Environmental Research 144 (2016) 158–164

Contents lists available at ScienceDirect

Environmental Research

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

Climate change and fetal health: The impacts of exposure to extreme temperatures in New York City

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ARTICLE INFO

Article history:
Received 30 July 2015
Received in revised form
3 November 2015
Accepted 13 November 2015
Available online 21 November 2015

Keywords:
Climate change
Fetal health
Urban sustainability

ABSTRACT

Background: Climate change is projected to increase the frequency, intensity, and duration of heat waves while reducing cold extremes, yet few studies have examined the relationship between temperature and fetal health.
Objectives: We estimate the impacts of extreme temperatures on birth weight and gestational age in Manhattan, a borough in New York City, and explore differences by socioeconomic status (SES).
Methods: We combine average daily temperature from 1985 to 2010 with birth certificate data in Manhattan for the same time period. We then generate 33 downscaled climate model time series to project impacts on fetal health.
Results: We find exposure to an extra day where average temperature < 25 °F and > 85 °F during pregnancy is associated with a 1.8 and 1.7 g (respectively) reduction in birth weight, but the impact varies by SES, particularly for extreme heat, where teen mothers seem most vulnerable. We find no meaningful, significant effect on gestational age. Using projections of temperature from these climate models, we project average net reductions in birth weight in the 2070–2099 period of 4.6 g in the business-as-usual scenario.
Conclusions: Results suggest that increasing heat events from climate change could adversely impact birth weight and vary by SES.

1. Introduction

Numerous studies have investigated the short- and long-run problems associated with climate change, such as damages to agriculture or reduced labor productivity (Intergovernmental Panel on Climate Change (IPCC), 2014; Graff Zivin and Neidell, 2013; McMichael et al., 2006; Easterling et al., 2000). The impacts on public health are also great, with a large literature associating heat and cold waves with higher mortality rates (Lee et al., 2006; Barreca, 2012; Barreca et al., 2012; Deschenes and Moretti, 2009; Deschenes and Greenstone, 2011; Deschenes, 2012; Gosling et al., 2009; Li et al., 2013; Gasparrini et al. 2015) and spontaneous fetal death rates (Fukuda et al., 2014). However, a handful of studies have begun to observe other possible climate-driven health outcomes, such as poor fetal health, which previous work shows affects later-life outcomes like educational attainment and income (Almond, 2006; Black et al., 2007; Deschenes et al., 2009a; Van Zutphen et al., 2012; Kent et al., 2014; Simenova, 2011). In fact, low birth weight and short gestation was responsible for 20% of deaths for infants < 1 year old in 2011 in New York City (NYC) (NYC Dept. of Health and Mental Hygiene, 2013). Consequently, NYC provides a valuable setting for examining the relationship between temperature and fetal health, not only due to its large urban population of 8.4 million, but because temperatures in NYC increased by approximately 1.5 °C between 1901 and 2011, which is greater than global and US national trends (Horton et al., 2010; Intergovernmental Panel on Climate Change (IPCC), 2014; U.S. Global Change Research Program, 2013). Further, it is critical we understand the public health implications of extreme heat events in cities since they may be worsened by the urban heat island effect. These vulnerabilities are recognized by the NYC government, which has made climate change and public health related issues a priority (NYC Office of the Mayor, 2014; Rosenzweig et al., 2011).

In this study, we investigate two timely and critical research questions regarding climate change and public health. First, what is the impact of maternal exposure to extreme temperatures on fetal health and how might it vary by socioeconomic status (SES)? Second, what are the projected impacts of climate change, via higher temperatures, on fetal health? To address the former, we

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http://dx.doi.org/10.1016/j.envres.2015.11.016
0013-9351/

exploit the variation in maternal exposure to extreme temperatures across years between 1985 and 2010 using micro-level data with ample, detailed information on maternal characteristics for the universe of births in Manhattan, a borough of NYC (Supplementary material, Figs. A1–A2). We observe the effects of temperature on important predictors of infant health: birth weight and gestational age. We also explore differences among socioeconomic groups to determine the possibility of mitigating factors (e.g., air conditioners (ACs)).

In examining the second question, we contribute to the growing understanding of the health impacts of climate change, which is expected to increase the frequency and duration of heat waves and reduce the occurrence of cold waves. A few studies have begun to use a range of climate models to assess public health risks, but to our knowledge, prior research has not applied this approach to future birth outcomes (Li et al., 2013; Petkova et al., 2013). In our study, we generated downscaled daily temperature outputs for Manhattan using 33 climate models and two Representative Concentration Pathways (RCPs): RCP4.5 (an emission scenario consistent with transition to cleaner technologies) and RCP8.5 (a business-as-usual (BAU) emission scenario). Using a suite of models specifically for Manhattan, we can sample the climate-driven range or uncertainty in future birth outcomes, which will inform and motivate public health and climate change related policies.

2. Methods

2.1. Data and measures

2.1.1. Birth certificate data

We used restricted birth certificate data from the New York City Department of Health and Mental Hygiene (NYCDHMH) New York City Vital Statistics (NYCVS) from 1985 to 2010. We obtained the appropriate institutional review board approvals to access New York City birth certificate data from the Bureau of Vital Statistics of New York City's Department of Health and Mental Hygiene Vital Statistics. This dataset includes the universe of births in Manhattan and has information on the month and year of birth, detailed data on infant health such as the dependent variables of interest which are birth weight (g) and gestational age (weeks). It also has ample information on maternal characteristics, including mother's age, education, ethnicity, marital status, smoking status, and if she participated in Aid to Families with Dependent Children (AFDC), which is often used as a measure of income on birth certificate data.

2.1.2. Weather data

We obtained data from the National Climatic Data Center using the Global Historical Climatology Network (GHCN)-Daily database which has information on minimum and maximum temperature in Central Park, Manhattan. Taking the average of these two values, we find average daily temperature.

2.1.3. Pollution data

We also collected daily ambient pollution data from the Environmental Protection Agency since we include pollution as a control variable in one of our sensitivity checks. Data were averaged across all pollution monitors in NYC. Pollutants of interest were SO_2, CO, NO_2, and PM_{10} between 1988 and 2005. We chose this time period for consistency since PM_{10} at pollution monitors in NYC were not measured prior to 1988 and after 2005.

2.2. Statistical analysis and climate models

2.2.1. Regression analysis

To address our first research question, we estimate impacts of maternal exposure to extreme and moderate temperatures on fetal health and, for consistency, use a similar approach to a study by Deschenes et al. (2009). The explanatory variable of interest is the number of days of maternal exposure during different trimesters of pregnancy to the following temperature bins: <25 °F, 25–45 °F, 45–65 °F, 65–85 °F, >85 °F. Since we only have information on birth month and birth year, we define the first trimester as the 8th' 7th, and 6th months prior to birth, the second trimester as the 5th, 4th, and 3rd months prior to birth, and the third trimester as the 2nd and 1st month prior to birth and the birth month. For example, to determine maternal exposure to extreme heat ($T>85$ °F) in the third trimester for a baby born July 12, 1990, we sum the number of days in Manhattan where average $T>85$ °F for May, June, and July 1990 (discussion of possible measurement error is discussed later in Section 4.1). We use a regression framework to observe the relationship between fetal health and temperature in Manhattan, where ample daily weather data are available. We combine these weather data with information on the universe of births in Manhattan from 1985 to 2010, which includes more than 500,000 births. On average in Manhattan between 1985 and 2010, mothers were exposed to 10 days where average $T<25$ °F and 3 days where average $T>85$ °F during their pregnancy. For more information on exposure to various temperature bins, see Table A5 in the Supplementary material.

We exploit the variation in extreme temperature from year to year which is plausibly exogenous to confounding variables common in observational studies, such as if the mother smokes, since we assume it is difficult for mothers to predict years when extreme temperatures will occur. Additionally, we control for detailed maternal characteristics, seasonality of birth, and annual trends. Our regression also addresses potential nonlinearities between temperature and fetal health by estimating impacts within different temperature bins. We use the following baseline regression:

$$health_{imy} = \varphi_0 + \sum_{j=1}^{4} \beta_j^{Tr1} Tavg_{jmy} + \sum_{j=1}^{4} \beta_j^{Tr2} Tavg_{jmy} + \sum_{j=1}^{4} \beta_j^{Tr3} Tavg_{jmy} + \Gamma \mathbf{X}_{imy} + month_{\mathbf{m}} + year_y + \epsilon_{imy} \quad (1)$$

where $health_{imy}$ is birth weight (g) or gestational age (weeks) for mother i who gives birth in month m and year y. The variable, $Tavg_{jmy}$, is the number of days a mother is exposed to average daily temperature bin j (<25 °F, 25–45 °F, 65–85 °F, >85 °F and 45–65 °F is the omitted category) in trimester 1 ($Tr1$), trimester 2 ($Tr2$), and trimester 3 ($Tr3$). To account for important covariates, $\boldsymbol{X}_{imy}$ includes a dummy variable for infant's sex and dummy variables for mother's age (categorized by year), education (categorized as ≤ 8 years, 9–11, 12, 13–14, 15, ≥ 16, or unknown years completed), ethnicity (categorized as Puerto Rican, Other Hispanic, Asian and Pacific Islander, White Non-Hispanic, Black Non-Hispanic, Other, or unknown), marital status, if the mother smoked, number of cigarettes smoked each week, number of previous deliveries, and if the mother participated in AFDC. The variable $month_m$ includes dummy variables for each birth month to control for seasonality. Studies also suggest birth month is correlated to maternal characteristics, so by including $month_m$, we compare mothers who give birth in the same month and mitigate omitted variable bias (Strand et al., 2011a; Buckles and Hungerman, 2013). Birth year trends, $year_y$, are also included to account for annual factors that change monotonically and ϵ_{imy} is the error term. Standard errors are clustered at the birth month-birth year level to account for serial correlation within each birth month-birth year.