Research Square

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Evaluation of associations between asthma exacerbations and distance to roadways using geocoded electronic health records data

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Abstract

Background: Asthma exacerbations in children often require medications, urgent care, and hospitalization. Multiple environmental triggers have been associated with asthma exacerbations, including particulate matter 2.5 (PM2.5) and carbon monoxide (CO), which are primarily generated by motor vehicle exhaust. There is mixed evidence as to whether proximity to highways increases risk of asthma exacerbations.

Methods: To test this hypothesis, we assessed the association between asthma exacerbations and the distance to two types of roadways in Durham County, accounting for other patient-level factors. We abstracted data from the Duke University Health System electronic health record (EHR), identifying 6,208 children with asthma between 2014 – 2019. We geocoded each child's distance to roadways (both 35 MPH+ and 55 MPH+). We classified asthma exacerbation severity into four tiers and fitted a recurrent event survival model to account for multiple exacerbations.

Results: There was a consistent weak effect of residential distance from 55+ MPH highway and any asthma exacerbation (Hazard Ratio: 0.98 (95% confidence interval: 0.94, 1.01)), but there was no effect from distance to 35+ MPH roadway (Hazard Ratio: 0.98 (95% confidence interval: 0.83, 1.15)).

Conclusions: While the results were negative, characteristics of a study sample – namely farther distance to roadways and generally good ambient environmental pollution may contribute to this. Compared to previous work which often relied on self-report measures, we are able to obtain a more objective assessment of outcomes. Overall, this work highlights the opportunity to use EHR data to study environmental impacts of disease.

Background

Asthma is one of the most common chronic respiratory diseases, affecting more than 25 million Americans, including 9 percent of children in the United States.[1,2] Asthma exacerbations are acute episodes of worsening shortness of breath, wheezing, cough, and chest tightness that cause the majority of healthcare utilization and morbidity associated with asthma.[3] Over three million children suffer from at least one asthma exacerbation per year, with more than 10 percent of exacerbations requiring hospitalization.[4] Various clinical and environmental risk factors for asthma exacerbations have been identified. Previous studies have shown that outdoor air pollution, including fine particulate matter and gaseous pollutants resulting from traffic and power generation can increase symptoms in children who have already been diagnosed with asthma.[5–9]

Specifically, Particulate matter 2.5 (PM2.5) and carbon monoxide (CO), which result primarily from motor vehicle exhaust, are well studied environmental triggers of asthma symptoms.[10–12] Areas close to major roadways can have high PM2.5 and CO levels,[13,14] and there is a growing body of evidence suggesting that proximity to car traffic sources can negatively affect asthma severity.[15–26] Importantly, the results of

these studies are somewhat mixed, with a few studies either finding no association or weak associations between asthma exacerbations and distance to roadways.[27–30] Some of the inconsistency in the results can be attributed to heterogeneity in study design, outcomes, cohort definition, and exposure assessments.[30] In particular, the majority of studies used self-reported questionnaires to collect exposure and outcomes data, which can result in potential misclassification and recall bias.[27] Thus, further studies are needed to evaluate the impact of distance to roadways on pediatric asthma exacerbations.

In this study, we sought to assess the association between the distance to two types of roadways (35 + MPH and 55 + MPH) and rates of pediatric asthma exacerbations in a medium sized eastern US city. To account for potential biases in the self-reporting of outcomes, we relied on data abstracted from our institution's electronic health record (EHR) system to objectively obtain information on asthma exacerbations.

Methods

Data sources

All data were extracted from the Duke University Health System Electronic Health Record (EHR) system. Duke University Health System consists of 3 hospitals – 1 tertiary care and 2 community based – and a network of primary care and specialty clinics. As the primary provider in Durham County, North Carolina, it is estimated that 80 percent of Durham County residents receive their care through Duke University Health System.[31] For the purposes of this study we abstracted analytic data from our data warehouse covering the years January 1, 2014 to December 31, 2019.

Study population

We identified children (age 5–18), living in Durham County with asthma. Children had to be at least 5 years old to rule out unclear respiratory related diagnoses in younger children. To phenotype asthma we applied two definitions. Our first definition was encounter-based. A child had to have: 1) two outpatient encounters or one inpatient encounter with an asthma diagnosis (see Appendix Table 1 for ICD9/10 codes) and 2) a prescription for an asthma medication (see Appendix Table 2). Our second definition was problem list-based. Problem lists are an EHR feature that serves as a comprehensive list of patient diagnoses that is intended to serve as a snapshot of the patient's health status. To be included under the problem list-based definition, a child had to have 1) asthma on their problem lists and 2) a prescription for an asthma medication. Internal validation of these phenotypes based on double chart-review yielded a positive predictive value of 97 percent.

Table 1
Baseline Patient Characteristics by Distance to Highway (55+) Categories

	< 0.25 mile N = 776	0.25–0.5 mile N = 988	0.5–1 mile N = 1,545	> 1 mile N = 3,202
Sex				
Male	441 (56.8%)	566 (57.3%)	848 (54.9%)	1,803 (56.3%)
Female	335 (43.2%)	422 (42.7%)	697 (45.1%)	1,399 (43.7%)
Age	8.0 (6.0–12.0)	9.0 (6.0–13.0)	9.0 (6.0–12.0)	9.0 (6.0–13.0)
Race				
Hispanic	154 (19.8%)	91 (9.2%)	221 (14.3%)	326 (10.2%)
Nonhispanic Black	465 (59.9%)	662 (67.0%)	888 (57.5%)	1,814 (56.7%)
Nonhispanic White	90 (11.6%)	143 (14.5%)	276 (17.9%)	773 (24.1%)
Other	54 (7.0%)	74 (7.5%)	118 (7.6%)	224 (7.0%)
Unavailable/Unknown	13 (1.7%)	18 (1.8%)	42 (2.7%)	65 (2.0%)
Atopy				
No	293 (37.8%)	354 (35.8%)	628 (40.6%)	1,211 (37.8%)
Yes	483 (62.2%)	634 (64.2%)	917 (59.4%)	1,991 (62.2%)
Obesity				
No	561 (72.3%)	707 (71.6%)	1,083 (70.1%)	2,426 (75.8%)
Yes	206 (26.5%)	264 (26.7%)	446 (28.9%)	749 (23.4%)
Missing	9 (1.2%)	17 (1.7%)	16 (1.0%)	27 (0.8%)
Insurance Type				
Private	179 (23.1%)	290 (29.4%)	494 (32.0%)	1,313 (41.0%)
Public	565 (72.8%)	648 (65.6%)	985 (63.8%)	1,746 (54.5%)
Self-pay	29 (3.7%)	44 (4.5%)	62 (4.0%)	118 (3.7%)
Unavailable/Unknown	3 (0.4%)	6 (0.6%)	4 (0.3%)	25 (0.8%)
Medication Category				
No prescriptions	475 (61.2%)	577 (58.4%)	917 (59.4%)	1,890 (59.0%)
Only ICS or only LTRA	229 (29.5%)	346 (35.0%)	510 (33.0%)	1,095 (34.2%)

	< 0.25 mile N = 776	0.25–0.5 mile N = 988	0.5–1 mile N = 1,545	> 1 mile N = 3,202
Combination	72 (9.3%)	65 (6.6%)	118 (7.6%)	217 (6.8%)
SES Status Category				
25–50	414 (53.4%)	663 (67.1%)	927 (60.0%)	1,485 (46.4%)
50–75	260 (33.5%)	318 (32.2%)	616 (39.9%)	1,717 (53.6%)
Missing	102 (13.1%)	7 (0.7%)	2 (0.1%)	0 (0.0%)
Number of Encounters in past year	2.0 (1.0–5.0)	2.0 (1.0–5.0)	2.0 (1.0–5.0)	3.0 (1.0–5.0)

ICS: Inhaled corticosteroids LTRA: Leukotriene receptor antagonist SES: Socio-economic Status

Table 2a. Association Between Asthma Exacerbations and Distances to 55 + MPH Highways

	Number of events	Unadjusted		Adjusted for SES Score		Adjusted for Race/Insurance/ Sex/Age		Adjusted for Number of Encounter/ Medication/Obesity/ Atopy	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Overall	3739	0.98	0.94, 1.01	0.98	0.94, 1.02	0.99	0.95, 1.02	0.99	0.96, 1.02
Inpatient	304	1.00	0.94, 1.06	0.98	0.91, 1.05	0.98	0.90, 1.06	0.97	0.89, 1.06
ED	895	0.96	0.90, 1.02	0.97	0.91, 1.03	0.97	0.92, 1.03	0.98	0.93, 1.03
Urgent	935	0.93	0.89, 0.98	0.93	0.89, 0.97	0.94	0.89, 0.98	0.94	0.89, 0.99
Outpatient	1850	0.99	0.96, 1.02	1.00	0.97, 1.03	1.00	0.97, 1.03	0.99	0.96, 1.03

HR: Hazard ratio 95% CI: 95% Confidence interval

ED: Emergency department SES: Socio-economic Status

Table 2
b. Association Between Asthma Exacerbations and Distances to 35 + MPH Roadways

	Number of events	Unadjusted		Adjusted for SES Score		Adjusted for Race/Insurance/ Sex/Age		Adjusted for Number of Encounter/ Medication/Obesity/ Atopy	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Overall	3739	0.98	0.83, 1.15	0.98	0.83, 1.16	1.02	0.86, 1.21	1.00	0.85, 1.18
Inpatient	304	1.25	0.89, 1.75	1.20	0.86, 1.69	1.34	0.96, 1.86	1.10	0.80, 1.52
ED	895	1.00	0.79, 1.27	1.03	0.81, 1.31	1.06	0.83, 1.35	1.07	0.83, 1.38
Urgent	935	0.88	0.70, 1.10	0.87	0.69, 1.09	0.89	0.70, 1.12	0.82	0.65, 1.04
Outpatient	1850	0.99	0.86, 1.14	1.01	0.87, 1.17	1.02	0.88, 1.18	0.99	0.85, 1.15

HR: Hazard ratio 95% CI: 95% Confidence interval

ED: Emergency department SES: Socio-economic Status

Person-time was calculated from time of positive asthma identification until censoring. Censoring was based on aging out of the cohort (> = 18), an indicated address outside of Durham County, or at the last known encounter.

Primary exposure

The primary exposure in our study was the residential distances to two types of roadways: roads with U.S. Census feature Class Code A1 (55 + MPH with limited access only accessible via ramps) and A2 (35 + MPH-primary road without limited access),[32–34] with these speeds corresponding to highways and major roadways, respectively.[15,16,18,25] We abstracted the address information of each individual in our cohort from our EHR system and geocoded them using ArcGIS (version 10.5; ESRI Inc., Redlands, CA). The accuracy of all address information was manually checked with Google Maps to verify the existence of residences at each address. Addresses were treated as a time-varying exposure based on when a child moved to a new address, as indicated in the EHR.

Straight-line distance to roadways, which was calculated using GIS, was used as our primary exposure (See Fig. 1). Durham County has three major roadways that intersect in central Durham (Fig. 1). For children who live within this triangular intersection, straight-line distance might not accurately capture

exposure. We therefore also constructed radial density measures of 1.0 mile in order to evaluate exposures associated with proximity to more than one roadway (Fig. 2).

Outcome of interest

The primary outcome of interest was an asthma-related exacerbation, which was defined as any encounter with an asthma-related ICD9 or -10 code and a prescription for a systemic steroid (see Appendix Table 1). We further categorized exacerbations into four different outcome tiers based on severity (listed in decreasing severity): 1) inpatient encounters lasting more than 24 hours, 2) emergency department and hospital encounters lasting less than 24 hours, 3) urgent care visits, and 4) outpatient (including telephone-based) encounters.

Covariates

We abstracted additional clinical and socio-demographic information on each child from the EHR, including sex, age, race, insurance type (public, private, self-pay), neighborhood socio-economic status (nSES), comorbidities (atopy, obesity), medication categories (only rescue, only inhaled corticosteroids or only Leukotriene receptor antagonist, or other controller medications), and number of overall encounters. Covariates were treated as time-varying and abstracted accordingly. To calculate nSES, we identified each child's census tract and linked data from the American Community Survey to calculate the Agency for Healthcare Research and Quality neighborhood deprivation index,[35] generating a score between 0–100, with higher scores indicative of greater deprivation.

Air quality exposure

To further characterize potential exposures, we abstracted publicly available data from Environmental Protection Agency sensors on daily PM2.5.[36] We note that Durham County only has one sensor, providing a general approximation of daily PM2.5 exposure.

Statistical analysis

We constructed a time-varying dataset, generating an encounter row each time a child moved (i.e., changed primary exposure) or had an asthma exacerbation. All time-varying covariates (e.g., medications) were calculated based on these encounter points. We categorized patients based on their baseline distance to roadway, compared clinical and demographic differences among these groups, and calculated the number of exacerbations per patient-year.

To assess the relationship between distance to roadway and asthma exacerbation rates we performed a survival time-to-event analysis, treating distance as a time-varying exposure. We fit separate models for straight-line distance and roadway density. In our cohort, about 25 percent of children had more than one asthma exacerbation over the study period. To account for multiple exacerbations, we conducted a recurrent events survival analysis using Andersen-Gill models.[37] As a sensitivity analysis, we used the Prentice, Williams and Peterson model and frailty model (random effects approach) as alternative

recurrent events models.[38] Four different models were fit: 1) unadjusted; 2) adjusted for nSES; 3) adjusted for sex, age, race, and insurance type; and 4) adjusted for all the other covariates specified above. Additionally, we assessed the linearity of the effect of distance to roadways and roadway density on asthma exacerbation outcomes. We categorized our distance to roadways variables into quartiles and refitted the models. We also stratified on sex, race, and assessed time to outcome specific tiers.

All the statistical analyses were perform using R version 3.6.0.

Results

Our analytic cohort consisted of 6,395 children with asthma, 187 of whom had invalid addresses and were excluded. Among the remaining 6,208 children with asthma, we identified 6,511 unique addresses and 3,739 asthma exacerbations (2 exacerbations per 10 patient years). Around half of the unique addresses represented in the cohort were within 1 mile of a 55 MPH + roadway among the unique addresses. Baseline characteristics are shown in Table 1. We first categorized patients based on their baseline initial straight-line distance to roadway: less than 0.25 mile, 0.25–0.5 mile, 0.5–1 mile, and greater than 1 mile – which roughly corresponded to the 10th, 25th and 50th quartiles. The median age of the cohort was ~ 9 years old and the majority of children were African Americans (~ 60 percent). Lower nSES scores were associated with residential locations close to roadways. There were no observed associations between asthma-related clinical factors (i.e. atopy, obesity, medication, and number of encounters in past year) and distance to roadway.

We assessed the relationship between distance to roadway and asthma exacerbation rates. We observed negligible relationships between distance to 55 + MPH roadways and overall, inpatient, emergency department, urgent, and outpatient asthma exacerbations, both before and after adjustment (Table 2a). While the results suggest some slight protective effect for living further from a roadway, most of the confidence intervals crossed 1. Examining distance to 35 + MPH roadways and asthma exacerbation rates, there was a clear lack of association, as the results were less consistent and the confidence intervals were much wider (Table 2b). Results were consistent when considering alternative statistical models (Appendix Table 3).

Table 3

a. Association Between Asthma Exacerbations and 1-mile Buffer Density Measurement Around 55 + MPH Highways

	Number of events	Unadjusted		Adjusted for SES Score		Adjusted for Race/Insurance/ Sex/Age		Adjusted for Number of Encounter/ Medication/Obesity/ Atopy	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Overall	1854	0.98	0.93, 1.04	0.98	0.93, 1.02	0.99	0.94, 1.03	0.98	0.94, 1.02
Inpatient	168	1.01	0.92, 1.11	1.04	0.93, 1.17	1.05	0.92, 1.19	1.02	0.92, 1.13
ED	497	0.98	0.93, 1.04	0.96	0.90, 1.02	0.97	0.90, 1.03	0.98	0.92, 1.05
Urgent	497	0.98	0.9, 1.03	0.99	0.94, 1.04	0.99	0.94, 1.05	1.00	0.95, 1.06
Outpatient	824	1.05	0.98, 1.12	1.03	0.98, 1.09	1.03	0.97, 1.08	1.03	0.97, 1.08

HR: Hazard ratio 95% CI: 95% Confidence interval

ED: Emergency department SES: Socio-economic Status

Table 3
b. Association Between Asthma Exacerbations and 1-mile Buffer Density Measurement Around 35 + MPH Roadways

	Number of events	Unadjusted		Adjusted for SES Score		Adjusted for Race/Insurance/ Sex/Age		Adjusted for Number of Encounter/ Medication/Obesity/ Atopy	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Overall	1854	1.00	0.98, 1.03	1.00	0.98, 1.03	1.00	0.98, 1.03	1.01	0.98, 1.04
Inpatient	168	1.00	0.95, 1.05	1.00	0.95, 1.05	1.01	0.96, 1.07	1.01	0.95, 1.08
ED	497	1.01	0.98, 1.05	1.01	0.98, 1.05	1.01	0.97, 1.04	1.00	0.97, 1.04
Urgent	497	0.98	0.95, 1.02	0.98	0.95, 1.02	0.98	0.95, 1.02	0.99	0.95, 1.03
Outpatient	824	1.00	0.98, 1.03	1.00	0.97, 1.03	1.00	0.97, 1.03	1.00	0.98, 1.03

HR: Hazard ratio 95% CI: 95% Confidence interval

ED: Emergency department SES: Socio-economic Status

We further assessed the relationship between the density of roadways within census tracts and risk of exacerbation, but found minimal associations (Table 3a & 3b). Finally, we assessed whether there was a non-linear association by evaluating distance groupings of 0–0.25 miles, 0.25–0.5 miles, 0.5–1 mile, 1 mile + (Fig. 3). Overall, there was no suggestion that children living closest to roadways had increased risk of asthma exacerbation.

In order to further contextualize our results, we assessed daily PM2.5 levels during the study period (Fig. 4). The exposure limit for PM2.5 is 35 $\mu g/m^3$.[39] As shown in this plot, there was only period that exceeded this limit from 2014 to 2019 – corresponding to wildfires in the region.

Discussion

In this study, we used EHR data to assess the association between residential distance to roadways on asthma exacerbation in children. There are a number of studies suggesting that proximity to high traffic areas, including roadways, have adverse effects on child respiratory health,[40,41] hospital admissions for asthma,[42] pulmonary function,[43,44] and atopy,[45] and there is some evidence that early life exposure to traffic-related pollution affects later asthma outcomes.[46] In our assessment of exacerbation rates in

children with diagnosed asthma, we found a negligible relationship between distance from 55 + MPH roadway and any asthma exacerbation. Distance from 35 + MPH roads did not affect exacerbations at all.

Though our results were negative, our study has a number of strengths that differentiates it from prior work. For one, our cohort was relatively large compared with previous studies, ranging from 2 times to 15 times larger.[16,19,25,27,30] Moreover, the majority of previous studies used questionnaires to collect information.[19,25,30] Such questionnaires are frequently complicated and time-consuming, and, because questionnaires rely on self-reports, they can cause some potential misclassification due to recall bias for outcomes and/or exposures.[27] Instead of relying on self-report, we directly extracted patient information from the EHR system, which efficiently provides data on a large number of individuals and avoids biases found with self-reported data.

The lack of significant association between residential distance to roadway and asthma exacerbation rates could potentially be explained by factors related to air quality and the built environment of Durham. First, the air quality in Durham is generally good (Fig. 4). Other studies that reported a weak or no association between asthma and traffic-related air pollution evaluated populations living in locations with good air quality, such as Sweden, Norway, and Germany.[27–30] Based on the worldwide air quality rankings for mid-2019, the air quality index for these countries were 17.45, 20.29 and 28.42 respectively.[47] In contrast, studies that reported strong associations were conducted in places such as the United Kingdom, Poland, and South Korea, whose air pollution indexes were 40.63, 52.88, and 54.80, respectively.[23–25, 48] Similar trends have been reported within the United States. A study conducted in Los Angeles reported that children and adults who suffer from asthma and live close to traffic are nearly three times more likely to visit the emergency department or be hospitalized than those who live near low traffic density.[18] In fact, cities in California, including Los Angeles, have ranked to have the worst particle pollution in the US.[49]

A second reason our results may differ is that compared to other studies our cohort lived further from roadways. Multiple studies reported a threshold of 150 meters (~ 0.1 mile) for finding the highest concentrations of traffic-related pollutions.[17,25] However, in our cohort, only 283 children live within this proximity to roadways. Two previous studies in California and South Korea utilizing radial density measures similar to ours found effects only at much closer distances of 500 feet and 200 meters respectively, than the 1-mile buffer we used.[23,25]

Only one other study, conducted in Minnesota, has utilized EHR data to assess the relationship between asthma exacerbation and traffic-related air pollution.[50] The authors used vehicle kilometers traveled within 250 meters and 500 meters of each individual's residence, as well as the traffic density as their exposures. Traffic exposures is similar to the radial density measures in our study. Assessing both pediatric and adult patients, the authors reported that traffic exposure at the residence increases the risk of asthma exacerbations. The authors reported lower odds ratio for vehicle kilometers traveled within 500

meters than the vehicle kilometers traveled within 250 meters and affirmed that 500 meters buffer distance does not effectively capture the traffic effect. Moreover, while air quality across Minnesota is generally within the healthy range, there are several days each year where fine particles levels can exceed to the unhealthy levels.[51] Overall this paper helps to contextualize some of the present findings highlighting that it is both close exposure to roadways that matters and that there may be air quality threshold that an environment needs to drop below.

There are a few limitations in our study. While our results suggest no association between residential distance to roadway and asthma exacerbation rates, a null result is hard to prove, as statistical tests are not designed to detect them. Moreover, our results are limited to one geographic area. As we noted above, Durham County has several unique characteristics, including relatively good air quality, which may cause effect heterogeneity between studies. Finally, while we believe that the use of EHR data produces more objective data measurements, EHR data are prone to their own biases.[52] In particular, type of health service utilization is often a reflection of both severity of disease as well as other social factors such as SES and health seeking behavior. Of note, though, our analyses did not indicate confounding due to nSES.

Conclusion

In conclusion, this study shows that proximity to roadways is not strongly associated with asthma exacerbation rates in Durham County between 2014–2019. Comparing these findings with reports from other locations, suggests that both close proximity and overall air quality are perhaps important modifiers of the association. Moreover, it illustrates how EHR data, combined with environmental data, can be used to assess environmental effects on population health.

Declarations

Ethical Approval: This study was approved by our institutions IRB, Pro00091342.

Consent for Publications: All authors give their support for publication.

Data Availability: The analysis data is not available as it contains protected health information.

Competing Interests: We have no Conflict of Interests to Report

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Tables

ble 1. Baseline Patient Characteristics by Distance to Highway (55+) Categories

	< 0.25 mile N = 776	0.25 – 0.5 mile N = 988	0.5 – 1 mile N = 1,545	> 1 mile N = 3,202
ɛ				
le	441 (56.8%)	566 (57.3%)	848 (54.9%)	1,803 (56.3%)
nale	335 (43.2%)	422 (42.7%)	697 (45.1%)	1,399 (43.7%)
e	8.0 (6.0 - 12.0)	9.0 (6.0 - 13.0)	9.0 (6.0 - 12.0)	9.0 (6.0 - 13.0)
ce				
spanic	154 (19.8%)	91 (9.2%)	221 (14.3%)	326 (10.2%)
nhispanic Black	465 (59.9%)	662 (67.0%)	888 (57.5%)	1,814 (56.7%)
nhispanic White	90 (11.6%)	143 (14.5%)	276 (17.9%)	773 (24.1%)
ner	54 (7.0%)	74 (7.5%)	118 (7.6%)	224 (7.0%)
available/Unknown	13 (1.7%)	18 (1.8%)	42 (2.7%)	65 (2.0%)
py				
	293 (37.8%)	354 (35.8%)	628 (40.6%)	1,211 (37.8%)
s	483 (62.2%)	634 (64.2%)	917 (59.4%)	1,991 (62.2%)
esity				
	561 (72.3%)	707 (71.6%)	1,083 (70.1%)	2,426 (75.8%)
s	206 (26.5%)	264 (26.7%)	446 (28.9%)	749 (23.4%)
ssing	9 (1.2%)	17 (1.7%)	16 (1.0%)	27 (0.8%)
urance Type				
vate	179 (23.1%)	290 (29.4%)	494 (32.0%)	1,313 (41.0%)
blic	565 (72.8%)	648 (65.6%)	985 (63.8%)	1,746 (54.5%)
f-pay	29 (3.7%)	44 (4.5%)	62 (4.0%)	118 (3.7%)
available/Unknown	3 (0.4%)	6 (0.6%)	4 (0.3%)	25 (0.8%)
dication Category				
prescriptions	475 (61.2%)	577 (58.4%)	917 (59.4%)	1,890 (59.0%)
ly ICS or only LTRA	229 (29.5%)	346 (35.0%)	510 (33.0%)	1,095 (34.2%)
mbination	72 (9.3%)	65 (6.6%)	118 (7.6%)	217 (6.8%)
S Status Category				
50	414 (53.4%)	663 (67.1%)	927 (60.0%)	1,485 (46.4%)

75	260 (33.5%)	318 (32.2%)	616 (39.9%)	1,717 (53.6%)
ssing	102 (13.1%)	7 (0.7%)	2 (0.1%)	0 (0.0%)
mber of Encounters in past year	2.0 (1.0 - 5.0)	2.0 (1.0 - 5.0)	2.0 (1.0 - 5.0)	3.0 (1.0 - 5.0)

S: Inhaled corticosteroids LTRA: Leukotriene receptor antagonist SES: Socio-economic Status

Table 2a. Association Between Asthma Exacerbations and Distances to 55+ MPH Highways

	Number of events	Unadjusted		Adjusted for SES Score		Adjusted for Race/Insurance/ Sex/Age		Adjusted for Number of Encounter/ Medication/Obesity/ Atopy	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Overall	3739	0.98	0.94, 1.01	0.98	0.94, 1.02	0.99	0.95, 1.02	0.99	0.96, 1.02
Inpatient	304	1.00	0.94, 1.06	0.98	0.91, 1.05	0.98	0.90, 1.06	0.97	0.89, 1.06
ED	895	0.96	0.90, 1.02	0.97	0.91, 1.03	0.97	0.92, 1.03	0.98	0.93, 1.03
Urgent	935	0.93	0.89, 0.98	0.93	0.89, 0.97	0.94	0.89, 0.98	0.94	0.89, 0.99
Outpatient	1850	0.99	0.96, 1.02	1.00	0.97, 1.03	1.00	0.97, 1.03	0.99	0.96, 1.03

HR: Hazard ratio 95% CI: 95% Confidence interval

ED: Emergency department SES: Socio-economic Status

Table 2b. Association Between Asthma Exacerbations and Distances to 35+ MPH Roadways									
	Number of events	Unadjusted		Adjusted for SES Score		Adjusted for Race/Insurance/ Sex/Age		Adjusted for Number of Encounter/ Medication/Obesity/ Atopy	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Overall	3739	0.98	0.83, 1.15	0.98	0.83, 1.16	1.02	0.86, 1.21	1.00	0.85, 1.18
Inpatient	304	1.25	0.89, 1.75	1.20	0.86, 1.69	1.34	0.96, 1.86	1.10	0.80, 1.52
ED	895	1.00	0.79, 1.27	1.03	0.81, 1.31	1.06	0.83, 1.35	1.07	0.83, 1.38
Urgent	935	0.88	0.70, 1.10	0.87	0.69, 1.09	0.89	0.70, 1.12	0.82	0.65, 1.04
Outpatient	1850	0.99	0.86, 1.14	1.01	0.87, 1.17	1.02	0.88, 1.18	0.99	0.85, 1.15
HR: Hazard ratio 95% CI: 95% Confidence interval ED: Emergency department SES: Socio-economic Status									

Figures

Table 3a. Association Between Asthma Exacerbations and 1-mile Buffer Density Measurement Around 55+ MPH Highways									
	Number of events	Unadjusted		Adjusted for SES Score		Adjusted for Race/Insurance/ Sex/Age		Adjusted for Number of Encounter/ Medication/Obesity/ Atopy	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Overall	1854	0.98	0.93, 1.04	0.98	0.93, 1.02	0.99	0.94, 1.03	0.98	0.94, 1.02
Inpatient	168	1.01	0.92, 1.11	1.04	0.93, 1.17	1.05	0.92, 1.19	1.02	0.92, 1.13
ED	497	0.98	0.93, 1.04	0.96	0.90, 1.02	0.97	0.90, 1.03	0.98	0.92, 1.05
Urgent	497	0.98	0.9, 1.03	0.99	0.94, 1.04	0.99	0.94, 1.05	1.00	0.95, 1.06
Outpatient	824	1.05	0.98, 1.12	1.03	0.98, 1.09	1.03	0.97, 1.08	1.03	0.97, 1.08
HR: Hazard ratio 95% CI: 95% Confidence interval ED: Emergency department SES: Socio-economic Status									

Table 3b. Association Between Asthma Exacerbations and 1-mile Buffer Density Measurement Around 35+ MPH Roadways

	Number of events	Unadjusted		Adjusted for SES Score		Adjusted for Race/Insurance/ Sex/Age		Adjusted for Number of Encounter/ Medication/Obesity/ Atopy	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Overall	1854	1.00	0.98, 1.03	1.00	0.98, 1.03	1.00	0.98, 1.03	1.01	0.98, 1.04
Inpatient	168	1.00	0.95, 1.05	1.00	0.95, 1.05	1.01	0.96, 1.07	1.01	0.95, 1.08
ED	497	1.01	0.98, 1.05	1.01	0.98, 1.05	1.01	0.97, 1.04	1.00	0.97, 1.04
Urgent	497	0.98	0.95, 1.02	0.98	0.95, 1.02	0.98	0.95, 1.02	0.99	0.95, 1.03
Outpatient	824	1.00	0.98, 1.03	1.00	0.97, 1.03	1.00	0.97, 1.03	1.00	0.98, 1.03

HR: Hazard ratio 95% CI: 95% Confidence interval

ED: Emergency department SES: Socio-economic Status

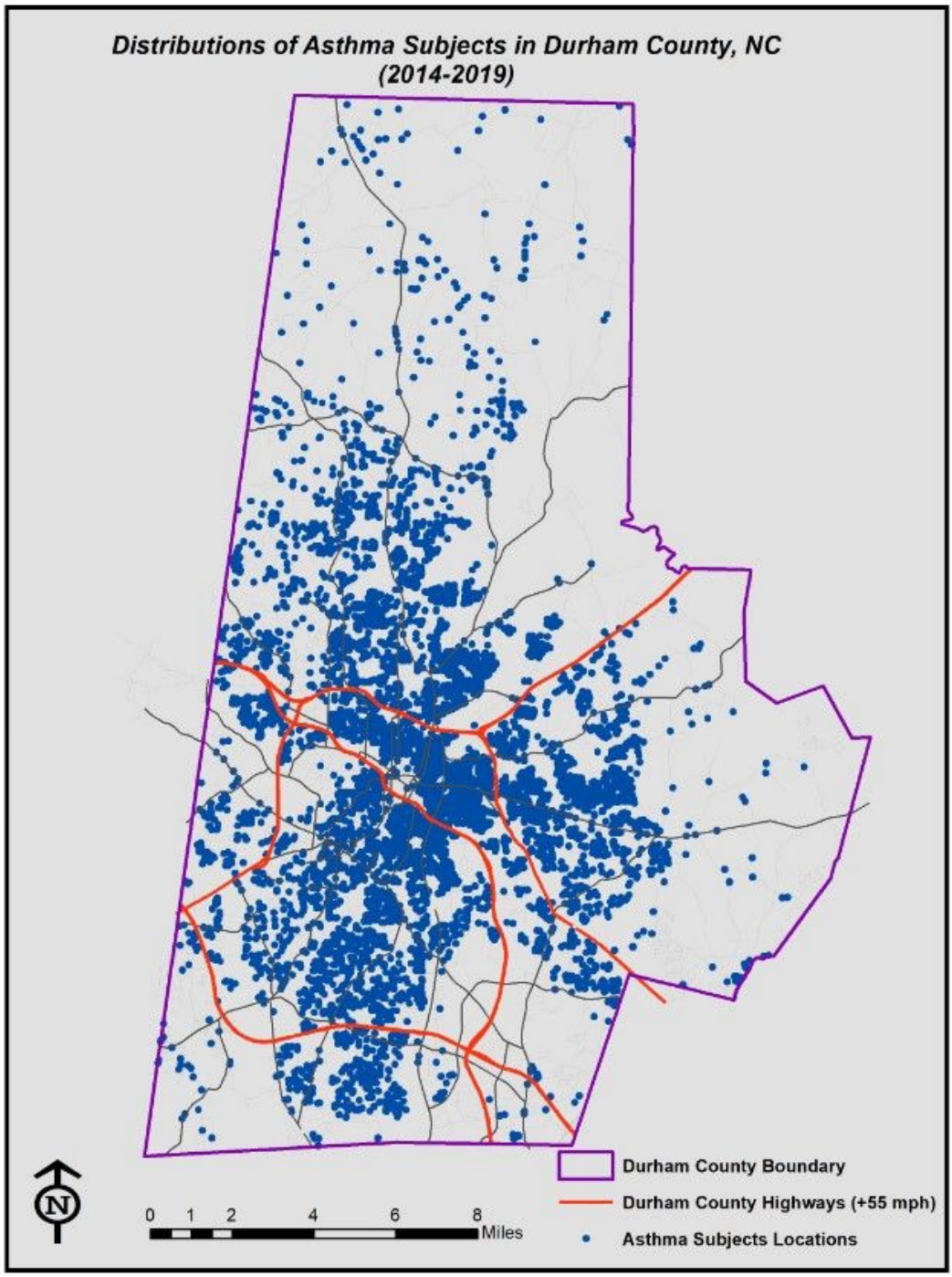

Figure 1

Living location of children in our cohort and proximity to major roadways in Durham County. These blue dots represent the living location of every children with asthma in our cohort, and the red lines are the 55+ MPH highways in Durham. The edge of the county is the rural area.

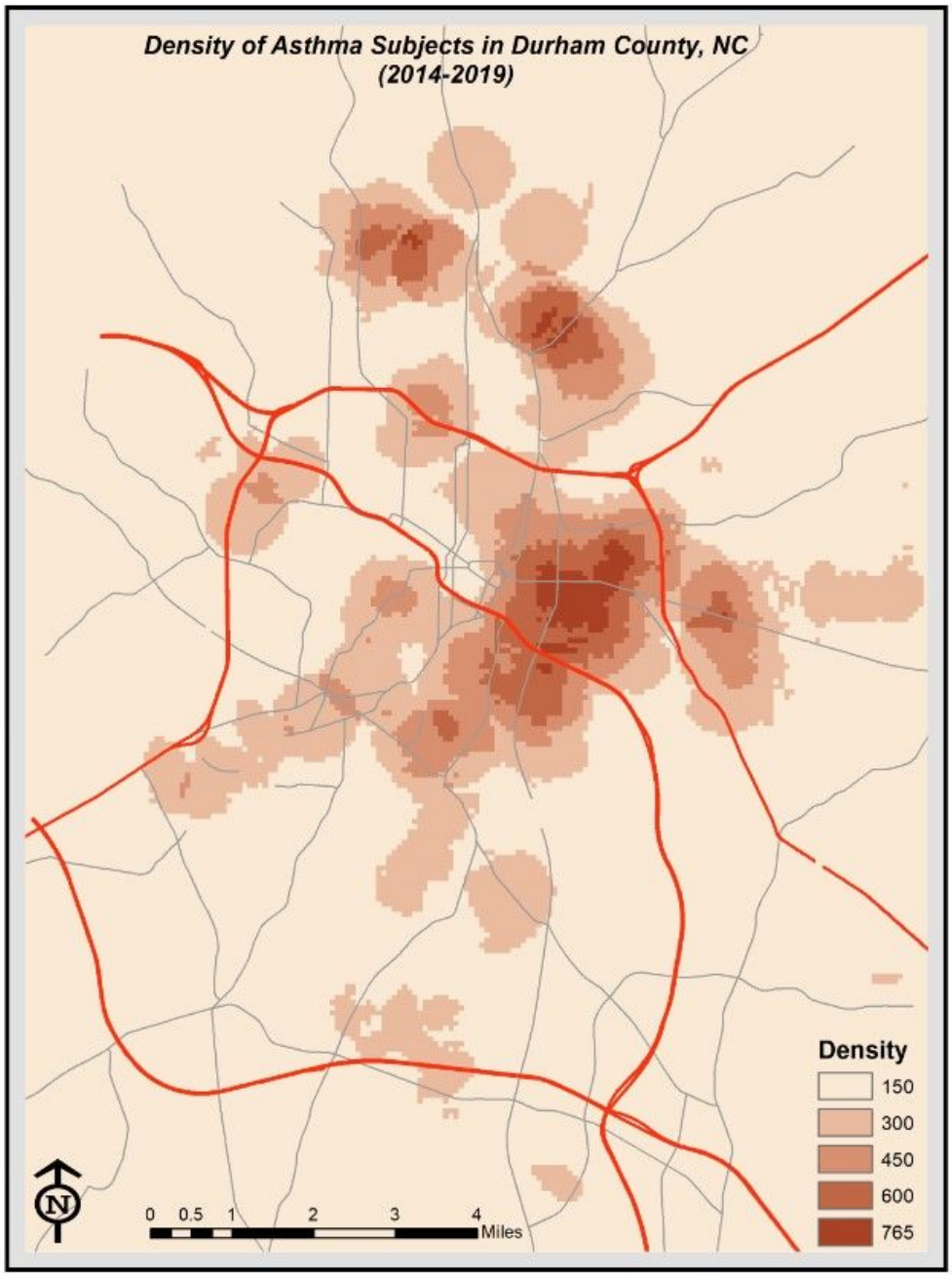

Figure 2

Demonstration of radial density measures of 1.0 mile: we calculated the length of each type of highways within in a 1-mile buffer around each geocoded address location.

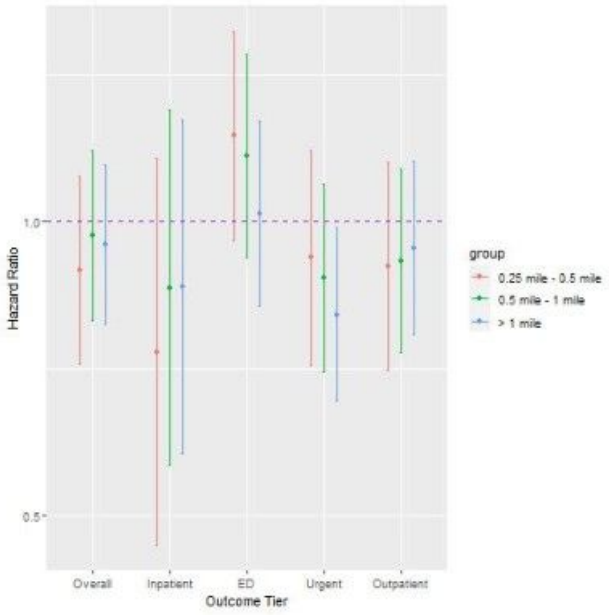

Figure 3

Assessment of non-linear associations between asthma exacerbation and distance to roadways among different distance groupings for different outcome tiers. The reference group here is < 0.25 mile, and there is no evidence showing children living closest to roadways had increased risk of asthma exacerbation

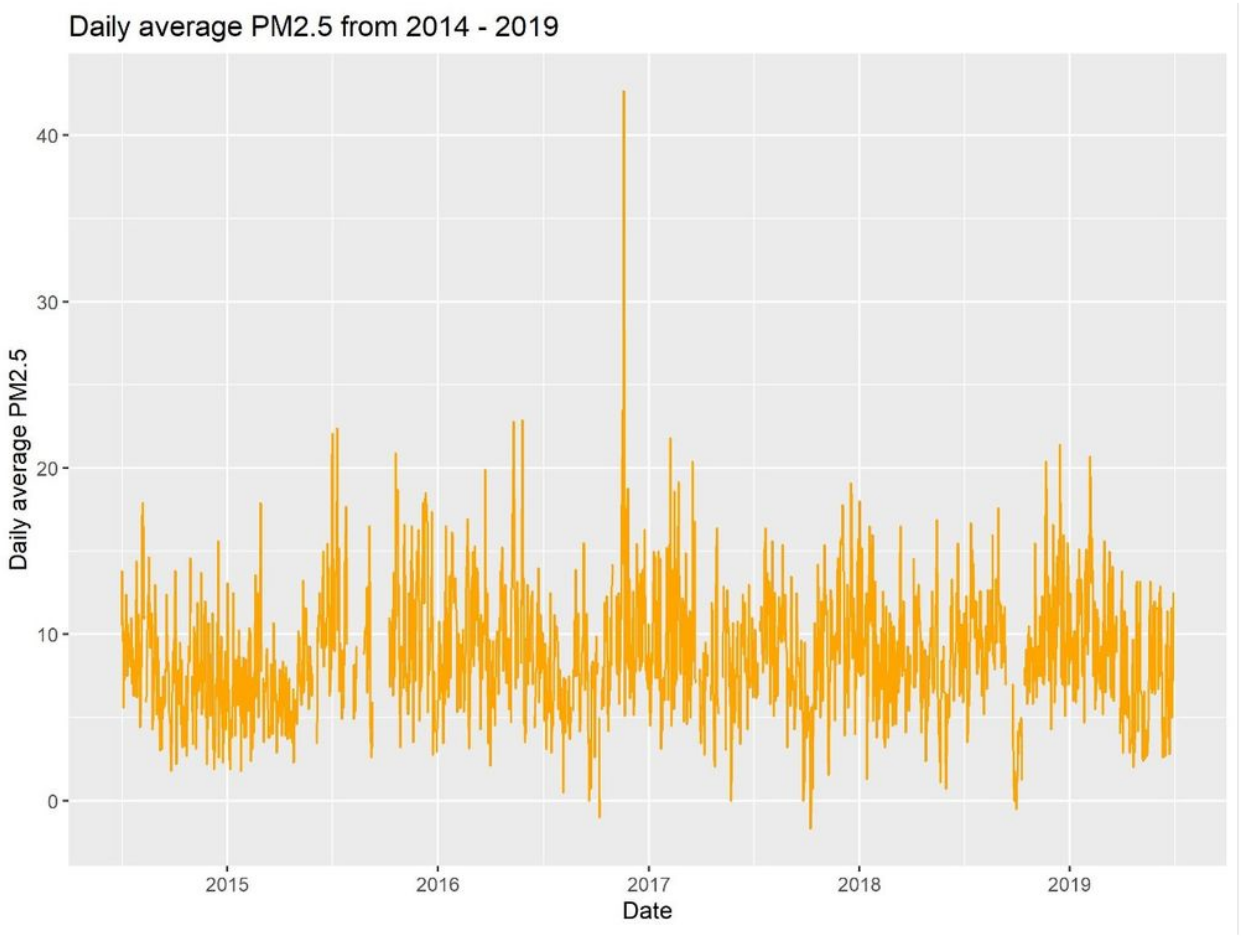

Figure 4

Daily 8-hour maximum PM2.5 levels from 2014 – 2019. The recommended exposure limit for PM2.5 is 35 µg/m3. There was only one period – fall of 2017, corresponding to wild fires in the region – that exceeded this threshold.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementalTables.docx