*HK J Paediatr (new series)* 2015;**20**:10-16

# Effect of Ambient Temperature on the Occurrence of Acute Appendicitis in Children Under 5 Years of Age

Y ***Lou***, SJ ***Huang***, JF ***Tou***, ZG ***Gao***, JF ***Liang***

**Abstract** ***Purpose:*** This study aimed to reveal the effect of ambient temperature on the occurrence of acute appendicitis (AA) in children under 5 years of age. ***Methods:*** We identified 4159 patients with AA from January 2003 to November 2012. Totally 1071 patients were under 5 years (younger patients), and 3088 aged 6-14 years (older patients). Pearson's correlation analysis was used to examine the correlation between ambient temperature and the occurrence of AA. We used Auto-Regressive Integrated Moving Average (ARIMA) models to examine the effects of climatic factors on incidence rates. ***Results:*** Pearson's correlation analysis showed a correlation between monthly incidence and monthly average temperature for entire sample ($r=0.404$, $p<0.001$), for younger patients ($r=0.209$, $p=0.023$), and for older patients ($r=0.421$, $p<0.001$). The correlation was lower than that between daily average cases of each temperature (DACET) and 1- to 12-day average temperature for entire sample ($0.80\pm0.04$, all $p<0.01$), for younger patients ($r=0.52\pm0.09$, all $p<0.05$), and for older patients ($r=0.79\pm0.04$, all $p<0.01$). According to age, younger patients had a much lower r value than older patients ($p<0.001$). The peak r value of the correlation between DACET and n-day average temperature indicated that n was 6 for entire sample, 3 for younger patients and 7 for older patients. A 1°C increase in 6-day average temperature was associated with an increase of 0.0202, 0.0044 and 0.0157 in daily average cases for entire sample ($r^2=0.78$, $p<0.001$), younger patients ($r^2=0.29$, $p=0.004$), and older patients ($r^2=0.68$, $p<0.001$), respectively. ARIMA models revealed that monthly incidence rate was associated with ambient temperature for both younger patients and older patients (both $p<0.01$). ***Conclusion:*** More AA occurred under higher ambient temperature. As compared with the older patients, ambient temperature had a weaker but quicker effect on the occurrence of AA in children under 5 years of age.

**Key words** Acute appendicitis; Ambient temperature; Daily average cases of each temperature

**Department of General Surgery, Children's Hospital, Zhejiang University School of Medicine, Hangzhou 310003, China**

| | |
|---|---|
| Y **Lou** (樓毅) | *MD* |
| SJ **Huang** (黃壽獎) | *PhD* |
| JF **Tou** (斜金法) | *PhD* |
| ZG **Gao** (高志剛) | *MD* |
| JF **Liang** (梁建鳳) | *MPH* |

**Correspondence to:** Dr SJ **Huang**

*Received December 12, 2013*

## Introduction

Acute appendicitis (AA) is the most common inflammatory disease of the abdominal cavity and the most common cause of surgical emergency in children.[1-4] Many studies reported a world-wide trend that the incidence rate of AA was higher in summer than in winter.[4-8] However, no study concerned the effect of climatic factors on AA in children under 5 years of age. Climatic factors can affect the incidence and prevalence of infections, and short-term

air temperature affect the markers of inflammation in potentially susceptible individuals.[9,10] We proposed that the most significantly different climatic factors between summer months and winter months in the northern hemisphere were ambient temperature, hours of sunshine and relative humidity. According to Wei et al,[4] the incidence of AA correlated to monthly average temperature, but not to other climatic factors. But AA is one of surgical emergencies with short latency period. The association between monthly incidence and monthly average temperature might conceal the truth. In this study, we tested the relationship between 1- to 28-day average temperature and daily average cases of each temperature (DACET; for example, if there were a total of 100 days, on which the 6-day average temperature were 20°C, and on these days 200 cases occurred, the daily average cases of 20°C of 6-day average temperature = 200 cases / 100 days = 2.0 cases/day of 20°C of 6-day average temperature). We aimed to expose the exact effect of ambient temperature on paediatric acute appendicitis especially in children under 5 years of age.

## Materials and Methods

The Institutional Review Board of Children's Hospital Zhejiang University School of Medicine approved the retrospective research of the relationship between ambient temperature and the incidence rate of paediatric acute appendicitis in Hangzhou.

Our department (Department of General Surgery, Children's Hospital Zhejiang University, School of Medicine) is the only paediatric general surgery centre in Hangzhou, Zhejiang Province. Nearly all children under 15 years old in the city with AA were treated in our department. From 1 January 2003 to 30 November 2012, 4159 cases were enrolled in this study according to the "International Classification of Diseases, 9th Revision, Clinical Modification" codes 540, 540.0, 540.1, and 540.9. The ambient temperature data including the 1- to 28-day average temperature, relative humidity, rainfall, atmospheric pressure, and hours of sun shine was provided by Hangzhou Meteorological Bureau. Population of children aged 0-14 years was 991,100 at 0:00 am on 1 November 2010, and data were obtained from Zhejiang Province Family Planning Commission. Statistical Package for the Social Sciences (SPSS 16.0 for Windows, Chicago, Illinois, USA) was used. Pearson's correlation analysis was performed to examine the correlation between the climatic factors and incidence rate of AA and the association between 1- to 28-day average temperature and DACET. Auto-Regressive Integrated Moving Average (ARIMA) test was widely used to explore the monthly variation of AA and other seasonal diseases.[4,7,11,12] ARIMA was also performed to test the effects of climatic and monthly factors on AA incidence rates.

## Results

Among the 4159 patients with AA, 1071 patients were under 5 years old (younger patients), and 3088 aged 6-14 years (older patients). The number of AA patients in different age groups are presented in Table 1. The incidence of AA was the highest in the summer months and lowest in the winter months, and monthly average temperature had a similar monthly pattern (Figure 1). The ARIMA regression models revealed monthly incidence of AA was significantly associated with ambient temperature for younger patients and older patients (both $p<0.01$) (Table 2). The results of correlation between DACET and 1-day to 12-day average temperature are shown in Figure 2 and Table 3. Pearson's correlation analysis was used. For entire sample, a peak r value was seen in the correlation between 6-day average temperature and DACET. According to age, younger patients had a much lower r value ($r=0.52\pm0.09$, with a peak seen in that between 3-day average temperature and

**Table 1** Cases of acute appendicitis according to age in Hangzhou 2003.01.01-2012.11.30

| Age (year) | Cases | | | Gender ratio |
|---|---|---|---|---|
| | Entire sample | Male | Female | |
| 1 | 30 | 21 | 9 | 2.3 |
| 2 | 59 | 40 | 19 | 2.1 |
| 3 | 228 | 165 | 63 | 2.6 |
| 4 | 372 | 219 | 153 | 1.4 |
| 5 | 382 | 213 | 169 | 1.3 |
| 6 | 430 | 251 | 179 | 1.4 |
| 7 | 400 | 231 | 169 | 1.4 |
| 8 | 462 | 273 | 189 | 1.4 |
| 9 | 377 | 234 | 143 | 1.6 |
| 10 | 366 | 235 | 131 | 1.8 |
| 11 | 337 | 225 | 112 | 2.0 |
| 12 | 289 | 195 | 94 | 2.1 |
| 13 | 234 | 167 | 67 | 2.5 |
| 14 | 193 | 128 | 65 | 2.0 |
| Total | 4159 | 2597 | 1562 | 1.7 |

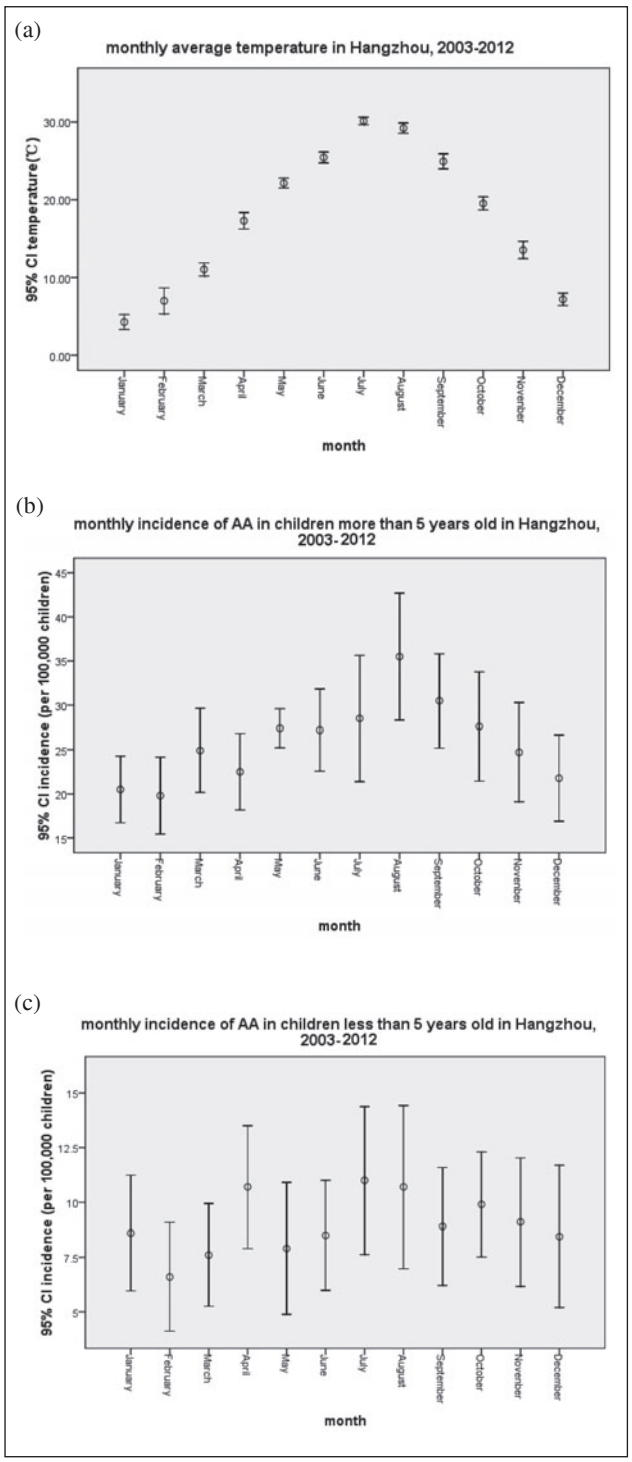



**Figure 1** Mean and 95% confidence of (a) monthly average temperature and (b) monthly incidence of acute appendicitis for older patients and (c) for younger patients in Hangzhou, 2003-2012.

DACET, all $p<0.05$) than older patients ($r=0.79\pm0.04$, with a peak seen in that between 7-day average temperature and DACET, all $p<0.01$). The correlation between monthly incidence of AA and monthly average temperature for entire sample ($r=0.404$, $p<0.001$), for younger patients ($r=0.209$, $p=0.023$), and for older patients ($r=0.421$, $p<0.001$) was much lower than that between 1- to 12-day average temperature and DACET. A 1°C increase in 6-day average temperature was associated with a 0.0202, 0.0044 and 0.0157 increase in daily average cases for entire sample ($r^2=0.78$, $p<0.001$), younger patients ($r^2=0.29$, $p=0.004$), and older patients ($r^2=0.68$, $p<0.001$), respectively. No correlation was found between the incidence of AA and other climatic factors including hours of sunshine, relative humidity, rainfall, and atmospheric pressure (all $p>0.05$) (data not shown).

## Discussion

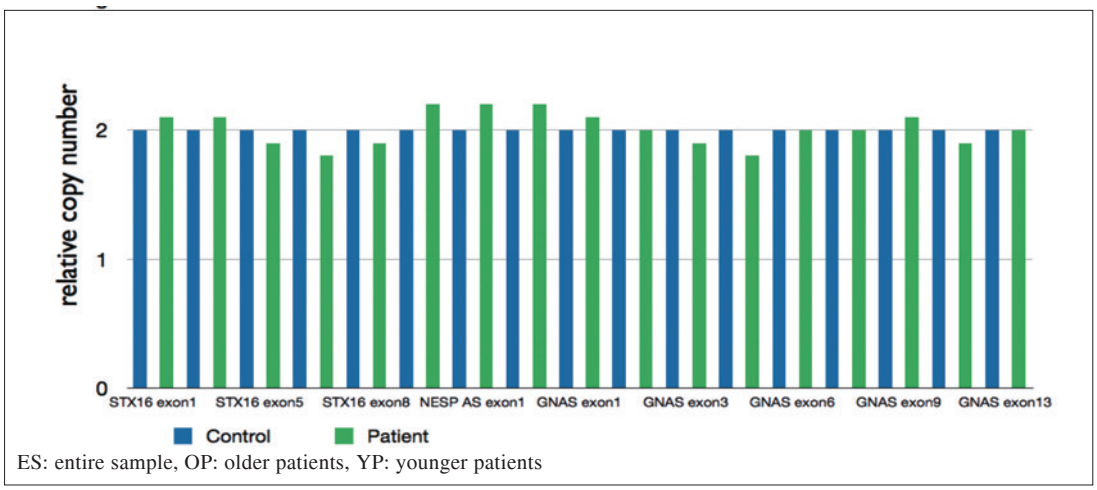
This study used a 10-year population-based dataset to examine the exact effect of ambient temperature on paediatric acute appendicitis especially in children under 5 years of age. Addis et al reported that the highest incidence of AA was found in patients aged 10-19 years;[5,13] while we found that children aged 6-8 years had the highest incidence. Boys had a higher incidence than girls with a gender ratio 1.7:1. These were consistent with previous reports.[4-6]

To date, many studies had revealed the monthly or seasonal variation in the incidence of AA,[4,7,13] duodenal ulcer,[14] pneumonia admission and mortality,[11,12] as well as gastroesophageal reflux disease,[15] but the exact role of ambient temperature hadn't been mentioned. Our study revealed that incidence of AA was the highest in July for younger patients, but in August for entire sample and for older patients. Meteorological data in Hangzhou city show that July and August are the hottest months of the year with high monthly average temperature. This suggested that ambient temperature might have an accumulative effect on the occurrence of paediatric acute appendicitis. If it was true, why does the highest incidence of AA in younger patients occur one month earlier than that in older patients? The peak r value of the correlation between DACET and n-day average temperature indicated that n was 6 for entire sample, 3 for younger patients and 7 for older patients. Thus, ambient temperature may have a quicker effect on the occurrence of AA in children under 5 years old. This may also explain that r value of the correlation between DACET and 1- to 12-day average temperature for younger

**Table 2** The results of ARIMA analysis

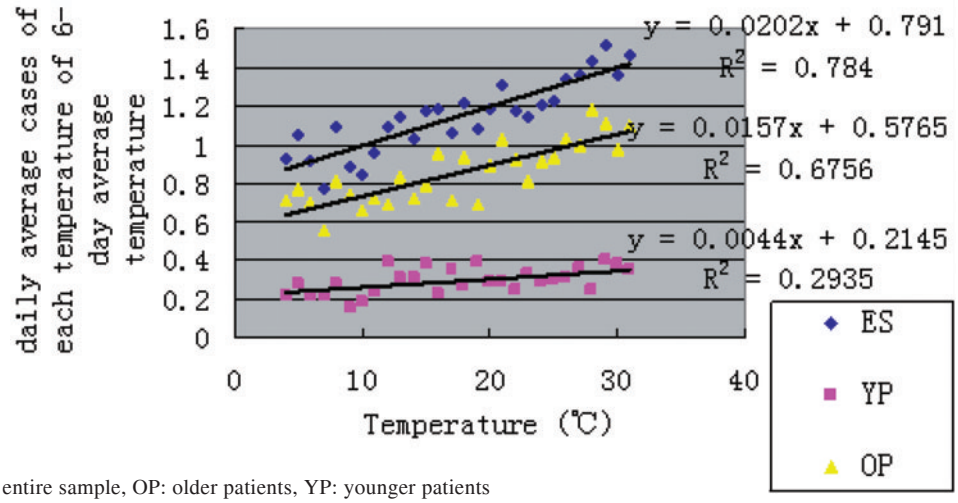
| Category | Variable | Estimate | SE | t value | p value | |
|---|---|---|---|---|---|---|
| Younger patients | Constant | -5.295 | 1.336 | -3.962 | 0.000 | <0.01 |
| | MA lag1 | 0.742 | 0.077 | 9.613 | 0.000 | <0.01 |
| | Temperature | 0.447 | 0.176 | 2.542 | 0.013 | <0.05 |
| | Trend | 0.003 | 0.002 | 1.527 | 0.130 | |
| | January | 4.169 | 0.882 | 4.728 | 0.000 | <0.01 |
| | February | | | Reference group | | |
| | March | 1.458 | 1.076 | 1.355 | 0.179 | |
| | April | .921 | 1.923 | 0.479 | 0.633 | |
| | May | -7.945 | 2.825 | -2.812 | 0.006 | <0.01 |
| | June | -5.479 | 3.304 | -1.659 | 0.100 | |
| | July | -5.697 | 4.158 | -1.370 | 0.174 | |
| | August | -9.022 | 4.005 | -2.253 | 0.026 | <0.05 |
| | September | -7.202 | 3.253 | -2.214 | 0.029 | <0.05 |
| | October | -2.333 | 2.314 | -1.008 | 0.316 | |
| | November | -2.632 | 1.365 | -1.928 | 0.057 | |
| | December | 1.188 | 0.620 | 1.916 | 0.058 | |
| Older patients | Constant | -9.240 | 3.258 | -2.836 | 0.006 | <0.01 |
| | MA lag1 | 0.716 | 0.077 | 9.252 | 0.000 | <0.01 |
| | Temperature | 1.105 | 0.396 | 2.791 | 0.006 | <0.01 |
| | Trend | 0.011 | 0.005 | 2.158 | 0.033 | <0.05 |
| | January | 3.067 | 2.518 | 1.218 | 0.226 | |
| | February | | | Reference group | | |
| | March | 1.310 | 2.775 | 0.472 | 0.638 | |
| | April | -13.506 | 4.392 | -3.075 | 0.003 | <0.01 |
| | May | -9.296 | 6.222 | -1.494 | 0.138 | |
| | June | -20.702 | 7.546 | -2.743 | 0.007 | <0.01 |
| | July | -22.906 | 9.313 | -2.460 | 0.016 | <0.05 |
| | August | -18.430 | 8.930 | -2.064 | 0.042 | |
| | September | -22.193 | 7.258 | -3.058 | 0.003 | <0.01 |
| | October | -17.151 | 5.295 | -3.239 | 0.002 | <0.01 |
| | November | -9.772 | 3.176 | -3.077 | 0.003 | <0.01 |
| | December | -0.067 | 2.063 | -0.033 | 0.974 | |

ARIMA: Auto-Regressive Integrated Moving Average; SE: standard error; MA: moving average




ES: entire sample, OP: older patients, YP: younger patients

**Figure 2** The results of the correlation between daily average cases of each temperature and 1- to 12-day average temperature.




ES: entire sample, OP: older patients, YP: younger patients

**Figure 3** Temperature variation of acute appendicitis.

**Table 3** The results of the correlation between daily average cases of each temperature and 1- to 12-day average temperature in Hangzhou, 2003-2012

| n-day average temperature | r value | | |
|---|---|---|---|
| n | Entire sample | Younger patients* | Older patients* |
| 1 | 0.78‡ | 0.44† | 0.73‡ |
| 2 | 0.82‡ | 0.53‡ | 0.82‡ |
| 3 | 0.79‡ | **0.70**‡ | 0.74‡ |
| 4 | 0.81‡ | 0.61‡ | 0.73‡ |
| 5 | 0.86‡ | 0.59‡ | 0.82‡ |
| 6 | **0.88**‡ | 0.51‡ | 0.82‡ |
| 7 | 0.83‡ | 0.49‡ | **0.85**‡ |
| 8 | 0.77‡ | 0.52‡ | 0.79‡ |
| 9 | 0.73‡ | 0.49‡ | 0.76‡ |
| 10 | 0.79‡ | 0.54† | 0.76‡ |
| 11 | 0.78‡ | 0.42† | 0.81‡ |
| 12 | 0.77‡ | 0.35† | 0.81‡ |

The results of the correlation between daily average cases of each temperature and 13- to 28-day average temperature were not shown because of all p>0.05 for younger patients.
†: p<0.05; ‡: p<0.01; *: using t test, as compared with older patients (0.79±0.04), the r value to younger patients (0.52±0.09) was much lower, p<0.001.

patients was much lower than that for older patients. Meanwhile, we found that ambient temperature had a weaker effect on the occurrence of AA in children under 5 years old. The r value of correlation between monthly incidence of AA and monthly average temperature was much lower than that between DACET and 1- to 12-day average temperature. So we concluded that the relationship between DACET and n-day average temperature may better reveal the real relationship between ambient temperature and acute appendicitis.

More AA occurred under higher ambient temperature (Figure 3). To confirm the effect of ambient temperature on the occurrence of AA, we underwent a further test. Twenty-two to 28°C was common temperature in summer months and non-summer months in Hangzhou in the past decade. No matter according to the 3- or 7-day average temperature, daily average cases under temperature of 22 to 28°C during non-summer months was very close to that in summer months for younger patients and for older patients (Table 4). This suggested that it was not the alteration of seasons but the increase of ambient temperature that affect the incidence rate of AA. The proposed mechanisms for this phenomenon were: firstly, high ambient temperature would increase bacterial infections;[16,17] secondly, high ambient temperature would aggravate air pollution, and air pollution might be a contributing factor to the pathogenesis of appendicitis.[18,19]

**Table 4** Daily average cases of 22 to 28°C of 3- and 7-day average temperature in summer months and non-summer months

| Temperature (°C) | Daily average cases of 22 to 28°C | | | | | |
|---|---|---|---|---|---|---|
| According to 3-day average temperature | | | | | | |
| | Summer months | | | Non-summer months | | |
| | Entire sample | 0-5 years | 6-14 years | entire sample | 0-5 years | 6-14 years |
| 22 | 1.15 | 0.22 | 0.93 | 1.21 | 0.29 | 0.92 |
| 23 | 1.20 | 0.31 | 0.89 | 1.10 | 0.26 | 0.84 |
| 24 | 1.21 | 0.37 | 0.84 | 1.24 | 0.32 | 0.92 |
| 25 | 1.47 | 0.24 | 1.22 | 1.04 | 0.26 | 0.77 |
| 26 | 1.51 | 0.42 | 1.08 | 1.20 | 0.30 | 0.91 |
| 27 | 1.40 | 0.30 | 1.10 | 1.55 | 0.35 | 1.20 |
| 28 | 1.64 | 0.36 | 1.28 | 1.48 | 0.31 | 1.17 |
| According to 7-day average temperature | | | | | | |
| | Summer months | | | Non-summer months | | |
| | Entire sample | Younger patients | Older patients | Entire sample | Younger patients | Older patients |
| 22 | 1.33 | 0.23 | 1.10 | 1.12 | 0.20 | 0.92 |
| 23 | 1.23 | 0.31 | 0.92 | 1.25 | 0.39 | 0.86 |
| 24 | 1.56 | 0.26 | 1.30 | 0.97 | 0.24 | 0.72 |
| 25 | 1.35 | 0.43 | 0.93 | 1.22 | 0.30 | 0.93 |
| 26 | 1.34 | 0.27 | 1.07 | 1.17 | 0.31 | 0.86 |
| 27 | 1.33 | 0.23 | 1.10 | 1.65 | 0.35 | 1.29 |
| 28 | 1.23 | 0.31 | 0.92 | 1.61 | 0.28 | 1.33 |

## Conclusions

More AA occurred with higher ambient temperature. As compared with the older children, ambient temperature had a weaker but quicker effect on the occurrence of AA in children under 5 years of age.

## Declaration of Interest

None

## References


1. Lamps LW. Appendicitis and infections of the appendix. Semin Diagn Pathol 2004;21:86-97.
2. Ohtani H, Tamamori Y, Arimoto Y, Nishiguchi Y, Maeda K, Hirakawa K. Meta-analysis of the results of randomized controlled trials that compared laparoscopic and open surgery for acute appendicitis. J Gastrointest Surg 2012;16:1929-39.
3. Prystowsky JB, Pugh CM, Nagle AP. Current problems in surgery. Appendicitis. Curr Probl Surg 2005;42:688-742.
4. Wei PL, Chen CS, Keller JJ, Lin HC. Monthly variation in acute appendicitis incidence: a 10-year nationwide population-based study. J Surg Res 2012;178:670-6.
5. Addiss DG, Shaffer N, Fowler BS, Tauxe RV. The epidemiology of appendicitis and appendectomy in the United States. Am J Epidemiol 1990;132:910-25.
6. Al-Omran M, Mamdani M, McLeod RS. Epidemiologic features of acute appendicitis in Ontario, Canada. Can J Surg 2003;46: 263-8.
7. Deng Y, Chang DC, Zhang Y, Webb J, Gabre-Kidan A, Abdullah F. Seasonal and day of the week variations of perforated appendicitis in US children. Pediatr Surg Int 2010;26:691-6.
8. Stein GY, Rath-Wolfson L, Zeidman A, et al. Sex differences in the epidemiology, seasonal variation, and trends in the management of patients with acute appendicitis. Langenbecks Arch Surg 2012;397:1087-92.
9. Bezirtzoglou C, Dekas K, Charvalos E. Climate changes, environment and infection: facts, scenarios and growing awareness from the public health community within Europe. Anaerobe 2011;17:337-40.
10. Schauble CL, Hampel R, Breitner S, et al. Short-term effects of air temperature on blood markers of coagulation and inflammation in potentially susceptible individuals. Occup Environ Med 2012;69:670-8.
11. Dowell SF, Whitney CG, Wright C, et al. Seasonal patterns of invasive pneumococcal disease. Emerg Infect Dis 2003;9:573-9.
12. Lin HC, Lin CC, Chen CS, Rose CE Jr, Schuchat A. Seasonality

of pneumonia admissions and its association with climate: an eight-year nationwide population-based study. Chronobiol Int 2009;26:1647-59.
13. Blewett CJ, Krummel TM. Perforated appendicitis: past and future controversies. Semin Pediatr Surg 1995;4:234-8.
14. Xirasagar S, Lin HC, Chen CS. Role of meteorological factors in duodenal ulcer seasonality: a nation-wide, population-based study. J Gen Intern Med 2007;22:1439-46.
15. Chen KY, Lou HY, Lin HC, Lee SH. Seasonal variation in the incidence of gastroesophageal reflux disease. Am J Med Sci 2009;338:453-8.
16. Hall GV, Kirk MD, Ashbolt R, Stafford R, Lalor K. Frequency of infectious gastrointestinal illness in Australia, 2002: regional, seasonal and demographic variation. Epidemiol Infect 2006;134: 111-8.
17. Sonnenberg A. Seasonal variation of enteric infections and inflammatory bowel disease. Inflamm Bowel Dis 2008;14:955-9.
18. Kaplan GG, Tanyingoh D, Dixon E, et al. Ambient ozone concentrations and the risk of perforated and nonperforated appendicitis: a multicity case-crossover study. Environ Health Perspect 2013;121:939-43.
19. Ren C, O'Neill MS, Park SK, Sparrow D, Vokonas P, Schwartz J. Ambient temperature, air pollution, and heart rate variability in an aging population. Am J Epidemiol 2011;173:1013-21.