PEDIATRIC PRIMARY HEADACHE SENSITIVITY TO WEATHER VARIABLES

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Title: Pediatric Primary Headache Sensitivity to Weather Variables

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Abstract:

Objective: To determine the relationship between weather patterns and pediatric Emergency Department visits for primary headache.

Methods**:** A retrospective descriptive correlational design was used. Chart reviews were done on 351 medical records of children less than 18 years of age. Study setting was visits to an Emergency Department at an academic pediatric hospital in the Southwest region of the United States. One calendar year of assessments of weather variables to include temperature, relative humidity, precipitation, and barometric pressure were obtained at multiple time points prior to presentation to identify weather-sensitive subsets. In addition, assessments of demographic (date of birth, sex, race, zip code) and clinical variables (chief complaint, diagnoses codes, imaging, medication, and disposition) were collected.

Results**:** Findings indicate that there is a correlation between weather variables and Emergency Department visits in pediatric patients, especially in forecasts of two to five days.

Conclusion**:** A subset of pediatric patients with primary headaches are sensitive to temperature changes within the 5 days preceding the presentation of the headache.

Keywords: pediatric, headache, weather, Arizona, public health

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Introduction:
Pediatric headaches are a frequent Emergency Department (ED) complaint with urban hospitals receiving hundreds of visits annually for a chief complaint of headache.[1] Primary headaches, which are headaches not associated with underlying disorders, have varying levels of disability and typically present as migraine, tension, or cluster headaches. Between 0.7% and 1.3% of all pediatric hospital visits are for headache. Of these visits, primary headaches make up between 10-20%, unlike adult populations where primary headaches are the most common diagnoses.[1,2]

Secondary headache can be attributed to underlying etiologies, which include viral or respiratory illness 20-28%, posttraumatic 20%, shunt malfunction 11%, with grave pathology like epidural or subdural hematoma, brain abscess and aseptic meningitis accounting for 0-7%.[1,2]

Headaches pose a substantial disability burden and financial burden to families impacting work and school performance.[3] Gilman *et al.* (2007) postulated that adolescents with headaches typically have difficulty coping and maintaining age appropriate functioning (*e.g*. attending school, working, engaging in sports or other social activities).[4]

Primary headaches in children and adolescents have been found to be distinct from adult headaches both by epidemiology and symptomatology; however, the International Classification of Headache Disorders (ICHD-2) uses the same classification system and diagnostic criteria for the discernment of both pediatric and adult headaches.[7]

A 2009 review showed the prevalence for migraine increased between the ages of 3-15. As the rates rise from 1.2%-3.2% for ages 3-7 and up to 8%-23% for age 15, the relative ratio of boys to girls decreases.[8] In 2017, another review aggregated the prevalence of primary headache at 88% for the pediatric and adolescent populations where 1-4% of the adolescent population experienced headaches on a daily basis.[9]

Substantial progress has been made in the prevention and pharmacological treatment of headaches, especially in adults. Identification and management of potential triggers is vital to successful care of the headache patient.[10] Headache triggers, or precipitating factors, act "alone or in combination to induce headache attacks in susceptible individuals."[11] Several adult studies have shown that primary headaches can be triggered by lifestyle factors such as alcohol, stressful life events, skipped meals, poor sleep hygiene, hot/cold weather, and certain foods.[3,12-14]

Adult Headache & Weather:

Adult primary headaches have been studied with greater specificity with respect to meteorological variables, which include temperature, precipitation, humidity, air quality, and barometric pressure. Though there are some contradictory results regarding multi-variable impact,[16-18] several studies indicate a subset of adult headache victims are weather-sensitive.[15-16]

In 2015, a study of 100 adult migraineurs used diary logs which were analyzed against weather variables within the preceding 24 hours. Within their limited sample size, 13% were identified as weather-sensitive.[15] This finding aligns with a 2004 analysis that looked at weather trends in adults over a prospective 2-year period. With a small sample size of 77, the author analyzed three dependent variables and found that 33.7% were sensitive to absolute temperature and humidity values, 14.3% were sensitive to changes in weather pattern, and 12.9% were sensitive to changes in barometric pressure.[16]

Pediatric Headache & Weather

Triggers for pediatric migraines have been well-studied internationally, though largely by self-reported measures. A 2009 retro- and prospective study in India identified triggers of sunlight, hot and humid climate, noise, crowdedness, and school stress, but were uncertain why environmental triggers were inconsistently impactful.[20] A 2015 large case-crossover analysis of air pollution levels in Taiwan found positive correlations in warm days and high CO_2 and on cool days NO_2 within 81,086 clinic visits. Particulate matter, O_3, and SO_2 were all positively correlated with visits independent of weather.[21] A 2013 Brazilian study identified self-reported triggers as: sun, heat, smoke, perfume, cleaning products, and gas.[22] A French retrospective questionnaire of children under 17 years of age found triggers of stress, sleep, warm climate, and video games. Results showed that the population self-reported a warm and humid climate trigger in 78% boys versus 55% girls.[23] A 2017 questionnaire-based study of 3,285 Japanese school children found that the incidence of both migraine and tension headaches in ages 6-15 rose from 3.5% and 5.4% to 5.0% and 11.2%, respectively. The authors reported migraine triggers of hunger, sun, and neck/shoulder pain.[24]

The data on seasonal variation and weather patterns are limited, mostly relating to the academic calendar. A 2014 retrospective analysis found that ED visits nadired May-June and peaked Sept-November suggesting the change in rhythm and increased stress to be responsible for these fluctuations rather than a presence or absence of school.[25] Similarly, a retrospective study of 6,572 encounters from 2010-2014 found a peak in September, while the rates did not lower during summer months.[26] A 2010 from Missouri used prospective self-reporting of headaches and time-stamps to monitor six weather variables in 25 patients, and they identified positive predictability with changes in humidity and precipitation, regardless of subjects' self-reported weather triggers.[27]

The purpose of this study was to evaluate the relationship between changing weather patterns in the metropolitan areas of Phoenix, Arizona and pediatric ED visits for primary headache. Specifically, the weather variables (temperature, relative humidity, precipitation, barometric pressure) were analyzed singularly and in concert within the 2, 5, and 10 days preceding the presentation for primary headache. Additionally, the frequency of headaches was examined by calendar year to evaluate seasonal variation with major weather events such as the monsoon season of June to September in Arizona. We hypothesized there would be an increase in migraine headache incidence with an increase in any of the following factors: temperature, humidity, precipitation, and barometric pressure.

Methods:

Using a retrospective descriptive correlational design, pediatric patients less than or equal to 18-years-old who presented to Phoenix Children's Hospital (PCH) for a primary headache from January 1, 2016 to December 31, 2016 were included in this study.

Excluded from analysis were patients with any of the following: age equal to or greater than 18 years, fever, meningitis, intracranial tumor, increased intracranial pressure, fall, closed head trauma, open head trauma, stroke, ventriculoperitoneal shunt placement, pregnancy, or other etiology consistent with secondary headache.

Electronic Medical Record chart review was conducted for the following demographic variables: date of birth, sex, race, zip code, chief complaint, coded diagnoses by International Statistical Classification of Diseases and Related Health Problems (ICD-10)[7], disposition, use of imaging, and use of medication treatment.

Weather variable data was accessed via the National Oceanic and Atmospheric Association (NOAA) database operated by the Northeast Regional Climate Center (NRCC) for the city of Phoenix, Arizona. Raw data were available online by request for variables of temperature, relative humidity, precipitation, and barometric pressure. Hourly data were averaged for daily level granularity.

Demographics and clinical characteristics of the patients who visited the ED for headaches were assessed using means, standard deviations for the continuous and frequency variables and proportions for the categorical variables. Spearman's Rho was used to correlate the number of visits to the ED with the change in temperature, pressure, precipitation, and relative humidity from baseline, respectively. Furthermore, Poisson regression was used to ascertain the incidence rate of the number of ED visits relative to the change in the same weather variables. The statistical model was controlled for age, sex, race, disposition at discharge, and month of visit. All p-values were two-sided and a $p<0.05$ was considered statistically significant.

Weather variable changes from two (2), five (5), and ten (10) days preceding Emergency Department visit were evaluated for predictive ability as a forecast for primary headache visits. Change in each weather variable was analyzed in its relationship to the number of patient visits on that date.

Daily weather variables were plotted across the calendar year alongside daily total number of ED visits to evaluate for chronologic correlations.

Results:

Initial study enrollment by ICD-10 code query was 385 with 34 omitted by exclusion criteria resulting in an analysis pool of 351 patients. Exclusion criteria counts were as follows: fever (5), ventriculoperitoneal shunt (5), trauma (4), abdominal pain (3), viral illness (3), mass effect (2), no documented complaint of headache (12). Analysis pool was 70% female with an average age of 14 years, 60% White, and 29% Hispanic. Our results indicate the top chief complaint was "headache" (69%) followed by "migraine" (7%), and that 89% of patients were discharged home for disposition. Greater than one third (38%) of patients had preexisting diagnoses of anxiety and/or depression. Imaging was obtained on day of presentation for 14% of patients and outpatient medication therapy was given as prescription for 33% and over the counter for 42% (**See Table 1**).

ZIP code frequency across 2016 is demonstrated in **Figure 1a** where 20 codes comprised 47% of the calendar year visits and thirty-nine different ZIP codes each accounted for a singular patient visit during the same year. See **Figure 1b** for a heat map indicating absolute visit volume by zip code on a map of metropolitan Phoenix, Arizona.

The maximum number of patient visits in one day across 2016 was 6 in this sample. Visit days of 5 or 6 patients were deemed "high volume" and days of 1 patient visit were deemed "low volume." Temperature, relative humidity, precipitation, and barometric pressure were analyzed by change in variable at two, five, and ten days preceding hospital visit. Temperature increase five days in advance of hospital visit for headache demonstrated statistical significance (p=0.04) for 5 patient visits on a given date (**Figure 2a**). Positive changes in barometric pressure **(Figure 2b)**, humidity (**Figure 2c**), or precipitation (**Figure 2d**) were not statistically significant for high volume days. No variable was statistically significant for low volume days at any predicting time interval.

Table 3 demonstrates the incident rate ratio for each weather variable across the two-, five-, and ten-day forecasts with 95% confidence intervals, where the only significance identified was for the 5-day forecast for temperature (IRR 0.96, CI 0.92-0.99, p=0.04).

Patient visits were displayed by frequency plot across the calendar year (see **Figure 3**) and peak in clusters in January-February and August-September. Each weather variable was plotted against visit frequency by daily maximum and daily average to evaluate for seasonal relationship to these high-volume visits. Precipitation was the variable with the closest subjective approximation.

Table 1: Demographics

Table 1: Demographics		n = 351	
Category	**Range**	**Mean**	**Standard Deviation**
Age (years)	5.5 to 18.0	13.9	2.8
Category	**Variable**	**Count**	**Percent (%)**
Sex	Female	247	70%
	Male	104	30%
Race	Asian	3	1%
	Black	18	5%
	Hispanic	101	29%

	Native American	3	1%
	White	212	60%
	Other	12	3%
Disposition	Admitted	40	11%
	Discharged	311	89%
Chief Complaint	Headache	241	69%
	Headache & Vomiting	6	2%
	Migraine	25	7%
	Other (including abdominal pain, dizziness)	79	23%
Mood Diagnoses	Anxiety	42	12%
	Depression	25	7%
	Anxiety & Depression	67	19%
Imaging Done	Yes	48	14%
	No	303	86%
Home Medication Plan	Prescription	115	33%
	Over the Counter	148	42%

Figure 1a: Top Zip Code Frequency Plot

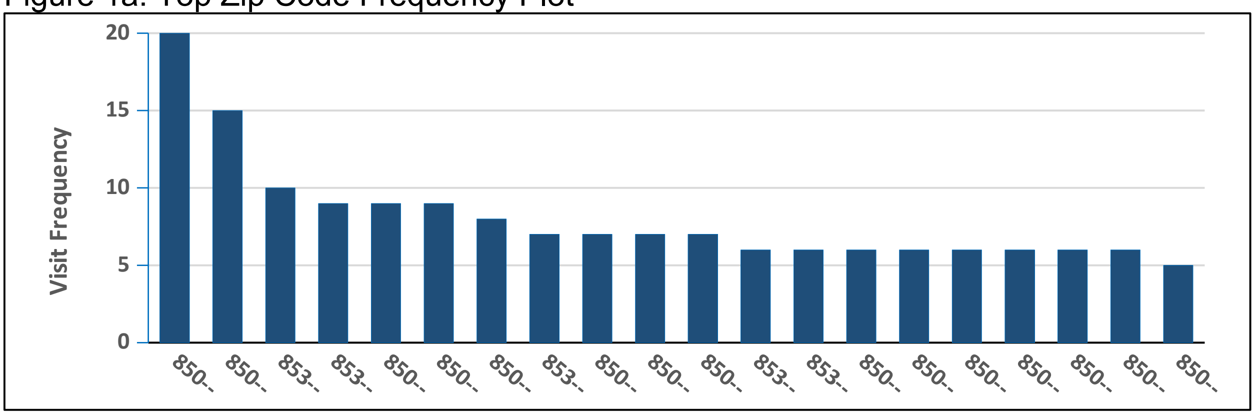


Figure 1b: Zip Code Heatmap by Zip Code

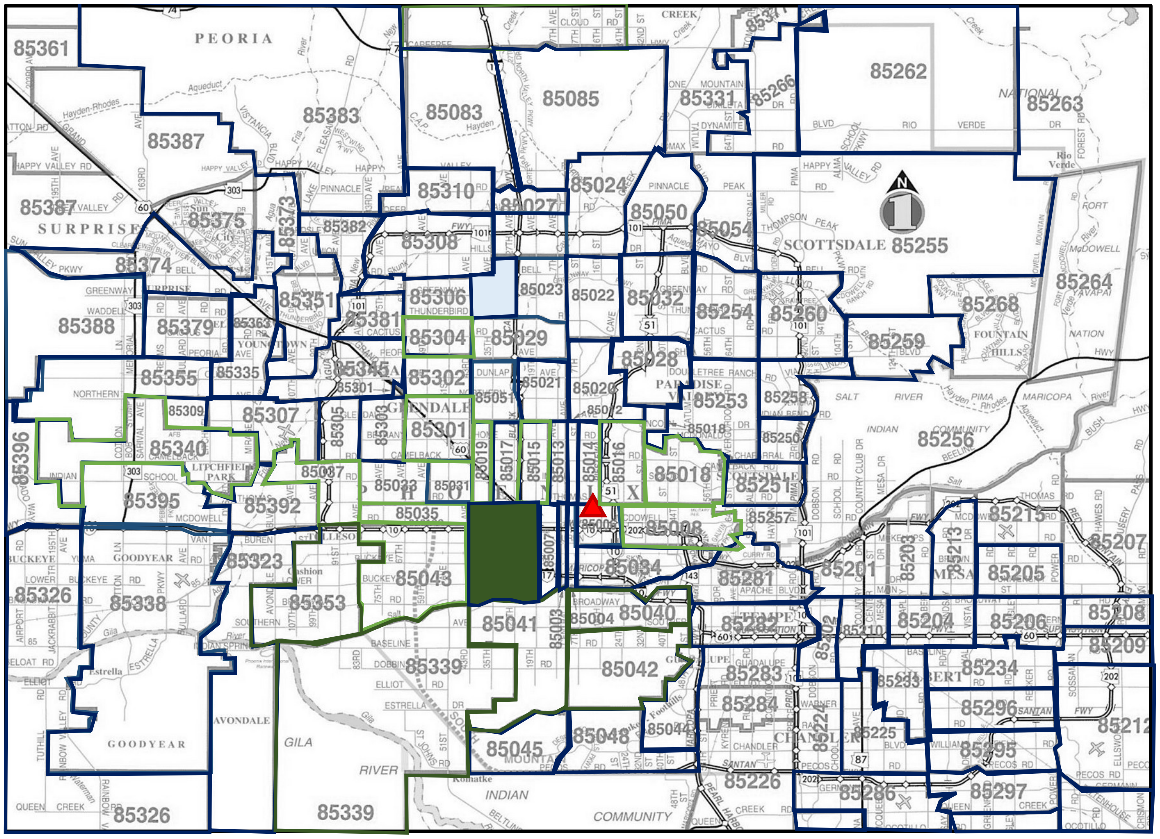


Table 2: Weather Variable Incident Rate Ratio

Variables	IRR (95% CI)	p-value
Temperature		
2 Day Change	1.02 (0.97, 1.07)	0.35
5 Day Change	0.96 (0.92, 0.99)	*0.04
10 Day Change	1.06 (0.99, 1.07)	0.054
Barometric Pressure		
2 Day Change	0.99 (0.96, 1.03)	0.93
5 Day Change	1.01 (0.97, 1.04)	0.57
10 Day Change	0.98 (0.96, 1.01)	0.36
Precipitation		
2 Day Change	0.67 (0.09, 5.00)	0.70
5 Day Change	1.17 (0.42, 3.24)	0.76
10 Day Change	1.48 (0.23, 9.43)	0.67
Relative Humidity		
2 Day Change	0.99 (0.98, 1.01)	0.58
5 Day Change	1.00 (0.99, 1.01)	0.58
10 Day Change	0.99 (0.99, 1.01)	0.84

Incident Rate Ratio calculated using Poisson Regression adjusting for age, sex, race, disposition at discharge and month of visit. Significance (p<0.05) indicated with asterisk.

Figure 2: Two-, Five-, and Ten-Day Forecast Correlation by Weather Variable
2a: Temperature Forecast
2b: Barometric Pressure Forecast
2c: Humidity Forecast
2d: Precipitation Forecast

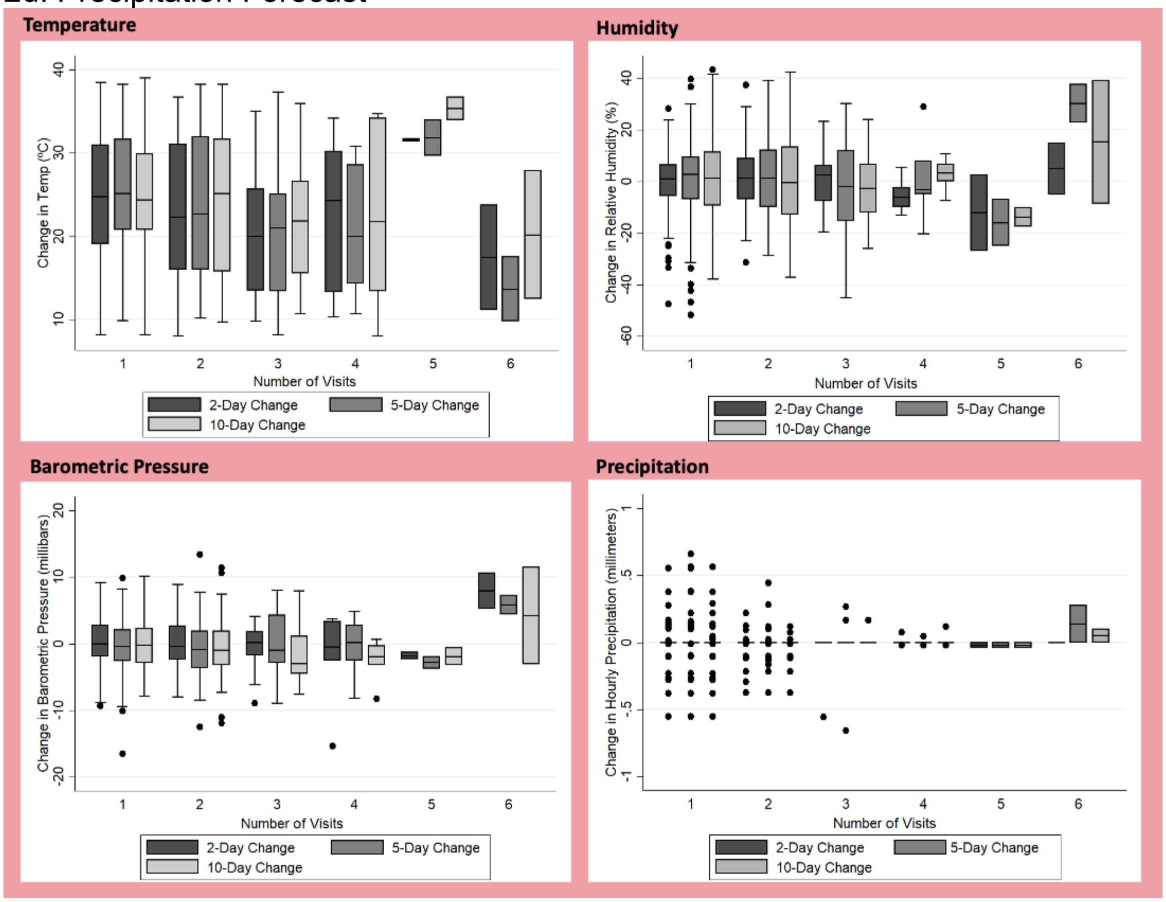
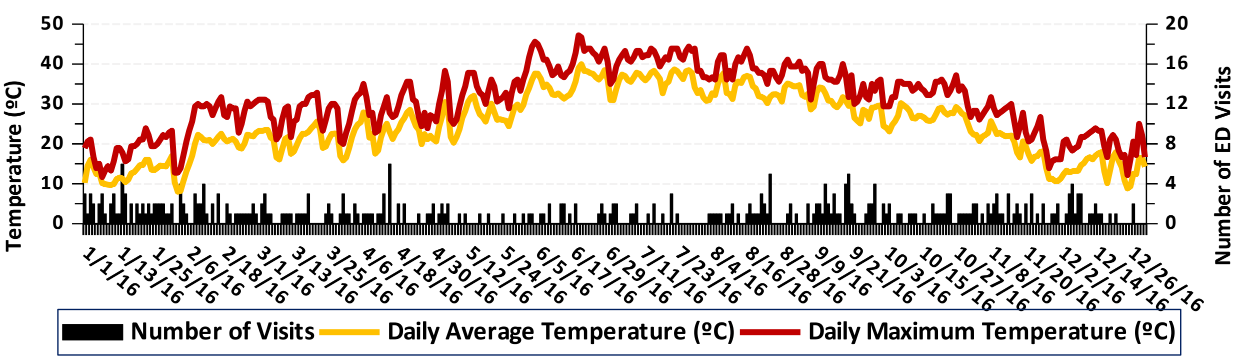
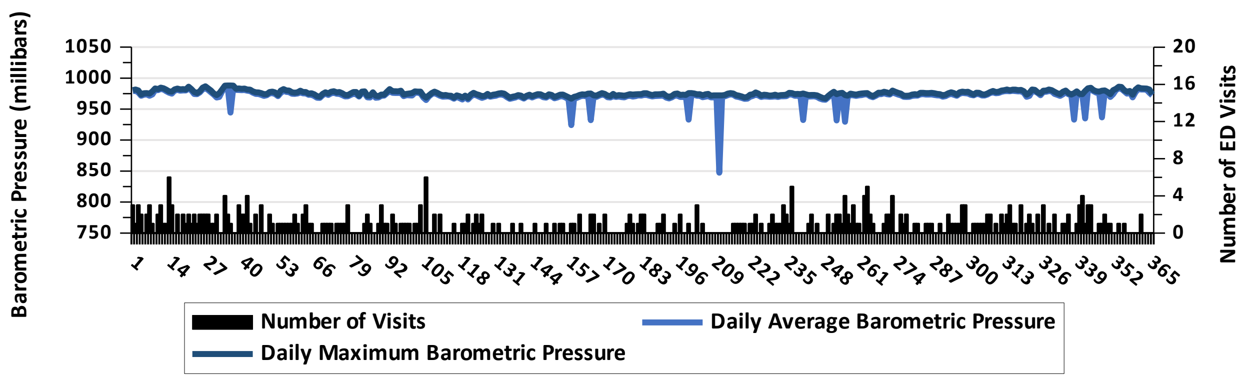


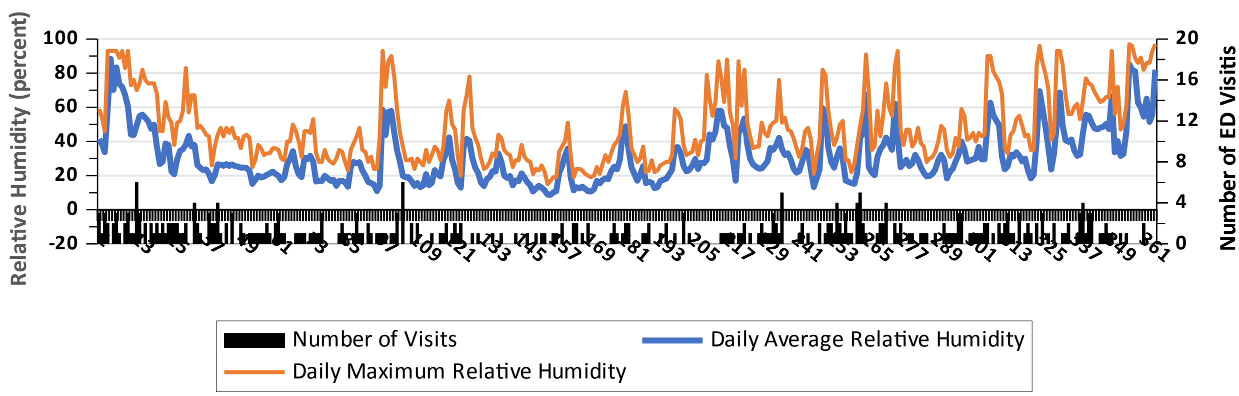
Figure 3: Headache Frequency & Weather Seasonal Variation
3a: Temperature



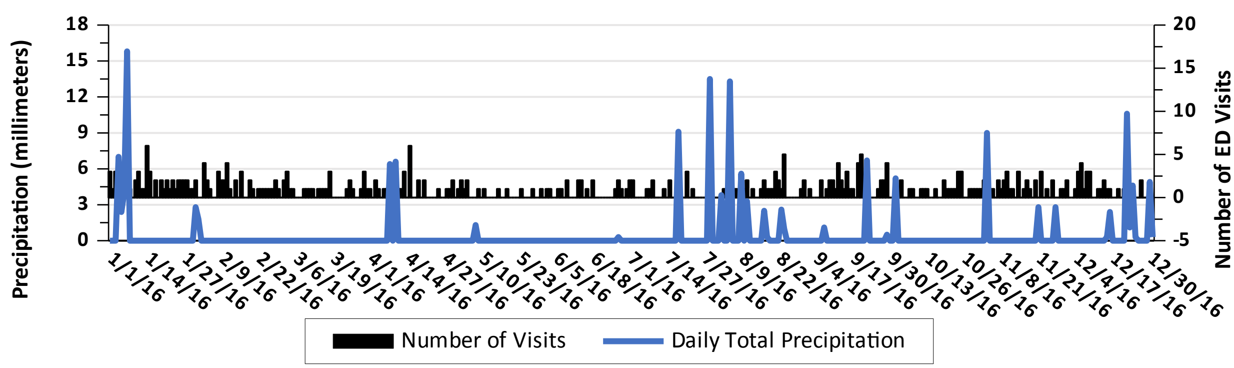
3b: Barometric Pressure



3c: Relative Humidity



3d: Precipitation



Discussion:

The impact of ambient temperature has been linked to adult primary headaches and ambient temperature also has been widely linked to children's health. A 2012 review describes literature linking heat and mortality in ages 0-18 but especially until the age of 4.[19]

Unlike much of the existing literature, this study used Emergency Department visits as the health care point of access. As such, these data may represent a skew towards a greater morbidity or pain severity and therefore underestimate weather sensitivity. This study may also be confounded by barriers to care where acute care services are the singular point of contact.

The majority of patient visits in this study lived in 6 ZIP codes (54%), which may offer insight for public health assessment of social determinants of health that may influence underlying confounders such as access to care, which could prompt Emergency Department visits as first access for primary headache.

The findings of this study indicate that temperature changes may predict Emergency Department visits for primary headache, particularly in forecasts five days. This may suggest the existence of weather-sensitive pediatric patients in the metropolitan areas of Phoenix, Arizona. A multi-year analysis would afford greater statistical power, especially for forecasts of two and five days. A subsequent study could be powered to track individual patients across multiple admissions to establish a more causal link between particular weather variables and Emergency Department visits for primary headache.

Calendar frequency distribution of visits was bimodal with peaks in January-February and August-September. This corroborates pediatric literature and aligns with the previously proposed hypothesis that disruptions in routine as linked with a return to school is more likely a confounding variable than is the attendance of school. This is further supported by the absence of a sustained peak across the Spring or Fall semester or a nadir in December.

The descriptive analysis of weather variables across the calendar year was did not closely reflect forecast accuracy for ED visits. The precipitation histogram included predictive peaks at about 5 days before high volume visit days during winter and spring, but importantly there was not a monsoon season visit peak as anticipated.

This analysis is limited in several aspects. The single-year analysis window likely is underpowered for a weather-sensitive subset identification. Widening the sample to 2 or 5 years may further separate the high from low volume visit days. This analysis is limited by the single-institution data source, although it represents the largest pediatric hospital in the county. An unlikely potential limitation to this study is the weather station location, as the majority of the patient visit ZIP codes are not separated significantly by mileage or altitude. As a retrospective analysis, this study is limited by physician documentation and billing code use, which is subject to human error.

This study adds to the body of knowledge regarding headaches and potential weather triggers in the pediatric population. It describes seasonal patient burden and may inform potential for staffing changes in the ED during the time when the weather pattern is more predictive of increase or decrease headaches in Phoenix and its metropolitan areas. In addition, this study allows patients, families, and public health workers to be better informed of the potential impact of weather variables on primary headaches within this geographic region.

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