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RESEARCH ARTICLE

RELATIONSHIP BETWEEN AMBIENT AIR POLLUTION ($PM_{2.5}$) AND LOW BIRTH WEIGHT DELIVERIES IN NEW JERSEY

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ABSTRACT

Background: A baby is said to be of low birth weight (LBW) if the estimated weight at birth is less than 2500g (5 pounds 8 ounces). LBW has serious and long lasting health implications for the baby, usually in the neonatal and infancy periods and may persist into adulthood. Several studies have been conducted in the past which looked into the relationship between exposure to ambient air pollution and the delivery of LBW babies with most of the studies concluding with inconsistent results. The goal of the study is to determine if an association exists between LBW and exposure of mothers to ambient air quality ($PM_{2.5}$) in the first trimester of pregnancy in New Jersey.
Method: A cross-sectional study using data derived from the 2008 Electronic Birth Certificates (EBC) for all live births to mothers residing in New Jersey and ambient air ($PM_{2.5}$) data for 2007 and 2008 were obtained from the New Jersey Department of Environmental Protection (NJDEP). Both sets of data were merged using SAS and the resulting dataset was run through a series of linear and logistic regression steps to demonstrate any possible association.
Result: Data analysis showed an increased risk for LBW with higher exposure to $PM_{2.5}$, (unadjusted OR: 1.25, 95% CI 1.03-1.53, $p<0.0271$). Adjusted odds ratio for LBW was no longer statistically significant when the model included known risk factors for LBW.
Conclusion: This study concludes that$PM_{2.5}$ exposure in the first trimester of pregnancy shows some positive association with LBW albeit weak with the condition compared with other known risk factors.

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INTRODUCTION

The birth weight (BW) of a baby is the first recording of its weight after birth; it is a good predictor of the survival, long term health and well-being of the baby. BW between 2500 g and 4200 g is regarded as normal. Low birth weight (LBW) is defined by the World Health Organization (WHO) as BW less than 2500 g (5.5lbs). This is further sub-classified as very low birth weight (VLBW) for babies born weighing less than 1500 g (3.31 lbs) and extremely low birth weight (ELBW) for babies born with weight less than 1000 g (2.2 lbs).

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The worldwide LBW rate is between 15%-17% and half of this estimate occur in South East Asia - of which India accounts for 40% of the world's LBW babies. Each year, up to 8%-9% of the babies born in the US is diagnosed with LBW as depicted in the preliminary data of the Child Health USA 2011. A LBW baby is at an increased risk of dying in the neonatal period (age up to 28 days) and also in the early months and years of life. According to the WHO, the LBW rate (the percentage of the total live births that are low birth weight) in a population is a good indicator of public health problems that includes long-term maternal malnutrition, ill health and poor health care delivery in pregnancy. It may also predispose a baby to having serious health problems beyond the neonatal period like immune disorders, lower IQs, growth and cognitive developmental milestone problems in childhood and chronic diseases like diabetes and heart disease later in life.

The Boston Children's Hospital information website lists the known risk factors for LBW as; Race: African Americans are more predisposed than Caucasians, premature delivery, intrauterine growth retardation (IUGR), multiple births (twinning), teenaged mothers, illicit drug, alcohol use/cigarette smoking in pregnancy, poor maternal nutrition in pregnancy, inadequate prenatal care, maternal low socioeconomic status and pregnancy complications. In recent times, environmental factors like air pollution have been studied as a possible factor in LBW deliveries. Evidence from epidemiological studies have shown an increased risk for adverse reproductive outcomes including LBW, IUGR, preterm delivery and neonatal death from an exposure to ambient air pollution in pregnancy (Bobak and Leon, 1999). Pollutants that have been studied either singly or in various combinations are Carbon monoxide (CO), Nitrogen dioxide (NO2), Sulphur dioxide (SO2), Ozone and particulate matter with a diameter less than 10µm (PM_{10}) and 2.5µm ($PM_{2.5}$). According to the New Jersey Department of Environmental Protection, particulate matter occurs both naturally in the form of dust and sea salt and can also be man-made from fossil fuel combustion, wood burning and major industrial processes. It can also be created in the atmosphere when gases from combustion activities react with sunlight and water vapor.

Of all pollutants, $PM_{2.5}$ or fine particulate matter is especially harmful to human health because of its small size; its ability to travel for miles suspended in air and the fact that it is readily inhalable and can go deeply into the lower lungs. Significant health problems like asthma, difficulty with breathing and even premature mortality are known to be caused by exposure to $PM_{2.5}$.The State of New Jersey has 24 monitoring sites for $PM_{2.5}$, the Federal Environmental Protection Agency (EPA) mean annual standards is set at 15.0 µg/m^{3}and the mean 24 hour standard is35µg/m^3.This study examines the association between exposure to particulate matter with diameter less than 2.5µm in the first trimester of pregnancy and the delivery of LBW babies. It is known that the impact of pollutants on fetal growth may depend upon the stage of fetal development when exposure occurred. A disruption in the maternal-fetal circulation function during pregnancy is the possible mechanism of action for the restriction in the fetal growth. Past studies have often shown mixed results possibly due to differences in the methodology of the studies, dispersion of the addresses of subjects to the air monitoring sites, and exposure periods during pregnancy (first, second, third trimester or entire pregnancy duration). Lately, it was postulated that differences in results of studies of exposure to particulate matter pollution in pregnancy and LBW may be a testament to the differences in the compositions of particulate matter from region to region.

Harris et al in their study considered whether the effect of $PM_{2.5}$ on birth weight may vary by location and gestational period. They compared LBW rates and $PM_{2.5}$ pollution in 7 US states and found an association between $PM_{2.5}$ exposure and LBW in New York for the full gestation period and all three trimesters, in Minnesota for the full gestation period and the first and third trimesters, and in New Jersey for the full gestation period and the first trimester. Fleischer et al studied the association between $PM_{2.5}$ and preterm delivery and LBW across 22 countries and found that $PM_{2.5}$ was not associated with preterm birth, but was associated with LBW. In China, the country with the largest $PM_{2.5}$ range in the study, preterm birth and low birth weight were both associated with the highest quartile of $PM_{2.5}$ only, which suggests a possible threshold effect. In their own effort at gathering epidemiological evidence on maternal exposure to particulate matter and adverse pregnancy outcomes, Bosetti et al reviewed 17 study papers on LBW or VLBW, 11 of them reported some increased risk (by about 10–20%) in relation to exposure to $PM_{2.5}$. They noted that even in studies that reported some excess risk, results were inconsistent across exposure levels and pregnancy periods. They concluded that epidemiologic studies on maternal exposure to $PM_{2.5}$ during pregnancy do not provide convincing evidence of apossible association with the risk of LBW/VLBW. It does appear from a cross section of studies however that the effects of ambient air pollution on birth weight is evident all through pregnancy unlike in the development of congenital abnormalities where the baby is most susceptible during the first trimester. This is supported by a study done by Warren et al in their analysis of ambient ozone's effect on LBW. Weekly windows of susceptibility were identified and they found that increased exposures during weeks 20-23 of the pregnancy were associated with LBW.

In a meta-analysis that combined the estimates of effect across different monitoring centers (~3 million births) and meta-regression to evaluate the influence of center characteristics and exposure assessment methods by Dady and et al., they also found that LBW was positively associated with an increased exposure to PM $_{10}$and $PM_{2.5}$during the entire pregnancy, after adjusting for maternal socioeconomic status. The discrepancies in results from various studies led to the birth of the International Collaboration on Air Pollution and Pregnancy Outcomes (ICAPPO). The objectives of the organization is to develop and conduct analyses using a standardized methodology across multiple investigator generated datasets from different study settings, to gain insights into how design options and analytic decisions affect results from perinatal environmental epidemiological studies and, potentially to provide comparable results for research synthesis. They hypothesized that some of the differences among the published results of pregnancy air pollution exposure studies can be attributed to identifiable differences in analytic methodologies, including the composition of the study populations, exposure assignments and the availability and use of covariates. However, the aim of our study is to add more evidence to the current available literature and secondly, to determine if an association really exists between LBW and exposure of mothers to ambient air quality ($PM_{2.5}$) in the first trimester of pregnancy in New Jersey.

METHODS

Data sources

Birth records: A dataset created by the Center for Health Statistics, NJ Department of Health from the electronic birth certificates of all babies born in New Jersey to resident mothers in the 2008 was obtained from the State.

Table 1. Demographic characteristics of the sample N= 87,040

Subjects demographics	Distribution N(%)	
Mother's age (years)		
Less than 17		
17 - 35	769	(0.86)
Greater than 35	69421	(77.50)
Race	19380 (21.64)	
White (including Mexicans, Puerto Rican)		
Black	61795	(80.00)
Other (Native Indians, Asians, Hawaiians)	15328	(19.84)
Mother's level of Education	116 (0.16)	
Less than 12th grade		
Some college	35641 (39.79)	
College graduate	17974 (20.07)	
Average Cigarettes Smoked/day	35955 (40.14)	
1 – 10		
11 - 20	4495 (81.64)	
Greater than 20	178 (3.23)	
Babies' birth weight	833 (15.13)	
Low birth weight		
Normal birth weight	2530 (2.82)	
Mean PM 2.5 in First Trimester (µg/m3)	87040 (97.18)	
Less than 9.0		
Greater than 9.0	4496 (5.02)	
Number of PM recordings	85074 (94.98)	
Less than 30 days ('expo' 1)		
Greater than 30 days ('expo' 0)	42199 (47.11)	
When PNC Began	47371 (52.89)	
Less than 3 months		
Greater than 3 months	17414 (19.44)	
	72156 (80.56)	

Table 2. Sample characteristics by Race

Characteristics	Caucasian/White (%)	African-American/Black (%)	Others (%)
Race of Mothers	80.0	19.8	0.2
Percent of LBW	2.2	4.5	3.5
Mother's age < 17 years	0.7	2.1	3.5
Pre-natal care onset < 3 months	83.0	68.3	71.6
Mother completed collage	41.3	19.7	13.8

The data included variables like gestational age of baby, birth weight and gender, mother's geocoded addresses, mother and father's race, mother and father's educational status, last menstrual period of mother, medical complications in pregnancy, recreational drugs use, smoking habits and month prenatal care began and how many visits had amongst others. In the final analysis, babies born before 37 completed weeks and multiple births were excluded as these ones are customarily born with a LBW. There were birth weight that were outliers on both ends e.g. 6000 g and 260 g, these would have weighted heavily on the data and so were also eliminated. The mean birth weight in the raw data was 3260 g.

P.M $_{2.5}$ data: $PM_{2.5}$ data for 2007 and 2008 were obtained from the NJDEP, the 2007 data was included because the first trimester of some of the babies born in 2008 was in 2007. There were recordings from 20 monitoring sites with many counties without monitoring sites being allocated data from sites in the closest counties to them. Counties with 2-3 monitoring sites had their recordings averaged to get a mean value.

Exposure period: The period of exposure considered in this study is the first trimester of pregnancy. Each mother had a possible 90-91 mean $PM_{2.5}$ daily recordings for the all the days in the trimester. However, just over 1% of mothers had a full 90 days of data on record. The range of the number of days of recordings was 21-91, the Q1 was 27 days, and the median number of recordings (Q2) was 30 days whilst the Q3 was 79. The IQR is 52. In running the analysis, we sorted the data into two categories based on the availability of data on record to see if the difference in number of recordings available would have any effect on the result. One category had $PM_{2.5}$ data recordings up to 30 days (expo '1'), the second category were those mothers who lived in areas where more than 30 days of recordings were available (expo '0'). Below is the distribution of the mean of the $PM_{2.5}$ exposure of the mothers in the study.

Statistical analysis

Both data sets were merged in Statistical Analysis System (SAS) software for data analysis. The merged data set was run through a series of univariate and multivariate logistic regressions to obtain the odds ratio for low birth weight and exposure to PM $_{2.5}$.Babies born prematurely, that is before 37 completed gestational weeks and multiple births were excluded. The final data set was run through a PROC FREQ procedure to determine the distribution of the various variables and a series of 2X2 tables to see any interaction between the variables.

A univariate logistic analysis was also ran to test the effect of $PM_{2.5}$ on the event 'LBW'; this same PROC LOGISTIC procedure was repeated, only this time with the data sorted by 'expo' (number of days of recordings available). A forward selection multivariate regression was run without $PM_{2.5}$ to select the best variables fit for the final model. The selected covariates; baby's gender (Sex),mothers' race (Race), mothers' educational level (Edu), cigarette smoking status (Tobacco) and use of recreational drugs (CorHerMarUse) were then run with $PM_{2.5}$to see if the effect was sustained.

Ethical consideration

This study received ethical approval from the Rutgers University Biomedical and Health Sciences (RBHS) Institutional Review Board and New Jersey Department of Health.

RESULTS

Among the 87,040 NJ births from 2008 that were included in the study, 2,530 (2.82%) were born with LBW, 51% of them were male 49% female. 6.15% of the mothers were smokers, 77.50% of the mothers were in the 17 to 35 age category, <1% were under the age of 17, while 21.64% of the mothers were over 35 years of age; the mean age of the mothers was 29 years. 8.25% of the mothers who used a recreational drug in pregnancy had a LBW baby compared to only 2.76% in mothers who did not use a recreational drug in pregnancy. 1.14% of the babies were born to mothers who used a recreational drug (cocaine/marijuana/heroin) in pregnancy (Table 1). 80% of the mothers were Caucasian (White, Mexican, Puerto Rican and other Caucasian), 19.84% were Black and others were 0.15%. 83.02% of White mothers began prenatal care before 3 months compared to 68.29% of Black

Table 2. Number of births, $PM_{2.5}$recordings and percent LBW by county

New Jersey County	Number of Births	PM 2.5 (µg/m3) (Mean± S.D)	% of LBW/County	% of NJ 2008 LBW
Atlantic	3272	10.9 ± 2.1	3.06	3.96
Bergen	10801	13.2 ± 2.2	2.50	10.68*
Burlington	2449	13.3 ± 2.3	2.49	2.41
Camden	6891	13.3 ± 2.3	3.56*	9.70
Cape May	403	11.1 ± 2.2	1.74	0.28
Cumberland	1803	10.8 ± 2.0	4.22*	3.01
Essex	11360	13.2 ± 1.9	3.49*	15.67*
Gloucester	2035	13.2 ± 2.4	3.14	2.53
Hudson	5464	13.8 ± 1.9	2.95	6.37
Hunterdon	1077	13.1± 2.3	1.39	0.59
Mercer	4845	11.8 ± 2.1	3.16	6.05
Middlesex	10402	12.3 ± 2.1	2.89	11.91*
Monmouth	7562	10.4 ± 1.8	2.22	6.65
Morris	5545	11.0 ± 2.7	1.84	4.04
Ocean	3997	10.4 ± 1.8	1.93	3.05
Passaic	3975	13.7 ± 2.2	3.47*	5.46
Salem	582	13.1 ± 2.3	2.75	0.63
Somerset	1185	12.3 ± 2.0	2.19	1.03
Sussex	602	13.8 ± 2.3	1.50	0.36
Union	4429	13.8 ± 1.8	2.89	5.07
Warren	896	13.2 ± 2.5	1.56	0.55

* denotes high LBW rates

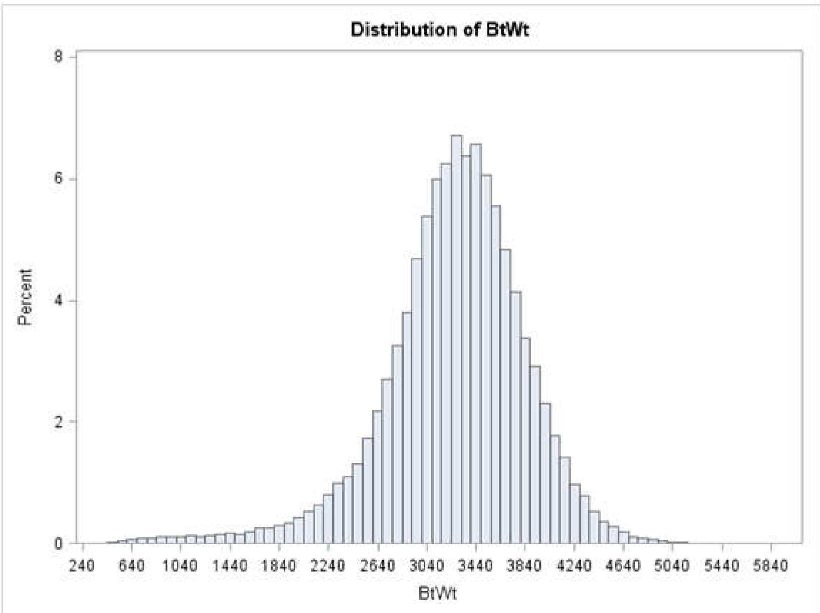

Figure 1. Distribution of birth weights in New Jersey

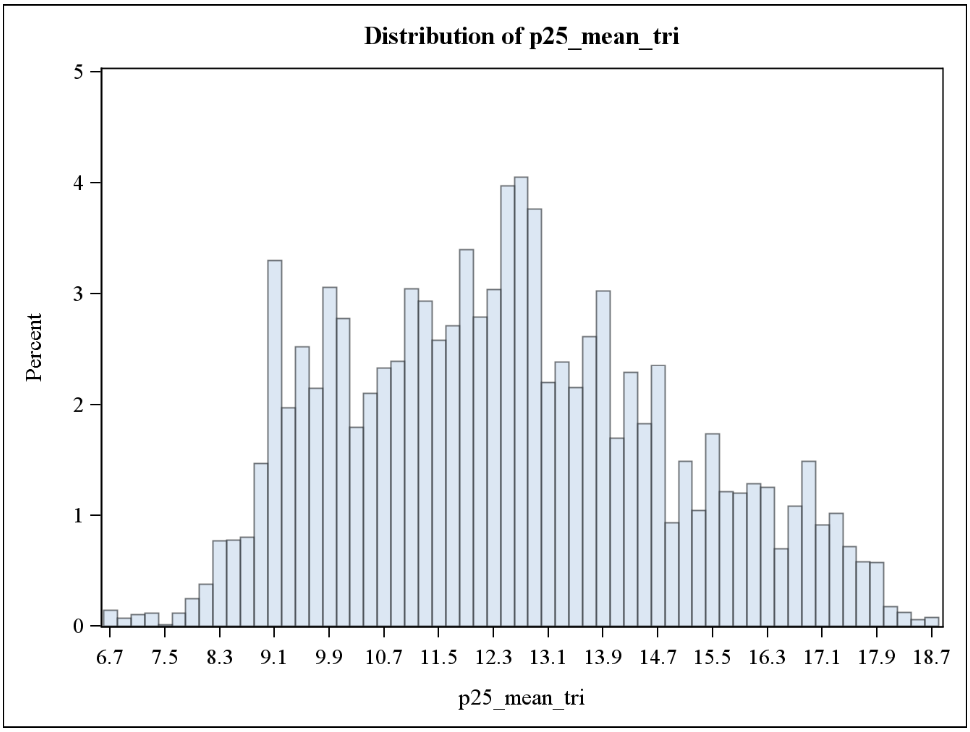

Figure 2. Distribution of mean $PM_{2.5}$ exposure in first trimester

mothers and 71.55% of Asian mothers. 2.23% of White mothers had a LBW baby, twice as many Black mothers (4.52%) had a LBW baby. 3.45% of Asian mothers had a LBW in NJ in 2008 (Table 2). Amongst mothers without any college education, 3.60% had a LBW baby, 2.74% of women with some college education had a LBW baby but only 2.10% of mothers who are college graduates had a LBW baby. Mothers who started prenatal care after 3 months were 1.5 times more likely to have babies with LBW compared to those who began before 3 months (2.60% s 3.74%).

The counties with the highest mean $PM_{2.5}$ areHudson (13.8µg/^{m3}), Union (13.8µg/^{m3}), Sussex 13.8µg/^{m3}), Passaic (13.7µg/^{m3}), Camden (13.3µg/^{m3}) and Burlington (13.3µg/^{m3}) whilst the counties with the lowest mean levels are Atlantic (10.9µg/$^{m3)}$, Cumberland (10.8µg/$^{m3)}$, Ocean (10.4µg/$^{m3)}$, Monmouth (10.4µg/$^{m3)}$ and Morris (11.0µg/$^{m3)}$.The following counties have 70 or more days of $PM_{2.5}$data recordings; Union, Ocean, Monmouth, Mercer, Hudson, Burlington, and Camden, representing less than 30% of the counties. The lowest data recordings ~30 days were obtained in Hunterdon, Middlesex, Morris, Passaic, Warren, Sussex, Salem, Somerset, Essex, Gloucester, Atlantic, Bergen, Cape May and Cumberland. 4.22% of the babies born to mothers in Cumberland County were LBW, the highest ratio in the data, 3.56% of Camden mothers had a LBW baby, 3.49% of Essex mothers, 3.47% of Passaic mothers and 3.16% of Mercer mothers also had a LBW baby. Conversely, only 1.39% of mothers in Hunterdon county had a LBW baby, 1.50% of Sussex, 1.56% of Warren, 1.74% of Cape May, 1.84% of Morris and 1.93% of Middlesex mothers had a LBW baby (Table 3). Final data analysis showed an increased risk of LBW with higher exposure to PM $_{2.5}$ (unadjusted OR 1.25, 95% CI 1.03-1.53, $p<0.0271$).

When sorted 'by expo' (categories of number of available $PM_{2.5}$recordings), the results revealed an odds ratio for an increased risk for LBW with higher exposure to $PM_{2.5}$ (OR: 1.35, 95% CI 1.04-1.74, $p<0.0221$) in the category with more data recordings (expo '0') and a less statistically significant result in the second category (expo '1') with less data recordings (OR: 1.06, 95% CI 0.77-1.45, $p<0.7351$). Adjusted odds ratios for LBW were no longer statistically significant (OR: 1.17, 95% CI 0.94-1.45, $p<0.1650$) when the models included baby's sex, mother's race, education status, the use of tobacco and recreational drugs in the multivariate analysis.

DISCUSSION AND LIMITATIONS

PM $_{2.5}$ appears to be weakly associated with LBW according to this study which may be due to the few number of air quality measurements utilized in the analysis, or secondly due to low levels of PM $_{2.5}$ pollution in New Jersey as compared to the EPA standards- mean annual standard set at 15.0 µg/m^{3}and mean 24 hour standard set at 35µg/m^3.After the model was adjusted for other known risk factors, the relationship remains minimal and was statistically insignificant. However, Twum at al found that long-term and short-term exposures to $PM_{2.5}$ have been known to cause premature death from heart and lung disease, soair pollution may have a role in the occurrence of LBW. Risk factors particularly education status and by extension, the socio-economic status of the mother and probably that of the father is a very strong factor in determining baby weight. This study confirms what other literatures have found as black mothers continue to have more LBW babies than their white counterparts suggesting that there might remain some gaps in access to quality healthcare.

Also, whites are generally more economically well off than blacks in the US. One major strength of this study is the large sample size and the availability of demographic and social information for each study participant that allowed for exploration and control of their effects while assessing the potential association between exposure to $PM_{2.5}$ and LBW. The study is limited in that levels of exposure to the pollutant as ascribed to the mothers are subject to error as each mother's address was not matched to the nearest monitoring site irrespective of the county of the address. For simplicity, we have used the data recorded from monitoring sites in each mother's county of residence for the analysis. It is possible for a mother to live closer to a monitoring site located in a different county from the county she lives in. There are studies that have been conducted on the state level whereby an average of the recordings statewide were used so our use of county level data may not be so far off from what others have used in the past. For mothers without a monitoring site in their county of residence, air pollution data from a monitoring site or sites in a neighboring county was used.

The exact level of exposure may not be accurate as some mothers may have stayed away from their usual residences for long periods during pregnancy. It may also be that the effect of ambient air pollution on birth weight may not be completely apparent with regards to exposure in the first trimester of pregnancy unlike the entire duration of pregnancy. The distances from the sources of pollution to the residences of the mothers e.g. high traffic areas and heavily industrialized areas may be more important than the distances to the monitoring sites. There has been a dramatic improvement in the outdoor air quality across board in NJ. A few counties in NJ are heavily industrialized and had been designated as by the EPA as 'nonattainment areas' meaning they are not attaining the national ambient air quality standards for a criteria pollutant e.g. PM2.5, this signifies that the air in the area is unhealthy to breathe. However, even those counties have PM2.5 values that are now lower than the National Ambient Quality Standards (NAAQS). These high standards may be responsible for the effect being statistically non-significant as effect may be enhanced where $PM_{2.5}$ values are higher. In addition, some counties had daily recordings of $PM_{2.5}$ while other had less daily recordings, this inconsistency in reporting may mask any true association that may exist between $PM_{2.5}$ and LBW.

Conclusion

A positive association appears to exist between exposure to $PM_{2.5}$in pregnancy and the delivery of LBW babies but the effect appears weak when compared to the other well known risk factors like mother's age, mother's educational status, use of tobacco and recreational drugs in pregnancy or the onset of prenatal care. It appears also that the relative low level of $PM_{2.5}$ could be a factor in the weak effect shown. This would suggest that it would be easier to demonstrate an effect in geographical locations where the air quality is still very poor for example, in developing countries. The quality of data also appears to have an effect on the result, the more data recordings available, the better it is for researchers to demonstrate an effect.

The known risk factors of LBW; prematurity, mother's race, educational and socio-economic status, use of tobacco and recreational drugs are still the strongest factors in the causation of LBW and efforts should be doubled to reduce those that are controllable (discouraging cigarette smoking and use of recreational drugs in pregnancy)especially in pregnancy, encouraging mothers to begin early and get adequate prenatal care in pregnancy, improving on the educational level and socio-economic status of mothers, especially in black communities. In the future, a cohort study of well-matched women in terms of education, race, age, inception of prenatal care and who neither smoke cigarettes nor use recreational drugs could be explored in two different regions with differing levels of $PM_{2.5.}$

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