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The Effect of Heat Waves on Preterm Birth Rates in Metropolitan Atlanta

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Abstract

The Effect of Heat Waves on Preterm Birth Rates in Metropolitan Atlanta By Maha Syed

Few studies have been conducted analyzing the changing climate's effects on health outcomes, particularly for vulnerable populations like pregnant women. This analysis will focus on understanding how elevated heat affects expectant mothers, a particularly vulnerable population. The study question addresses how heat waves in the metropolitan Atlanta, GA area affect preterm birth rates during the warm season between the years of 1994 through 2006. The null hypothesis is that there is no difference between preterm birth rates on heat wave days compared to non-heat wave days. Because rates of preterm birth differ by race and education, and because these population subgroups show different seasonal patterns of conception and birth, preterm birth counts were divided by race and education level and were controlled as potential confounders and assessed as potential effect modifiers in the Poisson regression model. A heat wave was defined using maximum temperature as a period of 2 or more consecutive days with maximum temperatures above the 95th percentile; only the second or later day above the 95th percentile is considered part of the heat wave. The overall rate of preterm births on heat wave days was 0.98 times that of the preterm birth rate on non-heat wave days (95% CI: 0.94-1.03; p-value=0.5361). The model including interaction terms between heat wave and education yielded significantly different rate ratios for heat wave and preterm births among the three levels of education (p-value=0.0445). Among women with less than a high school education, the rate ratio comparing heat wave days to non-heat wave days was 1.07 (95% CI: 0.98-1.16). While the overall model provided no evidence of a heat wave effect on preterm birth, there was suggestion that certain population subgroups may be more susceptible to the effects of heat waves. This could be due to access to resource issues due to potential lower socioeconomic status. Further analyses into elevated temperatures effects on birth outcomes would be beneficial in understanding the processes or vulnerabilities that may trigger early delivery.

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The Effect of Heat Waves on Preterm Birth Rates in Metropolitan Atlanta

Introduction

Many studies have been conducted on climate change and environmental consequences, as well as ones that have studied environmental exposures and health outcomes. However, few have been conducted analyzing the ever-changing climate's effects on health outcomes, particularly for vulnerable populations like pregnant women (Basu, Malig, & Ostro, 2010). The effects of climate change on heat and temperature motivates studies to understand the association between increased temperature and consequential health effects. This analysis will focus on understanding how elevated heat affects expectant mothers, a particularly vulnerable population. The study question addresses how heat waves in the metropolitan Atlanta, GA area affect preterm birth rates during the warm season between the years of 1994 through 2006.

Background

Heat waves affecting various health outcomes:

Studies have been conducted analyzing the effects of variable heat on various health outcomes. These include the effects of heat on mortality, renal disease, and birth defects.

One study that took place in 107 United States communities linked weather to mortality through time series models and demonstrated an overall increase of 3% in mortality risk when comparing the 99th and 90th percentiles of temperatures. Furthermore, mortality risk increased with the intensity and length of heat waves, and specific susceptibility was identified for specific age groups, socioeconomic status (SES) and conditions, urbanicity, and availability of central air conditioning. The strongest heat related mortality was observed for same or previous day exposure indicating the acute

effect of heat on mortality. There were notable differences in susceptibility related to SES, which may be a result of baseline health and nutrition status, access to healthcare, or individual response to extreme weather conditions. Finally, the presence of air conditioning has been observed to reduce the effects of high temperatures but not necessarily extreme heat events like heat waves. (B. G. Anderson & Bell, 2009)

Another study examining the impact of high temperatures on mortality utilized extended time-series data sets of daily mortality counts in three major European cities: London, Budapest, and Milan. A generalized estimating equations approach yielded results that there was an additional linear heat wave effect, or a log-linear increase in risk above a heat threshold, of 5.5% in London, 9.3% in Budapest, and 15.2% in Milan. However, the effects were reduced in nonlinear models, and when the overall summertime burden of heat on mortality was analyzed. (Hajat et al., 2006)

A study conducted in the United States analyzed the mortality risk of heat waves in 43 cities. Heat waves' timing, duration, and intensity were considered in these analyses. This analysis estimated nonaccidental mortality risk during a heat wave versus non-heat wave days, controlling for daily temperature. Research suggests that mortality risk increases on individual days of excessive heat; therefore, this study evaluated the potential of an added heat wave effect compared to those nonconsecutive individual days of elevated temperatures. The results highlighted that longer and more intense heat waves were more common in the southern United States, and that more intense heat waves tended to occur earlier in the season and for longer periods of time. The researchers found that there was a higher risk of mortality, on average, during heat waves compared to non-heat wave days. However, effect estimates were lower in the southern United States compared to the

Northeast or Midwest, albeit considering the southern cities had higher threshold temperatures. In a separate follow up analysis of this same study, two extreme heat wave events were analyzed in Chicago, IL and Milwaukee, WI. The estimated increased in mortality risk for Chicago was 18.9% and 10.3% for Milwaukee. In concluding remarks, the researchers explain the biological effect of high ambient temperature and the human body's response by dilating blood vessels near the body's skin to transfer heat from the body's core to the skin. The higher or longer the high temperature, the more work required by the cardiovascular system to maintain normal body temperature. Lengthy or intense heat waves could then contribute to consequential health effects. (G. B. Anderson & Bell, 2011)

Elevated heat can also have an effect on renal disease as seen in a study of a temperate city in Australia. Heat exposure can contribute to renal dysfunction through dehydration and hyperthermia. The researchers aimed to determine the relationship between heat exposure and renal morbidity as measured by hospital admissions in Southern Australia. The three admission types analyzed were for renal disease, acute renal failure, and renal dialysis. The study concluded that admissions for renal disease and acute renal failure were increased during heat waves compared to non-heat waves. Renal dialysis admissions did not illustrate a corresponding incidence. The study suggests that heat waves increase renal morbidity in susceptible individuals. (Hansen et al., 2008)

Extreme temperatures may also contribute to birth defects. A population based case-control study linked the New York State Congenital Malformations Registry to birth certificates from 1992-2006. Meteorological data was assigned based on maternal residence at time of birth. Cases and controls were selected that shared at least one week of

the extreme temperature period. An extreme temperature, defined as a five-degree increase in the mean daily minimum, turned out to be significantly associated with congenital cataracts. Inconsistent associations with various extreme temperature indicators were observed for other types of birth defects including renal agnesis/hypoplasia, anophthalmia/microphtalmia, and gastroschisis. (Van Zutphen, Lin, Fletcher, & Hwang, 2012)

Various exposures affecting preterm birth:

Pregnant women have been identified as a vulnerable population to various environmental exposures. The consequential health outcomes include preterm birth, a strong predictor of infant mortality and morbidity (Martin JA, 2007). Examples of these environmental exposures that may increase the risk of preterm birth include air pollution and other environmental contaminants.

A retrospective cohort study utilized vital records data and births that occurred between 1994 and 2004 in five metropolitan Atlanta counties. Using a time series approach, this data was examined by the relation of aggregate daily count of preterm birth to various indicators of ambient air pollution including: carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and particulate matter (both $PM_{2.5}$ and PM_{10}). Pollutant levels were collected through air quality monitors and subanalyses were restricted to mothers living within four miles of the air pollutant monitors. Analysis was conducted using Poisson regression and adjusted for seasonal and long-term trends. The results of this study demonstrated three positive associations: daily preterm rates with average nitrogen dioxide concentrations in the preceding six weeks, and with average $PM_{2.5}$ sulfate and $PM_{2.5}$ water-soluble metal concentrations in the preceding week. (Darrow, Klein, et al., 2009)

Another study that identified the increase in prematurity since 1990, utilized the US National Health and Nutrition Examination Survey (NHANES) to search for personal environmental factors that may contribute to preterm birth. Urine and blood markers that can identify allergens, pollutants, and nutrients were assayed in mothers who completed the survey and answered questions regarding a preterm birth. After controlling for various confounders including age, race/ethnicity, education, and household income, the strongest finding was the association between urinary bisphenol A and preterm birth. The authors suggest a larger epidemiological study to examine this specific relationship. (Patel et al., 2013)

Significance

Heat waves affecting preterm birth:

Understanding how elevated temperatures during heat waves affect pregnancy can help determine protective measures that need to be in place to reduce the amount of related preterm births. Furthermore, understanding during what stages of pregnancy women are most susceptible and whether a heat wave day acts as a trigger event into early labor can provide further insight to the vulnerabilities of this population (Strand, Barnett, & Tong, 2012). Because there is evidence of seasonality of conception patterns with more conceptions occurring in November and December, and more births occurring in the warmer months, any analysis of heat waves will have to consider this (Darrow, Strickland, et al., 2009).

With the increase of temperatures due to climate change, it is crucial to identify the health effects among vulnerable populations like expectant mothers. In a case-crossover analysis that included 60,000 births in a 16-county region of California during the months

of May-September between 1999 and 2006, authors identified the associations between preterm birth and heat and humidity. Utilizing birth registry data and meteorological and air pollution monitoring data, a conditional logistic regression model was run to identify any associations. A significant association between high ambient temperature and preterm birth was demonstrated for all mothers, regardless of confounders that included: race/ethnicity, age, education, and sex of infant. An 8.6% (95% CI: 6.0-11.3) increase in preterm deliveries was associated with a 10°F increase in weekly average apparent temperature, and there were more significant associations observed for younger mothers, black mothers, and mothers of Asian race/ethnicity. These associations were all independent of air pollutants and indicate a need for larger studies of temperature and preterm birth. (Basu et al., 2010)

With little known of the relationship between meteorology and pregnancy outcomes, one meta-analysis reviewed evidence on the relationships between meteorology and various pregnancy outcomes: the hypertensive disorders of pregnancy (including preeclampsia, eclampsia, and gestational hypertension), gestational length, and birth weight. The associations that were observed for the warm season include patterns of decreased gestational lengths and lower birth weights. Furthermore, the meta-analysis reported that the decreases in gestational lengths demonstrate an association with heat. One of the specific studies, a study from Japan, reported that rates of preterm births and monthly average temperature were positively correlated in the summer months ($R=0.549$, $p<0.001$). A second study included in the meta-analysis conducted in Israel found that preterm birth rates increased as monthly average maximum temperature increased. (Beltran, Wu, & Laurent, 2013)

Another meta-analysis identified various studies from electronic health databases that pertained to high environmental temperatures and preterm birth. Of the specific keywords used to search for papers, 159 papers were retrieved but eight met inclusion criteria for the meta-analysis. The review led to the finding that evidence supports an association between high environmental temperature and preterm birth, but the degree of association varies considerably. Furthermore, the review of evidence concludes that preterm birth rates appear to be linked to high environmental temperatures, and more specifically heat stress during extreme heat events or a sudden rise in temperature. The potential explanations include the body not being able to adapt quickly to extreme changes in temperature; potential solutions include research into the development of more effective cooling practices to lessen the effects of heat stress, and education for expectant mothers to take special care to avoid heat stress and stay cool during high environmental temperatures. (Carolan-Olah & Frankowska, 2013)

With the etiology of preterm birth still unknown, and preterm births representing the leading cause of perinatal mortality and morbidity in developed countries, a study out of Rome, Italy aimed to not only evaluate the effect of temperature on preterm birth but to also identify socio-demographic and clinical maternal risk factors that may contribute to individual susceptibility. Singleton, live births that occurred between 2001 and 2010 were analyzed through a time-series approach to estimate the effect of various temperature and pollutant exposures including heat waves during the month preceding delivery. The potential maternal risk factors (socio-demographic and clinical risk factors) were included as interaction terms. Of the entire cohort of births analyzed, 6% were preterm births. A 1.9% increase (95% CI: 0.86-2.87) was estimated in daily preterm births per one degree

Celsius increase in maximum apparent temperature in the two days before delivery. Age appeared to have a modifying effect including older women and women with higher education level having a lower effect of temperature on preterm birth risk, and younger women demonstrating a higher effect. A greater than 19% increase in preterm births was observed during heat waves, described as the daily maximum apparent temperature which is an index of discomfort including both air and dew-point temperatures (95% CI: 7.91-31.69). The results of this study demonstrate a short-term effect of heat on preterm birth risk and the disparity between some susceptible subgroups of women. (Schifano et al., 2013)

Environmental factors may be contributing to the almost 10% of all births that are classified as preterm. An Australian study between the years of 2005 and 2009 examined associations between ambient temperatures and adverse birth outcomes including preterm birth. A Cox proportional hazards model was utilized in this study, and specific periods during pregnancy with exposure to higher temperature were examined to determine if there was a greater effect during these times. Higher ambient temperatures seemed to have a greater effect on stillbirths than preterm births, but an association was observed to preterm births with the effect being greater at later gestational ages. (Strand et al., 2012)

Understanding the effects of temperature on vulnerable populations, like expectant mothers is crucial to avoid adverse birth outcomes, including preterm birth. This study will analyze this study question and keep race and education in consideration as potential confounders and effect modifiers.

Methods

Hypothesis

This study aims to understand if heat waves trigger expectant mothers into early labor. The null hypothesis is that there is no difference among preterm birth rates on heat wave days as opposed to the rate of preterm births on non-heat wave days. The predicted outcome is that there will be a higher rate of preterm births on a heat wave day versus a non-heat wave day.

Specific Aims

Using meteorological data that includes maximum, minimum, and mean temperature, along with dew point, a dichotomous heat wave exposure variable will be created using the maximum temperature variable (1-heat wave day, 0-non-heat wave day).

Utilizing Poisson Regression, a determination will be made if there is a statistically significant difference in the rate of preterm births on heat wave days compared to non-heat wave days.

This study aims to identify a current and generalizable definition of a heat wave and apply it as a dichotomous exposure in the analysis. The analysis of birth records data will determine if there is a statistically significant difference in preterm birth rates on heat wave days versus non-heat wave days during the warm season between the years of 1994-2006 in the 20-county metropolitan Atlanta, GA area.

Study Design

This retrospective cohort study involves two data sets linked by date. These data sets include meteorological data from the Hartsfield Jackson International Airport weather station, and birth records data from the Georgia Department of Public Health (GDPH). The

study will only look at the warm months (May-September) between the years of 1994-2006.

The definition of a heat wave for this analysis is defined as the second day or later of a period of two or more consecutive days with temperatures in at least the 95th percentile of the maximum temperature range for the entire study period. Heat waves will only be identified and assessed in relation to preterm birth during the warm season months (May-September) for the years 1994-2006 using daily maximum temperature (G. B. Anderson & Bell, 2011; Hansen et al., 2008)

Data

There will be two datasets involved in this analysis. One is a meteorological data set from the Hartsfield Jackson International Airport weather station that includes variables such as minimum, maximum, and mean temperatures, along with dew point for the metropolitan Atlanta area. Maximum temperature will be manipulated to create a dichotomous heat wave exposure variable based on this study's definition of a heat wave.

The second data set comes from birth records from the Georgia Department of Public Health (GDPH) for the 20-county metropolitan Atlanta area. This data set includes information about mother's demographics (age, race, etc.). Data are restricted to singleton, spontaneous births without major structural birth defects among women who are non-Hispanic white, non-Hispanic black, Asian or Hispanic. The data set is set up as one data line per baby representing one birth record. These birth records will be aggregated to create an analytic dataset indicating the count of preterm births on each day and the number of babies *in utero* at risk of preterm birth on that day (the risk set).

These two data sets will be linked by date during the warm season (May-September) between the years of 1994-2006.

Analysis

Utilizing Poisson regression, this study will analyze whether the rate of preterm births on heat wave days is different from the rate on non-heat wave days between the years of 1994-2006 during the warm season. The rate of preterm birth on a given day will be defined as the number of preterm births on that day divided by the number of ongoing gestations at risk of preterm birth on that day. Each day in the study will be assigned as exposed or unexposed to a heat wave to run this regression. Preterm birth will be defined as a live, singleton, spontaneous birth between 20-36 weeks gestation. Daily rates will be calculated separately for each gestational week, and eleven indicator variables will be created for gestational age to ensure adequate counts in each category (e.g. 20-26 weeks gestation, 27 weeks, 28 weeks, etc). Because rates of preterm birth differ by race and education, and because these population subgroups show different seasonal patterns of conception and birth, preterm birth counts will be divided by race and education level and will be controlled as potential confounders and assessed as potential effect modifiers in the model. The analysis is limited to the warm season during the years of 1994-2006, and indicator variables will be created for each month of the study. Finally, air pollution exposure may be another confounding variable, but will be acknowledged as a limiting factor in this analysis (Darrow, Klein, et al., 2009).

Results

A Poisson regression model was utilized controlling for race and education level using SAS 9.3 (Cary, NC). A heat wave was defined using maximum temperature and is a period of 2 or more consecutive days with maximum temperatures above the 95th percentile; only the second or later day above the 95th percentile is considered. The 95th percentile of the maximum temperature for the entire study period (all months 1994-2006) is 92°F. After limiting to only the warm season months (May-September) between the years 1994-2006, 189 days were classified as exposed heat wave days. During the warm season, the average maximum temperature was 85°F with the lowest maximum temperature at 56°F and the highest maximum temperature at 102°F. (Table 1)

After limiting the birth records data to only live, spontaneous, singleton births during the study period of interest (warm season months between 1994-2006), a total of 509,193 births were included in the analysis. This total represents any birth that contributed at least one person-day of risk *in utero* during the warm season. During the study period, there were 29,370 births occurring between 20-36 weeks gestation and classified as preterm births. (Table 2)

The analysis also involved identifying the rate ratios for preterm birth for the covariates of interest which include race/ethnicity and education. The preterm birth rate among black women was 1.59 times higher than white women (95% CI: 1.55-1.63; p-value <0.0001). Furthermore, Asian and Hispanic women had lower rates of preterm birth compared to white women. Asian women had a preterm birth rate 0.95 times white women (95% CI: 0.89-1.01; p-value=0.1114). Hispanic women had a preterm birth rate 0.77 times that of white women (95% CI: 0.74-0.81; p-value <0.0001). With college educated women

as the referent category, high school educated women had a higher rate of preterm birth at 1.16 times that of college educated women (95% CI: 1.13-1.20; p-value <0.001). Women with less than a high school education had an even higher rate of 1.32 times that of college educated women (95% CI: 1.28-1.36; p-value <0.0001). (Table 3)

Once the meteorological dataset and birth records data set were linked by date, an overall Poisson regression model was run to determine the effect of heat wave exposure on preterm birth rates, while controlling for race/ethnicity and education. Interaction models were also run to determine whether race/ethnicity or education modified the association between heat wave and preterm birth. The overall rate of preterm births on heat wave days was 0.98 times that of the preterm birth rate on non-heat wave days (95% CI: 0.94-1.03; p-value=0.5361). The model including interaction terms between heat wave and education yielded significantly different rate ratios for heat wave and preterm births among the three levels of education (p-value=0.0445). Results showed that the risk ratio for heat wave tended to be higher among women with lower education. (Table 4)

Discussion and Conclusions

This study addresses how heat waves in the metropolitan Atlanta, GA area affect preterm birth rates during the warm season between the years of 1994 through 2006. The rate ratios for the covariates of interest which include race/ethnicity and education demonstrate how rates of preterm birth differ by race and education (Table 3). The rate of preterm births among black women is higher than that of white women, the referent category ($RR=1.59$, $p\text{-value}<0.0001$). This racial disparity in preterm birth rates has been identified in the literature with a true cause still unidentified. Conducting studies of various environmental exposures can assist in determining what may lead to this disproportionate rate, including the underlying contributory factors to preterm birth which may be trigger events like heat waves. Furthermore, these types of studies can provide insight into protective measures that could be beneficial for expectant mothers to partake in to avoid adverse birth outcomes.

The overall Poisson regression model comparing the rate of preterm births on heat wave days versus non-heat wave days did not demonstrate significant results, leading to the conclusion that there is not a significantly different rate in preterm births caused by heat waves alone (Table 4). However, the model including interaction between education and heat wave demonstrated a statistically significant difference in heat wave effect based on education level (Table 4). The results provide some suggestion that heat waves increase the rate of preterm births among women with less education ($p\text{-value}=0.0445$). Future studies could utilize this finding by identifying the reasons less educated women are more vulnerable during heat waves. This could be due to access to resource issues due to potential lower socioeconomic status (SES). This finding is also consistent with the current

literature. The literature review highlighted that younger mothers and mothers with lower SES are more vulnerable to the negative effects of heat waves. This difference in susceptibility may be related to baseline health and nutrition status or access to healthcare (B.G. Anderson & Bell, 2009).

This study was limited by not including air pollution exposure which may be another potential confounding variable. Furthermore, misclassification of preterm birth could be a source of potential bias since conception date was utilized to determine preterm birth classification. Seasonality of birth is also a factor to consider in this analysis since there are more births in the summer months than any other season, but this was accounted for using a gestations-at-risk approach. Future studies analyzing the effects of heat waves on preterm birth could examine other definitions of heat waves. This could be a limiting factor in this study since this analysis only included one definition of a heat wave, and this exposure is not a clearly defined exposure across all studies.

Further analyses into elevated temperatures effects on birth outcomes would be beneficial in understanding the processes that may trigger early delivery. Understanding how elevated temperatures during heat waves affect vulnerable populations, including pregnant women, can help determine protective measures that need to be in place to reduce the amount of adverse birth outcomes.

Tables**Table 1. Characteristics of Metropolitan Atlanta, GA Meteorological Data of the Warm Season^a (1994-2006)**

	Mean Daily Temperature (°F)	Maximum Temperature (°F)	Minimum Temperature (°F)
Mean	76.1	84.9	66.8
S.D.	6.0	6.7	6.3
Minimum	53.0	56.0	41.0
Maximum	90.5	102.0	80.0
Range	37.5	46.0	39.0
Percentiles			
5th	64.0	72.0	54.0
25th	73.0	81.0	64.0
50th	77.0	86.0	69.0
75th	80.0	89.0	71.0
90th	82.5	93.0	73.0
95th	84.0	95.0	74.0
Heat Wave Day ^b	Yes (%)	No (%)	Total Days
	189 (9.5%)	1800 (90.5%)	1,989 (100%)

^aWarm season defined as May-September^bDefined as the second day or later of a period of 2 or more consecutive days with temperatures in the 95th percentile of entire study period (=92°F)

Table 2. Characteristics of a Cohort of Georgia's Singleton, Spontaneous, Live Births by Preterm Birth Status Based on Georgia Department of Public Health Birth Records Data

	Eligible Births ^a (n=509,193)		Preterm Births ^b (n=29,370)	
	No.	%	No.	%
Maternal education				
College	244,739	48.1	12,900	43.9
High School	149,224	29.3	9,256	31.5
Less than High School	115,230	22.6	7,214	24.6
Maternal race/ethnicity				
White	244,798	48.1	12,101	41.2
African American	170,802	33.5	13,114	44.7
Asian	20,290	4.0	948	3.2
Hispanic	73,303	14.4	3,207	10.9

^aAny birth contributing at least 1 person-day of risk *in utero* during warm season

^bPreterm birth includes live births that occurred at gestational ages 20-36 weeks

Table 3. Rate Ratios of Covariates to Preterm Birth^a

	Estimate	CI (95%)	P-value
Race/Ethnicity			
White (referent)	1.00		
Black	1.59	1.55-1.63	<0.0001
Asian	0.95	0.89-1.01	0.1114
Hispanic	0.77	0.74-0.81	<0.0001
Education			
College (referent)	1.00		
High School	1.16	1.13-1.20	<0.0001
Less than High School	1.32	1.28-1.36	<0.0001

^aPreterm birth includes live births that occurred at gestational ages 20-36 weeks

Table 4. Rate Ratios for Heat Waves^a, Overall and by Race and Education

	Estimate	CI (95%)	P-value
Overall	0.98	0.94-1.03	0.5361
Race/Ethnicity ^b			
White	0.99	0.93-1.06	0.7929
Black	0.97	0.91-1.04	0.4321
Asian	0.93	0.73-1.20	0.6001
Hispanic	1.03	0.89-1.18	0.7002
Education ^c			
College	0.94	0.87-1.00	0.0552
High School	0.99	0.92-1.07	0.8440
Less than High School	1.07	0.98-1.16	0.1371

^aDefined as the second day or later of a period of 2 or more days with temperatures in the 95th percentile of entire study period (=92°F)

^bOverall p-value of interaction terms of race/ethnicity with heat wave (3 df)=0.8712

^cOverall p-value of interaction terms of education with heat wave (2 df)=0.0445

References

- Anderson, B. G., & Bell, M. L. (2009). Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. *Epidemiology*, 20(2), 205-213. doi: 10.1097/EDE.0b013e318190ee08
- Anderson, G. B., & Bell, M. L. (2011). Heat waves in the United States: mortality risk during heat waves and effect modification by heat wave characteristics in 43 U.S. communities. *Environ Health Perspect*, 119(2), 210-218. doi: 10.1289/ehp.1002313
- Basu, R., Malig, B., & Ostro, B. (2010). High ambient temperature and the risk of preterm delivery. *Am J Epidemiol*, 172(10), 1108-1117. doi: 10.1093/aje/kwq170
- Beltran, A. J., Wu, J., & Laurent, O. (2013). Associations of meteorology with adverse pregnancy outcomes: a systematic review of preeclampsia, preterm birth and birth weight. *Int J Environ Res Public Health*, 11(1), 91-172. doi: 10.3390/ijerph110100091
- Carolan-Olah, M., & Frankowska, D. (2013). High environmental temperature and preterm birth: A review of the evidence. *Midwifery*. doi: 10.1016/j.midw.2013.01.011
- Darrow, L. A., Klein, M., Flanders, W. D., Waller, L. A., Correa, A., Marcus, M., . . . Tolbert, P. E. (2009). Ambient air pollution and preterm birth: a time-series analysis. *Epidemiology*, 20(5), 689-698. doi: 10.1097/EDE.0b013e3181a7128f
- Darrow, L. A., Strickland, M. J., Klein, M., Waller, L. A., Flanders, W. D., Correa, A., . . . Tolbert, P. E. (2009). Seasonality of birth and implications for temporal studies of preterm birth. *Epidemiology*, 20(5), 699-706. doi: 10.1097/EDE.0b013e3181a66e96
- Hajat, S., Armstrong, B., Baccini, M., Biggeri, A., Bisanti, L., Russo, A., . . . Kosatsky, T. (2006). Impact of high temperatures on mortality: is there an added heat wave effect? *Epidemiology*, 17(6), 632-638. doi: 10.1097/01.ede.0000239688.70829.63
- Hansen, A. L., Bi, P., Ryan, P., Nitschke, M., Pisaniello, D., & Tucker, G. (2008). The effect of heat waves on hospital admissions for renal disease in a temperate city of Australia. *Int J Epidemiol*, 37(6), 1359-1365. doi: 10.1093/ije/dyn165
- Martin JA, H. B., Sutton PD, Ventura SJ, Menacker F, Kirmeyer S, Munson ML. (2007). Births: Final data for 2005 *National Vital Statistics Reports* (Vol. 56). Hyattsville, MD: National Center for Health Statistics.
- Patel, C. J., Yang, T., Hu, Z., Wen, Q., Sung, J., El-Sayed, Y. Y., . . . Butte, A. J. (2013). Investigation of maternal environmental exposures in association with self-reported preterm birth. *Reprod Toxicol*, 45c, 1-7. doi: 10.1016/j.reprotox.2013.12.005
- Schifano, P., Lallo, A., Asta, F., De Sario, M., Davoli, M., & Michelozzi, P. (2013). Effect of ambient temperature and air pollutants on the risk of preterm birth, Rome 2001-2010. *Environ Int*, 61, 77-87. doi: 10.1016/j.envint.2013.09.005
- Strand, L. B., Barnett, A. G., & Tong, S. (2012). Maternal exposure to ambient temperature and the risks of preterm birth and stillbirth in Brisbane, Australia. *Am J Epidemiol*, 175(2), 99-107. doi: 10.1093/aje/kwr404
- Van Zutphen, A. R., Lin, S., Fletcher, B. A., & Hwang, S. A. (2012). A population-based case-control study of extreme summer temperature and birth defects. *Environ Health Perspect*, 120(10), 1443-1449. doi: 10.1289/ehp.1104671