Environmental Research 154 (2017) 109–114

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

The impact of maternal factors on the association between temperature and preterm delivery

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ARTICLE INFO

Keywords:
Temperature
Heat
Preterm delivery
Preterm birth
Case-crossover
California
Epidemiology

ABSTRACT

Background: Few studies have examined maternal modifiers of temperature and adverse birth outcomes because of lack of data. We assessed the relationship between apparent temperature, preterm delivery (PTD) and maternal demographics, medical and mental health conditions, and behaviors.

Methods: A time-stratified case-crossover analysis was conducted using 14,466 women who had a PTD (20 to less than 37 gestational weeks) from 1995 to 2009 using medical records from a large health maintenance organization in Northern California. Effect modifiers considered by stratification included several maternal factors: age, race/ethnicity, depression, hypertension, diabetes, smoking, alcohol use, pre-pregnancy body mass index, and Medicaid status. Apparent temperature data for women who had a monitor located within 20 km of their residential zip codes were included. All analyses were stratified by warm (May 1 through October 31) and cold (November 1 through April 30) seasons.

Results: For every 10°F (5.6 °C) increase in average cumulative weekly apparent temperature (lag06), a greater risk was observed for births occurring during the warm season (11.63%; 95% CI: 4.08, 19.72%) compared to the cold season (6.18%; −2.96, 16.18%), especially for mothers who were younger, Black, Hispanic, underweight, smoked or consumed alcohol during pregnancy, or had pre-existing /gestational hypertension, diabetes, or pre-eclampsia.

Conclusions: Our findings suggest that warmer apparent temperatures exacerbate the risk of PTD, particularly for subgroups of more vulnerable women.

1. Introduction

Premature births, defined as births occurring before 37 gestational weeks, have been associated with increased risk of deaths, hospitalizations, and cognitive impairment throughout childhood as well as neurological effects that continue into adulthood (Cuevas et al., 2005; Petrou et al., 2003). Approximately 12% of births in the US are currently preterm, and this estimate has remained relatively stable for the past five years (Martin et al., 2013). Many causes of preterm delivery (PTD) remain unknown, but factors such as maternal hypertension and chronic infections have been associated with increased risk (Mattison et al., 2003). In the past decade, researchers have made the connection between environmental exposures, such as air pollution and traffic exposures and PTD. More recently, positive associations between PTD and meteorology (Beltran et al., 2014), heat waves (Wang et al., 2013), and high ambient temperature (Carolan-Olah and Frankowska, 2014) have been found, identifying pregnant women as a vulnerable subgroup to heat exposure. With heat waves expected to increase in duration and frequency, it is essential to identify maternal risk factors to target high-risk mothers and propose interventions to help prevent preterm births that are exacerbated by heat exposure. However, previous studies have relied primarily on birth certificate data that have limited information on maternal factors, such as health, demographic, and behavioral factors, that could modify risk.

In this study, we examined whether certain maternal demographics, behavioral factors, and medical and mental health conditions may increase pregnant women's susceptibilities to heat-related PTDs using electronic health records from pregnant Kaiser Permanente Northern California (KPNC) members with delivery dates from 1995 through 2009.

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http://dx.doi.org/10.1016/j.envres.2016.12.017
Received 4 October 2016; Accepted 19 December 2016

2. Methods

2.1. Exposure classification

Meteorologic data consisting of temperature and relative humidity were provided by the California Irrigation Management Information System (CIMIS, 2014), the National Center for Environmental Information (NOAA, 2012) and the US Environmental Protection Agency Air Quality Data Mart (U.S. EPA, 2014) from 1995 through 2009. Apparent temperature was calculated using the following formula: −2.653+(0.994 x temperature in °C) +0.0153*(dew-point temperature in °C)^2. Each mother was assigned a value for mean daily apparent temperature from the meteorologic monitor closest to the centroid of her reported residential zip code and in the same county where she gave birth. Only those cases residing in zip codes with centroids located within 20 km of a meteorologic monitor, as identified by Hawth's Tools for ArcGIS 9.3 (Beyer, 1995–2008), were eligible for this study. Warm season was defined as May 1 through October 31 and cold season from November 1 through April 30. We did not consider air pollutants in this analysis because no confounding or effect modification was found in a previous study using the same exposure data (Basu et al., 2010).

2.2. Outcome

KPNC is an integrated healthcare delivery system with more than three million members and 40 clinical facilities and 16 delivery hospitals covering membership population in urban, suburban, and rural areas. KPNC has more than 33,000 deliveries each year. Coverage is provided for approximately 30% of the northern California population and is similar demographically, racially and ethnically to the population living in the geographic area. Over 99% of participants had reliable information on gestational age at delivery ascertained through KPNC's electronic health record (EHR) databases.

Gestational age at delivery was determined by obstetricians based on multiple sources including ultrasound dating and last menstrual period, and births were considered preterm if they occurred prior to 37 completed weeks of gestation. Other variables ascertained from the EHR included date of infant's birth, infant's sex, mother's residential zip code when she gave birth, maternal demographics (age, race/ethnicity), behavioral factors during pregnancy collected by self-reported questionnaire routinely as part of prenatal care (smoking and alcohol use), Medicaid Status (prior to or during pregnancy) and pre-pregnancy Body Mass Index (BMI). Additionally, data were ascertained on medical and mental health conditions during pregnancy (depression, diabetes (pre-existing or gestational), hypertension (pre-existing or gestational), and pre-eclampsia). Depression was based on either ICD-9 code diagnoses (296.2–296.3 excluding 296.26 and 296.36, 300.4, 309.0–309.1, 648.4) or antidepressant medication dispensing during pregnancy. Hypertension and pre-eclampsia were based upon ICD-9 codes 401–405 and 642.4–642.7, respectively. Diabetes diagnoses were identified through KPNC's Diabetes and Gestational Diabetes Registries.

Only singleton births in counties with at least 15 preterm births for which data on the variables of interest were available were included in the primary analyses to ensure the stability of our estimates. In addition, there had to be at least 5 preterm births in each county of the specified variable to be included in analyses involving effect modifiers. Small neighboring counties such as El Dorado/Amador, Sonoma/Mendocino, and Tulare/King were combined so that they could meet our study criteria to be included in the study. Deliveries induced prematurely because of pregnancy complications were excluded defined by the following ICD9 codes (73.0, 73.01, 73.09, 73.1x, 73.4x, and 74.x (without codes indicating labor or spontaneous delivery)), since these were likely due to medical issues rather than short-term apparent temperature exposure.

2.3. Study design

We used a time-stratified case-crossover method for data analyses (Levy et al., 2001). Apparent temperature exposures for up to one week before each birth were compared with exposures for the same mother at other times during the infant's birth month and year. Control periods were limited to the same day of the week as each case to inherently adjust for day of the week by study design. Consequently, there could be a maximum of four control periods per case occurring a minimum of seven days and a maximum of 28 days before or after each case period.

A linear term for apparent temperature was included in a conditional logistic regression model by season of birth, and the log(odds) of PTD (yes/no) served as the outcome measure. We added a squared term for apparent temperature to see it provided a better model fit. All analyses were performed in two steps: first, we calculated the county-level estimate based on maternal residential zip codes; second, we combined the county-level estimates to produce an overall estimate using meta-analytical techniques for all analyses(DerSimonian and Laird, 1986). Estimates are reported as percent change per 10°F (5.6 °C) increase in apparent temperature with corresponding 95% confidence intervals (CI). SAS version 9.3 software PROC LOGISTIC matching by each ID for case/control pair was used to conduct the first stage of the analysis by county. Meta-analyses were conducted to create overall estimates using Stata version 10.1 software.

In separate models, we stratified by the following demographic characteristics: maternal racial/ethnic group (non-Hispanic white, non-Hispanic black, Hispanic, non-Hispanic Asian), and maternal age (18–19, 20–24, 25–34, ≥35 years); dichotomized (yes/no) maternal pregnancy behavioral factors: smoking status and alcohol use; and maternal medical conditions: diabetes, hypertension, and depression during pregnancy. We also determined if Medicaid Status (prior to or during pregnancy vs. none) modified the association between temperature and PTD. Finally, we assessed the impact of pre-pregnancy BMI on PTDs using the following categories: underweight (< 18), normal weight (18–24), and overweight/obese (25+). This latter analysis was limited to pregnancies beginning in 2005 when pre-pregnancy BMI became available in the EHR databases. In sensitivity analyses, we added induced pregnancies to our final data set to see how our results might be affected. We also considered the potential impact from a fixed cohort bias (Strand et al., 2011) by limiting the analysis to women with conception dates (defined as 2 weeks post last menstrual period) to between August 28, 1995 and March 5, 2009.

Prior to beginning this study, the research protocol was approved by the KPNC Internal Review Board.

3. Results

Our total study population consisted of 14,466 preterm births within KPNC from January 1, 1995 through December 31, 2009, after excluding 6759 induced pregnancies and 1647 women without monitors located within 20 km of their residential zip codes. Demographic characteristics of the women who were excluded because of monitors too far away were similar to those in our study population (not shown). Fig. 1 depicts the map of the counties in Northern California that were included in our study based on the selection criteria described above. BMI data were available for 2382 women. As shown in Table 1, most mothers were between 25 and 34 years of age (54%) and White (40%). The average warm season apparent temperature for all study areas was 64.5°F (5th, 95th percentile: 54.2°F, 77.1°F) and 49.2°F (39.7°F, 58.4°F) during the cold season (Fig. 2).

All estimates presented correspond to weekly average cumulative apparent temperature (lag06), since we determined that this lag had the best model fit in our previous study (Basu et al., 2010). A squared term was not necessary, as the p-value was not significant during the warm or cold season. Greater overall risk was observed during the warm season (11.63%; 4.08, 19.72%) compared to the cold season