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The Relationship between Asthma, Race & Fine Particulate Matter in the United States

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☒ By checking this box, I indicate that my mentor has read and reviewed my draft proposal prior to submission

Abstract

Objective: To assess how environment and race may impact childhood asthma prevalence.

Methods: I analyzed data from CDC WONDER (www.wonder.cdc.gov). I performed descriptive statistics on average fine particulate matter for various states, as well as descriptive statistics on childhood asthma prevalence for various states. I determined if there was a correlation between states with higher prevalence of childhood asthma and states with higher levels of fine particulate matter using Pearson correlation. I used ANOVA with post hoc test to determine childhood asthma prevalence based on race/ ethnicity in the various states.

Results: The mean fine particulate matter in the 49 states was 11.653 μg/m³ (standard deviation = 1.559). The state with the lowest level of fine particulate matter was New Mexico with 9.09 μg/m³ and the state with the highest level of fine particulate matter was Indiana with 14.36 μg/m³. The mean asthma prevalence in the 29 states was 8.821% (standard deviation 2.67). The state with the lowest level of asthma prevalence was Minnesota 4.5% and the state with the highest asthma prevalence was Massachusetts with 15.8%. There is no correlation between the 27 states as it relates to asthma prevalence and fine particulate matter level. The correlation strength was 0.027 and the p value = 0.893. Blacks had the highest asthma prevalence compared to White Non Hispanic (NH), Other NH, and Hispanics and there was a statistically significant difference between blacks and the other races as it relates to asthma prevalence (Figure 1).

Key Words: Asthma, childhood asthma, environment, fine particulate matter, race, ethnicity & statistics

Introduction/Literature Review

Asthma is the most common chronic disease amongst children worldwide according to the World Health Organization[1]. Asthma is a chronic disease associated with a constellation of symptoms such as wheezing, shortness of breath, episodes of coughing and chest tightness[2]. It is important to study genetic and environmental factors that can enhance our knowledge on this incurable disease that especially targets the pediatric population.

The pathophysiology of asthma centers around respiratory airway inflammation and hyperresponsiveness due to stimuli such as exposure to environmental toxins, exercise and allergies. There are indoor and outdoor "triggers" that can exacerbate an asthma attack including exposure to certain pollutants. Fine particulate matter (PM) refers to certain inhalable solid particles found in the air like dust, soot and smoke.[3] Fine PM induces free radical chemical reactions that causes inflammation and developmental changes in the airway respiratory tract that can contribute to the risk of asthma and acute asthma exacerbations in children.[4]There is previous research on asthma pathogenesis and how fine particulate matter impacts the respiratory system.[4] This study aims to examine how levels of fine particulate matter might contribute to the prominence of childhood asthma in certain states; such knowledge will help health care professionals understand how to truly treat the root of this disease.

In addition to understanding how environment can contribute to asthma diagnosis, it is important to look at the genetic factors that explain childhood asthma prevalence. As mentioned by a similar study that analyzed the use of indoor environmental control (IEC) practices based on race/ethnicity, it was reported that: in the United States, non-Hispanic black children are more likely to be: diagnosed with asthma, hospitalized for asthma and die from asthma compared to non-Hispanic white children.[5] These statistics explain the need for future studies that help us better

understand how certain social determinants of health like race, ethnicity, socioeconomic status and thereby one's environment and exposures (i.e. to fine particulate matter) factor into their asthma diagnosis and can improve the prevention and management of childhood asthma.

Studies have looked at how environment and exposure to air pollutants can predict health outcomes.[6] The results of one study concluded that children residing near refineries and with increased sulfur dioxide exposure had higher number of visits to the emergency department and hospitals for asthma related emergencies.[7] Fine particulate matter is an air pollutant that has been linked to health outcomes such as cardiovascular mortality.[8] A study performed by Mikati et al. (2018) looked to see if there were any racial/ethnic and/or economic disparities based on exposure to particulate matter emitting facilities after previous research found that non-Hispanic Whites and below-poverty individuals had the most exposure.[6] It was determined that non-White, particularly blacks, and those living in poverty, faced a disproportionate exposure to particulate matter facilities.

My research aims to get to the root of the cause for this increasingly and disproportionally burdensome childhood illness. The local environment where someone lives can help to predict a patient's health and health status. A patient's environment is described by factors such as access to healthy food markets and parks & recreation centers, as well as exposure to particulate matter; for example. Studies around the world have determined that exposure to PM both during gestation and the early postnatal period is associated with childhood asthma development.[4] The association between fine PM and race/ethnicity in the United States have rarely been examined simultaneously. I performed descriptive statistics using the most recent CDC data to determine if there was a correlation between fine particulate matter and asthma prevalence for various states in America and what race/ethnicity had the highest childhood asthma prevalence.

Hypothesis/Specific Aims/Research Questions

The following research questions that I came up with, under the guidance of Dr. Amber Todd, are original:

- RQ1: What is the difference in average daily levels of fine particulate matter between the 50 states?
- RQ2: What is the difference in childhood asthma prevalence between the 50 states?
- RQ3: What is the correlation between childhood asthma prevalence and average daily level of fine particulate matter in the 50 states?
- RQ4: What is the difference in childhood asthma prevalence between different races/ethnicities?

Methods

Context/Protocol

This study was done using publicly available data and therefore IRB approval is not needed. I managed the data and analyzed the data for this project.

The data on fine particulate matter was collected by researchers under the NASA Marshall Space Flight Center / University Space Research Association. The CDC WONDER reports, average daily measures of fine particulate matter in $\mu g/m^3$ from January 1, 2003 – December 31, 2011. There was data for 49 states in America.

Data on childhood asthma prevalence in the year 2017 for 29 states was collected using the Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is a type of random digit

dialed telephone survey administered by the CDC that is used to obtain information on the health and health behaviors of non-institutionalized residents in the US states and territories. Questions on the asthma diagnosis and the child's current asthma status were asked about only one child per household. The age range used were children who were 17 years of age or younger.

Data on childhood asthma prevalence in the various racial groups: Black Non-Hispanic (NH), White NH, Other NH and Hispanic in the year 2017 within the United States was also collected using the Behavioral Risk Factor Surveillance System (BRFSS).

Data Collection

Three sets of publicly available data were obtained from the CDC WONDER (www.wonder.cdc.gov) to answer the four research questions. I used a data table on daily fine particulate matter (PM2.5 $\mu g/m^3$) from the year 2003-2011, which provided data for 49 states. I used a data table on childhood asthma prevalence (percentage) based on weighted number race/ethnicity and state for the year 2017. I used a third data table from CDC WONDER on childhood current asthma prevalence (percentage), for the year 2017, based on weighted number by state, which provided data for 29 states.

Data Analysis

Descriptive statistics were used to determine the state with the highest level of particulate matter and the state with the lowest level of fine particulate matter. Outliers were identified using z-scores. Descriptive statistics were used to determine the state with the highest and lowest level of asthma prevalence. Outliers were identified using z-scores. In order to determine if there was a correlation between the state's childhood asthma prevalence and fine particulate matter a Pearson correlation was performed using data only for the states that had both values represented (asthma prevalence and fine PM). As a result, data from 27 states was used to do the Pearson correlation. To determine if there was a difference in childhood asthma prevalence between different races/ ethnicities an ANOVA with post hoc test was performed.

Results

The mean fine particulate matter in the 49 states was 11.65 $\mu g/m^3$ (SD=1.56). The state with the lowest level of fine particulate matter was New Mexico with 9.09 $\mu g/m^3$ and the state with the highest level of fine particulate matter was Indiana with 14.36 $\mu g/m^3$. The mean asthma prevalence in the 29 states was 8.82% (standard deviation 2.67). The state with the lowest level of asthma prevalence was Minnesota with 4.50% and the state with the highest asthma prevalence was Massachusetts with 15.80%. There is no correlation among the 27 states as it relates to asthma prevalence and fine particulate matter level. Blacks had the highest asthma prevalence compared to White Non Hispanic (NH), Other NH, and Hispanics and there was a statistically significant difference between blacks and the other races as it relates to asthma prevalence (Figure 1). The average estimated prevalence for asthma in the year 2017 ranged from 6.94% for Non-Hispanic whites, followed by Other-Non Hispanic (8.59%), Hispanic (9.06%) and Non-Hispanic blacks (13.14%).

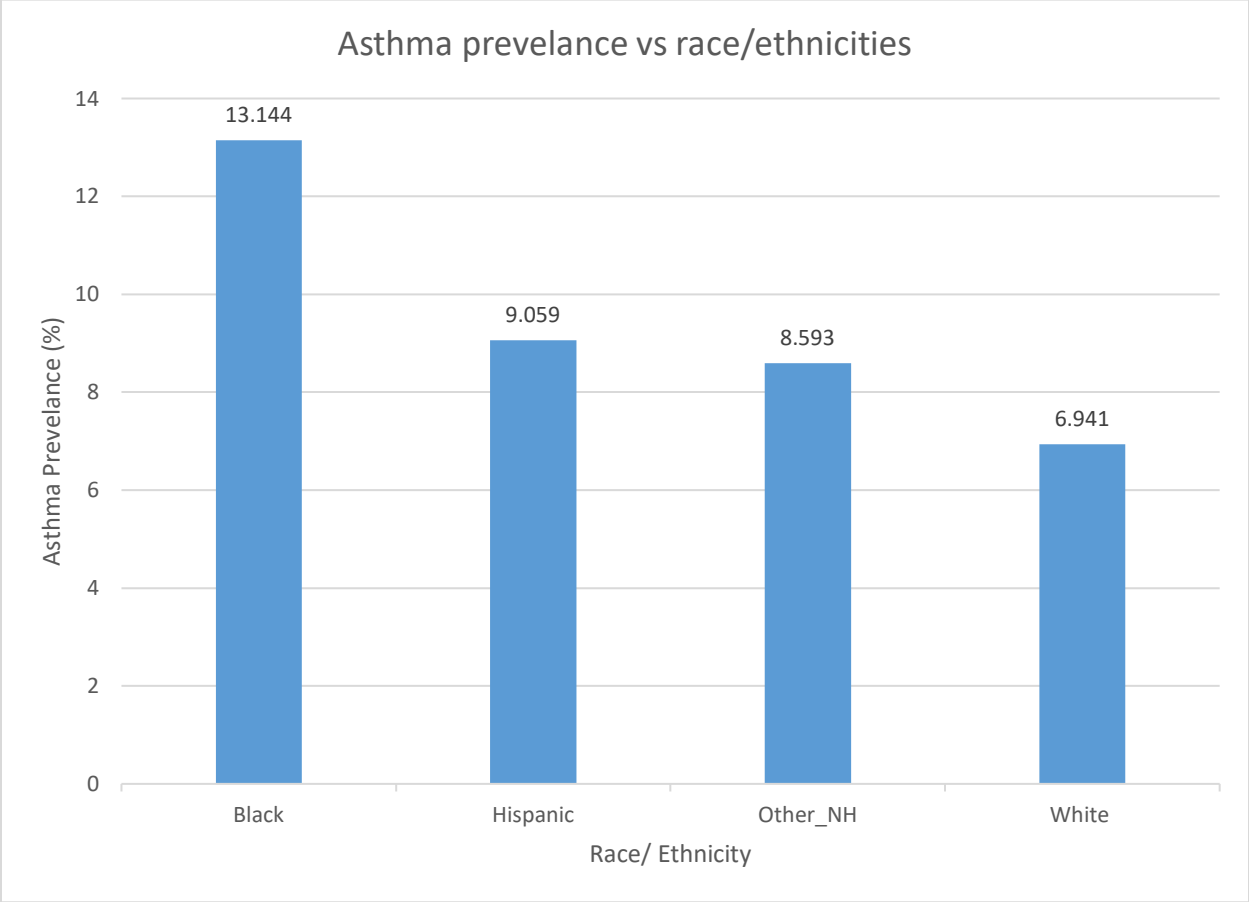

Figure 1: Childhood asthma prevalence in the year 2017 for the Black NH, White NH, Other NH and Hispanics. Sample size was 27 states. Blacks have the highest asthma prevalence compared to the other races.

Discussion

My aim was to determine if there was a correlation between fine particulate matter and asthma prevalence for various states in America and to determine what race/ethnicity had the highest childhood asthma prevalence. I first had to determine which states had the highest fine particulate matter. Data on fine particulate matter from the year 2003-2011 showed that Indiana has the highest level of fine particulate matter with an average fine particulate matter level of

14.36 µg/m³. The other states that had levels equal to or greater than 14.00 µg/m³ were Ohio (14.23 µg/m³), Kentucky (14.10 µg/m³), and Tennessee (14.02 µg/m³). These states all fall within the Ohio Valley (central) region of the United States. The state with the lowest level of fine particulate matter was New Mexico with 9.09 µg/m³. The other states with particulate matter levels less than 10.00 µg/m³ were Wyoming (9.81 µg/m³), Vermont (9.92 µg/m³), Oregon (9.13 µg/m³), New Hampshire (9.97 µg/m³), Maine (9.64 µg/m³), Idaho (9.53 µg/m³). These states do not all fall within one particulate region of America. These findings may suggest two things: certain states may have more mandates and regulations in place that address air pollution, and secondly, that high air pollution alone is not based on geography and/or the natural habitat.

Previous studies have focused on association between life expectancy-based levels of fine particulate matter in the United States.[9,10] Bennett et al. looked at the mean annual population weighted $PM_{2.5}$ concentration for US counties in the year 2015.[10] In this study, it was determined that, in 2015, Apache county, Arizona had the lowest $PM_{2.5}$ concentration with 2.8 µg/m3 and Tulare county, California had the highest level of fine particulate matter with 13.2 µg/m3.[10] This study reported an association between $PM_{2.5}$ concentration above 2.8 µg/m3 and higher cardiorespiratory disease related death rates.[10] Correia et al. also looked at $PM_{2.5}$ based on counties as it relates to life expectancy (2000-2007) and found a decrease of 10 µg/m was associated with a 0.35 years increase in mean life expectancy (SD = 0.16 years, P = 0.033).[9] Both studies did not compare $PM_{2.5}$ levels specifically with asthma prevalence, nor did they analyze their data based on the same span of time as this study. However, Bennet et al.'s research found that there is a connection between higher levels of particulate exposure and adverse respiratory health.

In order to answer my overall research question of whether there is a correlation between asthma prevalence and fine particulate matter in various states, I sought to determine which state

had the highest asthma prevalence. Massachusetts had the highest asthma prevalence with 15.8%. Puerto Rico had the second highest asthma prevalence with 15.5%. The state with the lowest asthma prevalence was Minnesota with 4.5%. The state with the second lowest asthma prevalence was Illinois with 5.7%.

The aim of this study was to see if there is a correlation between state levels of fine particulate matter and asthma prevalence. I performed a Pearson correlation and found there was no correlation between asthma prevalence and fine particulate matter levels in the 27 states. There is vast amounts of research on how fine PM impacts the respiratory system.[4] Jung et al. determined that children with increased exposure to $PM_{2.5}$ during gestational weeks 6 to 22 and 9 to 46 weeks after birth were at increased risk for asthma diagnosis as a child.[4] In this study I observed that that states with higher fine PM were not the states with higher asthma prevalence. To strengthen this study and research on the association between asthma incidence and fine PM exposure it is important to control for age of exposure, gender, socioeconomic status, etc. In addition, future studies may focus on the correlation between fine PM levels and asthma related hospitalizations.

Following my analysis, I researched air pollution in Massachusetts – the state with the highest asthma prevalence. Researchers found that tailpipe emissions from automobiles, trucks and buses is the leading contributor to PM levels in Massachusetts.[11] It was reported that in areas where the $PM_{2.5}$ is lower than the Massachusetts state average there are more white residents compared to the state fraction of white residents.[11] In area of Massachusetts where the $PM_{2,5}$ is higher than the state average, there are less whites compared to the state fraction of white resident.[11] Asian American, African American and Latino Massachusetts residents had the highest exposure to vehicle pollutants compared to white residents.[11] This research aimed to determine asthma prevalence in various states of America based on race/ethnicity. The data analysis showed that

Blacks had the highest asthma prevalence compared to White NH, Other NH, and Hispanics. Oraka et al. used data from the same National Health Interview Survey (NHIS) from the years 2001-2010 and reported asthma prevalence as follows: American Indian/Alaskan Natives (15.1%), Puerto Ricans (14.3%), Non-Hispanic blacks (12.5%), Other Hispanics (7%) and Asians (6.7%).[12] My study did not have as many racial groups represented i.e. Asians or American Indian/Alaskan Natives as in the study by Oraka et al. Also, where I included the racial group, Hispanic, the other study used Puerto Ricans. Lastly, my study was based on data provided by the CDC for the year 2017, which at the time was the most recent publicly available data, whereas Oraka et al. relied on data from 2001-2010. My findings show some consistency with Oraka et al. in that there are differences between prevalence of asthma based on racial/ethnic groups with underrepresented minorities having the highest prevalence.

The main strength of my study is that I used publicly available data from CDC WONDER; therefore, the data is fully transparent and can be replicated by other researchers. In addition, direct estimates on the effect of $PM_{2.5}$ on asthma prevalence in the various states were specifically made rather than comparing it to life expectancy as a whole.

The limitations of the study are that it is an observational study and therefore cannot predict cause and effect. In addition, there are several confounding variables that were not adjusted for when determining if there is a correlation between fine particulate matter and asthma prevalence such as race/ethnicity, healthcare quality, etc. When comparing the asthma prevalence based on race/ethnicity, I only had 4 racial groups represented. However, the CDC WONDER only provided data for these races. The data obtained from the NIHS was based on a survey done by telephone rather than directly by scientists or clinicians which adds room for error. Lastly, the CDC

WONDER did not provide data for all 50 states when doing analysis on asthma prevalence and fine particulate matter.

My study shows that policy related to addressing asthma in various race/ethnic groups is needed as underrepresented minorities had higher childhood asthma prevalence according to the most recent CDC data. In order to provide proper medical care, physicians need to be up to date on their patient's environment. Perhaps, improving one's exposures to toxins/ fine PM and overall air quality can help to lessen asthma exacerbations or prevent asthma diagnosis altogether if avoided in pregnant females and during vulnerable time windows during development. According to the Asthma and Allergy Foundation of America, in the 2007, there were $56 billion dollars in asthma related healthcare costs. If we can understand the risk factors for asthma diagnosis, as well as the asthma attacks that require hospitalization and treatment, then healthcare costs can be reduced for families and less children will be diagnosed with this chronic disease.

Conclusion

In summary, our reports provide evidence that there are differences in childhood asthma prevalence based on race/ethnicity. There was no association between asthma prevalence and $PM_{2.5}$ based on the data provided by the CDC WONDER. Other studies have reported that levels of fine particulate matter exposure can negatively impact one's health. Further research on fine particulate matter by counties rather than by state may show a correlation to asthma prevalence and therefore a need for interventions that improve air quality for certain demographics.

References

1. Asthma. https://www.who.int/news-room/q-a-detail/asthma. Accessed March 21, 2020.

2. Mims JW. Asthma: Definitions and pathophysiology. *Int Forum Allergy Rhinol*. 2015;5:S2-S6. doi:10.1002/alr.21609

3. Particulate Matter (PM) Basics | Particulate Matter (PM) Pollution | US EPA. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics. Accessed March 21, 2020.

4. Jung CR, Chen WT, Tang YH, Hwang BF. Fine particulate matter exposure during pregnancy and infancy and incident asthma. *J Allergy Clin Immunol*. 2019. doi:10.1016/j.jaci.2019.03.024

5. Rozwadowski FM, Chew GL, Zahran HS, Santorelli ML. Assessing indoor environmental control practices by race/ethnicity among children with asthma in 14 US States and Puerto Rico, 2013-2014. *Prev Chronic Dis*. 2019;16(12). doi:10.5888/pcd16.190199

6. Mikati I, Benson AF, Luben TJ, Sacks JD, Richmond-Bryant J. Disparities in distribution of particulate matter emission sources by race and poverty status. *Am J Public Health*. 2018;108(4):480-485. doi:10.2105/AJPH.2017.304297

7. Brender JD, Maantay JA, Chakraborty J. Residential proximity to environmental hazards and adverse health outcomes. *Am J Public Health*. 2011;101(SUPPL. 1):S37. doi:10.2105/AJPH.2011.300183

8. Brook RD, Rajagopalan S, Pope CA, et al. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the american heart

association. *Circulation*. 2010;121(21):2331-2378. doi:10.1161/CIR.0b013e3181dbece1

9. Correia AW, Dockery DW, Wang Y, Ezzati M, Dominici F. The Effect of Air Pollution Control on Life Expectancy in the United States: An Analysis of 545 US counties for the period 2000 to 2007. doi:10.1097/EDE.0b013e3182770237

10. Bennett ID JE, Tamura-Wicks H, Parks ID RM, et al. Particulate matter air pollution and national and county life expectancy loss in the USA: A spatiotemporal analysis. 2019. doi:10.1371/journal.pmed.1002856

11. (No Title). https://www.ucsusa.org/sites/default/files/attach/2019/06/Inequitable-Exposure-to-Vehicle-Pollution-MA.pdf. Accessed April 19, 2020.

12. Oraka E, Iqbal S, Flanders WD, Brinker K, Garbe P. Racial and ethnic disparities in current asthma and emergency department visits: Findings from the national health interview survey, 2001-2010. *J Asthma*. 2013;50(5):488-496. doi:10.3109/02770903.2013.790417