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Temperature Variation and Emergency Hospital Admissions for Stroke in Brisbane, Australia, 1996 – 2005

Xiao Yu Wang[a], Adrian G. Barnett[a], Wenbiao Hu[b], Shilu Tong[a*]

[a]School of Public Health, and Institute of Health and Biomedical Innovation, Queensland University of Technology, Australia.

[b]School of Population Health, University of Queensland, Australia

***Corresponding author:**

Dr. S. Tong, School of Public Health, and Institute of Health and Biomedical Innovation, Queensland University of Technology, Kelvin Grove, Qld. 4059, Australia.

Facsimile: +61-7-3138 3369; Telephone: +61-7-3138 9745

Email: s.tong@qut.edu.au

Abstract

Stroke is a leading cause of disability and death. This study evaluated the association between temperature variation and emergency admissions for stroke in Brisbane, Australia. Daily emergency admissions for stroke, meteorologic and air pollution data were obtained for the period of January 1996 to December 2005. The relative risk of emergency admissions for stroke was estimated with a generalized estimating equations (GEE) model. For primary intracerebral hemorrhage (PIH) emergency admissions, the average daily PIH for the group aged < 65 increased by 15% (95% Confidence Interval (CI): 5, 26%) and 12% (95% CI: 2, 22%) for a 1°C increase in daily maximum temperature and minimum temperature in summer, respectively, after controlling for potential confounding effects of humidity and air pollutants. For ischemic stroke (IS) emergency admissions, the average daily IS for the group aged ≥ 65 decreased by 3% (95% CI: -6, 0%) for a 1°C increase in daily maximum temperature in winter after adjustment for confounding factors. Temperature variation was significantly associated with emergency admissions for stroke, and its impact varied with different type of stroke. Health authorities should pay greater attention to possible increasing emergency care for strokes when temperature changes, in both summer and winter.

Keywords Emergency admissions, Season, Stroke, Temperature

Introduction

Stroke is a serious public health issue. For example, stroke is one of the major causes of death in the United States (ASA 2008). In Australia, stroke is a leading cause of disability and the second single greatest killer after coronary heart disease (SF 2008). One in five people die within one month after having a first stroke, and one in three die within a year. About 80 percent of all strokes occur to people over 55 years old. In the next ten years more than half a million people will suffer a stroke in Australia (SF 2008).

A number of studies have examined the influence of meteorological factors and seasonal variation upon stroke incidence (Piver et al. 1999; Oberg et al. 2000; Field et al. 2002; Hong et al. 2003; Wang et al. 2003; Chang et al. 2004; Liu et al. 2004; Kyobutungi et al. 2005; Jalaludin et al. 2006; Low et al. 2006; Kettunen et al. 2007; Myint et al. 2007; Dawson et al. 2008; Jimenez-Conde et al. 2008; Turin et al. 2008). These studies show that there were different patterns in stroke incidences across different areas during different periods. For example, several investigators observed the highest stroke incidence rates during summer (Piver et al. 1999; Oberg et al. 2000; Kettunen et al. 2007), while others found peak incidences in either winter (Wang et al. 2003; Jalaludin et al. 2006; Myint et al. 2007) or spring (Oberg et al. 2000; Turin et al. 2008). There is little agreement concerning the relationship between weather and the incidence of stroke, and additionally, few data are available on the relationship between temperature and stroke in a subtropical climate where people are acclimatised to warm weather.

We aimed to assess this relationship so that useful information can be obtained for planning and implementing stroke control and prevention programs. The purpose of this study was three fold: 1) to investigate the relationship between temperature variation and stroke emergency hospital admissions in Brisbane – a subtropical city; 2) to assess the confounding effects of other variables (e.g., humidity and air pollutants); and 3) to examine the impact of temperature variation on different stroke types in different seasons.

Methods

The data set used in this study consisted of ten-year time series of health outcomes, climate, and air pollution collected in Brisbane city from the 1st January 1996 to the 31st December 2005 (3,653 days). Brisbane is the state capital of Queensland, Australia, and has a sub-tropical climate with the latitude $27^{o}29'$S and longitude $153^{o}8'$E. It is Australia's third largest city, covering an urban area of 1326.8 km^2 with a population size of 896,649 on 1 July 2001 (BCC 2008).

Health outcome data were provided by the Health Information Centre of Queensland Health. The data included principal diagnosis and the day, month and year of emergency admission; age groups (0 – 14, 15 – 64, 65 – 74, 75 +); and the number of admitted patient episodes of care. Stroke data included subtypes such as subarachnoid hemorrhagic stroke (SHS; ICD-9 code 430, ICD-10 code I60), primary intracerebral hemorrhage (PIH; ICD-9 codes 431 to 432, ICD-10 codes I61 to I62), ischemic stroke (IS; ICD-9 codes 433 to 435, ICD-10 codes I63, I65 to I66), and other stroke (ICD-9 codes 436 to 438, ICD-10 codes I64, I67 and I69) (Tsai et al. 2003; Adams 2004).

Daily meteorologic data from four monitoring stations in Brisbane were provided by the Australia Bureau of Meteorology. The arithmetic average values of minimum temperature, maximum temperature and relative humidity were computed using the data from these stations. Air pollution data (including ambient 24-hour average concentrations of PM_{10} and daily average maximum 1-hour NO_2, O_3 and SO_2 concentrations) were provided by the Queensland Environmental Protection Agency. For each day, air pollution data were extracted from seventeen monitoring stations in Brisbane and averaged. When daily data were missing for a particular monitoring station, the observations recorded from the other monitoring stations were used to compute the daily average values.

We conducted univariate analyses to characterise each dependent and independent variables. We investigated the impact of heat and cold on emergency admissions for stroke separately using a generalized estimating equation (GEE) approach with a Poisson distribution (Agresti 2007; Fouillet et al. 2007; Baccini et al. 2008). GEE is a form of generalised linear model in which a correlation structure is specified for clusters of observations (Johnston et al. 1997). For this analysis each 3 month period was defined as a separate cluster. Observations during a single summer or winter period were assumed to be correlated while observations from different seasons were assumed to be independent. A prior definition of summer (1 December to 28 [or 29 for Leap year] February) and winter (1 June to 31 August) season was adopted for all the analyses. A similar approach was adopted by Fouillet et al (2007) and Baccini et al (2008). We used this model to regress daily PIH and IS emergency admissions with temperature (minimum and maximum) by season after adjustment for humidity and air pollutants (PM_{10}, NO_2, O_3 and SO_2). The confounding factors of humidity and air pollutants were adjusted for in the model as continuous variables. Analyses were performed using SAS V9.1 (SAS 2002 - 2003).

Results

There were 12,387 hospital emergency admissions for stroke in Brisbane city during the study period, including 577 SHS (5% of total strokes), 1,835 PIH (15%), 6,743 IS (54%), and 3,232 other strokes (26%). PIH and IS accounted for over two-thirds (69%) of all emergency admissions for stroke. Table 1 shows the statistical summary for both dependent (i.e., emergency admissions for SHS, PIH, IS, other types of stroke, and all stroke) and independent variables (i.e., maximum and minimum temperature, humidity, PM_{10}, NO_2, O_3 and SO_2). During the study period, there were on average 3 stroke emergency admissions every day in Brisbane (range: 0 – 12). The overall mean maximum and minimum temperature was 26.3°C and 14.7°C, respectively.

Brisbane's air pollution level was low compared with other metropolitan cities (Piver et al. 1999; Tsai et al. 2003; Wellenius et al. 2005) and the National Environmental Protection Measures (NEPM) for Ambient Air Quality standards (NEPC 2008). There were only 15 days which exceeded the NEPM standard of 50 $\mu g/m^3$ for 24-hour average concentrations of PM_{10}, and the levels of all other air pollutants were under NEPM standard.

[Table 1 about here]

In this study, we focused on PIH and IS because there were few cases of SHS (5%), and the other stroke causes of stroke (26%) were too complex. We also focused on two seasons, i.e., winter (between June and August) and summer (between December and February), because the associations between weather and PIH / IS were stronger during these periods.

Figure 1 shows the different patterns of PIH and IS in winter and summer for maximum and minimum temperatures. In winter, the risk of IS somewhat increased between 1–11°C and then decreased between 11–16°C for minimum temperature. However, the incidence of PIH was relatively stable between 1–6°C and then lightly decreased between 6–16°C. In summer, the incidence of PIH increased between minimum temperature of 11–16°C then remained relatively stable between 16–21°C, and then directly decreased between 21–26°C. The incidence of IS was relatively stable between 11–21°C and then slightly decreased between 21–26°C for minimum temperature. The incidence of PIH decreased when maximum temperature increased in both winter and summer. The incidence of IS increased between 11–21°C and then abruptly decreased between 21–26°C in winter. However, there was an opposite trend for summer, where the incidence of IS decreased before 36°C and then increased after.

[Figure 1 about here]

The associations between temperature (minimum and maximum) and stroke emergency admissions (PIH and IS) in different seasons are shown in Tables 2 and 3.

There were statistically significant relationships between minimum temperature and PIH emergency admissions for the group aged ≥ 65 and all ages in winter and for the group aged < 65 in summer (Table 2). After controlling for potential confounding effects of humidity and air pollutants (PM_{10}, NO_2, O_3 and SO_2), the average daily PIH for the group aged ≥ 65 and all ages decreased by 6% (95% Confidence Interval (CI): 2, 10%) and 5% (95% CI: 2, 9%), respectively, for a 1°C increase in daily minimum temperature in winter; but average daily PIH for the group aged < 65 increased by 12% (95% CI: 2, 22%) for a 1°C increase in daily minimum temperature in summer. There were no statistically significant relationships between minimum temperature and IS emergency admissions in winter and summer for any age groups.

[Table 2 about here]

The associations between maximum temperature and stroke emergency admissions of PIH were similar with minimum temperature. After controlling for potential confounding effects of humidity and air pollutants (PM_{10}, NO_2, O_3 and SO_2), the average daily PIH for the group aged ≥ 65 and all ages decreased by 7% (95% Confidence Interval (CI): 4, 11%) and 7% (95% CI: 3, 11%), respectively, for a 1°C increase in daily maximum temperature in winter. The associations of maximum temperature with PIH emergency admissions were stronger in summer than in winter for the group aged < 65. The average daily PIH for the group aged < 65 increased by 15% (95% CI: 5, 26%), but the average daily PIH for the group aged ≥ 65 decreased by 7% (95% CI: 1, 12%) in summer for a 1°C increase in daily maximum temperature after adjustment for confounding factors (Table 3). There was only one statistically significant relationship between maximum temperature and IS emergency admissions in winter for the group aged ≥ 65. The average daily IS for the group aged ≥ 65 decreased by 3% (95% CI: 0, 6%) for a 1°C increase in daily maximum temperature after adjustment for confounding factors. In summer, there were no statistical significant relationships between maximum temperature and IS emergency admissions for any age groups.

[Table 3 about here]

Discussion

This study demonstrates a seasonal (winter and summer) variation in the occurrence of primary intracerebral hemorrhage and ischemic stroke emergency admissions for residents aged < 65, ≥ 65 and all ages, after controlling for humidity and air pollutants in Brisbane, Australia. We found that temperature variation was statistically significantly associated with emergency admissions for stroke. Relative risks for the temperature increases were greater for primary intracerebral hemorrhage than for ischemic stroke emergency admissions; and these associations were similar for maximum temperature and minimum temperature, except the average daily PIH for the group aged ≥ 65 in summer which had a stronger association with maximum temperature.

Common cerebrovascular disease stroke confers a great health risk on the middle aged and elderly, especially for those with risk factors such as high blood pressure, family history of stroke, smoking, diabetes, high cholesterol and heart disease (ASA 2008; SF 2008). A few studies have investigated the association between meteorological variables and stroke, but the results are inconsistent. For example, Dawson et al (2008) found that maximum temperature was associated with an increase in ischemic stroke admissions in the west of Scotland. Tsai et al (2003) also demonstrated increased risk of stroke admissions for both PIH and IS on warmer days (≥ 20°C) compared to cooler days (< 20°C) in Kaohsiung, Taiwan. However, Kyobutungi et al (2005) found there was no risk of stroke associated with ambient maximum temperature in Heidelberg, Germany. Hong et al (2003) and Myint et al (2007) reported that decreased temperature was associated with high risk of stroke in Incheon, Korea and Norfolk, UK.

In winter, we found that higher maximum temperatures were associated with fewer IS emergency admissions for the group aged ≥ 65; while both higher minimum and maximum temperatures were associated with fewer PIH emergency admissions for the group aged ≥ 65 and all ages. We also found that higher temperatures (both minimum and maximum) were associated with more PIH emergency admissions for the group aged < 65 in summer. However, higher maximum temperatures in summer were associated with fewer PIH emergency admissions for the group aged ≥ 65. The exact reasons for this difference are unknown but we speculate that it may be because, during hot days, elderly people were more likely to stay indoors with the air conditioning on, whereas people aged < 65 were more likely to go to work or do outdoor activities. There were some similar but less significant impacts of temperature variation on emergency hospital admissions for stroke at the lags of one and two days. It remains unclear why IS and PIH responded to temperature variation differently. The results of this study corroborate Hong's and Myint's findings (i.e., cold weather was more likely to affect stroke, particularly, for the group aged ≥ 65) (Hong et al.

2003; Myint et al. 2007), but differ with other three studies described above (Tsai et al. 2003; Kyobutungi et al. 2005; Dawson et al. 2008).

Humidity has often been studied, as either an individual risk factor or in the form of an index (e.g., combining temperature and humidity) (Hong et al. 2003; Tsai et al. 2003; Liu et al. 2004; Low et al. 2006; Henrotin et al. 2007; Kettunen et al. 2007; Myint et al. 2007). The results of those studies were not consistent and depended on the usual climatic characteristics of the countries in which the studies were conducted. In the present study, the adjustment for humidity did not substantially change the stroke emergency admission estimates. This finding may reflect the fact that temperature is the key climatic variable in terms of stroke risk, and that humidity of is of secondary importance. Warmer skin temperatures mean lower blood pressures, and this could be the key mechanism for reducing the risk of stroke in winter. Interestingly people living in warmer climates show generally greater changes in blood pressure than people living in cold climates, possibly because the homes of people in colder climates are better insulated (Barnett et al. 2007). Brisbane has a subtropical climate and many houses are designed to increase air flow in order to provide relief from the summer heat. However, in winter such designs mean that people are frequently exposed to the outdoor temperature.

There are two major strengths in this study. Firstly, according to our knowledge, this is the first study to examine the impact of temperature variation on different stroke types after controlling for confounding effects of other meteorological variables (e.g., humidity) and air pollutants in a sub-tropical setting. Secondly, this study contains a comprehensive dataset which was collected from different sources and covered a ten-year period (1996–2005). There were very few missing values (e.g., temperature data < 1 % and air pollution data < 4 %). Thus the impact of missing data on the research outcomes is likely to be minimal.

This study also has some limitations. Firstly, ambient temperature rather than indoor temperature was used in this study as a measure of exposure, which may not necessarily correspond to the variation of temperature to which the individual was exposed. However, such measurement error may not play an important role as the residents in Brisbane usually keep windows open, even in winter. Secondly, air conditioning and/or indoor heaters may be a confounder for this study, but no data on this factor is available. A study that collects individual information on people suffering a stroke (including details on their air conditioning use and heating) would be needed to remove these biases. However, these studies are very costly compared to the study design used here, which used routinely collected data from a hospital admission registry. While this registry may be of high quality, there is still some potential for information bias such as case misclassification. This type of measurement error will bias any findings towards the null, and so the results shown here may slightly underestimate the true associations.

In conclusion, temperature variation was significantly associated with emergency admissions for stroke in different seasons in Brisbane. These associations were observed even after controlling for humidity and air pollutants. Susceptible people (especially the elderly) should pay greater attention to temperature change, particularly in winter. Health authorities may also need to prepare for an increased demand for stroke emergency care when temperature variation occurs during both winter and summer seasons.

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References

Adams HP (2004) Handbook of Cerebrovascular Diseases, 2nd Ed., Revised and Expanded. Available at http://books.google.com.au/books?id=N7ZcdIN0sOIC&printsec=frontcover#PPA458,M1 [accessed 26 June 2008]

Agresti A (2007) An introduction to categorical data analysis, Hoboken, NJ: Wiley-Interscience.

ASA (2008) American Stroke Association: Impact of Stroke. Available at http://www.strokeassociation.org/presenter.jhtml?identifier=1033 [6 May 2008]

Baccini M, Biggeri A, Accetta G, Kosatsky T, Katsouyanni K, Analitis A, Anderson HR, Bisanti L, D'Ippoliti D, Danova J, Forsberg B, Medina S, Paldy A, Rabczenko D, Schindler C, Michelozzi P (2008) Heat effects on mortality in 15 European cities. Epidemiology 19: 711-719

Barnett AG, Sans S, Salomaa V, Kuulasmaa K, Dobson AJ (2007) The effect of temperature on systolic blood pressure. Blood Press. Monit. 12: 195-203

BCC (2008) Brisbane City Council. Available at http://www.brisbane.qld.gov.au. [8 September 2008

Chang CL, Shipley M, Marmot M, Poulter N (2004) Lower ambient temperature was associated with an increased risk of hospitalization for stroke and acute myocardial infarction in young women. J Clin Epidemiol 57: 749-757

Dawson J, Weir C, Wright F, Bryden C, Aslanyan S, Lees K, Bird W, Walters M (2008) Associations between meteorological variables and acute stroke hospital admissions in the west of Scotland. Acta Neurol Scand 117: 85-89

Field TS, Hill MD (2002) Weather, Chinook, and stroke occurrence. Stroke 33: 1751-1757

Fouillet A, Rey G, Jougla E, Frayssinet P, Bessemoulin P, Hemon D (2007) A predictive model relating daily fluctuations in summer temperatures and mortality rates. BMC Public Health 7: 114

Henrotin JB, Besancenot JP, Bejot Y, Giroud M (2007) Short-term effects of ozone air pollution on ischaemic stroke occurrence: a case-crossover analysis from a 10-year population-based study in Dijon, France. Occup Environ Med 64: 439-445

Hong YC, Rha JH, Lee JT, Ha EH, Kwon HJ, Kim H (2003) Ischemic stroke associated with decrease in temperature. Epidemiology 14: 473-478

Jalaludin B, Morgan G, Lincoln D, Sheppeard V, Simpson R, Corbett S (2006) Associations between ambient air pollution and daily emergency department attendances for cardiovascular disease in the elderly (65+ years), Sydney, Australia. J Expo Sci Environ Epidemiol 16: 225-237

Jimenez-Conde J, Ois A, Gomis M, Rodriguez-Campello A, Cuadrado-Godia E, Subirana I, Roquer J (2008) Weather as a Trigger of Stroke. Daily Meteorological Factors and Incidence of Stroke Subtypes. Cerebrovasc Dis 26: 348-354

Johnston G, Stokes M (1997) Applications of GEE Methodology Using the SAS@ System.

Kettunen J, Lanki T, Tiittanen P, Aalto PP, Koskentalo T, Kulmala M, Salomaa V, Pekkanen J (2007) Associations of fine and ultrafine particulate air pollution with stroke mortality in an area of low air pollution levels. Stroke 38: 918-922

Kyobutungi C, Grau A, Stieglbauer G, Becher H (2005) Absolute temperature, temperature changes and stroke risk: a case-crossover study. Eur J Epidemiol 20: 693-698

Liu F, Zhang JL, Lu C (2004) The relationship of temperature and stroke incidence in Beijing: a time-series study. Zhonghua Liu Xing Bing Xue Za Zhi 25: 962-966 (in Chinese)

Low RB, Bielory L, Qureshi AI, Dunn V, Stuhlmiller DFE, Dickey DA (2006) The relation of stroke admissions to recent weather, airborne allergens, air pollution, seasons, upper respiratory infections, and asthma incidence, September 11, 2001, and day of the week. Stroke 37: 951-957

Myint PK, Vowler SL, Woodhouse PR, Redmayne O, Fulcher RA (2007) Winter excess in hospital admissions, in-patient mortality and length of acute hospital stay in stroke: A hospital database study over six seasonal years in Norfolk, UK. Neuroepidemiology 28: 79-85

NEPC (2008) National Environmental Protection Council. Available at http://www.ephc.gov.au/nepms/air/air_variation.html [accessed 10 November 2008]

Oberg AL, Ferguson JA, McIntyre LM, Horner RD (2000) Incidence of stroke and season of the year: evidence of an association. Am J Epidemiol 152: 558-564

Piver WT, Ando M, Ye F, Portier CJ (1999) Temperature and Air Pollution as Risk Factors for Heat Stroke in Tokyo, July and August 1980-1995. Environ Health Perspect 107: 911-916

SAS (2002 - 2003) Institute Inc. Statistical analysis software. SAS Institute Inc., Cary, NC, USA.

SF (2008) Stroke Foundation Facts, figures and stats. Available at http://www.strokefoundation.com.au/facts-figures-and-stats [accessed 6 May 2008]

Tsai SS, Goggins WB, Chiu HF, Yang CY (2003) Evidence for an association between air pollution and daily stroke admissions in Kaohsiung, Taiwan. Stroke 34: 2612-2616

Turin TC, Kita Y, Murakami Y, Rumana N, Sugihara H, Morita Y, Tomioka N, Okayama A, Nakamura Y, Abbott RD, Ueshima H (2008) Higher stroke incidence in the spring season regardless of conventional risk factors: Takashima Stroke Registry, Japan, 1988-2001. Stroke 39: 745-752

Wang Y, Levi CR, Attia JR, D'Este CA, Spratt N, Fisher J (2003) Seasonal variation in stroke in the Hunter Region, Australia: a 5-year hospital-based study, 1995-2000. Stroke 34: 1144-1150

Wellenius GA, Schwartz J, Mittleman MA (2005) Air pollution and hospital admissions for ischemic and hemorrhagic stroke among medicare beneficiaries. Stroke 36: 2549-2553

Figure legend

Figure 1. The mean number of daily PIH and IS emergency admissions in winter and summer (by each 5°C) in Brisbane, Australia, 1996–2005 (Left column: winter; right column: summer. Top row: minimum temperature; bottom row: maximum temperature. PIH = primary intracerebral hemorrhage, IS = ischemic stroke)

Winter Summer

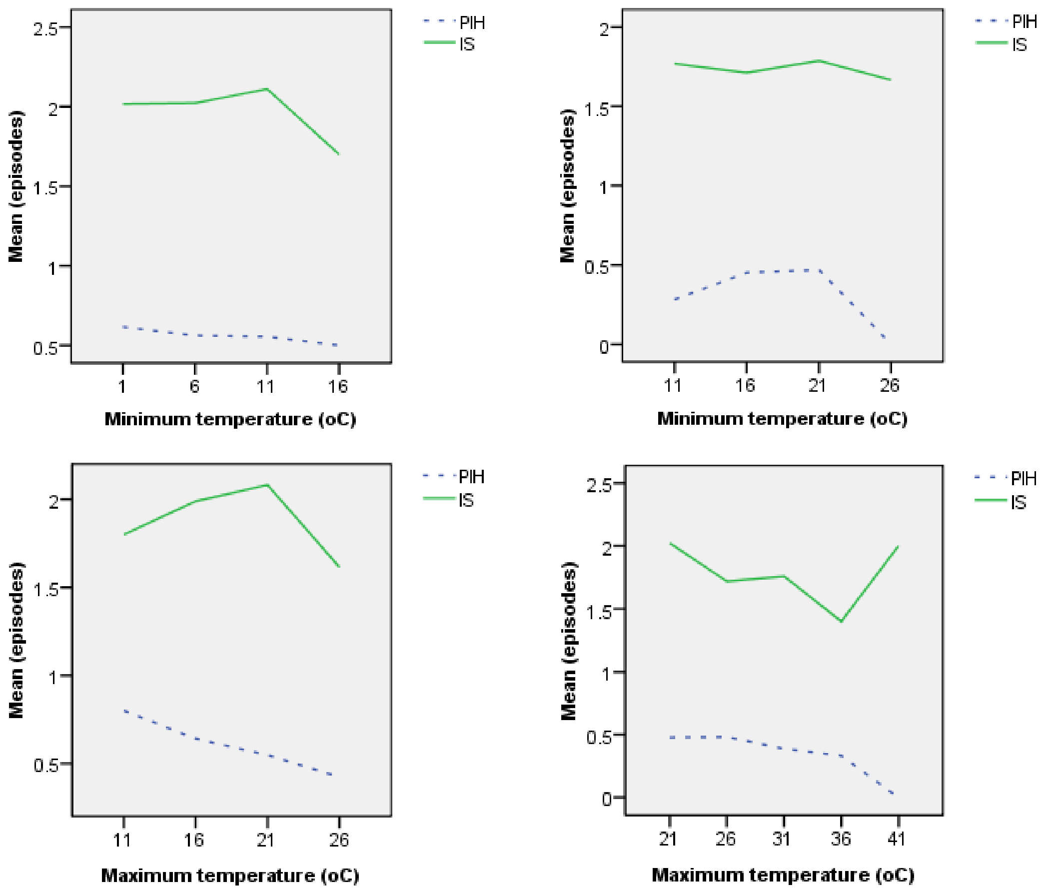

Table 1. Summary of daily emergency admissions for stroke, weather, air pollutants and daily emergency admissions for stroke

Variables	Mean	SD	Minimum	Low quartile	Median	Upper quartile	Maximum
Subarachnoid hemorrhagic stroke							
Age < 65	0.1	0.3	0	0	0	0	3
Age ≥ 65	0.1	0.2	0	0	0	0	2
Total	0.2	0.4	0	0	0	0	3
Primary intracerebral hemorrhage							
Age < 65	0.1	0.3	0	0	0	0	2
Age ≥ 65	0.4	0.6	0	0	0	1	4
Total	0.5	0.7	0	0	0	1	4
Ischemic stroke							
Age < 65	0.3	0.5	0	0	0	1	3
Age ≥ 65	1.6	1.3	0	1	1	2	9
Total	1.8	1.4	0	1	2	3	9
Other stroke							
Age < 65	0.1	0.4	0	0	0	0	3
Age ≥ 65	0.8	0.9	0	0	1	1	6
Total	0.9	0.9	0	0	1	1	6
All Stroke							
Age < 65	0.6	0.8	0	0	0	1	4
Age ≥ 65	2.8	1.7	0	2	3	4	11
Total	3.4	1.9	0	2	3	5	12
Weather							
Tmax (°C)[a]	26.3	3.9	12.6	23.3	26.4	29.2	41.5
Tmin (°C)[b]	14.7	5.3	0.4	10.7	15.4	18.8	27.6
RH (%)[c]	71.1	10.3	24.6	65.9	71.9	77.3	96.9
Air pollution							
PM_{10} (μg/m^3)	17.7	7.7	2.5	13.3	16.4	20.4	151.6
NO_2 (ppb)	18.0	6.7	3.3	12.8	17.1	22.4	46.3
O_3 (ppb)	31.8	9.8	7.1	25.1	30.0	36.7	88.2
SO_2 (ppb)	5.5	3.4	0.0	3.3	4.8	7.0	33.7

[a] maximum temperature; [b] minimum temperature; [c] relative humidity

Table 2. Relative risks (RR) for a one degree increase in minimum temperature and stroke emergency admissions by season in Brisbane, Australia, 1996 – 2005

Variables	Model I[a] RR (95% CI)	Model II[b] RR (95% CI)	Mode III[c] RR (95% CI)
Primary intracerebral hemorrhage			
Winter			
Age < 65	0.99 [0.93 - 1.06]	0.97 [0.90 - 1.05]	0.95[0.87 - 1.04]
Age ≥ 65	0.98 [0.95 - 1.00]	0.96 [0.93 - 0.99][d]	0.94 [0.90 - 0.98][e]
Total	0.98 [0.96 - 1.01]	0.96 [0.93 - 0.99][e]	0.95 [0.91 - 0.98][e]
Summer			
Age < 65	1.10 [1.02 - 1.19][d]	1.09 [1.00 - 1.18]	1.12 [1.02 - 1.22][d]
Age ≥ 65	1.00 [0.96 - 1.05]	0.98 [0.93 - 1.04]	0.99 [0.94 - 1.05]
Total	1.02 [0.98 - 1.07]	1.01 [0.96 - 1.05]	1.02 [0.97 - 1.07]
Ischemic stroke			
Winter			
Age < 65	1.00 [0.96 - 1.03]	0.99 [0.95 - 1.03]	1.00 [0.96 - 1.05]
Age ≥ 65	1.00 [0.99 - 1.02]	0.98 [0.97 - 1.00]	0.99 [0.97 - 1.01]
Total	1.00 [0.99 - 1.02]	0.98 [0.97 - 1.00]	0.99 [0.97 - 1.01]
Summer			
Age < 65	1.03 [0.98 - 1.08]	1.02 [0.97 - 1.07]	1.02 [0.97 - 1.08]
Age ≥ 65	1.01 [0.98 - 1.03]	0.99 [0.97 - 1.02]	1.00 [0.97 - 1.02]
Total	1.01 [0.99 - 1.03]	1.00 [0.98 - 1.02]	1.00 [0.98 - 1.02]

[a] Unadjusted ; [b] Adjusted for humidity ; [c] Adjusted for humidity, PM_{10}, NO_2, O_3 and SO_2 ; [d] $P < 0.05$; [e] $P < 0.01$

Table 3. Relative risks (RR) for a one degree increase in maximum temperature and stroke emergency admissions by season in Brisbane, Australia, 1996 – 2005

Variables	Model I[a] RR (95% CI)	Model II[b] RR (95% CI)	Mode III[c] RR (95% CI)
Primary intracerebral hemorrhage			
Winter			
Age < 65	0.93 [0.86 - 1.02]	0.93 [0.86 - 1.01]	0.93 [0.83 - 1.04]
Age ≥ 65	0.94 [0.90 - 0.98][e]	0.94 [0.90 - 0.98][e]	0.93 [0.89 - 0.96][e]
Total	0.94 [0.90 - 0.97][e]	0.94 [0.90 - 0.97][e]	0.93 [0.89 - 0.97][e]
Summer			
Age < 65	1.04 [0.98 - 1.11]	1.06 [0.99 - 1.14]	1.15 [1.05 - 1.26][e]
Age ≥ 65	0.93 [0.89 - 0.97][e]	0.94 [0.90 - 0.98][e]	0.93 [0.88 - 0.99][d]
Total	0.96 [0.92 - 0.99][d]	0.96 [0.93 - 1.00][d]	0.98 [0.93 - 1.03]
Ischemic stroke			
Winter			
Age < 65	0.99 [0.94 - 1.04]	0.99 [0.94 - 1.04]	0.99 [0.93 - 1.05]
Age ≥ 65	0.99 [0.97 - 1.02]	0.99 [0.96 - 1.01]	0.97 [0.94 - 1.00][d]
Total	0.99 [0.97 - 1.01]	0.99 [0.97 - 1.01]	0.97 [0.95 - 1.00]
Summer			
Age < 65	1.02 [0.98 - 1.07]	1.03 [0.99 - 1.08]	1.04 [0.98 - 1.11]
Age ≥ 65	0.98 [0.96 - 1.01]	0.99 [0.97 - 1.01]	0.99 [0.96 - 1.02]
Total	0.99 [0.97 - 1.00]	1.00 [0.98 - 1.02]	1.00 [0.97 - 1.02]

[a] Unadjusted ; [b] Adjusted for humidity ; [c] Adjusted for humidity, PM_{10}, NO_2, O_3 and SO_2 ; [d] $P < 0.05$; [e] $P < 0.01$;