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Disparities in Preterm Birth Following the July 1995 Chicago Heat Wave

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Abstract

Purpose: To evaluate if changes in preterm birth (PTB, <37 weeks of gestation) incidence differed between non-Hispanic (NH) Black and NH white births following the July 1995 Chicago heat wave—among the most severe US heat waves since 1950.

Methods: We used an ecologic study design. We obtained birth data from January 1990–December 1996 from the National Vital Statistics File to calculate the mean monthly PTB incidence in Chicago's Cook County, Illinois. Births between July 1995–February 1996 were potentially exposed to the heat wave *in utero*. We generated time series models for NH Black and NH white births, which incorporated synthetic controls of Cook County based on unexposed counties. We ran a secondary analysis considering socioeconomic status (SES).

Results: From 1990–1996, the mean monthly PTB incidence among NH Black births was 18.6% compared to 7.8% among NH white births. The mean monthly PTB incidence among NH Black

Research data for this article

The birth outcome data used in this manuscript are publicly available at https://wonder.cdc.gov/natality.html.

births from August 1995–January 1996 was 16.7% higher than expected (3 additional PTBs per 100 live births per month [95% CI: 1, 5]). A similar increase occurred among low-SES NH Black births. No increase appeared among NH white births.

Conclusions: Severe heat waves may increase racial disparities in PTB incidence.

Keywords

Premature Birth; Racism; Extreme Heat; Temperature; Socioeconomic Factors; Chicago

INTRODUCTION

Preterm birth (PTB, delivery before 37 weeks of gestation) is the leading cause of mortality among infants and children under 5 years globally and in the United States.[1–3] PTB is associated with various health problems, including respiratory, gastrointestinal, immunological, visual, auditory, neurological, and developmental complications.[4]

A key national public health priority is to close the gap in PTB incidence between non-Hispanic (NH) Black individuals (who have the highest incidence of any racial group in the U.S)[5] and NH white individuals.[6] From 2016–2020, the PTB incidence increased by 0.7% among NH white birthing people (9.04% to 9.10%), while it increased by 4.3% among NH Black birthing people (13.77% to 14.36%).[7,8] Compared to the PTB rate among NH white birthing people, the PTB rate among NH Black birthing people was 52.3% higher in 2016 and 57.8% higher in 2020.[7,8] These trends reflect a widening and persistent racial disparity in PTB.[9,10]

Several stressors, including racism, low socioeconomic status (SES), and disproportionate exposure to environmental hazards, likely explain these disparities.[6] Low SES—alone[11] and in combination with environmental exposures[12–14]—is a PTB risk factor.

One potential environmental risk factor for PTB is high ambient temperature.[14–22] Heat exposure may induce PTB via dehydration, hormone secretion, altered blood viscosity, premature rupture of membranes, and reduced thermoregulation of the birthing person.[15,23–29] Multiple studies found positive associations between heat waves (multiple days of anomalously warm temperatures)[30] and PTB.[14–16,19,21,22,31–34] Some studies did not find an association.[20,35] Differences in study location, heat wave definition, statistical methods, other environmental factors, or pregnant people's strategies to cope with heat may explain the heterogeneous results. A growing body of research shows PTB disparities following extreme heat exposure by individual race and area-level racialized economic disadvantage.[19,20,36]

The 1995 Chicago heat wave (July 12–16, 1995) was one of the most severe heat waves in the US since 1950[37] with maximum daily temperatures ranging from 33.9°C to 40.0°C.[38] High temperatures coincided with high humidity,[39] which reduced the evaporation of sweat and made it harder for people to cool down.[30,40–43] The heat index (a combined measure of temperature and humidity)[44] peaked on July 13th at a record-breaking 48.3°C.[38] The extreme heat was persistent, including a 48-hour period in which the heat index remained

above 31.5°C—even at night.[45] The heat in Chicago was exacerbated by the urban heat island effect.[37,46]

In Chicago's Cook County, Illinois, the heat wave resulted in an 11% increase in hospitalizations[47] and approximately 700 excess deaths.[48,49] Hospitalizations and mortality were disproportionately high among Black, older, and socially isolated adults, and adults with less than a high school education.[38,48,50,51] Despite extensive research on disparities in adult health outcomes following the 1995 heat wave,[50] few studies have estimated its effects on birth outcomes, and none have investigated racial or socioeconomic disparities in birth outcomes.[52]

The public health failings from this historic heat wave can inform future efforts to mitigate potential risks of heat waves on PTB. In many regions, including the Midwest, heat stress is projected to rise due to increases in temperature and humidity.[53,54] Heat waves are increasing in frequency, intensity, and duration due to climate change.[55,56] Changes in heat wave severity are projected to disproportionately affect NH Black people,[57–59] who already are at greater risk of heat-associated mortality and morbidity compared to NH white people.[58]

In this study, we extend prior scholarship on environmental justice and Black-white health disparities following the 1995 Chicago heat wave[50] to determine if differential changes in PTB incidence occurred among NH Black and NH white births post-heat wave exposure.

We hypothesized the mean monthly PTB incidence would be more elevated among NH Black births compared to NH white births and would be the most elevated among low-SES NH Black births.

METHODS

Data and Variables

We acquired birth data from January 1990 to December 1996 from the National Vital Statistics File. The National Vital Statistics dataset includes the self-reported race and ethnicity of the birthing person, the gestational age, the month of birth, and the county of residence at birth. We used the race and ethnicity of the birthing person to classify NH Black and NH white births. We treated race and ethnicity as social constructs that may serve as markers of historic and current structural and interpersonal racism.[60] We restricted analyses to Cook County, IL because its residents (especially those in Chicago and adjacent townships) suffered the greatest mortality during the July 1995 heat wave.[61] From 654,150 total live births, we restricted analyses to NH Black or NH white live singleton births with gestational ages between 19–46 weeks (n excluded = 200,818). After these exclusions, analyses included 212,347 NH Black and 240,985 NH white births over the 84-month test period (January 1990 to December 1996) in Cook County.

Analysis

We used an ecologic study design because we wanted to evaluate changes in preterm birth incidence (a population-level outcome) during the heat wave and because we had the county

of residence at birth (i.e., Cook County) but not the birthing person's location during the heat wave. Births in Cook County between July 1995 and February 1996 were potentially exposed to the July 1995 heat wave *in utero*, so we tested if Cook County had elevated PTB incidences during these months.

We stratified analyses by race. For each racial group in each month, we summed the PTB count and calculated the monthly PTB incidence by dividing the monthly PTB count by the monthly count of live births.

PTB incidence often exhibits autocorrelation in the form of seasonality, long-term trends, and other patterns. For example, even in the absence of the July 1995 heat wave, we would expect high PTB incidence in August and September of 1995 due to seasonal patterns in PTB.[62] We controlled for autocorrelation by regressing (separately for each racial group) the PTB incidence for Cook County in the 66 months before July 1995 (January 1990-June 1995) on a synthetic control time-series of PTB incidence derived from US counties unaffected by the heat wave.

The logic of the synthetic control strategy involves generating an artificial counterfactual population whose PTB incidence matches that of the affected population *before* the onset of the acute exposure (i.e., before the heat wave). We constructed two "synthetic" Cook Counties, one for each racial group, using weighted combinations of control counties unexposed to the heat wave (Supplementary Figure 1) to match the respective PTB incidences in Cook County in the 66 months prior to the heat wave (i.e., January 1990-June 1995; Supplementary Table 1).[63] We used the weighted combination of control units to approximate counterfactual PTB series for each racial group based on trends we would have expected in Cook County if it did not experience the 1995 heat wave (e.g., seasonal trends, national trends in PTB). From the two regressions of race-specific (i.e., NH Black, NH white) PTB incidence on the synthetic control time-series, we obtained residuals that measured pre-heat wave temporal variability in Cook County PTB incidence that was not explained by the weighted combination of counties unexposed to the heat wave (i.e., the synthetic controls).

For each racial group, we used Box-Jenkins time-series routines[64] to identify autocorrelation in the residuals of the regression models that would be particular to Cook County. If any appeared, we expanded the regression equations to include indicated Box-Jenkins parameters. The residuals of the expanded models had a mean of zero and exhibited no autocorrelation (i.e., satisfied the classical regression assumption of serially independent errors).

We fixed the coefficients of our race-specific regression models to those estimated from the 66 pre-heat wave months (January 1990-June 1996) and applied the models to the entire 84-month test period (January 1990-December 1996). We tested our hypothesis by using routines described by Chen and Liu,[65] using time-series software (Scientific Computing Associates, Villa Park, IL) to detect outlying sequences among the 84 residuals. We predicted high outlying sequences in PTB incidence among individuals who were pregnant during the heat wave and who, therefore, gave birth between July 1995 and February 1996.

However, given that we only had the month of birth and were missing the exact dates of birth, we were unable to distinguish between July births that occurred before and after the start of the heat wave. We therefore looked for outlying sequences from August 1995 to February 1996. We set the sequence-detection threshold at t =1.96 (i.e., $p<0.05$ as the level of statistical detection).

We conducted a secondary analysis restricted to births among NH Black birthing individuals who had less than a high school education, which we used as a measure of low SES, to determine whether higher incidence related to the heat wave was concentrated among low-SES births. Hereafter, we refer to births among individuals with less than a high school education as low-SES births. We did not run these models for low-SES NH white births due to small counts.

RESULTS

Over the 84-month test period (January 1990-December 1996), Cook County had 212,347 NH Black and 240,985 NH white live singleton births. A total of 39,599 PTBs occurred among NH Black births, while a total of 18,648 PTBs occurred among NH white births. Before the heat wave (January 1990-June 1995), the mean monthly incidence of PTB among NH Black births (18.8 per 100 live births, standard deviation [SD]=0.01) was 2.4-fold that among NH white births (7 per 100 live births, SD=0.007). **Panels A and C of** Figure 1 plot the mean monthly PTB incidences over the 84-month test period. Both NH Black and NH white PTB time series showed strong seasonality, with low points occurring predictably in September.

Panel B of Figure 1 shows the residuals of the regression of NH Black PTB incidence on the synthetic control series. The residuals exhibited no autocorrelation, so Box-Jenkins parameters were unnecessary.

Among NH Black births, outlier detection routines found a 6-month positive outlying sequence beginning in August 1995 and ending January 1996. This timing indicates that gestations *in utero* in July 1995, ranging from the late-first trimester to the third trimester, appear to have responded adversely to the heat wave. **Panel B of** Figure 1 shows this outlying sequence with “X’s.” Based on this outlying sequence, we defined a binary heat wave exposure variable equal to 1 for each month between August 1995 and January 1996 and 0 otherwise. We added the binary exposure variable to the regression equation and estimated the coefficients for the full 84 months. The results of that estimation, shown in Table 1, implied that, from August 1995–January 1996, the mean monthly PTB incidence among NH Black births was 16.7% higher than expected (18.6 PTB per 100 live births per month), which equated to 3 additional PTBs per 100 live births per month (95% CI: 1, 5) statistically attributable to the heat wave.

In our secondary analysis among low-SES NH Black births, the mean monthly PTB incidence was 21.4% between January 1990 and December 1996. From August 1995-January 1996, the mean monthly PTB incidence was 15.6% higher than the expected

subgroup mean monthly incidence, which equated to an additional 3 PTBs per 100 live births per month (95% CI, 1, 6).

For NH white births, inclusion of the synthetic controls (**Panel D of** Figure 1) removed all autocorrelation. Unlike the NH Black birth series, we discovered no outlying sequences in PTB among NH white births from July 1995 through February 1996 (Supplementary Table 2). The lack of a detected outlier is illustrated in Figure 1, **Panel D** where residual values for all eight months post-June 1995 fall inside the 95% detection interval.

Discussion

Despite growing research on perinatal responses to ambient heat, limited work has examined birth outcomes following the 1995 Chicago heat wave—one of the worst U.S. heat waves on record. We applied race-stratified synthetic control and time-series methods to test whether PTB incidence was higher than expected following the 1995 heatwave. Among NH Black births, the mean monthly incidence rose 16.7% above expected values across a 6-month period following the heat wave. A similar relation appeared among low-SES NH Black births. We observed no relation among NH white births. Our findings indicate a racial disparity in PTB incidence following the 1995 heat wave.

To our knowledge, our study is the first to investigate PTB incidence following the 1995 heat wave. A study on births in Cook County between June and August of 1995 did not find evidence of an association between the maximum heat index 0–3 days prior to delivery and shortened gestation time.[52] We, however, employed different methods (including health outcome), so we hesitate to compare results. We instead contextualize our study in the broader literature on PTB and heat exposure.

Our study builds on previous studies that found Black-white disparities in reproductive health outcomes,[6] including PTB.[66,67] Previous studies on heat waves and risk of PTB differed in their findings.[15,16,19–22,35] One study found that moderate increases in heat increased the risk of PTB but that heat waves did not.[20] Other studies found racial disparities in acute changes to PTB in the week following extreme heat exposure.[19,36,68] Many prior studies on heat and PTB examined acute effects (PTB incidence within a week of heat exposure).[15,16] Others evaluated associations between first and second trimester heat exposure and increased risk of PTB.[18,21,69] Our study considered heat wave exposure throughout gestation and found evidence of an exacerbated and prolonged racial disparity in PTB that persisted for several months (rather than just a few days) after heat wave exposure.

Because many studies reported a stronger heat-PTB relation in lower SES groups,[13,19,20] we anticipated, but did not observe, a stronger association among low-SES NH Black births. The relation between SES and PTB by race is complex. Braveman et al. (2015) found that, although the risk of PTB was similarly high among low-SES Black and white birthing people, higher SES appeared protective for NH white but not NH Black births.[70] Our findings suggest that race, rather than SES, may be a stronger predictor for PTB risk following the Chicago heat wave.

Self-identified race of the birthing person may be a proxy for variables (e.g., racist policies, interpersonal racism, internalized racism, or racially patterned environmental factors) that drive the PTB disparity.[6,66,71–73] Historically redlined neighborhoods and neighborhoods with high contemporary racial segregation are associated with higher odds of PTB.[74–76] Due to residential segregation, Black birthing people are disproportionately exposed to air pollution[77,78], lead[79,80], and other chemicals associated with increased risk of PTB.[66] These exposures may make Black birthing people more susceptible to heat.[21]

Heat is associated with increased risk of PTB in urban areas with low levels of green space.[20] Black people are more likely to live neighborhoods with reduced tree cover,[81] more heat risk-related land use[82], poor housing quality,[83] and urban heat island effects[84]—all of which could have contributed to different exposures to heat by race. Heat exposure may have varied based on the extent to which pregnant people left their homes or neighborhoods (e.g., for work or to find somewhere to cool down). Neighborhood violence can influence decisions to leave the house.[85] During the heat wave, some people kept their windows closed or stayed at home instead of traveling to cooler locations because of safety concerns.[50,86] Due to residential segregation, NH Black people are more likely to live in urban neighborhoods with higher levels of violence.[87]

Black people tend to have less access to central A/C and cooled public spaces.[88–90] A/C is protective against heat-related illness, hospitalization, and mortality,[91,92] and A/C use was associated with lower risk of mortality following the 1995 heat wave.[51] In the years preceding the heat wave, 41% of Chicago households had access to central A/C, including only 16% of Black households.[88] A/C units quickly sold out during the heatwave,[93] and both the cost of running A/C[93] and power outages[94] may have posed barriers to A/C use.

Increased stress among pregnant people may reduce gestational length.[95,96] Black pregnant people may have experienced greater stress during/following the heat wave due to higher heat exposure or loss of loved ones and social support given the higher morbidity and mortality among Black adults following the heat wave.[48,49]

Disasters can overwhelm the healthcare system and lead to sub-optimal prenatal care.[50,97] The quality of prenatal care during the heat wave may have varied by race (e.g., due to the healthcare resources available by neighborhood, level of care interruption, or racial discrimination from providers[98]). NH Black birthing people are more likely than NH white birthing people to have hypertension,[99] which is associated with PTB[100] and increased vulnerability during exposure to extreme heat.[101]

Our study had analytic strengths. The synthetic control accounted for all confounding variables—including any that exhibited autocorrelation—that Cook County shared with other counties in the US. Time-series modeling controlled for autocorrelation unique to Cook County.

Our study had limitations. Our ecologic study should be interpreted at the county-rather than individual-level. Births in Cook County between August 1995 and February 1996 were possibly, but not necessarily, exposed to the heat wave. Although we knew the county of residence at birth, we lacked the birthing person's location *during* the heat wave. The

exposure may have varied *within* the county or by individual, but we lacked individual-level data on protective factors (e.g., A/C use, neighborhood tree cover), risk factors (e.g., pre-existing health conditions, occupational exposures, urban heat island effect, housing quality), or stressors (e.g., racism, financial insecurity, availability of healthcare), any of which may have been effect modifiers or explained part of the racial disparity in PTB. We did not differentiate between spontaneous and medically induced births because this data was unavailable. Finally, the birth records listed the month (not the day) of birth, so we could not evaluate acute changes in PTB, including PTB in July 1995.

Conclusions—Our study is instructive about potential racial disparities in PTB following extreme heat exposure. Further research on contemporary heat waves is necessary to incorporate infrastructural and policy changes since 1995 (e.g., changes in A/C prevalence, reproductive healthcare, and emergency preparedness). More research is necessary to identify the root causes of racial disparities following heat events.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Declaration of interests

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Abbreviations and Acronyms

PTB	preterm birth
NH	non-Hispanic
SES	socioeconomic status
AR	auto-regressive
I	integrative
MA	moving average

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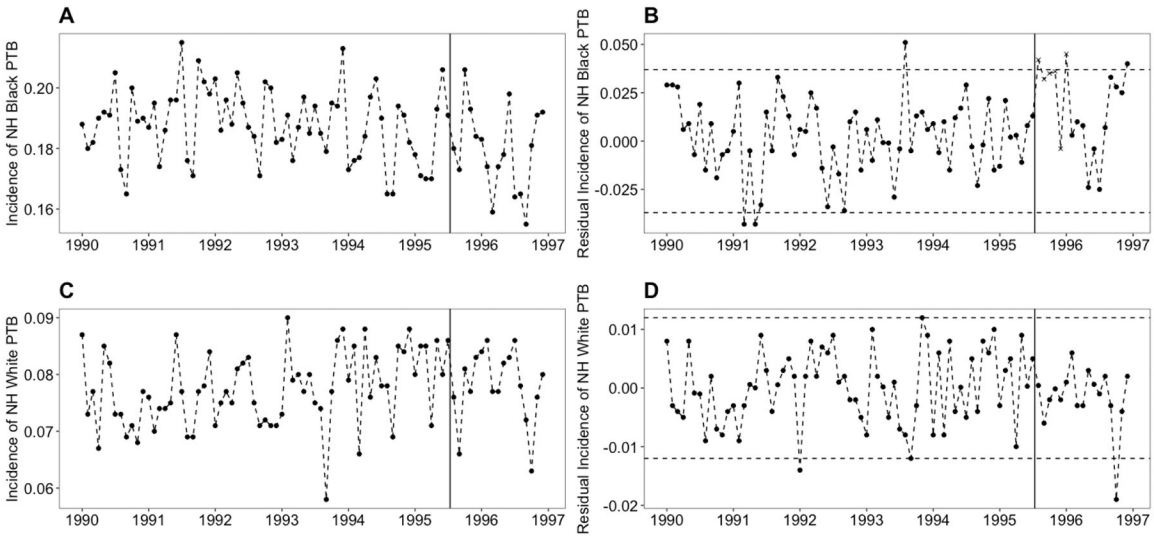

Figure 1.

Preterm birth incidence (per 100 live births) among NH Black and NH white births over 84 months in Cook County, IL. Panels A and C plot the observed NH Black and NH white incidences of PTB, respectively; Panels B and D plot the residual incidence of NH Black and NH white PTB, respectively, with mean=0, after the inclusion of a synthetic control series to remove autocorrelation. July 1995, the month of the heat wave, is indicated with a black vertical line in each panel. Panel B shows a positive outlying sequence with “X’s” in the 6 months post-heat wave.

Table 1.

Time-series results by race, predicting the preterm birth incidence in Cook County, IL as a function of the preterm birth incidence among a synthetic control series, autocorrelation and any discovered outliers in preterm birth during or after the July 1995 heat wave.

	Lag (months)	NH Black births		NH white births	
Parameter		**b**	**95% CI**	**b**	**95% CI**
PTB of synthetic control	0	0.99	0.96, 1.01	0.99	0.97, 1.01
Outlying sequence post-June 1995					
Yes	1 to 6	0.03	0.01, 0.05	N/A	N/A
No	*			*	

*Note: Box-Jenkins routines detected no auto-regressive (AR), integrative (I), or moving average (MA) parameters