajat S, Armstrong B, Baccini M, et al. Impact of high temperatures on mortality. *Epidemiology* 2006; 17: 632-638.
12 Dolney J, Sheridan SC. The relationship between extreme heat and ambulance response calls for the city of Toronto, Ontario, Canada. *Environ Res* 2006; 101: 94-103.
13 Semenza JC, Rubin CH, Falter KH, et al. Heat-related deaths during the July 1995 heatwave in Chicago. *N Engl J Med* 1996; 335: 84-90.
14 Diaz J, Linares C, Tobias A. A critical comment on heatwave response plans. *Eur J Public Health* 2006; 16: 600.
15 Ebi KL, Schmier JK. A stitch in time: improving public health early warning systems for extreme weather events. *Epidemiol Rev* 2005; 27: 115-121.
16 Davis RE, Knappenberger PC, Michaels PJ, Novicoff WM. Changing heat-related mortality in the United States. *Environ Health Perspect* 2003; 111: 1712-1718.
17 Australian Bureau of Statistics. Domestic use of water and energy, South Australia. Canberra: ABS, 2004. (ABS Catalogue No. 4618.4.)
18 Naughton MP, Henderson A, Mirabelli M, et al. Heat-related mortality during a 1999 heat wave in Chicago. *Am J Prev Med* 2002; 22: 221-227.
19 Vandentorren S, Bretin P, Zeghnoun A, et al. August 2003 heat wave in France: risk factors for deaths of elderly people living at home. *Eur J Public Health* 2006; 16: 583-591.

(Received 25 Jul 2007, accepted 31 Oct 2007) ❑