**Title:** Associations of PM2.5 exposure with emergency department visits and readmissions among preterm infants with bronchopulmonary dysplasia

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**ABSTRACT**

**Objectives:** To quantify the association of ambient air pollution (particulate matter, PM2.5) exposure with medically attended acute respiratory illness among infants with bronchopulmonary dysplasia (BPD).

**Study Design:** Single center, retrospective cohort study of preterm infants with BPD in Metropolitan Philadelphia. Multivariable logistic regression quantified associations of annual mean PM2.5 exposure (per μg/m3) at the census block group level with medically attended acute respiratory illness, defined as emergency department (ED) visits or hospital readmissions within a year after first hospital discharge adjusting for age at neonatal intensive care unit (NICU) discharge, year, sex, race, insurance, BPD severity, and census tract deprivation. As a secondary analysis, we examined whether BPD severity modified the associations.

**Results:** Ofthe 378 infants included in the analysis, 189 were non-Hispanic Black and 235 were publicly insured. Census block PM2.5 level was not significantly associated with medically attended acute respiratory illnesses, ED visits, or hospital readmissions in the full study cohort. We observed significant effect modification by BPD grade; each 1 µg/m3 higher annual PM2.5 exposure was medically attended acute respiratory illness (aOR 1.65, 95% CI: 1.06-2.63) among infants with grade 1 BPD but not among infants with grade 3 BPD (aOR 0.83, 95% CI: 0.47-1.48) (interaction p=0.024).

**Conclusions:** Cumulative PM2.5 exposure in the year after NICU discharge was not significantly associated with medically attended acute respiratory illness among infants with BPD. However, infants with grade 1 BPD had significantly higher odds with higher exposures. If replicated, these findings could inform anticipatory guidance for families of these infants to avoid outdoor activities during high pollution days after NICU discharge.

**Introduction**

Bronchopulmonary dysplasia (BPD) is the most common chronic morbidity affecting preterm infants. Infants with BPD are at increased risk of adverse long-term respiratory and neurologic outcomes as well as greater healthcare costs and utilization.1–3 Approximately half of all infants with BPD are readmitted to a hospital in the first two postnatal years and infants with BPD carry a two to three fold higher risk of developing wheeze or asthma by five years of age.4,5 There are known racial disparities in the prevalence of BPD, due to high rates of extreme preterm birth among Black and low-income families.6 Furthermore, after NICU discharge Black infants with BPD experience higher rates of adverse post-discharge outcomes compared to other infants with BPD.6–9 Additionally, infants with BPD residing in neighborhoods with greater social vulnerability have higher odds of emergency department (ED) visits and inpatient readmissions for respiratory illness in the first year after NICU discharge.8 Air pollution exposure is often higher in neighborhoods populated with minoritized and low-income communities, but whether air pollution exposure contributes to post-discharge respiratory outcomes among infants with BPD remains understudied.

Characterizing risk factors for adverse health outcomes of preterm infants with BPD after NICU discharge is necessary to improve health. Exposure to ambient air pollution is one of the first novel exposures that infants with BPD face upon NICU discharge. Particulate matter less than 2.5 microns in diameter (PM2.5) is a major constituent of air pollution produced by sources of combustion such as vehicle emissions, power plants, tobacco smoke, and cooking. Exposure to PM2.5 is associated with adverse health outcomes in older infants and adults but remains understudied as a risk factor for disease exacerbation in infants with BPD.10–12

Prior studies have examined PM2.5 exposure using proxies of exposure, such as residential proximity to a major roadway, or PM2.5 exposure at much broader levels by county and ZIP code.13–15 We sought to add to this small but growing evidence base regarding associations of air pollution with respiratory health among preterm infants. In the present study, we utilized granular air pollution predictions at the census block group level to characterize the association of residential PM2.5 exposure and medically attended acute respiratory illness in the first year after NICU discharge among infants with BPD. We hypothesized that higher exposure to PM2.5 would be associated with higher odds of medically attended acute respiratory illness.

**Methods**

We performed a retrospective cohort study of preterm infants with BPD. The dataset was generated from the Children’s Hospital of Philadelphia (CHOP) electronic health record (EHR) and a local research registry of infants receiving care within a local registry of CHOP and the University of Pennsylvania (Figure 1). We included infants born <32 weeks’ gestation between 1/1/2010 and 12/31/2020 who were diagnosed with BPD using the 2019 Neonatal Research Network (NRN) BPD criteria,16 and survived to hospital discharge. The 2019 NRN BPD Criteria categorizes infants with BPD into three grades based on respiratory support at 36 weeks’ postmenstrual age (PMA): (Grade 1) nasal cannula ≤2 L/min; (Grade 2) nasal cannula >2 L/min or non-invasive positive airway pressure; and (Grade 3) invasive mechanical ventilation.16 Infants born <32 weeks’ gestation who are in room air without supplemental respiratory support at 36 weeks’ PMA are not diagnosed with BPD. We assigned infants with tracheostomies at the time of CHOP NICU admission but unknown respiratory support at 36 weeks’ PMA as Grade 3 BPD. We excluded infants with missing documentation of home address at time of NICU discharge. We geographically restricted the cohort to the metropolitan Philadelphia region to decrease the likelihood of missing post-NICU discharge ED visits or inpatient readmissions in other hospital systems as we only had access to post-discharge data from the CHOP Network.

*Exposure ascertainment*

The exposure of interest was daily mean environmental PM2.5 level in the year after NICU discharge. Each infant’s residential address at time of NICU discharge was geocoded using ArcMAP Version 10.8 and ArcGIS Street Map Premium North America 2021.1 address locator, using a minimum match score of 75 and assigning a census block group based on the 2010 U.S. Census boundaries. PM2.5 estimates were generated using XGBoost-IDW Synthesis (XIS), a daily high-resolution PM2.5 machine-learning model covering the contiguous US from 2003-2021.17 PM2.5 exposure estimates were assigned to each infant based on the residential census block group of each infant’s residential address at time of NICU discharge. Block groups are smaller than census tracts, have an average population of 1000 residents, range in size from 600 to 3000 residents, and are not defined by set area measurement thresholds.18 Of note, a block group is a smaller geographic unit of exposure than those utilized previously in the literature.13–15 XIS uses satellite aerosol optic depth and a parsimonious set of satellite, land-use, meteorological, and topographical factors to make estimates at arbitrary points, capturing near-roadway gradients allowing approximation of local PM2.5 exposures with greater precision.19

*Outcome definition*

The primary outcome was medically attended acute respiratory illness, defined as a composite of either an ED visit or inpatient readmission for acute respiratory illness in the first year after NICU discharge, identified using ICD 9 and 10 codes. As a secondary analysis, we investigated ED visits for acute respiratory illness without inpatient readmission and inpatient readmissions as individual outcomes. Readmissions could be from the ED, a transfer from an outside hospital, or a direct admission. If an infant had separate ED visits and inpatient readmissions for distinct episodes separated by >1 day, they were included in the inpatient readmission category. Only the first ED visit or inpatient readmission was counted for infants with more than one ED visit or inpatient readmission in the study period to limit overestimation of the primary outcome due to repeated events in the same individual.

*Covariate ascertainment*

Individual-level variables were collected from the EHR, including gestational age, age at NICU discharge, sex, infant race and ethnicity, insurance status, and discharge year. To characterize area-level material deprivation that may impact the likelihood of medically attended acute respiratory illness, we used a nationwide Community Deprivation Index which includes the following five factors: census tract fraction of population with income below the poverty level, median household income, fraction with high school education, fraction without health insurance, fraction receiving public assistance, and fraction of vacant homes.20

*Statistical Analyses*

We calculated unadjusted associations of infant characteristics with medically attended acute respiratory illness in the first year after NICU discharge using two-sided *t* tests and Wilcoxon rank sum tests for continuous variables and Chi-square tests for categorical variables.

We modeled the association of mean PM2.5 exposure in the year after NICU discharge with medically attended acute respiratory illness using multivariable logistic regression. PM2.5 exposure was used linearly and effect estimates given per 1.0 μg/m3 increments, similar to one standard deviation of mean exposure in our study population. *A priori*, we chose to adjust for the following individual- and census tract-level variables that have been associated with risk for in-hospital or post-discharge illness: sex; race and ethnicity; insurance status; age at NICU discharge; discharge year; and census tract deprivation.20 We used mutually exclusive categories of infant race and ethnicity: non-Hispanic Black; non-Hispanic White; and a third group of all other races and ethnicities due to small sample sizes of other reported combinations. Of note, while changes in temperature and season can contribute to variability in PM2.5 concentration,17,21,22 we evaluated annual mean PM2.5 exposure in the first year after NICU discharge as a single summary exposure variable. Therefore, we did not adjust for temperature or season in our models. We examined if BPD severity might modify associations of PM2.5 with medically attended acute respiratory illness, including an interaction term of BPD Grade\*PM2.5 using Grade 1 BPD as the referent category and performed stratified analyses for interpretability.

To disaggregate the primary composite outcome of medically attended acute respiratory illness, we repeated the analysis using multinomial logistic regression to determine associations of annual mean PM2.5 exposure with the odds of an ED visit alone and with the odds of inpatient readmission for acute respiratory illness. To address potential ascertainment bias, we performed a sensitivity analysis excluding the 13 infants in the cohort who did not have follow-up within the CHOP Network in the year after NICU discharge as these infants may have been more likely to seek care within other hospital systems.

This research was approved and deemed exempt by the Institutional Review Board (IRB) of CHOP (IRB 20-018358). Given the retrospective nature of the study, the IRB did not require informed consent. All analyses were performed with R statistical software (v4.0.2; R Core Team 2021); code available at: <https://github.com/tnelin/Air-Pollution.git>.

**Results**

We identified 378 infants with BPD, of whom 127 (34%) were diagnosed with Grade 1 BPD, 153 (40%) with Grade 2 BPD, and 98 (26%) with Grade 3 BPD (Table 1). There were 189 infants (50%) identified as non-Hispanic Black and 235 (62%) as publicly insured. On a scale of 0 to 1, with 0 being least deprived and 1 being most deprived, mean (SD) census tract deprivation of the cohort was 0.43 (0.15).20

Figure 2 displays variation in PM2.5 concentration across the metropolitan Philadelphia region. Mean (SD) daily PM2.5 concentration was 8.7 (1.0) μg/m3 for the cohort. There were 175 (46%) infants with a medically attended acute respiratory illness in the first year after NICU discharge, including 42 infants (33%) with Grade 1 BPD, 73 infants (48%) with Grade 2 BPD, and 60 infants (61%) with Grade 3 BPD. Of all infants readmitted, 47 (12%) had an ED visit alone and 128 (34%) had an inpatient readmission.

Overall, we did not detect a significant association of annual mean PM2.5 exposure in the year after NICU discharge with medically attended acute respiratory illness in bivariate analyses (*p* = 0.27) (Table 1). Similar results were observed with multivariable adjustment; greater PM2.5,exposure was not associated with a statistically significant increase in the odds of medically attended acute respiratory illness (adjusted odds ratio (aOR) 1.16; 95% CI 0.85-1.59), ED visit only (aOR 1.26; 95% CI 0.80-2.01), or inpatient readmissions for respiratory reasons (aOR 1.04; 95% CI 0.76-1.43) (Tables 2 and 3).

Analyses stratified by BPD grade demonstrated a statistically significant interaction between Grade 1 versus Grade 3 BPD for the association of PM2.5 with medically attended acute respiratory illness (p = 0.024) (Table 2). In bivariate analyses, PM2.5 exposure was significantly higher among infants with grade 1 BPD who had medically attended acute respiratory illness compared to those who did not (9.3 vs 8.7 μg/m3, *p* = 0.003) (Table 1). This association persisted with multivariable adjustment. For infants with grade 1 BPD, each increment of 1.0 μg/m3 PM2.5 exposure was associated withhigher odds of medically attended acute respiratory illness (aOR 1.65; 95% CI 1.06-2.63) (Table 2). For the individual components of the primary outcome, greater PM 2.5 exposure in infants with grade 1 BPD was associated with a significant increase in the odds of ED visits (aOR 2.14; 95% CI 1.08-4.66) but not inpatient readmissions (aOR 1.04, 95% CI: 0.76-1.43) (Table 3). We did not detect significant associations between PM2.5 exposure and the primary or secondary outcomes in bivariate or multivariable analyses for infants with Grade 2 or 3 BPD (Tables 1-3).

Results from the sensitivity analysis, which excluded the 13 infants without follow-up care within the CHOP Network during the initial year after NICU discharge, demonstrated substantively equivalent findings to the primary analysis (Supplemental Table 1).

**Discussion**

In a contemporary cohort of preterm infants with BPD in the Philadelphia metropolitan area, we did not find a significant association of higher exposure to PM2.5 with medically attended acute respiratory illness. However, we found that among infants with Grade 1 BPD, the least severe and most common form of the disease,16 higher exposure to PM2.5 was associated with higher odds of medically attended acute respiratory illness. Our findings highlight the potential role of macroenvironmental pollutant exposures on acute care utilization among preterm infants with less severe baseline respiratory disease.

Our findings are consistent with recent studies demonstrating that direct measures of PM2.5 exposure and proxy measures of PM2.5 at the ZIP code level are associated with adverse respiratory health outcomes in infants. In a 2023 cohort study of 1,983,700 term and preterm infants in California, Teyton et al. found that higher PM2.5 exposure at the ZIP code level was associated with higher odds of ED visits in both term (aOR 1.051; 95% CI 1.049-1.053) and preterm (aOR 1.056; 95% CI 1.048-1.064) infants in the first year after birth.15 Kelchtermans et al. investigated the association of ambient air quality, measured by the Air Quality Index at the ZIP code level, in a cohort of infants with BPD in Baltimore and Philadelphia. Compared to infants in the lowest tertile of ambient air pollution exposure, infants in the highest tertile were more likely to receive systemic steroids (OR 2.17; 95% CI 1.34-3.51) and have an ED visit for respiratory illness (OR 1.59; 95% CI 1.02-2.48).14 Another study from 2020 found an association of closer home address proximity to a major roadway with reported activity limitations and nighttime cough in infants with BPD, but found no association with ED visits or inpatient readmissions.13

Our finding that PM2.5 exposure is a greater contributor to the odds of medically attended acute respiratory illness among infants with less compared to more severe BPD is new. We speculate that these infants may be more highly exposed to air pollution if their families feel more comfortable leaving home and more likely to go outside with them. They may also be more likely to be exposed to other factors that could combine with air pollution to trigger acute respiratory illness such as infections and allergens. However, we did not confirm or measure actual exposure using environmental samples for each infant. It is possible that infants with higher grade BPD are more susceptible to BPD exacerbations as 48% of infants with Grade 2 BPD and 61% of infants with Grade 3 BPD experienced an ED visit or inpatient readmission for respiratory illness compared to 33% of infants with Grade 1 BPD. The additional marginal effects of PM2.5 exposure may have little impact on the high baseline risk of acute respiratory illness among infants with higher grade BPD. Furthermore, our finding of higher PM2.5 exposure among infants with Grade 1 BPD compared to infants with Grade 2 or 3 BPD may be understood in the context of racial, urban, and socioeconomic disparities in PM2.5 exposure in the United States.23–25 Infants with higher grade disease may have transferred into CHOP from more affluent, suburban areas compared to infants with lower grade disease who may have been more likely to be born at the University birthing hospital and discharged to a local address in Philadelphia County. Our findings are consistent with our prior study showing greater susceptibility to social vulnerability among infants with Grade 1 BPD.8

It is plausible that the levels of PM2.5 observed in our study could have health effects on preterm infants with BPD. On February 7th, 2024, the United States Environmental Protection Agency announced that it was setting the annual PM2.5 standard to decrease to 9 from 12 μg/m3 as a reflection of new science based on harms caused by even levels of fine particulate matter historically considered low.26,27 Our data are consistent with this recommendation as we demonstrate that exposure to mean ambient PM2.5 at concentrations less than the previous EPA standards may be associated with adverse respiratory health outcomes in vulnerable infants with Grade 1 BPD. These findings suggest that cumulative exposure to even lower levels of PM2.5 may still pose a risk for adverse health outcomes in vulnerable populations.

Our study has several strengths. We had access to a reasonably large sample size of medically complex infants spanning a 10-year period. We utilized a contemporary and validated BPD grading scale to derive our cohort, improving classification of respiratory illness severity and baseline medical complexity.16 To our knowledge, this is the first study to use a machine-learning model to estimate daily, residential PM2.5 exposures, and its association with post-discharge outcomes in the first year after NICU discharge, among infants with BPD. We defined PM2.5 exposure with greater granularity (census block group) than prior research, improving the specificity of our main exposure variable. Lastly, we adjusted for neighborhood deprivation to limit confounding by area-level socioeconomic position, which is important as PM2.5 exposure and neighborhood deprivation are intertwined in the United States.24,28,29

Our study has limitations. First, a degree of ascertainment bias may exist as we captured ED visits and inpatient readmissions for acute respiratory illness only within the CHOP network. However, given the establishment of a specialized program for Newborn and Infant Chronic Lung Disease at CHOP in 2010 and the limited external inpatient services in our region for infants with BPD, we are confident that most patients with BPD return to CHOP for acute ED and inpatient care.30 To further limit this bias, we restricted the study population to those discharged from the NICU to addresses within the metropolitan Philadelphia region. Of note, there are three free-standing Children’s Hospitals, including CHOP, within the metropolitan Philadelphia region. Our sensitivity analysis that excluded the small number of patients who did not receive care within the CHOP network during the initial year following NICU discharge suggests minimal impact of ascertainment bias on the study findings. Second, our reliance on race and ethnicity data from the EHR may not fully capture an individual’s lived experience or identification, particularly in multiracial households.31 Third, we lacked access to indoor environmental exposures such as household smoke exposure, which can affect the risk of medically attended acute respiratory illness in preterm infants with BPD. Fourth, we lacked preterm infants without BPD in our cohort to serve as a control group.

In conclusion, overall, we found that higher annual average PM2.5 exposure was not associated with the composite of medically attended acute respiratory illness or its components among infants with BPD. However, we did show that higher PM2.5 exposure in the first year after NICU discharge was associated with both medically attended acute respiratory illness and ED visits among preterm infants with Grade 1 BPD in models adjusted for clinical, demographic, and neighborhood characteristics. Grade 1 BPD is the most common form of BPD and strategies that prevent subsequent acute respiratory illnesses among infants may be different depending on the severity of underlying BPD. Future studies investigating PM2.5 exposure and respiratory outcomes among infants with BPD residing in areas with different PM2.5 exposure levels, particularly in the setting of a warming climate and more common wildfires, are also warranted to better understand the relationship of ambient PM2.5 with post-discharge outcomes of infants with BPD. Lastly, research should prioritize the investigation of place-based strategies to mitigate the adverse health effects of PM2.5, particularly for vulnerable populations like infants with BPD.

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**Figure 1.** Flowchart of cohort generation

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| **Table 1.** Bivariate associations of characteristics with medically attended acute respiratory illness (ED visit or hospital admission) in the first year after NICU discharge among infants <32 weeks’ gestation with BPD | | | | |
| **Characteristic** | **Overall**  **(n = 378)** | **No Medically Attended Acute Respiratory Illness (n=203)** | **Medically Attended Acute Respiratory Illness**  **(n=175)** | ***p-*value** |
|  |  |  |  |  |
| GA (weeks), Median [IQR] | 27 [25-29] | 26 [24-28] | 27 [25-29] | 0.641 |
| Birth Weight◊ (g), Median [IQR] | 774 [577-971] | 794 [606-982] | 770 [554-986] | 0.662 |
| NICU Discharge Age (days), Median [IQR] | 138 [82-194] | 123 [79-167] | 152 [83-221] | 0.003 |
| Female Sex, n (%) | 158 (42) | 84 (42) | 74 (42) | 0.941 |
| BPD Grade, n (%)\* |  |  |  | <0.001 |
| Grade 1 | 127 (34) | 85 (42) | 42 (24) |  |
| Grade 2 | 153 (40) | 80 (39) | 73 (42) |  |
| Grade 3 | 98 (26) | 38 (19) | 60 (34) |  |
| Infant Race and Ethnicity, n (%) |  |  |  | <0.001 |
| Non-Hispanic Black | 189 (50) | 79 (39) | 110 (63) |  |
| Non-Hispanic White | 99 (26) | 67 (33) | 32 (18) |  |
| Non-Hispanic Other | 90 (24) | 57 (28) | 33 (19) |  |
| Insurance Type, n (%) |  |  |  | 0.064 |
| Commercial | 143 (38) | 86 (42) | 57 (33) |  |
| Public | 235 (62) | 117 (58) | 118 (67) |  |
| PM2.5 Exposure (μg/m3), Mean (SD)# |  |  |  |  |
| Overall | 8.7 (1.0) | 8.6 (1.0) | 8.8 (1.1) | 0.217 |
| Grade 1 BPD | 8.9 (1.1) | 8.7 (1.0) | 9.3 (1.0) | 0.003 |
| Grade 2 BPD | 8.6 (1.1) | 8.6 (1.0) | 8.7 (1.2) | 0.477 |
| Grade 3 BPD | 8.5 (1.0) | 8.5 (1.0) | 8.5 (1.0) | 0.797 |
| Census Tract Deprivation, Mean (SD)^ | 0.43 (0.15) | 0.39 (0.15) | 0.46 (0.16) | <0.001 |
|  |  |  |  |  |

Abbreviations: ED, emergency department; BPD, bronchopulmonary dysplasia; GA, gestational age; IQR, interquartile range; NICU, neonatal intensive care unit; SD, standard deviation; PM2.5, particulate matter <2.5µm in diameter

Two-way t-test used for continuous variables. Chi-square used for categorical variables.

\*BPD severity stratified at 36 weeks or hospital admission if hospital admission to CHOP occurred after 36 weeks post-menstrual age using 2019 NRN criteria (Jensen et al. 2019).

◊Missing data: birth weight (n = 7).

#Mean PM2.5 exposure in the year after neonatal intensive care unit (NICU) discharge.

^Census Tract-Level Deprivation Index from 2018 (Brokamp et al. 2019).

**Figure 2.** Average PM2.5 in the metropolitan Philadelphia region

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Mean PM2.5 in the metropolitan Philadelphia core-based statistical area comprised of 11 counties within Pennsylvania, New Jersey, and Delaware in 2015. PM2.5 estimates generated using XGBoost-IDW Synthesis (XIS), a daily high-resolution PM2.5 machine-learning model covering the contiguous US from 2003-2021. XIS uses satellite aerosol optical depth and a parsimonious set of predictors to make predictions at arbitrary points, capturing near-roadway gradients and allowing estimation of address block-group level exposures.

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| **Table 2.** Adjusted^ associations of PM2.5 exposure with medically attended acute respiratory illness in the first year after NICU discharge among infants with BPD | | | |
| **BPD Grade** | **PM2.5 (μg/m3), mean (SD)** | **Medically Attended Acute Respiratory Illness Overall**  **aOR (95% CI)** | **Interaction Term p-value**  **(BPD Grade\*PM2.5)** | |
| All (n=378) | 8.7 (1.0) | 1.16 (0.85-1.59) |  | |
| Grade 1 (n=127) | 8.9 (1.1) | 1.65 (1.06-2.63) | Ref. | |
| Grade 2 (n=153) | 8.7 (1.1) | 1.04 (0.66-1.62) | 0.072 | |
| Grade 3 (n=98) | 8.5 (1.0) | 0.83 (0.47-1.48) | 0.024 | |

^Model adjusted for age at NICU discharge, discharge year, sex, race, insurance, BPD grade, and census tract deprivation, estimates are per SD increment of PM2.5 exposure (1.0 μg/m3).

Abbreviations: PM2.5, particulate matter <2.5µm in diameter; NICU, neonatal intensive care unit; BPD, bronchopulmonary dysplasia; ED, emergency department; SD, standard deviation; aOR, adjusted odds ratio

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| **Table 3.** Adjusted^ associations of PM2.5 exposure with medically attended acute respiratory illness in the first year after NICU discharge among infants with BPD; 47 infants had an ED visit alone, and 128 infants had an inpatient readmission. | | | | |
| **BPD Grade** | **ED Visit aOR**  **(95% CI)** | **Interaction Term p-value**  **(BPD Grade\*PM2.5)** | **Inpatient Readmission aOR (95% CI)** | **Interaction Term p-value**  **(BPD Grade\*PM2.5)** |
| All (n = 378) | 1.26 (0.80-2.01) |  | 1.04 (0.76-1.43) |  |
| Grade 1 (n = 127) | 2.14 (1.08-4.66) | Ref. | 1.24 (0.79-1.97) | Ref. |
| Grade 2 (n = 153) | 0.78 (0.33-1.80) | 0.055 | 1.20 (0.76-1.92) | 0.594 |
| Grade 3 (n = 98) | * 1. (0.63-3.34) | 0.100 | 0.50 (0.23-1.03) | 0.122 |

^Model adjusted for age at NICU discharge, discharge year, sex, race, insurance, BPD grade, and census tract deprivation, estimates are per SD increment of PM2.5 exposure (1.0 μg/m3). There was no significant effect modification by BPD grade on the association of PM2.5 with either ED visits or inpatient readmission.

Abbreviations: PM2.5, particulate matter <2.5µm in diameter; NICU, neonatal intensive care unit; BPD, bronchopulmonary dysplasia; ED, emergency department; SD, standard deviation; OR, odds ratio