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Xu, Zhiwei, Hu, Wenbiao, Su, Hong, Turner, Lyle, Ye, Xiaofang, Wang, Jiajia, & Tong, Shilu
(2014)
Extreme temperatures and paediatric emergency department admissions.
Journal of Epidemiology and Community Health, *68*(4), pp. 304-311.

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https://doi.org/10.1136/jech-2013-202725

Journal of
EPIDEMIOLOGY AND
COMMUNITY HEALTH

Extreme temperatures and pediatric emergency department admissions

Journal:	*Journal of Epidemiology & Community Health*
Manuscript ID:	Draft
Article Type:	Research report
Date Submitted by the Author:	n/a
Complete List of Authors:	Xu, Zhiwei; Queensland University of Technology, School of Public Health and Social Work Hu, Wenbiao; University of Queensland, Su, Hong; Anhui Medical University, Turner, Lyle; Queensland University of Technology, School of Public Health and Social Work Ye, Xiaofang; Queensland University of Technology, School of Public Health and Social Work Wang, Jiajia; Queensland University of Technology, School of Public Health and Social Work Tong, Shilu; Queensland University of Technology, School of Public Health and Social Work
Keywords:	CHILD HEALTH, COMMUNICABLE DISEASES, ENVIRONMENTAL HEALTH

Extreme temperatures and pediatric emergency department admissions

Zhiwei Xu, [1] Wenbiao Hu, [2] Hong Su, [3] Lyle R. Turner, [1] Xiaofang Ye, [1,4] Jiajia Wang, [1] Shilu Tong [1*]

1 School of Public Health and Social Work & Institute of Health and Biomedical Innovation, Queensland University of Technology, Kelvin Grove, 4059, Qld, Australia.

2 School of Population Health, University of Queensland, Brisbane, Qld, 4066, Australia.

3 Department of Epidemiology and Health Statistics, School of Public Health, Anhui Medical University, Hefei, Anhui, China.

4 Shanghai Meteorological Bureau, Shanghai, China

[*] **Correspondence to:** Dr. Tong, School of Public Health and Social Work & Institute of Health and Biomedical Innovation, Queensland University of Technology, Kelvin Grove, Qld. 4059, Australia. Tel: +61 7 3138 9745; fax: +61 7 3138 3369. Email address: s.tong@qut.edu.au

Competing interest: None.

Ethics approval: Ethic Review Board of Queensland University of Technology.

Contributors: ZX and ST designed the study. ZX conducted the statistical analysis and wrote the first draft. WH, HS, LT, XY and JW contributed to the paper revision.

What is already known on this subject

- Extreme temperatures have impacts on pediatric intestinal infectious diseases and respiratory diseases.
- Children aged 0–4 years are particularly vulnerable to extreme temperatures.

What this study adds

- Our results show that male children were more vulnerable to temperature effects. Children aged 0–4 years were more vulnerable to hot effects while children aged 10–14 years were more sensitive to cold effects.
- There were hot temperature effects on several pediatric diseases, including intestinal infectious diseases, endocrine, nutritional and metabolic diseases, nervous system diseases, digestive system diseases, genitourinary system diseases and chronic obstructive pulmonary diseases (COPD), while cold temperature significantly affected pediatric respiratory diseases, acute upper respiratory infections, acute bronchitis and COPD.
- There was an added effect of heat waves on pediatric COPD.

Abstract

Background: Children are particularly vulnerable to the effects of extreme temperatures. This study aimed to examine the relationship between extreme temperatures and pediatric emergency department admissions (EDAs) in Brisbane, Australia, during 2003–2009.

Methods: A quasi-Poisson generalized linear model combined with a distributed lag non-linear model was used to examine the relationships between extreme temperatures and age-, gender- and cause-specific pediatric emergency department admissions, while controlling for air pollution, relative humidity, day of week, season and long-term trends. The model residuals were checked to identify whether there was an added effect due to heat waves or cold spells.

Results: Both hot and cold temperatures were significantly associated with an increase in pediatric EDAs in Brisbane. Male children and children aged 0–4 were more vulnerable to heat effects. Hot temperatures had a significant impact on several pediatric diseases, including intestinal infectious diseases, endocrine, nutritional and metabolic diseases, nervous system diseases, digestive system diseases, genitourinary system diseases, and chronic obstructive pulmonary diseases (COPD), while cold temperatures were significantly associated with respiratory diseases. An added effect of heat waves on childhood COPD was observed, while no added effect of cold spells was found.

Conclusions: As climate change continues, children, especially those aged 0–4 years, are at particular risk for a variety of diseases which might be triggered by extremely hot temperatures. This study suggests preventing the effects of extreme temperature on children with respiratory disease could reduce the number of EDAs in children.

INTRODUCTION

Climate change has been recognized as the biggest global health threat in the 21st century.[1] The average global surface temperature has increased, and the frequency and intensity of extreme weather events have also risen,[2 3] posing a huge threat to human health and wellbeing. In particular, the adverse effects of extreme temperatures on morbidity have become a great public health issue.[4]

Previous studies regarding the health impact of temperature on morbidity have focused mainly on adults, particularly the elderly.[5 6] Children are particularly vulnerable to environmental hazards, [7] but limited studies have examined the relationship between temperature and morbidity among children.[8] In previous studies, temperature was considered as a continuous risk factor, and the exposure–response relationship between temperature and specific pediatric morbidity was assessed. However, to date, no study has quantified the effects of extreme temperatures on a wide range of health outcomes among children.

Some public health literature has highlighted that persistent extreme temperatures may increase the incidences of pediatric diseases. Heat waves (or cold spells) were more likely to be considered as a distinct event in the literature, and the excess morbidity due to heat waves (cold spells) was calculated by comparing heat wave (cold spell) days with non-heat-wave (non-cold-spell) days.[9-12] Some researchers argued that the effects of heat waves and cold spells on human health may be due to not only the main effect of daily temperature fluctuations, but also the added effect of persistent extreme temperatures.[13-15] To the best of our knowledge, no study has separately quantified the effects of daily temperatures and added effects of persistent extreme temperatures on pediatric morbidity.

This study addressed three key issues: i) What is the relationship between extreme temperatures and pediatric emergency department admissions in Brisbane, Australia? ii) Is there any added effect due to heat waves and cold spells? iii) Which subgroups of children are more sensitive to extreme temperatures?

METHODS

Data collection

Brisbane is the capital city of Queensland, located on the east coast of Australia (27° 30' S, 153° 00' E). It has a sub-tropical climate, and generally experiences mild winters and hot summers. Children aged 0–14 years account for 20% of the residential population in Brisbane.[16] Emergency department admission (EDA) data for the period of 1st January 2003 to 31st December 2009 were obtained from Queensland Health. Ethical approval was obtained from the Ethic Review Board of Queensland University of Technology prior to the data being collected. Because the data were de-identified and aggregated, written consent was not needed. Data on EDAs were classified according to the International Classification of Disease, 10th version (ICD–code 10). The main pediatric diseases in Brisbane during 2003 to 2009 were analysed, including all cause diseases, intestinal infectious diseases (A00–A99), endocrine, nutritional and metabolic diseases (E00–E90), nervous system diseases (G00–G99), respiratory diseases (J00–J99), acute upper respiratory infections (J00–J06), acute bronchitis (J20–J21), chronic obstructive pulmonary diseases (COPD) (J40–J47) (most of which were EDAs for childhood asthma), digestive system diseases (K00–K93), and genitourinary system diseases (N00–N99).

Daily data on maximum and minimum temperatures and relative humidity in Brisbane for the same period were retrieved from the Australian Bureau of Meteorology. Daily data on average particular matter ≤ 10μm (PM_{10}) (μg/m^3) and daily average ozone (O_3) (ppb) were obtained from the Queensland Department of Environmental and Resources Management.

The definitions of heat wave and cold spell

To date, due to variations in population characteristics and adaptation,[17 18] there are no standard definitions for heat waves and cold spells. In this study, we combined intensity and duration of extreme temperatures to define both heat waves and cold spells: 1) Intensity: the 4th and 5th percentiles of daily mean temperature as the cold threshold, and the 95th and 96th percentiles of the daily mean temperature as the hot threshold. 2) Duration: a minimum of two to four consecutive days with temperatures below the cold threshold or above the hot threshold.

Statistical analyses

Stage-I: Estimation of the main temperature effects on pediatric EDAs

To quantify the main effect of temperature on pediatric EDAs, we used a quasi-Poisson generalized linear regression model combined with a distributed lag non-linear model (DLNM). Many studies have reported that there is a lagged effect of temperature on morbidity.[19 20] Further, the temperature–morbidity relationship has been observed to be non-linear.[21] Thus, we used the DLNM to examine both non-linear and lagged effects of temperature simultaneously.[22] Daily mean temperature was used in this study because it represents the exposure throughout the whole day and has been found to be a better indicator of temperature than the maximum or minimum temperature in identifying the relationship between temperature and health outcomes.[23] A "natural cubic spline–natural cubic spline"

DLNM was used to examine the temperature effect using 5 degree of freedom (*df*) and 4 *df* for the temperature and lag dimensions, respectively. Previous research has shown that the cold effects on morbidity last for more than seven days, while hot effects are relatively acute.[4] We found that there was a negligible effect of temperature on paediatric EDAs for lags above 21 days, and we therefore used a maximum lag of 21 days to examine the effect of temperature.

Several different covariates were included in the model. PM_{10}, O_3 and relative humidity were controlled for as potential confounders using a natural cubic spline with 4 *df*. Season and long-term trends were controlled for using a natural cubic spline with 7 *df* per year of data. Throughout, the choice of *df* for all non-linear functions was evaluated using the Akaike Information Criterion (AIC) and an analysis of residuals. Day of week was controlled for as a categorical variable.

We evaluated the relative risk of pediatric EDAs associated with high temperature (≥26.5 ºC, 95th percentile of mean temperature) relative to the reference temperature (calculated to be 24.0 ºC). Similarly, we evaluated the relative risk of pediatric EDAs associated with low temperature (≤13.8 ºC, 5th percentile of mean temperature) relative to the reference temperature (calculated to be 24.0 ºC). To select these reference temperatures, AIC values were iteratively calculated for the models by increasing the reference temperature in 1 ºC increments from 9 ºC to 34 ºC (the range of mean temperatures in this study). The temperature corresponding to the model with the lowest AIC value was chosen as the reference temperature.

Stage-II: Examining the added effects of heat waves and cold spells

Previous studies have reported that sustained periods of heat and cold produced an added effect on mortality independent of main temperature effects.[14 15 24] We analysed the residuals of the stage-I model to examine the possible added effects of heat waves and cold spells, that is, we estimated the added effects after removing the main effects of temperature. We assumed a maximum lag of 21 days for the delayed effects of heat waves and cold spells. EDAs for childhood asthma on extreme temperature days were compared with non-extreme temperature days.

Effect estimates were obtained for both male and female children, different age groups (0–4, 5–9 and 10–14 years old) and different EDA categories. To perform sensitivity analyses, we varied the *df* (8–15 per year) for both time to control for season and long-term trend. We also varied the *df* (5–7) for temperature and humidity and altered the maximum lag from 21 to 30 days for the DLNM. All data analysis was conducted using the R statistical environment (version 2.12.2) with the “dlnm” package used to fit the regression model.[25]

RESULTS

In total, there were 131249 EDAs among children in the whole study period. Table 1 shows the summary statistics for mean temperature, relative humidity, air pollutants and total, cause-specific, age-specific and gender-specific pediatric EDAs. The average mean temperature was 20.6 ºC (range: 9.0–34.2), and the average relative humidity was 57.3% (5.0%–98.0%). The average values of O_3 and PM_{10} were 12.6 ppb (1.7–31.6) and 16.0 μg/m^3 (4.4–355.2). The daily number of EDAs was greater among children aged 0–4 years (mean: 33.5, sd: 11.2) than those aged 5–9 years (mean: 9.3, sd: 4.0) and 10–14 years (mean: 8.7, sd:

3.9). The daily number of EDAs was greater among male children (mean: 28.9, sd: 9.6) than female children (mean: 22.5, sd: 7.9).

Table 1 Summary statistics for mean temperature, relative humidity, air pollution, total and cause-specific paediatric EDAs in Brisbane, Australia, during 2003-2009

Variables	Mean	SD	Min	Percentile 25	Percentile 50	Percentile 75	Max
Mean temperature (°C)	20.6	4.1	9.0	17.3	20.9	23.8	34.2
Relative humidity (%)	57.3	16.0	5.0	49.0	58.0	67.0	98.0
O_3 (ppb)	12.6	3.9	1.7	9.9	12.3	14.9	31.6
PM_{10} (μg/m^3)	16.0	10.1	4.4	11.7	14.5	17.9	355.2
Total morbidity	51.4	15.8	3	44	53	61	108
Intestinal infectious diseases	8.7	5.1	0	5	8	11	57
Endocrine, nutritional and metabolic diseases	1.2	1.1	0	0	1	2	7
Nervous system diseases	1.3	1.2	0	0	1	2	7
Respiratory diseases	20.0	9.5	0	13	20	26	53
Acute upper respiratory infections	5.6	3.3	0	3	5	8	19
Acute bronchitis	4.2	3.4	0	2	4	6	19
Chronic obstructive pulmonary diseases	5.5	3.4	0	3	5	7	24
Digestive system diseases	3.4	2.0	0	2	3	5	12
Genitourinary system diseases	2.2	1.5	0	1	2	3	8
Total morbidity in 0–4 year children	33.5	11.2	1	27	34	41	68
Total morbidity in 5–9 year children	9.3	4.0	1	6	9	12	27
Total morbidity in 10–14 year children	8.7	3.9	1	6	8	11	60
Total morbidity in male	28.9	9.6	1	24	29	35	85
Total morbidity in female	22.5	7.9	1	18	23	27	50

Figure 1 shows the cumulative effects of temperature on total, age- and gender-specific pediatric EDAs across a lag period of 0–13 days, and reveals that pediatric EDAs increased in both hot and cold temperatures. Hot and cold effects were much greater among male children than female children. In terms of age-specific pediatric EDAs, cold effects were greatest in children aged 10–14 years, while hot effects were greatest in children aged 0–4 years.

Figure 2 shows the effects of high temperature (95th percentile (26.5 ºC) relative to the threshold temperature (24.0 ºC)) and low temperature (5th percentile (13.8 ºC) relative to the threshold temperature (24.0 ºC)) on total pediatric EDAs along the lags. The hot effect was acute while the cold effect persisted.

Table 2 shows the cumulative effects of both hot (26.5 ºC) and cold (13.8 ºC) temperatures on total and cause-specific pediatric morbidity at lags 0–1, 0–13 and 0–21 days. Hot temperatures were statistically significantly associated with the following pediatric diseases: intestinal infectious diseases, endocrine, nutritional and metabolic diseases, nervous system diseases, digestive system diseases, genitourinary system diseases and COPD. Cold temperatures were significantly associated with respiratory diseases, acute upper respiratory infections, acute bronchitis and COPD.

Table 2 The cumulative effect of hot and cold temperatures on cause-specific paediatric EDAs, with 95th percentile (26.5 °C) and 5th percentile (13.8 °C) of temperature relative to reference temperature (24°C)

Diseases	Heat effect (Relative risk (95% CI))			Cold effect (Relative risk (95% CI))		
	Lag 0–1	Lag 0–13	Lag 0–21	Lag 0–1	Lag 0–13	Lag 0–21
Total paediatric morbidity	1.13(1.04,1.23)*	1.22(0.95,1.58)	1.33(0.92,1.93)	0.99(0.88,1.11)	1.67(1.19,2.34)*	1.51(0.93,2.45)
Intestinal infectious diseases	1.26(1.10,1.45)*	1.19(0.75,1.89)	1.17(0.59,2.30)	0.77(0.54,1.02)	1.76(0.97,3.18)	2.00(0.88,4.56)
Endocrine, nutritional and metabolic diseases	1.41(1.09,1.82)*	2.35(1.02,5.46)	2.80(0.82,6.59)	0.88(0.60,1.31)	0.92(0.29,2.93)	0.58(0.11,3.10)
Nervous system diseases	1.40(1.09,1.78)*	1.59(0.72,3.52)	1.45(0.45,4.67)	0.75(0.51,1.10)	0.62(0.21,1.88)	0.42(0.10,2.04)
Respiratory diseases	1.05(0.93,1.19)	1.33(0.92,1.90)	1.55(0.94,2.58)	1.27(0.85,1.48)	2.44(1.56,3.82)*	1.54(0.80,2.97)
Acute upper respiratory infections	1.06(0.90,1.24)	1.23(0.75,1.99)	1.36(0.68,2.71)	1.13(0.92,1.40)	2.60(1.39,4.85)*	1.92(0.77,4.78)
Acute bronchitis	0.98(0.77,1.23)	1.01(0.51,1.98)	1.39(0.56,3.47)	1.99(0.95,4.17)	1.55(1.21,1.98)*	0.78(0.26,2.35)
Chronic obstructive pulmonary diseases	1.19(1.02,1.39)*	1.74(1.07,2.84)*	1.90(0.95,3.81)	1.41(0.71,2.81)	1.37(1.09,1.73)*	0.87(0.32,2.36)
Digestive system diseases	1.23(1.05,1.46)*	2.50(1.49,4.19)*	3.71(0.73,8.96)	1.01(0.78,1.30)	1.40(0.66,2.95)	1.46(0.50,4.24)
Genitourinary system diseases	1.27(1.05,1.55)*	1.24(0.67,2.31)	1.37(0.55,3.41)	0.91(0.68,1.23)	0.97(0.39,2.38)	0.83(0.23,2.99)

*P-value<0.05

Table 3 shows the daily excess EDAs for total and cause-specific pediatric EDAs on heat wave (cold spell) days as opposed to non heat wave (cold spell) days. Using heat wave definitions of a minimum of 2 days' temperature sustained over the 95th or 96th percentile, we found there was no significant increase in EDAs for total and cause-specific in heat waves. However, using heat wave definitions of a minimum of 3 days' temperature over the 95th or 96th percentile, we found there were significant increases in EDAs for COPD in heat waves. There was no significant increase in pediatric EDAs during cold spells.

Table 3 Pediatric EDAs due to the added effect of heat waves and cold spells in Brisbane, Australia, from 2003 to 2009

	Heat Waves						Cold Spells					
	≥2		≥3		≥4		≥2		≥3		≥4	
	≥95th	≥96th	≥95th	≥96th	≥95th	≥96th	≤5th	≤4th	≤5th	≤4th	≤5th	≤4th
Total paediatric morbidity	0(-3,3)	-1(-5,4)	3(-7,12)	-1(-15,13)	-	-	-1(-3,2)	-1(-4,3)	0(-6,6)	-3(-11,4)	-6(-20,8)	-6(-20,8)
Intestinal infectious diseases	1(-1,3)	1(-2,4)	1(-6,7)	2(-7,11)	-	-	1(-1,2)	0(-2,2)	0(-4,4)	-2(-7,4)	-3(-13,6)	-3(-13,6)
Endocrine, nutritional and metabolic diseases	0(-1,2)	0(-3,2)	-1(-5,4)	-4(-11,3)	-	-	0(-1,1)	0(-2,1)	1(-2,4)	1(-3,4)	2(-4,9)	2(-4,9)
Nervous system diseases	-1(-2,1)	0(-3,2)	-2(-6,3)	0(-6,7)	-	-	0(-1,2)	1(-1,3)	2(-1,5)	1(-2,5)	2(-5,9)	2(-5,9)
Respiratory diseases	1(-2,4)	1(-3,4)	7(-1,15)	5(-7,16)	-	-	-1(-3,1)	-1(-3,2)	-1(-5,4)	-4(-10,2)	-7(-19,4)	-7(-19,4)
Acute upper respiratory infections	0(-2,2)	1(-2,3)	1(-5,7)	1(-8,9)	-	-	0(-2,1)	-1(-3,1)	-1(-4,3)	-2(-7,2)	-5(-14,3)	-5(-14,3)
Acute bronchitis	0(-2,2)	-2(-4,1)	3(-3,9)	-3(-11,6)	-	-	0(-2,1)	-1(-3,1)	0(-3,4)	-2(-7,2)	-3(-12,6)	-3(-12,6)
Chronic obstructive pulmonary diseases	1(-1,3)	1(-2,4)	**7(1,13)***	**8(1,17)***	-	-	-1(-2,1)	0(-2,2)	-2(-5,2)	-3(-8,1)	-6(-15,3)	-6(-15,3)
Digestive system diseases	0(-2,1)	-2(-4,1)	0(-5,5)	-4(-12,3)	-	-	-1(-2,1)	0(-2,1)	-1(-4,2)	-1(-5,3)	-3(-10,5)	-3(-10,5)
Genitourinary system diseases	0(-2,1)	-1(-3,1)	1(-4,6)	-2(-9,5)	-	-	-1(-2,0)	-1(-2,1)	-2(-5,1)	-2(-5,2)	-3(-10,4)	-3(-10,4)

*P<0.05

To conduct a sensitivity analysis, we changed the *df* (8–15 per year) for time to control for season. We also varied the *df* (5–7) for temperature and humidity. The results were found to change little (results not shown).

DISCUSSION

This study yielded several notable findings. Both hot and cold temperatures had significant impacts on pediatric EDAs. Male children were more vulnerable to temperature effects. Children aged 0–4 years were more vulnerable to hot effects while children aged 10–14 years were more sensitive to cold effects. Hot effects on pediatric EDAs were more acute, lasting for only a few days. There were hot temperature effects on several pediatric diseases, including intestinal infectious diseases, endocrine, nutritional and metabolic diseases, nervous system diseases, digestive system diseases, genitourinary system diseases and COPD, while cold temperature significantly affected pediatric respiratory diseases, acute upper respiratory infections, acute bronchitis and COPD. No significant added effects due to heat waves or cold spells were observed except for pediatric COPD.

The results of this study suggest that male children may be more vulnerable to extreme temperatures than female children, a finding that is supported by previous research.[26 27] The primary reasons for the observed gender difference in vulnerability to extreme temperatures may include variations in body composition (e.g., sexual dimorphism) and social behaviour (e.g., daily activity). During cold exposure, female children have a reduced thermal gradient for metabolic heat removal, a lower body core cooling rate, and lower cardiovascular and metabolic responses than male children.[28]

Another finding of our study is that children aged 0–4 or 10–14 years are more vulnerable to extreme temperatures than children aged 5–9 years. Children 0–4 years of age have been found to be vulnerable to hot and cold,[10 29] especially to persistent hot episodes.[10 12 30] Children aged 10–14 years may play outdoors more often than younger children, which may increase their exposures to extreme temperatures. In young females, menarche usually occurs between the age of 10 and 14,[13] and the increase in ovarian hormones among female children at this stage might influence their thermoregulation function,[31] which may consequently result in their vulnerability to extreme temperatures.

The lag structure of temperature effects on pediatric EDAs is similar to that found for the wider population, with shorter lags for hot effects and longer lags for cold effects. In this study, the effects of hot temperature lasted approximately three days, a figure that is comparable with previous studies reporting similar lagged effects.[20 32] In terms of cold effects on total pediatric EDAs, we found effects lasted for approximately seven days, which is consistent with the lag duration of cold effects on other health outcomes such as general practice consultations.[33]

In this study, we not only found associations for some commonly reported diseases in children, such as intestinal infectious diseases[34-37] and respiratory diseases,[11 20] but also for other conditions that, to date, have received less attention. These include endocrine, nutritional and metabolic diseases, nervous system diseases, digestive system diseases and genitourinary system diseases.

Respiratory disease admissions were observed to increase in cold temperatures in this study, which may be due partially to cross-infection from indoor crowding.[38 39] Low temperatures assist survival of bacteria in water droplets.[40] Interestingly, we found that while total respiratory disease and associated subcategories were not sensitive to hot temperatures, childhood COPD was vulnerable to hot temperatures. A potential mechanism for this relationship is the effect of heat on formation of ozone, a known respiratory irritant. A recent study estimated that ozone-related asthma emergency department visits for children could increase as much as 7% in a major metropolitan area due to temperature driven changes in ozone concentrations.[41]

The results show that there were large effects of high temperatures on endocrine diseases. This corresponds to a study conducted by Pudpong and Hajat in Thailand which demonstrated an increase of diabetic out-patient visits for high temperatures in the total population.[42] Semenza et al. found that diabetic admissions increased during heat waves in Chicago.[43] With regards to the biological mechanism, it was reported that the autonomic control and endothelial function of people with diabetes are sensitive to extreme temperatures.[44]

We found that nervous system disease admissions increased during hot days, which might be due to the negative effects of some psychotropic drugs,[45 46] decreased self-care capacity [45] and physiological vulnerability.[46] Hot temperatures may trigger the potential symptoms of people with existing nervous system disorders. An association found between hot temperature and genitourinary system disease admissions was observed in this study. Previous research suggests that hot temperatures affect both fluid and electrolyte balance, especially for those on medication,[47] and heat-related dehydration appears to promote acute renal failure.[43] Exposure to extreme hot weather can induce heat-related conditions including hyperthermia and heat stress in children.[43] This can be attributable to heat exposure causing blood to be redistributed away from splanchnic and renal vascular beds, placing stress on the kidneys and therefore compromising the function of the renal system.

In this study, we found there were no added effects due to heat waves or cold spells except for pediatric COPD, meaning that the increase of pediatric EDAs during persistent extreme temperatures was mainly due to daily temperature fluctuations, but not due to the effects caused by the persistent periods of high or cold temperatures. Persistent high temperatures were associated with 7 to 8 EDAs per day for pediatric COPD, depending on the severity of heat waves. This indicates that parents and caregivers should take more protective measures during extreme temperatures and persistent hot days to prevent their children from COPD attacks. COPD was one of the leading death causes globally in 2010,[48 49] and the findings of this study reveal that the more intense, frequent, and long heat waves in the future will probably increase the burden of disease caused by COPD in the coming decades. Two reasons may explain the fact that no added effect was found during cold spells. First, children may wear more clothes after experiencing a cold day. Second, Brisbane has a sub-tropical climate and rarely encounters really cold days for more than a few days, reducing the likelihood of a cold spell occurring.

Strengths and Limitations

This study has three major strengths. First, to the best of our knowledge, this is the first study which specifically examines the effect of extreme temperatures on a wide range of diseases in children. Even though children are regarded as a population subgroup vulnerable to temperature extremes, little empirical research has been conducted to date. Second, advanced statistical methods were used to quantify the lagged and cumulative effects of extreme temperatures on pediatric EDAs. Finally, vulnerabilities to extreme temperatures among different age and gender groups were assessed and compared.

Three limitations of this study should also be acknowledged. First, we only focused on one city, which means our findings should only be generalised to other regions and climates with caution. However, the findings from this study may stimulate further research in other populations. Second, infants were not specifically analysed as a subgroup in our study because of data availability issues, even though they are particularly vulnerable to temperature effects. Further studies should focus more on the impact of extreme temperatures on morbidity in infants. Finally, there may be some exposure misclassification bias because we used aggregated data on temperature and air pollution rather than individual exposure data.

CONCLUSIONS

The findings of this study demonstrate significant effects of extreme temperatures on a variety of pediatric diseases. The added effects of persistent extreme temperatures on most pediatric EDAs appeared to be negligible when compared with the main effects, but pediatric COPD was very sensitive to both extreme temperatures and heat waves. In addition, male and young children aged 0–4 years were at particular risk. These findings indicate that more attention needs to be paid to children in extreme temperatures.

Acknowledgements

We would like to thank Cunrui Huang for his valuable comments on the early draft.

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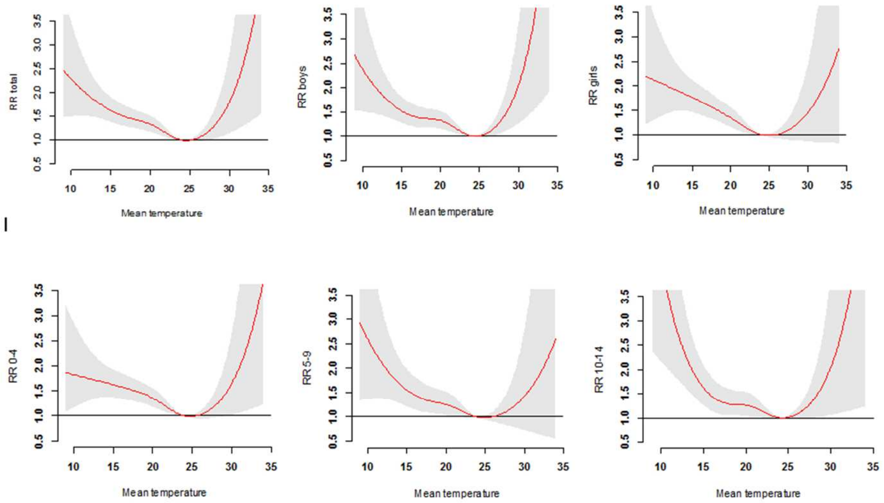
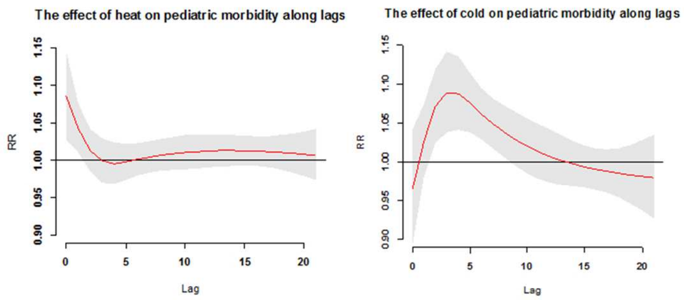


Figure 1 The overall effect of temperature on pediatric EDAs


The effect of heat on pediatric morbidity along lags

The effect of cold on pediatric morbidity along lags

Figure 2 The lagged effects of temperature on pediatric EDAs