HEALTHY LIVING, CHILDREN'S RESPIRATORY HEALTH, AND TRAFFIC-RELATED AIR POLLUTION IN AN UNDERSERVED COMMUNITY

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16. Abstract
This study characterizes the effects of traffic-related criteria air pollutants (particulate matter $[PM]_{2.5}$, PM_{10}, ozone $[O_3]$, nitrogen dioxide $[NO_2]$) on children with asthma living in near-road communities. We utilized portable air quality monitors to characterize air pollutants in near-road schools and conducted a concurrently panel-based respiratory health outcome study on a cohort of 23 asthmatic children aged between 6 and 12. Linear mixed effect models were used between air pollutant metric and effect estimates per interquartile range, 95 percent confidence intervals, and p-values. Effect modifications by significant factors were assessed for exhaled nitric oxide (eNO), forced vital capacity, and forced expiratory volume in 1-second responses.

The near-road monitors exhibited strong correlations for all pollutants, especially among PM. At a 1-hour time resolution, moderate to high spatial heterogeneity was observed for all measured pollutants. At 24-hour time averages, O_3 and NO_2 were more ubiquitous than PM. Heterogeneity in PM was observed at both time resolutions. Short-term (daily maximum hour, 24-, 48-, 72-, and 96-hour averages) changes in traffic-related criteria pollutants were weakly associated with pulmonary inflammation and lung function in asthmatic children. The only statistically positive association between pollutant concentrations and eNO was observed at one school between eNO and 72-hour O_3, implying that an eNO increase might be more related to gaseous pollutants. Subjects' lung functions decreased with increased 24-hour PM ($PM_{2.5}$ or PM_{10}) concentration. Health insurance and cooking fuel were both significant factors in modifying the PM effect on decreased lung function.

We found that a threshold of pollutant concentration for PM and other gaseous pollutants may exist such that a measurable response in eNO or lung functions can be observed. Furthermore, measurements could be highly obscured by the different chemical constituents of PM and medical control of asthmatic symptoms. Parents of asthmatic children tend to believe that exercise is not good for children with asthma. However, levels and durations of physical activities do not seem to have a direct relationship on airway inflammation or lung function in asthmatic children. In the short term, placement of natural barriers (e.g., shade trees, shrubs) at schools can mitigate the effects of air pollutants. In the long term, policy changes should integrate air monitoring into the consideration of where to locate elementary schools.

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Executive Summary

Numerous epidemiological studies have shown evidence of adverse health effects resulting from acute or chronic exposure to traffic-related air pollution. Studies have also shown that residents of underserved communities are likely to be exposed to excessive levels of air pollution since 68 percent of African Americans live within 30 mi of a coal-fired power plant and 66 percent of Latinos live in areas that do not meet the federal government's air quality standards. In addition, 17 million households in the United States lived within half a block of a four-or-more-lane highway, railroad, or airport in 2011. Associations exist between short-term exposures to traffic-related pollutants and airway inflammation in asthmatic children. At the same time, active living, which includes walking and bicycling, is being promoted to improve public health. However, active living practices aimed at improving health outcomes in underserved populations may, from an emissions exposure perspective, have a detrimental impact on health. The objectives of this project were (a) to understand children's exposure to and respiratory health associated with traffic-related air pollutants and (b) to develop guidelines on healthy living for the underserved roadside school children. Specific goals of the project were as follows:

- Conduct personal and stationary air monitoring for a select community and K–6 children attending near-road schools.
- Develop associations between air pollution, physical activity, and active transportation.
- Develop healthy living guidelines relative to air pollution and physical activity for underserved communities.

This project characterizes the effects of traffic-related criteria air pollutants (particulate matter $[PM]_{2.5}$, PM_{10}, ozone $[O_3]$, nitrogen dioxide $[NO_2]$) on children with asthma living in near-road communities. We utilized portable air quality monitors to characterize air pollutants at two near-road schools and one near-road dwelling. We conducted a concurrently panel-based respiratory health outcome study on a cohort of 23 asthmatic children between ages 6 and 12. Linear mixed effect models were used between air pollutant metric and effect estimates per interquartile range, 95 percent confidence intervals, and p-values. Effect modifications by significant factors were assessed for exhaled nitric oxide [eNO], forced vital capacity, and forced expiratory volume in 1-second responses.

All air monitors recorded similar trends per measured pollutant across all examined sites. The three monitored sites exhibited strong Spearman correlations for all pollutants, especially among particulate pollutants. In general, correlations were lower at one school site, while correlations between sites were moderate (≥0.6) for NO_2. Coefficients of divergence helped assess the spatial variability across the measured sites and a state-operated continuous air monitoring station (CAMS) located a few miles away from the community. For a 1-hour time resolution, moderate to high spatial heterogeneity can be implied for the three measured sites to the CAMS for all measured pollutants. At 24-hour time averages, O_3 and NO_2 between most sites appeared to be homogeneous. However, heterogeneity in particulate matter was observed at both time resolutions. Bliss Elementary showed the highest coefficients of divergence values for particulate matter, thereby implying greater heterogeneity between this site and the rest of El Paso. Investigating the association between children's exposure and traffic and meteorological variables is challenging due to the numerous variables involved. Spearman correlations, coefficient of divergence, and diurnal graphs do not completely elucidate the differences in the pollutant levels between sites.

Short-term (daily maximum hour, 24-, 48-, 72-, and 96-hour averages) changes in traffic-related criteria pollutants were found to be weakly associated with pulmonary inflammation and lung function in asthmatic children. The only statistically positive association between pollutant concentrations and eNO was observed at one school between eNO and 72-hour O_3, thus implying the eNO increase may be more related to gaseous pollutants. Subjects' lung functions were observed to decrease with increased 24-hour PM ($PM_{2.5}$ or PM_{10}) concentration. Health insurance and cooking fuel were both significant factors in modifying the PM effect on the decreased lung

function. It was observed that a threshold of pollutant concentration for PM and other gaseous pollutants may exist such that a measurable response in eNO or lung functions can be observed. Furthermore, the measurements could be highly obscured by the possibly different chemical constituents of PM and medical control of asthmatic symptoms.

Parents of asthmatic children tend to believe that exercise is not good for children with asthma. However, levels and durations of physical activities do not seem to have a direct relationship with airway inflammation or lung function in asthmatic children. In the short term, placement of natural barriers (e.g., shade trees, shrubs, natural vegetation, green roofs) at the school can mitigate the effects of air pollutants. In the long term, policy changes should aim to integrate air monitoring into consideration of where to locate elementary schools.

This study characterizes the effects of traffic-related air pollutants in children with asthma using objective measures of physical activity. Our findings suggest that school-based monitoring of air pollutants is an indicator of the health risk of children's exposures and the impact on their physical activity, although sometimes the associations are obscured by the low levels of pollution and application of medication. Our findings aid in the formulation of healthy living recommendations in this border region.

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Table of Contents

List of Figures ..... **xi**
List of Tables ..... **xii**
Introduction **1**
Background and Significance **2**
Traffic-Related Air Pollution and Children's Health 2
Transportation Emissions and Near-Road Communities 3
Previous Traffic-Related Air Pollution and Children's Respiratory Studies in the Paso del Norte Region 4
Objectives of the Study 5
Methods and Study Design **6**
Site Selection and Characterization 6
Topology and Meteorology 6
Site Selection 7
Instrumentation and Set-Up 8
Environmental Data Collection 8
Health Outcome Monitoring 10
Participant Recruitment 10
Health Outcome Data Collection 10
Statistical Methods and Data Analyses **15**
Determination of Sample Size and Frequency 15
Statistical Methods for Characterization of Outdoor Exposure Concentrations 15
Regulatory Compliance of Health Data 16
Statistical Methods for Epidemiologic Data Analyses 16
Results **18**
Air Pollutant Concentrations at the Two Schools and Residence 18
Summary of Data 18
Pollutant Correlations across the Study Sites 23
Interpollutant Correlations 24
Spatial Variation in Pollutant Concentrations 24
Temporal Variation 27
Study Population Characteristics 29
Health Outcome Characterization 33
Exhaled Nitric Oxide Measurements 33
Assessment of Exhaled Nitric Oxide Measurement Distributions 36
Lung Function Measurements 39
Asthma Control Questionnaire Data 56

Carotenoid Level Measurements....57
Physical Activity Rates....59
Discussion and Conclusions....64
Comparison in Pollutant Concentrations between the Three Sites....64
Associations between Traffic-Related Air Pollutants and Children's Respiratory Health....65
Comparison to Other PdN Studies....68
Associations between Traffic-Related Air Pollutants and Children's Physical Activities....70
Mitigation and Healthy Living Strategies That Can Be Implemented to Existing Infrastructure Such as Schools or Neighborhoods near Highways....71
Conclusions....73
Near-Road Traffic-Related Air Pollution Characterization....73
Health Near-Road Traffic-Related Air Pollution Characterization....73
Implications for Healthy Living....73
Outputs, Outcomes, and Impacts....75
Research Outputs, Outcomes, and Impacts....75
Education and Workforce Development Outputs, Outcomes, and Impacts....77
References.... Error! Bookmark not defined.
List of Abbreviations.... Error! Bookmark not defined.
Appendix A. Instrument Calibration.... Error! Bookmark not defined.
Appendix B. Documents Used in Health Outcome Study.... Error! Bookmark not defined.
Appendix C. Statistical Power for Detection of the Pollutant Effect on a Health Endpoint..... Error! Bookmark not defined.
Appendix D. Statistical Methods and Epidemiologic Analyses.... Error! Bookmark not defined.
Appendix E. Moderate to Vigorous Physical Activity Levels Negatively Correlate with Traffic Related Air Pollutants in Children with Asthma Attending a School near a Freeway.... Error! Bookmark not defined.

List of Figures

Figure 1. Map of sampling sites and wind roses across El Paso using TCEQ CAMS and airport meteorological data. 7
Figure 2. Monitoring station at FB, residential house, and CW. 9
Figure 3. NIOX VERO® Monitor and EasyOne Lung Function Spirometer. 12
Figure 4. Carotenoid levels meter and accelerometer. 13
Figure 5. Polar V800 fitness watch to measure HRV. 13
Figure 6. Time series of 1-hour averages of $PM_{2.5}$ for CW, FB, and RH during the study period. 19
Figure 7. Time series of 1-hour averages of PM_{10} for CW, FB, and RH during the study period. 20
Figure 8. Time series of 1-hour averages of NO_2 for CW, FB, and RH during the study period. 21
Figure 9. Time series of 1-hour averages of O_3 for CW, FB, and RH during the study period. 22
Figure 10. Box plots of 1-hour averages of $PM_{2.5}$, PM_{10}, NO_2, and Ozone for CW, FB, and RH during the study period. 23
Figure 11. Diurnal averages of $PM_{2.5}$ for measured sites and CAMS during the study period. 28
Figure 12. Diurnal averages of PM_{10} for measured sites and CAMS during the study period. 28
Figure 13. Diurnal averages of NO_2 for measured sites and CAMS during the study period. 28
Figure 14. Diurnal averages of O_3 for measured sites and CAMS during the study period. 29
Figure 15. Maximum daily 8-hour O_3 average for CW, FB, and RH during the study period. 29
Figure 16. Prevalence of overweight and obesity at CW. 30
Figure 17. Prevalence of overweight and obesity at FB. 30
Figure 18. Prevalence of overweight and obesity by sex at CW. 31
Figure 19. Prevalence of overweight and obesity by sex at FB. 31
Figure 20. Box plots of eNO measurements by subjects for CW. 35
Figure 21. Box plots of eNO measurements by subjects for FB. 35
Figure 22. Time-series plots of eNO measurements by subjects for CW. 36
Figure 23. Time-series plots of eNO measurements by subjects for FB. 36
Figure 24. Scatterplot of subject-specific eNO Measurements mean and variances at CW. 37
Figure 25. Scatterplot of subject-specific eNO measurements mean and variances at FB. 37
Figure 26. Histogram of overall eNO distribution at CW. 38
Figure 27. Histogram of overall eNO distribution at FB. 38
Figure 28. Box plots of FVC (*l*) by subjects at CW. 40
Figure 29. Time-series plots of FVC (*l*) by subjects at CW. 40
Figure 30. Box plots of FVC (*l*) by subjects at FB. 41
Figure 31. Time-series plots of FVC (*l*) by subjects at FB. 42
Figure 32. Scatterplot of subject-specific FVC mean and variance at CW. 42
Figure 33. Histogram of overall FVC (*l*) at CW. 43
Figure 34. Scatterplot of subject-specific FVC mean and variance at FB. 43
Figure 35. Histogram of overall FVC (*l*) at FB. 44
Figure 36. Box plots of FVC (% predicted) by subjects at CW. 45
Figure 37. Time-series plots of FVC (%) by subjects at CW. 45
Figure 38. Box plots of FVC (% predicted) by subjects at FB. 46
Figure 39. Time-series plots of FVC (% Predicted) by subjects at FB. 47
Figure 40. Box plots of FEV1 by subjects at CW. 48
Figure 41. Time-series plots of FEV1 by subjects at CW. 49
Figure 42. Box plots of FEV1 by subjects at FB. 50
Figure 43. Time-series plots of FEV1 by subjects at FB. 50
Figure 44. Scatterplot of subject-specific FEV1 mean and variance at CW. 51
Figure 45. Histogram of overall FEV1 at CW. 51
Figure 46. Scatterplot of subject-specific FEV1 mean and variance at FB. 52
Figure 47. Histogram of overall FEV1 at FB. 52
Figure 48. Box plots of FEV1 (% predicted) by subjects at CW. 53
Figure 49. Time-series plots of FEV1 (% predicted) by subjects at CW. 54

Figure 50. Box plots of FEV1 (% predicted) by subjects at FB. 55
Figure 51. Time-series plots of FEV1 (% predicted) at FB. 55
Figure 52. Mean ACQ scores for the students at CW. 57
Figure 53. Mean ACQ scores for the students at FB. 57
Figure 54. Veggie Meter scores for the study participants at CW. 58
Figure 55. Veggie Meter scores for the study participants at FB. 59
Figure 56. Overall and school-specific associations between eNO and $PM_{2.5}$, PM_{10}, NO_2, O_3 metrics. 66
Figure 57. Overall and school-specific associations between FVC and $PM_{2.5}$, PM_{10}, NO_2, O_3 metrics. 66
Figure 58. Overall and school-specific associations between FEV1 and $PM_{2.5}$, PM_{10}, NO_2, O_3 metrics. 67
Figure 59. Locations of schools participating in two previous PdN transportation air quality studies. 69
Figure 60. Comparison of eNO observations and PM concentrations. 69

List of Tables

Table 1. Statistics of Time-Series Data for 1-Hour Pollutant Concentrations across Monitoring Sites 23
Table 2. Intrasite and Interpollutant Spearman Correlation Coefficients 25
Table 3. Location of TCEQ CAMSs in El Paso 26
Table 4. Coefficient of Divergence Values Based on Hourly Concentrations 26
Table 5. Coefficient of Divergence Values Based on 24-Hour Average Concentrations 27
Table 6. Summary of Children's BMI at CW 31
Table 7. Summary of Children's BMI at FB 32
Table 8. Subject-Wise Characteristics of the Cohort at the Two Schools 32
Table 9. Study Population Characteristics for Asthma, Hay Fever, Eczema, and Allergy Phenotypes by School 33
Table 10. Study Subjects' Asthma Medication Intake by School 33
Table 11. Summary Statistics by Subject for eNO Measurements at CW 34
Table 12. Summary Statistics by Subject for eNO Measurements at FB 34
Table 13. Summary Statistics by Subject for FVC (*l*) at CW 39
Table 14. Basic Statistics FVC (*l*) at FB 41
Table 15. Summary Statistics by Subject for FVC (% Predicted) at CW 44
Table 16. Summary Statistics by Subject for FVC (% Predicted) at FB 46
Table 17. Summary Statistics by Subjects for FEV1 at CW 48
Table 18. Summary Statistics by Subject for FEV1 (*l*) at FB 49
Table 19. Summary Statistics by Subject for FEV1 (% Predicted) at CW 53
Table 20. Summary Statistics by Subject for FEV1 (%Predicted) at FB 54
Table 21. Basic Statistics of the ACQ Score for the Study Subjects at CW 56
Table 22. Basic Statistics of The ACQ Score for the Study Subjects at FB 56
Table 23. Carotenoid Level Measurements (Veggie Meter Scores) for the Study Participants 58
Table 24. Percentage of Physical Activity Rate for Students at CW 60
Table 25. Summary Statistics of Subject-Specific Factors and Physical Activity Rates per Factor Level 61
Table 26. Overall Associations between Moderate to Vigorous (MVPA) and Sedentary Physical Activity and Pollutant Metrics 63
Table 27. Air Quality Comparison with On-Site Studies 64
Table 28. Descriptive Statistics for eNO, FEV1, and FVC Measurements 65
Table 29. Summary of Effect Modifiers for Various Exposure-Effect Metrics 67
Table 30. Summary of Air Pollutant Concentrations Measured at Six Schools 70

Introduction

According to a recent national household survey (American Housing Survey [AHS], 2013), 16.9 million households in the United States lived within half a block of a four-or-more-lane highway, railroad, or airport in 2011, which implies that approximately 43.5 million people were exposed to high-level traffic emissions in 2011. Residents of underserved communities (in particular, low-income minority communities) are more likely to be exposed to excessive levels of air pollution. The U.S. demographics have shown that 68 percent of African Americans live within 30 mi of a coal-fired power plant, and 66 percent of Latinos live in areas that do not meet the federal government's air quality standards. Sensitive population subgroups, such as pregnant women, children with asthma or other respiratory symptoms, and the elderly, are most vulnerable to the ubiquitous pollution in their communities. Emerging evidence also suggests that living in close proximity to traffic is particularly harmful to children. Schoolchildren living 30–300 m from a major roadway had increased arterial stiffness (Iannuzi et al., 2010), increased carotid intima-media thickness (Armijos et al., 2015), decreased academic performance (Gilliland et al., 2001), increased absenteeism (Chen et al., 2000), and increased clinical asthma symptoms (Wendt el al., 2014). Elementary school children spend approximately 6–8 hours per day in various school microenvironments (classrooms and playgrounds) and almost the rest of the day in their local community, while elderly people are, either voluntarily or involuntarily, likely to spend 90 percent of their time in the community.

Numerous epidemiological studies have shown evidence of adverse health effects resulting from acute or chronic exposure to traffic-related air pollution (TRAP). At the same time, active living, which includes walking and bicycling, is being promoted to improve public health. Studies have also shown that residents of underserved communities are likely to be exposed to excessive levels of air pollution. Thus, active living practices aimed at improving health outcomes in underserved populations may, from an emissions exposure perspective, have a detrimental impact on health. Maintaining an active healthy lifestyle is key to an individual's health and productivity. An active healthy lifestyle consists of two major elements: routine exercise and healthy diet. During exercise, a person will be exposed to air pollution regardless of whether the exercise takes place indoors or outdoors. Recent studies (Peter et al., 2015; Hosseinpanah et al., 2010; Romieu et al., 2008) have also shown that exposure to air pollution could result in vitamin D deficiency in women and that some nutrients, such as B vitamins, vitamin C, vitamin E, vitamin D and omega-3 PUFA, have protective effects against the damage induced by airborne particulate matter (PM). An active lifestyle with reduced exposure to air pollutants and a healthy diet with adequate intake of essential micronutrients may be critical to prevent the development of chronic diseases in children and the elderly caused by air pollution. It is especially important to protect the sensitive populations living in an underserved community, who may be unaware of the adverse health effects related to traffic emissions, by understanding their exposure to traffic pollutants and by developing interventions and policies for a healthier living lifestyle.

This project quantifies air pollution exposures for vulnerable populations of underserved communities near busy roadways and develops general guidance on healthy living for these roadside communities that are subjected to severe air pollution.

Background and Significance

Traffic-Related Air Pollution and Children's Health

Urban air pollution is a major health concern. As per World Health Organization (WHO) estimates, approximately 4.2 million deaths worldwide are attributed to air pollution. Ninety-one percent of people in the world today live in areas where the levels of air pollution exceed WHO pollutant guidelines (WHO, 2018). Seventeen percent of deaths from acute lower respiratory infection and 43 percent of all deaths and disease from chronic obstructive pulmonary disease (COPD) can be attributed to ambient air pollution (WHO, 2016). Air quality in developed countries has improved in the last few decades due to stricter air pollution guidelines, improvement in fuel efficiency, cleaner car technology, and greening of the urban landscape. Nevertheless, a plethora of studies have documented that acute exposure to air pollutants can result in the exacerbation of various health conditions, such as wheezing, coughing, reduced lung function, tightness of chest, and onset of asthma attacks, especially in sensitive populations such as young children, pregnant women, and the elderly. The United Nations and its sister agencies have recognized air pollution as a grave risk and established the 2030 Agenda for Sustainable Development, which are a set of 17 goals formulated to achieve sustainable development by the year 2030.

Of the various sources of air pollution, TRAP is considered to have substantial impacts on ambient and indoor exposures in urban areas (Janssen et al., 2001; Spira-Cohen et al., 2011). A cross-sectional study conducted in Barcelona, Spain, investigated the impact of TRAP and noise on associated behavioral problems (Forns et al., 2016) and reported that increases in both indoor and outdoor elemental carbon (EC), black carbon (BC), and nitrogen dioxide [NO_2] were positively associated with children's frequent behavioral problems.

Lovinsky-Desir et al. (2016) conducted a cross-sectional study involving 163 African American and Dominican children in New York City and discovered that high BC levels offset the health benefits (improved cardiopulmonary health) accrued by physical activity, although active children exposed to 25 percent higher personal BC concentrations showed better respiratory health by exhibiting 20 percent lower exhaled nitric oxide (eNO) than nonactive children. Using telomere length (TL) as a biomarker of air pollution health effects, different studies have documented that high-traffic air pollution exposures result in the shortening of telomeres (Hou et al., 2012; Hoxha et al., 2009). Telomere is a specific DNA-protein structure found at both ends of each chromosome that shortens as age increases, and progressive shortening of telomeres leads to senescence, apoptosis, or oncogenic transformation of somatic cells, which affects the health and lifespan of an individual (Shammas, 2011). Exposure to polycyclic aromatic hydrocarbons, in particular, was found to be associated with shortening TL in 14 children, and asthmatic subjects had a shorter mean TL than non-asthmatics (Lee et al., 2017).

Expiratory function measured by spirometry has been used as a marker for children's respiratory health. The Child Heart and Health Study in England explored associations between primary traffic air pollutants (NO_2, nitric oxide [NO], nitrous oxides [NO_x], $PM_{2.5}$) and lung function in 4,884 children (Barone-Adesi et al., 2015). The study showed a nonsignificant inverse association between all pollutants (except O_3) and both forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC). A chemical-specific $PM_{2.5}$ exposure study conducted in five European-birth cohorts showed reduced lung functions in children 6–8 years of age are associated with PM mass and element concentrations (Eeftens et al., 2014). The study involved children from Sweden, Germany, the United Kingdom, and The Netherlands. Mean annual residential exposures of Cu, Fe, K, Ni, S, Si, Va, Zn, $PM_{2.5}$, and PM_{10} mass were computed using land regression models. The researchers observed reductions in FEV1, FVC, and peak expiratory flow (PEF) in children exposed to Ni and S. The independent effect of these elements on reduced lung function was not nullified after adjusting for PM mass. In addition, increased PM_{10} mass was consistently associated with reduced lung function. Gehring et al. (2013) documented the association between residential air pollution exposure and reduced lung function. Their study was part of the European Study of Cohorts for Air Pollution Effects (ESCAPE). Estimated levels of NO_x and $PM_{2.5}$ were associated with a small decrement in lung

function. For a 5 μg/m^3 increase in $PM_{2.5}$, FEV1 was reduced by 1.77 percent (95 percent confidence interval [CI]: −3.34, −0.18 percent). The FEV1 decreased by 0.86 percent for a 20 μg/m3 increase in NO_x.

In a clinical trial involving 1,003 asthmatic children, lung function measurements were examined against ozone, carbon monoxide (CO), NO_2, and sulfur dioxide levels (Ierodiakonou et al., 2016). A negative association was observed with 24-hour and 1-week average CO levels, and the post-bronchodilator percentage predicted FEV1 and FVC. A negative and statistically significant association was also observed between four-month averaged CO, O_3 levels, and FEV1/FVC. In addition, the reduced post-bronchodilator FEV1 and FVC percentage predicted was observed, with an increase in the four-month average NO_2 levels. Given the fact that levels for air traffic pollutants such as $PM_{2.5}$, NO_2, BC, and ultrafine particles (UFPs) decrease exponentially based on the distance from interstate roadways, it is prudent that school playgrounds are situated away from these major sources of air pollution. This action will reduce the exposure burden of these children while engaged in their daily physical activity. Physical activity at schools may also increase the respiratory breathing rates and tidal volumes and subsequent high inhalation doses of air pollution in children (McConnell et al., 2010; Oravisjarvi et al., 2011).

Transportation Emissions and Near-Road Communities

Air pollution is a complex issue that affects every living being. New data from the WHO show that 9 out of 10 people breathe air containing high levels of pollutants. It is estimated that around 7 million people die every year from exposure to $PM_{2.5}$ in polluted air that penetrates deep into the lungs and cardiovascular system, causing diseases that include stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases, and respiratory infections like pneumonia (Prüss-Ustün et al., 2016). In the United States, approximately 20 percent of mortality may be attributed to air pollution exposure (Lee et al., 2017; Jerrett, 2015). Air pollution deaths cost global economies U.S. $225 billion in lost labor income in 2013 (World Bank Group, 2016). It costs the global economy more than $5 trillion annually in welfare costs, with the most devastating damage occurring in the developing world.

Air pollution is not only a public health concern but also a social and economic inequality issue. Globally, more than 90 percent of air pollution-related deaths occur in low- and middle-income countries, mainly in Asia and Africa. In developed countries, people living in underserved, low-income neighborhoods are likely to be exposed to more severe air pollution. Further, residents of underserved communities (in particular, low-income minority communities) are more likely to be exposed to excessive levels of air pollution. The U.S. demographics have shown that 68 percent of African Americans live within 30 mi of a coal-fired power plant, and 66 percent of Latinos live in areas that do not meet the federal government's air quality standards. Highly polluting industries are likely to locate their facilities in less affluent and less regulated areas. Individuals with higher education and income are likely to be more aware or better informed of the causes and impacts of air pollution and to have the financial means to move away from poor air quality areas than people who do not. As we all know, public policy is heavily influenced by interested parties, and industries are said to be willing to invest more funds to support less restrictive environmental regulations than to invest in pollution control equipment. All these factors result in *pollution inequality*, as was concluded in a recently published study that revealed that non-Hispanic Whites experience a pollution advantage over Blacks and Hispanics (Tessum et al., 2019). On average, non-Hispanic Whites experience ∼17 percent less $PM_{2.5}$ exposure than Blacks and Hispanics. This disparity reflects a *pollution burden* of 56 percent and 63 percent excess exposure by Blacks and Hispanics, respectively, relative to the exposure caused by their consumption (or economic affluence).

Among the many sources of pollution, pollution caused by transportation-related activities is of particular importance to near-road communities because of their close proximity to the sources and toxicity of the pollutants. Traffic emissions have a substantial impact on indoor and outdoor exposures and on personal exposures that result in substantial detrimental health effects (Janssen et al., 2001; Spira-Cohen et al., 2011). A 2011 national household survey (AHS, 2015) showed that 16.88 million households in the United States lived

within half a block of a four-or-more-lane highway, railroad, or airport. Thus, based on an average people per household of 2.58 for that year, approximately 43.5 million people were exposed to traffic-related emissions in 2011. The numbers are consistent with a widely quoted statistic of 22 million total housing units and 45 million people living near traffic facilities (U.S. Environmental Protection Agency [EPA], 2010; Weinstock et al., 2013). Emerging evidence suggests that living in close proximity to traffic is particularly harmful to children. Between 2005 and 2006, it was estimated that approximately 3.2 million students attended schools located within 100 m of a major roadway, and an additional 3.2 million students attended schools located 100–250 m from major roadways (Kingsley et al., 2014). Schoolchildren living 30 to 300 m from a major roadway had increased arterial stiffness (Iannuzi et al., 2010), increased carotid intima-media thickness (Armijos et al., 2015), decreased academic performance (Gilliland et al., 2001), increased absenteeism (Chen et al., 2000), and increased clinical asthma symptoms (Wendt et al., 2014). A multitude of cross-sectional studies have also been conducted to study the effect of traffic-related air pollutants on the respiratory health, behavioral problems, and physical activities of children living near busy highways. It is well documented in the literature that TRAP has a very adverse effect on children's respiratory health (Barone-Adesi et al., 2015; Gehring et al., 2013; Ierodiakonou et al., 2016), behavioral problems (Forns et al., 2016), and physical activity (Lovinsky-Desir et al., 2016).

Previous Traffic-Related Air Pollution and Children's Respiratory Studies in the Paso del Norte Region

Exhaled NO and lung functions have been used as markers of the relationships between respiratory health effects and environmental exposures. Three pilot studies focusing on children's respiratory health and exposures to TRAP have been conducted in the Paso del Norte (PdN) region, a binational air quality basin encompassing the sister cities of El Paso, Texas, of the United States and Ciudad Juarez, Chihuahua, of Mexico. In 2001, a longitudinal traffic air pollution and children's respiratory health study was performed (Romieu et al., 2008; Holguin et al., 2007) in Ciudad Juarez at 33 elementary schools. Air quality data of $PM_{2.5}$, EC, and NO_2 were measured at participating schools, and children's eNO and lung capacity data were collected from 200 children, aged 6 to 12 years, in the study. They reported that in children with asthma, an interquartile increase in road density within the 50-, 100-, and 200-m home buffer areas was associated with increased eNO and reduced FEV1. Exposure to NO_2 at schools was marginally associated with reduced FEV1. In addition, the study did not observe significant associations with $PM_{2.5}$ or elemental carbon on eNO, nor significant reductions in lung volumes or changes in eNO among healthy children. In 2008, Sarnat et al. (2012) recruited 58 asthmatic children from two schools in Ciudad Juarez and two schools in El Paso. Data on eNO, respiratory symptom surveys, and TRAPs (in terms of 48-hour integrated $PM_{2.5}$, PM_{10}, and BC and 96-hour integrated NO_2 air samples) were collected at each school for 16 weeks. They reported small but consistent associations between eNO and numerous pollutant metrics, with estimated increases in eNO ranging from 1 to 3 percent per interquartile range (IQR) increase in pollutant concentrations. Traffic-related and non–traffic-related particles were typically more robust predictors of eNO than was NO_2, for which associations were highly sensitive to model specification. Associations differed significantly across the four school-based cohorts, consistent with heterogeneity in pollutant concentrations and cohort characteristics. Models examining respiratory symptoms were consistent with the null. They successfully showed the adverse effects of air pollution on the subclinical respiratory health of asthmatic children and suggested the use of air pollution monitors close to schools to track exposure and potential health risk in this population. Li et al. (2011) further tested the hypothesis that TRAP concentrations at schools could be used, directly or indirectly, as environmental health indicator(s) of children's respiratory health in El Paso. They observed (a) significant associations between weekly averages of several traffic-related air pollutant concentrations and both airway inflammation and lung function in asthmatic children (Greenwald et al., 2013); and (b) nonstatistically significant positive associations with Asthma Control Questionnaire (ACQ) scores (Zora et al., 2013). Furthermore, the strongest observed effects were with traffic-related volatile organic compounds (VOCs), including benzene, toluene, ethylbenzene, and xylene compounds, and to a lesser extent, particulate BC. Together, these findings provide additional indication of the acute impact of air

pollution, especially traffic-related pollution, on both airway inflammation and lung function of asthmatic children in the PdN region.

Objectives of the Study

The objectives of this project were (a) to quantify air pollution exposures for active and passive residents of underserved communities near busy roadways, and (b) to develop guidelines on healthy living for the underserved roadside communities that are subjected to severe air pollution. Specifically, we set the following goals:

- **Goal 1**: Conduct personal and stationary air monitoring for a selected community and K–6 children attending near-road schools.
- **Goal 2**: Develop associations between air pollution and physical activity, active transportation, and air pollution.
- **Goal 3**: Develop healthy living guidelines relative to air pollution and physical activity for underserved communities.

Methods and Study Design

This study collected ambient air quality data of $PM_{2.5}$, PM_{10}, NO_2, and O_3 and conducted activity surveys and respiratory health measurements on a cohort of young asthmatic children at two elementary schools. An additional air monitoring site was installed at a residential location in close proximity to one of the schools for upwind-downwind air monitoring. Air monitoring work was completed according to the U.S. EPA quality assurance/quality control (QA/QC) standards and practices. Concurrent air pollution monitoring and health outcome assessments were conducted for 9 weeks on a cohort of 23 asthmatic school children (ages 6 to 12). The examined environmental health indicators were subsequently used to predict children's respiratory health, with the goal of assessing which indicators are sensitive to changes in children's health.

Site Selection and Characterization

Air monitoring was conducted in El Paso, Texas, between October 10 and December 20, 2017, to measure the levels of ambient $PM_{2.5}$, PM_{10}, NO_2, and O_3 pollution. Three air monitoring stations in El Paso were installed at two schools and a near-road residential home next to US-54. Continuous samples were recorded at 5-minute intervals for all pollutants. By using the nearest Texas Commission on Environmental Quality (TCEQ) continuous air monitoring station (CAMSs), meteorological and pollutant data were extracted for comparison. Spatial variations were examined, and diurnal patterns were constructed for the measured sites and available CAMSs. Figure 1 shows the location of the two schools and the residential community sampled in this study, along with the regional TCEQ-operated CAMSs.

Topology and Meteorology

The city of El Paso is located at the westernmost edge of Texas, adjoining the state of New Mexico and the Mexican state of Chihuahua. The Mexican city of Ciudad Juarez is contiguous to El Paso, separated by the Rio Grande River, which serves as the international boundary. El Paso is approximately 3,800 ft above sea level and is currently the sixth largest city in Texas and the 22nd largest city in the United States. El Paso is a geographically isolated metropolitan area, more than 550 km (342 mi) east of the nearest large metropolitan city of Phoenix, Arizona. In general, El Paso is a flat desert area with a large range of mountains known as the Franklin Mountains, which rise to over 3,280 ft (1,000 m) above the surrounding area and are a north-south oriented mountain chain that is approximately 23.1 km (14.4 mi) long and 5.0 km (3.1 mi) wide (Harbour, 1972). The Franklins create a divide between the western one-third of El Paso and the central and eastern two-thirds of the city.

El Paso generally has an arid, warm climate with very hot summers and mild winters. Nicknamed Sun City, El Paso receives an average of 7.9 hours of sunshine in December and 12.8 hours of sunshine during June, with 85.8 percent of possible sunshine per annum. Rainfall averages 9.35 in. per year, most of which predominately occurs from July through September. The record high temperature for El Paso is 114 °F (46 °C) and the record low is -8 °F (−22 °C). Temperatures range from an average high of 57.2 °F (14.0 °C) and an average low of 32.9 °F (0.5 °C) in January to an average high of 95.3 °F (35.2 °C) in June and an average low of 72.0 °F (22.2 °C) in July.

Meteorological data were downloaded from TCEQ's CAMSs located nearest to the study school sites. Wind roses, which graphically depict the frequency of wind speeds and direction for a given area, during the study period were created from data retrieved from TCEQ. Wind roses for the various CAMS for the study period are also shown in Figure 1.

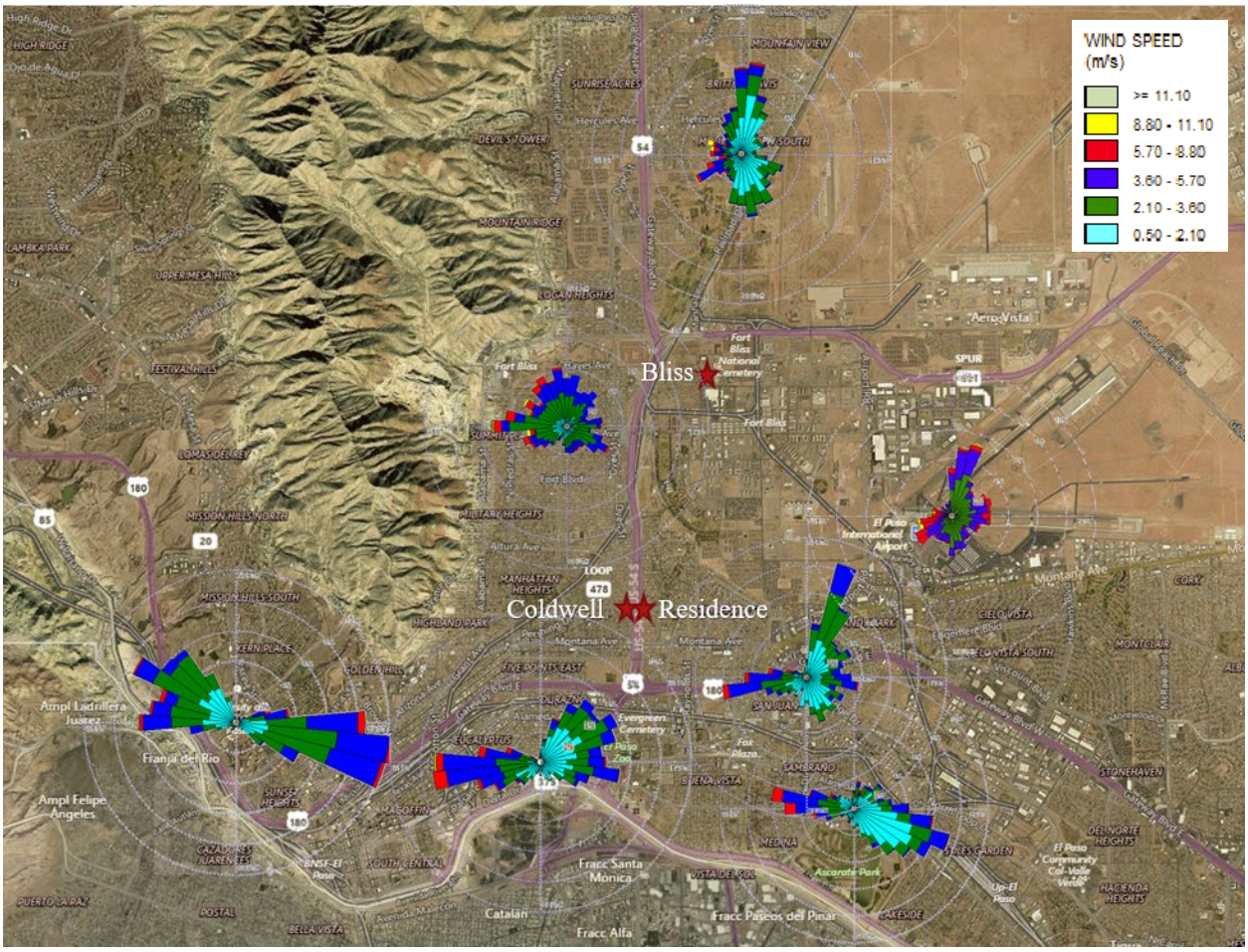


Figure 1. Map of sampling sites and wind roses across El Paso using TCEQ CAMS and airport meteorological data.

Site Selection

Criteria for school selection depended on annual average daily traffic (AADT), the proximity to the highway, the direction of the prevailing winds, and the number of asthmatic students at the schools. Two schools from the El Paso Independent School District that met the required criteria were identified. The proximity to US-54 made Fort Bliss and Coldwell Elementary prime choices for conducting the study. US-54 traffic counts are estimated at approximately 107,237 AADT, with easterly winds characterizing this region. School principals were first contacted, and necessary protocols were submitted to start the study. Figure 1 depicts the sampling sites and wind roses in the surrounding areas during the study period. Wind roses were plotted using software from Lakes Environmental Inc. A wind rose is a graphical representation of the joint frequency distribution of wind speed and wind direction at a location. Wind speed and direction were obtained from the nearest TCEQ CAMSs and El Paso Airport for the duration of the study period. Winds during the study period differ significantly by site due to the Franklin Mountains.

The first station was installed at Coldwell Elementary School (CW), located 190 ft west of US-54. This school had approximately 526 students enrolled. This site was located in a residential area, with the school wall on the west and predominantly paved roads in the immediate surroundings. The second station was installed at Fort Bliss Elementary School (FB), located inside of Fort Bliss, 460 ft east of US-54. Fort Bliss is the second largest United States Army post that houses military personnel and their families. Fort Bliss Elementary had approximately 655 students enrolled. The site was characterized as a large open space next to unpaved grounds, with the nearby railway located parallel to US-54. A third site, a residential house, was selected opposite of US-54 from CW. This

site, located 275 ft west of US-54, mirrored the CW site, with the house wall on the east and predominantly paved roads in the immediate surroundings. The residential and the CW locations were carefully selected in accordance with the upwind-downwind configuration relative to the prevailing wind direction and the orientation of the highway.

Instrumentation and Set-Up

Each air monitoring station is equipped with three instruments. The GRIMM Technologies Aerosol Spectrometer 11-A was used to measure $PM_{2.5}$ and PM_{10}, NO_2 was recorded with 2B Technologies Model 405 NO_2/NO/ NO_x, and O_3 was measured using 2B Technologies Model 202. At both schools, instruments were arranged inside a sheltered, perforated cabinet. The monitoring station at the residential house was kept under the front porch, open to the environment. Inflow PTFE (Teflon) tubing from the monitors to a sampling height of 5 ft was maintained with the aid of a retort stand tripod. The tubing was faced down at the ends to limit the influence of high winds and non-air pollutants from entering through the inlets. Inlets were covered by a metal dish, and monitoring stations were kept open to prevent overheating, with a table acting as shade and weather protection. Temperature ranges in El Paso during the study period fell well within the acceptable operating temperature ranges for the air monitors, therefore requiring no additional forms of climate control. Data were downloaded twice a week (Tuesday and Friday) unless school holidays prevented it. Weather was routinely monitored to ensure the safe operation of the monitoring stations. Figure 2 depicts the monitoring stations during installment at FB, the residential house, and CW.

Environmental Data Collection

All instruments were calibrated by locating the instruments immediately adjacent to the TCEQ CAMS 12 station. Calibration of instruments was performed prior to and after the study sampling session against data recorded at CAMS 12 using U.S. EPA FRM methods. Methods and procedures used during calibration are documented in Appendix A.

Air pollution measurements were performed at three locations between October 10 and December 20, 2017. Hourly average $PM_{2.5}$, PM_{10}, NO_2, and O_3 concentrations were collected during this period of time. In addition, ambient air pollutant data (including PM_{10}, $PM_{2.5}$, O_3, NO_2, and CO) and meteorological parameters (including wind direction, wind speed, temperature, pressure, and humidity) were concurrently collected by TCEQ at existing CAMS network stations. The dataset was evaluated and compared to that obtained in this study.

Monitoring station at FB

Monitoring station at the residential house

Monitoring station at CW

Figure 2. Monitoring station at FB, residential house, and CW.

Health Outcome Monitoring

Participant Recruitment

The school principals of the two elementary schools were first contacted and, in consultation with the school nurses, potential physician-diagnosed asthmatic children in the schools were identified. All contacts with the children's parents, including confirmation of the asthma diagnosis, were conducted confidentially by the school nurses only. The school principals distributed to all parents the study flyer, which was provided by the research team. A follow-up presentation about the objectives, health outcome measurements, and parents and children's rights to terminate participation at any time were made to all interested parents of the identified asthmatic children, followed by a question-and-answer section. Informed consent and assent were then obtained from each child (ages 6 to 12) and the parent/legal guardian. Another meeting with the interested parents of the study subjects was conducted to complete the requisite paperwork pertaining to this study. The presentations elicited great interest and enthusiasm among the parents, and their questions were satisfactorily answered by the research team. The name and telephone numbers of the parents were recorded after every presentation. The screening questionnaire was administered to the parents who expressed an interest in the study.

A total of 23 physician-diagnosed asthmatic children were recruited from both the schools—12 for CW and 11 for FB. In general, prospective participants were screened for the following:

- Age—Since many health effects studies found air pollution-mediated asthma effects among children, our sample was restricted to individuals between ages 6 and 12.
- Health Status—a physician's diagnosis of asthma.
- Parent's consent.
- Living in a nonsmoking household.
- Willingness and ability to complete (with the help of field staff) weekly questionnaires and a suite of health measurements.
- Residence near the school (in a corresponding pollution exposure zone).

Once the participants met the initial inclusion criteria, a formal baseline questionnaire was administered to all their guardians. The baseline questionnaire took approximately 30 minutes to administer. Parental consent forms were also signed by these guardians. The children participating in the study were matched on age, gender, ethnicity, and asthma severity in order to minimize the potential for spatial confounding in the epidemiological analyses. As an incentive, a $50 gift card was offered to all the participants at the end of the study. The panel selection process went smoothly, and we were able to recruit enthusiastic and committed students for the study. Documents related to the health recruitment are included in Appendix B.

Health Outcome Data Collection

Health measurements were conducted twice a week during the study period. Each Tuesday and Friday, field technicians visited the two schools to administer a brief (10-minute) questionnaire and conduct a suite of health measurements. At CW, the health measurements were usually conducted in a spacious teacher's meeting room opposite the school principal's office, whereas health measurements at FB were undertaken in a classroom. The questionnaire helped the researchers understand how well the study subject's asthma was controlled and if traffic air pollution had any respiratory health effects on the study subject. Throughout the sampling period, data on each child's daily symptoms (i.e., coughing, wheezing, shortness of breath, and congestion), medication use, school absenteeism, health care utilization, and time-activity patterns were obtained via weekly morbidity questionnaires administered to the subjects.

Exhaled Nitric Oxide

During each health sampling session, eNO measurements for each child were collected using a portable, noninvasive NIOX VERO® Airway Inflammation Monitor (NIOX MINO, Aerocrine AB, Solna, Sweden) (Khalili et al., 2007). This monitor measures eNO in the exhaled breath from humans and was chosen to determine how environmental indicators associate with quantifiable and standardized clinical asthma measures of control. Exhaled nitric oxide is a sensitive and noninvasive biomarker of airway inflammation, which is an important determinant in the causal pathway of asthma and other lung diseases (Centers for Disease Control and Prevention [CDC], 2008; Dupont et al., 2003). Figure 3 shows a typical NIOX VERO® Airway Inflammation Monitor.

Nitric oxide (NO) is usually produced and detected in the exhaled breath from the respiratory tract, where it serves certain important regulatory functions (Kharitonov & Barnes, 2002; Nevin & Broadley, 2002). Elevated NO values indicate airway inflammation or other pathological respiratory conditions and frequently increase in inflammatory processes such as asthma (Holguin et al., 2007; Steerenberg et al., 2003). In addition, eNO levels are approximately 3 to 10 times greater in asthmatics than healthy control levels (CDC, 2008). Exhaled nitric oxide measurements have been previously measured in large epidemiological studies and have been adopted by researchers to elucidate the deleterious impacts of air pollution on pulmonary inflammation in asthmatic children (Delfino et al., 2006; Holguin et al., 2007; Liu et al., 2009). Exhaled NO measurements were performed according to the American Thoracic Society and European Respiratory Society (2005) recommendations. Each eNO measurement took approximately 1 minute. Consumption of green leafy vegetables like spinach and of corned meat, as well as physical exercises, are known to affect eNO measurements. Thus, the measurements were conducted at least 1 hour after either the intake of these food items or after any strenuous physical activity. Repeated measurements were performed on each child on the same day and time to minimize fluctuations in participants' eNO due to natural variability and to enable each child to serve as his/her own control in longitudinal data analyses. In addition, it is imperative to mention here that our target number of person-days of sampling (n = 198, CW; n = 165, FB) were in agreement with previous studies examining children's pulmonary inflammatory response (Koenig et al., 2005; Steerenberg et al., 2003; Fischer et al., 2002; Adamkiewicz et al., 2004).

Over the course of the study, the research team developed an excellent rapport with school authorities. The field crew involved with health monitoring was able to develop a trusting relationship with the participants that in turn facilitated the collection of data every week.

NIOX VERO® Monitor

EasyOne Lung Function Spirometer

Figure 3. NIOX VERO® Monitor and EasyOne Lung Function Spirometer.

Lung Function Measurements

Lung function measurements were conducted using a handheld spirometer (EasyOne Spirometer by NDD Medical Technologies, Andover, Massachusetts), as shown in Figure 3. The instrument is noninvasive and requires the child to blow into a sterile mouthpiece for approximately 10–15 seconds. It measures inspiratory and expiratory flow rate by examining the change in the amount of time required for an ultrasonic sound pulse to travel across a disposable spirette through which subjects are breathing. Bilingual technicians coached participants through the maneuver in whichever language (English or Spanish) was most convenient for the subject. Lung function was assessed in terms of FVC, FEV1, PEF, and forced expiratory flow during the two interior quartiles of exhalation (FEF25-75). The best effort of each session was selected based on the maximum value of FEV1. The results from each subject's best effort were evaluated as a percentage of age, height, gender, and ethnicity-dependent predicted values using the algorithms suggested by the National Health and Nutrition Examination Survey (Hankinson et al., 1999).

Carotenoid Levels Measurements (Veggie Meter)

Carotenoid levels were assessed using a Veggie Meter (Figure 4). The Veggie Meter is a device that uses a simple LED light (like in a common flashlight) to measure a nutrient called carotenoids. Carotenoids, found primarily in fruits and vegetables, serve as antioxidants and can be assessed noninvasively with reflectance spectroscopy. The carotenoid level in the human body provides information about how many fruits and vegetables are consumed and may serve as an indicator of antioxidant level in the human body. It is known that exposure to cigarette smoke will decrease carotenoid levels; however, no study had been conducted to explore the association between air pollution exposure and carotenoid levels. We hypothesized in this research that high exposure to air pollution will decrease carotenoid levels and that intervention phase strategies will improve carotenoid status. Participants were asked to put their finger on this light, and the device measures his/her score. The process takes about 25 seconds and is harmless.

Physical Activity Rates

Physical activity rate was measured using an accelerometer, as shown in Figure 4. This instrument detects differing levels of intensity and was used during baseline periods to examine time spent in moderate to vigorous physical

activity. The accelerometer was tied on the wrist of the child from 9 a.m. to 3 p.m. during the Friday health measurements at CW.

Carotenoid Levels Meter **Accelerometer**

Figure 4. Carotenoid levels meter and accelerometer.

Heart Rate Variability

We also performed a few measurements of the heart rate variability (HRV) in participants by using the Polar V800 Fitness Watch, as shown in Figure 5. This watch is tied around the chest area for a limited period of time during the health measurement period. These instruments are totally noninvasive. The instrument records the average and the maximum heart rate in the study subject. Heart rate variability data are not presented nor further discussed in this study due to insufficient samples collected.

Figure 5. Polar V800 fitness watch to measure HRV.

Asthma Symptoms Reporting

Data on each child's daily symptoms (e.g., coughing, wheezing, shortness of breath, and congestion), medication use, school absenteeism, health care utilization, and time-activity patterns were obtained via an ACQ that was administered at every health session to the subjects. Asthma control was assessed by evaluating (with scores) the frequency and severity of respiratory symptoms, activity limitation, and use of rescue bronchodilators. In this study, both average scores and individual question scores were used to determine how the levels of air pollutants reduce asthma control. The ACQ was developed based on the Global Initiative for Asthma (GINA) guidelines, which have shifted from their previous classification of asthma by severity to a primary classification of asthma by level of control. Asthma severity involves not only the severity of the underlying disease but also its responsiveness to treatment. The inflammatory process is a primary driver of the degree of airway responsiveness, airway

obstruction, and symptoms. The assessment of the elements of control of the disease state reflects the overall management of the underlying inflammatory state of the airways. The degree with which asthma is controlled is now recognized as the primary issue in asthma management.

The ACQ used in this study is a 7-item questionnaire developed by Juniper et al. (1999) at McMaster University, Canada. It is used to measure the adequacy of asthma control both in clinical research studies and in clinical practice. The ACQ includes items on the following:

- Specific symptoms.
- Timing of symptoms (**four questions**).
- Activity limitation (**one question**).
- Use of rescue medications (**one question**).
- Lung function (**one question**)—FEV1 percent predicted.

It is scored using a 7-point scale from 0 (totally controlled) to 6 (extremely poorly controlled). The overall score is the mean of the seven questions. Therefore, the minimum overall ACQ score is 0.0 for well-controlled asthma and the maximum score is 6.0 for poorly controlled asthma. The lowest clinically relevant score for the ACQ among asthmatic children has been shown to be 0.53 ± 0.45 (Juniper et al., 2010). A score of 1.5 on the ACQ has been identified as the best discriminator between asthma patients who are well controlled or not well controlled.

The ACQ was initially developed for adults (Juniper et al., 1999) but has been subsequently validated for use among children 6–16 years of age (Juniper et al., 2010). As per international guidelines, in order to achieve good asthma control it is necessary that the treatment should minimize day and nighttime symptoms, activity limitation, airway narrowing, and rescue bronchodilator use, thereby reducing the risk of life-threatening exacerbations and long-term morbidity (Juniper et al., 2005).

In summary, we undertook the following health measurement activities during the 9-week health sampling period:

- Spirometry, eNO, and HRV measurements on school children.
- Asthma Control Questionnaires for respiratory symptoms, medication, food ingestion, and the like.
- Children's on-campus and after-school physical activities, quality of life, attitudes to healthy living, and more by using surveys, questionnaires, and school data.

Statistical Methods and Data Analyses

Determination of Sample Size and Frequency

As part of the study design, a computer simulation implemented in R version 3.2.2 was performed to determine the statistical power needed in the mixed effect model for the health effect observation study. A significance level of .05 was used in the study. We first considered the secondary health endpoint of HRV and focused on the main health endpoint of eNO. The simulation conducted in the power analysis of HRV used Gaussian general linear mixed effect models with hourly $PM_{2.5}$, whereas the simulation in the power calculation of eNO used the average of 48-hour $PM_{2.5}$. It was found that larger sample sizes (n) with a fewer numbers of repeated measurements (J) are a more cost-effective design. In our study, enrolling n = 24 children with J = 6 repeat measurements in the study period was superior to enrolling n = 12 children with J = 12 repeat measurements. Detailed analysis for determination of the statistical power is included in Appendix C.

Statistical Methods for Characterization of Outdoor Exposure Concentrations

Descriptive statistics for characterizing environmental exposure concentrations were calculated using SPSS for Windows, v. 15.0, 17.0 (SPSS, Inc., Chicago, IL), Microsoft Excel 2013, Python, and R online software. Time-series graphs and boxplots were plotted to characterize the pollutant concentrations at various sites. Specifically, Spearman correlation coefficients were computed to assess the inter-side associations for each pollutant and the intra-pollutant associations at each site, which helped understand any temporal similarity in pollutant concentrations at the paired sites (Pinto et al., 2004; Wilson et al., 2006). Moreover, the correlations between the pollutant concentrations from schools and meteorological parameters from the various CAMS (located nearest to the respective schools) were studied using Spearman correlation coefficients.

Spatial variability of the monitored pollutants, like PM and its components and NO_2, across all the sampling and CAMSs was assessed using coefficients of divergence (COD). The COD values provide indication of the differences between the absolute concentrations of pollutants at simultaneously sampled monitoring sites (Pinto et al., 2004; Krudysz et al., 2008). The COD provide a degree of uniformity between simultaneously sampled sites j and k, as expressed by the following equation:

$$COD_{i,k} = \sqrt{\frac{1}{p}\sum_{i-1}^{p}\left[\frac{x_{i,j} - x_{i,k}}{x_{i,j} + x_{i,k}}\right]^2}$$

where $x_{i,j}$ is the j^{th} concentration measured at site j over the sampling period, and p is the number of observations. A small COD ($r < 0.2$) indicates similar pollutant concentrations between two sites, whereas a value approaching unity indicates significant difference in the absolute concentrations and subsequent spatial nonuniformity between the sites. j and k are two different sites, and p is the number of observations.

Smaller COD values indicate similarities between pollutant concentrations measured at various sites, while COD values approaching unity indicate vast differences in the absolute concentrations between the sites. COD values > 0.20 are defined as relatively heterogeneously spatially distributed. COD values elucidate the differences between the absolute concentrations among simultaneously sampled sites (Krudysz et al., 2008).

Regulatory Compliance of Health Data

To ensure compliance with federal standards detailing personal health information for clinical research, the research team ensured that all the following conditions were met:

- All data were stored in firewalled and password-protected computers.
- Only the research team had access to the study data.
- Information was never shared with other third parties.
- Future publications and dissemination of results will carry no personal identifiers.
- No identifiable information (names, last names, etc.) were ever kept in the same documents that contain personal identifiers.
- All data were kept using special codes for each participant. Only the research team can link these identifiers to the participant's identity.
- Information will be stored for a maximum of 5 years and then destroyed.
- Parents or participants were also given the option to withdraw at any time during the study period.

Statistical Methods for Epidemiologic Data Analyses

Descriptive statistics were calculated to assess characteristics of respiratory health outcomes (i.e., eNO, FVC, and FEV1), Veggie Meter outcomes measured by fruit and vegetable intake (F/V), and physical activity (moderate/light/sedentary) outcomes. Box plots were plotted to characterize various outcomes at different sites, and school-specific means were compared using two-sided *t* tests. Correlation analyses using Spearman correlation were conducted to assess relationships between F/V, physical activity, and outdoor pollutant concentrations. Summary statistics of subject demographic information and characteristics were calculated. Comparisons of continuous characteristics (e.g., age, body mass index [BMI], height, weight) between schools were made using the two-sample *t* test. Fisher's exact test and corresponding *p*-values were also calculated to explore differences in subject-specific factors between the two schools.

Longitudinal associations between primary responses (eNO, FVC, FEV1, and F/V) and air pollution metrics were examined using linear mixed effect models, with pollutants modeled as fixed effects and subjects modeled as random effects. We assumed the subject-specific random intercept and included additional control for the repeated measures of the outcome data using a first-order autoregressive covariance structure. The 96-hour averages of temperature and relative humidity showed the strongest associations with response outcome, and we controlled for the 96-hour temperature and relative humidity as a priori fixed covariates in all models.

Separate models were run for each pollutant variable of interest (PM concentrations, NO_2, O_3, or air quality index) with various exposure periods (previous 24-, 48-, 72-, or 96-hour averages). Effect estimates for each measurement are presented as the percent change in eNO and changes in lung function parameters per increase in pollutant concentrations. We scaled effects to IQR (Q_3–Q_1) increases in pollutant metrics to compare the magnitude of effect across different scales of the pollutant concentrations. Effects standardized to IQRs allowed us to compare effects for a similar degree of increase relative to each metric's distribution of concentrations.

From school-stratified analyses, we examined significant associations between air pollution-health outcomes that differed by school. Subject-specific factors (sex, race, BMI category, hay fever status, health insurance, caretaker education, medication, etc.) were also considered as potential covariates in secondary analyses, including interaction terms of pollutant × factor.

For models predicting rates of moderate or sedentary physical activity, a generalized estimating equations (GEE) approach was used to address characteristics of proportion data with multiple categories, such as moderate/light/sedentary. GEE provides a general method for the analysis of correlated outcomes without making strong assumptions on the dependence structure. The GEE model yields unbiased estimates of population-

averaged regression coefficients together with robust variance estimates, even with misspecification of the correlation structure (Liang & Zeger, 1986). We assumed subject-specific cluster and exchangeable correlation structure, and controlled 96-hour temperature and relative humidity in the models. School-specific analyses were examined by adding interactions between the pollutant metric and school.

A p-value < .05 was considered statistically significant. All statistical analyses were performed using R version 3.2.2. The R packages “nlme” and “geepack” were used for linear mixed effect models and GEE fitting, respectively.

Results

Air Pollutant Concentrations at the Two Schools and Residence

Summary of Data

Hourly averages for each air pollutant were calculated from the 5-minute readings and adjusted according to the linear regression equations in Appendix A. Figure 6 through Figure 9 depict the hourly time-series data from each of the monitoring stations; CW represents the Coldwell Elementary School, FB represents Fort Bliss Elementary School and RH represents the residential location across Interstate-54 from CW. While all three monitoring stations demonstrated a similar trend throughout the study period for PM, the station at FB consistently logged the highest readings. For $PM_{2.5}$, FB recorded an average value of 17.8 µg/m³, CW had 11.6 µg/m³, and RH had 8.5 µg/m³. For PM_{10}, FB recorded an average value of 55.7 µg/m³, CW 42.9 µg/m³, and RH 30.4 µg/m³. In contrast, for NO_2, the station at CW exhibited the highest values. FB recorded an average value of 14.9 ppb, CW 18.4 ppb, and RH 16.1 ppb. As seen in Table 1, O_3 values were the most consistent across the sites. O_3 values for the three monitoring stations were nearly identical for CW and RH. FB exhibited the same general trend but recorded slightly higher values. An examination of the maximum 8-hour O_3 continuous averages supports the claim that O_3 is higher at FB. O_3 is a secondary pollutant with precursors, including NO_x and VOCs. The difference between nonrecorded precursor emissions from CW and FB could potentially play a role in the creation of O_3.

NO_2 and $PM_{2.5}$ are acknowledged to be good indicators for emissions originating from traffic. The distance to the highway is an important variable when determining near-road impact of traffic pollutants. The station at FB is located the farthest from the highway and had the lowest readings for NO_2. To prove that closer proximity to US-54 increases NO_2 would require measuring the background concentrations in the study region. This station at FB was also in an area with predominantly unpaved grounds. Particulate matter in arid regions is influenced more by geological sources than by traffic emissions. It is plausible that the surroundings have a greater influence on PM than do traffic emissions coming from US-54. Boxplots were plotted to illustrate the variation in pollutants across the three sites. As demonstrated in Figure 10, FB varied the greatest for PM_{10} and $PM_{2.5}$. The RH varied the greatest for NO_2, and O_3 was nearly identical at all three sites.

Pollutant concentrations may vary by season. Winter season pollutant concentrations in El Paso may be higher for PM and NO_2. Average pollutant concentrations for PM and NO_2 during the study period, seen in Table 1, may be a conservative representation for the year. However, the higher O_3 concentrations occur during the summer months, and thus average O_3 concentrations during the study may be lower than in other seasons.

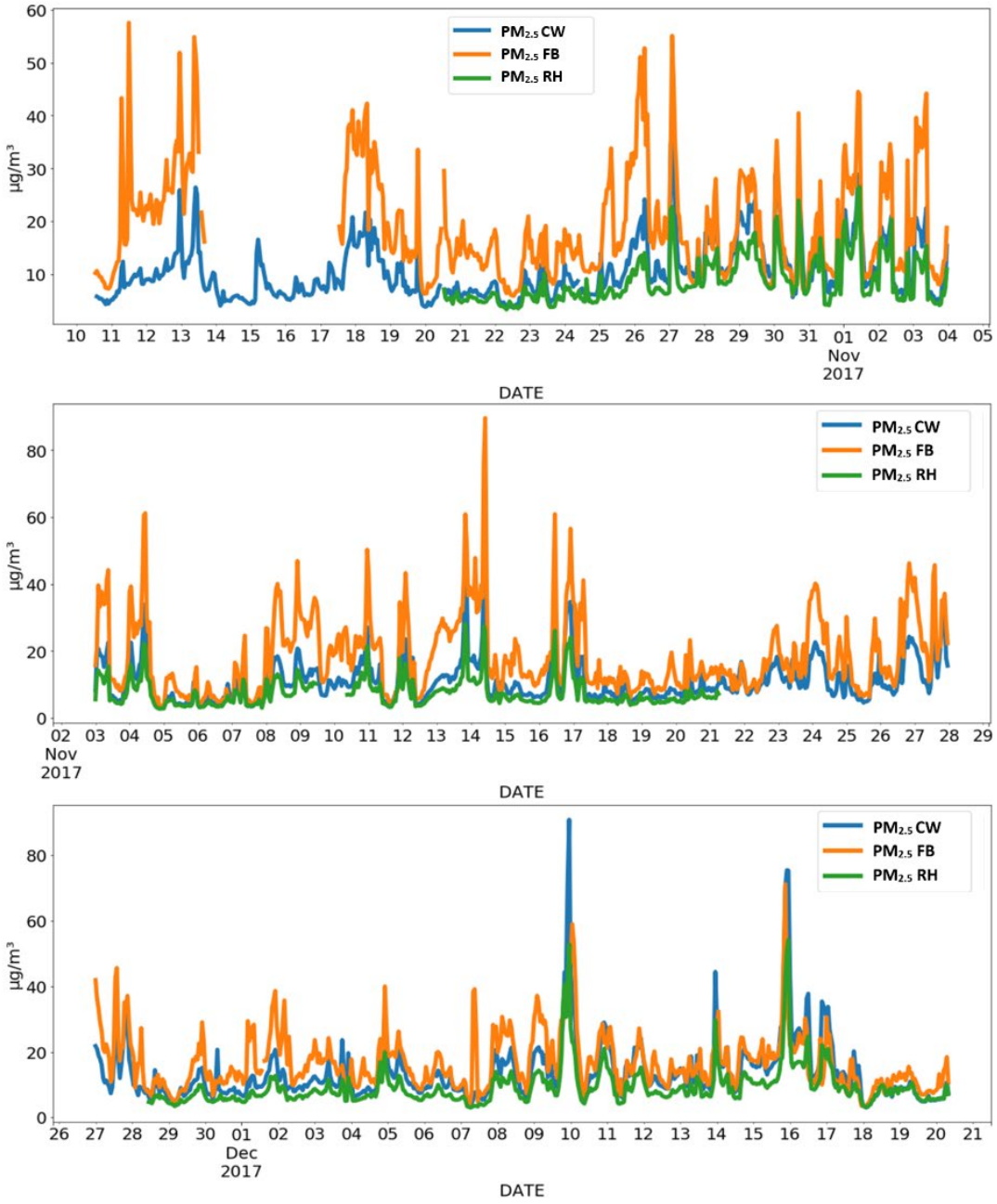


Figure 6. Time series of 1-hour averages of $PM_{2.5}$ for CW, FB, and RH during the study period.

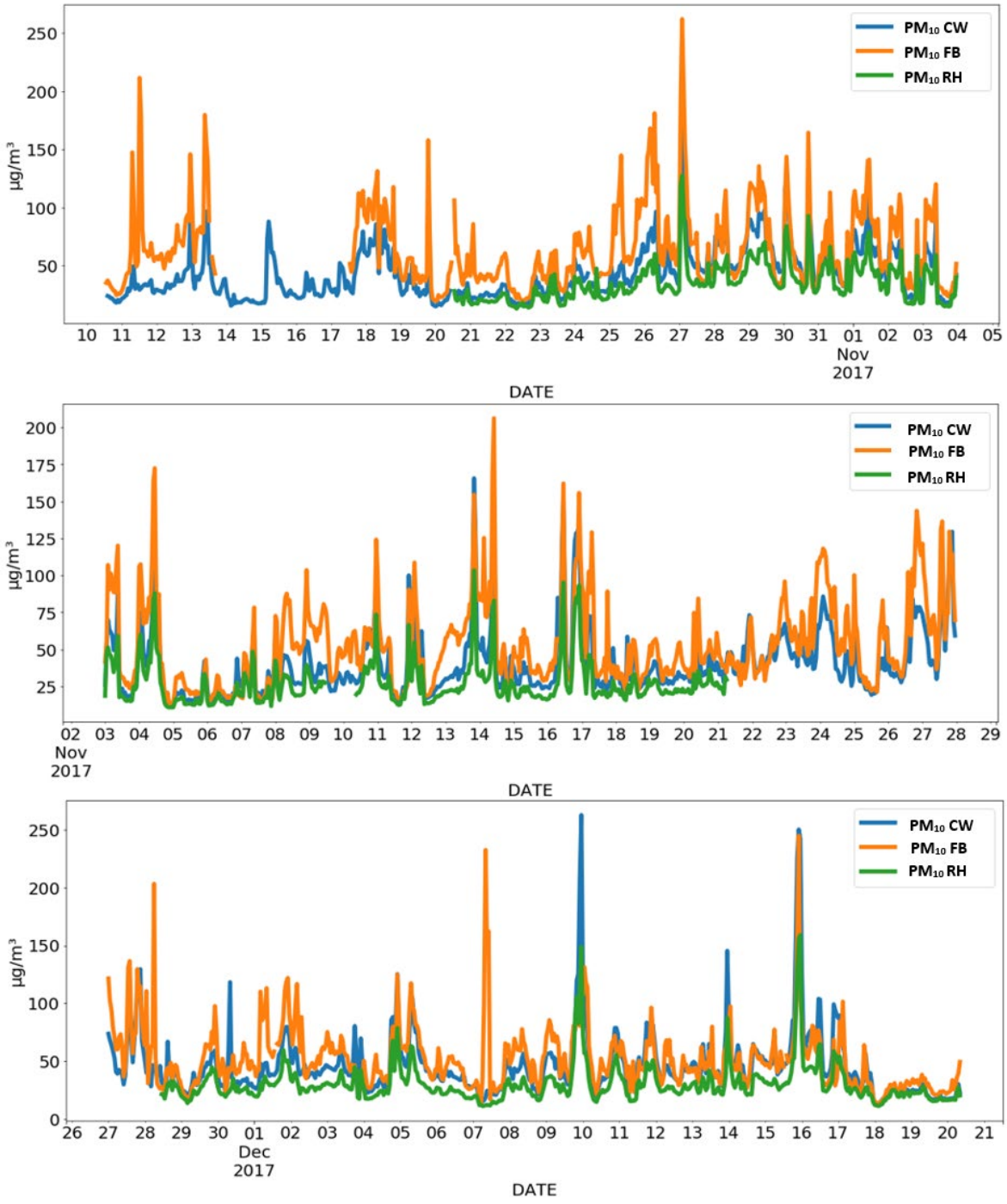


Figure 7. Time series of 1-hour averages of PM_{10} for CW, FB, and RH during the study period.

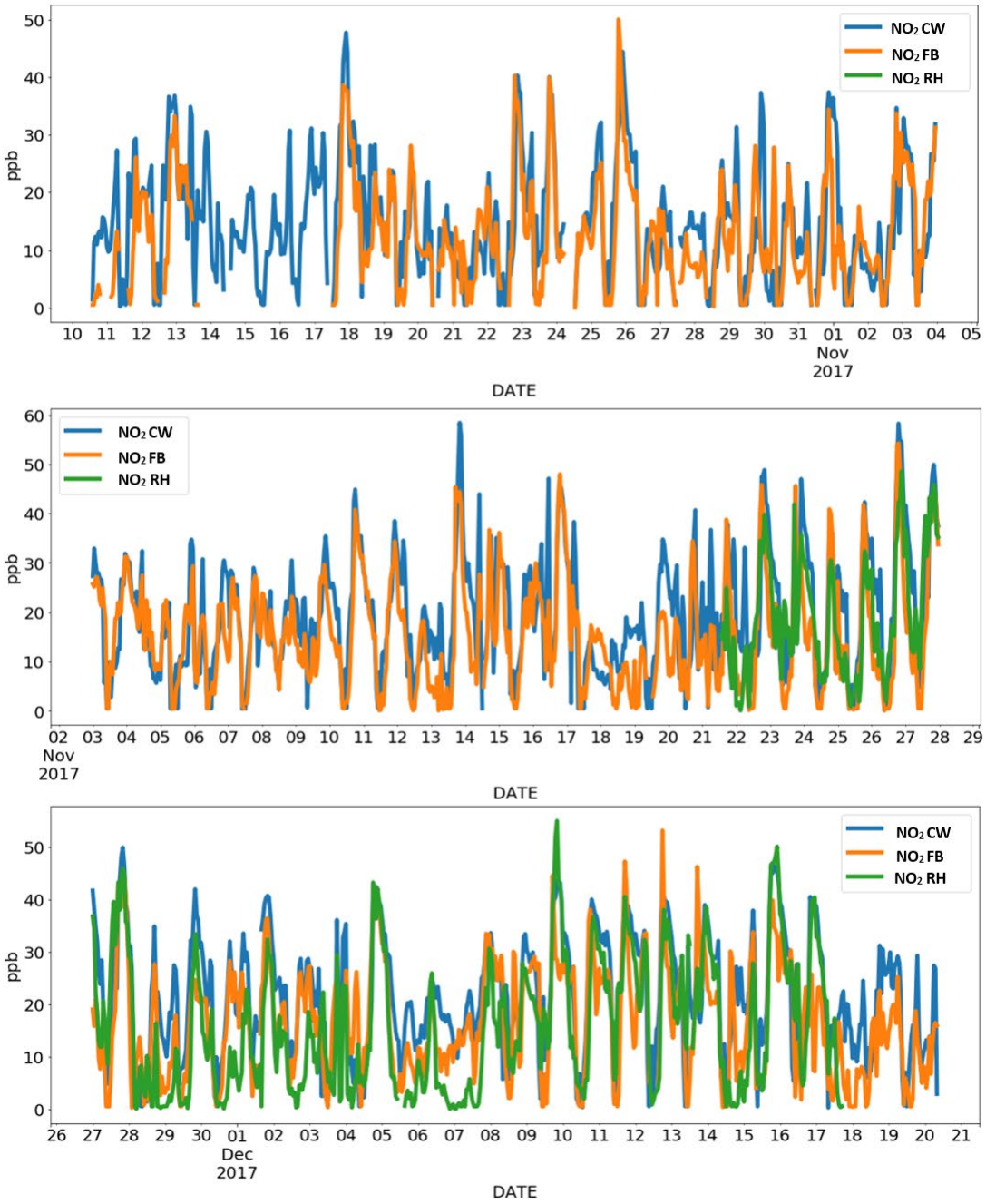


Figure 8. Time series of 1-hour averages of NO_2 for CW, FB, and RH during the study period.

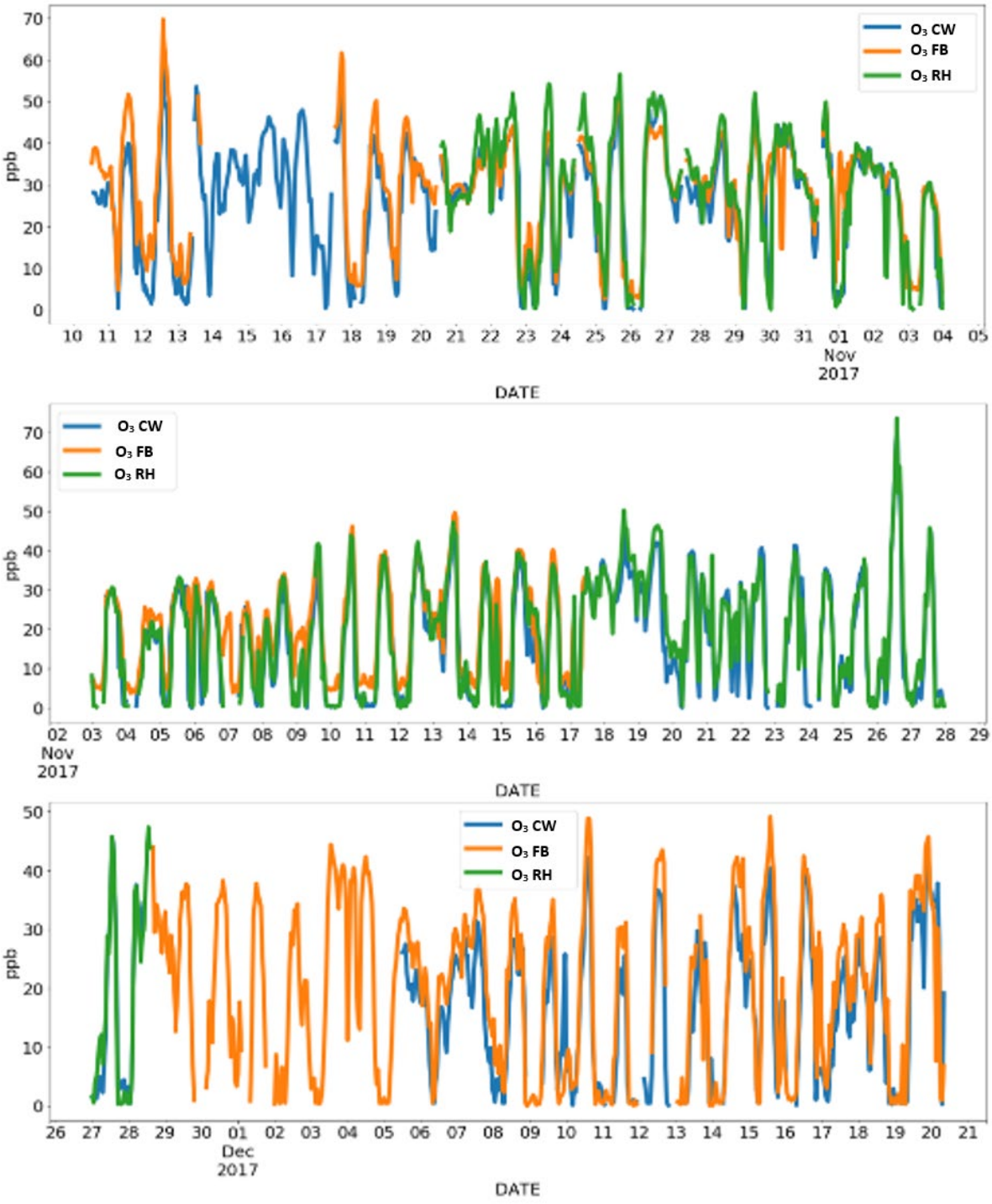


Figure 9. Time series of 1-hour averages of O_3 for CW, FB, and RH during the study period.

Table 1. Statistics of Time-Series Data for 1-Hour Pollutant Concentrations across Monitoring Sites

	Count	Mean	Std	Min	25%	50%	75%	Max	Units
$PM_{2.5}$ CW	1,695	11.6	7.3	2.73	7.07	9.60	14.35	90.88	µg/m³
$PM_{2.5}$ FB	1,605	17.8	10.2	3.15	10.62	14.82	22.66	89.63	µg/m³
$PM_{2.5}$ RH	1,268	8.5	5.1	2.71	5.33	7.02	10.16	54.13	µg/m³
PM_{10} CW	1,695	42.9	24.4	12.34	27.15	37.10	51.44	262.57	µg/m³
PM_{10} FB	1,605	55.7	30.8	13.15	34.78	47.90	67.38	262.03	µg/m³
PM_{10} RH	1,268	30.4	16.3	10.68	20.28	26.37	35.19	158.80	µg/m³
NO_2 CW	1,675	18.4	11.3	0.22	9.64	16.71	26.64	58.37	ppb
NO_2 FB	1,547	14.9	10.5	0.04	7.03	13.36	21.65	54.21	ppb
NO_2 RH	624	16.1	12.4	0.02	5.40	13.61	25.05	54.95	ppb
O_3 CW	1,410	21.3	13.9	0.01	8.10	22.62	31.97	73.30	ppb
O_3 FB	1,290	23.2	13.7	0.01	9.91	25.44	33.82	69.68	ppb
O_3. RH	874	23.4	14.8	0.05	10.69	25.44	34.41	73.59	ppb

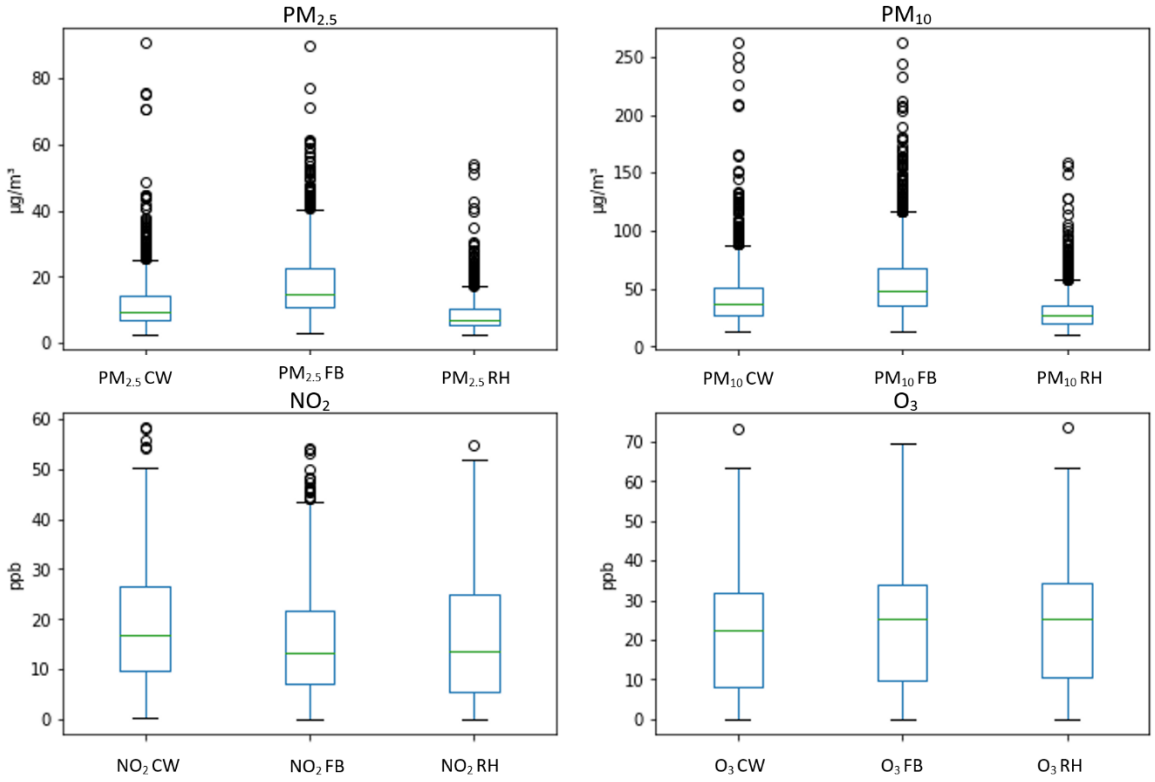


Figure 10. Box plots of 1-hour averages of $PM_{2.5}$, PM_{10}, NO_2, and O_3 for CW, FB, and RH during the study period.

Pollutant Correlations across the Study Sites

Spatiotemporal variation within the El Paso region can be attributed to meteorological conditions, sources of emissions, and topography. The Franklin Mountains dividing El Paso adds to the spatial variability of air pollution in the region. Vehicular traffic patterns and wind vary throughout El Paso. Higher vehicle activity is observed near the border crossings. Pollutants like PM and NO_2 from vehicle exhaust are of special interest. The neighborhoods at

the study sites do not have nearby CAMSs to gauge the background concentrations of pollutants within the community. It is important that different communities have knowledge of the spatial variability in the region.

Interpollutant Correlations

Interpollutant and intrapollutant correlations were calculated based on hourly concentrations with the intent to demonstrate similarity of paired sites (Raysoni, 2011; Pinto et al., 2004; Wilson et al., 2006; Physick et al., 2011). Table 2 shows the Spearman correlation coefficients for the pollutants at the three sites and available CAMSs. The three monitored sites exhibited strong correlations for all pollutants, which suggests that similar temporal trends can be observed in the communities surrounding these sites for all measured pollutants. Interpollutant Spearman correlations varied by site. In general, correlations were lower at FB. At every site, Spearman correlations were highest among particulate pollutants. $PM_{2.5}$ correlations with NO_2 were moderate for both CW ($r = 0.48$, p-value < 0.001) and FB ($r = 0.38$, p-value < 0.001). A previous study showed higher Spearman correlations between gases (NO, NO_x, CO) (Patton et al., 2014). We were not able to confirm this correlation because our study protocol only measured NO_2. However, the RH had high correlation between NO_2 and $PM_{2.5}$ ($r = 0.7$, p-value < 0.001). O_3 had negative correlations with NO_2 at FB ($r = -0.62$, p-value < 0.001) and CW ($r = -0.67$, p-value < 0.001).

The $PM_{2.5}$ and PM_{10} correlations between CW and RH exhibited the highest correlation ($r = 0.96$, p-value < 0.001 for both). It is assumed that the two sites have the highest correlation between sites due to their close proximity to one another. The correlation between the particulate species was also strong between CW and FB ($r = 0.8$, p-value < 0.001).

Spatial Variation in Pollutant Concentrations

Continuous air monitoring sites measure ambient air quality and meteorological data throughout the city, courtesy of TCEQ. A CAMS near the study area was not available to compare with the data collected. However, comparison with stations in different areas of El Paso could reveal if intra-urban spatial variability in air pollution levels exists. The location of CAMS 12, 37, 41, and 49 used for comparison are given in Table 3. CAMS 12 is located next to the University of Texas at El Paso campus. CAMS 37 is located inside Ascarate Park, north of the U.S.-Mexico border highway. CAMS 41 is located near the Chamizal National Memorial, north of Bridge of the Americas. CAMS 49 is located in the lower valley of El Paso.

Table 2. Intrasite and Interpollutant Spearman Correlation Coefficients

		$PM_{2.5}$							PM_{10}					NO_2					O_3				
	Site	CW	FB	RH	C12	C37	C41	C49	CW	FB	RH	C12	C41	CW	FB	RH	C12	C37	CW	FB	RH	C37	C41
$PM_{2.5}$	CW	1	0.8	0.96	0.54	0.57	0.54	0.4	0.93	0.78	0.88	0.47	0.46	0.48	0.37	0.7	0.47	0.42	-0.4	-0.4	-0.3	-0.4	-0.4
	FB	0.8	1	0.77	0.45	0.35	0.33	0.32	0.71	0.92	0.7	0.36	0.32	0.42	0.38	0.63	0.41	0.37	-0.3	-0.4	-0.4	-0.3	-0.4
	RH	0.96	0.77	1	0.51	0.53	0.51	0.37	0.86	0.72	0.88	0.37	0.39	0.4	0.31	0.7	0.38	0.38	-0.3	-0.3	-0.3	-0.3	-0.4
	C12	0.54	0.45	0.51	1	0.56	0.51	0.57	0.51	0.42	0.5	0.77	0.49	0.52	0.52	0.57	0.73	0.55	-0.4	-0.4	-0.4	-0.5	-0.6
	C37	0.57	0.35	0.53	0.56	1	0.62	0.59	0.52	0.32	0.45	0.43	0.49	0.41	0.42	0.57	0.53	0.65	-0.4	-0.3	-0.3	-0.5	-0.4
	C41	0.54	0.33	0.51	0.51	0.62	1	0.41	0.51	0.33	0.46	0.42	0.56	0.45	0.4	0.61	0.5	0.51	-0.3	-0.3	-0.3	-0.4	-0.5
	C49	0.4	0.32	0.37	0.57	0.59	0.41	1	0.42	0.31	0.4	0.43	0.4	0.41	0.47	0.55	0.42	0.59	-0.3	-0.3	-0.4	-0.5	-0.4
PM_{10}	CW	0.93	0.71	0.86	0.51	0.52	0.51	0.42	1	0.8	0.96	0.57	0.54	0.41	0.32	0.67	0.37	0.34	-0.2	-0.2	-0.2	-0.2	-0.3
	FB	0.78	0.92	0.72	0.42	0.32	0.33	0.31	0.8	1	0.8	0.46	0.37	0.35	0.31	0.55	0.31	0.27	-0.2	-0.2	-0.2	-0.2	-0.3
	RH	0.88	0.7	0.88	0.5	0.45	0.46	0.4	0.96	0.8	1	0.54	0.51	0.35	0.27	0.62	0.29	0.29	-0.2	-0.2	-0.2	-0.2	-0.3
	C12	0.47	0.36	0.37	0.77	0.43	0.42	0.43	0.57	0.46	0.54	1	0.62	0.3	0.29	0.42	0.48	0.29	-0.2	-0.1	-0.1	-0.1	-0.3
	C41	0.46	0.32	0.39	0.49	0.49	0.56	0.4	0.54	0.37	0.51	0.62	1	0.28	0.25	0.51	0.38	0.36	-0.2	-0.2	-0.2	-0.2	-0.3
NO_2	CW	0.48	0.42	0.4	0.52	0.41	0.45	0.41	0.41	0.35	0.35	0.3	0.28	1	0.74	0.75	0.63	0.6	-0.7	-0.6	-0.6	-0.6	-0.7
	FB	0.37	0.38	0.31	0.52	0.42	0.4	0.47	0.32	0.31	0.27	0.29	0.25	0.74	1	0.64	0.6	0.68	-0.6	-0.6	-0.5	-0.7	-0.6
	RH	0.7	0.63	0.7	0.57	0.57	0.61	0.55	0.67	0.55	0.62	0.42	0.51	0.75	0.64	1	0.75	0.83	-0.6	-0.7	-0.6	-0.7	-0.7
	C12	0.47	0.41	0.38	0.73	0.53	0.5	0.42	0.37	0.31	0.29	0.48	0.38	0.63	0.6	0.75	1	0.75	-0.6	-0.6	-0.6	-0.7	-0.8
	C37	0.42	0.37	0.38	0.55	0.65	0.51	0.59	0.34	0.27	0.29	0.29	0.36	0.6	0.68	0.83	0.75	1	-0.6	-0.6	-0.6	-0.8	-0.7
O_3	CW	-0.4	-0.3	-0.3	-0.4	-0.4	-0.3	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.7	-0.6	-0.6	-0.6	-0.6	1	0.91	0.95	0.79	0.84
	FB	-0.4	-0.4	-0.3	-0.4	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2	-0.1	-0.2	-0.6	-0.6	-0.7	-0.6	-0.6	0.91	1	0.91	0.8	0.81
	RH	-0.3	-0.4	-0.3	-0.4	-0.3	-0.3	-0.4	-0.2	-0.2	-0.2	-0.1	-0.2	-0.6	-0.5	-0.6	-0.6	-0.6	0.95	0.91	1	0.83	0.85
	C37	-0.4	-0.3	-0.3	-0.5	-0.5	-0.4	-0.5	-0.2	-0.2	-0.2	-0.1	-0.2	-0.6	-0.7	-0.7	-0.7	-0.8	0.79	0.8	0.83	1	0.89
	C41	-0.4	-0.4	-0.4	-0.6	-0.4	-0.5	-0.4	-0.3	-0.3	-0.3	-0.3	-0.3	-0.7	-0.6	-0.7	-0.8	-0.7	0.84	0.81	0.85	0.89	1

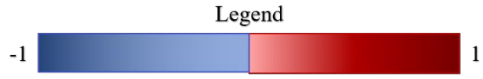


Table 3. Location of TCEQ CAMSs in El Paso

TCEQ Site	Latitude	Longitude	Address
CAMS 12 (UTEP)	31˚46' 6" N	-106˚30' 5" W	250 Rim Road
CAMS 37 (Ascarate)	31˚44' 48" N	-106˚24' 10" W	650 R E Thomason Loop
CAMS 41 (Chamizal)	31˚45' 56" N	-106˚27' 19" W	800 S. San Marcial Street
CAMS 49 (Socorro)	31˚40' 3" N	-106˚17' 17" W	320 Old Hueco Tanks Road

COD values were calculated from simultaneous on-site measurements and CAMS data for hourly and 24-hour averages, as shown in Table 4 and Table 5. A COD value less than or equal to 0.2 implies homogeneity in the pollutant concentration between two sites, which was observed for $PM_{2.5}$ between CW and RH (0.17). For PM_{10}, homogeneity is inferred between CW and RH (0.18) and CW and FB (0.18). A COD value >0.2 implies a higher degree of nonuniformity between two sites. Based on the hourly ambient air pollution concentrations, slight spatial heterogeneity exists between CW and CAMS 12 for $PM_{2.5}$ (0.27) and PM_{10} (0.24). Moderate to high spatial heterogeneity can be implied for the three measured sites and CAMSs.

Finer time resolutions reveal greater variability in pollutant concentrations. Examining the COD by 24-hour averages, shown in Table 5, reveals more homogeneity. O_3 and NO_2 levels between most sites were observed to be homogeneous for this larger time average. Heterogeneity in PM is still pronounced at this time scale. FB shows the highest COD values for PM, implying greater heterogeneity between this site and the rest of El Paso.

Table 4. Coefficient of Divergence Values Based on Hourly Concentrations

Pollutant	Site	FB	RH	UTEP CAMS12	Ascarate CAMS37	Chamizal CAMS41	Socorro CAMS49
$PM_{2.5}$	CW	0.25	0.17	0.27	0.32	0.45	0.36
	FB		0.35	0.40	0.42	0.53	0.48
	RH			0.24	0.36	0.41	0.32
	CAMS 12				0.34	0.43	0.30
	CAMS 37					0.44	0.36
	CAMS 41						0.45
PM_{10}	CW	0.18	0.18	0.24		0.56	
	FB		0.29	0.30		0.59	
	RH			0.25		0.54	
	CAMS 12					0.54	
NO_2	CW	0.36	0.44	0.43	0.41		
	FB		0.45	0.44	0.39		
	RH			0.39	0.37		
	CAMS 12				0.53		
O_3	CW	0.33	0.24	0.34	0.37	0.34	
	FB		0.33	0.34	0.41	0.37	
	RH			0.35	0.37	0.34	
	CAMS 12				0.35	0.28	
	CAMS 37					0.27	

Table 5. Coefficient of Divergence Values Based on 24-Hour Average Concentrations

Pollutant	Site	FB	RH	UTEP CAMS12	Ascarate CAMS37	Chamizal CAMS41	Socorro CAMS49
$PM_{2.5}$	CW	0.23	0.17	0.16	0.23	0.24	0.25
	FB		0.35	0.33	0.32	0.38	0.40
	RH			0.13	0.32	0.23	0.18
	CAMS 12				0.30	0.22	0.18
	CAMS 37					0.27	0.29
	CAMS 41						0.26
PM_{10}	CW	0.16	0.18	0.14		0.23	
	FB		0.29	0.22		0.33	
	RH			0.18		0.21	
	CAMS 12					0.23	
NO_2	CW	0.14	0.24	0.20	0.18		
	FB		0.17	0.17	0.17		
	RH			0.19	0.18		
	CAMS 12				0.17		
O_3	CW	0.10	0.07	0.08	0.13	0.06	
	FB		0.09	0.10	0.19	0.12	
	RH			0.08	0.15	0.07	
	CAMS 12				0.16	0.08	
	CAMS 37					0.12	

Temporal Variation

The three monitoring sites exhibited the same general trend for PM throughout the day. Figure 11 and Figure 12 depict the weekday and weekend diurnal averages for $PM_{2.5}$ and PM_{10} during the study period. During the weekdays, PM experienced peaks in the morning around 7:00 a.m. The 7:00 a.m. peak can be attributed to the morning rush hour, but the midnight peak could be the result of stable atmospheric conditions. In contrast, the weekends saw a spike in the nighttime hours, specifically from midnight to 2:00 a.m. It is interesting to observe the inconsistency between FB and CW during the weekend nighttime hours. An increase in PM occurred between midnight and 2:00 a.m. at FB, while there was a decrease at CW. Comparisons with CAMSs reveal varying trends. For $PM_{2.5}$, CAMSs 12, 41, and 49 follow similar trends with each other, comparable to CW and RH, where $PM_{2.5}$ peaked in the morning around 7:00 a.m. and in the evening around 7:00 pm when traffic peaked.

Figure 13 shows the diurnal weekday and weekend trends of NO_2. The three monitored sites and the CAMSs follow similar trends. Weekday concentrations of NO_2 reached a morning maximum around 7:00 a.m. There was a steady decrease until 3:00–4:00 p.m., apart from CW. NO_2 concentrations increased solely at CW around 8:30–11:00 a.m. However, NO_2 concentrations at CW began to increase earlier, around 12:00 p.m. Weekend concentrations were similar to the weekday concentrations except there was not a morning peak during the weekend. Overall, concentrations of NO_2 were highest after sunset, which is expected because of O_3 photochemistry, in which NO_2 is split into NO and an oxygen atom by sunlight.

Figure 14 shows the diurnal weekday and weekend O_3 cycle recorded. The monitored sites and CAMSs recorded similar trends with little variation. As expected, O_3 increased when sunlight was the greatest. O_3 began to increase in the morning until reaching a maximum concentration for both weekdays and weekends at approximately 2:00 p.m. Slight variations exist in the trends comparing weekdays and weekends, but weekends recorded higher average peak concentrations. Figure 15 shows the maximum 8-hour average O_3 concentration during the study period. All values were below the National Ambient Air Quality Stndards for the 8-hour O_3 of 70 ppb.

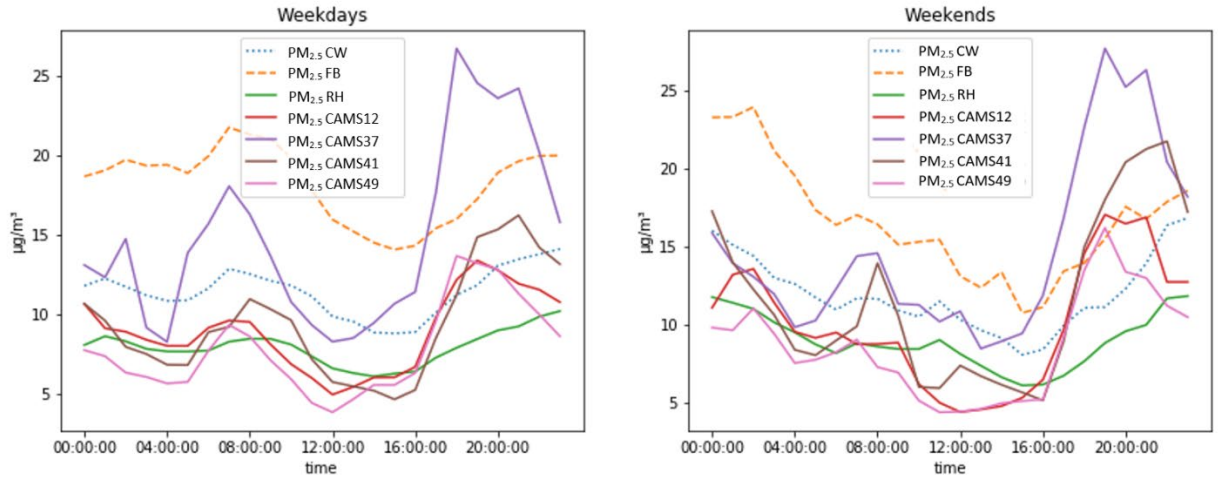


Figure 11. Diurnal averages of $PM_{2.5}$ for measured sites and CAMS during the study period.

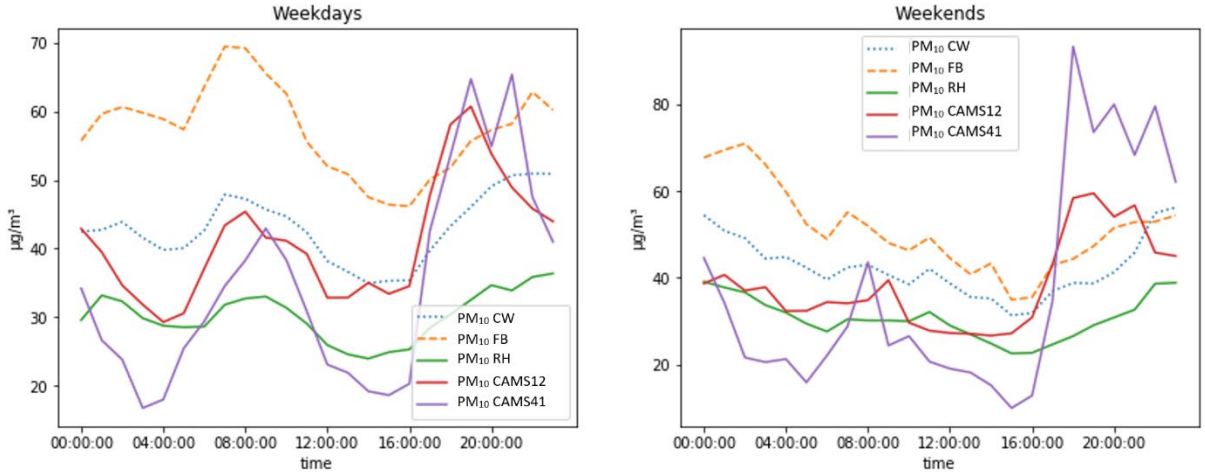


Figure 12. Diurnal averages of PM_{10} for measured sites and CAMS during the study period.

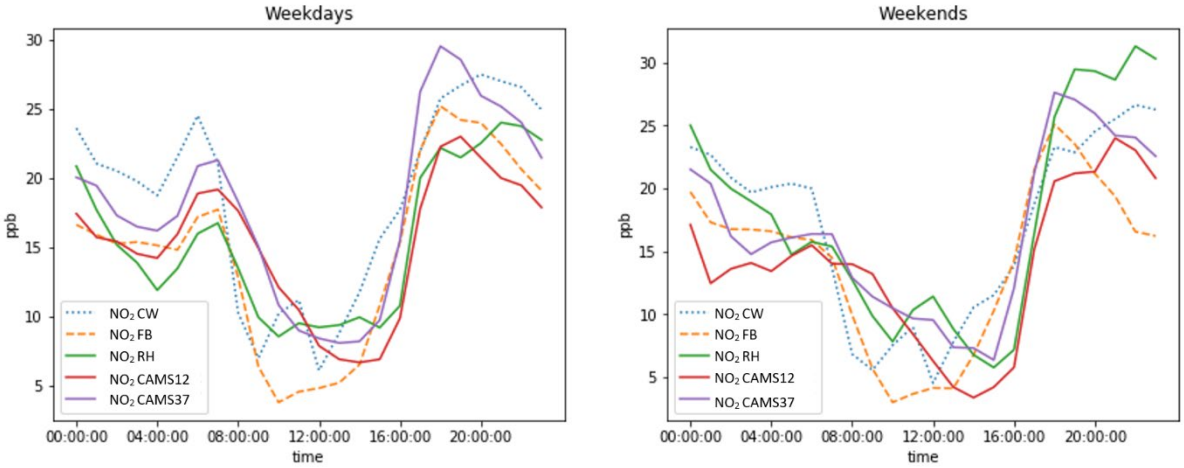


Figure 13. Diurnal averages of NO_2 for measured sites and CAMS during the study period.

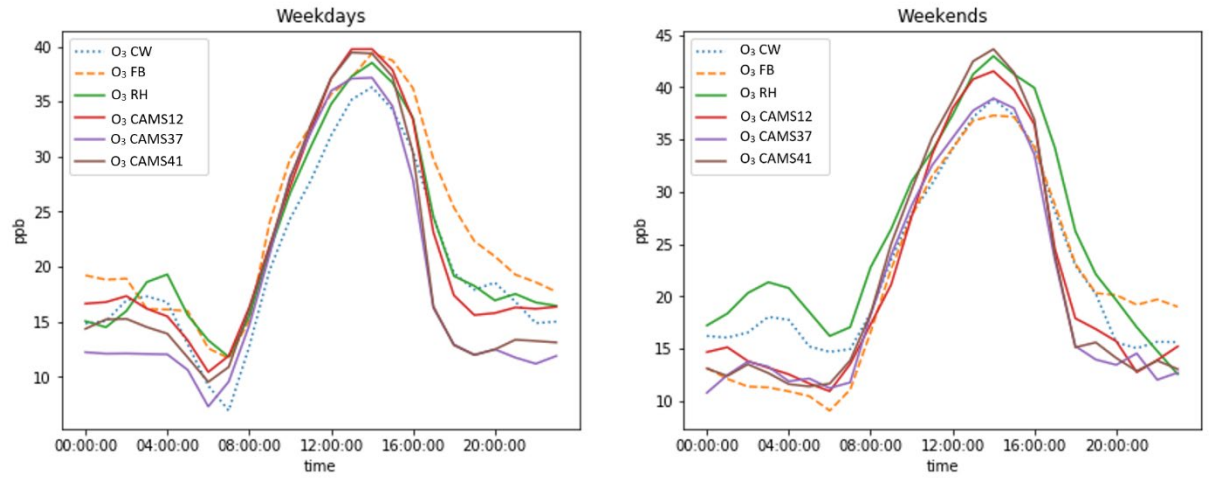


Figure 14. Diurnal averages of O_3 for measured sites and CAMS during the study period.

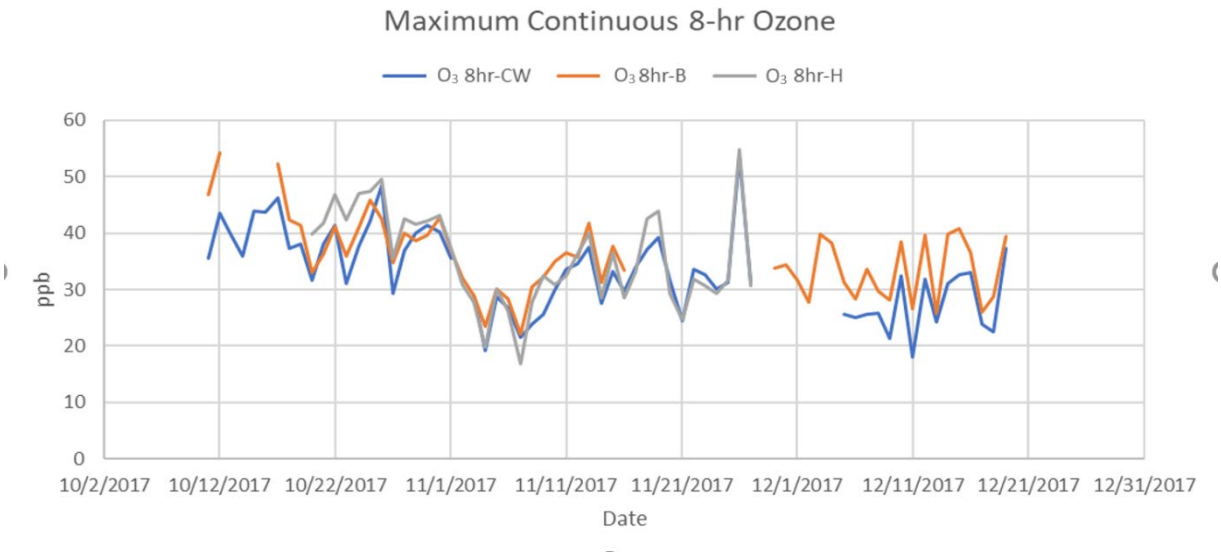


Figure 15. Maximum daily 8-hour O_3 average for CW, FB, and RH during the study period.

Study Population Characteristics

The study population included 12 subjects from CW and 11 subjects from FB living in close proximity to their schools (within 2 mi). The overall median age of the children was 8 (range: 6–12) years old. Although age and gender distributions were similar across the two school-based cohorts, significant differences were observed for other subject characteristics. All subjects at CW were Hispanic (Mexican American descent). At FB, four students were Black, one was White, and the remaining six students were Hispanic (five: Mexican American, one: Puerto Rican descent). Out of the complete cohort of 23 students, 11 were male. The BMI was calculated using CDC's BMI Percentile Calculator for Child and Teen. The calculator provides BMI results from height and weight data. The calculator also provides the BMI-for-age percentile values, which indicates how the subject's weight compares to that of other children of the same age and gender. The calculator categorizes the BMI-for-age percentiles according to the following cut points:

- Underweight = < 5th percentile.
- Healthy weight = 5th–85th percentile.
- Overweight = 85th–95th percentile.

- Obese = ≥ 95th percentile.

The BMI-for-age percentile is more appropriate for between subject and school comparisons than the raw BMI result. Figure 16 and Figure 17 show the prevalence of overweight and obesity at CW and FB, respectively. At CW, 33 percent of the students were classified as overweight or obese (≥85th percentile), and 25 percent were obese (≥95th percentile). In contrast, the prevalence of overweight or obese (≥85th percentile) and obese (≥95th percentile) students was 36 percent each at FB. Figure 18 and Figure 19 graphically show the prevalence of overweight and obese students by sex at CW and FB, respectively. At CW, 43 percent of the males and 20 percent of the females were overweight, whereas the prevalence of obesity at FB was 20 percent for both males and females each. In contrast, only 20 percent of the males were overweight, but 50 percent of the females were overweight at FB. Similarly, at this school, only 20 percent of the male students were obese, but 50 percent of females were obese. Table 6 and Table 7 show the summary statistics of the study participant's BMI at schools CW and FB, respectively. At CW, 50 percent of all the students had a normal BMI, and 64 percent of the students had a normal BMI at FB.

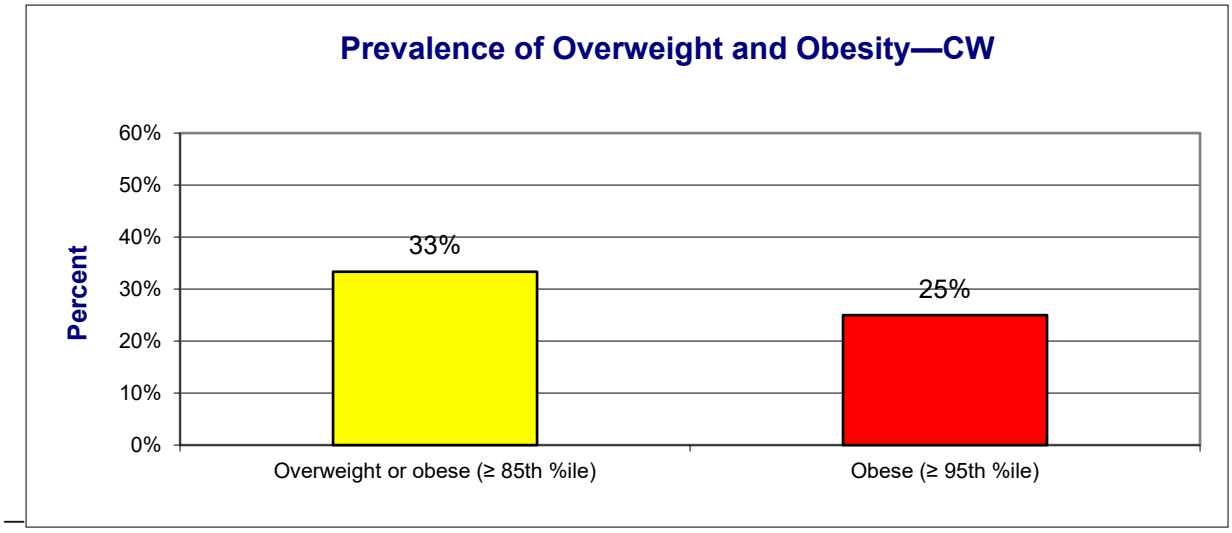


Figure 16. Prevalence of overweight and obesity at CW.

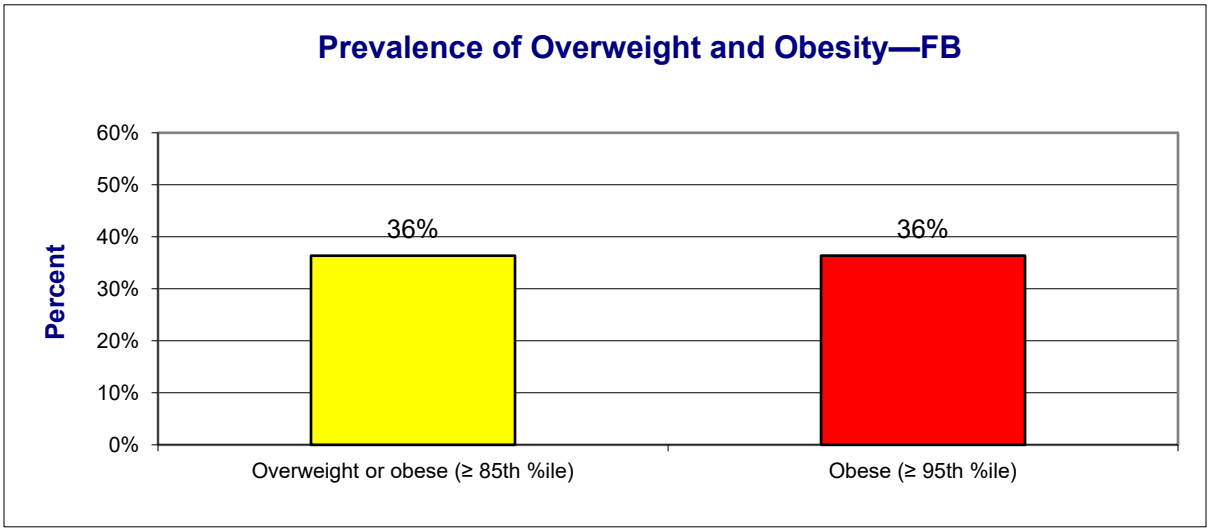


Figure 17. Prevalence of overweight and obesity at FB.

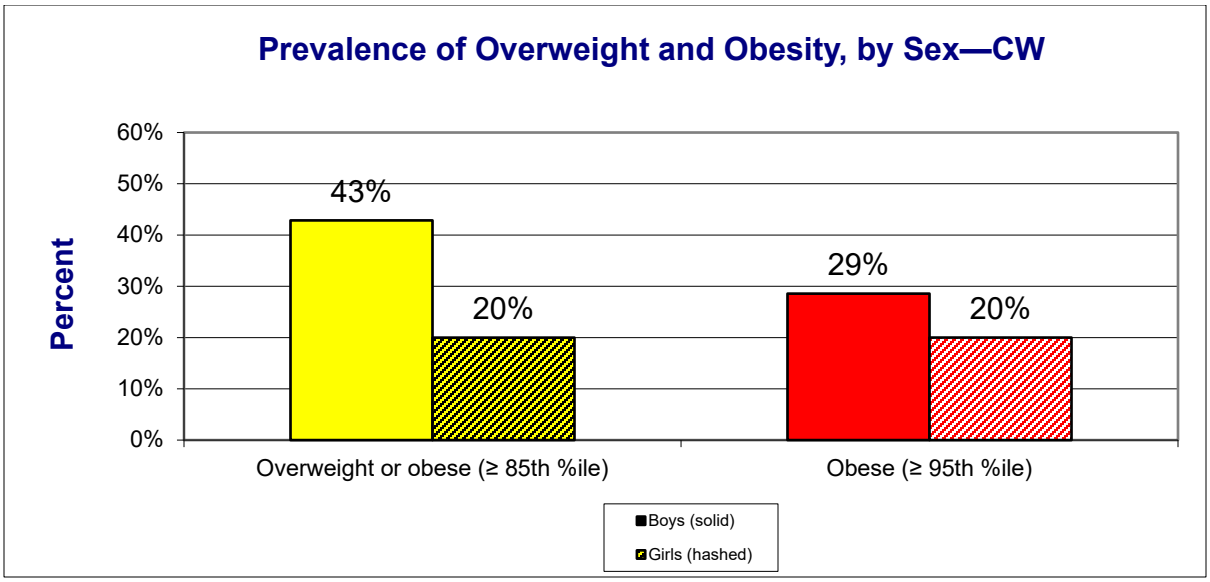


Figure 18. Prevalence of overweight and obesity by sex at CW.

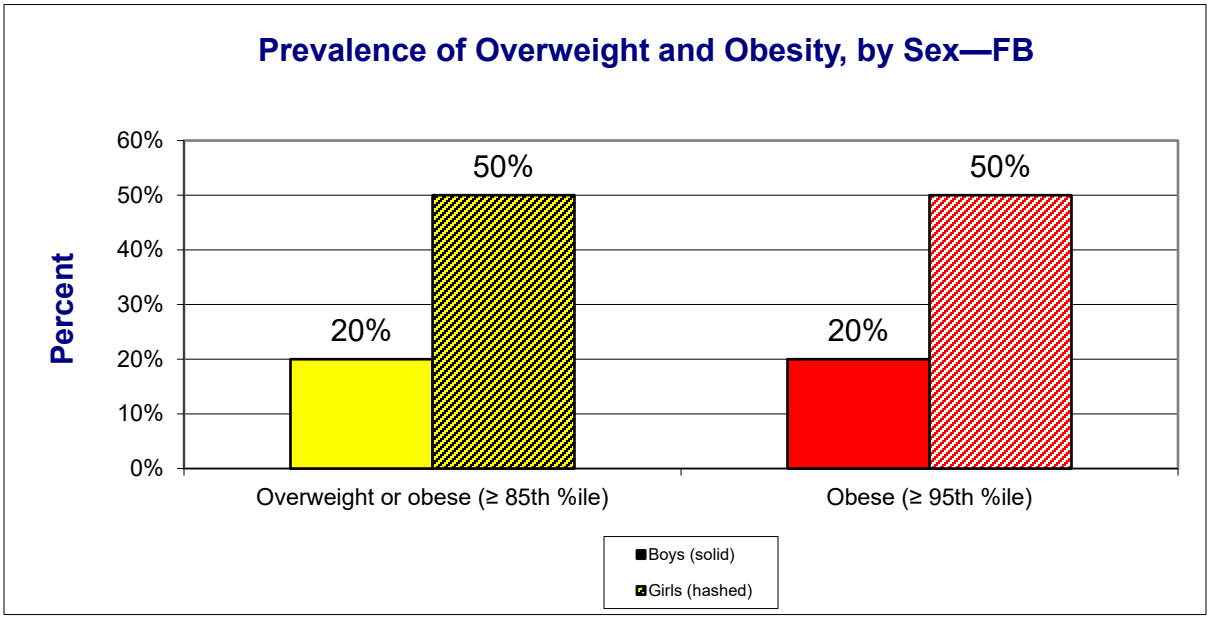


Figure 19. Prevalence of overweight and obesity by sex at FB.

Table 6. Summary of Children's BMI at CW

Summary of Children's BMI (CW)	Boys	Girls	Total
Number of children assessed:	7	5	12
Underweight (< 5th percentile)	29%	0%	17%
Normal BMI (5th–85th percentile)	29%	80%	50%
Overweight or obese (≥ 85th percentile)*	42%	20%	33%
Obese (≥ 95th percentile)	*29%*	*20%*	*25%*

*Terminology based on Barlow and the Expert Committee (2007).

Table 7. Summary of Children's BMI at FB

Summary of Children's BMI-for-Age (FB)	Boys	Girls	Total
Number of children assessed:	5	6	11
Underweight (< 5th percentile)	0%	0%	0%
Normal BMI (5th–85th percentile)	80%	50%	64%
Overweight or obese (≥ 85th percentile)*	20%	50%	36%
Obese (≥ 95th percent*ile)*	*20%*	*50%*	*36%*

*Terminology based on Barlow and the Expert Committee (2007).

Caretakers' education levels also differed across the two schools. At CW, parents or legal guardians of half the study subjects had an education level less than or equal to high school, and the other half of the cohort had an education level greater than high school. At FB, eights students had parents or legal guardians with an education level greater than high school, and only three students had parents or legal guardians with an education level less than or equal to high school (Table 8).

Table 9 shows the study population characteristics for asthma, hay fever, eczema, and allergy phenotypes of the two schools. Three students had food allergies at CW, and only one student had food allergies at FB. No students with blood eosinophilia were in this study cohort. Seven students had mothers with asthma in the study cohort. Twenty-five percent of the study cohort at CW and 36 percent of the study cohort at FB reported having eczema during the study period.

Table 8. Subject-Wise Characteristics of the Cohort at the Two Schools

School	Subject ID	Gender	Age	Weight (lb)	Height (in)	BMI (lb/in^2)	BMI for Age and Gender (pctl)	Weight Category	Race	Caretaker's Education
CW	CW1	F	10	67	53.35	16.55	39.2	Normal	Hispan	≤ High
	CW2	F	8	58.9	53.62	14.40	15.2	Normal	Hispan	≤ High
	CW3	F	8	64.4	54.72	15.12	27	Normal	Hispan	> High
	CW4	M	6	50	46.26	16.43	73.8	Normal	Hispan	> High
	CW5	M	8	45.8	51.18	12.29	0	Underwei	Hispan	≤ High
	CW6	M	8	45.8	51.18	12.29	0	Underwei	Hispan	≤ High
	CW7	M	8	134	58.27	27.75	99.4	Obese	Hispan	≤ High
	CW8	F	7	96.5	53.54	23.67	98.6	Obese	Hispan	> High
	CW9	M	6	82.5	50.39	22.84	99.4	Obese	Hispan	> High
	CW10	M	10	80.2	57.87	16.83	45.1	Normal	Hispan	> High
	CW11	F	10	77.2	61.97	14.13	5.2	Normal	Hispan	> High
FB	FB1	F	6	54	49.61	15.43	54.1	Normal	Black	> High
	FB2	M	9	152	58.27	31.48	99.4	Obese	Hispan	> High
	FB3	F	7	66	51.18	17.71	82.3	Normal	Hispan	≤ High
	FB4	M	5	40	43.31	14.99	37.4	Normal	Hispan	≤ High
	FB5	F	10	122	57.48	25.96	97.4	Obese	Hispan	> High
	FB6	M	6	52	47.64	16.11	69.1	Normal	Hispan	> High
	FB7	M	10	76	52.36	19.49	84.3	Normal	Hispan	≤ High
	FB8	F	5	46	44.09	16.63	82.6	Normal	White	> High
	FB9	F	7	89	52.76	22.48	98	Obese	Black	> High
	FB10	F	8	150	58.27	31.06	99.5	Obese	Black	> High
	FB11	M	8	62	51.97	16.14	57.4	Normal	Black	> High

Table 9. Study Population Characteristics for Asthma, Hay Fever, Eczema, and Allergy Phenotypes by School

Characteristics	All Subjects	CW	FB
n	23	12	11
Mother with Asthma	7 (30.4%)	5 (41.6%)	2 (18.1%)
Father with Asthma	6 (26%)	3 (25%)	3 (27%)
Mother with Hay Fever	14 (60.8%)	8 (66.6%)	6 (54.5%)
Father with Hay Fever	12 (52.1%)	8 (66.6%)	4 (36.3%)
Siblings with Asthma	9 (39.1%)	6 (50%)	5 (45.4%)
Siblings with Hay Fever	13 (56.5%)	8 (66.6%)	5 (45.4%)
Child with Eczema	7 (30.4%)	3 (25%)	4 (36.3%)
Child with Allergic Phenotype	14 (60.8%)	8 (66.6%)	6 (54.5%)
Child with Allergic Phenotype	4 (17.3%)	3 (25%)	1 (9%)
Child with Blood Eosinophilia	0 (0%)	0 (0%)	0 (0%)

Table 10 shows the details about the asthma medication intake by the study cohort at the two schools. All the students at FB took short-acting bronchodilators (SABA) for their asthma control. At CW, in comparison, only 7 out of the 12 students were on SABA. Two students at CW were on a combination of long-acting bronchodilators and inhaled corticosteroids (LABAIC). No students at FB were on LABAIC medication. Thirty percent of students at the two schools were on nasal corticosteroids (NC), and only four students out of 23 at the two schools were on systemic corticosteroids (SC) during the study period.

Table 10. Study Subjects' Asthma Medication Intake by School

Medicine Category	All Subjects	CW	FB
n	23	12	11
Leukotrieneblockers (LB)	14 (60.9%)	7 (58.3%)	7 (63.6%)
Short-Acting Bronchodilators (SABA)	18 (78.3%)	7 (58.3%)	11 (100%)
Inhaled Corticosteroids (IC)	14 (60.9%)	6 (50%)	8 (72.7%)
Combination of LABAIC	2 (8.7%)	2 (16.7%)	0 (0%)
NC	7 (30.4%)	4 (33.3%)	3 (27.3%)
SC	4 (17.4%)	2 (16.7%)	2 (18.2%)
Long-Acting Bronchodilators (LABA)	0 (0%)	0 (0%)	0 (0%)

Health Outcome Characterization

Exhaled Nitric Oxide Measurements

Table 11 and Table 12 contain the summary statistics by subjects for eNO measurements at CW and FB, respectively. Over the course of the study period, 363 eNO measurements were administered, with an average of 16 (range: 15–17) repeated measures per subject at CW and an average of 15 (range 13–16) repeated measures per subject at FB. These data are also presented graphically in box plots by subject for each school. The box plots for subject-wise eNO measurements at schools CW and FB are shown in Figure 20 and Figure 21, respectively. The overall median eNO levels at CW were 18.0 ppb (range: 5–74.5 ppb). These levels were in line with those found in other panel-based studies of asthmatic children (Delfino et al., 2006; Koenig et al., 2005; Liu et al., 2009). The overall spaghetti plots of the raw eNO data as a function of time for each subject at the two schools were plotted. Figure 22 and Figure 23 are these plots for CW and FB, respectively. The median level for eNO levels at FB was 32.0 ppb, with a huge range that varied from 5–112.5 ppb. This high variation in the raw data is more widespread than CW.

Table 11. Summary Statistics by Subject for eNO Measurements at CW

Subject ID	CW-01	CW-02	CW-03	CW-04	CW-05	CW-06	CW-07	CW-08	CW-09	CW-10	CW-11	CW-12
N	17	17	16	16	17	16	17	17	15	16	17	17
Mean	5.38	12.76	6.66	7.97	29.71	20.47	36.62	7.35	21.70	42.75	46.12	40.76
Median	5	12	5	6.75	29	19.75	35	6	22	43	41	38
SD	0.49	5.88	3.86	3.82	19.44	11.77	13.01	3.63	11.63	7.21	15.00	15.30
Max	6	26	20	16	66	39	70	19	39	55	74.5	68
Min	5	6	5	5	5	5	17	5	5	29.5	28	21
Q1(0.25)	5	7	5	5	10.5	10.75	26	5	12.5	39.5	33	28
Q2(Median)	5	12	5	6.75	29	19.75	35	6	22	43	41	38
Q3(0.75)	6	17.5	6	8.5	44	29.25	44	8	32.5	47.25	54	51.5
Q4(Max)	6	26	20	16	66	39	70	19	39	55	74.5	68
90th	6	18.4	8.75	14.5	55.4	36.5	49.6	10.6	35.3	52	68.9	63.8
99th	6	24.88	18.65	16	64.4	38.85	67.12	18.04	38.51	54.85	74.42	68

Table 12. Summary Statistics by Subject for eNO Measurements at FB

Subject ID	FB-1	FB-02	FB-03	FB-04	FB-05	FB-06	FB-07	FB-08	FB-09	FB-10	FB-11
N	13	16	16	14	16	16	16	13	15	15	15
Mean	7.38	13.06	78.25	25.14	33.25	6.94	75.41	6.92	45.20	64.47	30.20
Median	6	13	79	22	36	6.5	79	6	45	64	34
SD	3.12	4.43	12.70	11.24	7.08	2.35	24.14	2.47	14.26	8.86	14.50
Max	15	21	112	51	43	13	112.5	13	72	86	53
Min	5	5	57	13	20	5	25	5	25	49	6
Q1(0.25)	5	10	71.25	19.25	31	5	64.25	5	33	58	19.5
Q2(Median)	6	13	79	22	36	6.5	79	6	45	64	34
Q3(0.75)	8	17	82.75	23.75	38	8.25	90.5	8	57	69.5	37.5
Q4(Max)	15	21	112	51	43	13	112.5	13	72	86	53
90th percentile	11	17.5	87.5	42.1	40	9.5	103.5	9.8	60.6	72	46.6
99th percentile	14.52	20.55	108.4	49.96	42.55	12.55	111.8	12.64	70.46	84.04	52.44

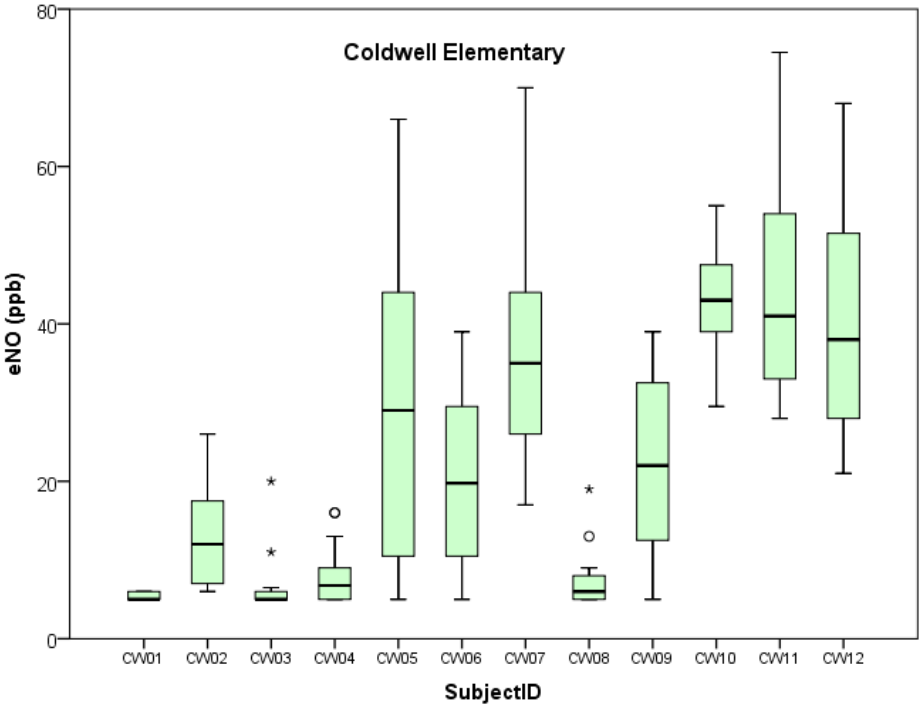


Figure 20. Box plots of eNO measurements by subjects for CW.

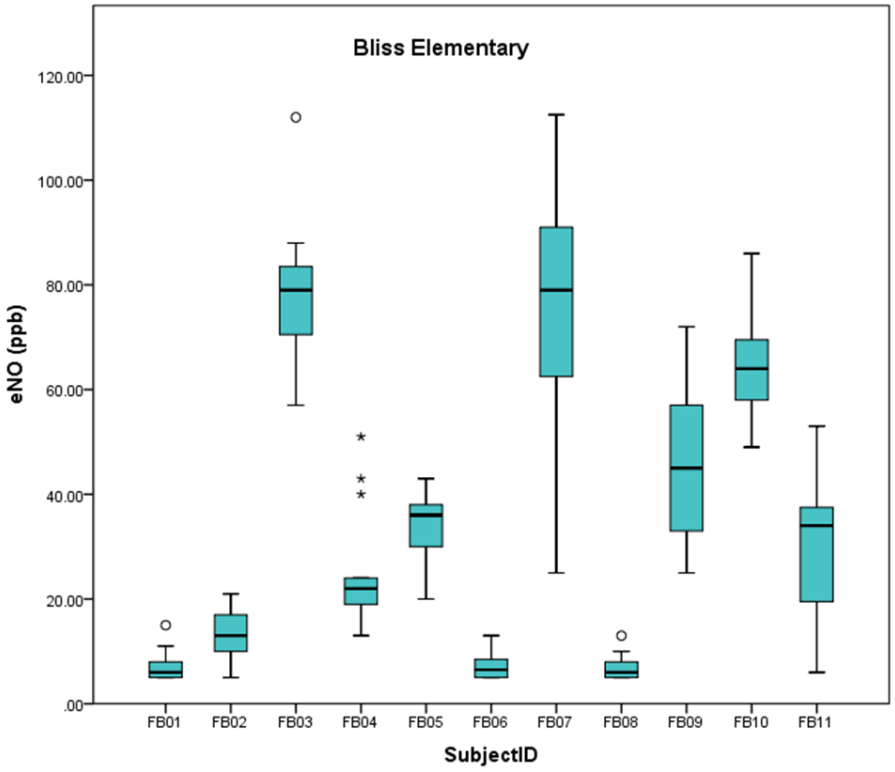


Figure 21. Box plots of eNO measurements by subjects for FB.

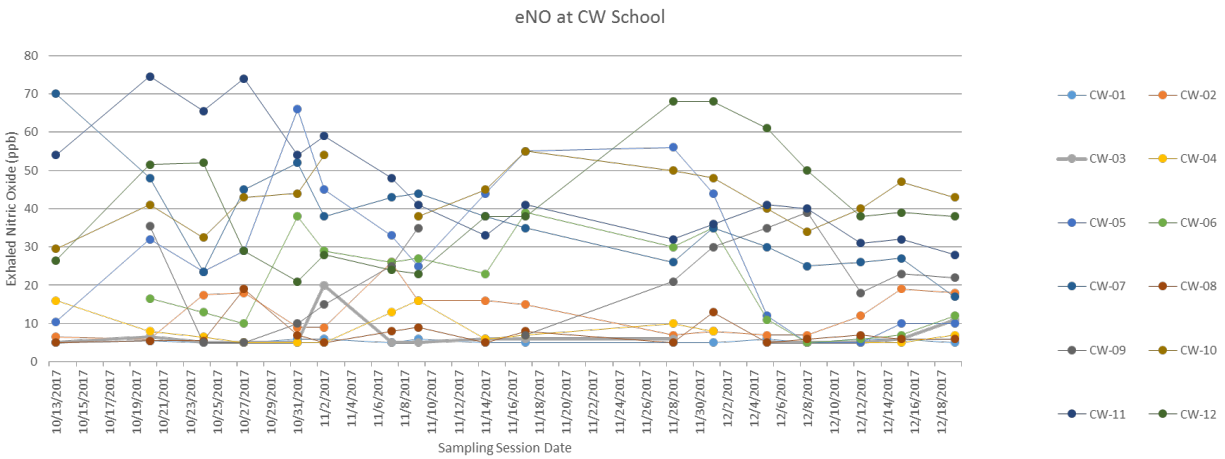


Figure 22. Time-series plots of eNO measurements by subjects for CW.

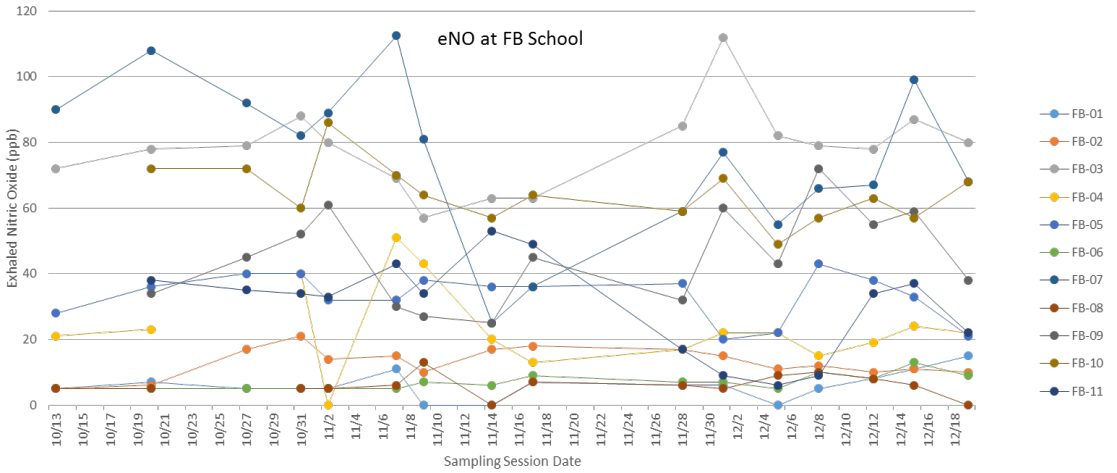


Figure 23. Time-series plots of eNO measurements by subjects for FB.

Assessment of Exhaled Nitric Oxide Measurement Distributions

The distribution of the eNO measurements across the two schools was assessed for epidemiologic analyses. Scatterplots of subject-specific means and variances of the eNO measurements at CW and FB are presented in Figure 24 and Figure 25, respectively. The corresponding Spearman correlations are shown in the graphs too. The subject-specific variance increased with the means; therefore, the log transformation of the eNO values was appropriate. Histograms of the outcome distributions, overall and by school, also illustrated the lognormal distribution of eNO. These are presented in Figure 26 for CW and Figure 27 for FB.

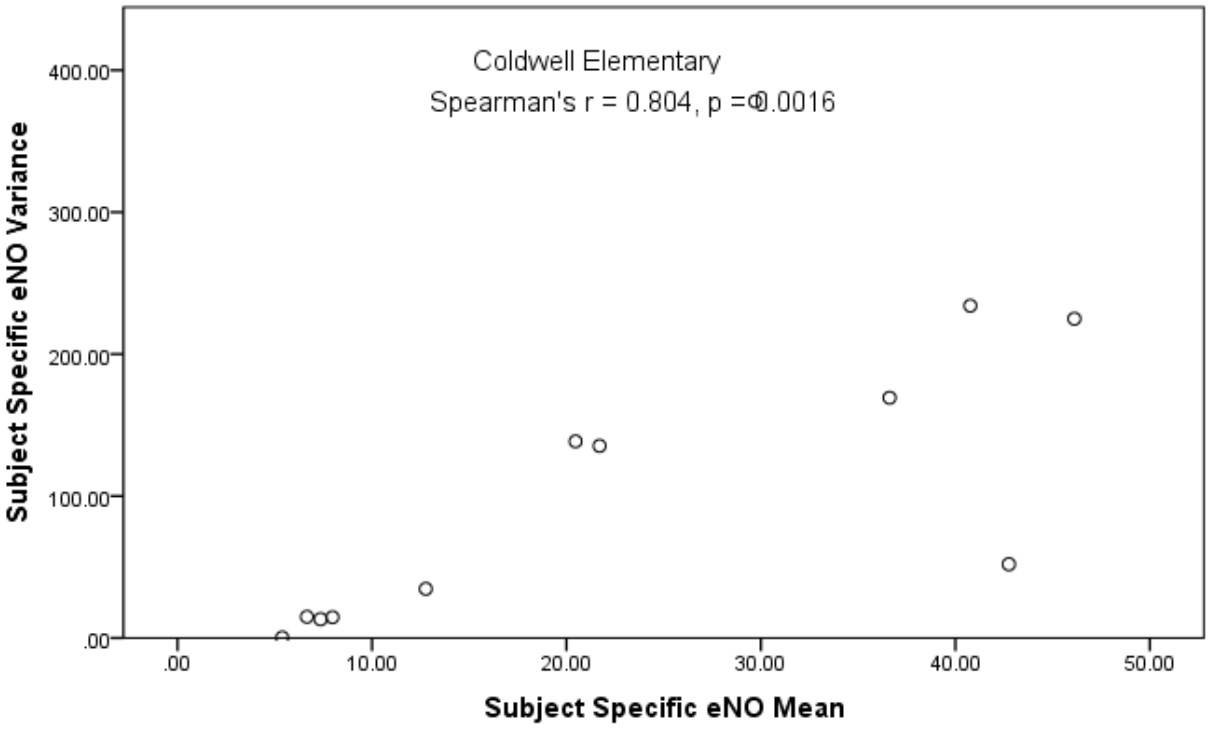


Figure 24. Scatterplot of subject-specific eNO Measurements mean and variances at CW.

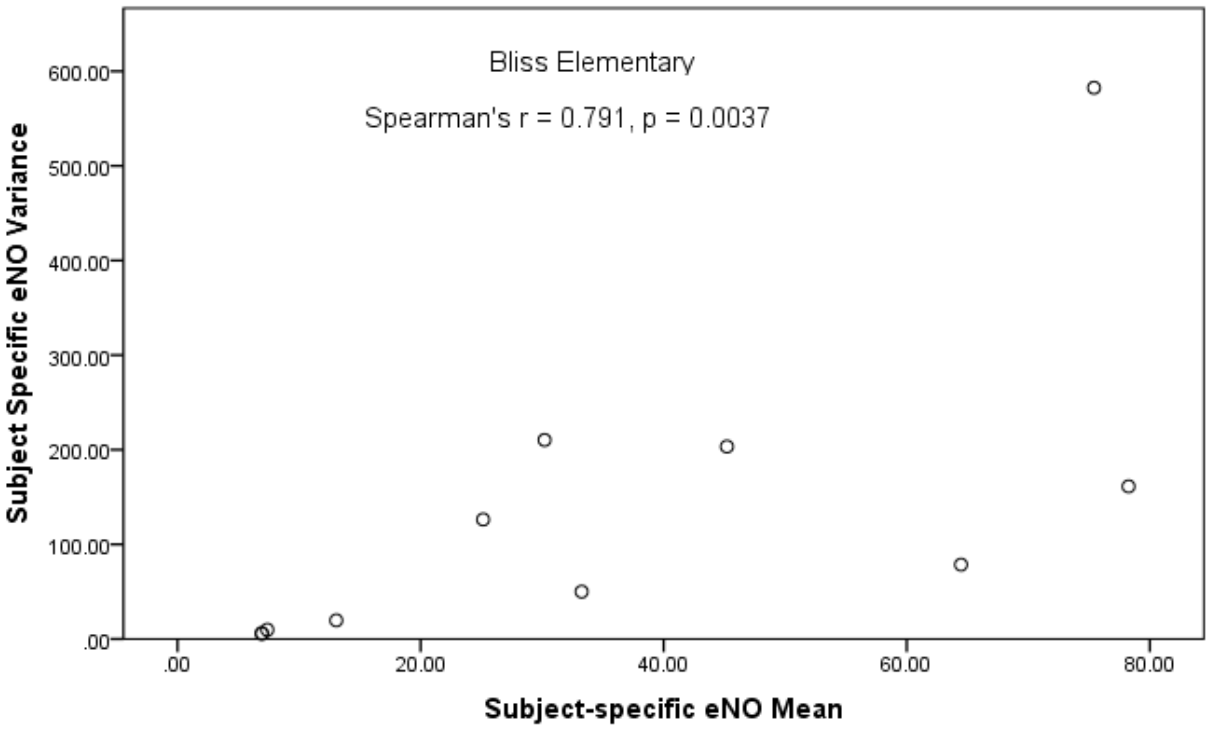


Figure 25. Scatterplot of subject-specific eNO measurements mean and variances at FB.

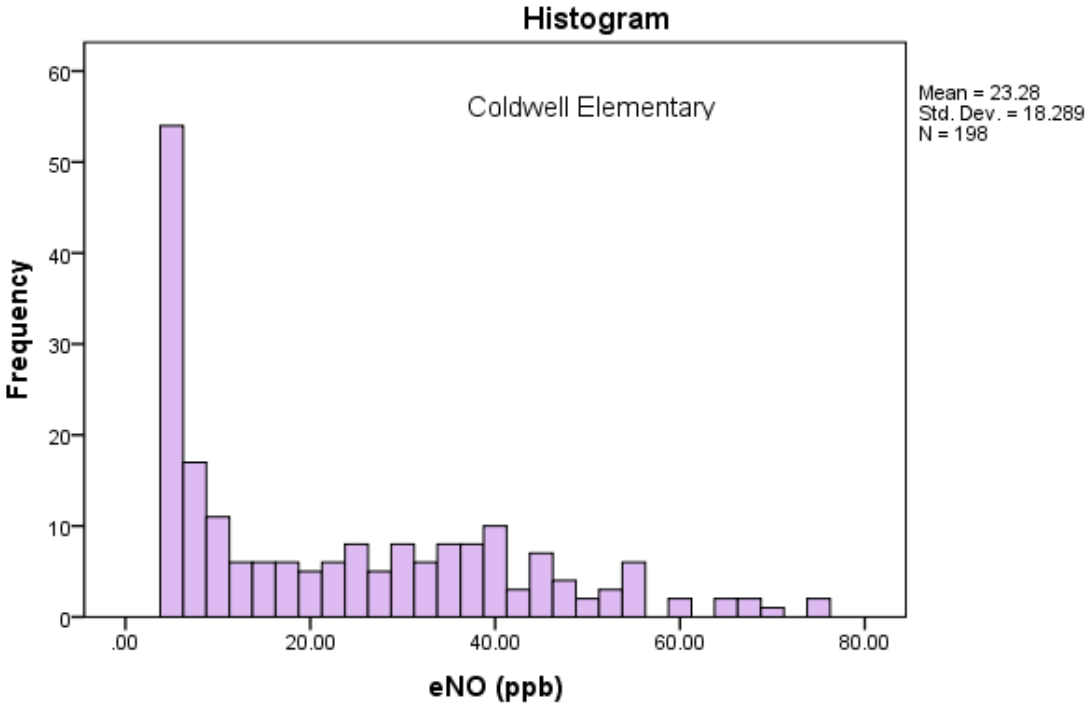


Figure 26. Histogram of overall eNO distribution at CW.

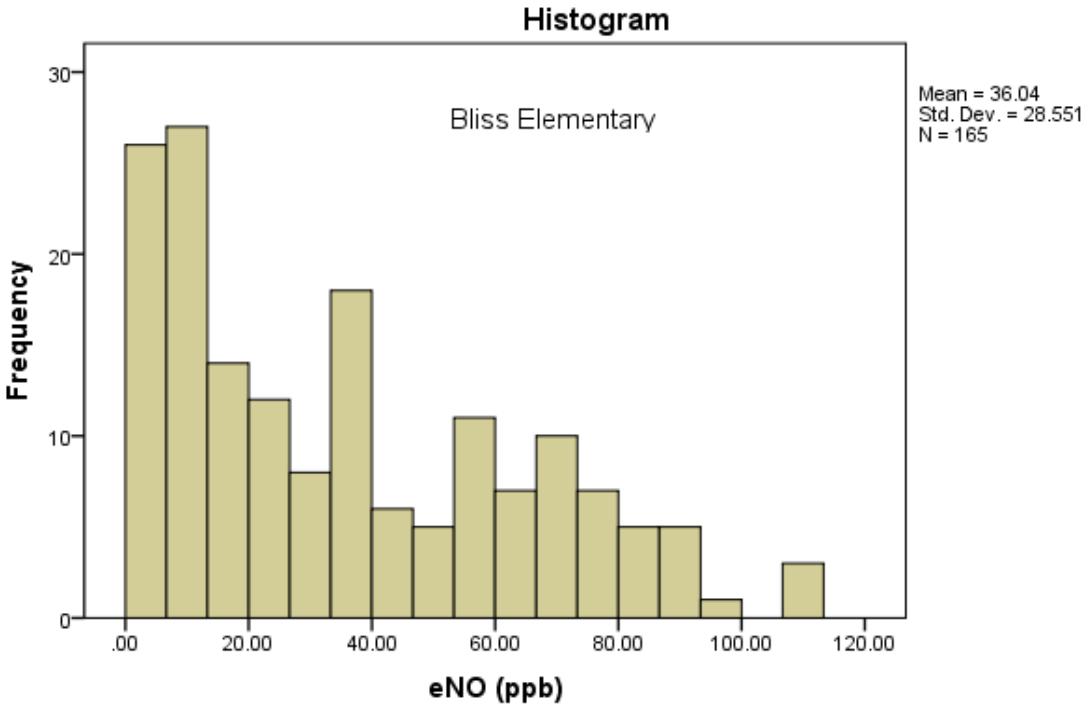


Figure 27. Histogram of overall eNO distribution at FB.

Lung Function Measurements

Spirometry measurement is one of the pulmonary function tests used widely in the medical field and research community. In this study, we used the EasyOne Spirometer by NDD Technologies. These tests are usually administered to people having chronic lung diseases, such as COPD, emphysema, and pulmonary fibrosis. Two important measurements gained from pulmonary function tests are FVC and FEV1. FVC measurement shows the amount of air a person can forcefully and quickly exhale after taking a deep breath. Doctors compare the FVC measurement with the predicted FVC based on the study subjects or patients' age, height, weight, and race/ethnicity. FVC helps the doctor diagnose a chronic lung disease, monitor the disease over time, and understand the severity of the condition. FVC can decrease in a similar way in both obstructive lung diseases (COPD) and restrictive lung diseases (pulmonary fibrosis).

FEV1 measurement shows the amount of air a person can forcefully exhale in 1 second of the FVC test. Determining the FEV1 measurement helps the doctor or the researcher understand the severity of the disease. Typically, low FEV1 scores show more severe stages of lung disease. In general, it is common in healthy individuals to be able to expel 75–80 percent of their vital capacity in the first second of the FVC test.

For CW, the summary statistics, box plots, and time-series plots for raw FVC (*l*) values for the study subjects are shown in Table 13, Figure 28, and Figure 29, respectively. The median value at CW for FVC was 2.02 *l* (range: 1–2.98 *l*). In contrast, the median value for FVC at FB was 1.46 ***l*** (Range: 0.55–2.72 ***l***). These raw values suggest that the lung function in general was better at CW than FB.

Table 13. Summary Statistics by Subject for FVC (*l*) at CW

Subject ID	CW-01	CW-02	CW-03	CW-04	CW-05	CW-06	CW-07	CW-08	CW-09	CW-10	CW-11	CW-12
N	17	17	16	17	17	16	17	17	16	16	17	17
Mean	2.04	1.84	2.21	1.37	1.77	1.87	2.82	1.60	1.83	2.53	2.49	2.68
Median	2.02	1.84	2.225	1.39	1.77	1.935	2.83	1.63	1.905	2.51	2.51	2.68
SD	0.05	0.10	0.14	0.18	0.26	0.31	0.11	0.18	0.24	0.10	0.11	0.10
Max	2.15	1.98	2.47	1.6	2.25	2.44	2.98	1.93	2.09	2.67	2.64	2.81
Min	1.96	1.56	1.92	1	1.06	1	2.66	1.25	1.32	2.42	2.28	2.47
Q1(0.25)	2.01	1.81	2.15	1.29	1.64	1.75	2.7	1.47	1.765	2.445	2.39	2.66
Q2(Median)	2.02	1.84	2.225	1.39	1.77	1.935	2.83	1.63	1.905	2.51	2.51	2.68
Q3(0.75)	2.06	1.91	2.27	1.52	1.9	2.025	2.92	1.73	1.972	2.642	2.6	2.76
Q4(Max)	2.15	1.98	2.47	1.6	2.25	2.44	2.98	1.93	2.09	2.67	2.64	2.81
90th percentile	2.10	1.934	2.37	1.578	2.014	2.115	2.942	1.77	2.04	2.66	2.61	2.794
99th percentile	2.14	1.973	2.46	1.598	2.213	2.396	2.976	1.904	2.084	2.67	2.635	2.808

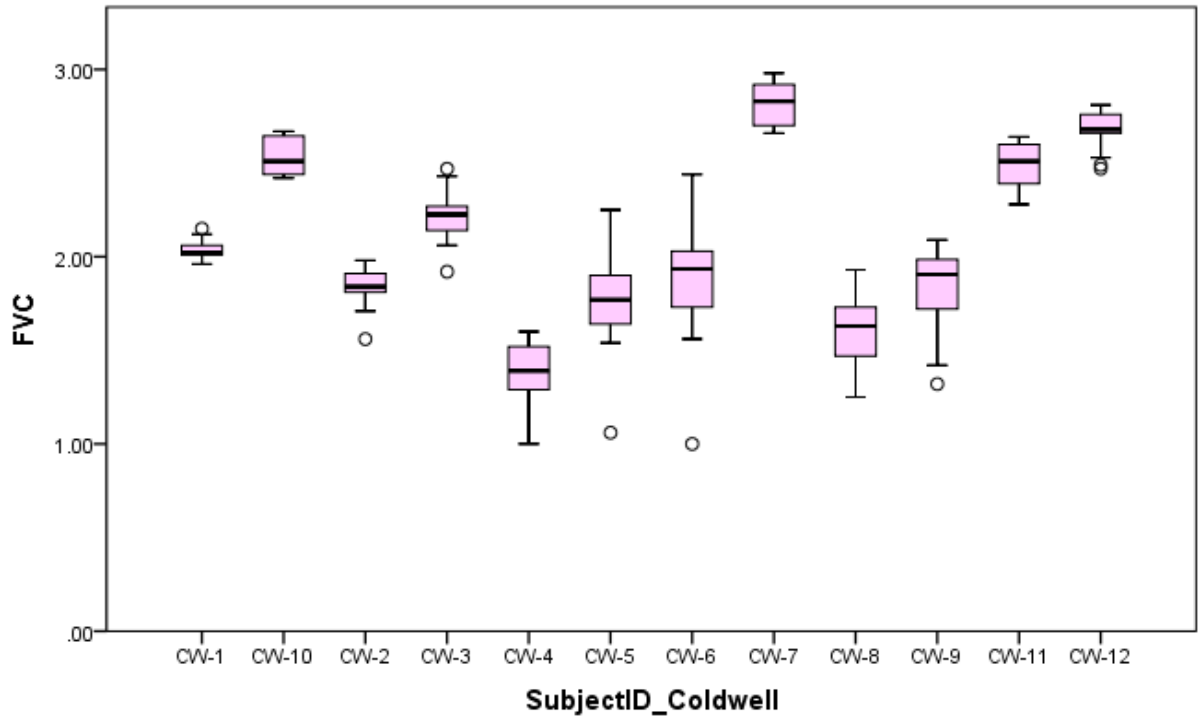


Figure 28. Box plots of FVC (*l*) by subjects at CW.

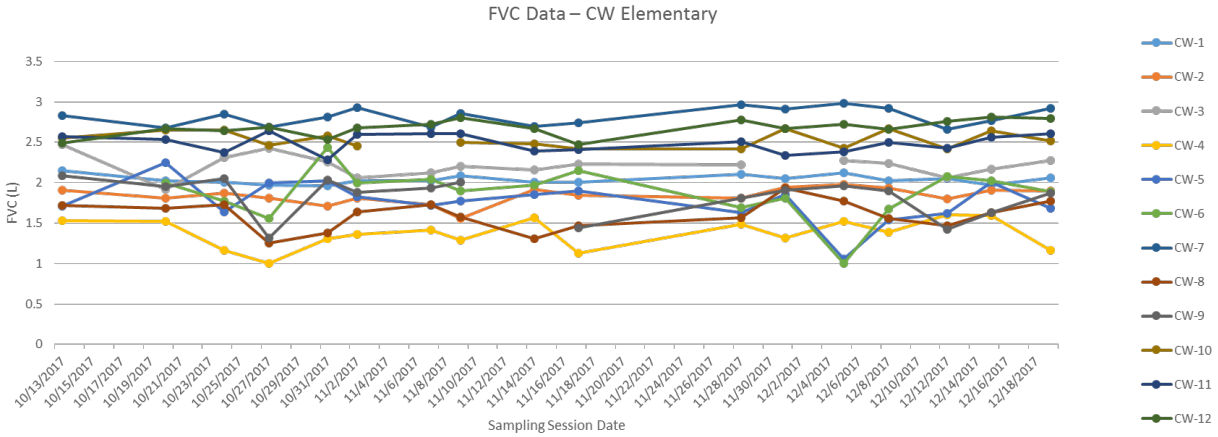


Figure 29. Time-series plots of FVC (*l*) by subjects at CW.

The summary statistics, box plots, and spaghetti plots for raw FVC (*l*) values for the study subjects at FB are shown in Table 14, Figure 30, and Figure 31, respectively. The scatterplot of subject-specific FVC mean and variance at CW and the histogram are shown in Figure 32 and Figure 33, respectively. The distribution of the raw data suggested no need for the log transformation of the FVC (*l*) data for epidemiologic analysis. Similarly, subject-specific FVC mean and variance and histogram at FB are shown in Figure 34 and Figure 35, respectively.

Table 14. Basic Statistics FVC (*l*) at FB

Subject ID	FB-1	FB-2	FB-3	FB-4	FB-5	FB-6	FB-7	FB-8	FB-9	FB-10	FB-11
N	13	16	16	14	16	16	16	13	15	15	15
Mean	1.20	2.37	1.46	1.01	1.88	1.30	2.11	1.10	1.33	1.93	1.35
Median	1.2	2.355	1.51	1.045	1.89	1.3	2.1	1.12	1.31	1.95	1.38
SD	0.10	0.20	0.12	0.19	0.09	0.19	0.27	0.13	0.13	0.10	0.18
Max	1.37	2.72	1.63	1.27	2.05	1.63	2.52	1.3	1.62	2.04	1.56
Min	1.02	2.08	1.26	0.55	1.69	0.84	1.55	0.86	1.18	1.72	0.92
Q1(0.25)	1.13	2.22	1.375	0.895	1.8375	1.255	2.06	0.98	1.215	1.865	1.285
Q2(Median)	1.2	2.355	1.51	1.045	1.89	1.3	2.1	1.12	1.31	1.95	1.38
Q3(0.75)	1.28	2.4625	1.5325	1.11	1.92	1.435	2.2	1.17	1.405	2.005	1.485
Q4(Max)	1.37	2.72	1.63	1.27	2.05	1.63	2.52	1.3	1.62	2.04	1.56
90th percentile	1.304	2.66	1.595	1.219	2.0	1.465	2.46	1.26	1.492	2.02	1.538
99th percentile	1.3628	2.7185	1.6285	1.2661	2.0455	1.606	2.52	1.2964	1.606	2.0372	1.5586

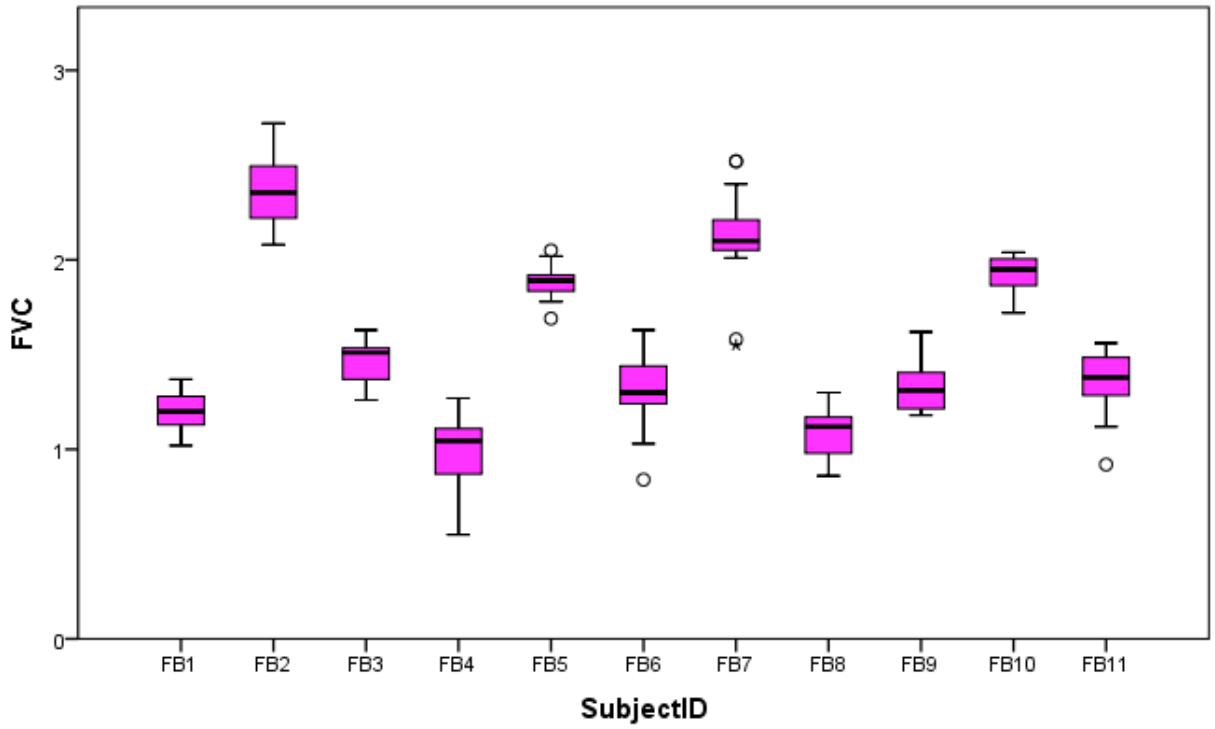


Figure 30. Box plots of FVC (*l*) by subjects at FB.

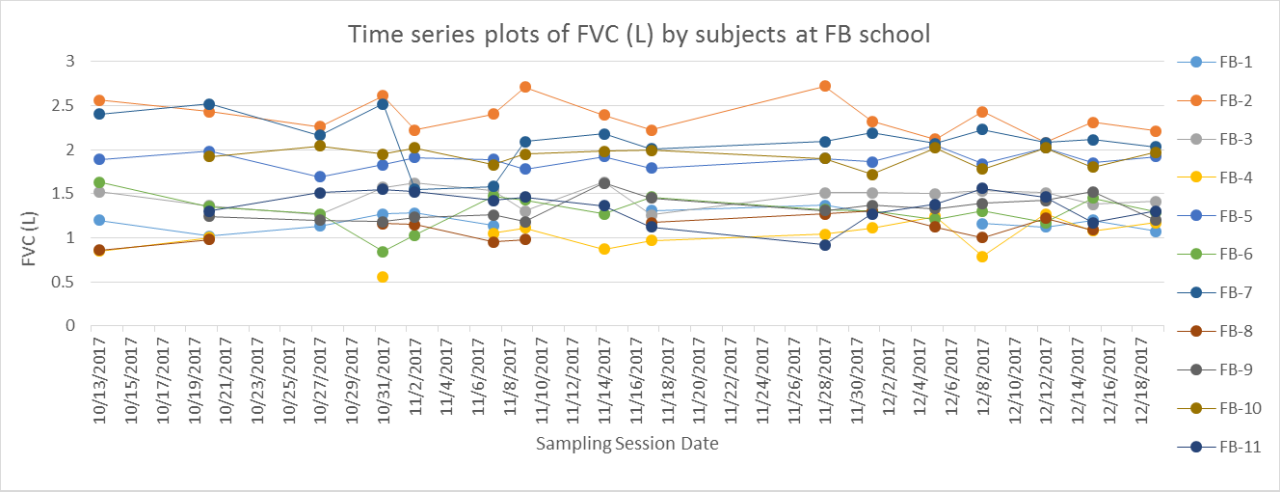


Figure 31. Time-series plots of FVC (*l*) by subjects at FB.

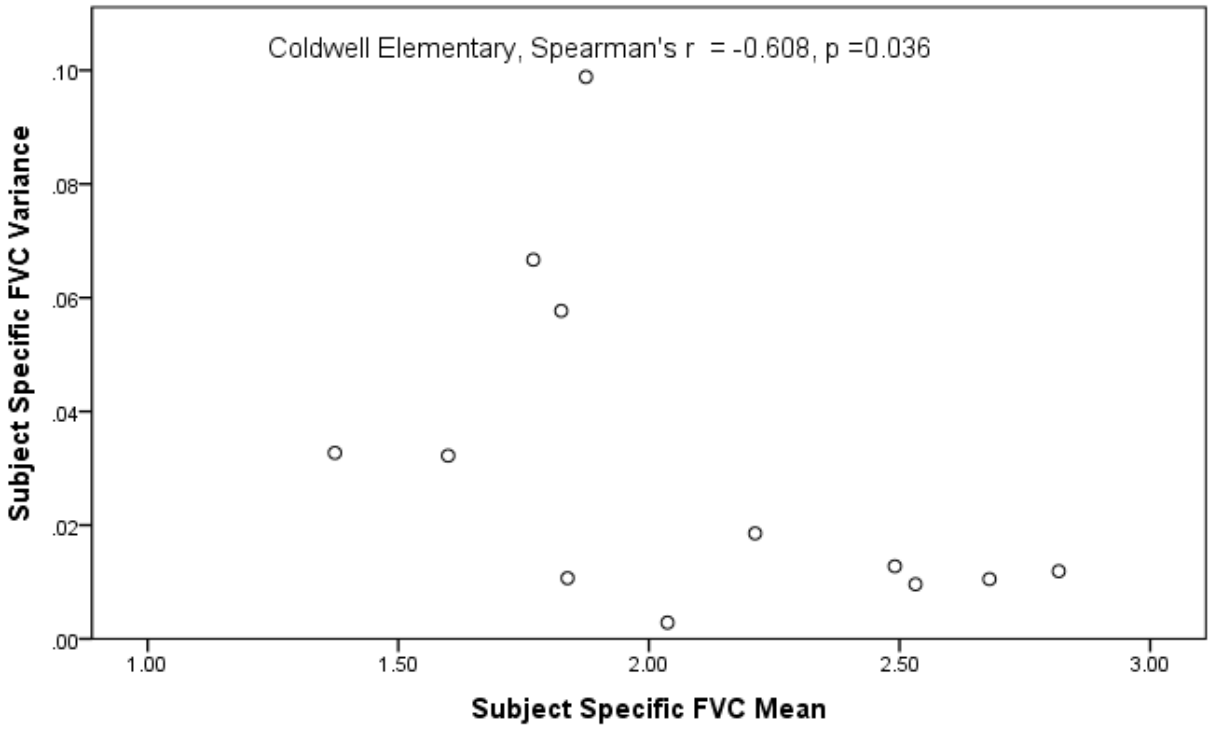


Figure 32. Scatterplot of subject-specific FVC mean and variance at CW.

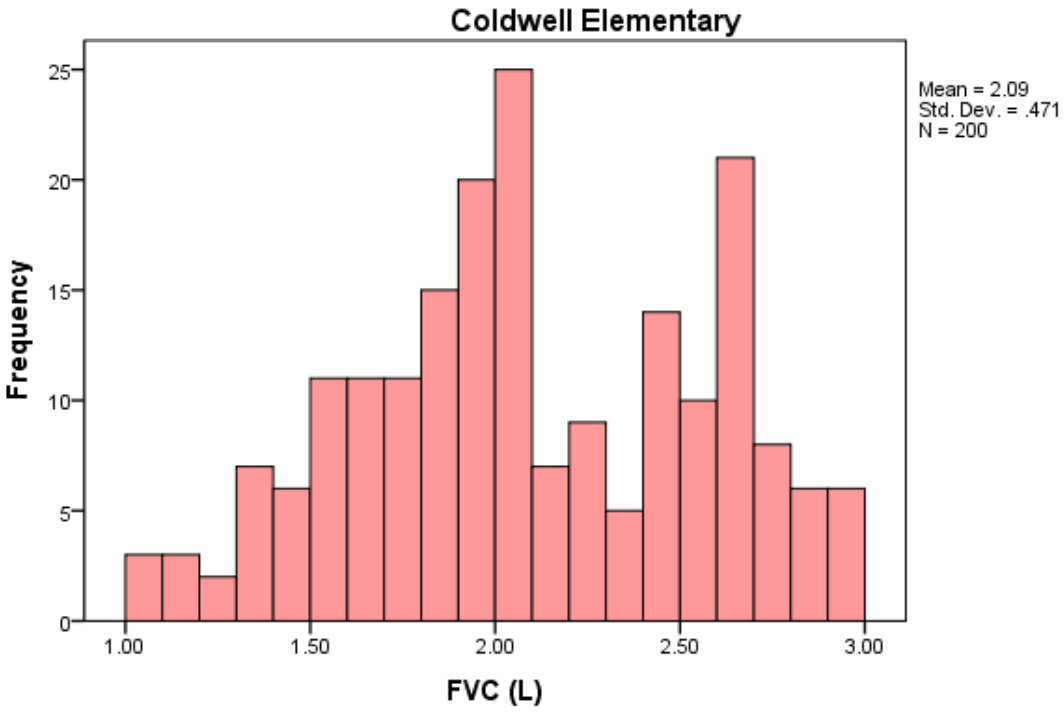


Figure 33. Histogram of overall FVC (*l*) at CW.

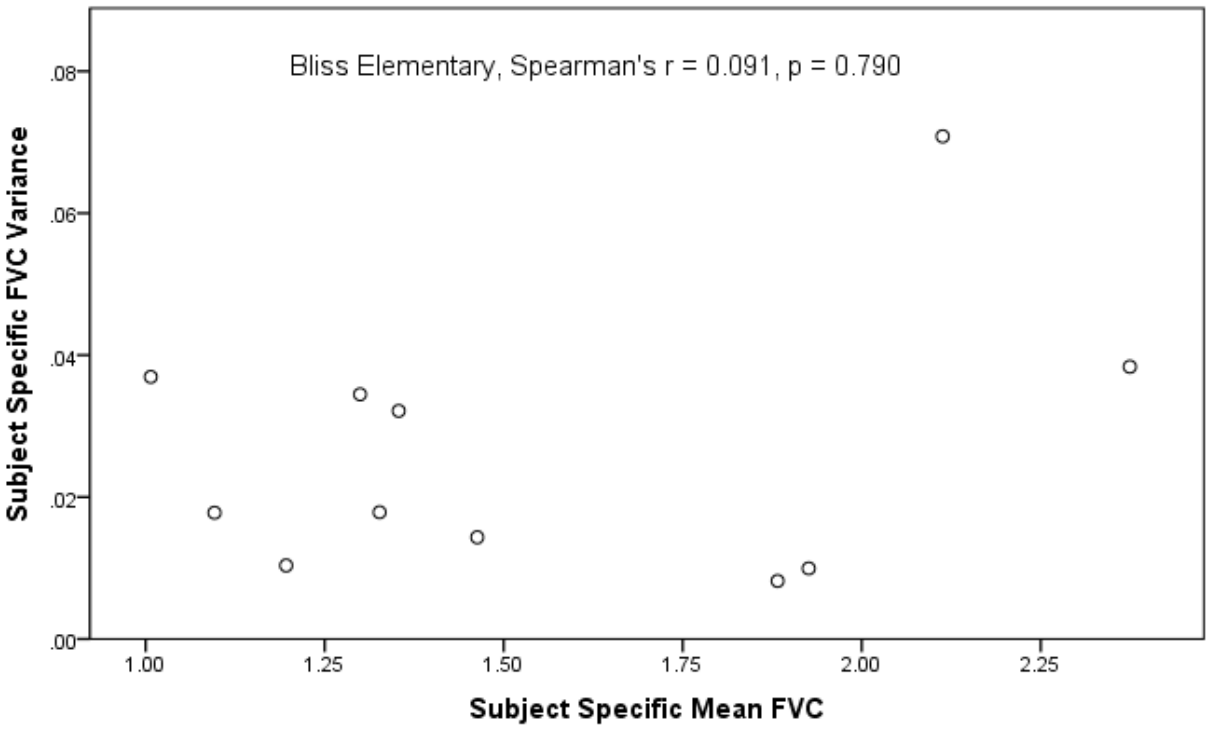


Figure 34. Scatterplot of subject-specific FVC mean and variance at FB.

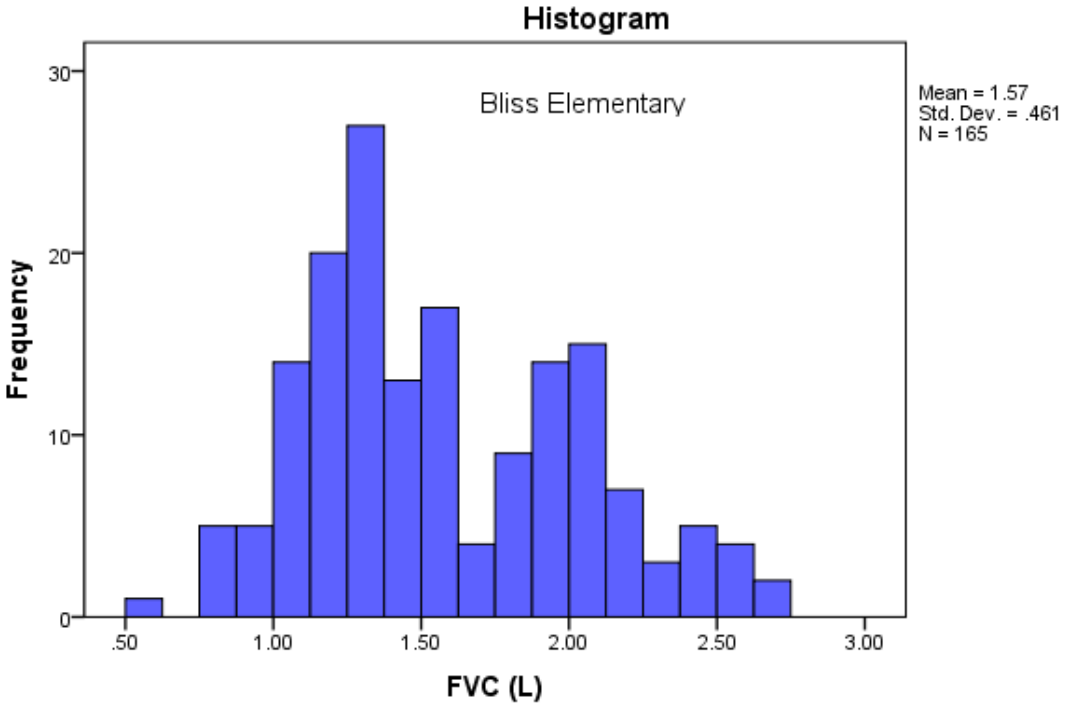


Figure 35. Histogram of overall FVC (*l*) at FB.

For CW, the summary statistics, box plots, and time-series plots for raw FVC (percent predicted) values for the study subjects are shown in Table 15, Figure 36, and Figure 37, respectively. The summary statistics, box plots, and time-series plots for raw FVC (percent predicted) values for the study subjects at FB are shown in Table 16, Figure 38, and Figure 39, respectively.

Table 15. Summary Statistics by Subject for FVC (% Predicted) at CW

Subject ID	CW-01	CW-02	CW-03	CW-04	CW-05	CW-06	CW-07	CW-08	CW-09	CW-10	CW-11	CW-12
N	14	14	13	14	14	14	14	14	13	13	14	14
Mean	97.14	93.57	107.0	104.5	90.50	94.50	102.4	83.36	100.0	92.69	82.79	91.07
Median	97	93	107	105	93	98	103	84	106	92	83	91.5
SD	2.25	6.16	5.32	13.88	12.87	18.15	3.98	10.79	13.90	3.30	3.96	3.34
Max	101	102	119	122	104	126	108	103	114	99	88	95
Min	94	80	98	76	55	52	97	67	74	88	76	84
Q1(0.25)	96	90	104	99.25	84.75	86.25	98.25	75.25	91	90	79.25	90
Q2(Median)	97	93	107	105	93	98	103	84	106	92	83	91.5
Q3(0.75)	98	98.75	109	115.5	97.5	104.7	106	91	110	96	86.75	93.75
Q4(Max)	101	102	119	122	104	126	108	103	114	99	88	95
90th percentile	100	99	111.6	121.4	104	109.8	106.7	94.4	112.6	96.8	87	94.7
99th percentile	100.8	101.6	118.1	122	104	124.0	107.8	101.9	113.8	98.76	87.87	95

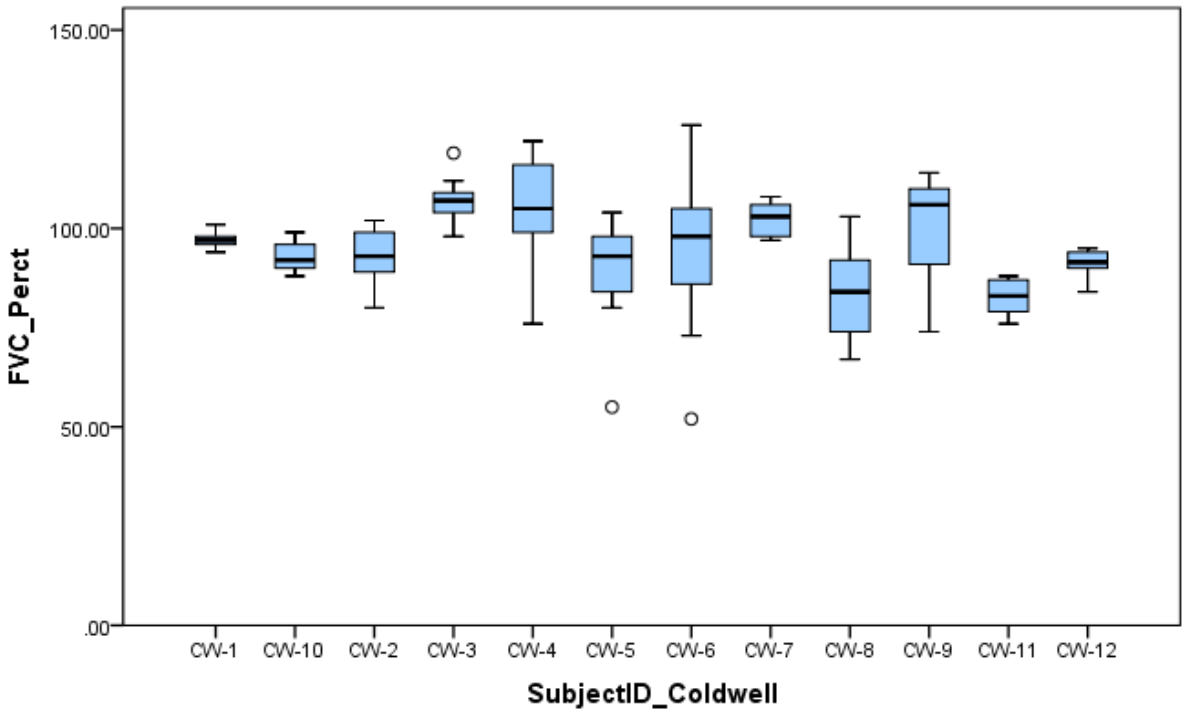


Figure 36. Box plots of FVC (% predicted) by subjects at CW.

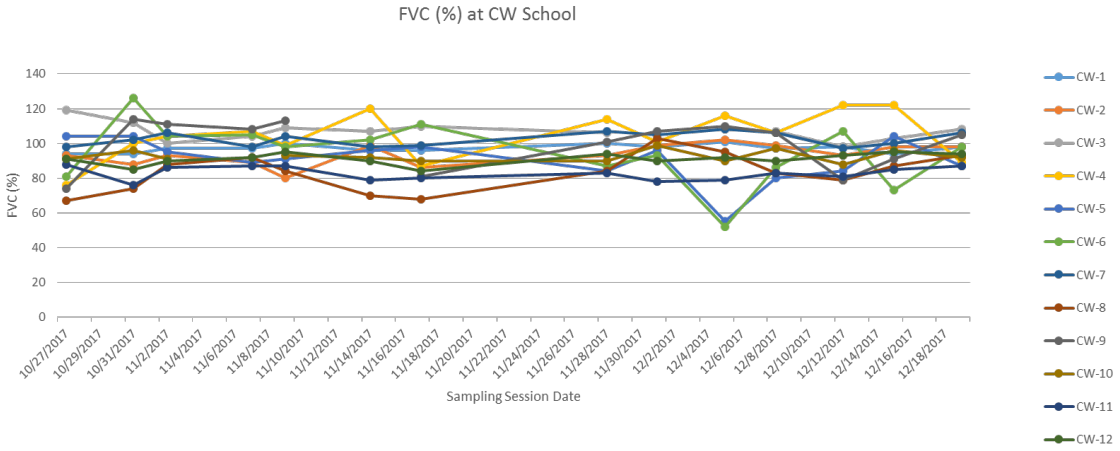


Figure 37. Time-series plots of FVC (%) by subjects at CW.

Table 16. Summary Statistics by Subject for FVC (% Predicted) at FB

Subject ID	FB-1	FB-2	FB-3	FB-4	FB-5	FB-6	FB-7	FB-8	FB-9	FB-10	FB-11
N	11	14	14	*	14	14	14	*	14	14	14
Mean	86.27	84.64	92.71		80.00	88.79	100.14		85.00	87.93	82.00
Median	89	83.5	94		80	90.5	101.5		84	89.5	84.5
SD	14.06	7.81	10.64		5.16	11.97	11.99		12.32	4.98	11.07
Max	101	98	120		92	102	123		106	94	94
Min	49	72	78		71	59	75		55	78	56
Q1(0.25)	83.5	80	86.5		77.25	85.25	98.75		78.5	84	77.25
Q2(Median)	89	83.5	94		80	90.5	101.5		84	89.5	84.5
Q3(0.75)	94	87.5	95.75		81	97.25	105.75		92.5	91.75	90.25
Q4(Max)	101	98	120		92	102	123		106	94	94
90th percentile	97	96.8	100.1		85.7	101.7	107.4		97.8	92.7	93.4
99th percentile	100.6	98	117.53		91.22	102	121.05		105.09	93.87	94

*No data collected.

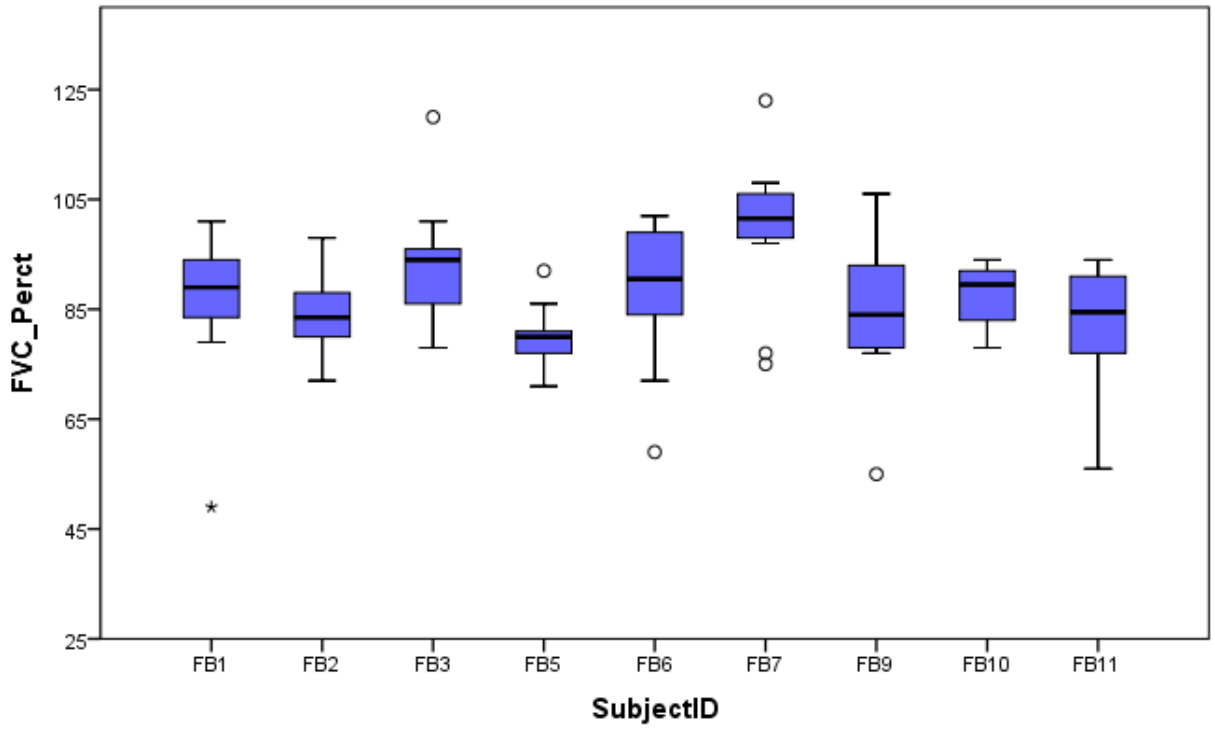


Figure 38. Box plots of FVC (% predicted) by subjects at FB.

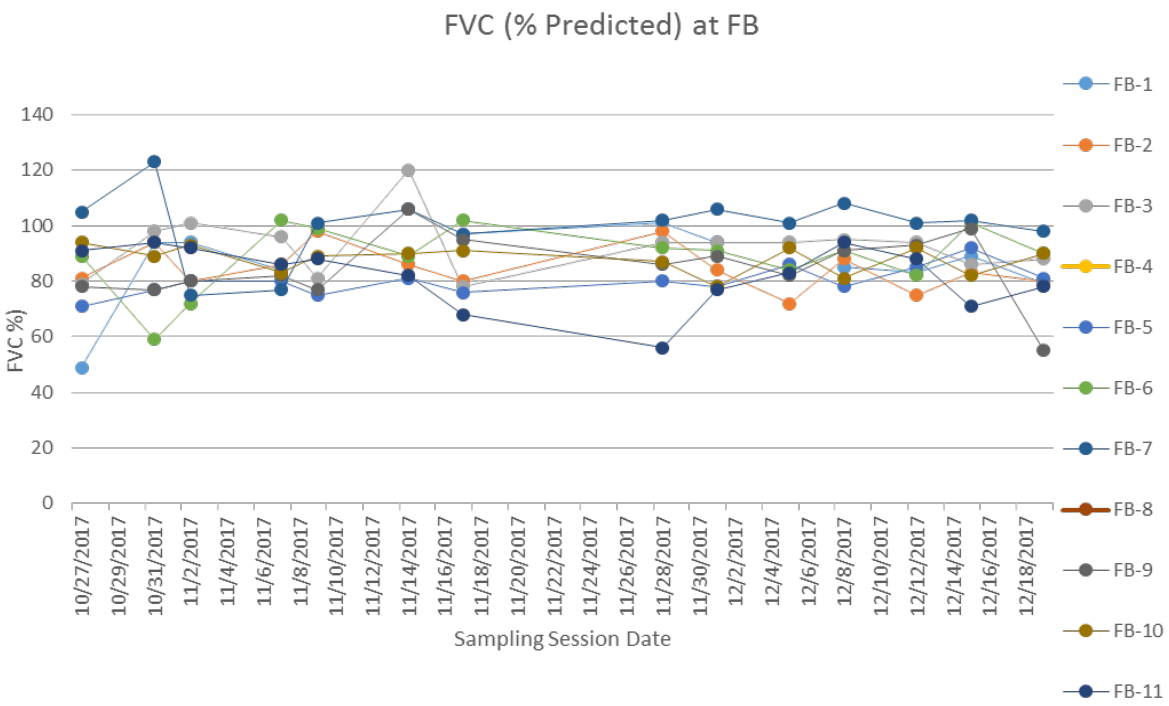


Figure 39. Time-series plots of FVC (% Predicted) by subjects at FB.

For CW, the summary statistics, box plots, and time-series plots for raw FEV1 (*l*) values for the study subjects are shown in Table 17, Figure 40, and Figure 41, respectively. The median value at school CW for FVC was 1.69 *l* (range: 0.48–2.55 *l*). In contrast, the median value for FEV1 (*l*) at FB was 1.27 *l* (range: 0.40–2.22 *l*). These raw values suggest that lung function in general was better at CW than FB.

The summary statistics, box plots, and spaghetti plots for raw FEV1 (*l*) values for the study subjects at FB are shown in Table 18, Figure 42, and Figure 43, respectively. The scatterplot of subject-specific FEV1 mean and variance at CW and the histogram are shown in Figure 44 and Figure 45, respectively. Similar to FVC data at the two schools, the distribution of the raw FEV1 data suggested no need for the log transformation for epidemiologic analysis. Similarly, Figure 46 and Figure 47 are the scatterplot of subject-specific FVC mean and variance and histogram, respectively, at FB.

Table 17. Summary Statistics by Subjects for FEV1 at CW

Subject ID	CW-01	CW-02	CW-03	CW-04	CW-05	CW-06	CW-07	CW-08	CW-09	CW-10	CW-11	CW-12
N	17	17	16	17	17	16	17	17	16	16	17	17
Mean	1.97	1.54	1.87	1.20	1.16	1.24	2.27	1.14	1.41	2.38	2.05	2.27
Median	1.99	1.57	1.865	1.2	1.19	1.38	2.28	1.14	1.47	2.395	2.08	2.27
SD	0.05	0.09	0.12	0.14	0.32	0.33	0.08	0.24	0.21	0.10	0.13	0.09
Max	2.04	1.63	2.11	1.36	1.59	1.63	2.42	1.5	1.77	2.55	2.24	2.42
Min	1.83	1.29	1.67	0.9	0.48	0.5	2.11	0.63	0.92	2.22	1.81	2.06
Q1(0.25)	1.95	1.49	1.782	1.14	0.95	1.022	2.21	0.98	1.347	2.287	1.97	2.24
Q2(Median	1.99	1.57	1.865	1.2	1.19	1.38	2.28	1.14	1.47	2.395	2.08	2.27
Q3(0.75)	2	1.61	1.935	1.34	1.44	1.512	2.34	1.34	1.505	2.452	2.12	2.34
Q4(Max)	2.04	1.63	2.11	1.36	1.59	1.63	2.42	1.5	1.77	2.55	2.24	2.42
90th percentile	2.03	1.63	2.015	1.354	1.506	1.57	2.352	1.484	1.555	2.515	2.21	2.358
99th percentile	2.038	1.63	2.098	1.36	1.580	1.625	2.412	1.498	1.741	2.548	2.235	2.412

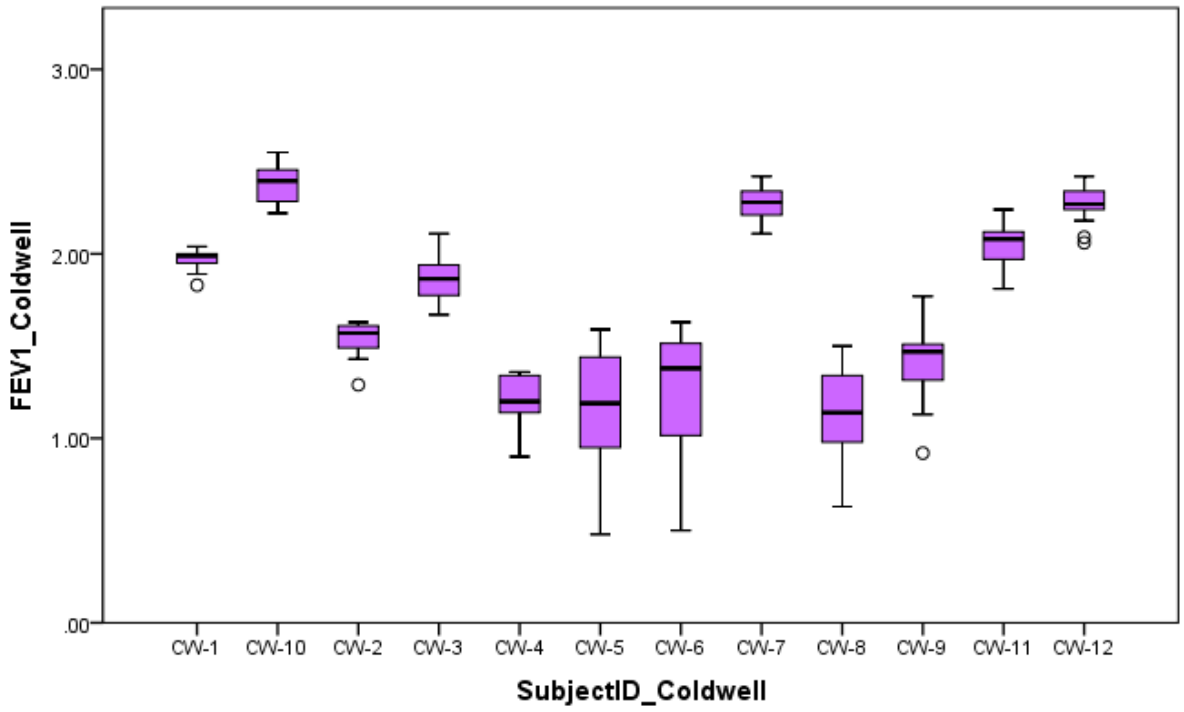


Figure 40. Box plots of FEV1 by subjects at CW.

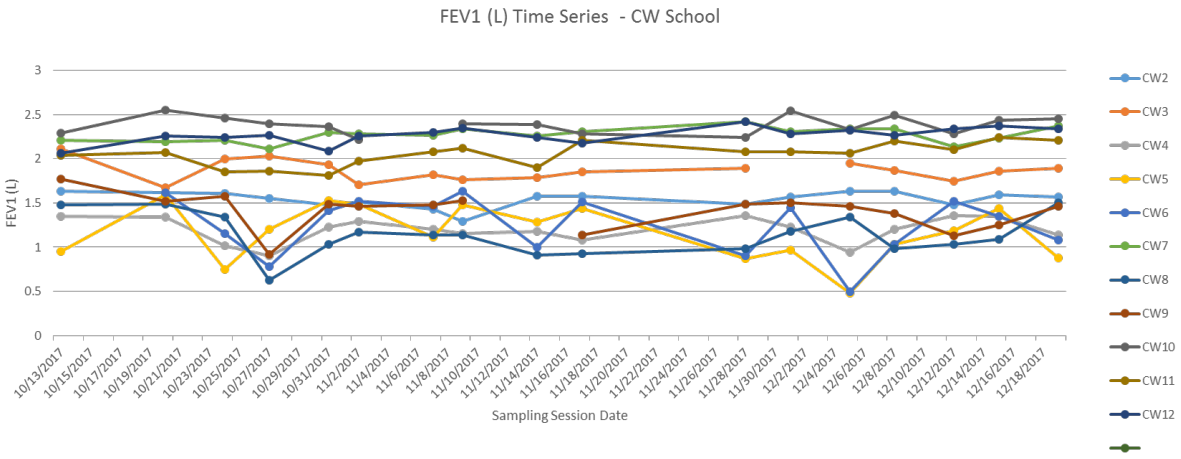


Figure 41. Time-series plots of FEV1 by subjects at CW.

Table 18. Summary Statistics by Subject for FEV1 (*l*) at FB

Subject ID	FB-1	FB-2	FB-3	FB-4	FB-5	FB-6	FB-7	FB-8	FB-9	FB-10	FB-11
N	13	16	16	14	16	16	16	13	15	15	15
Mean	0.91	1.85	1.19	0.75	1.69	1.22	1.59	1.05	0.99	1.83	1.17
Median	0.87	1.855	1.155	0.765	1.705	1.27	1.615	1	0.94	1.84	1.2
SD	0.12	0.21	0.18	0.22	0.09	0.19	0.20	0.12	0.14	0.10	0.19
Max	1.14	2.22	1.53	1.13	1.85	1.45	1.8	1.22	1.31	1.98	1.38
Min	0.72	1.48	0.94	0.4	1.52	0.8	0.99	0.81	0.85	1.65	0.69
Q1(0.25)	0.82	1.75	1.0625	0.665	1.6475	1.185	1.5775	0.97	0.88	1.775	1.065
Q2(Median)	0.87	1.855	1.155	0.765	1.705	1.27	1.615	1	0.94	1.84	1.2
Q3(0.75)	0.96	1.9425	1.325	0.8725	1.7325	1.315	1.74	1.16	1.095	1.89	1.32
Q4(Max)	1.14	2.22	1.53	1.13	1.85	1.45	1.8	1.22	1.31	1.98	1.38
90th percentile	1.07	2.105	1.46	0.994	1.8	1.425	1.755	1.176	1.14	1.936	1.372
99th percentile	1.134	2.211	1.521	1.1131	1.847	1.45	1.794	1.2152	1.2862	1.9744	1.38

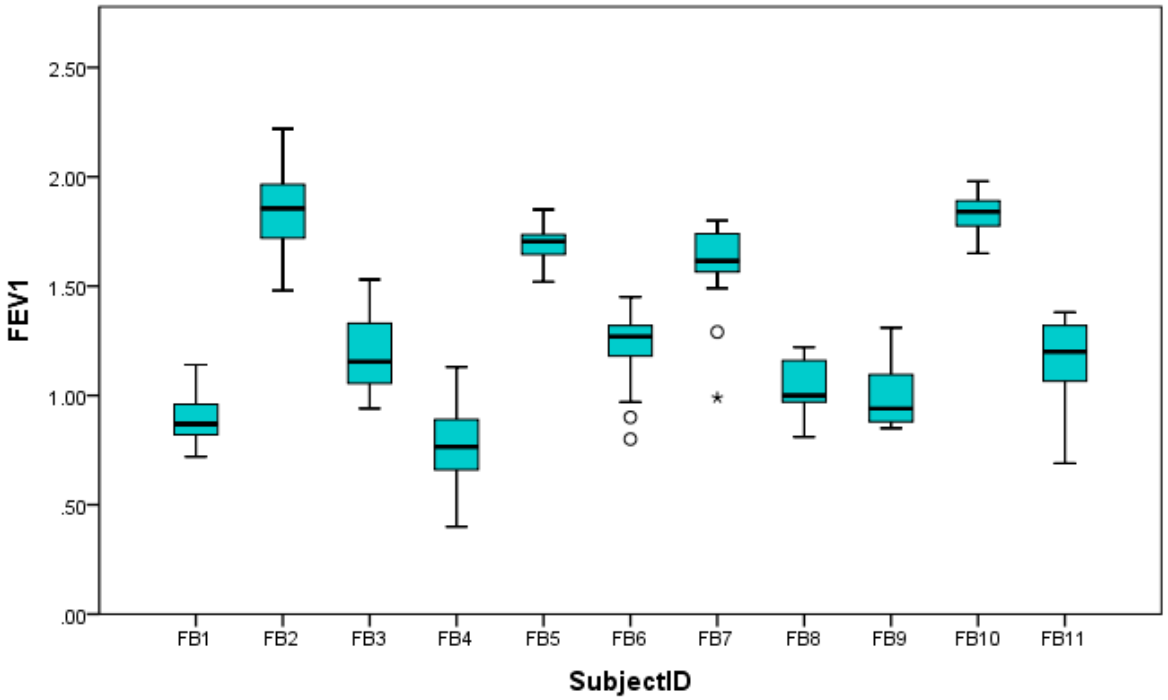


Figure 42. Box plots of FEV1 by subjects at FB.

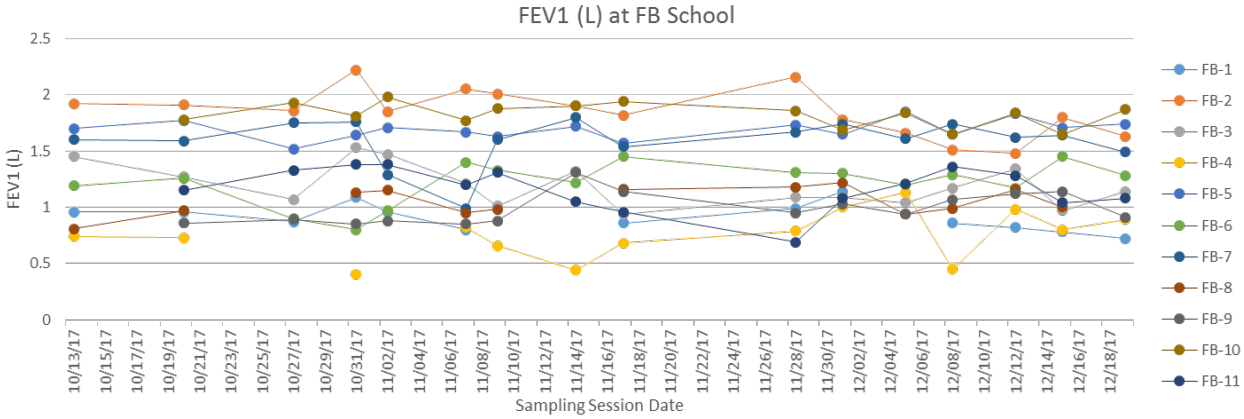


Figure 43. Time-series plots of FEV1 by subjects at FB.

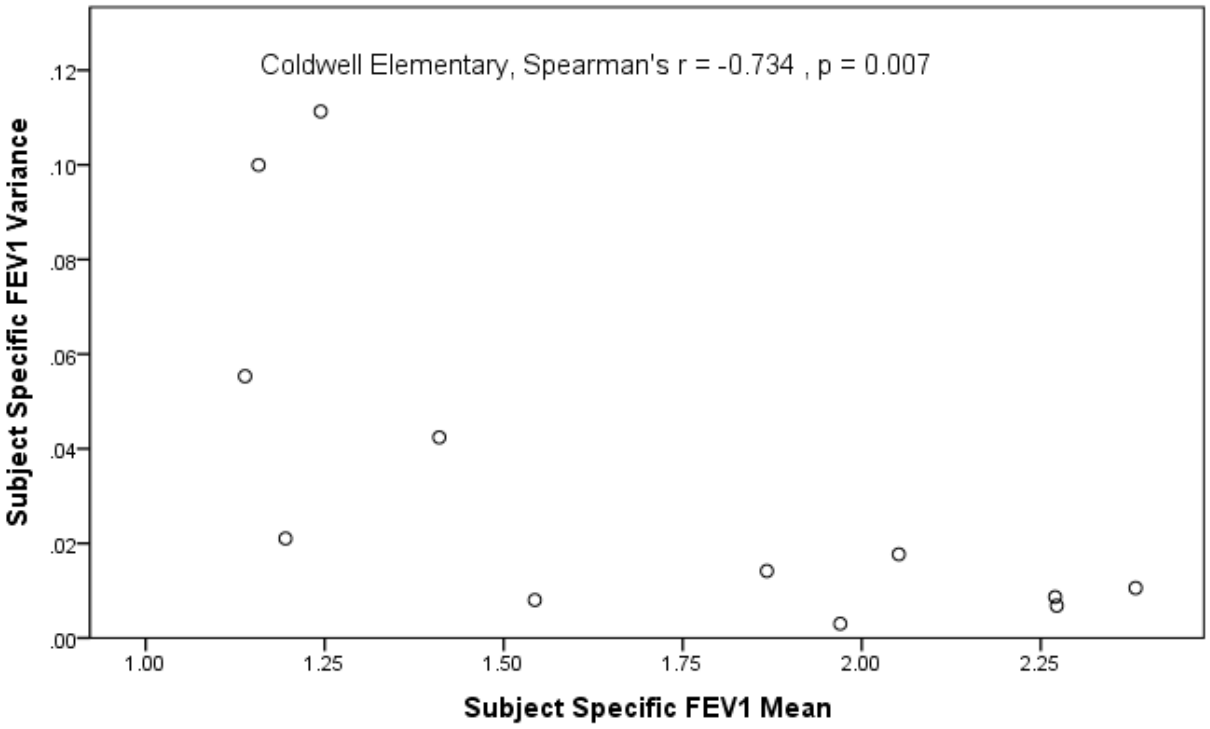


Figure 44. Scatterplot of subject-specific FEV1 mean and variance at CW.

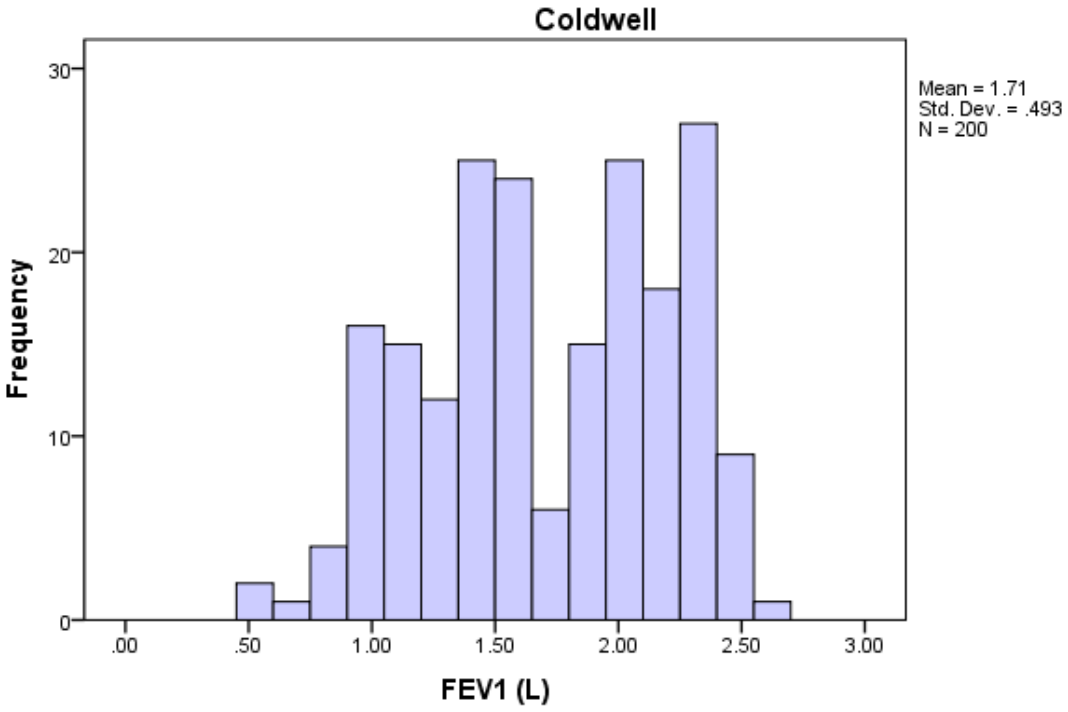


Figure 45. Histogram of overall FEV1 at CW.

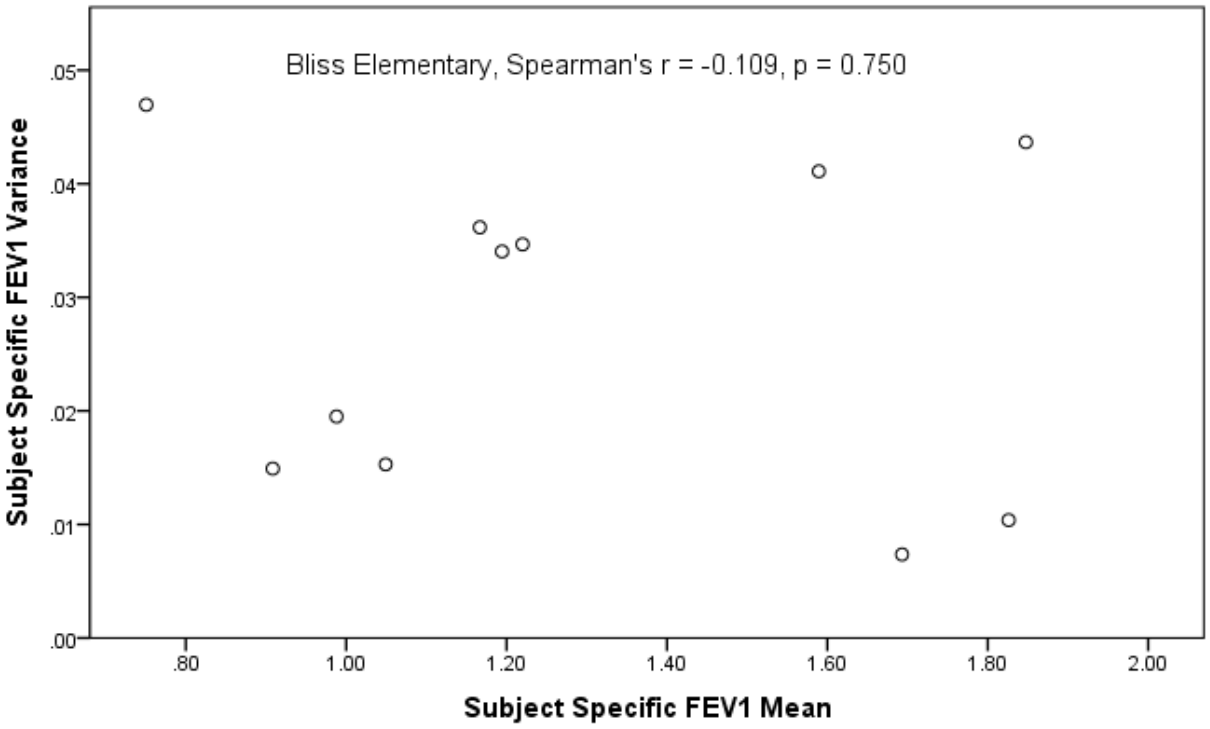


Figure 46. Scatterplot of subject-specific FEV1 mean and variance at FB.

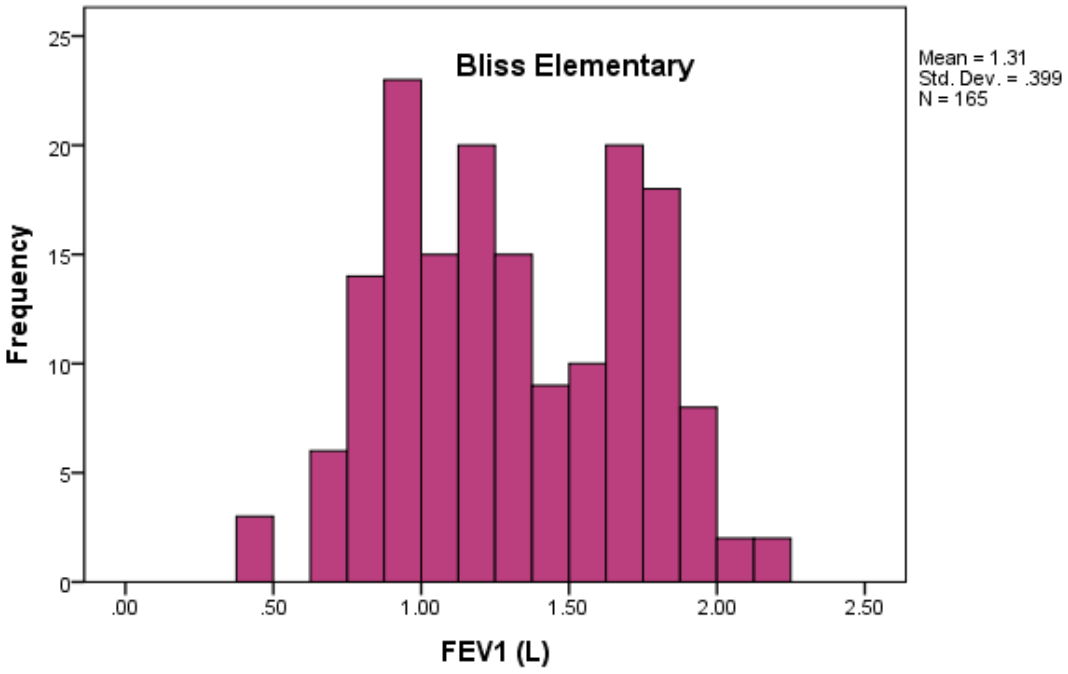


Figure 47. Histogram of overall FEV1 at FB.

In order to avoid redundancy, only the summary statistics and figures for FEV1 (percent predicted) at both the schools are presented. Table 19 is the summary statistics for FEV1 (percent predicted) at CW, and Figure 48 and

Figure 49 are the box plots and time-series plots of the raw FEV1 (percent predicted) at CW. Similarly, Table 20 is the summary statistics, and Figure 50 and Figure 51 are the box plots and time-series plots for the FEV1 (percent predicted) at FB.

Table 19. Summary Statistics by Subject for FEV1 (% Predicted) at CW

Subject ID	CW-01	CW-02	CW-03	CW-04	CW-05	CW-06	CW-07	CW-08	CW-09	CW-10	CW-11	CW-12
N	14	14	13	14	14	14	14	14	13	13	14	14
Mean	103.86	86.14	99.69	106.86	69.14	70.71	96.36	63.00	90.38	99.92	77.07	88.71
Median	105	87	99	108	71	73.5	97	62.5	97	101	77.5	88.5
SD	2.66	5.01	4.92	12.67	18.10	20.43	3.56	12.44	12.93	3.90	5.15	3.31
Max	107	92	112	122	91	96	102	89	102	108	84	94
Min	97	73	92	81	28	29	89	37	61	94	67	81
Q1(0.25)	103	84	98	103.25	58	57.5	95.25	57.25	82	97	74	88
Q2(Median)	105	87	99	108	71	73.5	97	62.5	97	101	77.5	88.5
Q3(0.75)	105	89	101	115.5	85	88.25	98.75	68.5	99	102	81.25	91
Q4(Max)	107	92	112	122	91	96	102	89	102	108	84	94
90th percentile	106.7	91.4	104.4	122	87.7	90.7	99.7	76	100.6	102.8	82.7	91.7
99th percentile	107	92	111.16	122	90.61	95.35	101.74	87.7	101.88	107.4	83.87	93.74

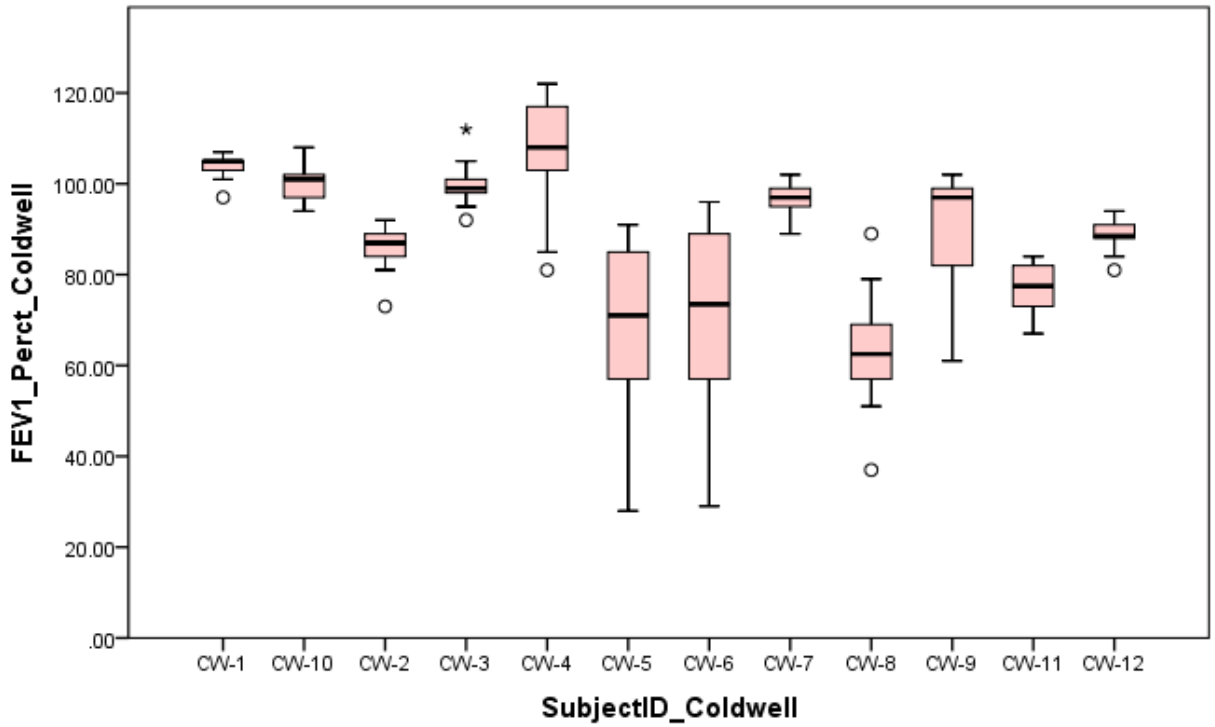


Figure 48. Box plots of FEV1 (% predicted) by subjects at CW.

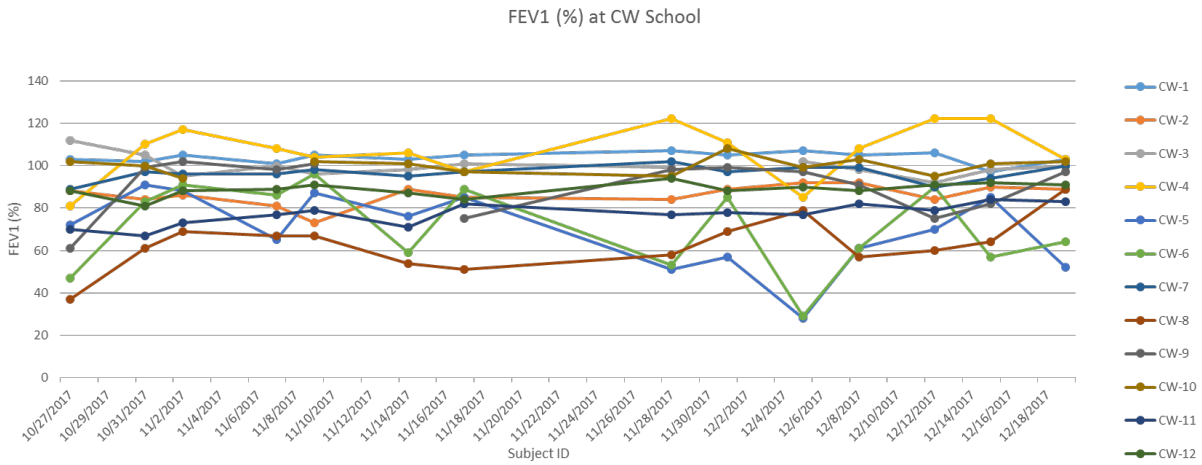


Figure 49. Time-series plots of FEV1 (% predicted) by subjects at CW.

Table 20. Summary Statistics by Subject for FEV1 (%Predicted) at FB

Subject ID	FB-1	FB-2	FB-3	FB-4	FB-5	FB-6	FB-7	FB-8	FB-9	FB-10	FB-11
N	11	14	14		14	14	14		14	14	14
Mean	80.18	76.14	89.43		79.93	100.36	87.57		76.64	96.93	82.79
Median	79	76.5	83.5		79	105.5	90		72.5	98	85.5
SD	16.06	9.43	16.18		6.13	16.43	11.90		13.37	6.11	13.99
Max	105	92	122		95	120	99		103	107	98
Min	48	61	70		71	66	55		51	87	49
Q1(0.25)	73	69.5	78.5		77	96.75	85.75		69	94	74.5
Q2(Median)	79	76.5	83.5		79	105.5	90		72.5	98	85.5
Q3(0.75)	90	82	98.5		81	109.5	96		87	99.75	93.75
Q4(Max)	105	92	122		95	120	99		103	107	98
90th percentile	101	88.5	112.8		86.7	117.8	96.7		90	104.1	97.4
99th percentile	104.6	91.74	120.96		93.96	119.87	98.74		101.31	106.74	98

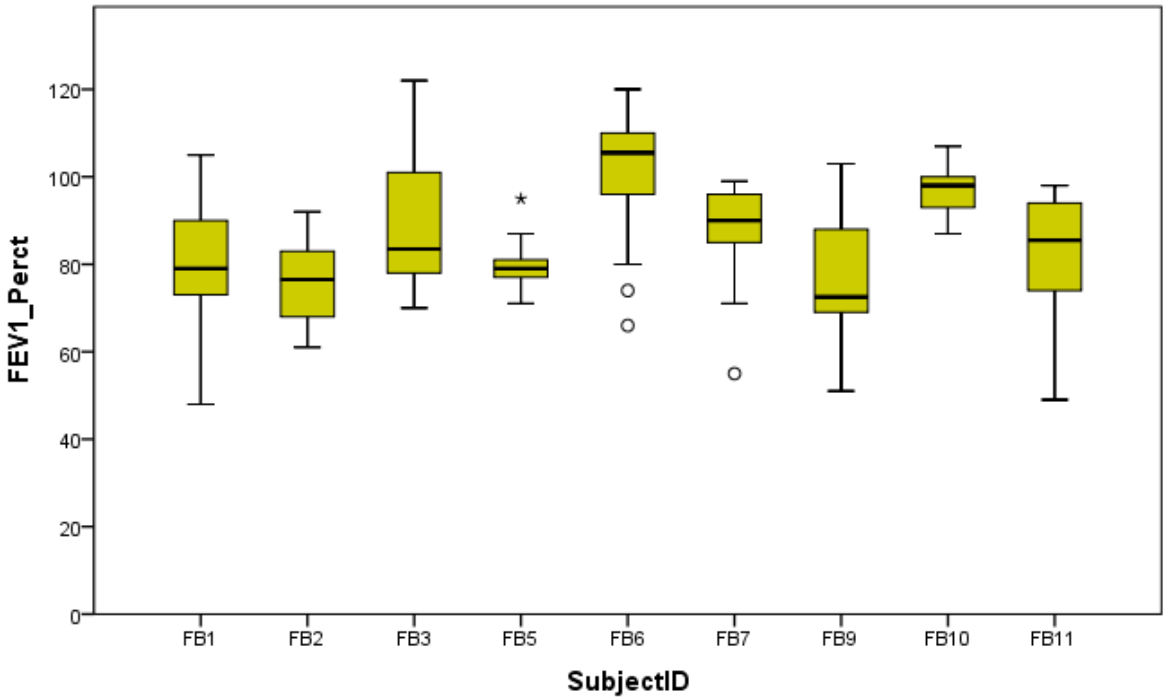


Figure 50. Box plots of FEV1 (% predicted) by subjects at FB.

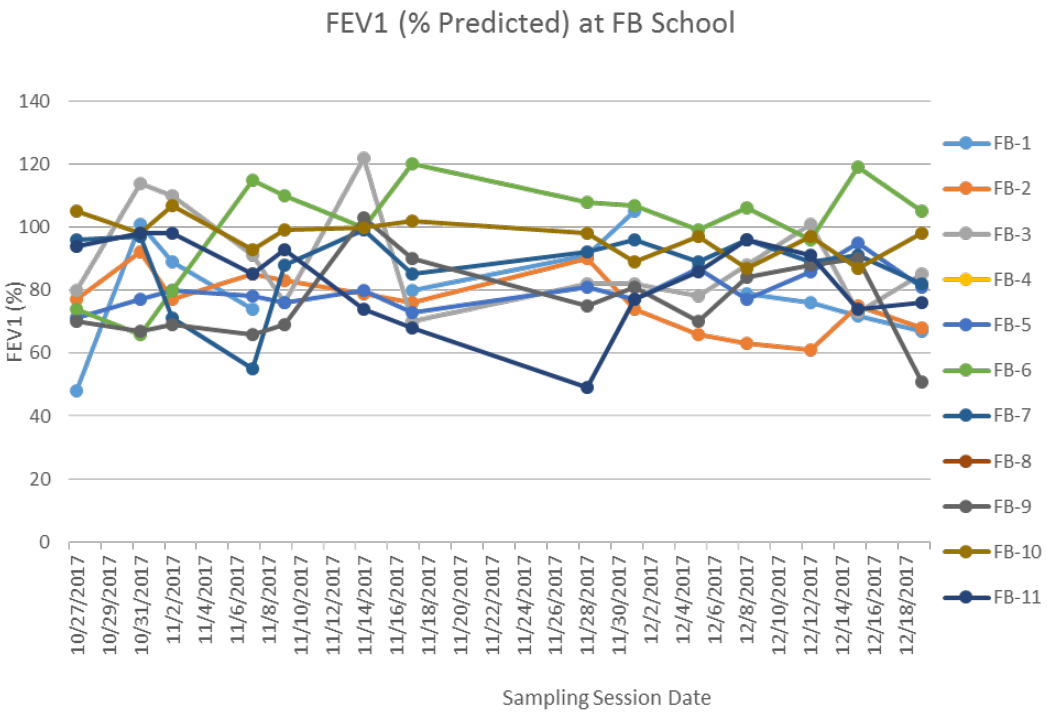


Figure 51. Time-series plots of FEV1 (% predicted) at FB.

Asthma Control Questionnaire Data

In all, 199 ACQs were completed over the course of the study period at CW. Sixteen to 17 repeated measures per subject were undertaken. The mean ACQ score for this school was 0.52 ± 0.51. The minimum ACQ score was 0.0, and the maximum was 2.71. At FB, 165 ACQs were completed. The number of repeated measures per subject at this school varied from 13 to 16. The mean ACQ score at FB for the study was 1.00 ± 0.64. The minimum score was 0.0, and the maximum score was 3.0 at this school. Table 21 and Table 22 contain the basic statistics of the ACQ score for the study subjects at CW and FB, respectively. Figure 52 and Figure 53 are the mean ACQ scores for the students at CW and FB, respectively.

Table 21. Basic Statistics of the ACQ Score for the Study Subjects at CW

Subject ID	CW-01	CW-02	CW-03	CW-04	CW-05	CW-06	CW-07	CW-08	CW-09	CW-10	CW-11	CW-12
N	17	16	16	17	17	16	17	17	16	16	17	17
Mean	0.63	0.46	0.14	0.07	0.86	1.13	0.16	0.85	0.45	0.10	1.03	0.34
Median	0.57	0.43	0.00	0.00	0.71	0.93	0.00	0.86	0.43	0.00	1.00	0.29
SD	0.21	0.40	0.26	0.21	0.61	0.70	0.23	0.22	0.32	0.29	0.37	0.12
Max	1.00	1.71	1.00	0.86	2.71	2.43	0.71	1.29	1.17	1.17	2.00	0.57
Min	0.14	0.00	0.00	0.00	0.17	0.14	0.00	0.33	0.00	0.00	0.57	0.17
Q1(0.25)	0.57	0.29	0.00	0.00	0.43	0.68	0.00	0.83	0.16	0.00	0.71	0.29
Q2(Median)	0.57	0.43	0.00	0.00	0.71	0.93	0.00	0.86	0.43	0.00	1.00	0.29
Q3(0.75)	0.71	0.57	0.18	0.00	1.00	1.54	0.33	1.00	0.61	0.04	1.17	0.43
Q4(Max)	1.00	1.71	1.00	0.86	2.71	2.43	0.71	1.29	1.17	1.17	2.00	0.57
90th percentile	0.86	0.71	0.31	0.11	1.34	2.07	0.46	1.00	0.86	0.14	1.43	0.43
99th percentile	0.98	1.59	0.90	0.77	2.51	2.39	0.68	1.24	1.12	1.01	1.91	0.55

Table 22. Basic Statistics of The ACQ Score for the Study Subjects at FB

Subject ID	FB-1	FB-2	FB-3	FB-4	FB-5	FB-6	FB-7	FB-8	FB-9	FB-10	FB-11
N	13	16	16	14	16	16	16	13	15	15	15
Mean	0.92	0.71	1.91	0.37	0.96	0.98	0.98	1.54	1.34	0.83	0.42
Median	1.00	0.71	2.00	0.17	0.86	0.79	0.93	1.50	1.14	0.86	0.43
SD	0.38	0.23	0.52	0.38	0.36	0.84	0.47	0.57	0.67	0.26	0.28
Max	1.57	1.00	2.71	1.50	2.00	2.57	2.00	3.00	2.71	1.14	1.00
Min	0.29	0.33	0.67	0.17	0.50	0.00	0.43	0.67	0.43	0.43	0.00
Q1(0.25)	0.67	0.57	1.57	0.17	0.82	0.25	0.64	1.33	0.93	0.62	0.21
Q2(Median)	1.00	0.71	2.00	0.17	0.86	0.79	0.93	1.50	1.14	0.86	0.43
Q3(0.75)	1.14	0.86	2.18	0.33	1.04	1.60	1.29	1.67	1.71	1.07	0.57
Q4(Max)	1.57	1.00	2.71	1.50	2.00	2.57	2.00	3.00	2.71	1.14	1.00
90th percentile	1.49	1.00	2.46	0.73	1.29	2.00	1.57	1.83	2.17	1.14	0.74
99th percentile	1.57	1.00	2.68	1.41	1.91	2.51	1.96	2.86	2.65	1.14	0.98

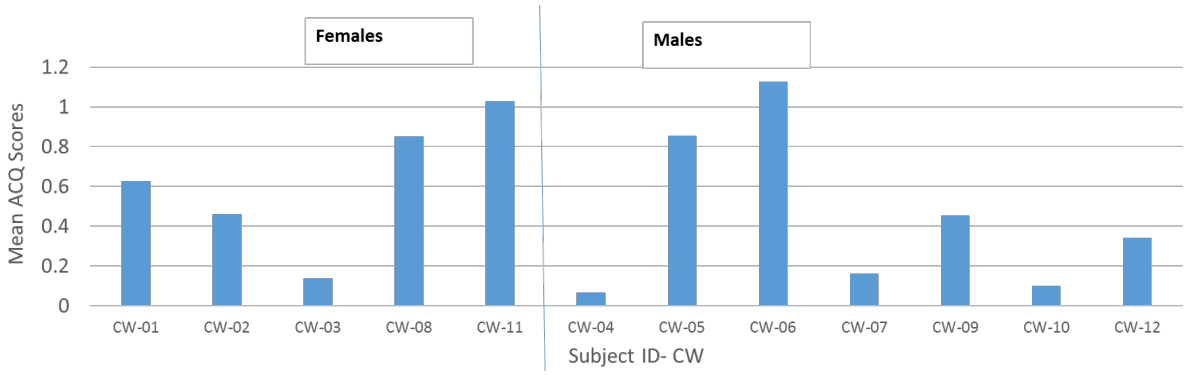


Figure 52. Mean ACQ scores for the students at CW.

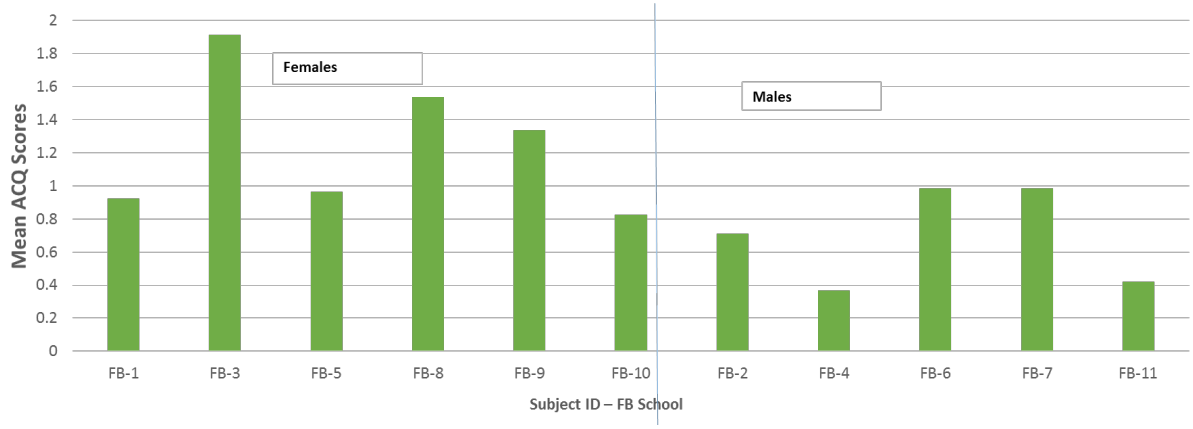


Figure 53. Mean ACQ scores for the students at FB.

Carotenoid Level Measurements

The carotenoid level measurements for the study cohort at CW and FB are shown in Table 23. Figure 54 and Figure 55 are the Veggie Meter scores for the study participants at CW and FB, respectively. Preliminary results showed that skin carotenoid levels correlated with $PM_{2.5}$ (r = -0.150), PM_{10} (r = -0.144), NO_2 (r = 0.192), and O_3 (r = -0.170). NO_2 was negatively correlated ($p < 0.001$) with the other pollutants PM_{10} (r = -0.390), $PM_{2.5}$ (r = -0.266), O_3 (r = -0.711). Negative correlations between carotenoid levels and $PM_{2.5}$, $PM_{10,}$ and O_3 might be due to antioxidant depletion.

Table 23. Carotenoid Level Measurements (Veggie Meter Scores) for the Study Participants

ID	VM1	VM2	VM3	VM4	VM5	VM6	VM7	VM8	VM9	VM10
CW-01	249	254	306	292	203	346	261	274	286	302
CW-02	199	188	108	186	169	191	204	185	118	137
CW-03	305	310	296	290	377	311	-	318	376	388
CW-04	154	150	139	158	189	227	208	162	160	197
CW-05	379	334	353	279	383	417	354	387	376	286
CW-06	-	353	346	278	329	299	356	338	342	301
CW-07	150	137	134	141	185	132	197	149	171	217
CW-08	126	113	81	122	144	116	132	150	131	100
CW-09	191	200	123	174	212	213	268	266	260	227
CW-10	91	117	147	221	-	165	303	284	250	277
CW-11	368	356	365	377	395	420	376	341	388	374
CW-12	262	243	257	285	285	272	280	276	267	260
FB-01	270	270	268	226	-	225	271	307	259	293
FB-02	192	169	193	-	178	154	162	200	198	158
FB-03	270	184	267	-	245	212	266	314	292	265
FB-04	301	276	-	-	287	240	254	301	261	235
FB-05	197	225	239	226	228	225	216	232	246	111
FB-06	96	80	79	59	117	81	89	125	111	111
FB-07	78	84	109	124	59	104	86	121	126	59
FB-08	265	229	-	151	236	200	237	266	250	-
FB-09	-	222	229	-	274	196	61	305	293	279
FB-10		155	152	207	169	131	132	164	187	92
FB-11	-	241	306	-	349	318	354	417	377	348

- Measurement not conducted.

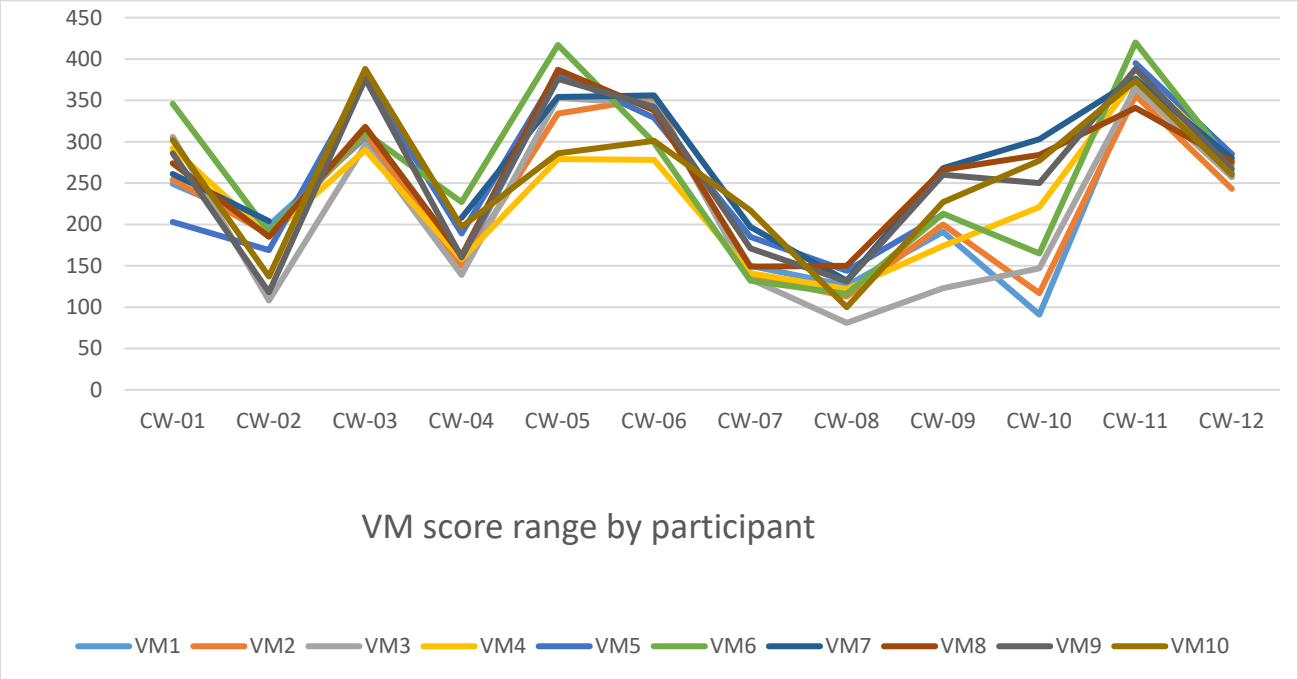


Figure 54. Veggie Meter scores for the study participants at CW.

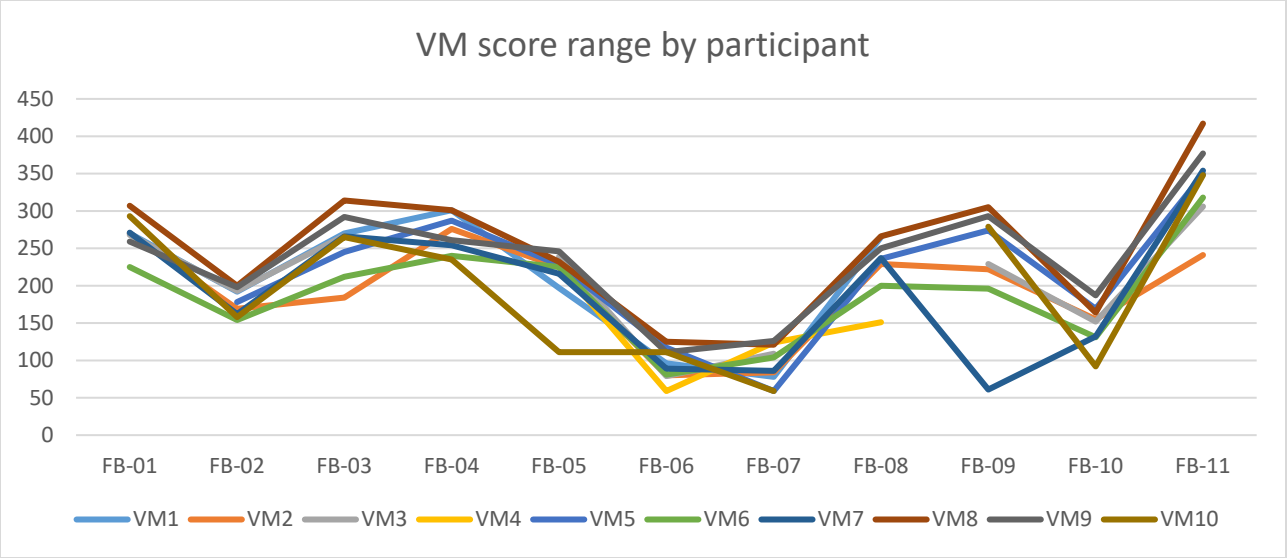


Figure 55. Veggie Meter scores for the study participants at FB.

Physical Activity Rates

Physical activity monitoring was conducted at CW only. Various exposure windows for the outdoor pollutants were analyzed in conjunction with aggregated 24-, 48-, 72-, and 96-hour averages for air pollutant concentrations measured at the school as well as at the nearest CAMS. The mean concentrations observed at the CAMS appeared to be lower, with a tendency toward larger variations, than the ones measured at the school.

Table 24 summarizes the percentage of sedentary, light, and moderate physical activity rates by hour for students at CW.

Table 24. Percentage of Physical Activity Rate for Students at CW

Sedentary Physical Activity										
ID	Hr -1	Hr-2	Hr 3	Hr-4	Hr=5	Hr-6	Hr-7	Hr-8	Hr-9	Hr-10
CW-01	-	32.50%	30.83%	30.85%	27.94%	33.28%	34.83%	34.83%	36.50%	45.67%
CW-02	-	17.11%	18.78%	22.94%	32.72%	22.89%	24.83%	20.89%	20.44%	40.06%
CW-03	-	60.56%	39.06%	24.64%	45.22%	39.50%	-	32.28%	36.83%	61.67%
CW-04	-	28.56%	20.50%	20.00%	22.22%	23.33%	24.78%	14.28%	33.06%	35.28%
CW-05	-	29.17%	21.00%	25.56%	21.89%	23.44%	23.28%	40.00%	29.89%	30.39%
CW-06	-	17.72%	22.94%	24.90%	14.72%	27.67%	28.67%	57.00%	33.11%	39.17%
CW-07	-	22.22%	13.72%	21.44%	20.11%	22.00%	19.56%	26.67%	45.06%	32.17%
CW-08	-	15.83%	16.67%	34.00%	17.33%	23.22%	19.17%	15.94%	22.39%	30.06%
CW-09	-	22.44%	30.17%	16.86%	17.06%	-	17.44%	18.00%	18.00%	30.28%
CW-10	17.72%	21.94%	24.61%	25.49%	18.28%	-	25.50%	20.44%	17.00%	32.89%
CW-11	30.72%	27.50%	31.22%	30.65%	32.83%	31.56%	31.72%	36.78%	40.00%	42.00%
CW-12	27.94%	22.11%	18.39%	27.19%	25.00%	32.17%	31.33%	24.56%	18.44%	33.67%
Light Physical Activity										
ID	Hr -1	Hr-2	Hr 3	Hr-4	Hr=5	Hr-6	Hr-7	Hr-8	Hr-9	Hr-10
CW-01	-	8.56%	10.67%	9.54%	10.61%	12.11%	9.00%	9.00%	7.17%	8.56%
CW-02	-	8.67%	8.17%	7.71%	8.06%	9.50%	7.39%	10.83%	7.06%	6.72%
CW-03	-	7.22%	10.50%	10.72%	9.72%	10.06%	-	11.33%	11.61%	7.89%
CW-04	-	11.78%	10.39%	10.59%	10.17%	8.56%	7.94%	9.33%	9.89%	11.28%
CW-05	-	9.39%	9.67%	12.03%	9.44%	10.06%	10.06%	8.78%	10.17%	7.56%
CW-06	-	8.89%	7.67%	10.20%	8.06%	10.50%	8.28%	8.50%	9.00%	7.17%
CW-07	-	11.50%	8.56%	13.79%	14.44%	13.22%	11.56%	13.50%	4.83%	10.44%
CW-08	-	9.78%	9.50%	6.89%	10.72%	10.56%	10.22%	11.83%	13.00%	9.56%
CW-09	-	10.06%	12.72%	9.93%	9.17%	-	9.17%	9.94%	10.89%	7.56%
CW-10	7.39%	7.61%	8.56%	8.76%	7.94%	-	8.56%	9.50%	11.17%	8.39%
CW-11	11.06%	12.28%	12.83%	11.83%	13.28%	10.61%	10.94%	10.94%	10.94%	12.17%
CW-12	12.94%	10.89%	11.00%	11.18%	12.17%	12.61%	10.44%	8.44%	7.94%	10.22%
Moderate Physical Activity										
ID	Hr -1	Hr-2	Hr 3	Hr-4	Hr=5	Hr-6	Hr-7	Hr-8	Hr-9	Hr-10
CW-01	-	58.94%	58.50%	59.61%	61.44%	54.61%	56.17%	56.17%	56.33%	45.78%
CW-02	-	74.22%	73.06%	69.35%	59.22%	67.61%	67.78%	68.28%	72.50%	53.22%
CW-03	-	32.22%	50.44%	64.64%	45.06%	50.44%	-	56.39%	51.56%	30.44%
CW-04	-	59.67%	69.11%	69.41%	67.61%	68.11%	67.28%	76.39%	57.06%	53.44%
CW-05	-	61.44%	69.33%	62.42%	68.67%	66.50%	66.67%	51.22%	59.94%	62.06%
CW-06	-	73.39%	69.39%	64.90%	77.22%	61.83%	63.06%	34.50%	57.89%	53.67%
CW-07	-	66.28%	77.72%	64.77%	65.44%	64.78%	68.89%	59.83%	50.11%	57.39%
CW-08	-	74.39%	73.83%	59.11%	71.94%	66.22%	70.61%	72.22%	64.61%	60.39%
CW-09	-	67.50%	57.11%	73.20%	73.78%	-	73.39%	72.06%	71.11%	62.17%
CW-10	74.89%	70.44%	66.83%	65.75%	73.78%	-	65.94%	70.06%	71.83%	58.72%
CW-11	58.22%	60.22%	55.94%	57.52%	53.89%	57.83%	57.33%	52.28%	49.06%	45.83%
CW-12	59.11%	67.00%	70.61%	61.63%	62.83%	55.22%	58.22%	67.00%	73.61%	56.11%

- Measurement not conducted

The subject-specific factors, including medication information, are characterized in Table 25. Rates of moderate to vigorous physical activity (MVPA) and sedentary activities by their factor levels were compared using the Kruskal-Wallis test to examine whether the mean rates between factor levels were statistically different. The test results showed significantly different rates for some factors (gender, BMI category, father with asthma status, siblings with asthma, having eczema, health insurance, smoking status, *Leukotrieneblockers* [LB], *LABAIC*, and *NC* medications) at both MVPA and sedentary activities (see bold *p*-values in Table 25). For example, types of insurance, (i.e., Medicaid versus private) were significant factors (*p*-value = 0.003) influencing different rates in the MVPA; participants with Medicaid spent more time in MVPA (0.665) than did participants with private insurance (0.612). Conversely, participants with Medicaid spent less time in sedentary activities (0.239) than did participants with private insurance (0.279, *p*-value = 0.039).

Table 25. Summary Statistics of Subject-Specific Factors and Physical Activity Rates per Factor Level

Subject-Specific Factor	Frequency, %		Physical Activity			
	(n = 12)		MVPA	*p*-value*	Sedentary	*p*-value*
Sex						
Male	7	58%	65.8%	**0.001**	24.2%	**0.001**
Female	5	42%	60.0%		29.2%	
BMI category						
Underweight & Normal	8	67%	61.9%	**0.010**	28.4%	**< 0.001**
Overweight & Obese	4	33%	66.5%		22.6%	
Mother with Asthma	5	42%	63.2%	0.895	26.1%	0.503
No	7	58%	63.6%		26.7%	
Father with Asthma	3	25%	60.9%	**0.041**	28.8%	**0.032**
No	9	75%	64.3%		25.7%	
Mother with Hay Fever	8	67%	63.4%	0.944	26.3%	0.595
No	4	33%	63.5%		26.8%	
Father with Hay Fever	8	67%	62.7%	0.305	26.9%	0.511
No	4	33%	64.8%		25.6%	
Siblings with Asthma	6	50%	61.2%	**0.005**	28.8%	**0.001**
No	6	50%	65.6%		24.1%	
Siblings with Hay Fever	8	67%	63.0%	0.602	27.2%	0.169
No	4	33%	64.2%		25.1%	
Having Eczema	3	25%	66.8%	**0.012**	23.2%	**0.011**
No	9	75%	62.2%		27.7%	
Allergic Phenotype (Aeroallergens)	8	67%	63.1%	0.597	26.7%	0.794
No	4	33%	64.1%		26.0%	
Allergic Phenotype (Food)	3	25%	61.8%	0.143	27.4%	0.366
No	9	75%	64.1%		26.1%	
Caretaker Education						
Less Than or Equal to High School	6	50%	63.8%	0.997	26.3%	0.771
Greater Than High School	6	50%	63.1%		26.6%	
Health Insurance Coverage (n = 11)						
Medicaid	6	55%	66.5%	**0.003**	23.9%	**0.039**
Private	5	45%	61.2%		27.9%	
Smoking (outside of household)	2	17%	59.9%	**0.013**	29.9%	**0.010**
No	10	83%	64.2%		25.7%	
Cooking Fuel						
Electric	1	8%	68.7%	**0.035**	22.7%	0.127

Gas	11	92%	62.9%		26.8%	
*Leukotrieneblockers (LB)***	7	58%	66.4%	**< 0.001**	23.7%	**< 0.001**
No	5	42%	59.4%		30.3%	
Short-acting bronchodilators (SABA)	7	58%	62.8%	0.155	27.3%	0.065
No	5	42%	64.4%		25.2%	
Inhaled corticosteroids (IC)	6	50%	63.2%	0.894	26.1%	0.493
No	6	50%	63.6%		26.8%	
LABAIC	2	17%	68.1%	**0.012**	22.0%	**0.013**
No	10	83%	62.6%		27.2%	
NC	4	33%	66.8%	**0.003**	23.4%	**0.007**
No	8	67%	61.7%		28.0%	
SC	2	17%	64.6%	0.641	25.3%	0.791
No	10	83%	63.2%		26.7%	

*p-value for mean difference in physical activity between factor levels using Kruskal-Wallis test.
*p-values <0.05 are bolded for statistical significance.
** All medications are expressed in italics.

Associations between physical activity (MVPA versus sedentary) and pollutant metrics are summarized in Table 26. In correlation analyses, MVPA was negatively correlated with previous 96-hour averages of $PM_{2.5}$ (r = -0.349), PM_{10} (r = -0.200) and NO_2 (r = -0.265), and positively correlated with O_3 (r = 0.247). In contrast, sedentary activity was positively correlated with 96-hour averages of $PM_{2.5}$ (r = 0.368), PM_{10} (r = 0.202), and NO_2 (r = 0.300), and negatively correlated with O_3 (r = -0.263). We did not find any significant correlations between pollutant measurements and light physical activity.

Table 26 presents effect estimates using GEE models, 95 percent confidence intervals, and corresponding p-values. We scaled the effects to IQR increases in pollutant metrics to compare the magnitude of effect across different scales of the pollutant concentrations. The 96-hour school pollutant concentrations ($PM_{2.5}$, $PM_{10,}$ and NO_2) were negatively associated with MVPA (p-values < 0.001 for PM; p-value = 0.036 for NO_2), whereas they were positively associated with sedentary activity (p-values < 0.001 for PM; p-value = 0.019 for NO_2). A negative 96-hour O_3 moderate to vigorous activity relationship was not significant (p-value = 0.661). However, the 72-hour maximum O_3 data were associated with a decreased rate in moderate to vigorous activity (p-value = 0.001).

The 96-hour average ambient PM and NO_2 concentrations at the Ascarate CAMS were significantly associated with physical activity levels, showing consistent patterns of association with 96-hour school concentrations. The largest percent time spent in MVPA per school pollutant increase in IQR was observed in the association between the 96-hour $PM_{2.5}$, which showed a 3.45 percent decrease in MVPA (95 percent CI: -5 percent, -1.9 percent). We saw a similar amount of percent change in sedentary activity (3.43 percent increase [95 percent CI: 1.78 percent, 5.09 percent]) as the IQR in $PM_{2.5}$ increases.

Table 26. Overall Associations between Moderate to Vigorous (MVPA) and Sedentary Physical Activity and Pollutant Metrics

Pollutant		IQR	MVPA				Sedentary			
			Change in rate per IQR	95% CI lower	95% CI upper	*p*-value	Change in rate per IQR	95% CI lower	95% CI upper	*p*-value
$PM_{2.5}$	24-hr	4.91	0.47%	-0.54%	1.48%	0.365	-0.96%	-1.92%	0.01%	0.051
	48-hr	4.13	0.80%	-0.37%	1.96%	0.180	-1.53%	-2.75%	-0.31%	0.014
	72-hr	3.11	-1.71%	-2.95%	-0.46%	0.007	1.43%	0.24%	2.61%	0.018
	96-hr	4.07	-3.45%	-5.00%	-1.90%	<0.001	3.43%	1.78%	5.09%	<0.001
	96-hr CAMS	5.22	-3.86%	-6.12%	-1.59%	0.001	4.04%	1.71%	6.37%	0.001
PM_{10}	24-hr	24.57	-0.43%	-1.50%	0.64%	0.427	-0.06%	-0.99%	0.87%	0.902
	48-hr	19.05	-0.58%	-1.66%	0.50%	0.293	-0.17%	-1.18%	0.83%	0.735
	72-hr	11.93	-1.32%	-2.24%	-0.39%	0.005	1.00%	0.09%	1.91%	0.031
	96-hr	9.56	-1.59%	-2.37%	-0.81%	<0.001	1.51%	0.69%	2.34%	<0.001
	96-hr CAMS	16.84	-2.87%	-4.65%	-1.08%	0.002	3.07%	1.19%	4.95%	0.001
NO_2	24-hr	7.81	-0.45%	-1.71%	0.82%	0.489	0.43%	-0.62%	1.47%	0.424
	48-hr	4.76	-0.28%	-1.41%	0.85%	0.626	0.29%	-0.72%	1.30%	0.574
	72-hr	2.76	-0.60%	-1.30%	0.11%	0.098	0.66%	-0.06%	1.38%	0.075
	96-hr	4.96	-1.35%	-2.62%	-0.09%	0.036	1.52%	0.25%	2.79%	0.019
	96-hr CAMS	5.19	-0.78%	-1.53%	-0.04%	0.040	0.63%	-0.12%	1.38%	0.099
O_3	72-hr Max$O_3$8hr	9.94	-3.99%	-6.35%	-1.63%	0.001	4.62%	2.15%	7.08%	<0.001
	24-hr	18.10	-0.25%	-3.51%	3.01%	0.881	1.16%	-2.10%	4.43%	0.486
	48-hr	11.69	-1.31%	-4.01%	1.40%	0.344	2.07%	-0.85%	4.98%	0.164
	72-hr	12.32	-0.66%	-2.33%	1.01%	0.437	1.41%	-0.37%	3.19%	0.120
	96-hr	8.57	-0.33%	-1.81%	1.15%	0.661	0.49%	-1.05%	2.04%	0.530
	96-hr CAMS	7.50	-0.04%	-1.51%	1.43%	0.955	0.24%	-1.34%	1.82%	0.766

Discussion and Conclusions

Comparison in Pollutant Concentrations between the Three Sites

The three measured sites revealed similar trends. CW and RH are located on opposite sides of the highway. The differences in local street traffic is a probable reason for the differences in air pollution levels. The pollutant data extracted from the nearest TCEQ CAMS for comparison revealed, apart from O_3, varying trends.

Comparing the results from the study sites with literature reveals interesting observations, as shown in Table 27. The average $PM_{2.5}$ concentrations for FB are consistent with concentrations found past studies in the PdN air basin. The average PM_{10} concentrations at both schools were exceptionally high compared to other studies outside the PdN region. The average NO_2 concentrations for FB is comparable to past studies in the PdN region, but CW aligns more with studies outside of this region.

Table 27. Air Quality Comparison with On-Site Studies

Reference	Location	Pollutant	Average	Site Similarity
Keeler et al., 2002	Two elementary schools in Detroit, Michigan	$PM_{2.5}$	20.6 µg/m^3	FB (17.81 µg/m^3)
		PM_{10}	30.8 µg/m^3	RH (30.37 µg/m^3)
Singer et al., 2004	Ten elementary schools in	NO_2	19-30 ppb	CW (18.37 ppb)
Kim et al., 2004	Ten schools in San Francisco Bay Area	$PM_{2.5}$	11–15 µg/m^3	CW (11.6 µg/m^3), FB (17.81 g/m^3)
		PM_{10}	29–32 µg/m^3	RH (30.37 µg/m^3)
		NO_2	19–31 ppb	CW (18.37 ppb)
Annesi-Maesano et al., 2007	Schoolyards in French cities	$PM_{2.5}$	20.7 µg/ m^3	FB (17.81 µg/m^3)
		NO_2	46.4 ppb	-
Kim et al., 2016	Seven elementary schools in South Korea	PM_{10}	24–45 µg/m^3	CW (42.85 µg/m^3), RH (30.37 µg/m^3)
		NO_2	11–48 ppb	ALL
		O_3	2–35 ppb	ALL
Peacock et el., 2003	Three schools in England	PM_{10}	18.4–22.7 µg/m^3	NA
		NO_2	17.1–19.2 ppb	CW (18.37 ppb)
		O_3	19-21.6 ppb (8-hr avg)	NA
Gonzales et al., 2005	El Paso, TX	NO_2	11–13 ppb	FB (14.94 ppb)
Holguin et al., 2007	Ciudad Juarez, Chihuahua	$PM_{2.5}$	17.5 µg/m^3	FB (17.81 µg/m^3)
		NO_2	18.2 ppb	CW (18.37 ppb)
Raysoni et al., 2011	El Paso and Ciudad Juarez	$PM_{2.5}$	14.5 µg/m^3	CW (11.6 µg/m^3), FB (17.81 µg/m^3)
		PM_{10}	39 µg/m^3	CW (42.85 µg/m^3)
		NO_2	14.2 ppb	FB (14.94 ppb)
Raysoni et al., 2013	El Paso, TX	$PM_{2.5}$	13–14 µg/m^3	CW (11.6 µg/m3), FB (17.81 µg/m^3)
		PM_{10}	35 µg/m^3	RH (30.37 µg/m^3)
		NO_2	9.47–10.69 ppb	NA

NA: Not available

Associations between Traffic-Related Air Pollutants and Children's Respiratory Health

Children's health outcomes were evaluated against various time-averaged exposures to traffic-related air pollutants. Hourly measurements of $PM_{2.5}$, PM_{10}, NO_2, and O_3 were aggregated to 24-, 48-, 72-, or 96-hour concentration averages to reflect a child's 24-, 48-, 72-, and 96-hour exposure prior to the health measurements. For example, a 24-hour average represents the average of the 24 hourly data points ending in the morning (10 a.m.) for CW and in the afternoon (2 p.m.) for FB. Hourly concentrations measured at the nearest CAMSs

were averaged over the same exposure window periods for comparison. For O_3 data, the daily maximum 8-hour average O_3 was also evaluated, and a 3-day average of the daily maximum 8-hour concentrations were also developed to further explore possible longitudinal associations with health outcomes for O_3. Summary statistics of the processed time-averaged concentrations as well as the subject data characterization, asthmatic questionnaire, and health outcome characteristics are included in Appendix D. Table 28 summarizes the descriptive statistics for the eNO, FEV1, and FVC measurements for study subjects by school.

Table 28. Descriptive Statistics for eNO, FEV1, and FVC Measurements

	Exhaled NO			FEV1			FEV1 (% pred.)			FVC			FVC (% pred.)		
	ALL (N = 391)	CW (N = 204)	FB (N = 187)	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB
Mean	29	23.2	36	1.5	1.7	1.3	87	87	86	1.9	2.1	1.6	92	95	88
SD	24.3	18.2	28.5	0.5	0.5	0.4	16	17	15	0.5	0.5	0.5	12	12	12
Median	23	18	32	1.5	1.7	1.3	89	91	85	1.9	2	1.5	92	96	88
IQR	36	32	49	0.8	0.8	0.7	21	21	21	0.8	0.7	0.7	15	15	14
Max	112	74.5	112	2.6	2.6	2.2	122	122	122	3	3	2.7	126	126	123
Min	5	5	5	0.4	0.5	0.4	28	28	48	0.6	1	0.6	49	52	49
N	363	198	165	365	200	165	288	165	123	365	200	165	288	165	123
p-value*	<0.0001			<0.0001			0.3435			<0.0001			<0.0001		

Longitudinal associations between primary responses (eNO, FVC, FEV1, and F/V) and air pollution metrics were examined using linear mixed effect models, with pollutants modeled as fixed effects and subjects modeled as random effects. We assumed the subject-specific random intercept and included additional control for the repeated measures of the outcome data using a first-order autoregressive covariance structure. The 96-hour averages of temperature and relative humidity showed strongest associations with response outcome, and we controlled for the 96-hour temperature and relative humidity as a priori fixed covariates in all models. Results from linear mixed effect models, or GEE IQRs, were calculated for air pollutant metric and effect estimates per IQR, 95 percent confidence intervals, and *p*-values (see Appendix D). Significant results from models examining modified effects by subject-specific factors are shown in Appendix D.

Figure 56 shows that eNO measurements, in general, demonstrate very weak and nonsignificant associations with children's exposures to traffic pollutants at the two schools. Negative associations between eNO and 24-hour outdoor PM_{10} and NO_2 concentrations were observed (*p*-values = 0.0215 and 0.0040, respectively). The 72-hour O_3 average measured outside CW was the only metric to be positively and significantly associated with eNO levels at *p*-value = 0.0278, which indicated a 12.38 percent increase in eNO (95 percent CI: 1.40–23.47 percent).

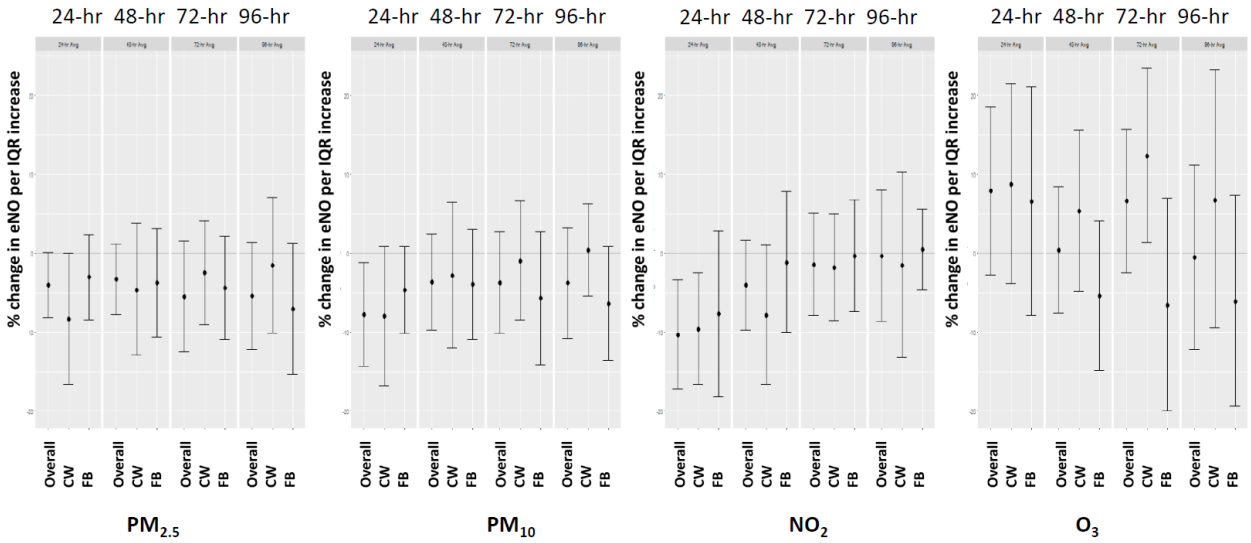


Figure 56. Overall and school-specific associations between eNO and $PM_{2.5}$, PM_{10}, NO_2, O_3 metrics.

As with eNO findings, the associations between FVC and transportation air pollutants were generally very weak and nonsignificant (Figure 57). However, significant associations were observed between the 24-hour PM concentrations and decreased lung function. Negative associations between FVC and 24-hour ambient PM_{10} concentrations (*p*-values = 0.0488) were observed. 24-hour PM concentrations (both $PM_{2.5}$ and PM_{10}) measured outside CW were significantly associated with decreased levels of lung function.

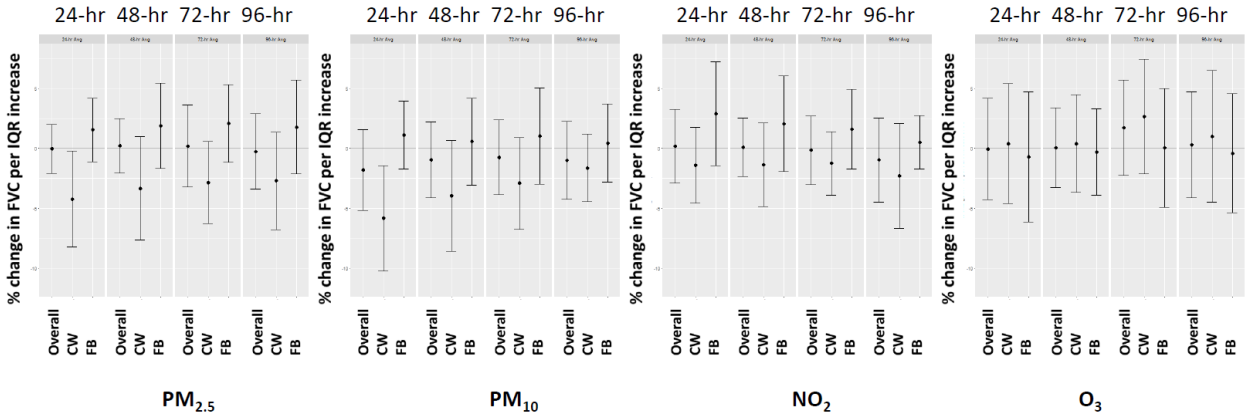


Figure 57. Overall and school-specific associations between FVC and $PM_{2.5}$, PM_{10}, NO_2, O_3 metrics.

Similar to the FVC findings, significant associations were observed between the 24-hour PM (both $PM_{2.5}$ and PM_{10}) concentrations and decreased FEV1 (Figure 58). Negative associations between FEV1 and 24-hour ambient PM (both $PM_{2.5}$ and PM_{10}) concentrations were observed at CW. The 24-hour PM concentrations (both $PM_{2.5}$ and PM_{10}) measured outside at CW were significantly associated with decreased levels of lung function; a decrease of 4.58 percent in FRV_1 per IQR increase (95 percent CI: -8.71, -0.44) for $PM_{2.5}$ was observed, and a 6.77 decrease in FEV1 (95 percent CI: -11.27, -2.28) was observed for PM_{10}. Again, no significant associations between other gaseous traffic-related pollutants (NO_2 and O_3) and FEV1 were observed.

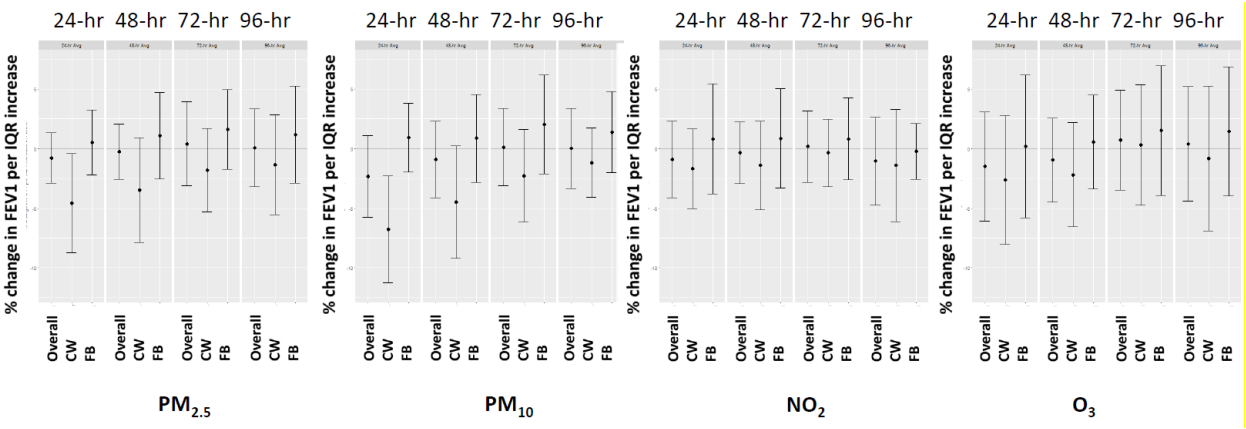


Figure 58. Overall and school-specific associations between FEV1 and $PM_{2.5}$, PM_{10}, NO_2, O_3 metrics.

To further explore the associations between various time-averaged exposure concentrations and children's respiratory health outcomes, effect modifications by significant factors were conducted for all health outcomes and various periods of exposure concentrations. Factors evaluated by category were as follows:

- Health insurance coverage: Medicaid versus private.
- Cooking fuel: Electric versus gas.
- Relatives with asthma: Parents versus siblings.
- Caretaker education: Less or equal to high school versus above high school.
- Medication: IC versus non-IC.

Subjects having a father with asthma showed more increased percent changes in eNO (26.05 [95 percent CI: 10.27, 42.09]). Caretaker education was a significant effect modifier of the eNO–O_3 relationship, with stronger associations observed for subjects whose caretakers had less than or equal to high school education (15.88 [95 percent CI: 3.55, 28.37]). Another significant effect modifier was health insurance; subjects with Medicaid health insurance showed a higher percent increase in eNO (19.31 [95 percent CI: 6.17, 32.63]) than did subjects with private insurance.

For FVC outcomes, health insurance and cooking fuel were both significant effect modifiers of FVC-PM associations. Subjects with Medicaid insurance showed more decreases in FVC than did subjects with private insurance: -6.06 (95 percent CI: -10.74, -1.37) for $PM_{2.5}$ and -8.96 (95 percent CI: -15.27, -2.64) for PM_{10}. The cooking fuel effect was significant, with subjects who used gas for cooking showing a stronger association between FVC-PM_{10} (-5.30 [95 percent CI: -9.62, -0.97] change in FVC per IQR) than subjects having an electric cooking system. The cooking factor was also significant for the association between FVC and the air quality gauge (AQG) measure. The category of father with asthma also had an impact on the association between FVC and NO_2, although there was no significant association in the previous model of FVC and NO_2.

Effect modifications for FEV1 outcomes are similar to the modifications for FVC. Health insurance was a significant effect modifier, as was the cooking fuel effect. Subjects using gas to cook at home showed stronger associations of PM_{10} with FEV1 than did subjects who used an electric cooking system. The medication factor of taking IC was also a significant effect modifier on the negative association between FEV1 and PM_{10}. Table 29 summarizes the significant effect modifiers identified in the pollutant-health outcome assessment.

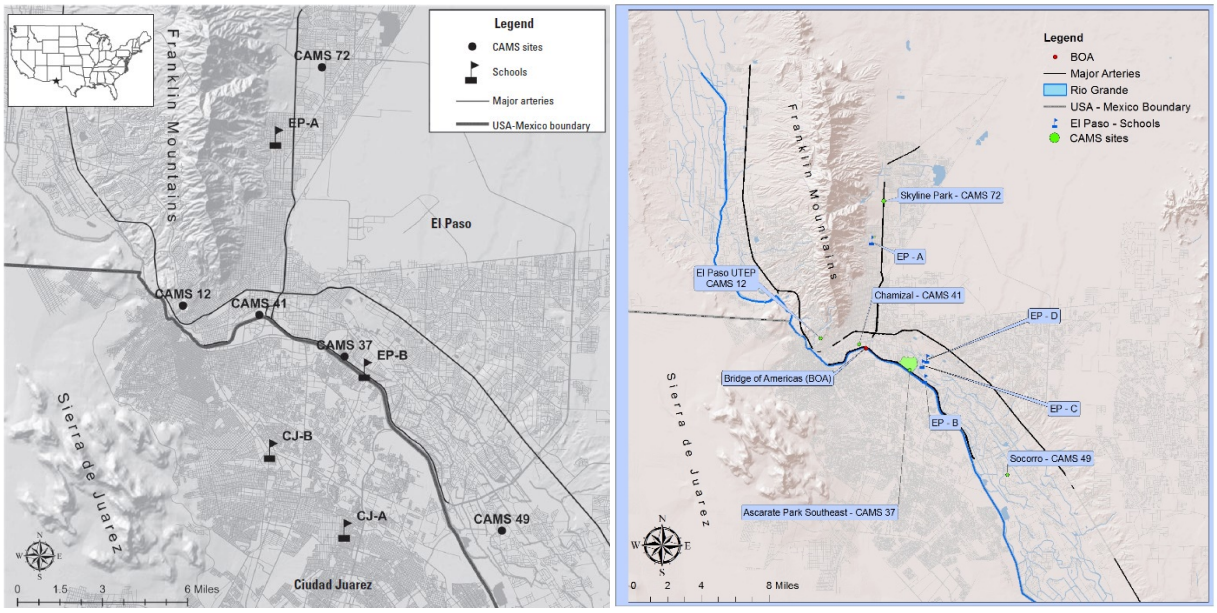
Table 29. Summary of Effect Modifiers for Various Exposure-Effect Metrics

Pollutant	Factor	% change in eNO per IQR (95% CI)	p-value	Interaction p-value	% change in FEV1 per IQR (95% CI)	p-value	Interaction p-value	% change in FVC per IQR (95% CI)	p-value	Interaction p-value
24-hr $PM_{2.5}$	Overall	-4.02 (-8.16, 0.15)	0.0598		-0.78 (-2.88, 1.32)	0.4657		-0.04 (-2.09, 2.00)	0.967	
	Health Insurance									
	Medicaid (n = 7)	-8.65 (-18.34, 1.19)	0.0854	0.0988	-7.30 (-12.13, -2.47)	0.0033	0.0109	-6.06 (-10.74, -1.37)	0.0117	0.0203
	Private (n = 15)	-3.17 (-7.92, 1.61)	0.1937		0.74 (-1.65, 3.14)	0.5441		1.45 (-0.89, 3.79)	0.2263	
	Cooking Fuel									
	Electric (n = 9)	-2.93 (-8.51, 2.69)	0.3065	0.1452	1.34 (-1.49, 4.17)	0.354	0.0731	2.35 (-0.40, 5.11)	0.0954	0.0431
	Gas (n = 14)	-5.37 (-11.57, 0.89)	0.0933		-3.31 (-6.41, -0.22)	0.0366		-2.87 (-5.87, 0.13)	0.0612	
24-hr PM_{10}	Overall	-7.76 (-14.32, -1.18)	0.0215		-2.33 (-5.76, 1.09)	0.183		-1.81 (-5.17, 1.55)	0.2922	
	Health Insurance									
	Medicaid (n = 7)	-6.33 (-18.99, 6.39)	0.33	0.0621	-9.86 (-16.32, -3.40)	0.003	0.0117	-8.96 (-15.27, -2.64)	0.0057	0.019
	Private (n = 15)	-8.84 (-16.61, -1.05)	0.0268		0.08 (-3.96, 4.13)	0.9672		0.71 (-3.27, 4.69)	0.7273	
	Cooking Fuel									
	Electric (n = 9)	-7.03 (-16.32, 2.29)	0.1403	0.0697	1.82 (-3.08, 6.72)	0.4667	0.0298	2.63 (-2.19, 7.46)	0.2851	0.0266
	Gas (n = 14)	-8.38 (-17.03, 0.29)	0.0591		-5.65 (-10.08, -1.22)	0.0129		-5.30 (-9.62, -0.97)	0.0169	
	IC									
	Yes (n = 14)	-7.64 (-15.73, 0.48)	0.0661	0.0715	0.45 (-3.74, 4.65)	0.8319	0.0337	-0.35 (-4.49, 3.79)	0.8697	0.2836
	No (n = 9)	-7.95 (-18.12, 2.25)	0.1276		-6.96 (-12.24, -1.68)	0.0102		-4.22 (-9.43, 0.98)	0.1128	
72-hr O_3	Overall	6.62 (-2.43, 15.75)	0.1531		0.72 (-3.45, 4.90)	0.7353		1.72 (-2.26, 5.69)		0.3973
	Health Insurance									
	Medicaid (n = 7)	19.31 (6.17, 32.63)	0.0041	0.011	1.04 (-4.86, 6.93)	0.731	0.9248	2.52 (-3.02, 8.07)	0.3733	0.6255
	Private (n = 15)	-2.81 (-14.65, 9.18)	0.6446		0.74 (-4.50, 5.99)	0.7813		1.58 (-3.32, 6.48)	0.5278	

Comparison to Other PdN Studies

Figure 59 shows the locations of the schools where previous air quality measurements were conducted in the PdN region. Figure 60 compares the eNO responses associated with various types of PM ($PM_{2.5}$ and PM_{10}) and exposure durations (24-, 48-, 72- and 96-hour) for the three PdN studies. Although we have observed in the 2008 study that both $PM_{2.5}$ and PM_{10} were robust predictors of eNO (with statistically significant health associations between eNO and the various pollutant metrics and increases in eNO ranging from 1–3 percent per IQR increase in PM

concentrations), the same conclusion cannot be reached under different PM exposure metrics (except with transportation BC) in 2010 and 2017. Several reasons may account for the inconclusive association between eNO responses and various PM exposure metrics.



a) Schools EP-A, EP-B, CJ-A, CJ-B **b) Schools EP-A, EP-B, EP-C, EP-D**

Figure 59. Locations of schools participating in two previous PdN transportation air quality studies.

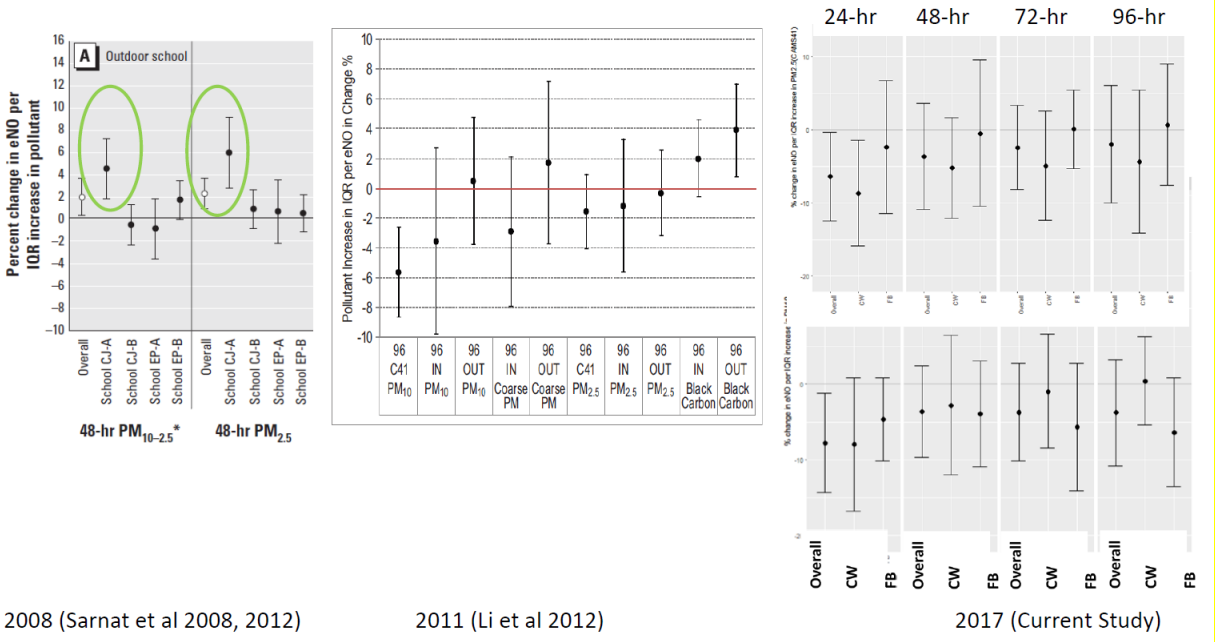


Figure 60. Comparison of eNO observations and PM concentrations.

First, a threshold of PM concentration may exist for a significant response in eNO. The roadside schools in El Paso are exposed to lower levels of PM and possibly different chemical constituents of PM. Figure 60 shows that only one of the near-road schools in Ciudad Juarez (CJ-A) has a statistically significant association between increased eNO and increased PM_{10} concentration. The PM_{10} concentration (87.7±30.3 µg/m3 for 48-hour averages) at CJ-A

was much more elevated than at any other schools in El Paso or Ciudad Juarez (Table 30). None of the schools in all three studies showed a statistically significant association between eNO and $PM_{2.5}$ metrics in asthmatic children. In addition, chemical constituents in PM are known to vary spatially and temporally. It is possible that the PM_{10} concentrations measured during winter of 2008 in Ciudad Juarez are very different from concentrations measured in 2010 and 2017 El Paso.

Second, eNO measurements may be obscured by the use of medication for asthma control. Children living in El Paso are either covered by Medicaid or private health insurance and have access to asthma control medications. For instance, the 2008 study reported that the subjects who did not take IC had more decreased lung function (FEV1) per IQR increase in PM_{10} (-7 percent [95 percent CI: -12 percent, -1.7 percent]) than did those subjects who did take the medication.

Table 30. Summary of Air Pollutant Concentrations Measured at Six Schools

Schools	Duration	Data Format	PM_{10}	$PM_{2.5}$	NO_2	O_3
2008						
EP-A	48 hr	Mean±SD	18.8±11.0	8.8±5.0	*	*
	96 hr		*	*	4.5±3.5	*
EP-B	48 hr	Mean±SD	41.0±22.3	15.6±9.5	*	*
	96 hr		*	*	14.2±3.2	*
CJ-A	48 hr	Mean±SD	87.7±30.3	31.1±14.0	*	*
	96 hr		*	*	18.7±5.8	*
CJ-B	48 hr	Mean±SD	54.8±25.3	20.4±9.9	*	*
	96 hr		*	*	27.2±10.5	*
2012						
EP-A	96 hr	Mean±SD	20.4±14.9	9.9±4.8	6.5±3.2	*
EP-B			35.2±12.1	13.8±4.4	17.5±6.1	*
2017						
FB	48 hr	Mean±SD	58.2±18.1	18.7±6.3	15.5±3.6	24.0±5.3
	96 hr		57.2±11.4	18.2±3.9	15.4±3.1	23.6±5.4
CW	48 hr		47.5±15.7	12.0±3.0	18.6±4.1	20.6±6.3
	96 hr		44.8±10.1	12.1±3.1	18.7±4.1	20.3±5.4

*Data not available

Associations between Traffic-Related Air Pollutants and Children's Physical Activities

During physical activity, changes in the frequency of breathing patterns as well as a switch to a predominantly oral respiration and bypass of nasal filtration could exacerbate the effects of air pollutants. Assuming adverse health effects are related to the amount of pollutants inhaled, in children with asthma this practice may lead to an increased chance of triggering asthma symptoms when performing activities in an outdoor environment exposed to air pollutants. The proximity to a major freeway could potentially lead to adverse health outcomes for children attending the school and participating in outdoor activities.

Differences in physical activity rates between sexes in this study are consistent with other published values but not with BMI. In our study, overweight and obese children were more physically active than underweight and normal children. The effect of health insurance could be related to the asthma severity. A study among children with asthma aged 3 to 17 showed that children enrolled in Medicaid were more likely to have a preventive care visit during the last year, and about half of them received a clinician's advice about physical activity (Perry & Kenney, 2007). Having a father or a sibling with asthma (but not a mother) significantly correlated with more time spent in sedentary behavior and less time spent in MVPA. This finding is somewhat consistent with a study in Canada that

found that having a parent with asthma increased the odds for asthma and wheezing outcomes (Barry et al., 2014). This same study found increased odds of symptom severity if a mother was a previous smoker but did not report any data on having either a father or a sibling with asthma.

We found negative correlations between the 96-hour averages of $PM_{2.5}$, PM_{10}, and NO_2 and the amount of time spent in MVPA during school hours. In contrast, sedentary activity was positively correlated with pollutant concentrations. We could not find studies that directly observed the effects of pollutants on physical activity. However, some studies have demonstrated adverse health effects related to physical activity. In healthy males, inhalation of PM during exercise led to adverse respiratory health related to reduced lung function (Rundell et al., 2010). The GEE models allowed us to account for individual factors that further validate the longitudinal association between physical activities and traffic-related air pollutants. Meteorological parameters (humidity and temperature) were also potential confounders in the analysis. We initially found positive correlations with O_3 and physical activity, possibly because high O_3 days imply more sunshine (less cloud cover) and increased outdoor temperatures. Consequently, the outdoor environment is more inviting for outdoor activities during winter months. Once the statistical approach took into account meteorology factors, associations with O_3 were in the same direction as the other pollutants but not significant. However, the use of maximum values did yield a significant association, which might mean that O_3 levels can vary in effect, or the effects might be more significant if the values reach a certain threshold. Some studies that have looked at O_3 exposure showed that a high daytime O_3 concentration was consistent with an increased likelihood of new-onset of asthma or exacerbation of undiagnosed asthma in physically active children (McConnell et al., 2002). Additional discussions on limitations of this study and other considerations are provided in Appendix E.

Mitigation and Healthy Living Strategies That Can Be Implemented to Existing Infrastructure Such as Schools or Neighborhoods near Highways

Vulnerable populations such as children might be more susceptible to the effects of air pollutants. Children attending school spend about 6–8 hours per day in various school microenvironments. In many countries, severe air pollution conditions frequently require cancellation of physical or sport activities while in school, which may lead to an increase in health problems.

Mitigation strategies can be divided into three options, each with their own benefits and challenges: controlling the quantity of pollution, controlling the emission intensity, and controlling the source-receptor pathways (McNabola et al., 2010; Tong et al., 2016). The first two focus on approaches that require policy changes and implementation—measures such as mandatory greenhouse emissions, fuel efficiency standards, charging drivers who enter congestion zones, carbon taxes, shifting to electric mass transit, reduction of vehicle idling times, and climate change goals (Galinato & Yoder, 2010).

The third option, controlling source-receptor pathways, considers passive control measures that can be implemented into roads or built environments in order to decrease pathways by which pollutants disseminate. The addition of low boundary walls located between roads and footpaths can act as baffle plates that direct the flow of pollutants away from footpaths/sidewalks (McNabola, 2010).

Another approach is to construct solid or porous barriers to enhance pollutant dispersion at the street level or in microenvironments (Gallagher et al., 2015). Green plants can intercept PM_{10} and $PM_{2.5}$, which can adhere temporarily to their surface. Eventually, these particles are resuspended in the atmosphere or washed off by rain. Several studies suggest different types of barriers, such as trees, hedgerows, and green roofs. Natural barriers lead to the improvement of air quality and overall health of those individuals living in an urban environment.

To reduce NO_2 concentrations, an additional approach is to install barriers or walls painted with a photocatalytic paint. Titanium dioxide paint has been suggested in the literature, which acts by deposition of NO_2 particles

(Jeanjean et al., 2017). Through the use of photochemical oxidation processes, the NO and NO_2 gases are oxidized and removed from the air. Regarding O_3, the presence of enough tree shade can reduce higher temperatures on asphalt, which leads to a decrease in atmospheric O_3 concentration. In addition, several types of trees and plants are helpful in reducing O_3 concentrations through stomatal and nonstomatal processes; examples include curtain fig, camphor, savin juniper, and Australian laurel (Jim & Chen, 2008).

Thus, two potentially viable design options are revealed: (a) a wide vegetation barrier with high leaf density, and (b) vegetation–solid barrier combinations that include plating trees next to a solid barrier that can use photocatalytic agents to decrease NO_2. Both designs should reduce downwind particle concentrations significantly.

Conclusions

This study characterizes the effects of traffic-related air pollutants in children with asthma using objective measures of physical activity. Our findings suggest that school-based monitoring of air pollutants is an indicator of the health risk of children's exposures and the impact on their physical activity, although sometimes the associations are obscured by the low levels of pollution and application of medication. Our findings aid in the formulation of healthy living recommendations in this border region.

Near-Road Traffic-Related Air Pollution Characterization

This study utilized portable air quality monitors to characterize air pollutants in near-road schools. Ambient air monitoring stations were installed at selected schools, ambient air quality data for $PM_{2.5}$, PM_{10}, NO_2, and O_3 were collected, and comparisons between various CAMS throughout El Paso were produced to characterize air pollution in the surrounding schools and communities.

All monitors recorded similar trends per measured pollutant across all examined sites. The unexpected higher concentrations of PM_{10} at FB is of concern. Considering that PM_{10} is characterized by natural sources, it is plausible that an increase in unpaved roads or dust from the Franklin Mountains may increase the concentration of PM_{10} around the selected sites. The three monitored sites exhibited strong Spearman correlations for all pollutants, especially among particulate pollutants. In general, correlations were lower at FB. Correlations between sites were moderate (≥0.6) for NO_2. Coefficients of divergence helped assess the spatial variability across the measured sites and CAMS. At 1-hour time resolutions, moderate to high spatial heterogeneity can be implied for the three measured sites to CAMS for all measured pollutants. At 24-hour time averages, O_3 and NO_2 between most sites was assumed to be homogeneous. However, heterogeneity in PM was observed at both time resolutions. Bliss Elementary showed the highest COD values for PM, implying greater heterogeneity between this site and the rest of El Paso. Investigating the association between children's exposure to pollutants and traffic and meteorological variables is challenging due to the numerous variables involved. Spearman correlations, COD, and diurnal graphs do not completely elucidate the differences in the pollutant levels between sites.

Health Near-Road Traffic-Related Air Pollution Characterization

We conducted a panel-based health outcome and exposure study on a cohort of 23 asthmatic children between ages 6 and 12. Linear mixed effect models or GEE IQRs were calculated for air pollutant metric and effect estimates per IQR, 95 percent confidence intervals, and *p*-values. Effect modifications by significant factors were assessed for eNO, FVC, and FEV1 responses.

Short-term (daily maximum hour, 24-, 48-, 72-, and 96-hour averages) changes in traffic-related criteria pollutants ($PM_{2.5}$, PM_{10}, O_3, NO_2) were found to be weakly associated with pulmonary inflammation and lung function in asthmatic children. The only statistically positive association between pollutant concentrations and eNO was observed at one school between eNO and 72-hour O_3, implying that an eNO increase may be more related to gaseous pollutants. Subjects' lung functions were observed to decrease with increased 24-hour PM ($PM_{2.5}$ or PM_{10}) concentration. In addition, health insurance and cooking fuel were both significant factors in modifying the PM effect on the decreased lung function. As discussed previously, a threshold of pollutant concentration for PM and other gaseous pollutants may exist such that a measurable response in eNO or lung functions can be observed. Furthermore, the measurements could be highly obscured by the possibly different chemical constituents of PM and medical control of asthmatic symptoms.

Implications for Healthy Living

This study's results show a dual response in both airway inflammation and lung function in association with traffic-related air pollutants in a pediatric asthma panel study. Our findings support previous studies and demonstrate

that there are associations between air pollution and acute pulmonary health response in a cohort of asthmatic children.

Parents of asthmatic children tend to believe that exercise is not good for children with asthma, which is consistent with our findings that children spend less time in MVPA and more time in sedentary activity when air pollution levels increase. Although levels and durations of physical activities do not seem to have a direct relationship with airway inflammation or lung function in asthmatic children, reduction of ambient levels of air pollution is believed to have a positive effect on children's respiratory health.

In the short term, placement of natural barriers (shade trees, shrubs, natural vegetation, green roofs) at the school can mitigate the effects of air pollutants. Green plants can intercept PM, which can adhere temporarily to their surface. Eventually, these particles are resuspended in the atmosphere or washed off by rain. Natural barriers lead to improvement of air quality and overall health of those living in an urban environment. In the long term, policy changes should aim to improve air monitoring programs on a local scale (instead of regional) and consider measurement of air pollutants next to highways. This information will be crucial in determining appropriate locations in order to build future schools farther from heavily trafficked roads.

Outputs, Outcomes, and Impacts

Research Outputs, Outcomes, and Impacts

Following are the research outputs, outcomes, and impacts.

- Peer-reviewed publications:

    - Aguilera, J, & Whigham, L D (2018). Using the 13C/12C carbon isotope ratio to characterize the emission sources of airborne particulate matter: a review of literature. Isotopes in environmental and health studies, 54(6), 573–587.
    - Aguilera J, Soyoung J, Raysoni A, Rangel A, Whigham L, WW Li Moderate to vigorous physical activity levels negatively correlate with traffic related air pollutants in children with asthma attending a school near a freeway. (Submitted for publication).
    - Li, W-W, 2020. Chapter 2: Air pollution, air quality, vehicle emissions and environmental regulations, in Traffic-Related Air Pollution: Emissions, Human Exposures, and Health, edited by Khreis H. et al., Elsevier S&T Books.
    - Rangel A. 2018. A Comparative Study Characterizing Traffic Related Air Pollutant Concentrations at NearRoad Communities In El Paso, Texas, M.S. Thesis, The University of Texas at El Paso. https://scholarworks.utep.edu/cgi/viewcontent.cgi?article=2523&context=open_etd
    - Raysoni, AU, Jeon S, Chavez M, Aguilera J, Whigham L, Li W-W. Evaluation of asthma control questionnaire as a metric of asthma control during an air pollution study at two roadside El Paso elementary schools. (In preparation, to be submitted to International Journal of Environmental Research and Public Health).
    - Rangel A, Raysoni, AU, Chavez M, Jeon S, Aguilera J, Whigham L, Li W-W. Monitoring of Air Pollution at two elementary schools and a residential community in El Paso, TX. In preparation, to be submitted to the Atmosphere Environment).

- Presentations at conferences and technical meetings:

    - Li W-W, Jeon S, Chavez M, Ramirez I, Rangel A, Urbina A, Vallamsundar S, Farzaneh, R, 2019. Determination of background $PM_{2.5}$ concentrations for a potential transportation project site. Presented and published at 2019 TRB annual meeting, Washington DC, Jan. 13–17, 2019. TRB Paper No. 19-02174R.
    - Aquilera J., Jeon S, Raysoni A, Rangel A, Whigham L, Li W-W, 2019. Moderate to vigorous physical activity levels negatively correlate with traffic related air pollutants in children with asthma attending a school near a highway. Presented and published at 2019 TRB annual meeting, Washington DC, Jan. 13–17, 2019. TRB Paper No. 19-01943.
    - Uwak I, Aguilera J, Ramirez I, Johnson N, Whigham L, Li W-W, Ramani T, Vallamsundar S, 2019. Exposure assessment of Traffic-Related Air Pollution in El Paso, Texas using personal and ambient monitoring, presented in the TRB Annual Meeting, Washington, DC.
    - Aguilera J. Moderate to vigorous physical activity levels negatively correlate with traffic related air pollutants in children with asthma attending a school near a freeway. Oral presentation as an attendee to the Stanford Postdoctoral Recruitment Initiative in Sciences and Medicine. Stanford CA. Oct. 2019.
    - Aguilera J. Interdisciplinary research brief: Physical activity relationships with traffic related air pollutants in children with asthma attending a school near a highway. Oral presentation at The Graduate Student Assembly general meeting. University of Texas at El Paso. Oct. 2019.
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attending road-side schools, presented at the Transportation, Air Quality, and Health Symposium, Austin, Texas, Feb. 18–20, 2019.

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- Raysoni, AU, Jeon S, Aguilera J, Li W-W, 2019. Assessment of Asthma Control Questionnaire (ACQ) as a metric for children's traffic air pollution exposures at two roadside El Paso elementary schools, presented in the Transportation, Air Quality, and Health Symposium, Austin, Texas, Feb. 18–20, 2019.
- Jeon S, Staniswalis, JG, Raysoni A, Li, W-W, 2019. Determination of the optimal sample size for a limited longitudinal cohort study of children's respiratory health and air quality, presented at the Transportation, Air Quality, and Health Symposium, Austin, Texas, Feb. 18–20, 2019.
- Aguilera J, Perez D, Redelfs A, Jeon S, Raysoni A, Li, W-W, Whigham L, 2019. Relationship between physical activities, fruits and vegetables, and air quality in children with asthma, presented at the Transportation, Air Quality, and Health Symposium, Austin, Texas, Feb. 18–20, 2019.
- Aguilera J, Whigham L., 2019, Using the 13C/12C Carbon Isotope Ratio to Characterize the Emission Sources of Airborne Particulate Matter; Poster presentation, Transportation, Air Quality, and Health Symposium; Austin, TX.
- Li W-W, Jeon S, Raysoni A, Aguilera J, Whigham L, Rangel A, Chavez M, Ramirez I, 2018. Association of respiratory responses with traffic air pollution for asthmatic children attending road schools, presented at the Air Sensor International Conference, Oakland, CA. Sep. 12–14, 2018.
- Aguilera J, Jeon S, Chavez M, Whigham L, Li, W-W, 2018. Moderate to vigorous physical activity levels negatively correlate with traffic related air pollutants in children with asthma attending a school near a freeway. presented at the 73rd meeting of the Joint Advisory Committee for the Improvement of Air Quality in the Cd. Juarez, Chihuahua, El Paso, Texas, and Dona Anna County, New Mexico Air Basin, Las Cruces, NM, Sep. 20, 2018.
- Amit U. Raysoni, Juan A. Aguilera, Leah D. Whigham, Stephanie Garcia, Moises Garcia, Adan Rangel, Mayra C. Chavez, Ivan M. Ramirez, Wen-Whai Li, 2018. Airway inflammation and lung function measurements in asthmatic children at two road-side elementary schools in El Paso, TX. Presented at the American Public Health Association 2018 Annual Meeting and Expo, Nov. 10–14, 2018, San Diego, CA.
- Aguilera J, 2018. School near a freeway: Health outcomes for children with asthma; Connector presenter, 6th Interdisciplinary Research Education Symposium, University of Texas at El Paso; El Paso, TX.
- Aguilera J, Chavez M, 2018. Moderate to vigorous physical activity levels negatively correlate with traffic related air pollutants in children with asthma attending a school near a freeway; Oral presentation, Air Quality Joint Advisory Committee; Las Cruces, NM.
- Li W-W, 2017. U.S. DOT Center for Advancing Research in Transportation Emission, Energy, and Health (CARTEEH): Research Activities in El Paso, presented at the 69th meeting of Joint Advisory Committee (JAC) for the Improvement of Air Quality in the Ciudad Juárez, Chihuahua/El Paso, Texas/Doña Ana County, New México Air Basin, El Paso, Texas, May 25, 2017.
- Aguilera J, Whigham L., 2017. Elucidation of the effects of air pollution on asthma using naturally-occurring carbon stable isotope ratios; Poster presentation, 2nd Interdisciplinary Research Expo; University of Texas at El Paso, El Paso, TX.

Education and Workforce Development Outputs, Outcomes, and Impacts

Following are the education and workforce development outputs, outcomes, and impacts.

- Media References:
    - El Paso Herald-Post: **UTEP Team Awarded up to $3.8m Grants to Study Transportation Emissions, Air Quality, Public Health.** https://elpasoheraldpost.com/tag/professor-wen-whai-li-ph-d/
    - **The Eagle, Texas A&M transportation and health researchers combine forces on air pollutants.** https://www.theeagle.com/news/local/texas-a-m-transportation-and-health-researchers-combine-forces-on-air-pollutants/article_d623fc57-07c6-5ada-8984-6d5a6fc9000f.html
    - **UTEP News Releases: Wen-Whai Li and Leah Whigham,** Health, Air Quality Study Seeks Pollution Solutions. https://www.utep.edu/newsfeed/campus/health,-air-quality-study-seeks-pollution-solutions.html
    - **UTEP Student Profile: Jun Aguilera,** Juan Aguilera, an interdisciplinary health sciences doctoral student, is a campus leader who has seized the opportunities UTEP provides. https://www.utep.edu/newsfeed/campus/UTEP-Student-Profile-Juan-Aguilera.html

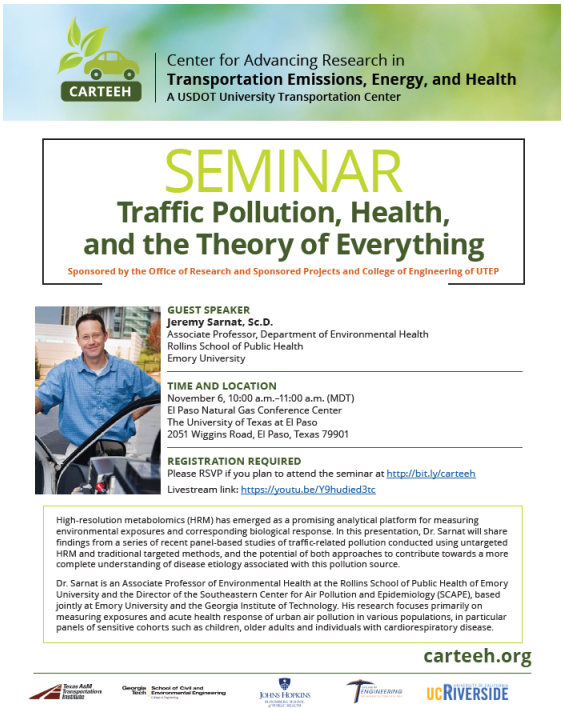
- Students involved in the project:
    - Dr. Amit Raysoni, MPH candidate.
        - Graduated August 2018.
        - Current title and position: Assistant Professor, The University of Texas at Rio Grande Valley.
    - Mayra Chavez, Ph.D. Student (1/4 time).
        - Graduated August 2019.
        - Current title and position: Postdoctoral Research Fellow, UTEP.
    - Juan Aguilera, Ph.D. Student.
        - Graduated August 2020.
        - Current title and position: Postdoctoral Research Fellow, Stanford University.
    - Dr. Soyoung Jeon, Research Scientist.
        - Co-PI of the project.
        - Current title and position: Assistant Professor (tenure-track), New Mexico State University.
    - Adan Rangel, M.S. Student.
        - Graduated August 2018.
        - Current title and position: Utility Engineering Group, New Braunfels, Texas.
    - Ivan Ramirez, M.S. Student.
        - Graduation pending (Dec. 2020, due to employment).
        - Current title and position: Engineer, Kentucky Department for Environmental Protection.
    - Moises Garcia, B.S. Student.
        - Graduated May 2018.
        - Current title and position: Project Engineer, Mimbela Contractors Inc., El Paso, Texas.
    - Stephanie Garcia, B.S. Student.
        - Graduated May 2019.
        - Current title and position: Engineer, Engineering Consulting Company, El Paso.
    - Alexandrina Urbina, High School Intern and B.S. Student at UTEP.
        - Transferred in September 2018 to Columbia University.
        - Current title and position: Junior, Columbia University.
    - Evan Williams, B.S. Student.
        - Undergraduate Research Assistant.
        - Current title and position: Junior, UTEP.

- K–12 and university-level presentations as part of the project:

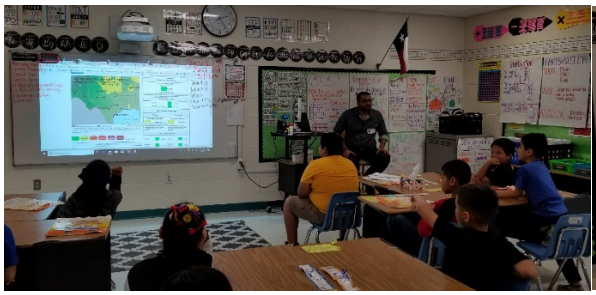
    - Coldwell Elementary School Math and Science Night (Feb. 23, 2018), Presentation given to parents and children of Coldwell Elementary School on a Math Night Event.



    - Webinar presentation of traffic pollution, health, and the theory of everything by Dr. Jeremy Sarnat (November 6, 2019).



    - Sullivan Elementary School, San Benito, TX: What is Air Pollution? (March 08, 2019), Presentation given to about 10 groups (each group comprising 12 elementary students) that explains the importance of air quality.




- International Museum of Art & Science, McAllen, TX (May 25, 2019). Presentation given to the public about air pollution issues facing the U.S.-Mexico border community.

- HESTEC 2020—Hispanic Engineering, Science, and Technology Week (January 28, 2020).
  - HESTEC Week is a nationally recognized model for promoting science, technology, engineering and math (STEM) careers to young people of all backgrounds and ethnicities. The University of Texas at Rio Grande Valley is building on the program's long-standing legacy of promoting STEM education to further prepare the next generation of students who will be changing the world through STEM.
  - 400 ninth-grade students plus their teachers attended this event. Dr. Raysoni showcased the functioning of the O_3 monitor to the students and also provided information on air quality issues. Below are three pictures from the event.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List of Abbreviations

µm	Micrometer, 10^{-6} m
ACQ	Asthma Control Questionnaire
AQR	Air Qualiy Gauge
BC	Black Carbon
BOA	Bridge of the Americas
CAMS	Continuous Ambient Monitoring Station
CO	Carbon Monoxide
COD	Coefficient of Divergence
eNO	Exhaled Nitric Oxide, ppb
EC	Elemental Carbon
ETS	Environmental Tobacco Smoke
FEF_{25-75}	Forced Expiratory Flow during the Two Interior Quartiles of Exhalation
F_{ENO}	Fractional Exhaled Nitric Oxide
FEV1	Forced Expiratory Volume in 1 Second
FEM	Federal Equivalent Mathod
FRM	Federal Referenced Method
FVC	Forced Vital Capacity
GEE	Generalized Estimating Equations
HIPAA	Health Insurance Portability and Accountability Act
ICS	Inhaled Corticosteroids
IQR	Interquartile Range
LABA	Long-Acting Bronchodilators
LB	Leukotriene Blockers
LIBAIC	Long-Acting Bronchodilators and Inhaled Corticosteroids
LOD	Limit of Detection
LT	Leukotriene Blocker
MDL	Method Detection Limit
MVPA	Moderate to Vigorous Physical Activity
NC	Nasal Corticosteroids
NHANES	National Health and Nutrition Examination Survey
nm	Nanometer, 10^{-9} m
NO_2	Nitrogen Dioxide
O_3	Ozone
PE	Physical Exercise
PEF	Peak Expiratory Flow
PM_{10}	Particle with Aerodynamic Diameters of Less Than 10 µm
$PM_{10-2.5}$	Particle with Aerodynamic Diameters between 10 and 2.5 µm
$PM_{2.5}$	Particle with Aerodynamic Diameters of Less Than 2.5 µm
ppb	Parts per Billion (in volume)
ppm	Parts per Million (in volume)
SABA	Short-Acting Bronchodilators
SC	Systemic Corticosteroids
TAKS	Texas Assessment of Knowledge and Skills Test
TCEQ	Texas Commission on Environmental Quality
TRAP	Traffic-related Air Pollution
UTEP	University of Texas at El Paso
VOCs	Volatile Organic Compounds

Appendix A. Instrument Calibration

Instrument Calibration

Calibration of instruments was performed before and after the study sampling session. During calibration, all instruments were positioned next to TCEQ CAMS 12. Prior to the study, instruments were positioned inside a van parked next to CAMS 12, as shown in Figure A.1. Tubes ran from the end of the monitors to the top of the van through gap openings. After the study, monitors were arranged inside a sheltered cabinet next to CAMS 12. Instrument 1-hour averages were compared with data collected from CAMS 12's FRM and FEM devices and with each other to determine precision and accuracy. The readings from both calibrations were lumped together to determine a best-fit curve.

Figure A.1. Instrument calibration set-up at CAMS 12.

Precision

Precision is defined as the closeness in performance of two of the same instruments. Five-minute measurements were obtained and converted to hourly averages. Instrument 1-hour averages were used for comparison. The linear regression and correlation between two of the same instruments were calculated to determine the precision of the instruments. Table A.1 summarizes the results obtained for $PM_{2.5}$ and PM_{10} from GRIMM Technologies Aerosol Spectrometer 11-A, NO_2 from 2B Technologies Model 405, and O_3 from 2B Technologies Model Ozone.

Table A.1. Linear Regression and Correlation between Instruments

X	Y	Linear Regression (R^2)
GRIMM-$PM_{2.5}$ 1	GRIMM-$PM_{2.5}$ 2	y = 0.9048x + 0.1511 (0.997)
GRIMM-$PM_{2.5}$ 1	GRIMM-$PM_{2.5}$ 3	y = 0.9896x – 0.0067 (0.999) [A]
GRIMM-$PM_{2.5}$ 2	GRIMM-$PM_{2.5}$ 3	y = 0.9778x + 0.0501 (0.999) [A]
GRIMM-PM_{10} 1	GRIMM-PM_{10} 2	y = 0.7824x + 0.5804(0.985)
GRIMM-PM_{10} 1	GRIMM-PM_{10} 3	y = 1.1895x – 0.4676 (0.997) [A]
GRIMM-PM_{10} 2	GRIMM-PM_{10} 3	y = 1.1703x – 0.2454 (0.998) [A]
2B Tech-405 1	2B Tech-405 2	y = 1.3628x + 13.341 (0.729) [B]
2B Tech-405 1	2B Tech-405 3	y = 1.1272x + 0.4275 (0.890) [B]
2B Tech-405 2	2B Tech-405 3	y = 0.6599x – 5.1537 (0.794)
2B Tech-Ozone 1	2B Tech-Ozone 2	y = 1.0366x – 0.1236 (0.996) [A]
2B Tech-Ozone 1	2B Tech-Ozone 3	y = 1.0305x – 0.3499 (0.986)
2B Tech-Ozone 2	2B Tech-Ozone 3	y = 1.0107x + 0.9002 (0.996) [A]

[A] *Pre-calibration comparison only*
[B] *Post-calibration comparison only*

Ozone

As shown in Figure A.2, Instrument 1 was relocated from the house to Bliss to replace Instrument 2, which malfunctioned in November. Instruments 1 and 3 operated for the complete duration of the study. No post-calibration was performed on Instrument 2 because the instrument was sent back to the manufacturer for checks after it malfunctioned. All three instruments demonstrated a close one-to-one linear relationship and strong correlation with each other.

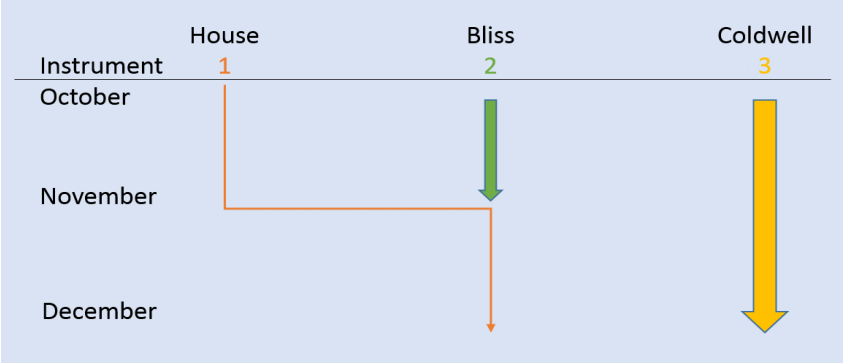

Figure A.2. O_3 monitor locations during the study period.

Nitrogen Dioxide

Instruments 2 and 3 operated for the complete duration of the study. Unforeseen complications with Instrument 1 prevented us from obtaining measurements at the house until November 21st. All three instruments showed a high correlation with each other, but the linear regression between Instrument 2 and the other instruments varied.

Particulate Matter

Table 3.2 reveals the slopes between GRIMM instruments. Debris in the inlet of Instrument 2 arose during post-calibration and prompted us to return to Bliss and CAMS 12 to re-run the GRIMM instruments again 2 months later to assess the validity of the data. Similar results were obtained from side-by-side comparisons at Bliss and CAMS 12 (Post-1 and Post-2). Instruments 1 and 2 remained consistent throughout the study, but a drift from pre- and

post-study was observed for Instrument 3. As seen in Table 3.1, for $PM_{2.5}$, all instruments demonstrated a close linear regression with each other and strong correlation. The linear regression between the instruments for PM_{10} was similar to $PM_{2.5}$.

Table A.2. Slope between GRIMM Instruments

Unit	PM	Pre	Post-1	Bliss	Post-2
1~2	2.5	1.011	-	0.931	0.903
	10	1.016	-	0.823	0.771
1~3	2.5	0.978	0.616	0.591	0.593
	10	1.189	0.518	0.491	0.466

Accuracy

Accuracy is defined as the closeness of measured values from an instrument to a standard value. The accuracy of the instruments was evaluated by computing the linear regression and correlation of each instrument with TCEQ CAMS 12. The instruments at central ambient monitoring stations use the U.S. EPA-approved Federal Reference Method (U.S. EPA, 2017). By calibrating our instruments to a CAMS, comparisons with other CAMSs could be established from the results obtained at the study sites. Five-minute measurements were obtained and converted to hourly averages. Table 3.3 summarizes the results obtained for $PM_{2.5}$ and PM_{10} from GRIMM, NO_2 from 2B Technologies Model 405, and O_3 from 2B Technologies Model Ozone.

Table A.3. Linear Regression and Correlation between Instruments and TCEQ CAMS12

X	Y	Linear Regression (R^2)
GRIMM-$PM_{2.5}$ 1	CAMS12	y = 0.6649x + 2.3405 (0.856)
GRIMM-$PM_{2.5}$ 2	CAMS12	y = 0.6703x + 2.7425 (0.836)*
GRIMM-$PM_{2.5}$ 3	CAMS12	y = 1.0749x + 2.1609 (0.835)
GRIMM-PM_{10} 1	CAMS12	y = 1.2395x + 9.8322 (0.905)
GRIMM-PM_{10} 2	CAMS12	y = 2.4181x + 5.7214 (0.857)*
GRIMM-PM_{10} 3	CAMS12	y = 1.9944x + 11.160 (0.762)
2B Tech-405 1	CAMS12	y = 1.0880x + 1.3371 (0.895)
2B Tech-405 2	CAMS12	y = 0.6083x – 3.3454 (0.706)
2B Tech-405 3	CAMS12	y = 0.8601x + 2.1692 (0.777)
2B Tech-Ozone 1	CAMS12	y = 1.1650x – 3.1970 (0.889)
2B Tech-Ozone 2	CAMS12	y = 0.9268x + 2.9831 (0.751)
2B Tech-Ozone 3	CAMS12	y = 1.1253x – 2.6891 (0.892)

**Post-calibration was performed 2 months after other instruments.*

Ozone

The 2B Technologies Ozone instruments performed the best in contrast to the other instruments. As seen in Figure A.3, all O_3 instruments show a high correlation and a linear regression close to one-to-one.

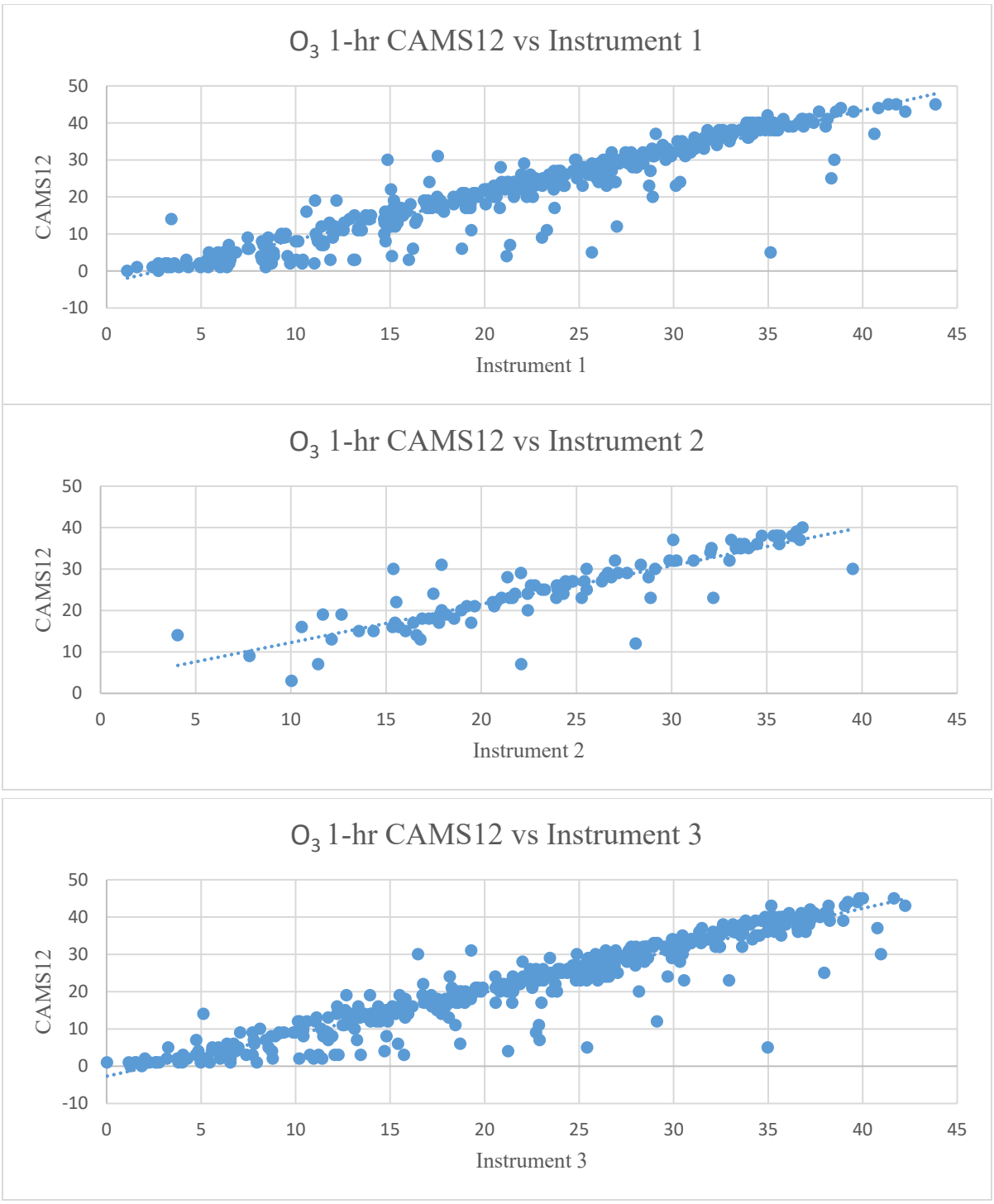

Figure A.3. O_3 1-hour CAMS12 versus instrument calibration.

Nitrogen Dioxide

As seen in Figure A.4, the NO_2 instruments varied in both correlation and linear regression. Instrument 1 had a strong correlation and linear regression close to one-to-one. Instrument 3 performed second best. Instrument 2 was the least reliable, with a linear regression slope of 0.6, although it still showed a high correlation (0.706).

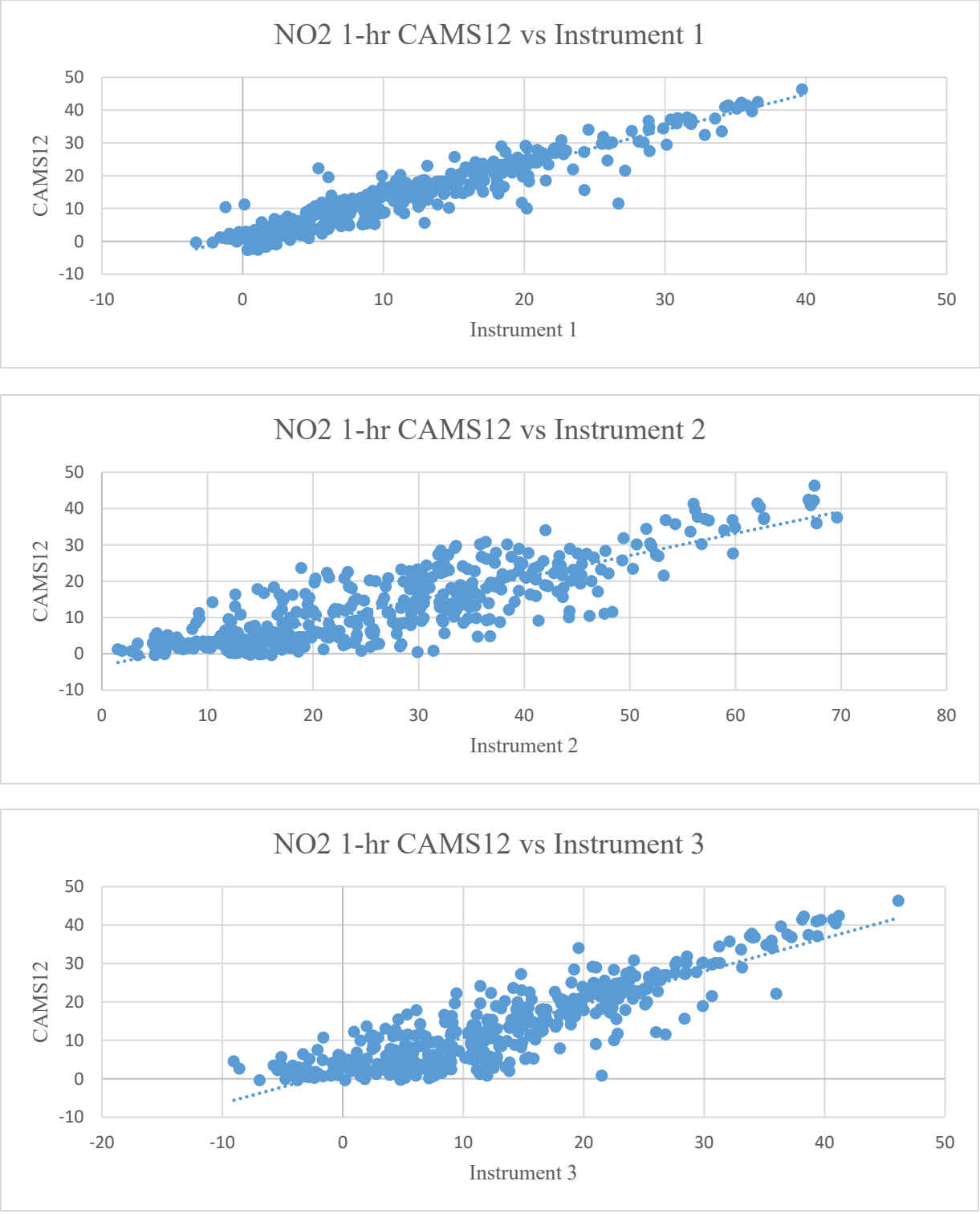

Figure A.4. NO_2 1-hour CAMS12 versus instrument calibration.

Particulate Matter

For $PM_{2.5}$, all the instruments showed a high correlation. Instrument 3 recorded similar values as CAMS 12, but Instruments 1 and 2 over-recorded. For PM_{10}, the linear regression varied significantly from the $PM_{2.5}$ regression

line obtained from the same instruments. PM_{10} was under-recorded in all instruments. A shown in Table 3.4, a drift from pre- and post-study is observed for all GRIMM instruments.

Table A.4. Slope of GRIMM Instruments versus CAMS12

Unit	PM	Pre	Field	Post-1	Post-2
1	2.5	0.576	Pre + Post-1	0.667	0.597
	10	1.214		1.245	2.010
2	2.5	0.567	Pre + Post-2	-	0.661
	10	1.188		-	2.610
3	2.5	0.581	Pre + Post-1	1.08	0.996
	10	1.017		2.363	4.315

Data Adjustments

The downtime from when data were being downloaded from the instruments left an hour of missing data. To avoid having additional missing data, the hour was interpolated. Negative values indicated a below detection limit and were assigned a value of 0.5 µg/m³ for $PM_{2.5}$ and 0.5 ppb for O_3 and NO_2, half of the detection limit.

Appendix B. Documents Used in Health Outcome Study

Recruitment Flyer—English and Spanish

Healthy Living and Traffic-Related Air Pollution in an Underserved Community

Does your child have physician-diagnosed asthma?

Are you interested in the effects of traffic air pollution on your child's asthma symptoms?

Researchers from the University of Texas at El Paso (UTEP) are currently enrolling children between the ages of 6 and 12 living in El Paso for a research study examining the impact of traffic air pollution on asthma symptoms at your child's school.

Your child may be eligible to participate in this study if he/she has **physician-diagnosed asthma**; is willing and able to complete (with the help of field staff) **weekly questionnaires** about their asthma symptoms and to provide **weekly breath samples**, which will be tested for exhaled nitric oxide, a measure of lung inflammation. In addition, we will administer **lung function** measurements tested by a spirometer, assess **carotenoid levels** – a biomarker suggesting the daily intake of fruits and vegetables, **physical activity rates** using an accelerometer, and **heart-rate variability** measurements using a simple holder monitor. The study will last for 12 weeks during the fall of 2017 and the weekly questionnaires and measurements will take approximately 15-20 minutes per week, during the school day. In addition, you must also be willing and able to complete an initial questionnaire (which will take approximately 30 minutes).

Children completing this study will receive a $50 gift certificate to a local bookstore for their participation.

For more information, please contact either:

Dr. Wen-Whai Li	Dr. Leah D. Whigham	Dr. Juan A. Aguilera (Se Habla Español)
(915) 747-8755	(915) 747 8095	(915) 274 3475
UTEP	UTEP	UTEP
500 W. University Ave.	500 W. University Ave.	500 W. University Ave.
El Paso, TX 79968	El Paso, TX 79968	El Paso, TX 79968

Department of Civil Engineering & Department of Public Health Sciences, The University of Texas at El Paso, 500 W University Avenue, El Paso, TX 79968

Una Vida Sana Y La Contaminación Del Aire Relacionada Con El Tráfico En Una Zona Subatendida

¿A su niño/niña le ha diagnosticado asma algún médico?

¿Está usted interesado/a en saber los efectos que tiene la contaminación del aire debido al tráfico en los síntomas asmáticos de su niño/niña?

Investigadores de la Universidad de Texas en El Paso están actualmente matriculando a niños entre los 6 y 12 años que vivan en El Paso para llevar a cabo un estudio de investigación, en la escuela de su niño/niña, examinando el impacto de la contaminación del aire relacionado con el tráfico en los síntomas asmáticos de los niños.

Su niño/niña puede calificar para participar en este estudio si él/ella ha sido diagnosticado con asma por un médico; si está dispuesto/a completar (con la ayuda de nuestro personal) cuestionarios semanales sobre sus síntomas asmáticos y a proveer muestras de aliento semanales, los cuales serán sometidos a pruebas buscando óxido nítrico exhalado, la cual es una medida de inflamación pulmonar. Además, le mediremos la función pulmonar usando un espirómetro, evaluaremos niveles de carotenoides – un biomarcador que sugiere la ingestión diaria de frutas y verduras, el rango de actividad física usando un acelerómetro, y las medidas de variabilidad en el pulso, usando un simple *monitor Holter*. El estudio durará doce semanas y tendrá lugar en el otoño de 2017 y los cuestionarios y medidas necesarias que se tomen requerirán aproximadamente de 15 a 20 minutos por semana y se harán durante los días de escuela. Además, usted deberá estar dispuesto/a y disponible para completar un cuestionario inicial (el cual le tomará aproximadamente 30 minutos.)

Los niños que completen este estudio recibirán un certificado de regalo por $50 (dólares) para una librería local por su participación.

Para más información, llame a cualquiera de las personas cuyos teléfonos aparecen aquí:

Dr. Wen-Whai Li	Dra. Leah D. Whigham	Dr. Juan A. Aguilera (Se habla español)
(915) 747-8755	(915) 747-8095	(915) 274-3475
UTEP	UTEP	UTEP
500 W. University Ave.	500 W. University Ave.	500 W. University Ave.
El Paso, TX 79968	El Paso, TX 79968	El Paso, TX 79968

Department of Civil Engineering & Department of Public Health Sciences, The University of Texas at El Paso, 500 W University Avenue, El Paso, TX 79968

Parents' Meeting Flyer (English); Parents' Meeting Flyer (Spanish)

Invitation to a Meeting on Healthy Living and Children's Health
Time: **3:45 to 4:15 pm, Sep 28 (R), 2017**
Location: **School Cafeteria**

Dear Parent:

Does your child have asthma?

Are you interested in the effects of traffic air pollution on your child's asthma symptoms?

Are you interested in registering your child in a non-invasive, playful test study to understand the effect?

If yes, please attend a presentation organized by researchers from the University of Texas at El Paso (UTEP) on **September 28th 2017 at 3:45 pm**. The presentation will take place in the **school cafeteria**. The researchers will discuss the details about this traffic air pollution and asthma study and answer any questions you may have. Please contact the school nurse for further details. Children are welcome to the presentation.

Children completing this study will receive a $50 gift certificate to a local bookstore for their participation

- **The [redacted] School and UTEP Research Team**

Please contact Dr. Juan Aquilera (915)274-3475 or Dr. Amit Raysoni (915)704 9923 if you have any questions

Invitación para Junta sobre Vida Saludable y Salud de los Niños

Tiempo: **3:45 a 4:15 pm, Sep. 28 (R), 2017**

Lugar: **Cafetería Escolar**

Estimado Padre de Familia:

¿Su hijo(a) tiene asma?

¿Está interesado en los efectos que la contaminación del aire por el tráfico tiene sobre los síntomas de asma en su hijo(a)?

¿Está interesado en registrar a su hijo(a) en un estudio no-invasivo y entretenido para entender los efectos? Si es así, por favor acuda a la presentación organizada por los investigadores de la Universidad de Texas en el Paso (UTEP) el día **28 de septiembre del 2017 a las 3:45 pm**. La presentación se llevará a cabo en la **cafetería de la escuela**. Los investigadores discutirán los detalles sobre este estudio de contaminación de aire por el tráfico y asma, responderán cualquier pregunta que tenga. Favor de contactar a la enfermera de la escuela para más detalles. Los niños son bienvenidos durante la presentación.

Los(as) niños(as) que completen este estudio recibirán una tarjeta de regalo de $50 dólares para una librería local por su participación

- [redacted] **School e Investigadores de UTEP**

Favor de contactar a Dr. Juan Aquilera (915)274-3475 si tiene preguntas

Screening Questionnaire—English and Spanish

SCREENING QUESTIONNAIRE
UTEP – Fall 2017

Date: _____Screened By: _____

Parent/Guardian's Name: _____

Child's Name: _____

Home Phone: _____Other Phone: _____

Address (include zip code):_____

Questionnaire Administered (circle one): By Phone In Person

Date Called: _____ Date Called Back: _____

1) Does another member in your household have asthma? Yes ☐ No ☐

2) Has your child ever been diagnosed with asthma? Yes ☐ No ☐
If yes, when: _____

3) Does your child have any allergies? Yes ☐ No ☐
If yes, to what? _____

4) What is your child's age? _____ Date of Birth: _____

5) a. What medications is your child currently taking for their asthma?

_____

b. Other medications? _____

6) Does your child have an active lung disease other than asthma (e.g. chronic bronchitis, emphysema, cystic fibrosis, chronic obstructive pulmonary disease, chronic heart failure)? Yes ☐ No ☐

7) Does anyone in your household smoke? Yes ☐ No ☐

8) Has your child used oral steroid medication to treat asthma in the last 4 months (Inhaled Steroids>500mg/Day BDP)? Yes ☐ No ☐

9) Does your child take more than 8 puffs/day of an inhaler? Yes ☐ No ☐
How many puffs/day? _____
What is the name of the medication (e.g., Albuterol)? _____

10) Other information: _____

Inclusion Criteria: To be completed by field staff only	**YES**	**NO**	**Comments**
Age 6-12 yrs?	☐	☐	
Diagnosed asthmatic?	☐	☐	
No other lung disease or major illness?	☐	☐	
Lives in non-smoking household?	☐	☐	
Approximate distance (km) between residence and school: _____			
Residence near school?	☐	☐	
Subject eligible for study?	☐	☐	

CUESTIONARIO DE SELECCIÓN

UTEP –Otoño de 2017

Fecha: _____Seleccionado/a por: _____
Nombre del padre/madre/tutor: _____
Nombre del niño/niña: _____
Teléfono en casa: _____Otro teléfono: _____
Domicilio (incluya el código postal):_____
Cuestionario administrado (encierre en un círculo): Por teléfono En persona
Fecha en que se llamó: _____Fecha en la que se volvió a llamar:_____
……..

1) ¿Alguien más en su casa tiene asma? Sí ☐ No ☐

2) ¿Alguna vez le han diagnosticado asma a su niño/niña? Sí ☐ No ☐
Si la respuesta es "sí", ¿cuándo fue?: _____

3) ¿Tiene alergias su niño/niña? Sí ☐ No ☐
Si la respuesta es "sí" ¿a qué?: _____

4) ¿Cuál es la edad de su niño/niña? _____ Fecha de nacimiento: _____

5) a. ¿Cuáles medicamentos está tomando su niño/niña para el asma actualmente?

_____

b. ¿Otros medicamentos? _____

6) ¿Tiene su niño/a alguna enfermedad pulmonar activa, otra que no sea el asma (por ejemplo: bronquitis crónica, enfisema, fibrosis quística, enfermedad pulmonar obstructiva crónica, insuficiencia cardiaca crónica)?
Sí ☐ No ☐

7) ¿Hay alguien en su casa que fume? Sí ☐ No ☐

8) ¿Ha usado su niño/niña esteroides orales para tratar el asma en los últimos 4 meses? (¿Ha inhalado esteroides>500mg/día BDP)? Sí ☐ No ☐

9) ¿Aspira su hijo más de 8 veces al día del inhalador? Sí ☐ No ☐
¿Cuántas veces lo inhala? _____
¿Cuál es el nombre del medicamento? (ejem., ¿Albuterol?) _____

10) Otra información: _____

Criterios de inclusión: Sólo para completarse por el equipo del área o campo	**SÍ**	**NO**	**Comentarios**
¿Edad 6-12 años?	☐	☐	
¿Diagnosticado como asmático/a?	☐	☐	
¿Ninguna otra enfermedad pulmonar o enfermedad seria?	☐	☐	
¿Vive en un hogar donde nadie fuma?	☐	☐	
Distancia aproximada (km.) entre la casa y la escuela: _____			
¿Está la casa cerca de la escuela?	☐	☐	
¿Califica este/a niño/niña para el estudio?	☐	☐	

CHILD BASELINE INTERVIEW

Healthy Living and Traffic-Related Air Pollution in an Underserved Community

SECTION A. GENERAL INFORMATION

A1. Study ID:

A2. Screening ID: ____ ____ ____ ____ ____ ____

A3. Questionnaire completion date: ___ ___ / ___ ___ / ___ ___
M M D D Y Y

A4. Interviewer's initials: _____

A5. Child's date of birth: ___ ___ / ___ ___ / ___ ___
M M D D Y Y

A5a. Sex: MALE FEMALE

A6. Caretaker's name:

A6a._____ A9b._____
[FIRST] [LAST]

A7. Caretaker's relationship to child:

Mother (bio or adoptive) 1
Father (bio or adoptive) 2
Step-mother 3
Step-father 4
Foster parent 5 [Not allowed]
Grandmother 6
Grandfather 7
Sibling 8
Other family 9 [Specify: a. _____]
Other non-family 10 [Specify: a. _____]
Don't know -2

SECTION B: CHILD AND FAMILY MEDICAL HISTORY

The first questions are about [CHILD]'s health in general. Let's start with the time [CHILD] was born.

B1. How much did [CHILD] weigh at birth?
[If caretaker responds with only pounds, prompt with "How many ounces?"
If caretaker knows only lbs, enter the number of pounds in B1a and enter -2 for ounces in B1b.
If caretaker does not know either pounds or ounces, enter -2 in both spaces and answer B1c.
If caretaker reports 1/2 ounces, round to nearest ounce, e.g. 8 lbs 5.5 oz = 8 lbs 6 oz.]

B1a._____ lbs B1b._____ ounces
_____ kgs _____ grams

B1c. Did [CHILD] weigh greater than or less than 5 lbs at birth? [ONLY ANSWER IF B1a=-2.]

Greater than 5 lbs..... 1
Less than 5 lbs..... 2
Don't know..... -2

B2. When [CHILD] was first born, was he/she in an intensive care unit, premature nursery, or any type of special care facility?

YES NO DON'T KNOW

B3. When [CHILD] was first born, was he/she on a respirator (breathing machine)?

YES NO DON'T KNOW

The next set of questions relate to [CHILD]'s medical history.

B4. Has [CHILD] had 4 or more wheezing episodes?	**YES**	**NO**
B5. Does [CHILD] have physician diagnosed atopic dermatitis/eczema?	**YES**	**NO**
B6. Does [CHILD] have allergic sensitization to 1 or more aeroallergens?	**YES**	**NO**
B7. Does [CHILD] have allergic sensitization to milk, eggs or peanuts?	**YES**	**NO**
B8. Does [CHILD] have wheezing other than with colds?	**YES**	**NO**
B9. Does [CHILD] have blood eosinophilia?	**YES**	**NO**

The next set of questions relate to [CHILD]'s family medical history.

B10. Does mother of [CHILD] have asthma?	**YES**	**NO**
B11. Does father of [CHILD] have asthma?	**YES**	**NO**
B12. Does mother of [CHILD] have allergies/hay fever?	**YES**	**NO**
B13. Does father of [CHILD] have allergies/hay fever?	**YES**	**NO**
B14. Does any sibling(s) of [CHILD] have asthma?	**YES**	**NO**

B15. Does any sibling(s) of [CHILD] have allergies/hay fever? YES NO

The next set of questions relate to [CHILD]'s medical history in the past three months. In particular, I would like to know how often [CHILD] has asthma flares (e.g., an increase in signs of asthma for more than a day, or the need to take more albuterol or other quick relief medicines)? I would also like to know how [CHILD] is in between asthma flares. Think about the past three months and answer the following questions: **[Asthma Control Tool questions, except for B21]**

B16. How many asthma flares did [CHILD] have?

0 1 2 3 4 5 or more

B17. How many times did [CHILD] have an asthma flare that lasted a week or more?

0 1 2 3 4 5 or more

B18. How many times did [CHILD] start on a steroid medicine by mouth for asthma such as prednisone (Prelone, Pediapred or Orapred)?

0 1 2 3 4 5 or more

B19. How many times did [CHILD] make an emergency visit for asthma?

0 1 2 3 4 5 or more

B20. How many times did [CHILD] stay overnight in the hospital for asthma?

1 2 3 4 5 or more

B21. How many days did [CHILD] miss school due to asthma?

1 2 3 4 5 or more

B22. Asthma symptoms with light activity such as walking up steps or laughing or crying

Never 0
Once or twice a month 1
Once or twice a week 2
Every other day 3
Every day 4
More than once a day 5

B23. Asthma symptoms with running or sports

Never 0
Once or twice a month 1
Once or twice a week 2
Every other day 3
Every day 4
More than once a day 5

B24. Asthma symptoms while asleep at night

Never 0
Once or twice a month 1
Once or twice a week 2
Every other day 3

Every day **4**
More than once a day **5**

B25. Asthma symptoms in the morning when he or she woke up
Never **0**
Once or twice a month **1**
Once or twice a week **2**
Every other day **3**
Every day **4**
More than once a day **5**

B26. He or she needed to take albuterol or another quick-relief medicine for asthma symptoms
Never **0**
Once or twice a month **1**
Once or twice a week **2**
Every other day **3**
Every day **4**
More than once a day **5**

SECTION C: MEDICAL RISK ASSESSMENT

Now I have a few questions about the medical care [CHILD] receives and the medicines that he/she takes.

C1. During the past 12 months, when [CHILD] went to a doctor for asthma care, was it usually in an ER or clinic or doctor's office? [DO NOT READ LIST.]

ER 1
Clinic/office 2
Both, mostly ER 3
Both, mostly clinic/office 4
Never had doctor's visit 5

C2. During the past 2 months, did [CHILD] take any medicines for asthma?

YES NO [If no, skip to C2b]

C2a. If yes, is [CHILD] currently taking any medicines prescribed for asthma every day, even when he/she is well, to prevent symptoms?

YES NO [If yes, skip to C3]

C2b. If no, in the past 2 months, has [CHILD] been prescribed any medicines for asthma to use every day, even when he/she is well, to prevent symptoms?

YES NO DON'T KNOW

C3. Of the list below, please indicate which medicines [CHILD] currently takes every day and/or when [CHILD] is having asthma signs/symptoms.
[PROMPT: with pictures and/or sample boxes of medicines. For data entry, each medicine below is grouped into one of the following categories: SC=systemic corticosteroids; IC=inhaled corticosteroids; NC=nasal corticosteroids; SABA=short-acting bronchodilators; LABA=long-acting bronchodilators; LIBAIC=combination of long-acting bronchodilators and inhaled corticosteroids; LB=leukotrieneblockers]

ORAL:

[SABA] Liquid albuterol ..... YES NO
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[LB] Montelukast (Singulair) ..... YES NO
If yes, which dosage: 4mg 5mg 10mg
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[LB] Zafirlukast (Accolate) ..... YES NO
If yes, which dosage: 10mg 20mg
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[LB] Zileuton (Zyflo), 600 mg ..... YES NO
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[SC] **Prednisone or prednisolone (Orapred)** **YES** **NO**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

[LABA] **Theophylline** **YES** **NO**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

INHALED:

[SABA] **Ventolin (Proventil, Albuterol) HFA** **YES** **NO**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

[SABA] **Ventolin (Proventil, Albuterol), by nebulizer** **YES** **NO**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

[SABA] **Ipratropium (Atrovent) HFA** **YES** **NO**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

[SABA] **Ipratropium (Atrovent), by nebulizer** **YES** **NO**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

[SABA] **Cromolyn sodium (Intal) inhaler** **YES** **NO**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

[SABA] **Cromolyn sodium (Intal), by nebulizer** **YES** **NO**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

[IC] **Budesonide (Pulmicort) Flexhaler** **YES** **NO**
If yes, which dosage: **90 mcg** **180 mcg**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

[IC] **Budesonide (Pulmicort), by nebulizer** **YES** **NO**
If yes, which dosage: **0.25mg** **0.50 mg**
If yes, number of puffs/day: **2 puffs 2x/day** **Other:_____**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

[LABAIC] **Budesonide/Formoterol (Symbicort) HFA** **YES** **NO**
If yes, which dosage: **80/4.5 mcg** **160/4.5 mcg**
If yes, number of puffs/day: **2 puffs 2x/day** **Other:_____**
[CHILD] takes every day? **YES** **NO**
[CHILD] takes only for symptoms? **YES** **NO**

[IC] **Fluticasone (Flovent) HFA** **YES** **NO**
If yes, which dosage: **44 mcg** **110 mcg** **220 mcg**

If yes, number of puffs/day: 2 puffs 2x/day Other:_____
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[LABAIC] Fluticasone/Salmeterol (Advair) HFA ..... YES NO
If yes, which dosage: 45/21 mcg 115/21 mcg 230/21 mcg
If yes, number of puffs/day: 2 puffs 2x/day Other:_____
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[LABAIC] Fluticasone/Salmeterol (Advair) Diskus ..... YES NO
If yes, which dosage: 100/50 mcg 250/50 mcg 500/50 mcg
If yes, number of puffs/day: 2 puffs 2x/day Other:_____
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[IC] Mometasone (Asmanex) twisthaler ..... YES NO
If yes, which dosage: 110 mcg 220 mcg
If yes, number of puffs/day: 2 puffs 2x/day Other:_____
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[IC] Beclomethasone (Qvar) HFA ..... YES NO
If yes, which dosage: 40 mcg 80 mcg
If yes, number of puffs/day: 2 puffs 2x/day Other:_____
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

NASAL SPRAYS:

[NC] Fluticasone propionate (Flonase) ... YES NO
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[NC] Fluticasone furoate (Veramyst) ..... YES NO
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[NC] Mometasone (Nasonex) ..... YES NO
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

[NC] Budesonide (Rhinocort aqua) ..... YES NO
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

INJECTED:

[SC] Triamcinolone (Kenalog) ..... YES NO
[CHILD] takes every day? YES NO
[CHILD] takes only for symptoms? YES NO

C4. Have you had any problems in dealing with [CHILD]'s taking medications at school?

YES NO NO MEDS TAKEN AT SCHOOL

C5. During the past 12 months, was [CHILD] covered at any time by Medicaid?

YES NO DON'T KNOW

C6. Is [CHILD] now covered by a health insurance plan which pays any part of a hospital, doctor's or surgeon's bill?

YES NO DON'T KNOW

C6a. If yes, what is the name of the health insurance plan? _____

Managed Care 1
Medicaid 2
Medicaid Managed Care 3
Private 4
Don't know ..... -2

SECTION D: CHILD'S AND FAMILY DEMOGRAPHICS

Most of the interview so far has asked about [CHILD]'s health. Now I have some more general questions about [CHILD], you and your family.

D1. What grade is [CHILD] currently enrolled in? _____
[Code as follows: P=preschool, K=kindergarten, 1-6= grades 1-6]

D2. How long has [CHILD] lived at his/her current address? a._____ years b._____ months

D3. What is the highest grade or school level that you have completed? _____
[Use education codes below.]

D4. How many people live in [CHILD]'s home, including [CHILD] and you? _____
[The respondent should be included, if appropriate.]

D5. How many of these household members are adults? (i.e., 18 years and over) _____

D6. Thinking about where [CHILD] lives, who would you say is the head or heads of the household?
[PROMPT: Who would you say is "in charge"? If caretaker is the only adult in the household (i.e., B5=1), then enter caretaker's information in D6a and D6b. Use relationship and education codes listed below]

Name: _____ [HEAD OF HOUSEHOLD 1]

D6a1. How is [HEAD OF HOUSEHOLD 1] related to [CHILD]? _____

D6b1. What highest grade or school level has [HEAD OF HOUSEHOLD 1] completed? _____

Name: _____ [HEAD OF HOUSEHOLD 2]

D6a2. How is [HEAD OF HOUSEHOLD 2] related to [CHILD]? _____

D6b2. What highest grade or school level has [HEAD OF HOUSEHOLD 1] completed? _____

Relationship codes:
1=Mother (bio or adoptive)
2=Father (bio or adoptive)
3=Step-mother
4=Step-father
5=Foster parent
6=Grandmother
7=Grandfather
8=Sibling
9=Other family
10=Other non-family
-2 = Don't know

Education codes:
0 = Never attended school
1-11 = Specific grade completed for grades 1-11
12 = GED or 12th grade
13 = 1 or 2 years of college/technical/voc training
14 = 3 or 4 years of college/technical/voc training
15 = 5+ years of college/technical/voc training
16 = Other
-2 = Don't know

D7. How would you describe [CHILD]'s race, nationality, or ethnic background?
[Ask open-ended and use codes below. PROMPT: "What is [CHILD]'s race?"]

HISPANIC: [If necessary, prompt with 'Which ethnic group or nationality?']
Puerto Rican 1
Dominican 2
Mexican 3
South American 4
Central American 5
Cuban 6
Other Hispanic 7
BLACK: [If necessary, prompt with 'Which ethnic group or nationality?']
African American/Black American .. 8
West Indian 9
Caribbean Black 10
Other Black 11
WHITE 12
ASIAN 13

D8. And how would you describe your race, nationality, or ethnic background?
[Ask open-ended and use codes below]

HISPANIC: [If necessary, prompt with 'Which ethnic group or nationality?']
Puerto Rican 1
Dominican 2
Mexican 3
South American 4
Central American 5
Cuban 6
Other Hispanic 7

BLACK: [If necessary, prompt with 'Which ethnic group or nationality?']
African American/Black American .. 8
West Indian 9
Caribbean Black 10
Other Black 11
WHITE 12
ASIAN 13

D9. What is your current marital status?
Married 1
Divorced 2
Single 3
Widowed 4
Separated 5
Other 6 Specify: a. _____

SECTION E: ENVIRONMENTAL RISK FACTORS

Now I would like to ask you some questions about smoking in [CHILD]'s home.

E1. How many people who live in [CHILD]'s home smoke? ___ people
[Include respondent if smoker.]

E2. Does anyone else who takes care of [CHILD], such as a babysitter or day care worker, smoke?

YES NO

E3. Do you smoke cigarettes, even occasionally?

YES NO [If no, skip to E4]

E3a. About how many years have you been smoking? ___ years

E3b. About how many cigarettes a day do you smoke? ___ # cigarettes/day

E3c. How many of these are smoked in the home? ___ # of daily cigarettes at home

E4. Does [CHILD] smoke cigarettes?

YES NO DON'T KNOW

E5. Many people have difficulties keeping their children away from tobacco smoke. Do you have problems keeping [CHILD] away from people who are smoking?

YES NO DON'T KNOW

E6. How frequently is your child around people who are smoking?

Daily 1
Several times a week 2
Several times a month 3
Rarely 4

Now I have some questions regarding other features of [CHILD]'s home.

E7. Does [CHILD]'s home use gas or electric fuel for cooking?
Gas 1

Electric **2**
Wood, other biofuel **3**

E8. If gas fuel is used, does the gas stove have a constant pilot light?

YES **NO** **DON'T KNOW**

ENTREVISTA PARA ELABORAR BASE DE REFERENCIA DEL NIÑO/NIÑA
Vida Sana y Contaminación del Aire Relacionada con el Tráfico en una Zona Subatendida

SECCIÓN A. INFORMACIÓN GENERAL

A1. Identificación del estudio: _____

A2. Identificación de la selección: ____ ____ ____ ____ ____ ____

A3. Fecha en que se complete el cuestionario: ___ ___ / ___ ___ / ___ ___
M M D D A A

A4. Iniciales del/de la entrevistador(a): _____

A5. Fecha de nacimiento del niño/de la niña: ___ ___ / ___ ___ / ___ ___
M M D D A A

A5a. Sexo NIÑO NIÑA

A6. Nombre de la persona que lo/la cuida:

A6a._____ A9b._____
[Nombre] [Apellido]

A7. Relación que tiene el niño/a con la persona que lo cuida:

Madre (biológica o adoptiva) 1
Padre (biológico o adoptivo) 2
Madrastra 3
Padrastro 4
Padre/madre de crianza 5 [No se permite]
Abuela 6
Abuelo 7
Hermano/a 8
Otro familiar 9 [Especifique: a. _____]
Otro/no pariente 10 [Especifique: a. _____]
No se sabe -2

SECCIÓN B : EL NIÑO/LA NIÑA Y LA HISTORIA MÉDICA DE LA FAMILIA

Las primeras preguntas son sobre la salud en general [del niño/la niña]. Comencemos desde que [el niño/la niña] nació.

B1. ¿Cuánto peso [el niño/la niña] al nacer?
[Si la persona al cuidado del niño/de la niña responde sólo el peso en libras, pregúntele "y cuántas onzas?"
Si la persona sólo sabe cuánto pesó en libras, escriba el número de libras en el B1a y escriba -2 por las onzas en el B1b.
Si la persona no sabe ni el número de libras ni onzas, escriba -2 in en ambos espacios y conteste el B1c.
Si la persona reporta ½ onzas, redondee la cantidad a la onza más cercana, [por ejemplo: 8 libras 5.5 onzas = 8 libras 6 onzas]

B1a._____ libras B1b._____ onzas
_____ kilos _____ gramos

B1c. El niño/la niña pesó más de o menos de 5 libras al nacer? [SÓLO RESPONDA SI EL B1A = -2]

Más de 5 libras 1
Menos de 5 libras 2
No se sabe -2

B2. Cuando [el niño/la niña] nació, ¿estuvo él/ella en la unidad de terapia intensiva o alguna unidad de cuidado intensivo, cunero para prematuros o alguna clase de instalación de cuidados especiales?

SÍ NO NO SE SABE

B3. Cuando [el niño/la niña] nació, ¿estuvo él/ella en un respirador (máquina para respirar)?

SÍ NO NO SE SABE

La siguiente serie de preguntas se relaciona con la historia médica [del niño/de la niña].

B4. ¿Ha tenido el niño/la niña 4 o más episodios de sibilancias (silbidos)? SÍ NO

B5. ¿Ha diagnosticado algún médico al niño/la niña con dermatitis atópica/eczema? SÍ NO

B6. ¿Tiene el niño/la niña sensibilización alérgica a 1 o más aeroalergenos? SÍ NO

B7. ¿Tiene el niño/la niña sensibilización alérgica a la leche, los huevos o los cacahuates?
SÍ NO

B8. ¿Tiene el niño/la niña sibilancias (silbidos) además de cuando tiene catarro? SÍ NO

B9. ¿Tiene el niño/la niña altos eosinófilos (eosinofilia) en sangre? SÍ NO

La siguiente serie de preguntas se relacionan con la historia médica de la familia [del niño/de la niña].

B10. ¿La madre [del niño/de la niña] tiene asma? SÍ NO

B11. ¿El padre del niño/de la niña tiene asma? SÍ NO

B12. ¿La madre [del niño/de la niña tiene alergias/fiebre de heno? SÍ NO

B13. ¿El padre [del niño/de la niña] tiene alergias/fiebre de heno? SÍ NO

B14. ¿Tiene asma alguno(a) de los hermanos/hermanas [del niño/de la niña]? SÍ NO

B15. ¿Tiene alergias/fiebre de heno alguno(a) de los hermanos/hermanas [del niño/de la niña]? SÍ NO

La siguiente serie de preguntas se relaciona con la historia médica [del niño/de la niña] durante los últimos tres meses. En particular, yo quisiera saber con qué frecuencia tiene [el niño/la niña] ataques de asma (por ejemplo, un aumento en las señales de asma por más de un día, o la necesidad de tomar Albuterol o algún otro medicamento para un alivio rápido)? Yo también quisiera saber cómo está [el niño/la niña] entre los ataques que tiene. Piense en los últimos tres meses y conteste las siguientes preguntas: **[Preguntas herramienta para el control del asma, excepto por el B21]**

B16. ¿Cuántos ataques de asma tuvo [el niño/la niña]?
0 1 2 3 4 5 o más

B17. ¿Cuántas veces tuvo [el niño/la niña] algún ataque de asma que le haya durado una semana o más?

0 1 2 3 4 5 o más

B18. ¿Cuántas veces empezó [el niño/la niña] a tomar por vía oral un medicamento con esteroides para el asma, tales como prednisona (Prelone, Pediapred o Orapred)?

0 1 2 3 4 5 o más

B19. ¿Cuántas veces tuvo [el niño/la niña] que ir a emergencias debido al asma?

0 1 2 3 4 5 o más

B20. ¿Cuántas veces tuvo [el niño/la niña] que pasar la noche en el hospital debido al asma?

1 2 3 4 5 o más

B21. ¿Cuántos días faltó [el niño/la niña] a la escuela debido al asma?

0 1 2 3 4 5 o más

B22. Síntomas asmáticos provocados por actividades ligeras, tales como subir escaleras, reír o llorar
Nunca 0
Una o dos veces al mes 1
Una o dos veces a la semana 2
Cada tercer día 3
Todos los días 4
Más de una vez al día 5

B23. Síntomas asmáticos al correr o al hacer deporte
Nunca 0
Una o dos veces al mes 1
Una o dos veces a la semana 2
Cada tercer día 3
Todos los días 4
Más de una vez al día 5

B24. Síntomas asmáticos mientras dormía por la noche
Nunca 0
Una o dos veces al mes 1
Una o dos veces a la semana 2
Cada tercer día 3
Todos los días 4
Más de una vez al día 5

B25. Síntomas asmáticos por la mañana cuando él o ella se despertó
Nunca 0
Una o dos veces al mes 1
Una o dos veces a la semana 2
Cada tercer día 3
Todos los días 4
Más de una vez al día 5

B26. Él o ella tuvo que tomar Albuterol u otro medicamento de alivio rápido para los síntomas asmáticos
Nunca 0
Una o dos veces al mes 1
Una o dos veces a la semana 2
Cada tercer día 3
Todos los días 4
Más de una vez al día 5

SECCIÓN C: EVALUACIÓN DE RIESGO MÉDICO

Ahora tengo unas cuantas preguntas sobre el cuidado médico que [el niño/la niña] recibe y las medicinas que toma.

C1. Durante los últimos 12 meses, cuando [el niño/la niña] fue al doctor para su cuidado del asma, ¿fue la mayoría de las veces a emergencias, a la clínica o al consultorio del doctor? [NO LEA LA LISTA]

Emergencias 1
Clínica/consultorio 2
Ambos, más bien Emergencias 3
Ambos, más bien clínica/consultorio 4
Nunca tuvo ninguna visita con el doctor 5

C2. Durante los últimos 2 meses, tomó [el niño/la niña algún medicamento para el asma?

SÍ NO [Si la respuesta es "no", vaya al C2b]

C2a. Si la respuesta es "sí" actualmente está [el niño/la niña tomando cualquier medicamento recetado ara el asma todos los días, aunque él/ella esté bien, para prevenir los síntomas?

SÍ NO [Si la respuesta es "sí", vaya al C3]

C2b. Si no, durante los últimos 2 meses, le han recetado [al niño/a la niña] cualquier medicamento para el asma que deba usar todos los días aunque él/ella esté bien, para prevenir los síntomas?

SÍ NO NO SE SABE

C3. De la lista que aparece abajo, favor de indicar ¿cuáles medicinas toma el niño/la niña actualmente a diario y/o cuando el niño/la niña está teniendo señales/síntomas de asma,
[SUGIERA: con fotos y/o muestras de cajas de medicamentos. Captación de datos, cada medicamento que aparece abajo forma parte de un grupo, clasificado en las siguientes categorías: SC= corticosteroides sistemáticos; IC= corticosteroides inhalados; NC=nasal corticosteroides nasales; SABA= broncodilatadores de corta acción; LABA=broncodilatadores de larga duración; LIBAIC=combinación de broncodilatadores de larga duración y corticosteroides inhalados; LB= bloqueadores de leucotrienos]

ORAL:

[SABA]	**Albuterol líquido**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[LB]	**Montelukast (Singulair)**	**SÍ**	**NO**
Si la respuesta es sí, ¿qué dosis?	**4mg 5mg**	**10mg**	
	¿Lo toma el niño/la niña a diario?	**SÍ**	**NO**
	¿Lo toma el niño/niña sólo cuando tiene síntomas?	**SÍ**	**NO**
[LB]	**Zafirlukast (Accolate)**	**SÍ**	**NO**
	Si la respuesta es sí, ¿qué dosis?	**10mg**	**20mg**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[LB]	**Zileuton (Zyflo), 600 mg**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[SC]	**Prednisona or prednisolona (Orapred)**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[LABA]	**Teofilina**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/niña]¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**

INALADO:

[SABA]	**Ventolin (Proventil, Albuterol) HFA**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[SABA]	**Ventolin (Proventil, Albuterol), por nebulizador**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[SABA]	**Ipratropio (Atrovent) HFA**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[SABA]	**Ipratropio (Atrovent), por nebulizador**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**

[SABA]	**Cromolín sódico (Intal) por inalador**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[SABA]	**Cromolín sódico (Intal), por nebulizador**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[IC]	**Budesonida (Pulmicort) Flexhaler**	**SÍ**	**NO**
	Si la respuesta es sí, ¿qué dosis?	**90 mcg**	**180 mcg**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[IC]	**Budesonida (Pulmicort), por inalador**	**SÍ**	**NO**
	Si la respuesta es sí, ¿qué dosis?:	**0.25mg**	**0.50 mg**
	Si la respuesta es sí, ¿cuántas nebulizaciones al día?:	**2 veces**	**2x/al día**
	Otro:_____		
	[El niño/la niña] lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[LABAIC]	**Budesonida/Formoterol (Symbicort) HFA**	**SÍ**	**NO**
	Si la respuesta es sí, ¿qué dosis?:	**80/4.5 mcg**	**160/4.5 mcg**
	Si la respuesta es sí, ¿cuántas veces al día?:	**2 veces**	**2x/al día**
	Otro:_____		
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[IC]	**Fluticasona (Flovent) HFA**	**SÍ**	**NO**
	Si la respuesta es sí, ¿qué dosis?: 44 mcg	**110 mcg 220 mcg**	
	Si la respuesta es sí, ¿cuántas veces al día?:	**2 veces**	**2x/ al día**
	Other:_____		
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[LABAIC]	**Fluticasona/Salmeterol (Advair) HFA**	**SÍ**	**NO**
	Si la respuesta es sí, ¿qué dosis?: 45/21 mcg	**115/21 mcg**	**230/21 mcg**
	Si la respuesta es sí, ¿cuántas veces al día?:	**2 veces**	**2x/ al día**
	Otro:_____		
	[El niño/la niña] ¿lo toma todos los días?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[LABAIC]	**Fluticasona/Salmeterol (Advair) Diskus**	**SÍ**	**NO**
	Si la respuesta es sí, ¿qué dosis?: 100/50 mcg	**250/50 mcg**	**500/50 mcg**
	Si la respuesta es sí, ¿cuántas veces al día?:	**2 veces**	**2x/ al día**
	Otro:_____		
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[IC]	**Mometasona (Asmanex) twisthaler**	**SÍ**	**NO**
	Si la respuesta es sí, ¿qué dosis?:	**110 mcg 220 mcg**	
	Si la respuesta es sí, ¿cuántas veces al día?:	**2 veces**	**2x/ al día**
	Otro:_____		
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**

[IC]	**Beclometasona (Qvar) HFA**	**SÍ**	**NO**
	Si la respuesta es sí, ¿qué dosis?:	**40 mcg**	**80 mcg**
	Si la respuesta es sí, ¿cuántas veces al día?:	**2 veces**	**2x/ al día**
	Otro:_____		
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**

AEROSOL (spray) NASAL:

[NC]	**Propionato de Fluticasona (Flonase)**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[NC]	**Furoato de Fluticasona (Veramyst)**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[NC]	**Mometasona (Nasonex)**	**SÍ**	**NO**
	El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**
[NC]	**Budesonida (Rhinocort aqua)**	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿lo toma sólo cuando tiene síntomas?	**SÍ**	**NO**

INYECTADO:

[SC]	**Triamcinolona (Kenalog)**	**SÍ**	**NO**
	[El niño/la niña] ¿se lo aplican a diario?	**SÍ**	**NO**
	[El niño/la niña] ¿sólo cuando tiene síntomas?	**SÍ**	**NO**

C4. Ha tenido algún problema con que [el niño/la niña] tome medicamentos en la escuela?

SÍ NO NO TOMA MEDICAMENTOS EN LA ESCUELA

C5. Durante los últimos 12 meses, estaba [el niño/la niña] cubierto/a por Medicaid en todo momento?

SÍ NO NO SE SABE

C6. Está [el niño/la niña] ahora cubierto/a por algún plan de seguro médico (aseguranza) que pague parte de la cuenta del hospital, del doctor o del cirujano?

SÍ NO NO SE SABE

C6a. Si la respuesta es "sí", cuál es el nombre del plan de seguro médico?

Managed Care 1
Medicaid 2
Medicaid Managed Care 3
Privado 4
No se sabe -2

SECCIÓN D: LA DEMOGRAFÍA DEL NIÑO/DE LA NIÑA Y LA FAMILIA

Hasta ahora, la mayor parte de la entrevista ha preguntado sobre la salud de su [niño/niña]. Ahora voy a hacerle algunas preguntas más generales sobre [el niño/la niña], usted y su familia.

D1. ¿En qué año escolar (grado) está su niño/niña matriculado/a actualmente? _____
[Código como sigue: P=pre-escolar, K=kindergarten (kinder), 1-6= grados 1-6]

D2. ¿Cuánto tiempo ha vivido [el niño/la niña en su domicilio actual? a._____años b._____ meses

D3. ¿Hasta qué año llegó o terminó usted en la escuela? _____
[Use los códigos de educación que aparecen abajo.]

D4. ¿Cuántas personas viven en la casa donde vive [el niño/la niña, incluyéndo a [el niño/la niña] y a usted?
_____
[La persona que responde debe incluirse, si corresponde hacerlo.]

D5. ¿Cuántos miembros en este hogar son adultos (es decir, tienen 18 años o más) _____

D6. Pensando sobre el lugar donde vive [el niño/la niña], ¿quién diría usted es la cabeza o quiénes serían las cabezas del hogar?
[PROMPT: ¿Quién diría usted que "está a cargo"? Si la persona que cuida al niño/a la niña es el único adulto en el hogar(es decir, B5=1), entonces, escriba la información sobre esta persona en el D6a y el D6b. [Use los códigos sobre la relación o parentesco que aparecen en la lista de abajo].

Nombre: _____ [LA CABEZA DEL HOGAR O DE LA FAMILIA 1]

D6a1. ¿Qué relación o parentesco tiene [LA CABEZA DEL HOGAR O DE LA FAMILIA 1] con [el niño/la niña?_____

D6b1. ¿Hasta qué año asistió a la escuela [LA CABEZA DEL HOGAR O DE LA FAMILIA 1]?_____

Nombre: _____ [LA CABEZA DEL HOGAR O DE LA FAMILIA 2]

D6a2. ¿Qué relación o parentesco tiene [LA CABEZA DEL HOGAR O DE LA FAMILIA 2 con [el niño/la niña?_____

D6b2. ¿Hasta qué año llegó o asistió a la escuela [LA CABEZA DEL HOGAR O FAMILIA 2] _____

Códigos de relación o parentesco:
1=Madre (biológica o adoptiva)
2=Padre (biológico o adoptivo)
3=Madrastra
4=Padrastro
5=Padre/madre de crianza (foster)
6 = Abuela
7 = Abuelo
8 =Hermano/hermana
9 = Algún otro familiar
10 = Otra persona que no es de la familia
-2 = No se sabe

Códigos de educación:
0 = Nunca asistió a la escuela
1-11 = Año específico terminado para los grados 1-11_____
12 = GED o 12avo. grado
13 = 1 o 2 años de universidad/escuela técnica o entrenamiento vocacional
14 = 3 o 4 años de universidad/ escuela técnica/entrenamiento vocacional
15 = 5+ años de universidad/escuela técnica/entrenamiento vocacional
16 = Otro
-2 = No se sabe

D7. ¿Cómo describiría usted la raza, la nacionalidad o los antecedentes étnicos [del niño/de la niña]?
[Haga preguntas abiertas—que exijan opinar y no sólo responder con un simple "sí" o "no" y use los códigos que aparecen abajo. SUGIERA: "Cuál es la raza [del niño/ de la niña]?

HISPANO/A: [Si es necesario, sugiera: '¿De cuál grupo étnico o nacionalidad?']
Puertorriqueño/a 1
Dominicano/a 2
Mexicano/a 3
Sudamericano/a 4
Centroamericano/a 5
Cubano/a 6
Otro grupo hispano 7
[Si es necesario, sugiera: '¿De cuál grupo étnico o nacionalidad?']
Africano Americano/Negro Americano 8
Indio Occidental 9
Negro Caribeño 10
Negro de otro lugar 11
BLANCO/A 12
ASIÁTICO/A 13

D8. ¿Y cómo describiría usted su raza, nacionalidad o antecedentes étnicos?
[Haga preguntas abiertas que exijan una opinión y no simplemente un "si" o un "no" y use los códigos que aparecen abajo]

HISPANO/A: [Si es necesario, sugiera '¿De cuál grupo étnico o nacionalidad?']
Puertorriqueño/a 1
Dominicano/a 2
Mexicano/a 3
Sudamericano/a 4
Centroamericano/a 5
Cubano/a 6
Otro grupo hispano
NEGRO/A: [Si es necesario sugiera ¿'De cuál grupo étnico o nacionalidad?']
Afroamericano/Negro americano 8
Indio occidental 9
Negro caribeño 10
Otro grupo de negro 11
BLANCO/A 12
ASIÁTICO/A 13

D9. ¿Cuál es su estado civil actual?
Casado/a 1
Divorciado/a 2
Soltero/a 3
Viudo/a 4
Separado 5
Otro 6 Especifique: a. _____

SECCIÓN E: FACTORES DE RIESGO AMBIENTALES

Ahora, quisiera hacerle unas preguntas sobre si se fuma en el hogar [del niño/de la niña].

E1. ¿Cuántas personas que viven en el hogar [del niño/de la niña] fuman? ___ personas
[Incluya a la persona que responde si acaso es fumador/a.]

E2. ¿Hay alguien más que cuida [al niño/a la niña], que fume, como su niñera, o la persona en la guardería?

SÍ NO

E3. ¿Fuma usted cigarros, ocasionalmente?

SÍ NO [Si la respuesta es "no" vaya al E4]

E3a. ¿Más o menos hace cuántos años que fuma? ___ años

E3b. ¿Más o menos cuántos cigarros fuma al día? # ___ de cigarros al día

E3c. ¿Cuántos de éstos los fuma en casa? # ___ de cigarros al día en casa

E4. ¿Fuma [el niño/la niña cigarros?

SÍ NO NO SÉ

E5. Muchas personas tienen dificultad para mantener a sus niños alejados del humo del tabaco. ¿Tiene usted problemas para mantener [al niño/la niña] alejado de las personas que están fumando?

SÍ NO NO SÉ

E6. ¿Con qué frecuencia está su [niño/niña] cerca de personas que están fumando?

Diariamente 1
Varias veces a la semana 2
Varias veces al mes 3
Raras veces 4

Ahora, quiero preguntarle sobre algunas características del hogar [del niño/de la niña].

E7. ¿En el hogar [del niño/de la niña] se usa gas o electricidad para cocinar?
Gas 1
Electricidad 2
Leña, u otro tipo de biocombustible 3

E8. Si se usa gas, ¿tiene la estufa de gas el piloto encendido constantemente?

SÍ NO NO SE SABE

Informed Written Consent Form—English and Spanish

University of Texas at El Paso (UTEP) Institutional Review Board
Informed Consent Form for Research Involving Human Subjects

Protocol Title: Healthy Living and Traffic-Related Air Pollution in an Underserved Community

Principal Investigator: Wen-Whai Li, Ph.D., P.E., Department of Civil Engineering, UTEP

Co-Principal Investigators:

Leah D. Whigham, Ph.D., F.T.O.S., Department of Public Health Sciences, UTEP

William (Bill) H. Hargrove, Ph.D., Center for Environmental Resource Management, UTEP

Joan G. Staniswalis, Ph.D., Department of Mathematical Sciences, UTEP

In this consent form, "you" always means the study subject. If you are a legally authorized representative (such as a parent or guardian), please remember that "you" refers to the study subject.

1. Introduction

You and your child are being asked to take part voluntarily in the research project described below. Please take your time making a decision and feel free to discuss it with your friends and family. Before agreeing to take part in this research study, it is important that you read the consent form that describes the study. Please ask the study researcher or the study staff to explain any words or information that you do not clearly understand.

2. Why is this study being done?

We would like permission to enroll your child as a participant in a research study. This study examines the impact of traffic pollution on the respiratory health of asthmatic children in El Paso. In order to obtain a better understanding of the health effects from traffic pollution, we will visit your child's school for 12 Fridays over a three-month sampling period. During this three-month period, we will be conducting simultaneous air pollution sampling inside and directly outside your child's school and a designated neighborhood location near the school. In order to examine whether there is a link between emissions of traffic pollutants and various respiratory health metrics, we will conduct the following measurements on your child during the Friday visit.

Study Eligibility:

Willingness to participate in our study and the following characteristics are necessary from our participants:

- be physician-diagnosed asthmatic between the ages of 6 and 12 years old;
- live in a non-smoking household; and
- be in good general health.

3. What is involved in the study?

Each Friday during the study, field technicians will come to your child's school to conduct a brief (10 minute) questionnaire and conduct a suite of health measurements. The 10-minute questionnaire would help the researchers understand how well your child's asthma is controlled and if air pollution is having any respiratory health effects in your child. The health measurements are explained in detail below.

Exhaled Nitric Oxide (eNO)

We will analyze a breath sample for exhaled nitric oxide, which is an indicator of lung inflammation. The exhaled breath monitor (shown above) is non-invasive and requires your child to breath into a sterile mouthpiece inlet for 15 seconds.

Lung Function Measurements

Lung function measurements would also be conducted using a hand-held spirometer shown above. The instrument is non-invasive and requires your child to blow into a sterile- mouthpiece for approximately 10-15 seconds.

Carotenoid Levels Measurements (Veggie Meter)

Carotenoid levels would be assessed using the Veggie-Meter shown above. The Veggie-meter is a device that uses a simple LED light (like in a common flashlight) to measure a nutrient called carotenoids. Beta-carotene, the nutrient that makes carrots orange, is one example. The carotenoid level gives us an idea of how many fruits and vegetables your child eats. The child puts their finger on this light, and the device measures his/her score. The process takes about 25 seconds and is harmless to your child.

Physical Activity Rates

Physical activity rates will be measured using accelerometers as shown above. This instrument detects differing levels of intensity and will be used during baseline periods to examine time spent in moderate to vigorous physical activity. The accelerometer would be tied on the wrist of your child for a certain period of time during the Friday health measurements.

Heart Rate Variability

We will also measure the heart rate variability in your child by using the Polar V800 Fitness Watch as shown above. This watch is tied around the chest area for a limited period of time during the Friday health measurement period. These instruments are totally non-invasive. The above instrument records the average and the maximum heart rate in your child.

In addition, we will ask your child several questions about whether they experienced any respiratory symptoms such as asthma attacks, coughing, or wheezing during the previous week that air pollution is conducted.

Procedure for parents or legal guardian:

Before sampling begins, we will give you a baseline questionnaire which will be administered to record information such as the age, gender, height, weight, preexisting health conditions, medications and socio-economic status of your child. This baseline questionnaire will take approximately 30 minutes to administer. This questionnaire will provide information concerning factors that may influence your child's response to air pollution. Before the study starts, we will schedule a meeting session where you will be invited to come and complete the baseline questionnaire. This meeting session will take place in the school premises and would be coordinated as per your convenience.

4. What are the risks and discomforts of the study?

There are no known risks associated with this research. However, undergoing the health measurements and answering the field technician's questions regarding the incidence of asthma-related symptoms may take approximately 15 to 20 minutes. Given the logistical considerations for conducting this study, this protocol will be conducted during the school day. We will make every effort to limit any inconveniences this may cause for you and your child and work with your child and his/her teachers to ensure that any disruption is minimal. If you have any questions during the study, you may call our field staff. Our phone number will be distributed to you prior to commencement of the study.

5. What will happen if I am injured in this study?

The University of Texas at El Paso and its affiliates do not offer to pay for or cover the cost of medical treatment for research related illness or injury. No funds have been set aside to pay or reimburse you in the event of such injury or illness. You will not give up any of your legal rights by signing this consent form. You should report any such injury to *(Dr. Wen-Whai Li, 915-747-8755)* and to the UTEP Institutional Review Board (IRB) at (915-747-7693) or irb.orsp@utep.edu.

6. Are there benefits to taking part in this study?

There will be no direct benefits to you for taking part in this study. It is our hope that the information we collect in this study will help us understand the role of air pollution exposure on childhood asthma.

7. What other options are there?

You have the option not to take part in this study. There will be no penalties involved if you choose not to take part in this study.

8. Who is paying for this study?

The sponsor of this study is the United States Department of Transportation.

9. What are my costs?

There are no direct costs associated with your child's participation in this study.

10. Will I be paid to participate in this study?

As a token of appreciation, children successfully completing the study protocol will receive a $50 gift certificate to a local bookstore after the study completion.

11. What if I want to withdraw, or am asked to withdraw from this study?

Taking part in this study is voluntary. You have the right to choose not to take part in this study. If you do not take part in the study, there will be no penalty or loss of benefit. If you choose to take part, you have the right to skip any questions or stop at any time. However, we encourage you to talk to a member of the research group so that they know why you are leaving the study. If there are any new findings during the study that may affect whether you want to continue to take part, you will be told about them. The researcher may decide to stop your participation without your permission, if he or she thinks that being in the study may cause you harm, or if you are unable to accomplish the various health measurements enlisted above.

12. Who do I call if I have questions or problems?

You may ask any questions you have now. If you have questions later, you may call any of the following:
Dr. Wen-Whai Li, Department of Civil Engineering, UTEP, (915)-747-8755, wli@utep.edu.
Dr. Juan A. Aguilera, Department of Public Health Sciences, UTEP, (915)-274-3475, jaaguilera2@miners.utep.edu
(Se, Habla Español)
If you have questions or concerns about your participation as a research subject, please contact the UTEP Institutional Review Board (IRB) at (915-747-7693) or irb.orsp@utep.edu.

13. What about confidentiality?

People other than those doing the study may look at the study records. Agencies that make rules and policy about how research is done have the right to review these records. So do agencies that pay for the study. Those with the right to look at your study records include the Department of Transportation, Department of Health and Human Services, and the University of Texas at El Paso Institutional Review Board. Records can also be opened by court

order. Because of the need to release information to these parties, absolute confidentiality cannot be guaranteed. We will keep your child's records private to the extent allowed by law. We will do this even if outside review occurs. We will use a study ID number rather than your child's name on study records where we can. Your child's name and other facts that might point to your child will not appear when we present this study or publish its results. No pictures will be taken. The results of this research study may be presented at meetings or in publications; however, your child's identity will not be disclosed in those presentations.

14. Mandatory Reporting

During the course of the study, if information is revealed about child abuse or neglect, or potentially dangerous future behavior to others, the law requires that this this information be reported to the proper authorities.

15. Authorization Statement

I have read each page of this paper about the study (or it was read to me). I know that being in this study is voluntary and I choose to be in this study. I know I can stop being in this study without penalty. I will get a copy of this consent form now and can get information on results of the study later if I wish.

Participant Name: _____ Date: _____

Participant Signature: _____ Time: _____

Participant or Parent/Guardian Signature: _____

Consent form explained/witnessed by: _____

Signature

Printed name: _____

Date: _____ Time: _____

Consejo de Revisión Institucional, Universidad de Texas en El Paso (UTEP)

Formulario de Consentimiento Informado para Investigación

Involucrando Seres Humanos

Título del Protocolo: Vida Sana y la Contaminación del Aire relacionada con el Tráfico en una Zona Subatendida

Principal Investigador: Wen-Whai Li, Ph.D., P.E., Departamento de Ingeniería Civil, UTEP

Co-Principales Investigadores:

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William (Bill) H. Hargrove, Ph.D., Centro para Manejo de Recursos Ambientales, UTEP

Joan G. Staniswalis, Ph.D., Departamento de Ciencias Matemáticas, UTEP

En este formulario de consentimiento, "usted" siempre significa o se refiere al sujeto del estudio. Si usted es el representante autorizado legalmente (tal como el padre, la madre o el tutor legal), favor de recordar que "usted" se refiere al sujeto (el participante) del estudio.

1. Introducción

Se les está pidiendo, a usted y a su niño/niña que voluntariamente formen parte del Proyecto de estudio que se describe abajo. Por favor tómese su tiempo para decidirse y siéntase con toda libertad de discutirlo con sus amigos y su familia. Antes de estar de acuerdo en formar parte de este estudio de investigación, es importante que usted lea el formulario de consentimiento que describe el estudio. Por favor pídale al investigador del estudio o al equipo del estudio que le expliquen cualquier palabra o información que usted no entienda claramente.

2. ¿Por qué se está haciendo este estudio?

Quisiéramos tener su permiso para matricular a su niño/niña como participante en un estudio de investigación. Este estudio examina el impacto de la contaminación que hay debido al tráfico en la salud respiratoria de los niños asmáticos en El Paso. Con el fin de obtener un mejor entendimiento de los efectos en la salud causados por la contaminación que provoca el tráfico, visitaremos la escuela de su niño/niña cada viernes, por un total de 12 viernes, durante un periodo de tres meses para el muestreo. Durante este periodo de tres meses, conduciremos simultáneamente muestreos de contaminación del aire tanto dentro como directamente fuera de la escuela de su niño/niña y un vecindario designado ubicado cerca de la escuela. Con el fin de examinar si hay relación entre las emisiones de los contaminantes debido al tráfico y varias mediciones de la salud respiratoria, conduciremos las siguientes mediciones de su niño/niña durante la visita de cada viernes.

Para calificar como candidato a participar en el estudio es necesario:

Estar dispuesto a participar en nuestro estudio; además de las siguientes características, se requiere de nuestros participantes:

- Tener entre 6 y 12 años de edad y haber sido diagnosticado/a por un médico como asmático/a
- Vivir en un hogar donde nadie fume; y
- Estar en buen estado de salud en general.

3. ¿Qué involucra el estudio?

Cada viernes, durante el estudio, algunos técnicos del área o campo vendrán a la escuela de su niño/niña a conducir un breve cuestionario (10 minutos) y a realizar una serie de mediciones de salud. El cuestionario de 10 minutos, les ayudaría a los investigadores a entender qué tan bien está controlado el asma de su niño/niña y si la contaminación del aire está teniendo algún efecto de salud respiratorio en su niño/niña. Las mediciones de salud se explican en detalle más abajo.

Óxido Nítrico Exhalado (eNO)

Analizaremos una muestra de aliento para ver si hay óxido nítrico exhalado, el cual es un indicador de inflamación de los pulmones. El monitor para aliento exhalado (que aparece arriba) no es invasivo y sólo requiere que su niño/niña respire dentro de una boquilla estéril por 15 segundos.

Mediciones de la Función Pulmonar

Se realizarían también mediciones de la función pulmonar usando un espirómetro que se sostiene en la mano (aparece arriba). El instrumento no es invasivo y sólo requiere que su niño/niña sople dentro de una pieza estéril que se coloca en la boca por aproximadamente 10-15 segundos.

Mediciones de Niveles de Caroteno (*Veggie Meter*) (Medidor de consumo de frutas y verduras)

Los niveles de caroteno se evaluarían usando un medidor de consumo de frutas y verduras llamado *Veggie-Meter* (aparece arriba). El medidor *Veggie-Meter* es un aparato pequeño que usa una luz LED simple (igual que en una linterna común) para medir un nutriente llamado caroteno. El beta-caroteno, el nutriente que les da color a las zanahorias, es un ejemplo. El nivel de carotenos nos da una idea de qué cantidad de frutas y verduras come su niño/niña. El niño/niña coloca su dedo sobre la luz y el aparato anota su puntuación. El proceso toma alrededor de 25 segundos y es inofensivo para su niño/niña.

Rangos de Actividad Física

Los rangos de actividad física se medirán usando los acelerómetros que aparecen arriba. Este instrumento detecta los diversos niveles de intensidad y se usará durante periodos de referencia para examinar el tiempo que se pasa en actividad física desde moderada a vigorosa. El acelerómetro se ataría a la muñeca de su niño/niña por cierto periodo de tiempo durante las mediciones de salud de los viernes.

Variabilidad del Pulso

También mediremos la variabilidad del pulso de su niño/niña, usando el reloj llamado *Polar V800 Fitness Watch*, el cual aparece arriba. Este reloj se ata alrededor del área del pecho por un tiempo limitado durante el periodo de medición de salud de los viernes. Estos instrumentos no son invasivos; en lo absoluto. El instrumento que aparece arriba anota el pulso promedio y el máximo de su niño/niña.

Además, le haremos varias preguntas a su niño/niña sobre si tuvieron algún síntoma respiratorio, tales como ataques de asma, tos, o sibilancias (silbidos) durante la semana anterior a la que se conduzca el estudio del aire contaminado.

Procedimiento para los padres o tutor legal:

Antes de que comience el muestreo, le daremos un cuestionario preliminar que servirá de base, el cual será administrado para anotar alguna información de su niño/niña, tal como edad, sexo, estatura, peso, condiciones de salud pre-existentes, medicamentos y estatus socio-económico. Este cuestionario tomará aproximadamente 30 minutos. Este cuestionario dará información sobre factores que pudieran influenciar cómo responda a la contaminación del aire. Antes de que comience el estudio, programaremos una junta donde lo/la invitaremos a que venga a llenar el cuestionario. Esta junta tendrá lugar en la escuela y sería coordinada conforme a su conveniencia.

4. ¿Cuáles son los riesgos y las incomodidades del estudio?

No se conoce ningún riesgo asociado con esta investigación. Sin embargo, someterse a las mediciones de salud y contestar las preguntas de los técnicos del área sobre la incidencia de los síntomas relacionados con el asma puede tomar aproximadamente de 15 a 20 minutos. Dadas las consideraciones logísticas para conducir este estudio, este protocolo se conducirá durante un día de escuela. Haremos todos los esfuerzos por limitar cualquier inconveniencia que esto pudiera causarle a usted o a su niño/niña, y trabajaremos con su niño/niña y sus maestros para asegurarnos que cualquier molestia sea mínima. Si acaso tiene cualquier pregunta durante el estudio, puede llamar a nuestro equipo del área. Nuestro número de teléfono se les dará antes de que principie el estudio.

5.¿Qué pasará si me lastimo en este estudio?

La Universidad de Texas en El Paso y sus afiliados no ofrecen pagar ni cubrir el costo de tratamientos médicos por lastimaduras o enfermedad relacionadas con las investigaciones. No se han destinado fondos para pagar o reembolsarle a usted en el caso de tal lastimadura o enfermedad. Al firmar este formulario de consentimiento, usted no está renunciando a ninguno de sus derechos legales. Usted deberá reportar cualquier lastimadura al *(Dr. Wen-Whai Li, 915-747-8755)* y a UTEP, al Consejo de Revisión Institucional (*Institutional Review Board*) (IRB) al (915-747-7693) o al sitio: irb.orsp@utep.edu.

6. ¿Hay beneficios al tomar parte en este estudio?

No habrá ningún beneficio directo para usted al tomar parte en este estudio. Esperamos que la información que recopilemos nos ayude a entender el papel de la exposición y los perjuicios que causa el aire contaminado en el asma de la niñez.

7. ¿Qué otras opciones hay?

Usted tiene la opción de no tomar parte en este estudio. No le perjudicará en ningún sentido si decide no tomar parte.

8. ¿Quién está pagando este estudio?

El patrocinador es el Departamento de Transportación de los Estados Unidos.

9. ¿Cuáles son mis costos?

No hay ningún costo directo asociado con la participación de su niño/niña en este estudio.

10. ¿Me van a pagar por participar?

Para demostrarles nuestro agradecimiento, los niños/niñas que terminen el estudio exitosamente, recibirán un certificado de regalo por $50 para una librería de la localidad al concluir el estudio.

11. ¿Y si quiero retirarme o me piden que me retire del estudio?

Tomar parte en este estudio es voluntario. Usted tiene el derecho de decidir no tomar parte. Si usted no toma parte, no habrá ningún perjuicio ni pérdida de beneficios. Si decide tomar parte, tiene el derecho a saltarse cualquier pregunta o dejar de participar en cualquier momento. Sin embargo, lo/la alentamos a hablar con un miembro del grupo de investigación para que ellos sepan por qué se retira del estudio. Si hay cualquier hallazgo nuevo durante el estudio que pueda afectar el hecho de que usted quiera o no continuar tomando parte, nosotros

se lo diremos. El investigador o investigadora pudiera decidir descontinuar su participación sin el permiso de usted, si acaso él o ella cree que estar en el estudio pudiera causarle daño, o si usted no pudiera lograr las mediciones sobre salud que aparecen en la lista anterior.

12. ¿A quién le llamo si tengo preguntas o problemas?

Usted puede hacer las preguntas que tenga ahora. Si tiene preguntas más tarde, es decir, después, puede llamar a cualquiera de las siguientes personas:
Dr. Wen-Whai Li, Departamento de Ingeniería Civil, UTEP, (915)-747-8755, wli@utep.edu.
Dr. Juan A. Aguilera, Departamento de Ciencias de Salud Pública, UTEP, (915)-274-3475, jaaguilera2@miners.utep.edu (Se habla español)
Si tiene alguna pregunta o preocupación acerca de su participación como sujeto del proyecto, por favor comuníquese al Consejo de Revisión Institucional de UTEP (IRB) al (915-747-7693) o al sitio: irb.orsp@utep.edu.

13. ¿Qué puede decirme sobre la confidencialidad?

Hay personas, además de aquéllas haciendo el estudio quienes pueden ver los expedientes. Las agencias que dictan las reglas y las políticas sobre cómo se debe conducir una investigación tienen el derecho a revisar estos expedientes. Asimismo las agencias que pagan por el estudio. Aquéllos con el derecho de leer los expedientes incluyen al Departamento de Transportación, el Departamento de Salud y Servicios Humanos de El Paso, El Consejo de Revisión Institucional de la Universidad de Texas. Los expedientes también pueden abrirse cuando haya una orden de la Corte. Debido a la necesidad de dar a conocer la información a estas entidades, la confidencialidad absoluta no se puede garantizar. Nosotros mantendremos los expedientes de su niño/niña en privado hasta donde lo permiten las leyes. Haremos esto aún en el caso de que sean revisados por personas que se consideran fueran del estudio. Usaremos un número de identificación en vez del nombre de su niño/niña en los expedientes donde se pueda hacerlo. El nombre de su niño/niña y otros datos que pudieran señalar a su niño/niña no aparecerán cuando presentemos este estudio o publiquemos sus resultados. No se tomará ninguna fotografía. Los resultados de la investigación pueden ser presentados en juntas o en publicaciones; sin embargo, la identidad de su niño/niña no se dará a conocer en esas presentaciones.

14. Reportes Obligatorios

Durante el transcurso del estudio, si se da a conocer alguna información sobre maltrato o negligencia del niño/de la niña, o comportamiento futuro potencialmente peligroso hacia otras personas, las leyes requieren que la información sea reportada a las autoridades correspondientes.

15. Declaración de Autorización

He leído cada una de las páginas de este documento sobre el estudio (o me lo han leído). Sé que mi participación es totalmente voluntaria y he decidido formar parte. Sé que puedo retirarme sin que nada me perjudique. Obtendré una copia de este consentimiento ahora y podré obtener información sobre los resultados de este estudio si así lo deseo.

Nombre del participante: _____ Fecha: _____

Firma del participante: _____ Hora: _____

Padre/madre/tutor(a) legal del/de la participante: _____

Firma

Formulario de consentimiento explicado/atestiguado por:

Firma _____

Nombre en letra de molde: _____

Fecha: _____ Hora: _____

Assent Form—English and Spanish

University of Texas at El Paso (UTEP) Institutional Review Board
Assent Form for Research Involving Human Subjects

Protocol Title: Healthy Living and Traffic-Related Air Pollution in an Underserved Community

Principal Investigator: Wen-Whai Li, Ph.D., P.E.
UTEP: Civil Engineering

I am being asked to decide if I want to be in this research study because

- *I am between the ages of 6 and 12,*
- *a doctor has said that I have asthma,*
- *no one smokes cigarettes or cigars in my house or apartment, and*
- *I have good health.*

This study will tell me if air pollution is affecting my health or not. This study will start at the beginning of September and end in mid-December, 2017.

I know that to be in this study I will:

- *Do some simple health tests every Friday? These health tests will tell me if air pollution is affecting my health or not. These health tests are as follows:*
- *See how many vegetables and fruits I eat (I will put my finger on a small LED light for 25 seconds to get my Veggie-meter score),*
- *See how my heart beats,*
- *I will wear a small wrist band that will tell me how much I move for a couple of hours every day,*
- *See if my lungs are working well by blowing into a mouthpiece of an instrument that would have music and moving clouds on the instrument screen, and*
- *See if I have strong lungs by blowing into a tube of an instrument for 10 to 15 seconds.*
- *At the end of study, I will receive a $50 gift card to a local book-store for buying nice story books.*

I asked and got answers to my questions. I know that I can ask questions about this study at any time.

I know that I can stop being in the study at any time without anyone being mad at me. I will not get in trouble if I stop being in the study.

I know that only the people who work on this research study will know my name.

I want to be in the study at this time. I can ask about what happened in the study.

Child's Printed Name: _____

Child's Signature: _____ Date: _____

Witness or Mediator: _____ Date: _____

I have explained the research at a level that is understandable by the child and believe that the child understands what is expected during this study.

Signature of Person Obtaining Assent:

_____ Date _____

Universidad de Texas en El Paso (UTEP) Consejo de Revisión Institucional
Formulario de Consentimiento para Investigación Involucrando Seres Humanos

Título del Protocolo: Vida Sana y Contaminación del Aire Relacionada con el Tráfico en una Zona Subatendida

Principal Investigador: Wen-Whai Li, Ph.D., P.E.
UTEP: Ingeniería Civil

Se me ha pedido que decida si quiero formar parte de este estudio de investigación porque

- *estoy entre los 6 y 12 años de edad,*
- *un doctor ha dicho que tengo asma,*
- *nadie fuma ni cigarros ni puros en mi casa o apartamento, y*
- *tengo buena salud.*

Este estudio me dirá si la contaminación del aire está afectando mi salud o no. Este estudio comenzará a principios de septiembre y terminará a mediados de diciembre de 2017.

Yo sé que para formar parte de este estudio tendré que:

- *Hacer algunas pruebas simples de salud cada viernes. Estas pruebas de salud me dirán si la contaminación del aire está o no afectando mi salud. Estas pruebas de salud son como sigue:*
- *Ver qué cantidad de frutas y verduras como (pondré un dedo en una pequeña luz LED por 25 segundos para obtener mi puntuación en el medidor llamado Veggie meter),*
- *Ver cuántas palpitaciones tengo.*
- *Llevaré puesta una pequeña banda en la muñeca que me dirá cuánto me muevo durante un par de horas cada día.*
- *Ver si mis pulmones están funcionando bien al soplar en una pieza que se coloca en la boca de un instrumento que tendría música y nubes en movimiento en la pantalla del instrumento, y*
- *Ver si tengo pulmones fuertes, soplándole a un tubo de un instrumento por 10 o 15 segundos.*

- *Al final del estudio, recibiré una tarjeta de regalo por $50 para una librería de la localidad para comprarme algunos bonitos libros de cuentos.*

Hice preguntas y me las contestaron. Sé que puedo hacer preguntas sobre este estudio en cualquier momento.

Sé que puedo dejar de participar en el estudio en cualquier momento sin que nadie se enoje conmigo. No me meteré en problemas si dejo de participar en el estudio.

Sé que sólo las personas que trabajan en este estudio de investigación sabrán mi nombre.

Quiero estar en el estudio ahora. Puedo preguntar acerca de lo que pasó en el estudio.

Nombre del niño/niña: _____
(en letra de molde)

Firma del niño/niña: _____ Fecha: _____

Testigo o Mediador: _____ Fecha: _____

Yo le he explicado al niño/niña de qué se trata la investigación, usando un nivel de vocabulario entendible para él/ella y creo que el niño/niña entiende lo que se espera de él/ella durante este estudio.

Firma de la persona que obtiene el consentimiento:

_____ Fecha:_____

Study Authorization Revoke Form—English and Spanish

Date: _____

Dr. Wen-Whai Li, Principal Investigator
'Healthy Living and Traffic-Related Air Pollution in an Underserved Community',
Department of Civil Engineering,
University of Texas at El Paso,
500 W University Avenue,
El Paso, TX 79968

Dear Dr. Li,

I want to end my participation in the research study that is named above. In addition to ending my participation I would like to [choose one of the following options]:

REVOKE MY AUTHORIZATION FOR THE RESEARCHERS TO COLLECT AND USE MY INFORMATION:

_____ I will not participate in the research study, and I revoke my authorization to permit the researchers to collect and use any more information about me. I understand and agree that in certain circumstances the researchers may need to use my information even though I have revoked my authorization, for example, to let me know about any safety concerns, or to make any required reports to governmental regulatory agencies.

CONTINUE MY AUTHORIZATION FOR THE RESEARCHERS TO COLLECT AND USE MY INFORMATION:

_____ I will not actively participate in the research study any more, but the researchers may continue to collect and use information from my medical record as needed for the research study, but only for the reasons discussed in the consent form that I signed.

I understand that the researchers will respond to this letter by letting me know that they have received it.

Sincerely,_____ _____
Signature of Study Participant ----Date Signature of Parent or Legal Guardian --- Date

Fecha: _____

Dr. Wen-Whai Li, Principal Investigador
'Vida Sana y Contaminación del Aire relacionada con el Tráfico en un Área Subatendida',
Departamento de Ingeniería Civil,
Universidad de Texas en El Paso,
500 W University Avenue,
El Paso, TX 79968

Estimado Dr. Li,

Quisiera dar por terminada mi participación en el estudio de investigación arriba mencionado. Además de dar por terminada mi participación, quisiera [seleccionar una de las siguientes opciones]:

REVOCAR MI AUTORIZACIÓN PARA QUE LOS INVESTIGADORES RECOPILEN Y USEN MI INFORMACIÓN:

_____ No participaré en el estudio de investigación y revoco mi autorización de permitir a los investigadores recopilar y continuar usando, de hoy en adelante, la información sobre mi persona. Tengo entendido y estoy de acuerdo en que bajo ciertas circunstancias los investigadores pueden necesitar usar mi información aunque yo haya revocado mi autorización; por ejemplo, para hacerme saber sobre preocupaciones de seguridad, o para presentar cualquier informe requerido por las agencias regulatorias gubernamentales.

CONTINUAR MI AUTORIZACIÓN PARA QUE LOS INVESTIGADORES RECOPILEN Y USEN MI INFORMACIÓN:

_____ Ya no continuaré participando activamente en el estudio de investigación, pero los investigadores pueden continuar recopilando y usando la información contenida en mi expediente médico según se necesite para el estudio de investigación, pero sólo cuando se deba a las razones discutidas en el formulario de consentimiento que firmé.

Tengo entendido que los investigadores responderán a esta carta haciéndome saber que la recibieron.
Atentamente,

_____ _____

Firma del participante en el estudio----Fecha Firma del padre/de la madre/ tutor legal---Fecha

Letter of Confidentiality—English and Spanish

To whom it may concern:

The '**Healthy Living and Traffic-Related Air Pollution in an Underserved Community'** meets the United States federal standards to safeguard any information that is provided by parents and students under the framework of the research project.

To ensure compliance with federal standards in detailing with personal health information for clinical research, the researchers have ensured that the following conditions are met:

1) All data are stored in fire-walled and password-protected computers;
2) Only the research team has and will have access to the study data;
3) Information will never be shared with other third parties;
4) Publications and dissemination of results will carry no personal identifiers;
5) No identifiable information (names, last names, etc.) are ever kept in the same documents that contain personal identifiers. All data are kept using special codes for each participant. Only the research team can link these identifiers to the participant's identity;
6) Information will be stored for a maximum of five years and then destroyed;
7) Parents or participants may decide to withdraw at any time, even after the study is completed. In this case, all information pertaining to the study would be immediately deleted from the database;
8) All of these safety regulations have been approved by the Institutional Research Board of the University of Texas at El Paso.

If there are further questions, please do not hesitate to contact any member of the research team.

Thank you again for your kind participation in this research project.

Sincerely,

Wen-Whai Li Ph.D., P.E.
Principal Investigator
Department of Civil Engineering

Leah D. Whigham, Ph.D., FTOS
Co-Principal Investigator
Department of Public Health Sciences

A quien corresponda:

'Una Vida Sana y la Contaminación del Aire Relacionada con el Tráfico en un Zona Subatendida" cumple con las normas del gobierno federal de los Estados Unidos para salvaguardar cualquier información que provean los padres y estudiantes dentro del marco del proyecto de investigación.

Con el fin de asegurar el cumplimiento con las normas federales al recoger y reportar información relativa a la salud personal para servir en investigación clínica, los investigadores se han asegurado que se lleven a cabo las siguientes condiciones:

1) Todos los datos estarán guardados en computadoras con barreras (fire-walled) y protegidas por códigos;
2) Solamente el equipo de investigación tiene y tendrá acceso a los datos del estudio;
3) La información nunca se compartirá con otras terceras personas;
4) Las publicaciones y diseminación de los resultados no llevarán identificadores personales;
5) Ninguna información que sea identificable (nombres, apellidos, etc.) será jamás mantenida dentro de los mismos documentos que contengan identificaciones personales. Todos los datos se mantendrán usando códigos especiales para cada participante. Solamente el equipo de investigadores podrá enlazar o vincular estos identificadores con la identidad del participante;
6) La información se guardará por un máximo de cinco años y luego se destruirá;
7) Los padres o los participantes podrán retirarse en cualquier momento, aún después de que el estudio se haya terminado. En este caso, toda la información relacionada con el estudio sería inmediatamente eliminada de la base de datos;
8) Todos estos reglamentos de seguridad habrán sido aprobados por el Consejo de Investigación Institucional de la Universidad de Texas en El Paso.

Si tiene preguntas adicionales, favor de ponerse en contacto con cualquier miembro del equipo de investigación.

Gracias de nuevo por su amable participación en este proyecto de investigación.

Atentamente,

Wen-Whai Li Ph.D., P.E.
Investigador Principal
Departamento de Ingeniería

Leah D. Whigham, Ph.D., FTOS
Co-Investigadora Principal
Departamento de Ciencias en Salud Pública

Asthma Control Questionnaire—English and Spanish

Modified Asthma Control Tool*
[To be administered weekly]

Child Study ID #: _____

Date: _____

Field Staff: _____

1. **How many asthma flares did you have the past week?**

   0 1 2 3 4 5 or more

2. **Did your asthma flare last the entire week?**

   0 1 2 3 4 5 or more

3. **How many times did you start on a steroid medicine by mouth for asthma such as prednisone (Prelone, Pediapred, or Orapred)?**

   0 1 2 3 4 5 or more

4. **How many times did you make an emergency visit for asthma?**

   0 1 2 3 4 5 or more

5. **How many times did you stay overnight in the hospital for asthma?**

   0 1 2 3 4 5 or more

During the past week, how many times have you had:

6. **Asthma symptoms with light activity such as walking up steps or laughing or crying**

   0 Never
   1 Once or twice a week
   2 Every other day
   3 Every day
   4 More than once a day

7. **Asthma symptoms with running or sports**

   0 Never
   1 Once or twice a week
   2 Every other day
   3 Every day
   4 More than once a day

8. Asthma symptoms while asleep at night

0 Never
1 Once or twice a week
2 Every other day
3 Every day
4 More than once a day

9. Asthma symptoms in the morning when you woke up

0 Never
1 Once or twice a week
2 Every other day
3 Every day
4 More than once a day

10. To take Albuterol or another quick-relief medicine for asthma symptoms

0 Never
1 Once or twice a week
2 Every other day
3 Every day
4 More than once a day

ASTHMA CONTROL QUESTIONNAIRE (To be administered weekly)

Circle the number of the response that best describes how you have been during the past week.

1) **On average, during the past week, how often were you woken by your asthma/how often did you asthma wake you up during the night?**

   0 Never
   1 Hardly Ever
   2 A few times
   3 Several Times
   4 Many times
   5 A great many times
   6 Unable to sleep because of asthma

2) **On average, during the past week, how bad were your asthma symptoms when you woke up in the morning?**

   0 No symptoms
   1 Very mild symptoms
   2 Mild symptoms
   3 Moderate symptoms
   4 Quite severe symptoms
   5 Severe symptoms
   6 Very severe symptoms

3) **In general, during the past week, how limited were you in your activities/how often could you not do things you normally do like playing games, sports, cleaning up your room etc. because of your asthma?**

   0 Not limited at all
   1 Very slightly limited
   2 Slightly limited
   3 Moderately limited
   4 Very limited
   5 Extremely limited
   6 Totally limited

4) **In general, during the past week, how much shortness of breath did you experience because of your asthma?**

   0 None
   1 A very little
   2 A little
   3 A moderate amount
   4 Quite a lot
   5 A great deal
   6 A very great deal

5) **In general, during the past week, how much of the time did you wheeze?**

   0 Not at all
   1 Hardly any of the time

2 A little of the time
3 A moderate amount of the time
4 A lot of the time
5 Most of the time
6 All the time

6) On average, during the past week, how many puffs of short-acting bronchodilator (e.g. Ventolin, Proventil, Albuterol) have you used each day?

0 None
1 1-2 puffs most days
2 3-4 puffs most days
3 5-8 puffs most days
4 9-12 puffs most days
5 13-16 puffs most days
6 More than 16 puffs most days

***Modified from:**

1. Zorc JJ, Pawlowski NA, Allen JL, Bryant-Stephens T, Winston M, Angsuco C, Shea JA, 2006. Development and Validation of an Instrument to Measure Asthma Symptom Control in Children. Journal of Asthma, 43:10, 753-758.
2. Juniper EF, O'Byrne PM, Ferrie PJ, King DR, Roberts JN, 2000. Measuring Asthma Control – Clinic Questionnaire or Daily Diary? American Journal of Respiratory and Critical Care Medicine, 162: 1330- 1334.

Instrumento Modificado para Medir el Control del Asma*

[Para administrarse semanalmente]

Número de identificación del niño/niña en el estudio: _____

Fecha: _____

Personal del área/de campo: _____

11. ¿Cuántos ataques o crisis de asma tuvo la semana pasada?

0 1 2 3 4 5 o más

12. ¿Duró toda la semana la crisis de asma?

0 1 2 3 4 5 o más

13. ¿Cuántas veces comenzó a usar una medicina de esteroides oral para el asma, tales como prednisona (Prelone, Pediapred, u Orapred)

0 1 2 3 4 5 o más

14. ¿Cuántas veces hizo una visita de emergencia debido al asma?

0 1 2 3 4 5 o más

15. ¿Cuántas veces tuvo que pasar la noche en el hospital debido al asma?

0 1 2 3 4 5 o más

Durante la semana pasada, ¿cuántas veces tuvo:

16. ¿Síntomas asmáticos al hacer cualquier actividad ligera, tal como subir escaleras, reír o llorar?

0 Nunca
5 Una o dos veces a la semana
6 Cada tercer día
7 Todos los días
8 Más de una vez al día

17. ¿Síntomas asmáticos al correr o hacer deportes?

0 Nunca
9 Una o dos veces a la semana
10 Cada tercer día
11 Todos los días
12 Más de una vez al día

18. ¿Síntomas asmáticos mientras dormía por la noche?

5 Nunca
6 Una o dos veces a la semana
7 Cada tercer día

8 Todos los días
9 Más de una vez al día

19. ¿Síntomas asmáticos en la mañana al despertar?

5 Nunca
6 Una o dos veces a la semana
7 Cada tercer día
8 Todos los días
9 Más de una vez al día

20. ¿Tomó Albuterol o cualquier otro medicamento de alivio rápido para los síntomas asmáticos?

5 Nunca
6 Una o dos veces a la semana
7 Cada tercer día
8 Todos los días
9 Más de una vez al día

CUESTIONARIO PARA CONTROL DEL ASMA (debe administrarse semanalmente)

Encierre en un círculo el número de la respuesta que mejor describe cómo estuvo durante la semana pasada.

7) **En promedio, durante la semana pasada, ¿con qué frecuencia lo despertaron sus síntomas de asma/con qué frecuencia lo/la despertó el asma durante la noche?**

0 Nunca
1 Casi nunca
2 Algunas veces
7 Varias veces
8 Muchas veces
9 Muchísimas veces
10 El asma no me dejó dormir

8) **En promedio, durante la semana pasada, ¿qué tan fuertes eran sus síntomas asmáticos cuando se despertó en la mañana?**

0 No tuve ninguno
1 muy leves
2 leves
6 moderados
7 bastante fuertes
8 fuertes
6 muy fuertes

9) **En general, durante la semana pasada, ¿qué tan limitado/a estuvo en sus actividades/ con qué frecuencia no pudo hacer las cosas que normalmente hace, como participar en juegos, jugar deportes, limpiar su cuarto, etc. debido a su asma?**

0 No estuve limitado/a para nada
1 Muy levemente limitado/a
2 Un poco limitado/a
6 Moderadamente limitado/a
7 Muy limitado/a
8 Sumamente limitado/a
6 Totalmente limitado/a

10) **En general, durante la semana pasada, ¿qué tanto sintió que le faltó la respiración debido al asma?**

0 Ninguna vez
1 Muy poco
2 Un poco
6 Una cantidad moderada
7 Bastante
8 Mucho
6 Muchísimo

11) **En general, durante la semana pasada, ¿cuánto tiempo sintió las sibilancias (los silbidos) en el pecho?**

0 No, nunca
1 Casi nunca

3 Un poco
4 Una cantidad moderada del tiempo
6 Mucho tiempo
7 Casi siempre
6 Todo el tiempo

12) En promedio, durante la semana pasada, ¿cuántas inhalaciones de un broncodilatador de corta acción (ejemplo: Ventolin, Proventil, Albuterol) ha utilizado al día?

0 Ninguno
1 1-2 inhalaciones la mayoría de los días
2 3-4 inhalaciones la mayoría de los días
6 5-8 inhalaciones la mayoría de los días
7 9-12 inhalaciones la mayoría de los días
8 13-16 inhalaciones la mayoría de los días
6 Más de 16 inhalaciones la mayoría de los días

***Modificado de:**

3. Zorc JJ, Pawlowski NA, Allen JL, Bryant-Stephens T, Winston M, Angsuco C, Shea JA, 2006. Development and Validation of an Instrument to Measure Asthma Symptom Control in Children. Journal of Asthma, 43:10, 753-758.
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Appendix C. Statistical Power for Detection of the Pollutant Effect on a Health Endpoint

We report on computer simulations implemented in R version 3.2.2 for the determination of statistical power for an observational study planned for Fall 2017 among asthmatic school-aged children in El Paso, Texas. The significance level of .05 was used throughout. We first consider the secondary health endpoint of heart rate variability (HRV) and focus on the main health endpoint exhaled NO (eNO). The reader may skip to the summary for the final recommendation.

Heart Rate Variability

We describe the procedure used for the generation of data by computer simulation for the purpose of computing the power of various experimental designs for detecting the association between the health endpoint High Frequency (HF [ms2]) of HRV and $PM_{2.5}$, denoted by Y and x, respectively. We consider designs with nJ measurements of Y obtained by enrolling a sample of n children who are measured once a week over a J-week calendar time period. We hold nJ fixed at some constant value: for example, $nJ = 144$ could be implemented with either 12 children sampled with the health endpoint Y measured weekly for 12 weeks, or 24 children sampled but measured weekly over a 6-week period of time.

Random Effects Model

A Gaussian random effects model was used to simulate data for repeated measurements of Y taken on a randomly sampled child conditional on centered hourly $PM_{2.5}$ (x):

$$ln\ Yt = b_0 + b_1 x_t + \varepsilon_t,$$

for times $t \in \{t_1, \ldots, t_J\}$, with $(b_0, b_1)^t$ and ε_t mutually independent. The $PM_{2.5}$values were sampled from the hourly $PM_{2.5}$ measurements taken between 8 a.m. and 9 a.m. in El Paso, Texas, from CAMS 12 during the months of September, October, and November in the years 2000–2005. This 8 a.m. to 9 a.m. hourly measurement was selected because a previous study [1] found the highest association between daily mortality and hourly $PM_{2.5}$ occurred at this time. The measurement Y of the health endpoint is to be taken at one-week intervals on Friday afternoons; here we simulated a $PM_{2.5}$ lagged effect on Y by taking values of $PM_{2.5}$ from 8:00 to 9:00 a.m. on Friday.

The random intercept (b_0) is the average $ln\ Y$ at the mean of $PM_{2.5}$. The random slope (b_1) is interpreted as follows: $100(e^{b1} - 1)$ is the subject-specific percentage change in Y associated with a unit increase in x. When b_1 is small, for example less than 0.1, then $e^{b1} - 1 \approx b_1$, so that b_1 is interpreted as the subject-specific relative change in Y associated with a unit change in x. The distributions of $(b_0, b_1)^t$ and ε_t in the random effects model are given as specified in Table C.1 and Table C.2. The variance terms σ_0^2 and σ_1^2 describe intersubject (between) variability of ln Y, and τ^2 the intra-subject (within) variability of $ln\ Y$. We exploited the known relationship between the mean and standard deviation for the normal and lognormal distributions. When values of parameters in the distribution of Y could not be deduced from the published literature reporting on children, we used values reported for adults. When only the interquartile range (IQR) was published, we used the relationship between IQR and standard deviation (σ) for the Gaussian distribution, namely, σ = IQR/1.34. When only the minimum and the maximum were published, we used the approximation σ ≈ range/c, c = 4 or 6 for the Gaussian distribution, where range = maximum − minimum.

Some executive decisions had to be made for the value of the parameters in the simulation, such as the value assigned to σ_{01}, while other parameters are modeled. The simulation included an exploration of the effect on power of the starting times t_1: (1) all subjects first sampled at the same time t_1, and (2) subjects with random starting times t_1.

Table C.1. Distribution of the Random Intercept (b_0), Slope (b_1), and Noise (ε)

	Independent Random Variables	
	$(b_0, b_1)^t$	ε
distribution	$N\left(\begin{pmatrix}\beta_0\\ \beta_1\end{pmatrix}, \Sigma = \begin{pmatrix}\sigma_0^2 & \sigma_{01}\\ \sigma_{10} & \sigma_1^2\end{pmatrix}\right)$	$N(0, \tau^2)$

Table C.2. Values for the Parameters of Model for Y

Parameter	Value	Reference	Cohort
τ_Y^2	130	[2], see Table C.3	elite athletes
δ_Y	36	[3], see Table C.3 change in Y for unit change in x adjusted for HRV and ambient temperature	adult cyclists
μ_Y	1224	[4], see Table C.3	children 6–8 years
σ_Y	(2874-512)/1.34	[4], see Table C.3	children 6–8 years
σ_0	$\sqrt{ln\left[1+\left(\frac{\sigma_Y}{\mu_Y}\right)^2\right]}$	relationship between distributions variance between	
τ	$\sqrt{ln\left[1+\left(\frac{\tau_Y}{\mu_Y}\right)^2\right]}$	relationship between distributions variance within	
β_0	$ln\,\mu_Y - \frac{1}{2}\sigma_0^2$	relationship between distributions mean of ln Y	
β_1	$ln[1+\delta_Y/\mu_Y]$	$e^{b1} - 1$ has interpretation δ_Y/Y for unit change in x	
σ_{01}	0	modeled	
σ_1	$P * \beta_1$	modeled	
P	P > 0	varied	

Simulation Results

The simulation generates HF data from the distributions assumed for the random intercept, slope, and noise. It first samples centered $PM_{2.5}$ data (x) for a sample of n children, each measured J times, and returns HF values on the logarithmic scale ($ln\ Y$). Realizations of ln(HF) for 10 children, each measured four times against $PM_{2.5}$ sampled (a) at the same time t_1, and (b) with random time t_1, are illustrated in Figures C.1 and C.2, respectively. Figures C.1 and C.2 show sample realizations with the following: (a) $P = 1$ and (b) $P = 2$, where P controls the variation in b_1. Here, b_1 is the random slope of the linear dose-response between $PM_{2.5}$ and the health endpoint in this simulation.

To calculate the power for detecting the association between HF and $PM_{2.5}$, we ran 500 simulations generating 500 independent sets of HF data on the logarithmic scale. For each of the 500 realizations of HF data, the linear mixed effect model allowing for the child-level random effect is fitted. We compute the power = P(reject null hypothesis, $H_0 : b_1 = 0 \mid H_1$ is true) by reporting the proportion of times (out of 500) that the null hypothesis of no $PM_{2.5}$ effect is rejected at the .05 level of significance. The power is calculated for different values of n and J. Table C.3 shows the power calculations at different values of P at the same starting times and random times for different pairs of (n, J) when nJ = 144. Whether the first time of measurement is synchronized for the n children at the same starting time or set as random has negligible effect on the power of the design.

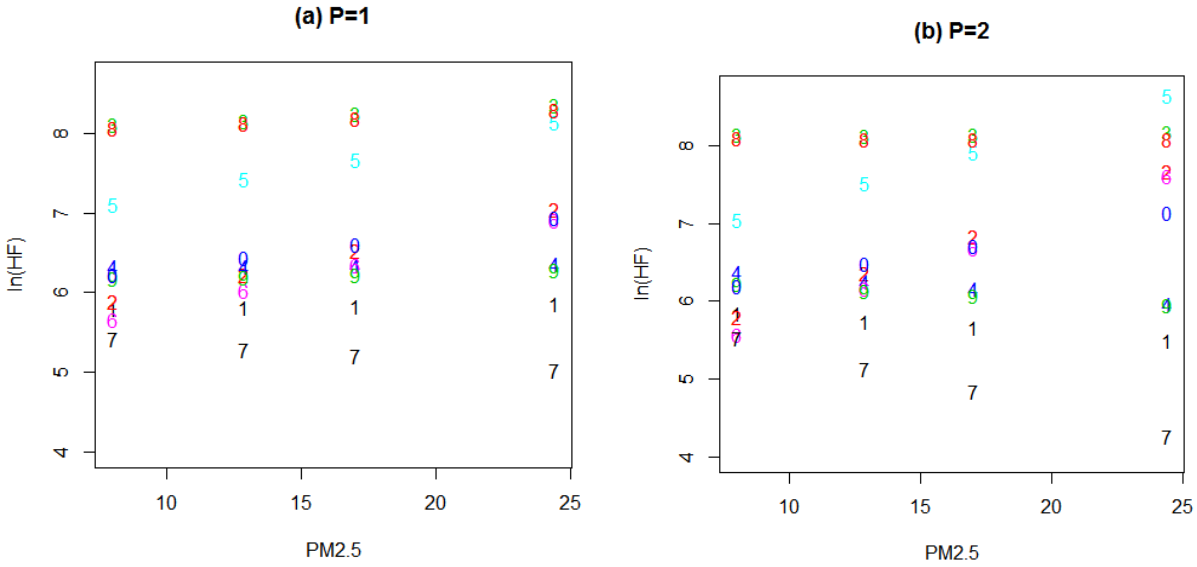

Figure C.1. Realization of HF data against PM2.5 sampled at the same starting times with different values of P (n = 10, J = 4).

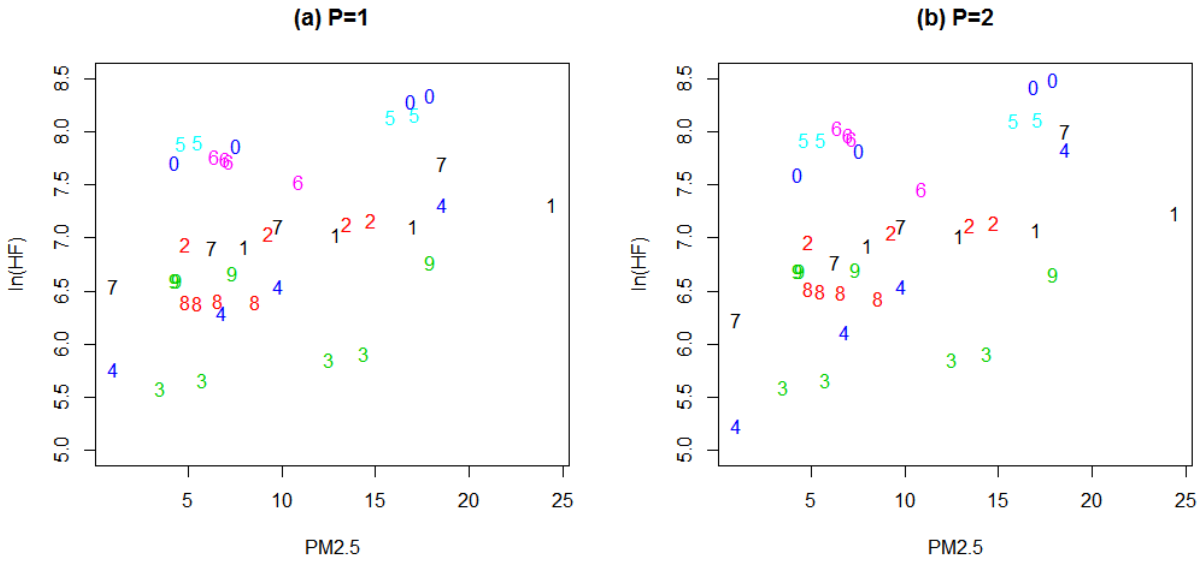

Figure C.2. Realization of HF data against PM2.5 sampled at the random starting times with different values of *P* (*n* = 10, *J* = 4).

Table C.3. Power Calculation for Different Pairs of (n, J) When nJ = 144

n	*J*	Power					
			same t_1			random t_1	
		P = 1	*P* = 1.2	*P* = 2	*P* = 1	*P* = 1.2	*P* = 2
6	24	0.676	0.526	0.290	0.674	0.608	0.280
8	18	0.778	0.628	0.326	0.836	0.706	0.324
9	16	0.832	0.716	0.404	0.816	0.710	0.336
12	12	0.930	0.816	0.418	0.916	0.828	0.430
16	9	0.972	0.906	0.532	0.976	0.894	0.580
18	8	0.990	0.940	0.562	0.986	0.944	0.558
24	6	0.994	0.980	0.666	1.000	0.978	0.704

Exhaled NO

To compute the power of experimental designs for the association between our primary health endpoint, eNO (Y) and $PM_{2.5}$ (x), parameter values in Table C.2 were estimated from the data, collected during 16 consecutive weeks from January through May 2008, of a previous study on the impact of air pollution on eNO in asthmatic children in Ciudad Juarez, Mexico, and El Paso, USA [5]. Fitting of a linear mixed effect model assuming random intercept for subjects (29 children from two schools in El Paso) with first-order autoregressive covariance structure, also known as AR(1), was conducted to estimate the effect of ambient 48-hour $PM_{2.5}$ on log-transformed eNO values. Mimicking the analyses in the study (see [5], Table C.3), the 48-hour temperature, 48-hour humidity, and indoor NO level were included in the model as covariates. The pilot parameter estimates obtained indicate a weak eNO and $PM_{2.5}$ association, as shown in Table C.4.

Table C.4. Pilot Mixed Effect Model Parameters for eNO–Pollutant Association

Random effects:	parameter	std. dev		
	intercept	0.7378		
	residual	0.4141		
	AR(1) correlation	0.5141		
Fixed effects:	parameter	value	std. error	*p*-value
	intercept	3.1470	0.1412	<0.0001
	$PM_{2.5}$	0.0027	0.0038	0.4704
	temperature	0.0077	0.0024	0.0013
	humidity	0.0074	0.0018	0.0001
	indoor NO	0.0028	0.0011	0.0122

Given the constraints of the planned study design (time and number of children with asthma), the sample size n = 24 with J = 6 is recommended. The power for this design is less than 8 percent, smaller than the targeted power of 80 percent. Table C.5 shows power calculation for different pairs of (n, J), from which we read that the required sample size is about n = 1575 to have the targeted power with J = 6. In order to achieve 80 percent of power with the design of 24 children and six measurements, the effect size of $b_1 \approx 0.0225$ is needed, implying that the percent of change on eNO per IQR change of $PM_{2.5}$ would have to be about 12 percent. Figure C.4 shows power curves for b_1 and sample size desired to achieve 80 percent of power.

Table C.5. Power Calculation for Different Pairs of (n, J)

n J	9 16	12 12	16 9	18 8	24 6	36 4	... ...	1500 6	1575 6	1600 6
power	0.079	0.070	0.074	0.074	0.077	0.064	...	0.767	0.810	0.827

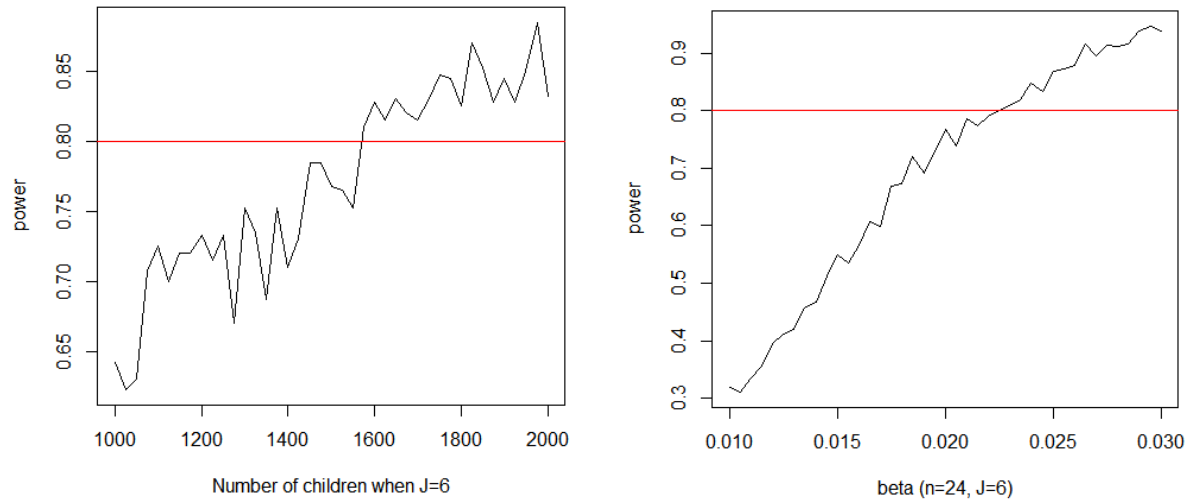

Figure C.3. Realization of eNO data against sampled 48-hour $PM_{2.5}$ when n = 30 and J = 16 (left) and plot of actual eNO data against 48-hour $PM_{2.5}$ (right).

Summary for Power Analysis

The simulation conducted in the power analysis of HRV used Gaussian general linear mixed-effect models with hourly $PM_{2.5}$, whereas the simulation in the power calculation of eNO used the average of 48-hour $PM_{2.5}$. The proposed study will be using hourly $PM_{2.5}$ with a historical functional linear model [5]. Although the proposed study has low power, the use of a historical functional linear model will allow for an exploration of the lag effect of $PM_{2.5}$, i.e., the time it takes for the body to mount a response to the exposure to $PM_{2.5}$. Whether the first time of measurement is synchronized for the *n* children at the same starting time or set as random has negligible effect on the power of the design.

We recommend enrolling $n = 24$ children with $J = 6$ repeat measurements over the Fall 2017 study period instead of $n = 12$ with $J = 12$ repeat measurements. Our findings for repeated measures of a Gaussian health endpoint are consistent with Dang et al. [6], who discussed power estimation in mixed models with correlated binary outcomes, suggesting that larger sample sizes (n) with a fewer numbers of repeated measurements (J) are a more cost-effective design.

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Appendix D. Statistical Methods and Epidemiologic Analyses

Descriptive statistics were calculated to assess characteristics of air pollution metrics, respiratory health outcomes (i.e., exhaled nitric oxide [eNO], forced vital capacity [FVC], and forced expiratory volume in 1 second [FEV1]), Veggie Meter outcomes measured by fruit and vegetable intake (F/V), and physical activity (moderate/light/sedentary) outcomes. Box plots were plotted to characterize various outcomes at different sites, and school-specific means were compared using a two-sided *t* test. Correlation analyses using Spearman correlations were conducted to assess relationships between F/V, physical activity, and outdoor pollutant concentrations.

Summary statistics of subject demographic information and characteristics were calculated. Comparisons of continuous characteristics (e.g., age, BMI, height, weight) between schools were made using the two-sample *t* test. Fisher's exact test and corresponding *p*-values were also calculated to explore differences in subject-specific factors between the two schools.

Longitudinal associations between primary responses (eNO, FVC, FEV1, and F/V) and air pollution metrics were examined using linear mixed effect models, with pollutants modeled as fixed effects and subjects modeled as random effects. We assumed the subject-specific random intercept and included additional control for the repeated measures of the outcome data using a first-order autoregressive covariance structure. 96-hour averages of temperature and relative humidity showed strongest associations with response outcome, and as a priori fixed covariates in all models, the 96-hour temperature and relative humidity were controlled.

Separate models were run for each pollutant variable of interest (PM concentrations, NO_2, O_3, or air quality gauge) with various exposure periods (previous 24-, 48-, 72-, or 96-hour averages). Effect estimates for each measurement are presented as the percent change in eNO and changes in lung function parameters per increase in pollutant concentrations. We scaled effects to interquartile range (IQR = Q_3-Q_1) increases in pollutant metrics to compare the magnitude of effect across different scales of the pollutant concentrations. Effects standardized to IQRs allowed us to compare effects for a similar degree of increase relative to each metric's distribution of concentrations (Liang and Zeger 1986).

We examined significant associations between air pollution-health outcomes that differed by school from school-stratified analyses. Subject-specific factors (sex, race, BMI category, hay fever status, health insurance, caretaker education, medication, etc.) were also considered as potential covariates in secondary analyses, including interaction terms of pollutant × factor.

For models predicting rates of moderate or sedentary physical activity, a generalized estimating equations (GEE) approach was used to address characteristics of proportion data with multiple categories, such as moderate/light/sedentary. GEE provide a general method for the analysis of correlated outcomes without making strong assumptions on the dependence structure. The GEE model yields unbiased estimates of population-averaged regression coefficients together with robust variance estimates, even with misspecification of the correlation structure (Liang and Zeger 1986). We assumed subject-specific cluster and exchangeable correlation structure, and controlled 96-hour temperature and relative humidity in the models. School-specific analyses were examined by adding interactions between pollutant metric and school.

A *p*-value < .05 was considered statistically significant. All statistical analyses were performed using R version 3.2.2. The R packages "nlme" and "geepack" were used for linear mixed effect models and generalized estimating equations fitting, respectively.

Results

Pollutant Concentrations

We considered various exposure windows for outdoor and ambient pollutants. Hourly measurements were aggregated to 24-, 48-, 72-, and 96-hour averages, matching the school-based measurements, for example, ending in the morning (10 a.m.) for Coldwell and in the afternoon (2 p.m.) for Bliss. Hourly concentrations measured at the nearest CAMS locations were averaged over the same exposure window periods for comparisons. For O_3 data, additional 72-hour averages of maximum 8-hour O_3 were collected and used to explore longitudinal associations with health outcomes.

$PM_{2.5}$ Concentrations

Descriptive statistics for 24-, 48-, 72-, and 96-hour averaged $PM_{2.5}$ are listed in Table D.1. Table D.1 compares the concurrently measured outdoor and ambient $PM_{2.5}$ concentrations at the two distinct schools, respectively. The mean and standard deviation (SD) ambient $PM_{2.5}$ concentrations remained nearly similar between Coldwell and Bliss schools, whereas average concentrations of outdoor $PM_{2.5}$ at Bliss were 6–7 µg/m^3 higher than concentrations at Coldwell. The measurements at CAMS 41 were lower than outdoor measurements.

Table D.1. Summary Statistics for Outdoor and Ambient $PM_{2.5}$

	24-hr Avg			48-hr Avg			72-hr Avg			96-hr Avg		
	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB
Outdoor												
Mean	16.3	12.8	19.9	15.3	12.0	18.7	14.8	11.8	17.8	15.2	12.1	18.2
SD	7.2	3.9	8.1	5.9	3.0	6.3	4.9	3.0	4.7	4.6	3.1	3.9
Median	14.9	13.3	19.1	14.4	12.6	16.9	13.5	11.9	18.4	14.5	12.1	17.4
IQR	6.6	6.2	7.7	5.7	5.0	8.5	6.9	3.7	6.1	5.4	4.2	5.0
Max.	39.5	19.7	39.5	30.7	16.0	30.7	25.3	18.8	25.3	24.5	17.6	24.5
Min.	6.3	6.3	8.7	6.2	6.2	7.9	7.0	7.0	8.2	6.9	6.9	12.4
N	34	17	17	34	17	17	34	17	17	34	17	17
Ambient (CAMS41)												
Mean	9.8	9.8	9.8	9.7	9.7	9.7	10.1	10.1	10.0	10.4	10.4	10.4
SD	5.6	5.9	5.6	5.3	5.4	5.4	5.6	5.7	5.7	5.3	5.5	5.4
Median	8.0	7.9	8.0	9.1	8.9	9.3	9.5	9.6	9.4	10.1	10.1	10.1
IQR	7.5	7.0	7.5	6.4	5.3	6.8	5.9	6.3	4.7	6.3	6.3	6.2
Max.	22.3	22.3	21.3	22.6	22.4	22.6	26.3	26.2	26.3	22.9	22.7	22.9
Min.	1.4	2.5	1.4	2.6	2.8	2.6	2.3	2.7	2.3	3.3	3.4	3.3
N	34	17	17	34	17	17	34	17	17	34	17	17

PM_{10} Concentrations

Table D.2 shows descriptive statistics for 24-, 48-, 72-, and 96-hour averaged PM_{10}. Table D.2 also presents comparisons of the concurrently measured outdoor and ambient PM_{10} concentrations at the two distinct schools. Similar to $PM_{2.5}$ data, the mean and SD ambient PM_{10} concentrations remained nearly constant between Coldwell and Bliss schools. However, average outdoor PM_{10} concentrations at Bliss were 12–15 µg/m^3 higher than concentrations at Coldwell. Outdoor PM_{10} concentrations were approximately 15 µg/m^3 higher than ambient pollution measured at the CAMS.

Table D.2. Summary Statistics for Outdoor and Ambient PM_{10}

	24-hr Avg			48-hr Avg			72-hr Avg			96-hr Avg		
	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB
Outdoor												
Mean	55.0	47.5	62.4	51.2	44.1	58.2	49.8	43.7	55.9	51.0	44.8	57.2
SD	19.2	15.7	19.9	17.0	12.6	18.1	14.2	10.6	15.0	12.3	10.1	11.4
Median	53.6	48.2	61.9	50.4	44.5	55.5	48.4	43.1	55.4	50.0	47.2	59.9
IQR	28.9	27.3	19.9	22.5	21.0	22.9	18.1	15.1	20.9	16.8	10.4	15.9
Max.	94.3	74.1	94.3	97.5	62.3	97.5	86.3	63.3	86.3	78.3	62.0	78.3
Min.	24.5	24.5	27.6	24.3	24.3	25.1	25.7	27.1	25.7	28.4	28.4	36.7
N	34	17	17	34	17	17	34	17	17	34	17	17
Ambient (CAMS41)												
Mean	36.3	36.8	35.7	35.1	34.9	35.3	34.2	34.3	34.2	36.3	36.2	36.4
SD	25.8	26.6	25.9	17.9	17.6	18.7	15.2	14.9	15.9	13.0	13.1	13.3
Median	25.8	23.7	27.8	35.0	35.1	34.1	35.0	34.9	35.0	40.2	40.2	40.9
IQR	47.7	46.8	48.0	23.3	21.9	23.7	22.5	21.5	22.6	19.0	19.1	18.6
Max.	85.5	85.5	74.5	65.7	63.3	65.7	58.7	57.4	58.7	51.6	51.6	50.8
Min.	5.6	7.4	5.6	6.4	7.2	6.4	6.7	7.6	6.7	6.7	6.7	6.7
N	34	17	17	34	17	17	34	17	17	34	17	17

NO_2 Concentrations

Table D.3 reports descriptive statistics for outdoor and ambient 24-, 48-, 72-, and 96-hour averaged NO_2 concentrations with comparisons between the two distinct schools. For all exposure windows, outdoor mean NO_2 at Coldwell was 2.7-3.6 ppb higher than concentrations at Bliss. Outdoor NO_2 concentrations were relatively lower than ambient pollution measured at CAMS 37.

Table D.3. Summary Statistics for Outdoor and Ambient NO_2

	24-hr Avg			48-hr Avg			72-hr Avg			96-hr Avg		
	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB
Outdoor												
Mean	17.8	19.2	16.5	17.1	18.6	15.5	16.7	18.5	14.9	17.1	18.7	15.4
SD	5.5	5.8	5.1	4.1	4.1	3.6	3.9	3.9	3.2	4.0	4.1	3.1
Median	19.0	19.6	16.7	16.5	18.5	15.6	16.6	18.6	14.5	16.2	19.9	14.9
IQR	8.0	6.8	7.1	4.7	5.1	4.9	4.9	3.7	3.7	6.0	6.1	2.0
Max.	26.5	26.5	25.5	25.9	25.9	22.4	26.0	26.0	21.8	24.8	24.8	21.1
Min.	7.2	7.2	7.9	9.9	11.1	9.9	9.7	11.8	9.7	9.8	11.6	9.8
N	34	17	17	34	17	17	34	17	17	34	17	17
Ambient (CAMS37)												
Mean	18.4	18.5	18.2	18.2	18.4	17.9	17.7	17.7	17.8	18.2	18.2	18.2
SD	8.6	8.9	8.5	4.7	5.0	4.7	5.2	5.2	5.3	5.0	5.1	5.0
Median	17.5	18.1	17.2	16.4	16.7	16.4	16.9	16.9	16.1	18.2	17.8	18.4
IQR	11.9	10.2	13.0	6.4	6.9	6.3	7.8	6.5	7.8	6.5	5.8	6.5
Max.	35.2	35.2	32.5	28.4	28.0	28.4	29.9	29.9	29.8	27.9	27.7	27.9
Min.	3.8	3.9	3.8	12.6	12.9	12.6	11.4	11.4	12.0	11.0	11.0	11.0
N	32	16	16	32	16	16	34	17	17	34	17	17

Concentrations

O_3 concentrations for outdoor and ambient environments are listed in Table D.4. Comparisons of mean O_3 between the two distinct schools show that O_3 concentrations at Bliss were higher than at Coldwell. For all exposure windows, the outdoor mean O_3 at Coldwell was lower than concentrations at Bliss. The 72-hour averaged max 8- hour O_3 data have similar patterns, with higher mean concentrations at Bliss than at Coldwell. Outdoor O_3 concentrations at Bliss Elementary were relatively higher than ambient concentrations, whereas both concentrations were nearly constant at Coldwell.

Table D.4. Summary Statistics for Outdoor and Ambient O_3

	24-hr Avg			48-hr Avg			72-hr Avg			96-hr Avg		
	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB
Outdoor												
Mean	22.2	20.8	23.6	22.4	20.6	24.0	22.5	21.2	23.8	21.9	20.3	23.6
SD	8.3	9.2	7.3	6.0	6.3	5.3	6.0	6.7	5.0	5.6	5.4	5.4
Median	20.2	19.6	21.1	20.7	19.6	23.1	21.3	18.7	22.2	20.5	17.6	20.9
IQR	13.0	13.9	12.1	7.6	8.3	6.0	9.7	10.7	7.9	10.4	10.0	8.5
Max.	38.9	38.9	36.4	33.0	31.8	33.0	34.5	34.5	32.5	32.9	29.7	32.9
Min.	8.7	8.7	14.3	11.8	11.8	15.4	12.1	12.1	15.1	13.6	13.6	14.8
N	31	15	16	31	15	16	32	16	16	32	16	16
Ambient (CAMS41)												
Mean	20.1	20.0	20.2	20.0	20.0	20.0	20.1	20.1	20.2	19.7	19.7	19.8
SD	8.3	8.7	8.1	5.2	5.4	5.2	5.2	5.3	5.2	5.1	5.2	5.2
Median	17.3	17.1	17.7	19.5	19.7	19.3	18.9	19.0	18.7	17.6	17.7	17.4
IQR	13.6	13.7	13.3	6.1	6.4	5.3	7.3	7.8	6.9	8.0	8.0	7.8
Max.	39.1	39.1	36.7	29.9	29.9	28.8	29.0	29.0	28.6	28.4	28.4	28.2
Min.	8.4	8.4	11.2	11.0	11.0	11.0	11.5	11.5	12.0	13.5	13.5	13.6
N	34	17	17	34	17	17	34	17	17	34	17	17

	72-hr average of 8-hr max O_3		
	ALL	CW	FB
Outdoor			
Mean	34.4	32.7	36.0
SD	6.1	6.3	5.7
Median	35.5	32.7	35.9
IQR	10.0	11.3	6.3
Max.	50.5	42.4	50.5
Min.	23.7	23.7	26.8
N	32	16	16

AQG Measurements

Table D.5 shows descriptive statistics of the air quality gauge obtained from amounts of outdoor $PM_{2.5}$, NO_2, and O_3. Comparisons of mean AQG between the two distinct schools show that Bliss experienced more severe air pollution than Coldwell. For all exposure windows, the outdoor mean O_3 at Coldwell was lower than concentrations at Bliss. The 24-hour averaged AQG measurements at Bliss had larger variations (SD = 25.8, range = 63.8–162.3) than at Coldwell (SD = 15.4, range = 58.0–105.8).

Table D.5. Summary Statistics for AQG

	24-hr Avg			48-hr Avg			72-hr Avg			96-hr Avg		
	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB	ALL	CW	FB
Outdoor												
Mean	95.5	84.8	105.6	91.7	81.9	100.9	89.6	81.2	98.1	90.9	82.3	99.4
SD	23.6	15.4	25.8	19.7	13.4	20.5	16.4	11.1	16.7	15.4	11.4	14.3
Median	94.5	87.5	102.5	92.7	84.5	100.1	89.5	82.2	99.0	90.0	84.3	97.8
IQR	27.6	21.2	28.3	21.7	21.7	22.7	19.4	16.0	22.3	14.0	19.5	26.2
Max.	162.3	105.8	162.3	135.3	101.1	135.3	120.8	97.4	120.8	118.8	95.8	118.8
Min.	58.0	58.0	63.8	57.4	57.4	65.9	57.8	57.8	66.3	59.7	59.7	78.0
N	31	15	16	31	15	16	32	16	16	32	16	16

Subject Data Characterization

The study collected data on 23 children from two schools (12 children at Coldwell and 11 children at Bliss) in El Paso, Texas. The subjects are characterized in Table D.6. The table presents summary statistics of subject information and the information stratified by school. *P*-values of *t*-tests and Fisher's exact tests are provided to examine differences in subject characteristics between the two schools.

The mean age was 7.8 years (SD = 1.7), and the mean body mass index (BMI) was 19.2 (SD = 5.7) for all students. The mean BMI-for-age percentile (49.8±41.2) for subjects at Coldwell was lower than the mean BMI-for-age percentile (78.3 ± 21.1) at Bliss, with *p*-value = 0.0503. While all students at Coldwell were Hispanic, students at Bliss included a variety of races; Black, Hispanic, and White. Fisher's exact test indicated that the proportion of student race at Coldwell was significantly different than that of the Bliss school (*p*-value = 0.0137).

Types of cooking fuel— electric versus gas—were also a significant factor (*p*-value = 0.0028) that differed by school; a higher proportion of Coldwell subjects used gas (11 of 12, 92 percent) than at Bliss (3 of 11, 27 percent). All gas fuel users at Bliss had pilot light gas. Another factor to note was student's health insurance coverage, although the insurance factor was not significant (*p*-value = 0.0635). Most Bliss students were enrolled in private insurance (10 of 11, 91 percent), whereas only 45 percent of Coldwell subjects were covered under private insurance (5 of 12).

Medication information was also collected for all subjects. Fisher's exact test indicated a significantly (*p*-value = 0.0373) lower proportion of subjects with SABA intake at Coldwell (7 of 12, 58 percent) than at Bliss (11 of 11, 100 percent).

Table D.6. Summary of Demographics and Subject Information

Variable	All (n = 23)		CW (n = 12)		FB (n = 11)		*p*-value*
	mean	range	mean	range	mean	range	
Age (yrs)	7.8	(5–10)	8.3	(6–10)	7.4	(5–10)	0.2156
Height (in)	53.0	(43.3–70.0)	54.3	(46.3–70.0)	51.5	(43.3–58.3)	0.1848
Weight (lb)	79.3	(40–152)	76.3	(45.8–134)	82.6	(40–152)	0.6685
BMI	19.2	(12.3–31.5)	17.9	(12.3–27.8)	20.7	(15.0–31.5)	0.2537
BMI (%)	63.5	(0–99.5)	49.8	(0–99.4)	78.3	(37.4–99.5)	0.0503

* *p*-value for mean difference between schools using a two-sample *t* test.

Variable	All (n = 23)		CW (n = 12)		FB (n = 11)		*p*-value**
	Frequency,%		Frequency,%		Frequency,%		
Gender							
Male	12	52%	7	58%	5	45%	0.6843
Female	11	48%	5	42%	6	55%	
Race							
Black	4	17%	0	0%	4	36%	
Hispanic	18	78%	12	100%	6	55%	**0.0137**
White	1	4%	0	0%	1	9%	
BMI category							
Underweight	2	9%	2	17%	0	0%	
Normal	13	57%	6	50%	7	64%	0.6135
Overweight	1	4%	1	8%	0	0%	

Obese	7	30%	3	25%	4	36%	
Mother with Asthma	7	30%	5	42%	2	18%	0.3707
Father with Asthma	6	26%	3	25%	3	27%	1.0000
Mother with Hay Fever	14	61%	8	67%	6	55%	0.6802
Father with Hay Fever	12	52%	8	67%	4	36%	0.2203
Siblings with Asthma	11	48%	6	50%	5	45%	1.0000
Siblings with Hay Fever	13	57%	8	67%	5	45%	0.4136
Having Eczema	7	30%	3	25%	4	36%	0.6668
Allergic Phenotype (Aeroallergens)	14	61%	8	67%	6	55%	0.6802
Allergic Phenotype (Food)	4	17%	3	25%	1	9%	0.5901
Blood Eosinophilia	0	0%	0	0%	0	0%	1.0000
Caretaker Education							
Less than or Equal to High School	9	39%	6	50%	3	27%	0.4003
Greater than High School	14	61%	6	50%	8	73%	
Health Insurance Coverage (n=22)							
Medicaid	7	32%	6	55%	1	9%	0.0635
Private	15	68%	5	45%	10	91%	
Smoke	2	9%	2	17%	0	0%	0.4783
Cooking Fuel							
Electric	9	39%	1	8%	8	73%	**0.0028**
Gas	14	61%	11	92%	3	27%	
Pilot Light for Gas (n = 14)	4	29%	1	9%	3	100%	**0.0110**
Medication							
LB	14	61%	7	58%	7	64%	1.0000
SABA	18	78%	7	58%	11	100%	**0.0373**
IC	14	61%	6	50%	8	73%	0.4003
LABAIC	2	9%	2	17%	0	0%	0.4783

NC	7	30%	4	33%	3	27%	1.0000
SC	4	17%	2	17%	2	18%	1.0000
LABA	0	0%	0	0%	0	0%	1.0000

**p-value for difference between schools using Fisher's exact test.

Health Outcome Characterization

Table D.7 presents descriptive statistics for all health outcomes (eNO, FVC, FEV1) by school, along with p-values from two-sample t-tests examining whether mean responses are different between the schools. Figures D1 and D2 present boxplots of the health responses overall and by school as a visual comparison of the tabular summary.

Exhaled NO levels were higher on average among students at Bliss (36.04±28.55) than at Coldwell (23.28±18.29), with an indication of significant difference between the two schools (p-value < 0.0001). For lung function parameters (FVC, FVC [percent], FEV1, FEV1 [percent]), all mean outcome levels were lower at Bliss than Coldwell. The t-test results showed significant differences between the two schools for all parameters except for the FEV1 (percent) results.

For epidemiologic analyses, the diagnostics of the health outcomes were performed to check their skewness and determine whether it was necessary to transform them. Figures D3 and D4 illustrate histograms of the main outcomes to assess distributions of the outcome. The eNO was obviously skewed to the right (see Figure D3), indicating log transformation of eNO values. This outcome was not the case for FVC and FEV1 (Figure D4). We found that a normal quantile plot of log-transformed eNO was close to the linear line, and the log-transformed eNO was used for linear mixed effect modeling.

Table D.7. Summary Statistics of Respiratory Health Outcomes and Corresponding p-Values for the Difference in Mean Outcome Levels between the Schools Using t-Tests

	Exhaled NO		
	ALL	CW	FB
Mean	29.08	23.28	36.04
SD	24.33	18.29	28.55
Median	23.00	18.00	32.00
IQR	36.00	32.00	49.00
Max.	112.50	74.50	112.50
Min.	5.00	5.00	5.00
N	363	198	165
p-value*			<0.0001

	FVC			FVC (% pred.)		
	ALL	CW	FB	ALL	CW	FB
Mean	1.85	2.09	1.57	91.74	94.87	87.53
SD	0.53	0.47	0.46	12.29	11.90	11.55
Median	1.88	2.02	1.46	92.00	96.00	88.00
IQR	0.82	0.74	0.73	15.00	15.00	14.00
Max.	2.98	2.98	2.72	126.00	126.00	123.00
Min.	0.55	1.00	0.55	49.00	52.00	49.00
N	365	200	165	288	165	123
p-value*			<0.0001			<0.0001

	FEV1			FEV1 (% pred.)		
	ALL	CW	FB	ALL	CW	FB
Mean	1.53	1.71	1.31	86.72	87.49	85.68
SD	0.49	0.49	0.40	16.38	17.48	14.79
Median	1.51	1.69	1.27	89.00	91.00	85.00
IQR	0.77	0.80	0.68	21.00	21.00	20.50
Max.	2.55	2.55	2.22	122.00	122.00	122.00
Min.	0.40	0.48	0.40	28.00	28.00	48.00
N	365	200	165	288	165	123
p-value*			<0.0001			0.3435

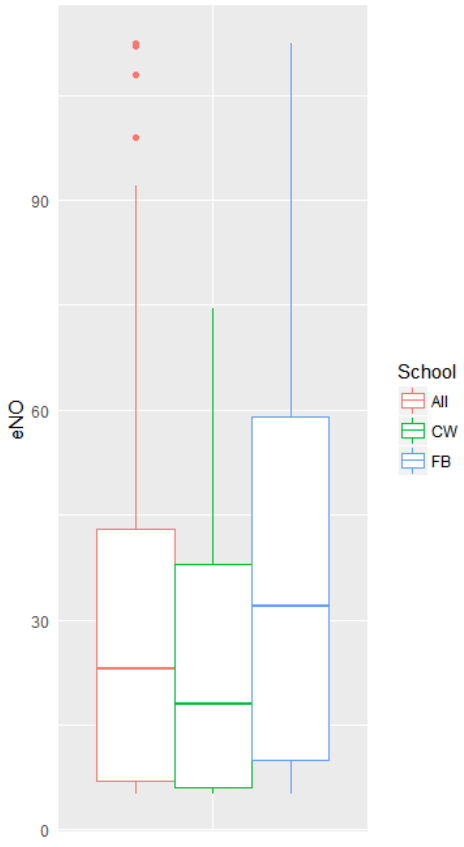

Figure D1. Boxplots of eNO measurements by school.

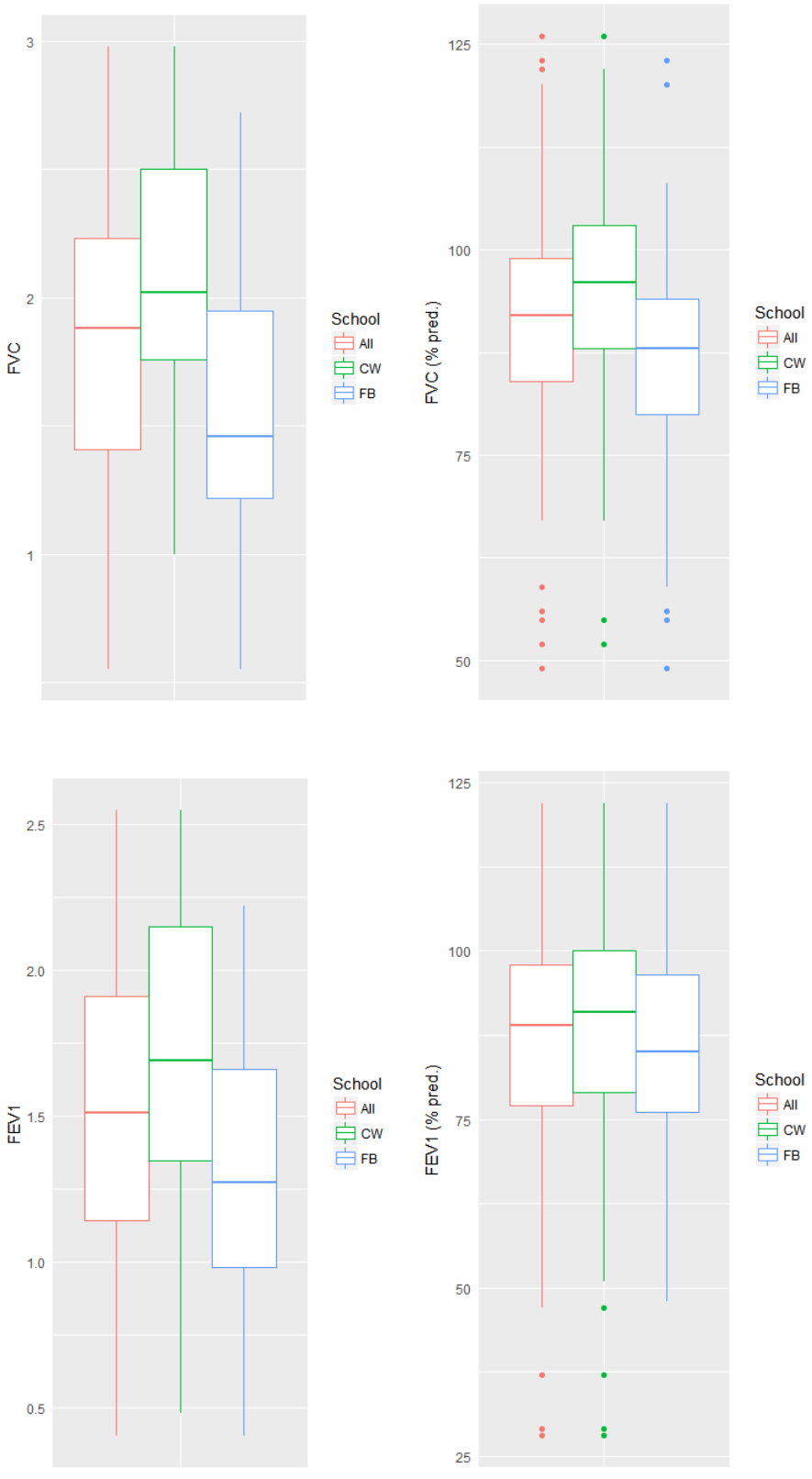

Figure D2. Boxplots of lung function outcomes by school.

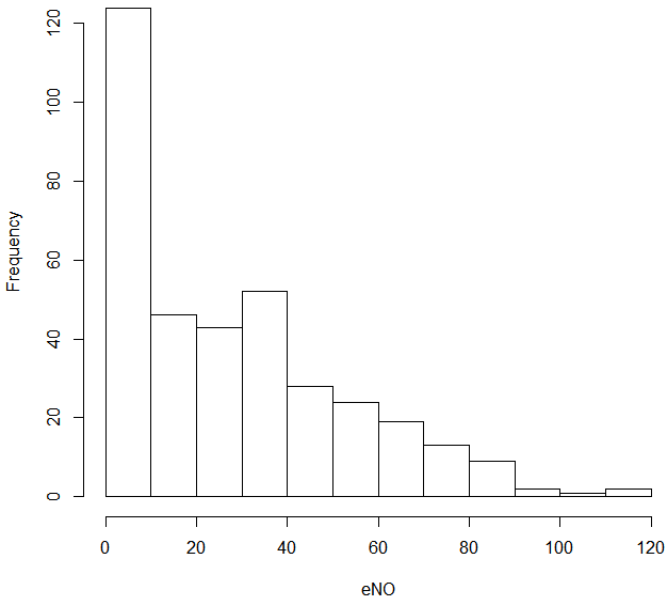

Figure D.3. Histograms of eNO outcome distribution.

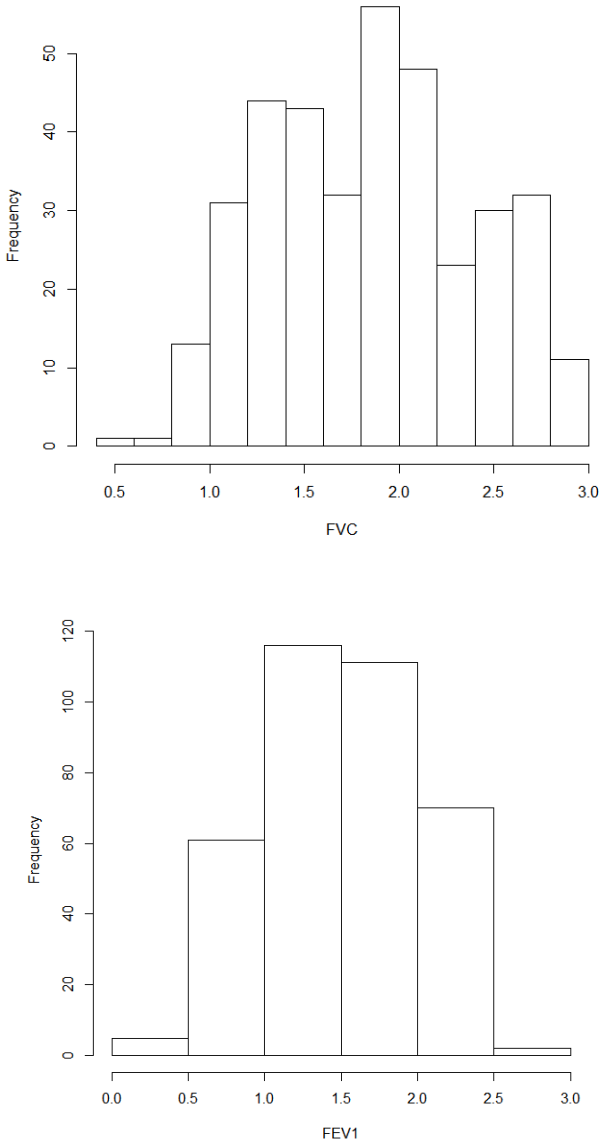

Figure D.4. Histograms of FVC (left) and FEV1 (right) distributions.

Veggie Meter Outcome Characterization

Table D.8 presents descriptive statistics for F/V intake levels by school, along with a *p*-value from a two-sample *t* test. Students at Coldwell showed a tendency of more fruit and vegetable intake on average (246.30 ± 90.18) than students at Bliss (207.10 ± 81.70); a significant difference was found between the two schools (*p*-value = 0.0010). Figure D.5 presents boxplots of the outcomes overall and by school as a visual comparison of the tabular summary. The distribution of Veggie Meter data was assessed in Figure D.6, which presents no need of transforming the values.

Table D.8. Summary Statistics of Veggie Meter Outcomes

	Veggie Meter (F/V)		
	ALL	CW	FB
Mean	228.60	246.30	207.10
SD	88.43	90.18	81.70
Median	228.50	258.50	225.00
IQR	136.50	148.00	130.00
Max.	420.00	420.00	417.00
Min.	59.00	81.00	59.00
N	216	118	98
p-value*			0.0010

**p*-value for the difference in means between schools using a two-sided *t* test.

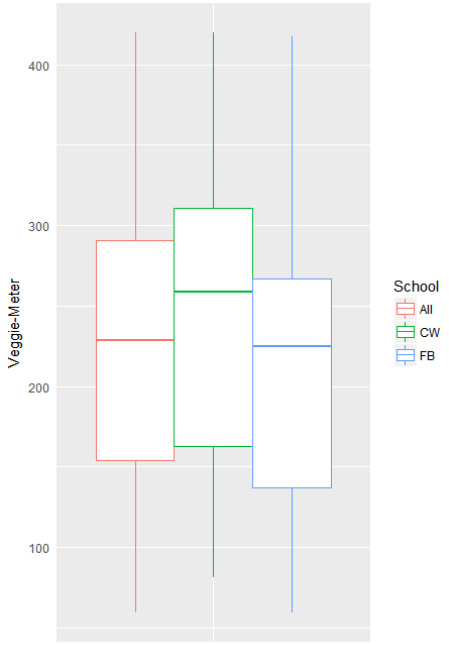

Figure D.5. Boxplots of Veggie Meter outcomes by school.

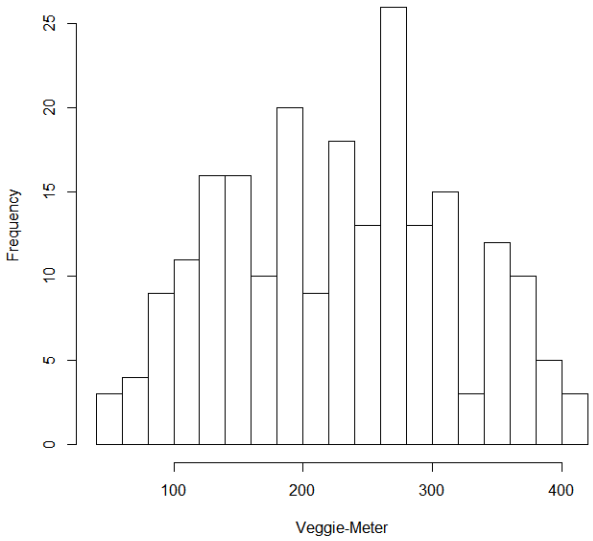

Figure D.6. Histograms of F/V intake level distribution.

Physical Activity Outcomes Characterization

Physical activity data were collected via accelerometer from 12 children at Coldwell Elementary School. Table D.9 presents descriptive statistics for physical activity rates by level (moderate, light, and sedentary) along with *p*-values from pairwise *t* tests for multiple comparisons. The mean (SD) levels for moderate, light, and sedentary activity are 0.634 (0.082), 0.101 (0.017), and 0.265 (0.079), respectively. Pairwise *t*-test results indicated the rates between three groups of activity level were significantly different from each other. The distributions of moderate and sedentary outcomes were assessed in Figure D.7. The skewed shapes of proportion data in physical activity level suggests a generalized linear mixed effect modeling or GEE-based approach.

Table D.9. Summary Statistics of Physical Activity Outcomes

	Physical Activity (CW only)		
	moderate	light	sedentary
Mean	0.634	0.101	0.265
SD	0.082	0.017	0.079
Median	0.647	0.101	0.250
IQR	0.115	0.024	0.112
Max.	0.777	0.144	0.617
Min.	0.304	0.071	0.137
N	102	102	102
p-value*			<2e-16

**p*-values for the difference in means between physical activity groups using pairwise *t* test with Bonferroni adjustment.

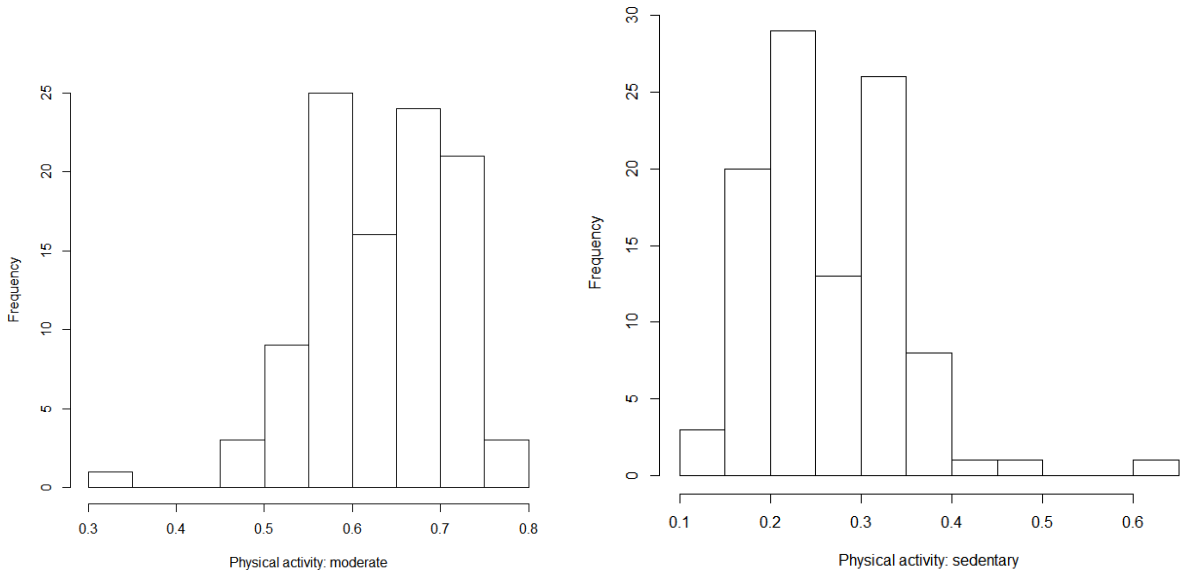

Figure D.7. Histograms of moderate (left) and sedentary (right) physical activity outcomes.

Epidemiologic Associations

Results from linear mixed effect models or GEE IQRs were calculated for air pollutant metric and effect estimates per IQR, 95 percent confidence intervals, and p-values are presented in Tables D.10, D.12, D.14, D.16, and D.17. Significant findings in tables may have been driven by subject characteristics. Tables D.11, D.13, and D.15 present the significant results from models examining modified effects by subject-specific factors. Figures D8 to D22 visualize the confidence intervals by school for various averaging times.

Models Predicting Exhaled NO

Exhaled NO generally showed very weak and nonsignificant associations with pollutant concentrations. We observed negative associations between eNO and 24-hour outdoor PM_{10} and NO_2 concentrations (*p*-values = 0.0215 and 0.0040, respectively). The 72-hour O_3 measurement outside the Coldwell site was the only metric to be positively and significantly associated with eNO levels; at *p*-value = 0.0278, it showed a 12.38 percent increase in eNO (95 percent CI: 1.40 percent - 23.47 percent).

We explored effect modifications by significant factors, focusing on eNO and the 72-hour outdoor O_3 (Table D.11). Subjects having a father with asthma showed more increased percent changes in eNO (26.05 [95 percent CI: 10.27, 42.09]). Caretaker education was a significant effect modifier of the eNO–O_3 relationship, with stronger associations observed for subjects whose caretakers had less than or equal to a high school education (15.88 [95 percent CI: 3.55, 28.37]). Another significant effect modifier was health insurance, which showed a higher percent increase in eNO for subjects with Medicaid health insurance (19.31 [95 percent CI: 6.17, 32.63]) than those with private insurance.

Table D.10. Overall and School-Specific Associations between eNO and Pollutant Metrics

Pollutant		Site	IQR	% change in eNO per IQR	95% CI lower	95% CI upper	*p*-value
$PM_{2.5}$	24 hr	Overall	6.69	-4.02	-8.16	0.15	0.0598
		CW	6.25	-8.31	-16.53	0.02	0.0514
		FB	7.62	-3.02	-8.37	2.37	0.2718
	24 hr (CAMS41)	Overall	7.61	-6.41	-12.49	-0.29	**0.0408**
		CW	6.99	-8.68	-15.87	-1.42	**0.0199**
		FB	7.62	-2.39	-11.41	6.74	0.6072
	48 hr	Overall	5.87	-3.28	-7.75	1.23	0.1545
		CW	5.00	-4.64	-12.90	3.76	0.2778
		FB	8.07	-3.77	-10.60	3.12	0.2836
	72 hr	Overall	7.08	-5.45	-12.42	1.58	0.1293
		CW	3.66	-2.48	-9.02	4.18	0.4642
		FB	5.44	-4.41	-10.89	2.14	0.1869
	96 hr	Overall	5.50	-5.41	-12.19	1.46	0.1231
		CW	4.15	-1.56	-10.03	7.09	0.7217
		FB	5.10	-7.02	-15.25	1.34	0.1004
PM_{10}	24 hr	Overall	30.82	-7.76	-14.32	-1.18	**0.0215**
		CW	27.29	-7.97	-16.80	0.89	0.0789
		FB	20.65	-4.66	-10.14	0.83	0.0973
	24 hr (CAMS41)	Overall	48.08	-7.61	-13.84	-1.38	**0.0173**
		CW	46.81	-7.12	-15.36	1.13	0.0918
		FB	48.80	-8.07	-17.20	1.08	0.0848
	48 hr	Overall	22.86	-3.63	-9.70	2.44	0.2417
		CW	20.96	-2.81	-12.01	6.44	0.5520
		FB	23.04	-3.90	-10.85	3.08	0.2737
	72 hr	Overall	19.50	-3.71	-10.17	2.76	0.2613
		CW	15.13	-0.93	-8.44	6.62	0.8084
		FB	20.53	-5.67	-14.12	2.82	0.1914
	96 hr	Overall	16.86	-3.76	-10.75	3.26	0.2936
		CW	10.42	0.40	-5.42	6.25	0.8930
		FB	12.17	-6.35	-13.56	0.90	0.0866
NO_2	24 hr	Overall	8.14	-10.30	-17.19	-3.35	**0.0040**
		CW	6.81	-9.56	-16.61	-2.43	**0.0091**
		FB	7.56	-7.66	-18.09	2.92	0.1560
	24 hr (CAMS37)	Overall	11.74	-7.06	-14.18	0.11	0.0544
		CW	10.18	-6.50	-14.07	1.14	0.0960
		FB	12.15	-6.71	-16.77	3.43	0.1951
	48 hr	Overall	4.69	-4.04	-9.70	1.70	0.1679
		CW	5.13	-7.83	-16.53	1.02	0.0834
		FB	5.26	-1.17	-9.98	7.80	0.7976

	72 hr	Overall	5.02	-1.44	-7.90	5.10	0.6641
		CW	3.68	-1.80	-8.49	5.02	0.6035
		FB	3.90	-0.35	-7.42	6.86	0.9236
	96 hr	Overall	5.85	-0.31	-8.55	8.05	0.9423
		CW	6.11	-1.55	-13.16	10.28	0.7954
		FB	2.40	0.47	-4.63	5.67	0.8582
O_3	72 hr avg 8-hr Max.	Overall	9.61	-4.05	-11.99	3.96	0.3210
		CW	11.31	0.98	-10.49	12.57	0.8676
		FB	5.74	-7.35	-14.67	0.08	0.0533
	24 hr	Overall	13.46	7.90	-2.71	18.59	0.1458
		CW	13.87	8.78	-3.80	21.48	0.1730
		FB	12.99	6.57	-7.81	21.12	0.3727
	48 hr	Overall	8.06	0.42	-7.54	8.46	0.9174
		CW	8.33	5.35	-4.83	15.66	0.3051
		FB	6.56	-5.42	-14.86	4.16	0.2668
	72 hr	Overall	9.75	6.62	-2.43	15.75	0.1531
		CW	10.68	12.38	1.40	23.47	**0.0278**
		FB	8.16	-6.61	-19.96	6.97	0.3387
	72 hr (CAMS41)	Overall	7.24	-4.15	-12.42	4.22	0.3308
		CW	7.76	-1.67	-12.80	9.62	0.7710
		FB	6.23	-6.53	-16.57	3.67	0.2089
	96 hr	Overall	9.82	-0.54	-12.14	11.21	0.9284
		CW	9.97	6.76	-9.46	23.25	0.4166
		FB	8.68	-6.08	-19.33	7.37	0.3742
AQG	24 hr	Overall	28.36	-2.66	-8.36	3.06	0.3624
		CW	21.24	-1.21	-9.54	7.15	0.7761
		FB	31.10	-3.29	-10.45	3.88	0.3689
	48 hr	Overall	22.45	-1.72	-7.49	4.07	0.5612
		CW	21.65	3.23	-6.72	13.22	0.5261
		FB	20.87	-3.51	-9.77	2.76	0.2730
	72 hr	Overall	20.49	-2.98	-9.19	3.24	0.3478
		CW	15.96	0.63	-7.68	8.98	0.8828
		FB	23.92	-5.89	-14.99	3.25	0.2071
	96 hr	Overall	15.38	0.18	-4.75	5.12	0.9431
		CW	19.45	7.58	-2.00	17.22	0.1222
		FB	26.51	-7.86	-19.57	3.89	0.1904

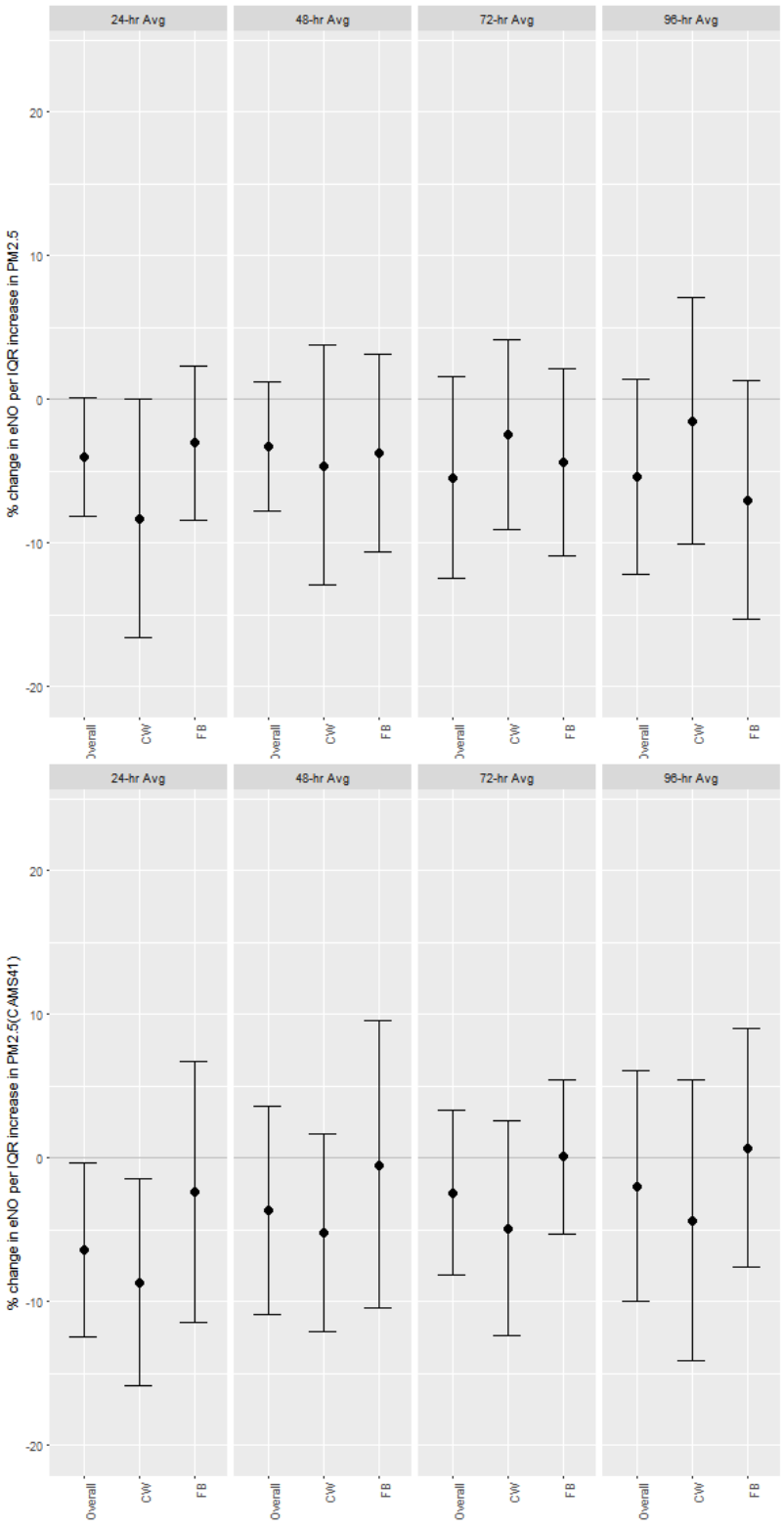

Figure D.8. Overall and school-specific associations between eNO and $PM_{2.5}$ metrics.

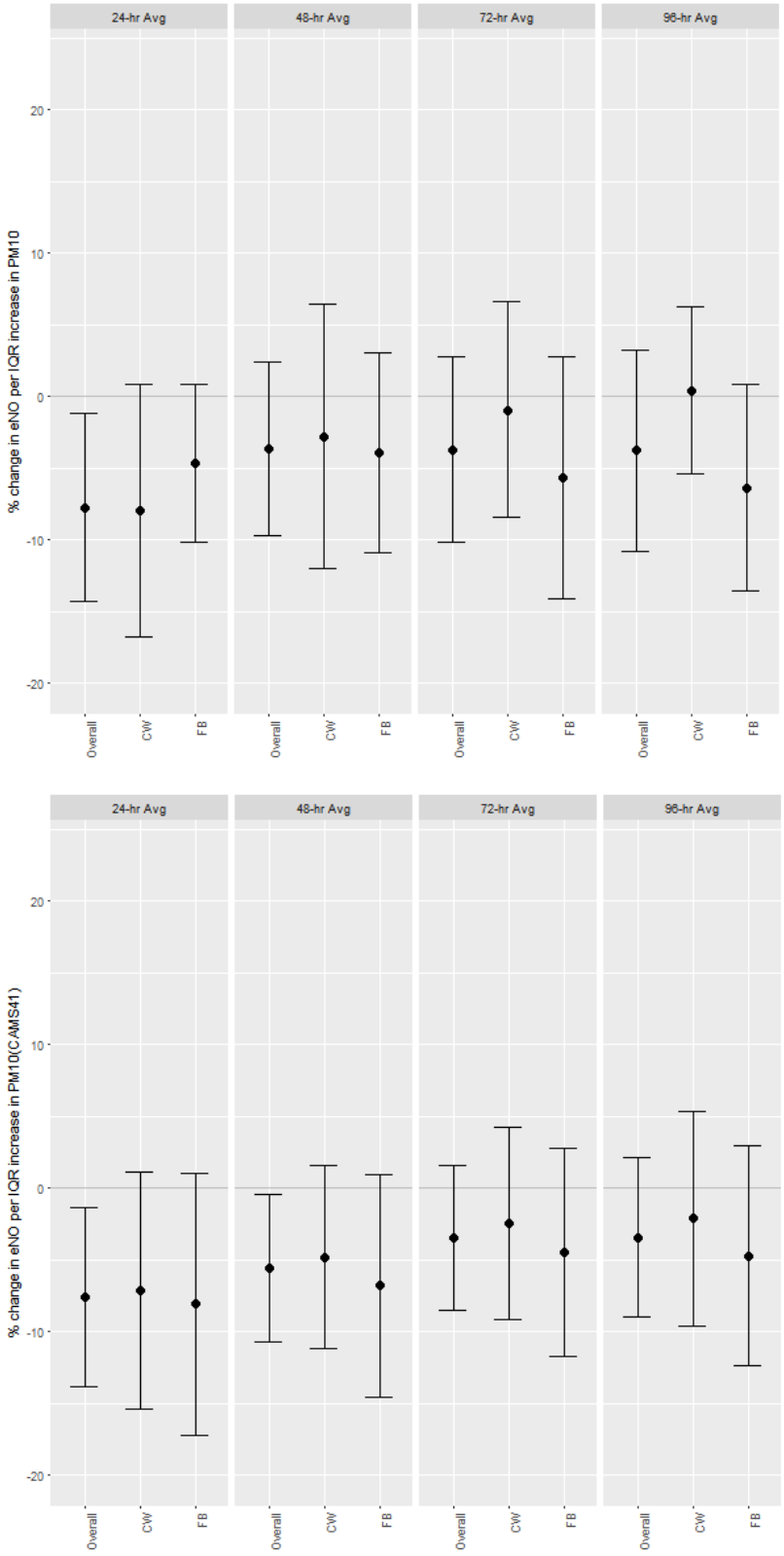

Figure D.9. Overall and school-specific associations between eNO and PM_{10} metrics.

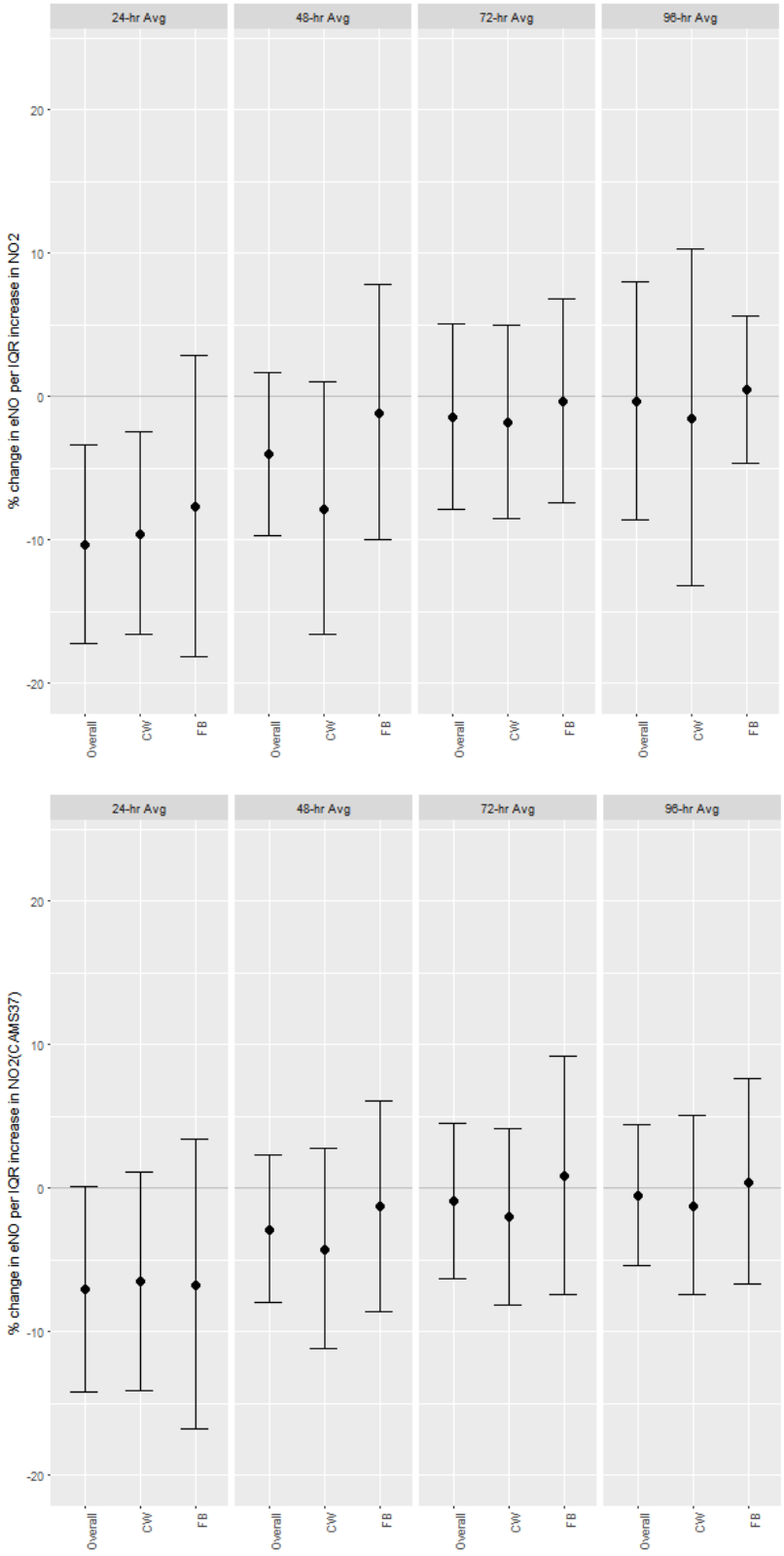

Figure D.10. Overall and school-specific associations between eNO and NO_2 metrics.

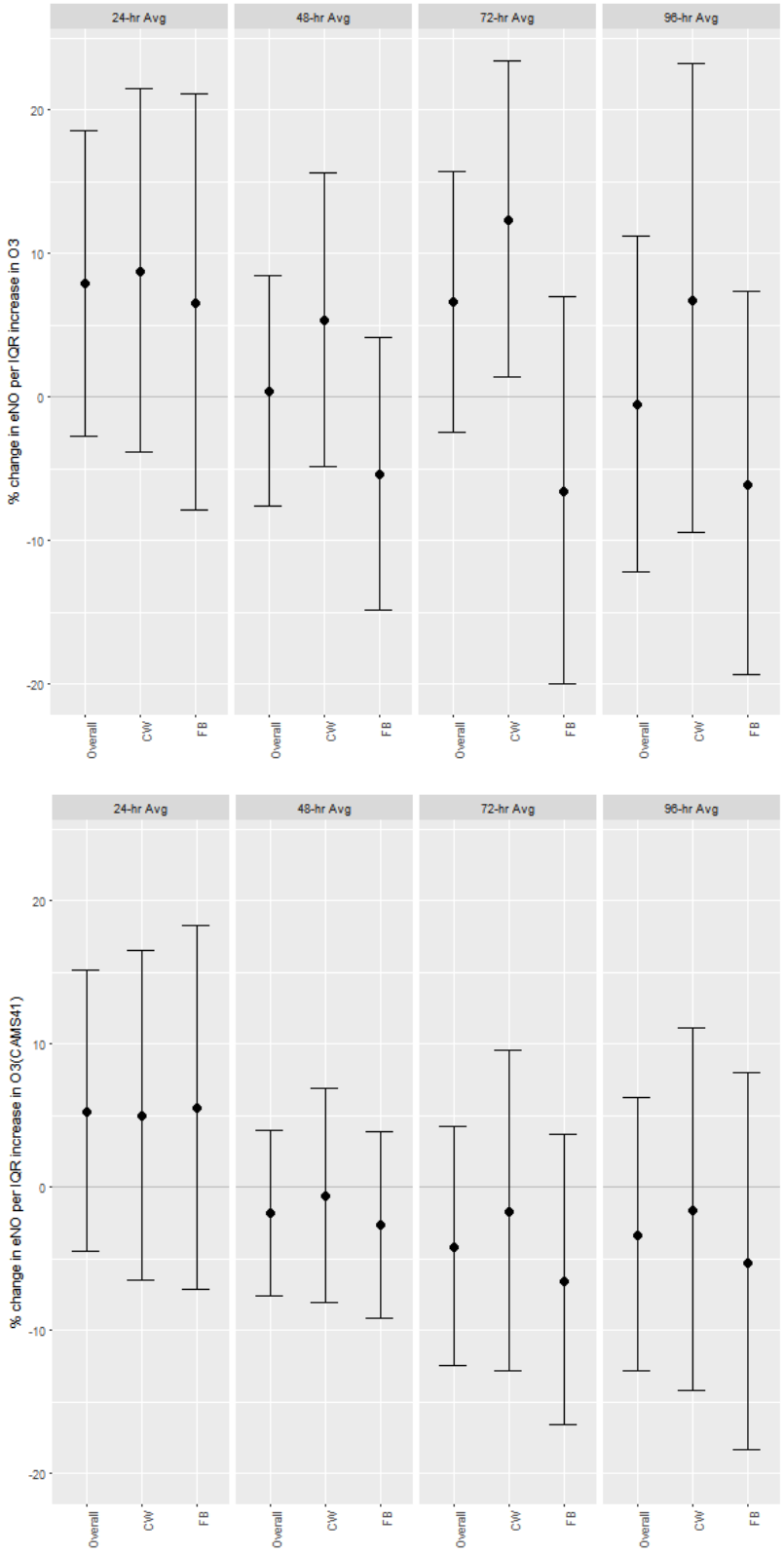

Figure D.11. Overall and school-specific associations between eNO and O_3 metrics.

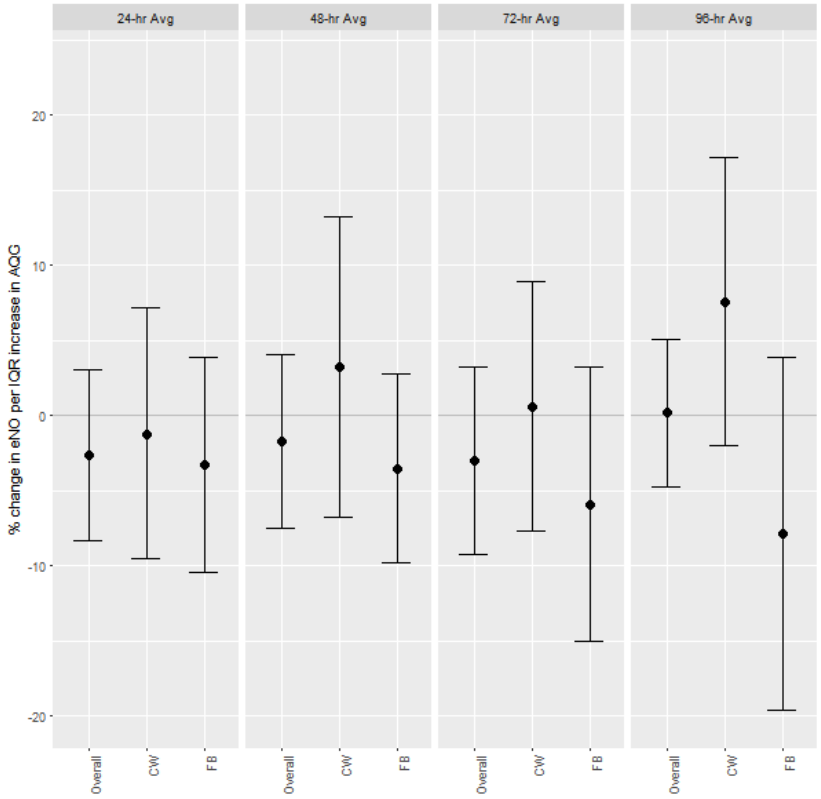

Figure D.12. Overall and school-specific associations between eNO and AQG metrics.

Table D.11. Percent Change in eNO per IQR Increase in 72-Hour Outdoor O_3 Concentrations from Models Stratified by Specific Subject Characteristics

Factor	% change in eNO per IQR	95% CI lower	95% CI upper	*p*-value	Interaction *p*-value
Father with Asthma					
Yes	26.05	10.27	42.09	**0.0013**	**0.0047**
No	-0.57	10.59	9.56	0.9123	
Caretaker Education					
Less than or Equal to High School	15.88	3.55	28.37	**0.0119**	**0.0346**
Greater than High School	-1.40	12.79	10.13	0.8112	
Health Insurance Coverage					
Medicaid	19.31	6.17	32.63	**0.0041**	**0.0110**
Private	-2.81	14.65	9.18	0.6446	

Models Predicting FVC

As with eNO findings, the associations between FVC and pollutants were generally very weak and nonsignificant (Table D.12). However, significant associations were observed for 24-hour PM concentrations and decreased lung function. We observed negative associations between FVC and 24-hour ambient PM_{10} concentrations (*p*-values = 0.0488). The 24-hour PM concentrations (both $PM_{2.5}$ and PM_{10}) measured outside the Coldwell site were significantly associated with decreased levels of lung function—a 4.24 decrease in FVC (95 percent CI: -8.23, -0.24) for $PM_{2.5}$, and 5.84 decrease in FVC (95 percent CI: -10.23, -1.45) for PM_{10}.

We explored effect modifications by significant factors, focusing on FVC and 24-hour outdoor PM concentrations (Table D.13). Health insurance and cooking fuel were both significant effect modifiers of FVC-PM associations. Subjects with Medicaid insurance showed more decreases in FVC than subjects with private insurance: -6.06 (95 percent CI: -10.74, -1.37) for $PM_{2.5}$, -8.96 (95 percent CI: -15.27, -2.64) for $PM_{10.}$ Cooking fuel effect was significant, with subjects using gas for cooking showing a stronger association between FVC-PM_{10} (-5.30 [95 percent CI: -9.62, -0.97] change in FVC per IQR) than subjects who used an electric cooking system. The interaction with cooking factor was also significant for the association between FVC and AQG measures. The category of a father with asthma had an impact on the association between FVC and NO_2, although there was no significant association in the previous model of FVC–NO_2.

Table D.12. Overall and School-Specific Associations between FVC and Pollutant Metrics

Pollutant		Site	IQR	Change in FVC per IQR	95% CI lower	95% CI upper	*p*-value
$PM_{2.5}$	24 hr	Overall	6.69	-0.04	-2.09	2.00	0.9670
		CW	6.25	-4.24	-8.23	-0.24	**0.0385**
		FB	7.62	1.53	-1.14	4.20	0.2611
	24 hr (CAMS41)	Overall	7.61	-2.57	-5.34	0.21	0.0704
		CW	6.99	-4.57	-7.77	-1.38	**0.0053**
		FB	7.62	0.63	-3.32	4.58	0.7563
	48 hr	Overall	5.87	0.20	-2.07	2.47	0.8622
		CW	5.00	-3.34	-7.65	0.97	0.1292
		FB	8.07	1.86	-1.70	5.43	0.3058
	72 hr	Overall	7.08	0.19	-3.23	3.62	0.9117
		CW	3.66	-2.86	-6.29	0.57	0.1037
		FB	5.44	2.07	-1.18	5.32	0.2120
	96 hr	Overall	5.50	-0.25	-3.38	2.87	0.8738
		CW	4.15	-2.72	-6.78	1.34	0.1906
		FB	5.10	1.76	-2.15	5.67	0.3789
PM_{10}	24 hr	Overall	30.82	-1.81	-5.17	1.55	0.2922
		CW	27.29	-5.84	-10.23	-1.45	**0.0096**
		FB	20.65	1.10	-1.75	3.94	0.4506
	24 hr (CAMS41)	Overall	48.08	-3.32	-6.62	-0.03	**0.0488**
		CW	46.81	-7.18	-11.42	-2.94	**0.0010**
		FB	48.80	1.56	-3.27	6.39	0.5274
	48 hr	Overall	22.86	-0.96	-4.11	2.20	0.5525
		CW	20.96	-3.94	-8.56	0.67	0.0951
		FB	23.04	0.56	-3.08	4.21	0.7623
	72 hr	Overall	19.50	-0.76	-3.89	2.38	0.6362
		CW	15.13	-2.92	-6.74	0.89	0.1344
		FB	20.53	1.02	-3.00	5.03	0.6197
	96 hr	Overall	16.86	-1.00	-4.24	2.24	0.5462
		CW	10.42	-1.63	-4.46	1.20	0.2589
		FB	12.17	0.43	-2.83	3.69	0.7948

NO_2	24 hr	Overall	8.14	0.16	-2.92	3.24	0.9190
		CW	6.81	-1.42	-4.59	1.75	0.3808
		FB	7.56	2.88	-1.45	7.21	0.1930
	24 hr (CAMS37)	Overall	11.74	-2.11	-5.50	1.28	0.2229
		CW	10.18	-3.26	-6.75	0.23	0.0684
		FB	12.15	0.25	-4.55	5.04	0.9197
	48 hr	Overall	4.69	0.11	-2.33	2.54	0.9325
		CW	5.13	-1.37	-4.83	2.10	0.4403
		FB	5.26	2.05	-1.93	6.04	0.3132
	72 hr	Overall	5.02	-0.16	-3.01	2.69	0.9111
		CW	3.68	-1.25	-3.90	1.40	0.3547
		FB	3.90	1.59	-1.74	4.91	0.3501
	96 hr	Overall	5.85	-0.97	-4.48	2.54	0.5885
		CW	6.11	-2.31	-6.69	2.08	0.3036
		FB	2.40	0.51	-1.73	2.75	0.6551
O_3	72 hr avg Max. 8 hr	Overall	9.61	2.54	-1.06	6.15	0.1675
		CW	11.31	2.56	-2.65	7.77	0.3361
		FB	5.74	1.85	-1.31	5.01	0.2523
	24 hr	Overall	13.46	-0.06	-4.30	4.18	0.9788
		CW	13.87	0.39	-4.61	5.39	0.8780
		FB	12.99	-0.73	-6.15	4.70	0.7933
	48 hr	Overall	8.06	0.06	-3.27	3.38	0.9734
		CW	8.33	0.38	-3.69	4.45	0.8547
		FB	6.56	-0.31	-3.91	3.30	0.8674
	72 hr	Overall	9.75	1.72	-2.26	5.69	0.3973
		CW	10.68	2.64	-2.15	7.43	0.2811
		FB	8.16	0.04	-4.93	5.00	0.9884
	72 hr (CAMS41)	Overall	7.24	0.20	-3.40	3.80	0.9117
		CW	7.76	0.88	-3.71	5.47	0.7078
		FB	6.23	-0.57	-4.74	3.60	0.7902
	96 hr	Overall	9.82	0.30	-4.14	4.73	0.8960
		CW	9.97	1.00	-4.48	6.48	0.7208
		FB	8.68	-0.42	-5.38	4.54	0.8673
AQG	24 hr	Overall	28.36	0.18	-2.32	2.68	0.8889
		CW	21.24	-2.63	-6.23	0.97	0.1527
		FB	31.10	1.70	-1.50	4.90	0.3000
	48 hr	Overall	22.45	0.17	-2.37	2.70	0.8980
		CW	21.65	-2.02	-6.49	2.45	0.3768
		FB	20.87	1.03	-1.76	3.82	0.4696
	72 hr	Overall	20.49	0.06	-2.58	2.70	0.9667
		CW	15.96	-2.10	-5.86	1.67	0.2761

		FB	23.92	1.59	-2.22	5.40	0.4136
	96 hr	Overall	15.38	-0.05	-2.17	2.06	0.9606
		CW	19.45	-1.16	-5.64	3.32	0.6123
		FB	26.51	0.94	-4.04	5.93	0.7114

Values less than 0.05 are marked in bold

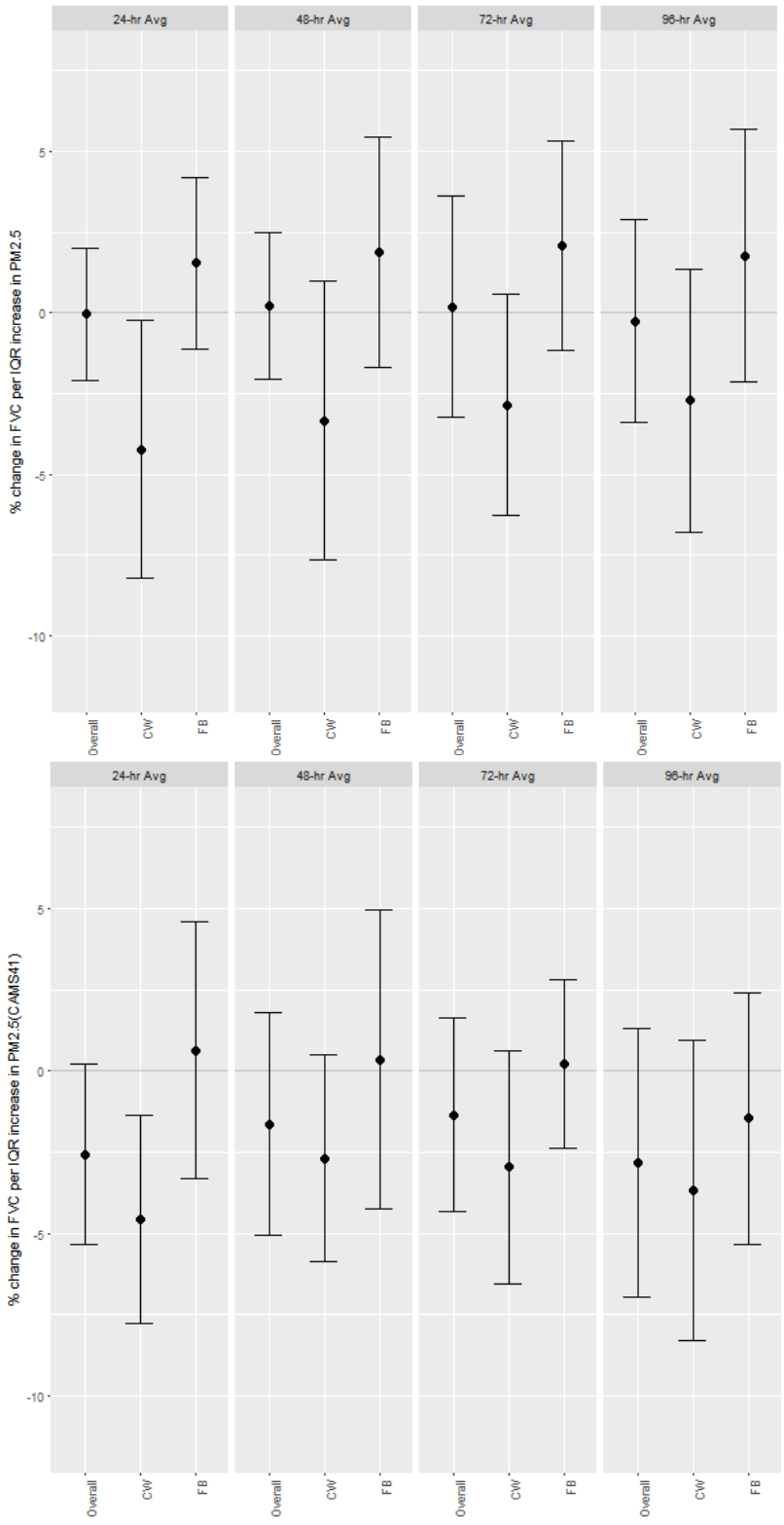

Figure D.13. Overall and school-specific associations between FVC and $PM_{2.5}$ metrics.

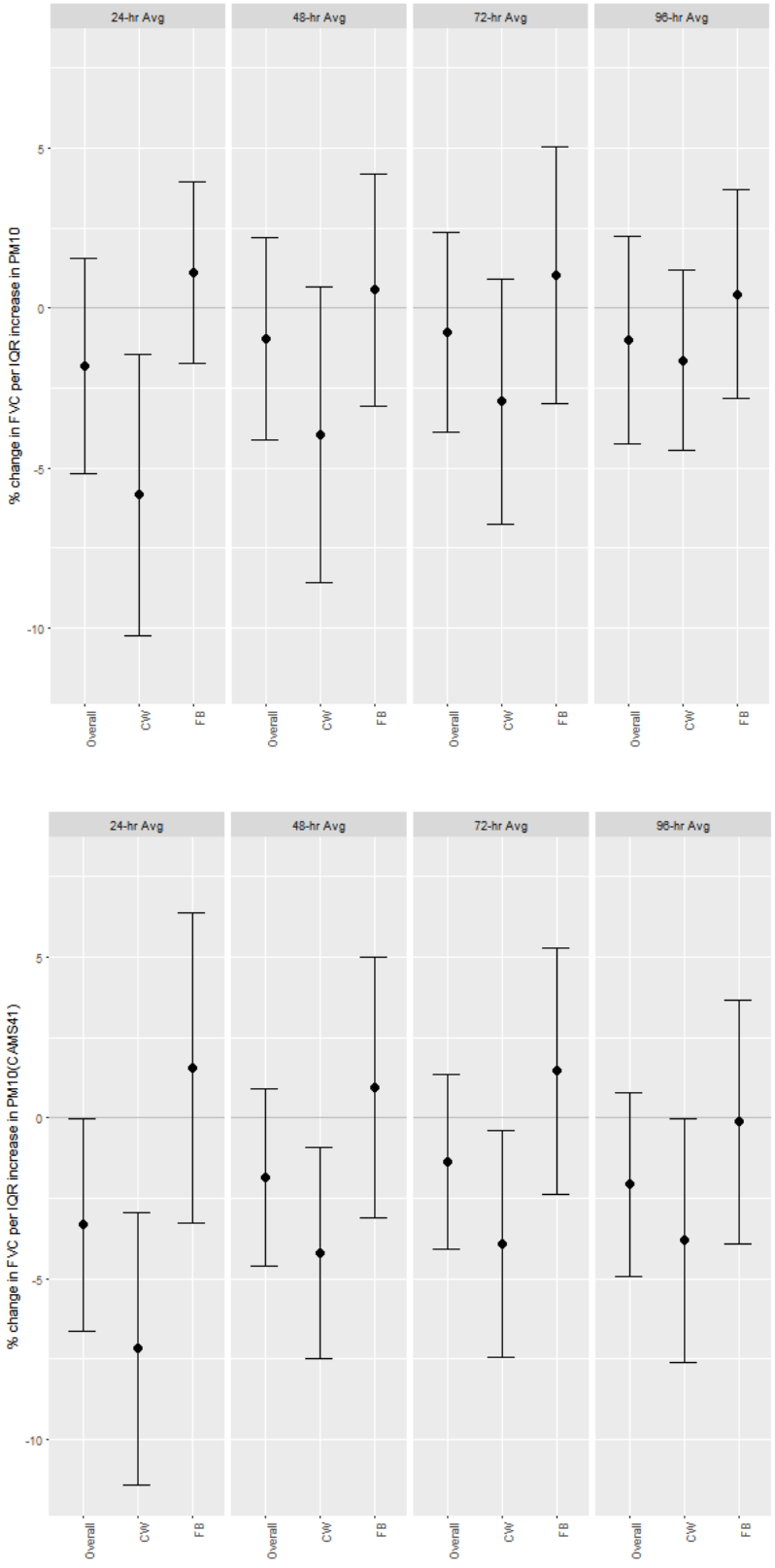

Figure D.14. Overall and school-specific associations between FVC and PM_{10} metrics.

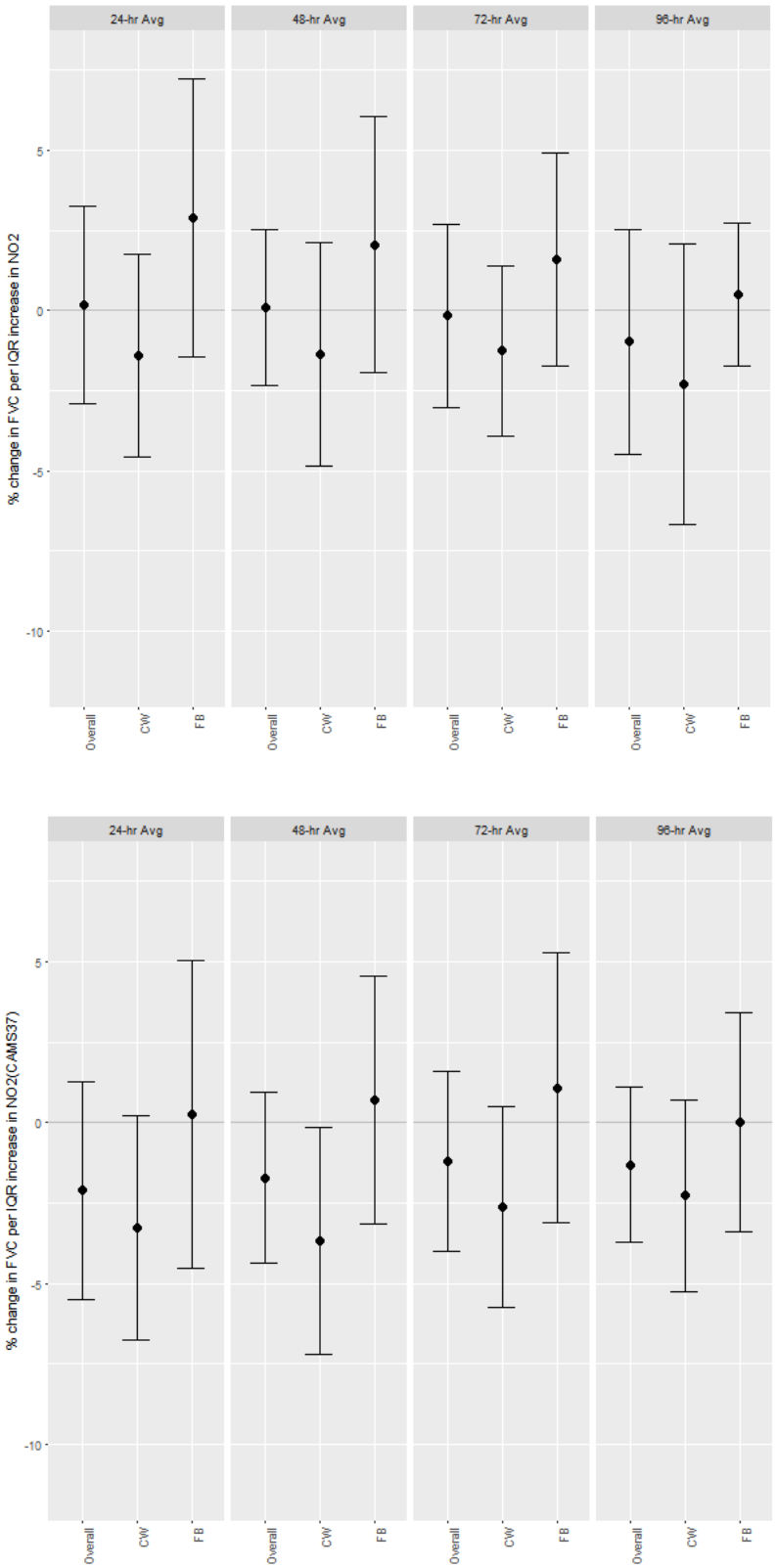

Figure D.15. Overall and school-specific associations between FVC and NO_2 metrics.

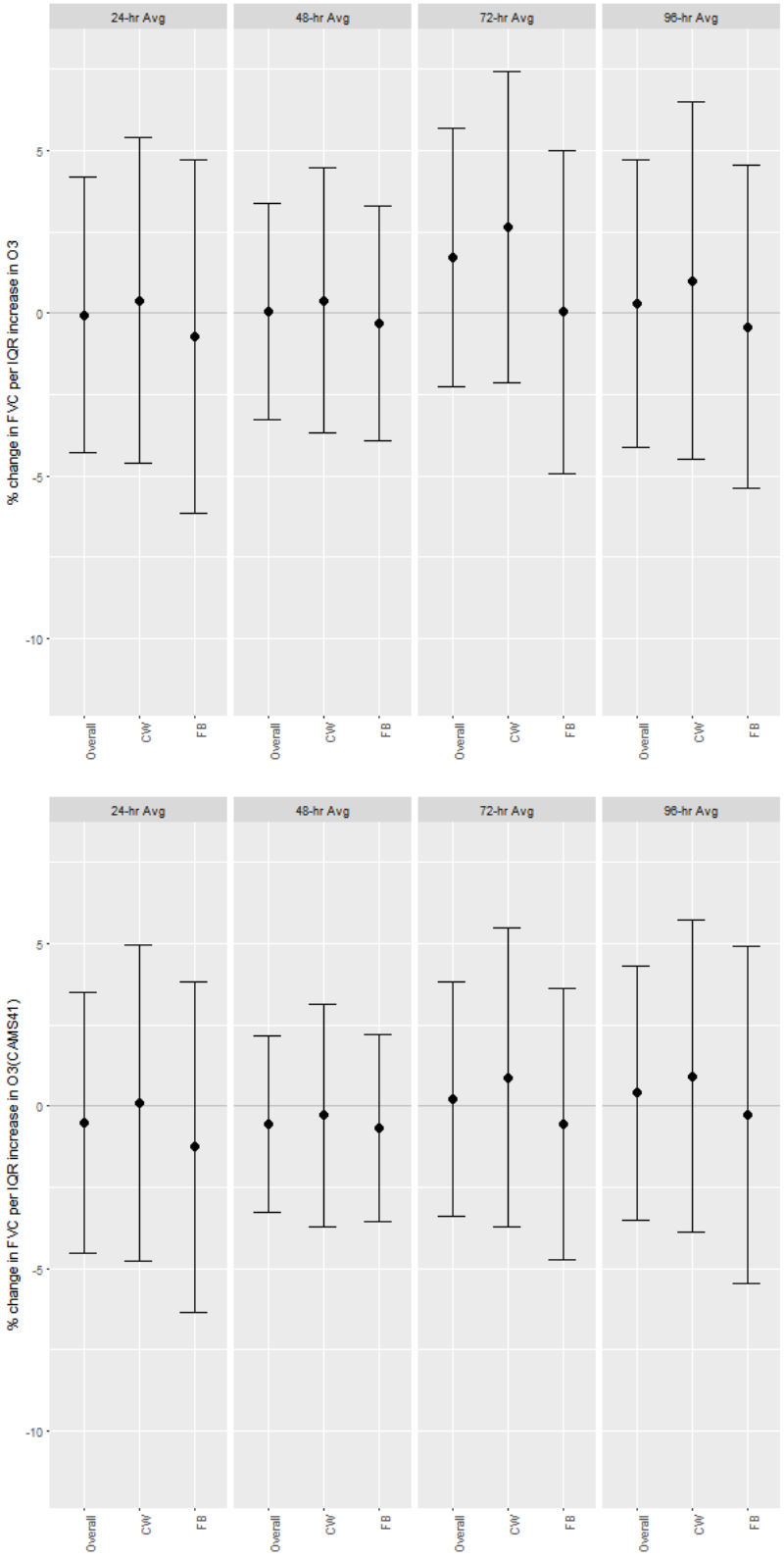

Figure D.16. Overall and school-specific associations between FVC and O_3 metrics.

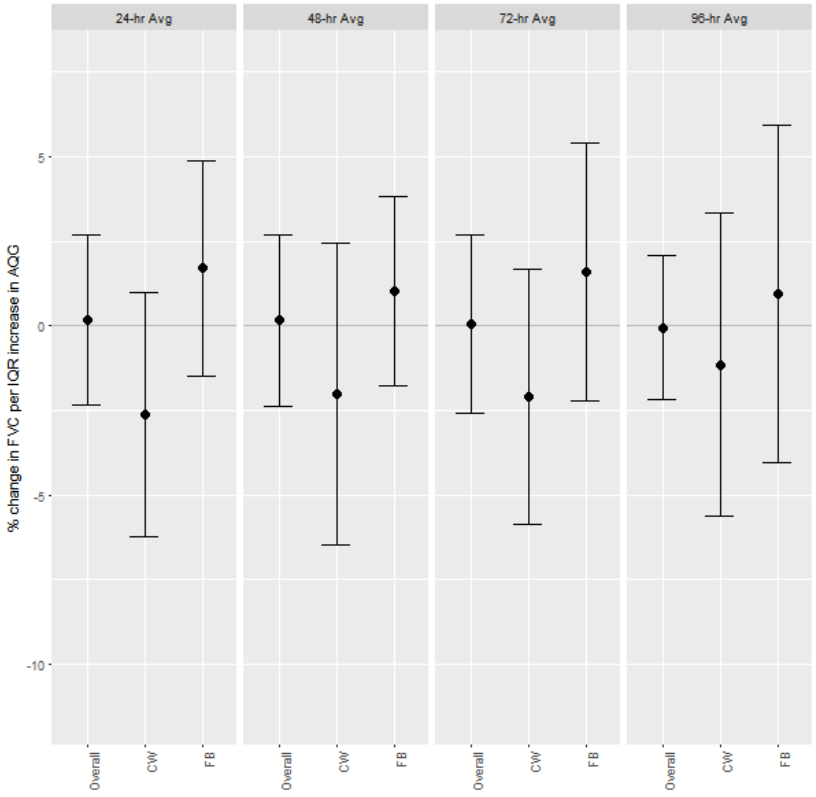

Figure D.17. Overall and school-specific associations between FVC and AQG metrics.

Table D.13. Change in FVC per IQR Increase in 24-Hr Outdoor Pollutant Concentrations from Models Stratified by Specific Subject Characteristics

Pollutant	Factor	Change in FVC per IQR	95% CI lower	95% CI upper	*p*-value	Interaction *p*-value
$PM_{2.5}$	*Health Insurance Coverage*					
	Medicaid	-6.06	-10.74	-1.37	**0.0117**	**0.0203**
	Private	1.45	-0.89	3.79	0.2263	
	Cooking Fuel					
	Electric	2.35	-0.40	5.11	0.0954	**0.0430**
	Gas	-2.87	-5.87	0.13	**0.0612**	
PM_{10}	*Health Insurance Coverage*					
	Medicaid	-8.96	-15.27	-2.64	**0.0057**	**0.0190**
	Private	0.71	-3.27	4.69	0.7273	
	Cooking Fuel					
	Electric	2.63	-2.19	7.46	0.2851	**0.0266**
	Gas	-5.30	-9.62	-0.97	**0.0169**	
NO_2	*Father with Asthma*					
	Yes	-5.92	-11.48	-0.36	**0.0375**	**0.0383**
	No	2.27	-1.17	5.71	0.1973	
AQG	*Cooking Fuel*					
	Electric	3.36	-0.03	6.75	0.0529	**0.0276**
	Gas	-3.29	-6.83	0.25	0.0696	

Models Predicting FEV1

As with FVC findings, significant associations were observed for 24-hour PM concentrations and decreased FEV1 (Table D.14). We observed negative associations between FEV1 and 24-hour ambient PM_{10} concentrations (-3.46 [95 percent CI: -6.80, -0.11], *p*-value = 0.0435). The 24-hour PM concentrations (both $PM_{2.5}$ and PM_{10}) measured outside the Coldwell site were significantly associated with decreased levels of lung function—a 4.58 decrease in FEV1 (95 percent CI: -8.71, -0.44) for $PM_{2.5}$, and a 6.77 decrease in FEV1 (95 percent CI: -11.27, -2.28) for PM_{10}. We also found significantly negative associations between FEV1 and 24-hour outdoor AQG at Coldwell (-3.92 [95 percent CI: -7.72, -0.13]).

We examined effect modifications by factors, focusing on significant relationships between FEV1 and 24-hour outdoor pollutants ($PM_{2.5}$, PM_{10}, and AQG). Health insurance was a significant effect modifier for all three pollutant metrics, showing more decreases in FVC for subjects with Medicaid insurance than for subjects with private insurance (-7.03 [95 percent CI: -12.13, -2.47] for $PM_{2.5}$; -9.86 [95 percent CI: -16.32, -3.40] for PM_{10}; -7.67 [95 percent CI: -13.38, -1.96] for AQG). The cooking fuel effect was significant, with subjects using gas for cooking showing stronger associations of PM_{10} and AQG with FEV1 (-5.65 [95 percent CI: -10.08, -1.22] for PM_{10}; -4.42]95 percent CI: -8.17, -0.67] for AQG) than subjects using an electric cooking system. The medication factor of taking IC was also a significant effect modifier on the negative association between FEV1 and PM_{10}. The subjects who did not take IC had more decreased lung function per IQR increase in PM_{10} (-6.96 [95 percent CI: -12.24, -1.68]) than subjects who did take the medication (Table D.15).

Table D.14. Overall and School-Specific Associations between FEV1 and Pollutant Metrics

Pollutant		Site	IQR	Change in FEV1 per IQR	95% CI lower	95% CI upper	*p*-value
$PM_{2.5}$	24 hr	Overall	6.69	-0.78	-2.88	1.32	0.4657
		CW	6.25	-4.58	-8.71	-0.44	**0.0309**
		FB	7.62	0.52	-2.22	3.26	0.7096
	24 hr (CAMS41)	Overall	7.61	-2.18	-5.08	0.71	0.1405
		CW	6.99	-3.74	-7.10	-0.37	**0.0304**
		FB	7.62	0.29	-3.87	4.46	0.8905
	48 hr	Overall	5.87	-0.26	-2.58	2.06	0.8278
		CW	5.00	-3.48	-7.87	0.91	0.1213
		FB	8.07	1.08	-2.54	4.70	0.5597
	72 hr	Overall	7.08	0.40	-3.12	3.93	0.8227
		CW	3.66	-1.82	-5.32	1.69	0.3101
		FB	5.44	1.63	-1.71	4.97	0.3392
	96 hr	Overall	5.50	0.07	-3.18	3.33	0.9650
		CW	4.15	-1.36	-5.56	2.85	0.5285
		FB	5.10	1.19	-2.88	5.25	0.5682
PM_{10}	24 hr	Overall	30.82	-2.33	-5.76	1.09	0.1830
		CW	27.29	-6.77	-11.27	-2.28	**0.0033**
		FB	20.65	0.93	-1.95	3.81	0.5253
	24 hr (CAMS41)	Overall	48.08	-3.46	-6.80	-0.11	**0.0435**
		CW	46.81	-7.63	-11.94	-3.33	**0.0006**
		FB	48.80	1.77	-3.11	6.65	0.4781
	48 hr	Overall	22.86	-0.92	-4.12	2.29	0.5755
		CW	20.96	-4.49	-9.21	0.23	0.0632
		FB	23.04	0.87	-2.82	4.56	0.6448
	72 hr	Overall	19.50	0.12	-3.10	3.35	0.9404
		CW	15.13	-2.28	-6.18	1.62	0.2531
		FB	20.53	2.03	-2.12	6.18	0.3378
	96 hr	Overall	16.86	0.01	-3.35	3.37	0.9954
		CW	10.42	-1.17	-4.08	1.74	0.4307
		FB	12.17	1.39	-2.01	4.79	0.4243
NO_2	24 hr	Overall	8.14	-0.91	-4.14	2.33	0.5833
		CW	6.81	-1.70	-5.03	1.64	0.3193
		FB	7.56	0.82	-3.79	5.44	0.7272
	24 hr (CAMS37)	Overall	11.74	-1.69	-5.19	1.81	0.3451
		CW	10.18	-2.15	-5.79	1.48	0.2463
		FB	12.15	-0.60	-5.57	4.37	0.8142
	48 hr	Overall	4.69	-0.35	-2.92	2.21	0.7866
		CW	5.13	-1.41	-5.13	2.31	0.4571
		FB	5.26	0.85	-3.32	5.02	0.6896

	72 hr	Overall	5.02	0.18	-2.81	3.16	0.9082
		CW	3.68	-0.35	-3.18	2.48	0.8069
		FB	3.90	0.81	-2.64	4.27	0.6439
	96 hr	Overall	5.85	-1.04	-4.73	2.64	0.5784
		CW	6.11	-1.41	-6.11	3.28	0.5555
		FB	2.40	-0.22	-2.56	2.12	0.8530
O_3	72 hr avg Max. 8 hr	Overall	9.61	0.99	-2.74	4.72	0.6033
		CW	11.31	-0.33	-5.73	5.06	0.9035
		FB	5.74	1.77	-1.55	5.09	0.2974
	24 hr	Overall	13.46	-1.49	-6.09	3.10	0.5243
		CW	13.87	-2.61	-8.02	2.80	0.3453
		FB	12.99	0.19	-5.78	6.17	0.9494
	48 hr	Overall	8.06	-0.97	-4.51	2.57	0.5923
		CW	8.33	-2.19	-6.57	2.18	0.3270
		FB	6.56	0.56	-3.40	4.51	0.7829
	72 hr	Overall	9.75	0.72	-3.45	4.90	0.7353
		CW	10.68	0.32	-4.73	5.37	0.9001
		FB	8.16	1.52	-3.93	6.96	0.5857
	72 hr (CAMS41)	Overall	7.24	-1.02	-4.79	2.75	0.5958
		CW	7.76	-2.28	-7.12	2.55	0.3557
		FB	6.23	0.45	-3.95	4.86	0.8408
	96 hr	Overall	9.82	0.38	-4.42	5.18	0.8761
		CW	9.97	-0.83	-6.90	5.24	0.7884
		FB	8.68	1.47	-3.95	6.88	0.5952
AQG	24 hr	Overall	28.36	-0.97	-3.60	1.65	0.4676
		CW	21.24	-3.92	-7.72	-0.13	**0.0437**
		FB	31.10	0.59	-2.74	3.92	0.7286
	48 hr	Overall	22.45	-0.50	-3.16	2.17	0.7148
		CW	21.65	-3.36	-8.02	1.31	0.1593
		FB	20.87	0.68	-2.23	3.59	0.6469
	72 hr	Overall	20.49	0.20	-2.60	3.00	0.8881
		CW	15.96	-1.99	-5.91	1.94	0.3223
		FB	23.92	1.82	-2.24	5.88	0.3803
	96 hr	Overall	15.38	0.12	-2.12	2.35	0.9198
		CW	19.45	-0.61	-5.25	4.02	0.7958
		FB	26.51	0.95	-4.36	6.26	0.7259

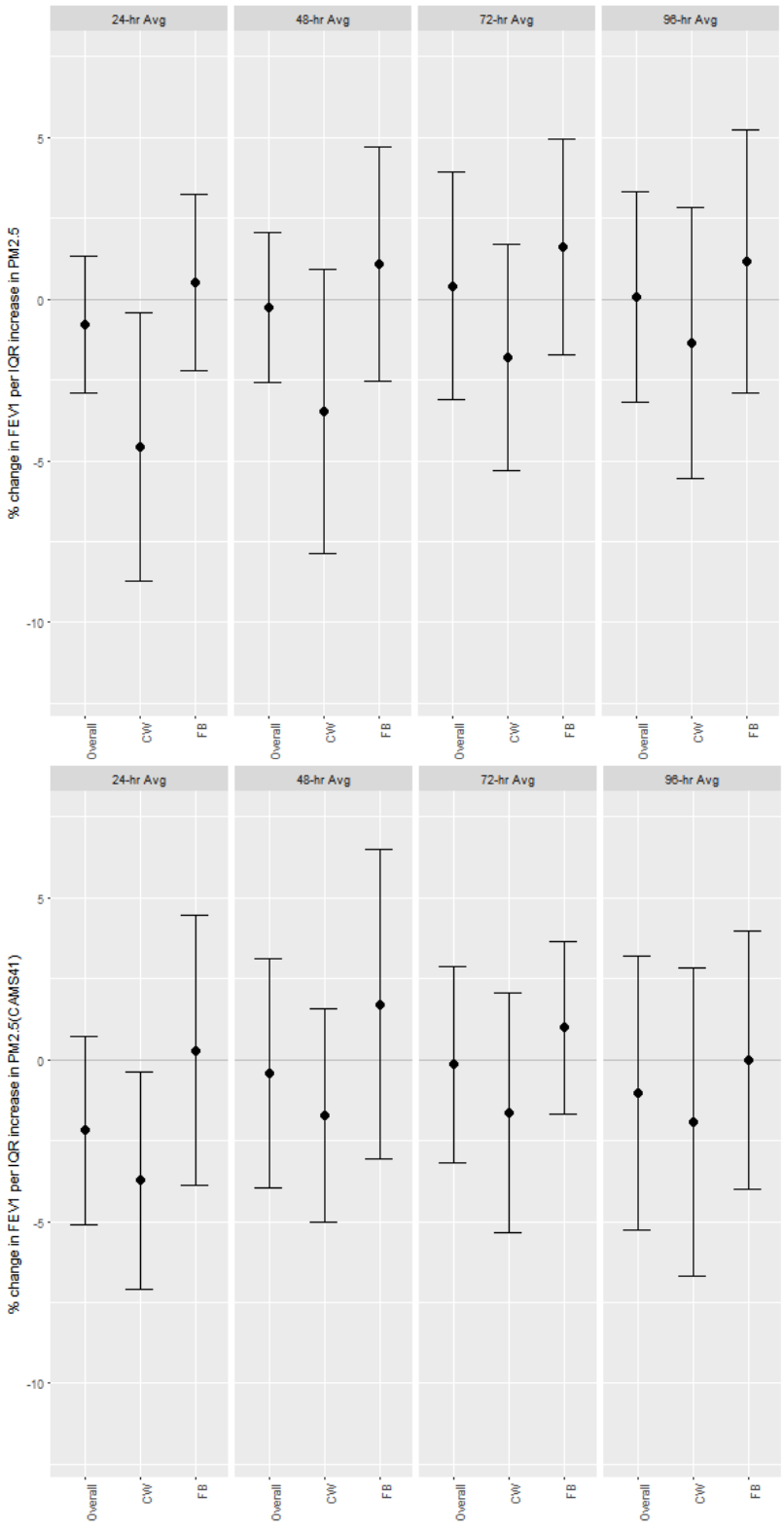

Figure D.18. Overall and school-specific associations between FEV1 and $PM_{2.5}$ metrics.

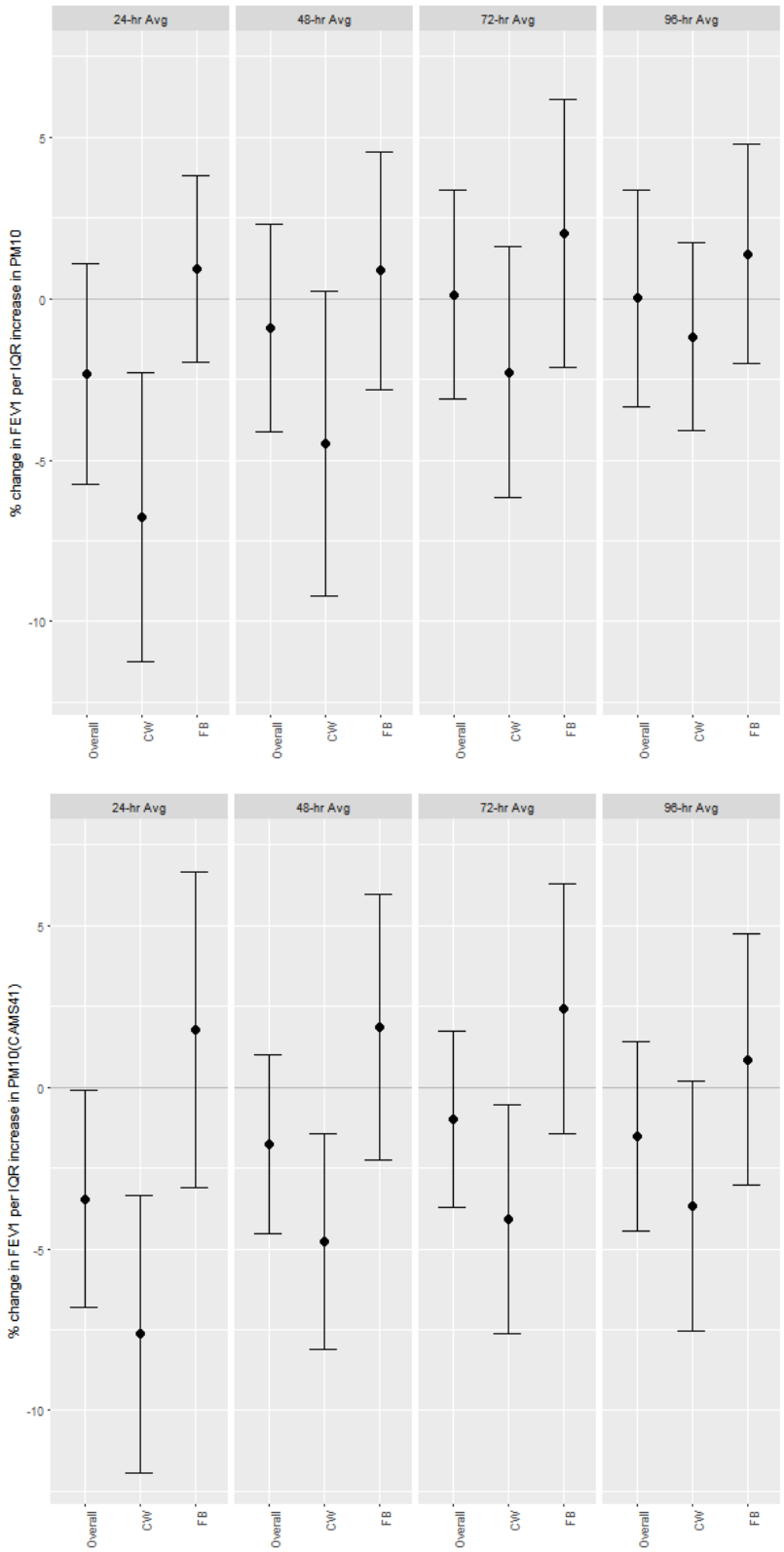

Figure D.19. Overall and school-specific associations between FEV1 and PM_{10} metrics.

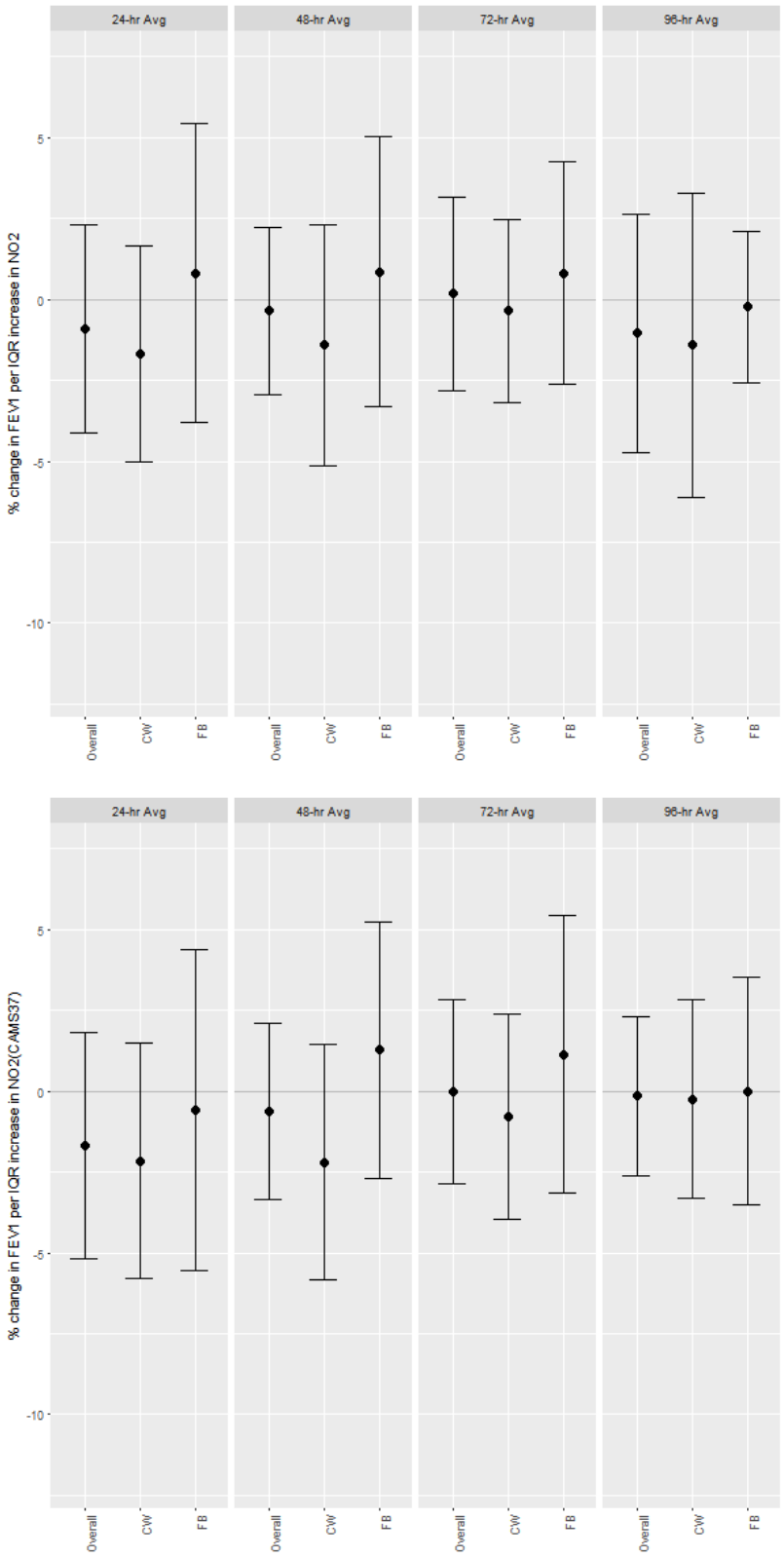

Figure D.20. Overall and school-specific associations between FEV1 and NO_2 metrics.

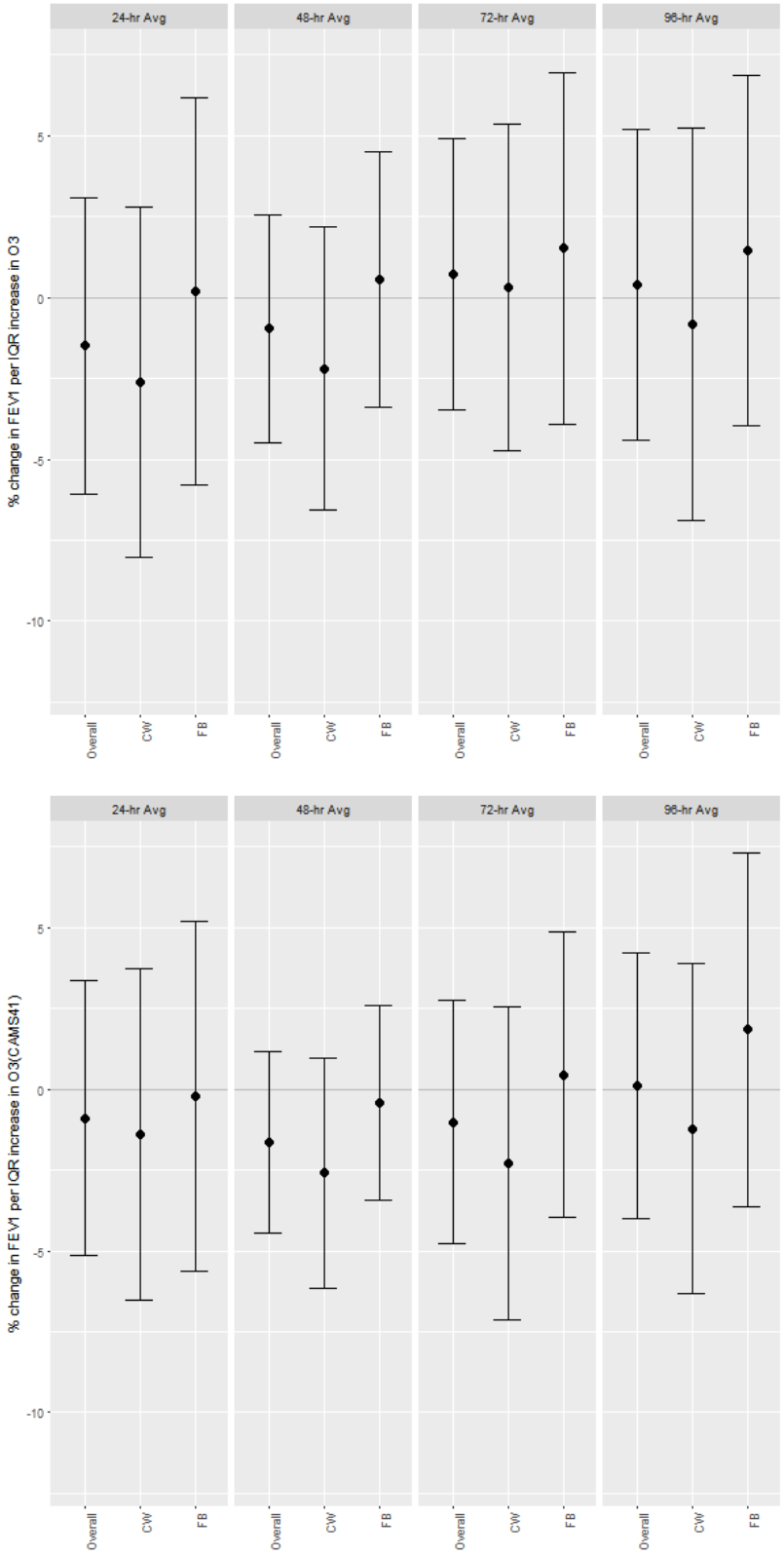

Figure D.21. Overall and school-specific associations between FEV1 and O_3 metrics.

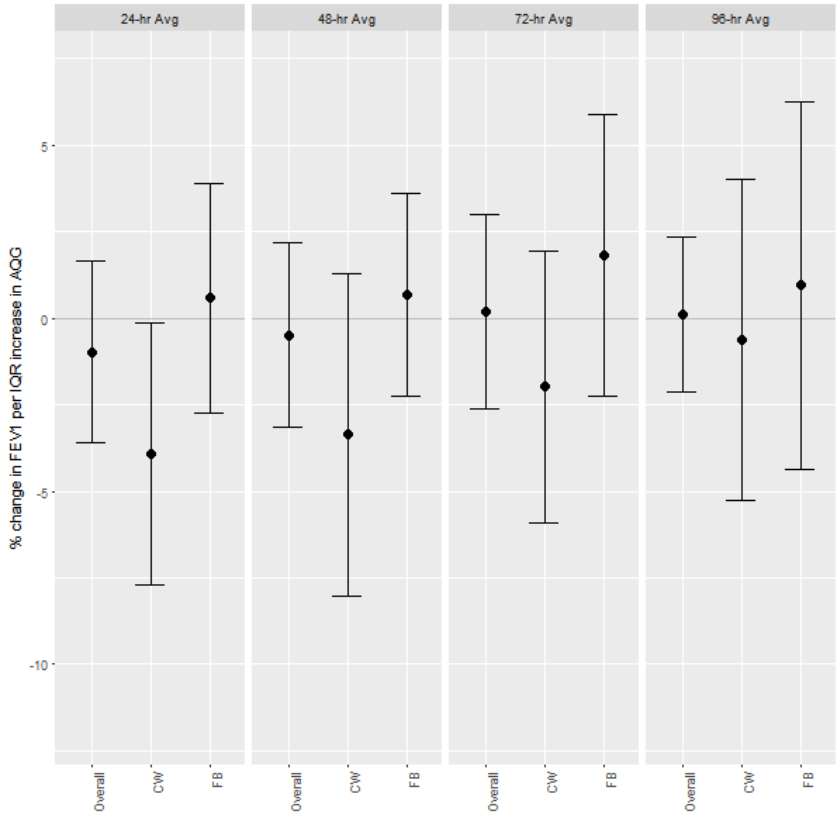

Figure D.22. Overall and school-specific associations between FEV1 and AQG metrics.

Table D.15. Change in FEV1 per IQR Increase in 24-Hour Outdoor Pollutant Concentrations from Models Stratified by Specific Subject Characteristics

Pollutant	Factor	Change in FEV1 per IQR	95% CI lower	95% CI upper	*p*-value	Interaction *p*-value
$PM_{2.5}$	*Health Insurance Coverage*					
	Medicaid	-7.30	-12.13	-2.47	**0.0033**	**0.0109**
	Private	0.74	-1.65	3.14	0.5441	
PM_{10}	*Health Insurance Coverage*					
	Medicaid	-9.86	-16.32	-3.40	**0.0030**	**0.0117**
	Private	0.08	-3.96	4.13	0.9672	
	Cooking Fuel					
	Electric	1.82	-3.08	6.72	0.4667	**0.0298**
	Gas	-5.65	-10.08	-1.22	**0.0129**	
	IC					
	Yes	0.45	-3.74	4.65	0.8319	**0.0337**
	No	-6.96	-12.24	-1.68	**0.0102**	
AQG	*Health Insurance Coverage*					
	Medicaid	-7.67	-13.38	-1.96	**0.0090**	**0.0280**
	Private	0.71	-2.28	3.70	0.6420	
	Cooking Fuel					
	Electric	2.08	-1.45	5.62	0.2483	**0.0342**
	Gas	-4.42	-8.17	-0.67	**0.0216**	

Models Predicting Veggie Meter Data

As shown in Table D.16, significant associations were observed for 24- and 48-hour outdoor pollutant ($PM_{2.5}$, NO, and AQG) concentrations and increased F/V intake. Those positive associations were significant for the pollutant metrics measured outside the Bliss school. However, 96-hour averaged ambient PM concentrations were negatively associated with skin carotenoid levels in F/V data (-11.27 [95 percent CI: -21.83, -0.71] for ambient $PM_{2.5}$; -10.39 [95 percent CI: -18.34, -2.45] for ambient PM_{10}). The 96-hour ambient PM concentrations (both $PM_{2.5}$ and PM_{10}) measured outside the Bliss site were significantly associated with decreased skin carotenoid levels—a 14.44 decrease in F/V intake (95 percent CI: -25.53, -3.34) for $PM_{2.5}$, and a 13.48 decrease in F/V intake (95 percent CI: -23.31, -3.65) for PM_{10}.

The longitudinal associations from linear mixed effect modeling coincided with correlation analyses between F/V intake and PM concentrations. Skin carotenoid levels were correlated with 96-hour averaged $PM_{2.5}$ (r = -0.150), PM_{10} (r = -0.144), NO_2 (r = 0.192), and O_3 (r = -0.170). NO_2 was negatively correlated (p-value < 0.001) with the other pollutants—PM_{10} (r = -0.390), $PM_{2.5}$ (r = -0.266), and O_3 (r = -0.711). The epidemiologic associations between Veggie Meter outcomes and 96-hour NO_2 and O_3 were not significant.

Table D.16. Overall and School-Specific Associations between Veggie Meter Measurements and Pollutant Metrics

Pollutant		Site	IQR	Change in VM per IQR	95% CI lower	95% CI upper	*p*-value
$PM_{2.5}$	24 hr	Overall	6.62	6.86	0.82	12.90	**0.0271**
		CW	4.91	-1.58	-9.98	6.81	0.7118
		FB	8.35	13.08	4.12	22.05	**0.0047**
	48 hr	Overall	7.17	10.65	0.78	20.53	**0.0357**
		CW	4.13	-4.55	-16.30	7.19	0.4481
		FB	6.89	15.07	4.55	25.59	**0.0055**
	72 hr	Overall	7.06	7.19	-6.22	20.61	0.2946
		CW	3.11	-12.90	-24.96	-0.85	**0.0372**
		FB	5.73	18.43	4.90	31.95	**0.0082**
	96 hr	Overall	5.99	-2.84	-12.17	6.49	0.5516
		CW	4.07	-5.39	-16.67	5.89	0.3505
		FB	5.61	0.63	-11.80	13.06	0.9213
	96 hr (CAMS41)	Overall	6.16	-11.27	-21.83	-0.71	**0.0378**
		CW	5.22	-5.90	-16.09	4.29	0.2582
		FB	5.22	-14.44	-25.53	-3.34	**0.0115**
PM_{10}	24 hr	Overall	31.85	4.80	-5.12	14.71	0.3443
		CW	24.57	-1.61	-11.51	8.29	0.7500
		FB	21.12	7.90	-0.75	16.55	0.0749
	48 hr	Overall	21.70	6.31	-3.78	16.40	0.2217
		CW	19.05	-1.83	-14.63	10.97	0.7799
		FB	20.75	9.55	-1.03	20.13	0.0786
	72 hr	Overall	18.17	2.87	-7.65	13.39	0.5933
		CW	11.93	-5.74	-16.21	4.73	0.2838
		FB	20.63	9.54	-3.98	23.06	0.1682
	96 hr	Overall	18.14	-2.87	-12.42	6.67	0.5556
		CW	9.56	-3.65	-10.87	3.56	0.3222
		FB	16.57	0.75	-11.11	12.61	0.9020
	96 hr (CAMS41)	Overall	18.71	-10.39	-18.34	-2.45	**0.0111**
		CW	16.84	-5.56	-14.95	3.82	0.2469
		FB	16.54	-13.48	-23.31	-3.65	**0.0078**
NO_2	24 hr	Overall	8.61	9.84	0.20	19.48	**0.0469**
		CW	7.81	9.37	-1.27	20.01	0.0858
		FB	7.19	7.49	-5.50	20.48	0.2600
	48 hr	Overall	4.30	10.51	3.17	17.85	**0.0055**
		CW	4.76	11.59	-0.07	23.25	0.0530
		FB	3.46	8.48	0.37	16.59	**0.0418**
	72 hr	Overall	4.91	9.61	0.84	18.38	**0.0330**
		CW	2.76	5.56	-1.23	12.34	0.1102

		FB	1.32	2.51	-0.96	5.99	0.1583
	96 hr	Overall	5.50	8.01	-1.74	17.76	0.1091
		CW	4.96	7.65	-3.17	18.46	0.1675
		FB	1.67	2.17	-2.58	6.93	0.3716
	96 hr (CAMS37)	Overall	5.76	0.04	-5.66	5.73	0.9904
		CW	5.19	2.60	-4.22	9.41	0.4566
		FB	6.07	-3.87	-12.97	5.23	0.4058
O_3	72 hr avg MaxO3.8hr	Overall	8.49	-2.97	-12.99	7.04	0.5612
		CW	9.94	-10.08	-25.06	4.91	0.1894
		FB	6.64	1.68	-8.09	11.45	0.7367
	24 hr	Overall	16.11	-0.62	-16.57	15.33	0.9392
		CW	18.10	-8.04	-26.82	10.74	0.4026
		FB	12.61	12.28	-4.78	29.35	0.1600
	48 hr	Overall	8.59	-5.64	-16.13	4.84	0.2928
		CW	11.69	-14.09	-30.98	2.80	0.1037
		FB	7.16	1.77	-11.01	14.55	0.7860
	72 hr	Overall	9.46	0.35	-9.88	10.58	0.9463
		CW	12.32	1.13	-13.05	15.32	0.8757
		FB	8.37	-1.68	-18.77	15.40	0.8470
	96 hr	Overall	9.60	-11.21	-24.71	2.28	0.1049
		CW	8.57	-12.49	-26.44	1.47	0.0812
		FB	8.18	-5.51	-22.14	11.12	0.5170
	96 hr (CAMS41)	Overall	7.84	-9.05	-20.72	2.62	0.1302
		CW	7.50	-12.93	-26.22	0.35	0.0579
		FB	7.64	-2.89	-18.23	12.46	0.7127
AQG	24 hr	Overall	28.54	14.53	5.81	23.24	**0.0013**
		CW	22.62	3.64	-8.34	15.61	0.5527
		FB	29.15	18.59	8.56	28.63	**0.0004**
	48 hr	Overall	27.69	16.53	4.55	28.52	**0.0075**
		CW	20.28	1.69	-13.67	17.05	0.8297
		FB	20.03	14.85	5.53	24.18	**0.0021**
	72 hr	Overall	18.65	3.93	-5.54	13.40	0.4170
		CW	11.83	-7.28	-17.80	3.25	0.1770
		FB	25.54	13.70	-1.19	28.58	0.0729
	96 hr	Overall	14.72	0.47	-5.48	6.41	0.8779
		CW	15.09	-0.63	-10.55	9.28	0.9005
		FB	27.08	2.26	-12.43	16.94	0.7637

Models Predicting Physical Activity Data

In correlation analyses, moderate physical activity significantly correlated with previous 96-hour averages of $PM_{2.5}$ (r = -0.349), PM_{10} (r = -0.200), NO_2 (r = -0.265), and O_3 (r = 0.247). Table D.17 presents overall and school-specific associations between physical activity (moderate versus sedentary) and pollutant metrics using a GEE-based approach. Significant associations were observed for the 96-hour outdoor pollutant ($PM_{2.5}$, $PM_{10,}$ NO, and AQG) concentrations. Pollutant concentrations were negatively associated with moderate physical activity, whereas they were positively associated with sedentary activity. The 96-hour averaged ambient PM concentrations were also significantly associated with physical activity levels, showing consistent patterns of association with outdoor PM concentrations. The largest percent change in moderate physical activity levels per outdoor pollutant increases was observed in the association between 96-hour $PM_{2.5}$—a 3 percent decrease in moderate activity (95 percent CI: -5 percent, -2 percent). We found the same amount of percent change in sedentary activity (3 percent increase [95 percent CI: 2 percent, 5 percent]) as the IQR in PM increases.

Table D.17. Overall and School-Specific Associations between Physical Activity and Pollutant Metrics.

Pollutant		IQR	Moderate				Sedentary			
			Change in rate per IQR	95% CI lower	95% CI upper	*p*-value	Change in rate per IQR	95% CI lower	95% CI upper	*p*-value
$PM_{2.5}$	24 hr	4.91	0.00	-0.01	0.01	0.3647	-0.01	-0.02	0.00	0.0513
	48 hr	4.13	0.01	0.00	0.02	0.1795	-0.02	-0.03	0.00	**0.0138**
	72 hr	3.11	-0.02	-0.03	0.00	**0.0073**	0.01	0.00	0.03	**0.0183**
	96 hr	4.07	-0.03	-0.05	-0.02	**0.0000**	0.03	0.02	0.05	**0.0000**
	96 hr CAMS	5.22	-0.04	-0.06	-0.02	**0.0008**	0.04	0.02	0.06	**0.0007**
PM_{10}	24 hr	24.57	0.00	-0.02	0.01	0.4270	0.00	-0.01	0.01	0.9023
	48 hr	19.05	-0.01	-0.02	0.01	0.2929	0.00	-0.01	0.01	0.7353
	72 hr	11.93	-0.01	-0.02	0.00	**0.0054**	0.01	0.00	0.02	**0.0313**
	96 hr	9.56	-0.02	-0.02	-0.01	**0.0001**	0.02	0.01	0.02	**0.0003**
	96 hr CAMS	16.84	-0.03	-0.05	-0.01	**0.0016**	0.03	0.01	0.05	**0.0014**
NO_2	24 hr	7.81	0.00	-0.02	0.01	0.4888	0.00	-0.01	0.01	0.4235
	48 hr	4.76	0.00	-0.01	0.01	0.6264	0.00	-0.01	0.01	0.5742
	72 hr	2.76	-0.01	-0.01	0.00	0.0983	0.01	0.00	0.01	0.0745
	96 hr	4.96	-0.01	-0.03	0.00	**0.0363**	0.02	0.00	0.03	**0.0193**
	96 hr CAMS	5.19	-0.01	-0.02	0.00	**0.0397**	0.01	0.00	0.01	0.0991
O_3	72 hr Max. O3.8 hr	9.94	-0.04	-0.06	-0.02	**0.0009**	0.05	0.02	0.07	**0.0002**
	24 hr	18.10	0.00	-0.04	0.03	0.8810	0.01	-0.02	0.04	0.4859
	48 hr	11.69	-0.01	-0.04	0.01	0.3443	0.02	-0.01	0.05	0.1640
	72 hr	12.32	-0.01	-0.02	0.01	0.4370	0.01	0.00	0.03	0.1198
	96 hr	8.57	0.00	-0.02	0.01	0.6612	0.00	-0.01	0.02	0.5297
	96 hr CAMS	7.50	0.00	-0.02	0.01	0.9554	0.00	-0.01	0.02	0.7658
AQG	24 hr	22.62	0.01	-0.03	0.04	0.7729	-0.01	-0.04	0.02	0.3841
	48 hr	20.28	-0.02	-0.15	0.11	0.7868	0.00	-0.11	0.10	0.9569
	72 hr	11.83	-0.02	-0.04	-0.01	**0.0022**	0.02	0.01	0.04	**0.0018**
	96 hr	15.09	-0.03	-0.05	-0.02	**0.0000**	0.04	0.02	0.05	**0.0000**

References

Liang K and Zeger S (1986) Longitudinal data analysis using generalized linear models. *Biometrika*, 73: 13–22.

Appendix E. Moderate to Vigorous Physical Activity Levels Negatively Correlate with Traffic Related Air Pollutants in Children with Asthma Attending a School near a Freeway

Moderate to vigorous physical activity levels negatively correlate with traffic related air pollutants in children with asthma attending a school near a freeway.

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ABSTRACT

Epidemiologic studies have established linkages between adverse health effects and traffic air pollution. People with asthma are more likely adversely affected by traffic emissions, particularly young children. Studies showed regular exercise reduces asthma exacerbation and improves lung function. However, few studies have looked at the physical activity and air quality relationship. An air pollution and physical activity study was conducted to develop healthy living guidelines for children attending a school near a freeway. Twelve children (ages 6-12 years) participated in a repeated measures study at a school in El Paso, TX. Air pollutants ($PM_{2.5}$, PM_{10}, NO_2, and O_3) were continuously measured at the school and we measured rates of physical activity by accelerometry weekly for 10 weeks. In addition, we collected baseline data on medical status and weekly data using the Asthma Control Questionnaire. Generalized estimating equations approaches showed that school pollutant concentrations of $PM_{2.5}$, PM_{10}, and NO_2 were negatively associated with moderate to vigorous physical activity (MVPA) (PM concentrations: $p<0.001$; NO_2: $p=0.036$), whereas they were positively associated with sedentary activity (PM concentrations: $p<0.001$; NO_2: $p=0.019$). 72-hr maximum O_3 data were associated with decreased rate in MVPA ($p=0.001$). Higher levels of traffic pollution correlate with lower levels of physical activity in children with asthma. Short-term guidelines in response to these results include pollutant mitigation measures (e.g. placement of natural barriers) followed by reassessment of the air quality and physical activity of the children. Long-term guidelines include recommendations to build future schools at locations farther from high-traffic.

Keywords: Air quality, Children with Asthma, Physical Activity, Near-road, PM2.5, O_3

INTRODUCTION

In a polluted environment, people who engage in outdoor physical activity are likely to have increased health risk compared to those who have a more sedentary lifestyle, which could be counterproductive to the promotion of physical activity.

Exposure to air pollutants and physical activity

The benefits of physical activity are essential for overall health (*1*). Regular outdoor activities, like walking, jogging, or dancing, can lead to a significantly lower risk of cardiovascular disease and metabolic syndrome (*2*). However, outdoor physical activity exposes people to air pollutants which might lead to adverse health problems such as cardiovascular (*3; 4*) or respiratory diseases (*5; 6*).

During physical activity, deposition of air pollutants in the lungs may occur due to increased respiratory intake (*7*). In controlled studies, the exposure to air pollutants during exercise has led to a reduction in performance (*8*), and inhalation of airborne particles during exercise has been associated with reduction in lung function (*9*). Also, increased levels of air pollutants are associated with self-reported inactivity (*10; 11*). For this reason, exposures to an environment with an increased level of air pollution might lead to adverse health effects due to airway exposure to airborne pollutants and lack of physical activity.

Air pollutants in the school environment

Research suggests that spending time in an environment near heavy traffic is particularly harmful to children. Children attending elementary school spend about 6-8 hours per day in various school microenvironments. Outdoor activities are relatively common in elementary schools due to the lack of indoor playgrounds. In many countries, severe conditions of air pollution frequently required cancellation of physical or sport activities in elementary schools, which may lead to an increase in sedentary behavior and contribute to the overweight and obesity epidemic (*7*). One of US Environmental Protection Agency's initiatives to alleviate this problem is to reduce children's exposure in schools and conduct outdoor air monitoring near schools (*12*). This is particularly important for schools located near busy traffic intersections or freeways where children may be exposed to an even higher level of traffic pollution. Among the traffic–related air pollutants that children of roadside communities are commonly exposed to are coarse particulate matter (PM_{10} or particles less than 10 μm in diameter), fine particulate patter ($PM_{2.5}$ or particles less than 2.5 μm in diameter), nitrogen dioxide (NO_2), and ozone (O_3).

Physical activity in those who have asthma

Some studies have shown that people with asthma (or even those with mild asthmatic symptoms) may have reduced physical activity and avoid aerobic fitness and leisure-time energy expenditure due to concerns of triggering asthma symptoms (*13; 14*). Given that asthma affects children at a young age when they are likely to establish their health habits, it is important to emphasize physical activity with asthma patients (*15*). National management guidelines for asthma state that the majority of patients can be controlled well enough to perform physical activity and that additional therapy options can be made available to them (*16; 17*). Therefore, it is in the best interest of those who have asthma to achieve a balance between having a healthy amount of physical activity and controlling their respiratory symptoms. However, the impact of air pollution on people with asthma often prevents people from achieving a physically active lifestyle. Asthmatics who performed exercise in an environment that had high levels of pollution were at a higher risk of having an asthma attack (*3*) and lung pathologies (*7*). Children with asthma living in low income communities are likely to have increased clinical asthma symptoms when they are exposed to short-term increases in air pollutants (*18*).

In summary, the importance of promoting physical activity for overall health conflicts with the negative consequences of physical activity in environments with high levels of air pollutants. While studies have documented that air pollutants are inhaled into lungs during exercise and, air quality is a concern in school environments, and people with asthma may reduce or avoid physical activity, there are no studies that assess changes in air quality over time and how those changes correlate with objectively measured physical activity in

children with asthma in a school setting. The findings of this study are expected to shed light on the implementation of policies and health recommendations for communities to reduce the adverse impact of air pollution on physical activity.

METHODS

This study was conducted in El Paso, Texas from October to December 2017 at an elementary school located within 300 ft of a heavy traffic freeway. Air pollutants and concurrent meteorological data were continuously monitored through the duration of the study, and physical activity was assessed weekly during the school hours. The International Review Board of The University of Texas at El Paso approved the protocol for this study prior to participant recruitment and data collection.

Children with asthma were recruited by contacting the school nurse and disseminating flyers to each student. The participant's parent or legal guardian provided written consent and children provided assent. English and Spanish versions of consent and assent forms were available for the participants and parents. The selection criteria for the study included children between 6 and 12 y with a physician diagnosis of asthma and no other lung disease, no major illness, and living in a non-smoking household. Twelve children satisfied the eligibility requirements and participated in the study.

At the start of the study, parents were asked to answer a baseline questionnaire that provided information on health status, current allergies, insurance status, medication usage, household characteristics, symptoms and activity limitation due to symptoms, emergency room visits, and hospital admissions. In addition, each Friday during the study, the participants answered questions about symptoms and medication use using the Asthma Control Questionnaire (ACQ) (*19*). English and Spanish versions were available.

Physical activity rates categorized by activity intensity of moderate to vigorous (MVPA), light, and sedentary were measured using an accelerometer (wGT3X-BT; ActiGraph). The accelerometer was tied on the wrist of the participants during school hours during the Friday visits. Physical activity rates were calculated using the ActiLife (V.6.13.3) software and the embedded algorithm for children (*20*). The software allowed determination of a participant's percentage in either sedentary, light, or MVPA during a specific time window (9:00 AM to 2:00 PM).

Air pollutants were continuously measured throughout the study in an outdoor environment close to the school. The analysis included measurements for PM_{10}, $PM_{2.5}$, NO_2, and O_3. Samplers for these measured particles and gases were located in a fenced area outside of the school. $PM_{2.5}$ and PM_{10} mass concentrations were measured using GRIMM Technologies Aerosol Spectrometer 11-A. NO_2 measurements were obtained using 2B Technologies Model 405 NO_2/NO/NO_x. Ozone (O_3) was measured using 2B Technologies Model 202. Temperature and relative humidity were collected from the El Paso International Airport. The Texas Commission on Environmental Quality (TCEQ) operates a continuous ambient monitoring station (CAMS) at Chamizal which were used for comparison for $PM_{2.5}$, PM_{10}, and O_3. Another CAMS site at Ascarate Park was used to compare NO_2 (Figure 1). Hourly measurements were averaged to calculate values for 96, 72, 48, and 24-hours prior to the physical activity measurements.

FIGURE 1 Location of school and CAMS stations

Statistical analysis

Descriptive statistics were calculated to assess characteristics of air pollution metrics and physical activity (MVPA/light/sedentary) status. Correlation analyses using Spearman correlation have been conducted to explore relationships between physical activity, and outdoor pollutant concentrations. Summary statistics of subject demographic information and characteristics were calculated. Physical activity outcomes between the subject-specific factor groups were compared using Kruskal-Wallis test.

Longitudinal associations between MVPA/sedentary physical activity responses and air pollution metrics were examined using generalized estimating equations (GEE) approach (*21*). We assumed the subject-specific cluster and exchangeable correlation structure for the repeated measures of the outcome data. 96-hr averages of temperature and relative humidity showed strongest associations with response outcome, and as a priori fixed covariates in all models, we controlled for the 96-hr temperature and relative humidity.

Separate models were run for each pollutant variable of interest (PM concentrations, NO_2, or O_3) with various exposure periods (previous 24-hr, 48-hr, 72-hr, or 96-hr averages). Effect estimates for each measurement are presented as the percent change in rate of physical activity per increase in pollutant concentrations. A p-value < 0.05 was considered statistically significant. All statistical analyses were performed using R version 3.2.2.

RESULTS

We considered various exposure windows for the outdoor pollutants. Hourly measurements were aggregated to 24-hr, 48-hr, 72-hr, and 96-hr averages. Hourly concentrations measured at a nearest CAMS location were also averaged over the 96-hr window periods for comparisons. Descriptive statistics for 24-, 48-, 72-, and 96-hr averaged pollutant measures are listed in Table 1. Table 1 also compares the outdoor and ambient concentrations, averaged for the 96-hr exposure time. The mean concentrations at CAMS monitoring site were lower than the school measurements, with a tendency of larger variations than those at the school.

TABLE 1 Summary statistics for school and ambient pollutant metrics: mean, standard deviation (SD), median, interquartile range (IQR), minimum (min), and maximum (max)

	24-hr	48-hr	72-hr	96-hr	96-hr (CAMS)
$PM_{2.5}$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Mean	12.52	11.73	11.48	12.16	10.17
SD	3.71	2.40	1.88	2.80	5.25
Median	13.15	11.13	11.35	11.27	9.75
IQR	4.91	4.14	3.12	4.07	5.22
Max	18.86	15.65	14.33	17.58	18.69
Min	6.33	8.98	8.60	8.61	3.40
PM_{10}	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Mean	45.30	43.05	42.55	44.94	36.89
SD	17.36	12.47	8.70	9.13	12.43
Median	40.30	38.47	40.32	45.84	38.67
IQR	24.57	19.06	11.93	9.56	16.84
Max	74.14	62.31	56.99	60.10	51.61
Min	24.49	25.87	31.36	28.54	13.84
NO_2	ppb	ppb	ppb	ppb	ppb
Mean	17.63	18.20	18.40	18.94	17.90
SD	6.06	3.25	3.06	3.72	5.11
Median	19.22	18.59	18.47	19.04	16.33
IQR	7.81	4.76	2.76	4.96	5.20
Max	26.17	22.16	22.70	23.64	27.13
Min	7.21	12.20	12.17	11.62	13.02
O_3	ppb	ppb	ppb	ppb	Ppb
Mean	21.41	20.37	21.75	20.35	19.85
SD	10.51	6.66	7.25	5.47	5.08
Median	19.60	18.94	19.37	18.29	18.85
IQR	18.09	11.69	12.32	8.57	7.51
Max	38.90	31.13	34.52	29.71	28.43
Min	9.16	12.52	13.86	15.59	14.81

The participants (n=12) are characterized in Tables 2 and 3. Table 2 includes summary statistics of subjects' demographic information and the physical activity rates by level (MVPA, light, and sedentary). The mean age was 8.3 yrs (SD=1.5) and mean body mass index (BMI) was 17.9 (SD=5.0). The mean BMI-for-age percentile was 49.8±41.2. The mean (±SD) physical activity levels for MVPA, light, and sedentary activity were 63.4% (±8.2%), 10.1% (±1.7%), and 26.5% (±0.079%), respectively. Pairwise *t*-test indicated the three activity levels were significantly different from each other (all *p*-values <0.001, with Bonferroni adjustment).

TABLE 2 Summary of subject demographics and physical activity information

	mean ± sd	range
Age (yrs)	8.3 ± 1.5	(6-10)
Height (in)	54.3 ± 4.4	(46.3-70.0)
Weight (lb)	76.3 ± 27.3	(45.8-134)
BMI (kg/m^2)	17.9 ± 5.0	(12.3-27.8)
BMI (%)	49.8 ± 41.2	(0-99.4)
Physical Activity (%, N=102)		
MVPA	63.4 ± 8.2	(30.4-77.7)
Light	10.1 ± 1.7	(7.1-14.4)
Sedentary	26.5 ± 7.9	(13.7-61.7)

The subject-specific factors including medication information are characterized in Table 3. Rates of MVPA and sedentary activities by their factor levels were compared using Kruskal-Wallis test to examine whether the mean rates between factor levels are statistically different. The test results showed significantly different rates for some factors (gender, BMI category, father with asthma status, siblings with asthma, having eczema, health insurance, smoking status, and *Leukotrieneblockers* (LB), (*Long-acting bronchodilators and inhaled corticosteroids)* LABAIC, *Nasal corticosteroids (*NC) medications) at both MVPA and sedentary activities (see bold *p*-values in Table 3). For example, types of insurance, i.e., Medicaid vs. private, was a significant factor (*p*-value = 0.003) to have different rates in the MVPA, participants with Medicaid spent more time in MVPA (0.665) than those with private insurance (0.612). Conversely, participants with Medicaid spent less time in sedentary activities (0.239) than those with private insurance (0.279, *p*-value=0.039).

TABLE 3 Summary Statistics of subject specific factors and physical activity rates per factor level.

Subject-specific Factor	Frequency,%		Physical activity			
	(n=12)		MVPA	p-value*	Sedentary	p-value*
Sex						
Male	7	58%	65.8%	**0.001**	24.2%	**0.001**
Female	5	42%	60.0%		29.2%	
BMI category						
Underweight & Normal	8	67%	61.9%	**0.010**	28.4%	**< 0.001**
Overweight & Obese	4	33%	66.5%		22.6%	
Mother with Asthma	5	42%	63.2%	0.895	26.1%	0.503
No	7	58%	63.6%		26.7%	
Father with Asthma	3	25%	60.9%	**0.041**	28.8%	**0.032**
No	9	75%	64.3%		25.7%	
Mother with Hay Fever	8	67%	63.4%	0.944	26.3%	0.595
No	4	33%	63.5%		26.8%	
Father with Hay Fever	8	67%	62.7%	0.305	26.9%	0.511
No	4	33%	64.8%		25.6%	
Siblings with Asthma	6	50%	61.2%	**0.005**	28.8%	**0.001**
No	6	50%	65.6%		24.1%	
Siblings with Hay Fever	8	67%	63.0%	0.602	27.2%	0.169

No	4	33%	64.2%		25.1%	
Having Eczema	3	25%	66.8%	**0.012**	23.2%	**0.011**
No	9	75%	62.2%		27.7%	
Allergic Phenotype (Aeroallergens)	8	67%	63.1%	0.597	26.7%	0.794
No	4	33%	64.1%		26.0%	
Allergic Phenotype (Food)	3	25%	61.8%	0.143	27.4%	0.366
No	9	75%	64.1%		26.1%	
Caretaker Education						
Less than or Equal to High School	6	50%	63.8%	0.997	26.3%	0.771
Greater than High School	6	50%	63.1%		26.6%	
Health Insurance Coverage (n=11)						
Medicaid	6	55%	66.5%	**0.003**	23.9%	**0.039**
Private	5	45%	61.2%		27.9%	
Smoking (outside of household)	2	17%	59.9%	**0.013**	29.9%	**0.010**
No	10	83%	64.2%		25.7%	
Cooking Fuel						
Electric	1	8%	68.7%	**0.035**	22.7%	0.127
Gas	11	92%	62.9%		26.8%	
*Leukotrieneblockers (LB)***	7	58%	66.4%	**< 0.001**	23.7%	**< 0.001**
No	5	42%	59.4%		30.3%	
Short-acting bronchodilators (SABA)	7	58%	62.8%	0.155	27.3%	0.065
No	5	42%	64.4%		25.2%	
Inhaled corticosteroids (IC)	6	50%	63.2%	0.894	26.1%	0.493
No	6	50%	63.6%		26.8%	
Long-acting bronchodilators and inhaled corticosteroids (LABAIC)	2	17%	68.1%	**0.012**	22.0%	**0.013**
No	10	83%	62.6%		27.2%	
Nasal corticosteroids (NC)	4	33%	66.8%	**0.003**	23.4%	**0.007**
No	8	67%	61.7%		28.0%	
Systemic corticosteroids (SC)	2	17%	64.6%	0.641	25.3%	0.791
No	10	83%	63.2%		26.7%	

**p*-value for mean difference in physical activity between factor levels using Kruskal-Wallis test.
** All medications are expressed in italic.

Models Predicting Physical Activity Data

Associations between physical activity (MVPA vs. sedentary) and pollutant metrics are summarized in Table 4. In correlation analyses, MVPA was negatively correlated with previous 96-hr averages of $PM_{2.5}$ (r = -0.349), PM_{10} (r = -0.200), and NO_2 (r = -0.265), and positively correlated with O_3 (r = 0.247), Table 4. In contrast, sedentary activity was positively correlated with 96-hr averages of $PM_{2.5}$ (r = 0.368), PM_{10} (r = 0.202), and NO_2 (r = 0.300), and negatively correlated with O_3 (r =- 0.263). We did not find any significant correlations between pollutant measurements and light physical activity.

Table 4 presents effect estimates using GEE models, 95% confidence intervals, and corresponding p-values. We scaled the effects to interquartile range (IQR) increases in pollutant metrics to compare the magnitude of effect across different scales of the pollutant concentrations. The 96-hr school pollutant concentrations ($PM_{2.5}$,

$PM_{10,}$ and NO_2) were negatively associated with moderate to vigorous physical activity (*p*-values<0.001 for PM; *p*-value=0.036 for NO_2), whereas they were positively associated with sedentary activity (*p*-values<0.001 for PM; *p*-value=0.019 for NO_2). Negative 96-hr O_3-moderate to vigorous activity relationship was not significant (*p*-value=0.661). However, the 72-hr maximum O_3 data were associated with decreased rate in moderate to vigorous activity (*p*-value=0.001).

96-hr averaged ambient PM and NO_2 concentrations at the Ascarate CAMS were significantly associated with physical activity levels, showing consistent patterns of association with 96-hr school concentrations. The largest percent time spent in MVPA per school pollutant increase in IQR was observed in the association between 96-hr $PM_{2.5}$; 3.45% decrease in MVPA (95% CI: -5%, -1.9%). We have the similar amount of percent change in sedentary activity [3.43% increase (95% CI: 1.78%, 5.09%)] as the IQR in $PM_{2.5}$ increases.

TABLE 4 Overall associations between moderate to vigorous (MVPA) and sedentary physical activity and pollutant metrics.

Pollutant		IQR	MVPA				Sedentary			
			Change in rate per IQR	95% CI lower	95% CI upper	*p* value	Change in rate per IQR	95% CI lower	95% CI upper	*p* value
$PM_{2.5}$	24-hr	4.91	0.47%	-0.54%	1.48%	0.365	-0.96%	-1.92%	0.01%	0.051
	48-hr	4.13	0.80%	-0.37%	1.96%	0.180	-1.53%	-2.75%	-0.31%	**0.014**
	72-hr	3.11	-1.71%	-2.95%	-0.46%	**0.007**	1.43%	0.24%	2.61%	**0.018**
	96-hr	4.07	-3.45%	-5.00%	-1.90%	**< 0.001**	3.43%	1.78%	5.09%	**< 0.001**
	96-hr CAMS	5.22	-3.86%	-6.12%	-1.59%	**0.001**	4.04%	1.71%	6.37%	**0.001**
PM_{10}	24-hr	24.57	-0.43%	-1.50%	0.64%	0.427	-0.06%	-0.99%	0.87%	0.902
	48-hr	19.05	-0.58%	-1.66%	0.50%	0.293	-0.17%	-1.18%	0.83%	0.735
	72-hr	11.93	-1.32%	-2.24%	-0.39%	**0.005**	1.00%	0.09%	1.91%	**0.031**
	96-hr	9.56	-1.59%	-2.37%	-0.81%	**< 0.001**	1.51%	0.69%	2.34%	**< 0.001**
	96-hr CAMS	16.84	-2.87%	-4.65%	-1.08%	**0.002**	3.07%	1.19%	4.95%	**0.001**
NO_2	24-hr	7.81	-0.45%	-1.71%	0.82%	0.489	0.43%	-0.62%	1.47%	0.424
	48-hr	4.76	-0.28%	-1.41%	0.85%	0.626	0.29%	-0.72%	1.30%	0.574
	72-hr	2.76	-0.60%	-1.30%	0.11%	0.098	0.66%	-0.06%	1.38%	0.075
	96-hr	4.96	-1.35%	-2.62%	-0.09%	**0.036**	1.52%	0.25%	2.79%	**0.019**
	96-hr CAMS	5.19	-0.78%	-1.53%	-0.04%	**0.040**	0.63%	-0.12%	1.38%	0.099
O_3	72-hr Max$O_3$8hr	9.94	-3.99%	-6.35%	-1.63%	**0.001**	4.62%	2.15%	7.08%	**< 0.001**
	24-hr	18.10	-0.25%	-3.51%	3.01%	0.881	1.16%	-2.10%	4.43%	0.486
	48-hr	11.69	-1.31%	-4.01%	1.40%	0.344	2.07%	-0.85%	4.98%	0.164
	72-hr	12.32	-0.66%	-2.33%	1.01%	0.437	1.41%	-0.37%	3.19%	0.120
	96-hr	8.57	-0.33%	-1.81%	1.15%	0.661	0.49%	-1.05%	2.04%	0.530
	96-hr CAMS	7.50	-0.04%	-1.51%	1.43%	0.955	0.24%	-1.34%	1.82%	0.766

DISCUSSION

During physical activity, changes in the frequency of breathing patterns as well as a switch to a predominantly oral respiration and bypass of nasal filtration could exacerbate the effects of air pollutants (*7*). Assuming the adverse health effects are related to the amount of pollutants inhaled, in children with asthma this may lead to an increased chance of triggering asthma symptoms when performing activities in an outdoor environment exposing to air pollutants.

At the school, the mean 96-hr average concentration for each of the pollutants was higher than what was reported by the reference CAMS stations. This would indicate that a higher exposure to air pollutants took place at this site compared to the "central-site", which is typically reported at a publicly operated CAMS location for the region. The proximity to a major freeway could potentially lead to adverse health outcomes for children attending the elementary school and participating in outdoor activities. In addition, as observed from the pollutant concentrations, we can infer that the larger time window average provides a better representation of the current air pollutant exposure for physical activity at the study site.

Differences in physical activity rates between sexes are consistent with other published values (Trojano, 2008) but not with BMI. In this study, overweight and obese children were more physically active than underweight and normal children. The effect of health insurance could be related to the asthma severity and more frequent visits in the Medicare setting when compared to those in the private setting. A study among children with asthma aged 3 to 17 showed that those enrolled in Medicaid were more likely to have a preventive care visit during the last year, and about half of them did receive a clinician's advice about physical activity (*22*).

Having a father or a sibling with asthma (but not a mother) was significantly correlated with more time spent in sedentary behavior and less time spent in MVPA. This is somewhat consistent with a study in Canada that found that having a parent with asthma increased the odds for asthma and wheezing outcomes (*23*). This same study found increased odds of symptom severity if a mother was a previous smoker but did not report any data on having either a father or a sibling with asthma.

The treatment options for children with asthma depend on the severity of their condition (*24*). Those with persistent asthma are recommended to take inhaled corticosteroids (ICS) in order to control airway inflammation. The addition of long-acting β_2-agonist (LABA) for patients is an option for those who remain symptomatic with ICS treatment only (*25*). Higher levels of MVPA in children using some medications could be a result of increased control over asthma symptoms. Furthermore, in a study in healthy adults, pre-treatment with an LB (*Montelukast*) before exercise attenuated the effects of PM inhalation in endothelial dysfunction (a cardiovascular health marker) (*26*).

Perceptions of health benefit vs. detriment of exercise is associated with asthma severity: participants with a more severe asthma condition were more likely to believe exercise was not good for asthma patients (*15*). In another study that included 27 adults with mild to moderate asthma, exercise participation was rated only 1.6 in a 4-point physical activity scale (*14*). Among children with asthma, the severity of the disease and parental beliefs about physical activity and asthma predict the activity level, although this was based on self-reported data (*27*).

We found negative correlations between the 96-hr averages of $PM_{2.5}$, PM_{10}, and NO_2 and the amount of time spent in MVPA during school hours. In contrast, sedentary activity was positively correlated with pollutant concentrations. We could not find studies that observed directly the effects of pollutants on physical activity. However, some studies have demonstrated adverse health effects related to physical activity. In healthy males, inhalation of particulate matter during exercise lead to adverse respiratory health related to a reduced lung function (*8*). Furthermore, a study conducted in California noted positive association between wheezing and increase levels of NO_2 pollutants (*28*).

GEE models allowed us to account for individual factors which further validates the longitudinal association for the mentioned pollutants. In addition, meteorological parameters (humidity and temperature) were also controlled for in the approach. We initially found positive correlations with O_3 and physical activity, possibly because high O_3 days imply more sunshine (less cloud cover) and increased outdoor temperatures. Consequently, the outdoor environment is more inviting for outdoor activities during winter months. Once the statistical approach took into account meteorology factors, associations with O_3 were on the same direction as the other pollutants but not significant. However, the use of maximum values did yield a significant association. This could mean that O_3 levels affect differently, or the effects might be more significant if the values reach a certain threshold. Some studies that have looked at O_3 exposure showed that a high daytime O_3 concentration was consistent with an increased likelihood of new-onset of asthma or exacerbation of undiagnosed asthma in physically active children (*29*).

The following limitations of this study are noted. First, measuring physical activity in children is difficult. Children tend to have short burst of activities that are more difficult to measure when compared to adults (*30*). The gold standard for assessing physical activity is the double-labeled water method (*31*). However, this method does not provide data about activity patterns and is expensive and more logistically challenging. Accelerometers

record movement of the specific part of the body to which they are attached and thus differences in types of physical activities are mostly accurate (*30*) and correlate reasonably with the gold standard (*32*).

In addition, the sample size was small given the few number of students that have an asthma diagnosis attending the school. However, during the 10 weeks of the study, the children were compliant, and we managed to obtain a sizeable number of repeated measurements (n=102).

Although this study was longitudinal (repeated measures within individuals over time), there might be latent variables that affect children with asthma are and cause and effect cannot be inferred from the results.

Further research is recommended regarding the effect of air pollution and the physical activity of children with asthma. A recent meta-analysis using accelerometry data did not show any differences for activity between children with and without asthma (*33*). However, based on the increased sensitivity of children with asthma to air pollutants, the findings of this study need further validation with objective measures of physical activity. Innovative approaches include using specific immunogenic makers to compare the benefits of physical activity against the risk of a high air pollutant exposure (*34*).

CONCLUSION

To our knowledge, this is the first study to characterize the effects of traffic related air pollutants in children with asthma using objective measures of physical activity. Our findings suggest that school-based monitoring of air pollutants is an indicator of the health risk of children's exposures and the impact on their physical activity. This research work will also aid in the formulation of healthy living recommendations in this border region.

In the short term, placement of natural barriers (shade trees, shrubs, natural vegetation, green roofs) at the school can mitigate the effects of air pollutants. Green plants can intercept particulate matter, which can adhere temporarily to their surface. Eventually, these particles are re-suspended in the atmosphere or washed of by rain (*35; 36*). Natural barriers lead to improvement of air quality and overall health of those living in urban environment (*37*).

In the long term, policy changes should aim to improve air-monitoring programs at a local scale (instead of regional) and consider measurement of air pollutants next to highways (*38*). This information will be key to determine appropriate locations to build future schools further from heavy traffic roads.

AUTHOR CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: Li, Whigham, Raysoni, Aguilera; data collection: Raysoni, Aguilera; analysis and interpretation of results: Li, Rangel, Jeon, Aguilera, Whigham; draft manuscript preparation: Aguilera, Whigham, Li, Jeon. All authors reviewed the results and approved the final version of the manuscript.

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