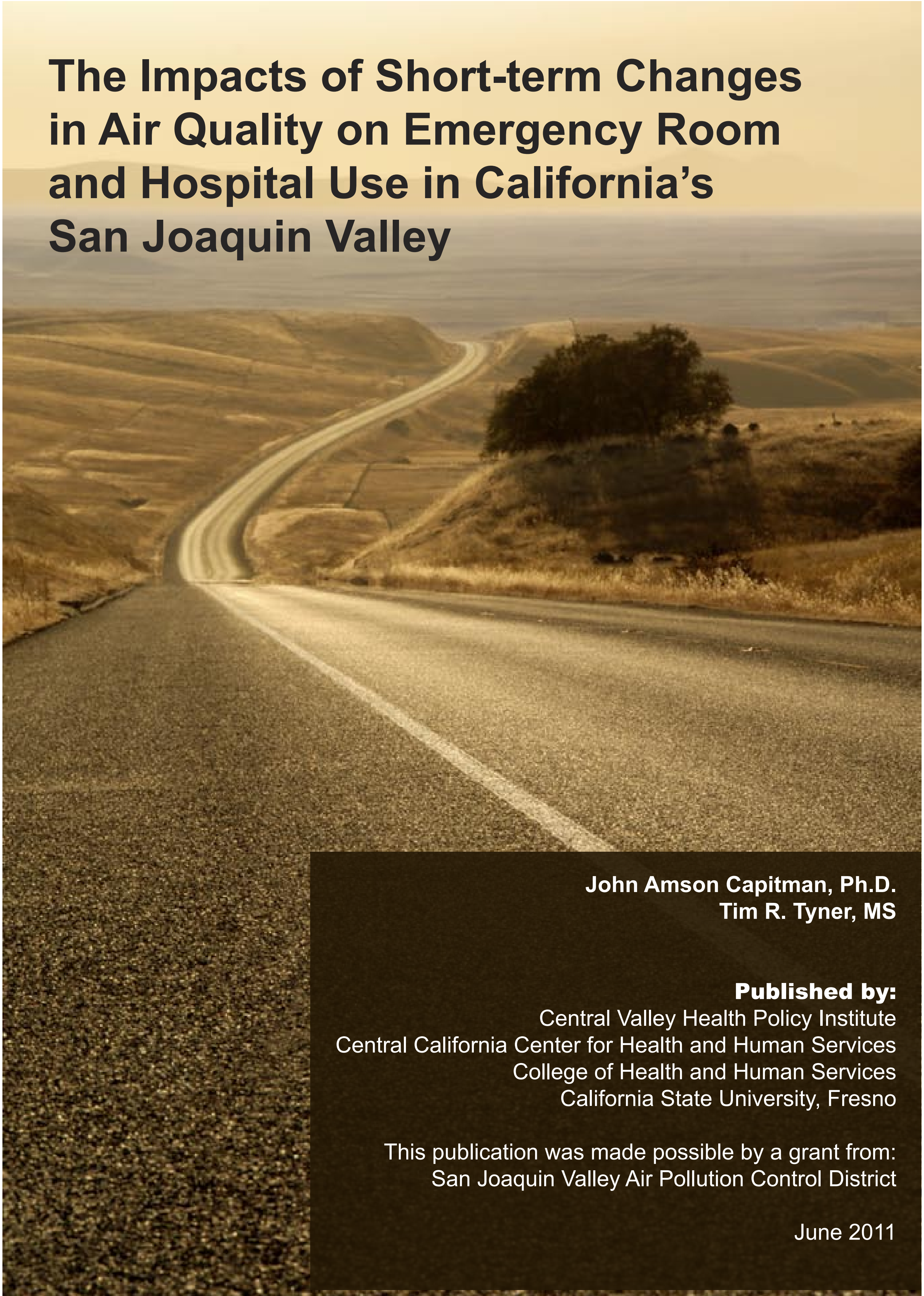


The Impacts of Short-term Changes in Air Quality on Emergency Room and Hospital Use in California's San Joaquin Valley

John Amson Capitman, Ph.D.
Tim R. Tyner, MS

Published by:
Central Valley Health Policy Institute
Central California Center for Health and Human Services
College of Health and Human Services
California State University, Fresno

This publication was made possible by a grant from:
San Joaquin Valley Air Pollution Control District

June 2011

Suggested Citation:

Capitman, J.A., and Tyner, T.R. (2011). The Impacts of Short-term Changes in Air Quality on Emergency Room and Hospital Use in California's San Joaquin Valley. California State University, Fresno, Fresno CA.

Copyright Information

This report was supported through a grant from San Joaquin Valley Air Pollution Control District to the California State University, Fresno. The views expressed in this report are those of the authors and do not necessarily reflect those of the funders or the University.

The Impacts of Short-term Changes in Air Quality on Emergency Room and Hospital Use in California's San Joaquin Valley

John Amson Capitman, Ph.D.
Tim R. Tyner, MS

Published by:
Central Valley Health Policy Institute
Central California Center for Health and Human Services
College of Health and Human Services
California State University, Fresno

This publication was made possible by a grant from:
San Joaquin Valley Air Pollution Control District

June 2011

ACKNOWLEDGEMENTS

The authors would like to thank the following people for their invaluable assistance with the publication of this report.

LEADERSHIP

David Lighthall, PhD Senior Science Advisor and Program Officer, San Joaquin Valley Air Pollution Control District
Andrew Hoff, Dean, College of Health and Human Services, California State University, Fresno
William A. Covino, Provost and Vice President for Academic Affairs, California State University, Fresno
The Members of the Regional Advisory Council, Central Valley Health Policy Institute

DATA ANALYSIS:

Armando Cortez, BS, Tophat Data Services: Data Analysis & GIS Mapping Consultant
Paul Mills, PhD, Epidemiologist, Department of Medicine, UCSF Fresno

EDITING

Donna DeRoo, Assistant Director, Central California Center for Health and Human Services

COMMUNICATIONS

Office of University Communications, California State University, Fresno

THE CENTRAL VALLEY HEALTH POLICY INSTITUTE

The Central Valley Health Policy Institute improves equity in health and health care by developing the region's capacity for policy analysis and program development through integrating the resources of California State University, Fresno and the institutions and communities of the San Joaquin Valley. The Institute was funded in July 2003 by The California Endowment, in partnership with the university, to promote health policy and planning in the region.

Additional information about the Central Valley Health Policy Institute, its program and activities (including this report), can be found at: **www.cvhpi.org.**

Central Valley Health Policy Institute
Central California Center for Health and Human Services
College of Health and Human Services
California State University, Fresno

1625 E. Shaw Avenue, Suite 146
Fresno, CA 93710-8106
559.228.2150
Fax: 559.228.2168

This report may be downloaded from
www.cvhpi.org

Contents

Figures

Tables

Appendix Figures

Appendix Tables

Executive Summary

The Impacts of Short-term Changes in Air Quality on Emergency Room and Hospital Use in California's San Joaquin Valley

Study Goals: The San Joaquin Valley is arguably the most polluted air basin in the United States. In particular, Bakersfield and Fresno are consistently ranked by the American Lung Association as the #1 and #2 city in the nation, respectively, for the highest concentrations of short-term ambient fine particulate matter (PM2.5). While prior projects have addressed key scientific and policy questions about the health consequences of exposure to PM2.5 and ozone in the San Joaquin Valley, they have relied on exposure data and estimates of health effects from other communities to project the health consequences of current or potential exposure levels of concern to policy makers. From the perspective of policy makers, this leaves room for doubt about the scale of health effects associated with initiatives to reduce air pollution levels in the region. In order to address some of these concerns, this study used California OSHPD hospital and emergency room data linked to San Joaquin Valley Air Pollution Control District (SJVAPCD) air monitoring data from Fresno/Clovis, Bakersfield and Modesto to address three related questions:

1. Are short-term increases in PM2.5 levels during the cooler months in the San Joaquin Valley associated with respiratory and cardiovascular emergency department and hospital admissions?

2. Are short-term increases in ozone levels during the warmer months in the San Joaquin Valley associated with respiratory and cardiovascular emergency department and hospital admissions?

3. Are there spatial (city) differences in how short-term increases in PM2.5 and ozone in the San Joaquin Valley are associated with respiratory and cardiovascular emergency department and hospital admissions?

Methods: We conducted a comparative, longitudinal, population study of the correlation between daily air quality (PM2.5 and ozone) and daily emergency room and in-patient hospital admissions for respiratory and cardiovascular conditions. We used zip code-level population data and identified the most compact set of contiguous zip codes whose geographic centroids were within six miles of the Fresno, Bakersfield and Modesto air quality monitors with a population in 2005 of about 300,000. We considered emergency room (ER) admissions to all hospitals in the three urban areas for 2005-2007 and in-patient admissions to all hospitals for 2002-2007. Individual-level data on ER use prior to 2005 was not available. Our dependent variables were counts of admissions for asthma, other respiratory conditions, acute myocardial infarction, and other cardiovascular conditions for children and adults. Our independent variables were quintiles of ambient daily PM2.5 or ozone. Because of the count dependent variable, we used Poisson regression modeling, controlling for meteorological conditions and other environmental and temporal factors, to assess differences in health care use at increasing air pollutant levels.

Findings: Our findings show that asthma ER admissions are strongly linked to increasing PM2.5 across the region, with a higher risk in children. Risk for asthma hospitalizations also increased dramatically with PM2.5 in children and adults across the region. Moderate risk for acute Myocardial Infarction hospital admissions were also linked to PM2.5 levels regionally, as were pneumonia ER visits in children and acute bronchitis ER visits in adults. Hospital admissions for other respiratory and cardiovascular conditions were not linked to PM2.5 levels in consistent ways across the region. At the city level, strong correlations between asthma ER visits and PM2.5 were seen in all three communities for children, but only in Fresno for adults. A strong association between asthma hospitalizations and PM2.5 levels was only seen in children in Fresno, while a moderate association was found in Bakersfield adults. In contrast, significant associations between PM2.5 and ER visits for acute bronchitis and pneumonia were only seen in children in Bakersfield. Surprisingly, while no effect was seen at the regional level, a strong inverse relationship between elevated PM2.5 and hospitalizations for congestive heart failure (CHF) was identified in adults in Bakersfield.

Due to the high collinearity of ozone and temperature, combined with other seasonal factors that are thought to influence asthma exacerbations during the warm season but for which data are not available, the ozone study period was restricted to the summer months of June – August. During the summer months, ozone was found to be strongly linked to increased risk for asthma ER visits in children at the regional level. No other respiratory or cardiovascular condition (risk of ER visit or hospital use) was found to be consistently linked with elevated ozone at the regional level. City-level ozone findings were less clear, again reflecting smaller samples. While trends for increased asthma ER visits in children associated with increasing ozone quintiles were seen in Fresno and Modesto, there were no statistically significant correlation between ozone and any of the health endpoints at the city-level.

Discussion: This study offers the first local evidence of short-term population-level health effects associated with elevations in PM2.5 and ozone for the San Joaquin Valley. While the study examined these relationships both regionally and within three individual cities, the number of observations available within each quintile of exposure in the regional analyses provides more stable measurements. We find linear increases in rates of asthma ER and hospital admissions with increasing exposure to fine particulate matter, with effects more pronounced for children. Further, hospital admissions for acute MI in adults also increased in a linear fashion with increasing PM2.5. Further analysis of relationships among the pollutants and contextual variables supported the validity of the identified health risks associated with elevated PM2.5. By contrast, ozone was found to be associated only with increased risk for asthma ER visits in children at the regional level. Some degree of uncertainty about the ozone findings from this analysis is warranted because of 1) the high degree of collinearity between ozone and temperature necessitating the exclusion of temperature as a co-variate, 2) the artificial relationship between temperature and asthma visits resulting from other factors not available for this analysis and the subsequent temporal restriction to only the three hottest months, and 3) the significant differences between communities during the warm season in other pollutant and weather conditions. While precise comparisons to other studies are made difficult by differences in the pollutants and meteorological co-variates, the age, racial/ethnic, and social class distributions of study populations, as well as the lag times considered, our observed relationships are of similar magnitudes to what has been observed elsewhere. For example, using the methods in BenMap, we found a concentration-response function for the relationship between PM2.5 elevation and asthma ER admissions for children of .0949 (.023), somewhat larger than the BenMap report, but in the same range. While these findings leave little doubt that there are short-term health effects of PM2.5 in the Valley, they also raise a number of additional points for consideration. In particular, our study time frame does not permit a full assessment of the impacts on long-term and short-term health effects of recent policy choices that have reduced PM2.5 levels. Further, there is room for more in-depth understanding of whether the observed city differences are best linked to the composition of fine particulate matter or health care system operational differences between the three urban areas.

The Impacts of Short-term Changes in Air Quality on Emergency Room and Hospital Use in California's San Joaquin Valley

John Amson Capitman, Ph.D.
Tim R. Tyner, MS

Published by:
Central Valley Health Policy Institute
Central California Center for Health and Human Services
College of Health and Human Services
California State University, Fresno

This publication was made possible by a grant from:
San Joaquin Valley Air Pollution Control District

June 2011

Introduction

A. Study Overview and Questions: In this project, the Central Valley Health Policy Institute, California State University, Fresno, and the Center for Clinical and Translational Research, UC San Francisco – Fresno, sought to build on prior efforts to understand the health effects of initiatives to reduce PM2.5 emissions and ozone in urban areas of the region. The study links data on concurrent PM2.5 and ozone levels and emergency department use and hospitalization associated with selected cardiovascular and respiratory conditions. A number of projects have addressed key scientific and policy questions about the health consequences of exposure to fine particulates and ozone in the San Joaquin Valley (Lighthall et al, 2008; Hall et al 2008), but they have relied on Central Valley exposure data and estimates of health effects from other communities to project the health consequences of current or potential exposure levels of concern to policy makers. These studies did not utilize actual experience in the Valley with its unique environmental, population and healthcare contexts to assess health impacts. Further, while the Lighthall study did project short-term health effects of reduction in PM2.5 associated with the wood burning rule, it did not address how short-term variations in ambient PM2.5 influence these health end-points in the context of the unique setting of the Valley. From the perspective of policy makers, this not only leaves room for doubt about the scale of health effects associated with initiatives to reduce PM2.5 levels, but also leaves open the question of whether policies should target potential causes of annual average PM2.5 levels or shorter-term fluctuations in these levels. In order to address some of these concerns, this study used California Office of Statewide Health Planning and Development (OSHPD) hospital and emergency room data linked to San Joaquin Valley Air Pollution Control District (SJVAPCD) monitoring data from Fresno/Clovis, Bakersfield and Modesto to address three related questions:

1. Are short-term increases in PM2.5 exposure during the cooler months in the San Joaquin Valley associated with respiratory and cardiovascular emergency department and hospital admissions?

2. Are short-term increases in ozone exposure during the warmer months in the San Joaquin Valley associated with respiratory and cardiovascular emergency department and hospital admissions?

3. Are there spatial (city) differences in how short-term increases in PM2.5 and ozone in the San Joaquin Valley are associated with respiratory and cardiovascular emergency department and hospital admissions?

B. Prior Research: Although there is extensive epidemiological data on the links between PM 2.5 and ozone exposure levels and health outcomes, most studies have focused on spatial variation in annual exposure to assess impacts.[i] A smaller number of studies have examined how shorter term variations in air pollution are linked to health in large populations served by specific health care systems or persons with established heart or respiratory conditions.[ii] Mann et al (2002) used data on hospitalizations for Kaiser Permanente members in the Southern California air basin for 1988-1995 and found that day-to-day variations in ischemic heart disease admissions were linked to daily levels of air pollution, although impacts varied based on the pollutant, secondary diagnoses and demographic patterns. Pope et al (2006) examined data for members of a cardiac catheterization registry serving Utah's Wasatch Front and found that PM 2.5 elevation was associated with increased risk for acute ischemic coronary events and this effect was most pronounced for persons with demonstrated coronary artery disease. [iii]

Studies have also examined the relationships between short-term variations in fine particulate matter and short-term variation in emergency room use and hospitalization within geographically defined populations. These studies consistently find that short-term variations in fine particulate matter are associated with cardiovascular and respiratory emergency room and hospital use and mortality.[iv] But a review of recent studies demonstrates that there is ongoing uncertainty about how these effects are moderated by the population and diseases, the composition of the fine particulate matter, and the lag time (time between fine particulate matter elevation and health outcome measurement) being considered.[v] For example, Belleudi and colleagues found that elevated levels of PM 2.5 were associated with increased emergency hospital admissions in Athens, Greece from 2001-2004.[vi] While there was an immediate effect on coronary admissions for older adults, the effect on respiratory admissions was delayed by several days. A related study by Samoli et al found that there were components of PM 2.5 (such as elemental carbon) that were most strongly linked to pediatric asthma admissions.[vii] An analysis of data from El Paso using similar methods, found that increasing PM 2.5 was associated with increasing daily mortality, with the effect most pronounced one day after the elevation in particulate matter. In a statewide study in New York, short-term elevations in fine particulate matter were associated with short-term increases in cardiovascular disease hospitalizations in communities near monitors. The effects were most pronounced for heart failure admissions on the day of elevated PM 2.5 for older adults.[viii] In another study focusing on older adults, Peng et al combined data on PM 2.5 levels in over 100 urban counties and Medicare hospital admissions data on over 12 million beneficiaries. They found that an interquartile range increase in elemental carbon was associated with 0.8% increase in same day cardiovascular admissions, while a similar increase in organic carbon was associated with 1.07% increase in respiratory admissions for the two-day lag. [ix]

Health effects of ozone exposure have also been studied extensively. As noted in a 2005, there is extensive support for short-term impacts of ozone on respiratory and cardiovascular admissions from studies in the US and abroad.[x] Most studies examine relationships between ozone and respiratory or cardiovascular morbidity for a quarter or longer, however, as in the Moore et al (2008) 18-year study in Southern California, where hospital admissions for asthma in children increased with increasing ozone exposure.[xi] But numerous studies have examined the relationships between ozone exposure and short-term health care use. For example, Linn et al (2008) used daily ozone levels and daily children's respiratory hospital admissions from 11 regions of New York over an 11-year period and found that higher daily ozone was associated with higher daily admissions at two day lag in 5 of the 11 regions, but not in a statewide model.[xii] Similarly, a study of nearly 400,000 ED visits to 14 hospitals in seven Canadian cities examined relationships between daily levels of multiple pollutants and meteorological conditions and visits for angina/myocardial infarction, heart failure, asthma, chronic obstructive pulmonary disease (COPD), and respiratory infections. At two day lag, ozone was consistently associated with increases in asthma and COPD visits during the warm season.[xiii] Evidence around ozone impacts on cardiovascular ER and hospital admissions has been more mixed,[xiv] and a recent study in Taipei indicates that population sub-groups with co-morbid hypertension and congestive heart failure show greater increases in daily risk of arrhythmia hospitalization in response to higher daily ozone levels.[xv]

With respect to San Joaquin Valley studies, at least three projects have added to the literature on PM 2.5 and ozone exposure health effects. In a prior study, Lighthall (2008), investigators showed that the San Joaquin Valley Air Pollution Control District (SJVAPCD) Rule 4901 that placed an AQI-triggered ban on residential wood burning contributed to an average annual daily PM 2.5 reduction of 13.63% in Fresno/Clovis and 12.94% in Bakersfield.[xvi] Using the U.S. EPA, BenMAP model, Lighthall et al estimated that had there been similar reductions in PM 2.5 in the years prior to rule implementation there would have been 35 (2001) to 85 (2002) fewer lives lost in Fresno/Clovis and from 18 (2003) to 48 (2002) fewer lives lost in Bakersfield. These data confirmed the utility of the SJVAPCD amendment of Rule 4901 in October 2008 to ban residential wood burning when the AQI is predicted to exceed 90. Similarly, Hall et al (2008) using the REHEX model projected that with attainment of the EPA PM 2.5 standard there would be 814 fewer premature deaths and 289 fewer cardiovascular and respiratory condition hospitalizations annually in the San Joaquin Valley. The models used in these studies address annual projected impacts of changes in levels of ambient PM 2.5 on cardiovascular and respiratory health-related end-points.

As part of the longitudinal Fresno Asthmatic Children Environment Study (FACES), Mann and her colleagues have been examining the effects of exposure to air pollutants on the long-term course of asthma in children. In a recent publication, they reported on how short-term variations in ambient concentrations of PM 2.5 effect self-reports of asthma symptoms (wheezing) and found that components of particulate matter were associated with increased symptoms after controlling for other exposure and child features.[xvii] Similarly, in a study funded by the SJVAPCD, Joseph et al found correlations between short-term ambient PM 2.5 levels and increasing respiratory symptoms (wheezing and dyspnea) in asthmatic subjects.[xviii] The study also reported an association between elevated ambient PM 2.5 and decreased lung function in both asthmatic and non-asthmatic subjects in the presence of an upper respiratory virus infection.

No prior studies in California or nationally have appeared to date in the literature that (1) examine impacts of daily variations in PM 2.5 across multiple communities with differing average exposure levels on cardiovascular and respiratory end-points for the community as a whole, and (2) that examine how spatial and temporal exposure gradients influence emergency room and hospitalization impacts on a population-adjusted basis. The proposed study utilized similar analytical techniques developed in the Mann et al and Pope et al studies, but applied these methods to a more inclusive population with additional health end-points.

Although this review of current studies does demonstrate that daily variations in PM2.5 and ozone exposure have been associated with elevated risks for asthma emergency room and hospital admissions and at least some evidence for temporal variation in particulate matter and ozone and exposure impacts on other health end-points, it is hard to sort out how differences in findings are influenced by differences in study design. At least four important variations in methods can be noted:

1) **Population definition:** The geographic and health system variations among selected populations are not well categorized in prior studies. Not all studies include children or adopt varied definitions of age groups. There is no specific theoretical frame for selecting area or population segments available in the literature. We began by examining populations defined by three urban areas separately because their patterns of PM2.5 and ozone exposure, population

demographics, and health systems while similar in comparison to other parts of California and nation, still showed some differences. We examine utilization outcomes for all persons within the study communities and for children (0-19) and adults (20+ or 20-54 and 55+) separately. One of the rationales for selecting these age bands was because California health policies provided enhanced access to primary care for children 0-18. For respiratory ER visits, we excluded patients < 1 year old due to the high number of RSV and other infections associated with visits within these diagnoses.

Preliminary analyses suggest that there may be insufficient statistical power in the separate city analyses for several of the health outcomes examined (particularly in the lowest exposure days) and this may limit the reliability of these analyses. Combined data from the three cities involved larger samples and more variability in exposure, thus these analyses are presented first (regional analysis). Because of the keen interest in city-specific outcomes, we also present and discuss the individual city findings.

2) **Lag times:** Prior studies adopted varied numbers of days between elevations in exposure and measurement of health care utilization---the lag time between exposure and health status change resulting in emergency room or hospital in-patient use. The lag time between exposure and use may be determined by exposure characteristics, individual vulnerability, and health system factors that have not been well characterized. We examine utilization for the same day and 1, 2, and 3 days subsequent ("1 day lag" etc.) for both ER and in-patient admissions end-points in the regional analysis because it is unclear from prior literature at which lag time health effects are most likely to be pronounced and for which condition. We also examine same day and 1, 2, and 3 day lags for the individual city analyses to allow the possibility that variations between the three urban areas in the composition of air pollution, other meteorological conditions, ambulatory care access and quality, and demographics may all impact the relationships between temporal variations in PM2.5 and ozone, health effects of air quality and health care use.

3) **Exposure gradient categorization:** PM2.5 and ozone exposure gradients are most often categorized in quartiles, but also used continuously in prior studies. There is no specific framework for linking exposure variations to health effects or for separating the effects of variations in long-term baseline exposure. We established quintiles of exposure (for PM2.5 and ozone) as a better reflection of the exposure distribution, with the lowest quintile representing a baseline level for relative risk comparisons.

4) **Effect metric:** Depending on how the exposure gradient is categorized, alternative measures of the temporal effects of differences in PM2.5 or ozone are considered, with the inter-quartile range (IQR) being most common. The IQR only compares average use levels at two points in the distribution and does not test the linear trend (e.g. increasing exposure in relation to use). We examined differences between each quintile and the linear trend across all quintiles in a Poisson regression that

also controlled for meteorological and other environmental covariates.

Methods

A. Overview of design: We conducted a comparative, longitudinal, population study of the correlation between daily air quality (PM2.5 and ozone) and daily emergency room and in-patient hospital admissions for respiratory and cardiovascular conditions. We used zip code-level population data and identified the most compact set of contiguous zip codes whose geographic centroids were within 6 miles of the Fresno, Bakersfield and Modesto air quality monitors with a population in 2005 of about 300,000. We considered emergency department (ER) admissions to all hospitals in the three urban areas for 2005-2007 and in-patient admissions to all hospitals for 2002-2007. Individual-level data on ER use prior to 2005 was not available. Our dependent variables were counts of admissions (within specific respiratory and cardiovascular diagnoses for children and adults) and our independent variables were quintiles of exposure. Because of the count dependent variable, we used Poisson regression controlling for meteorological conditions and other environmental and temporal factors to assess differences in health care use at increasing levels of exposure.

B. Defining the study communities: We focused this analysis on the three largest urban areas in the central San Joaquin Valley. We sought to define populations of similar size – approximately 300,000 in 2005 – within close proximity to the SJVAPCD air quality monitors providing data on both PM2.5 and ozone for Fresno, Modesto and Bakersfield. Because the OSHPD ER and in-patient admissions data are geo-coded by zip code, we used the geographic proximity of zip code centers to locate population groups (the exposed population) in relation to the monitors. We examined the population size in 2005 for each zip-code with a geographic centroid less than 6 miles from the air quality monitor. We selected the most compact set of contiguous zip codes that met the population size objective. For Modesto, the largest population we could define that met these criteria was less than 300,000 people. The Modesto study area with a population of 221,000 is also geographically larger than for Fresno and Bakersfield. However, by examining 2005 census tracks, we found that at least 90% of the persons in each of the three study areas lived within 6 miles of the air quality monitor (Figure 1).

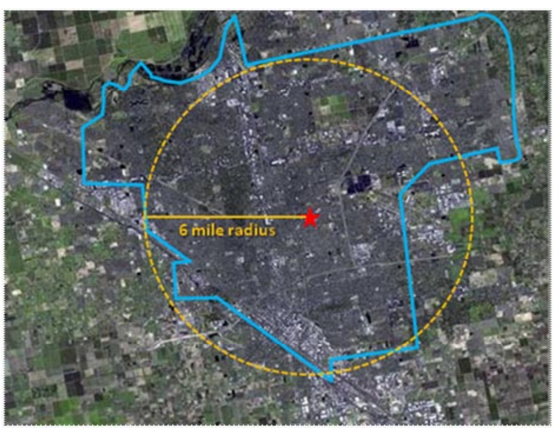
Table 1: Demographics by City and Region

	Total Population	Median Income	Percent 0-19 yrs	Percent > 55 yrs	Percent Hispanic
MODESTO	221,315	$43,786	32.6%	18.9%	35.5%
FRESNO	321,036	$36,791	33.5%	18.8%	41.9%
BAKERSFIELD	323,488	$47,301	35.4%	15.8%	41.2%
REGIONAL (combined)	865,839	$42,488	33.9%	17.7%	40.0%

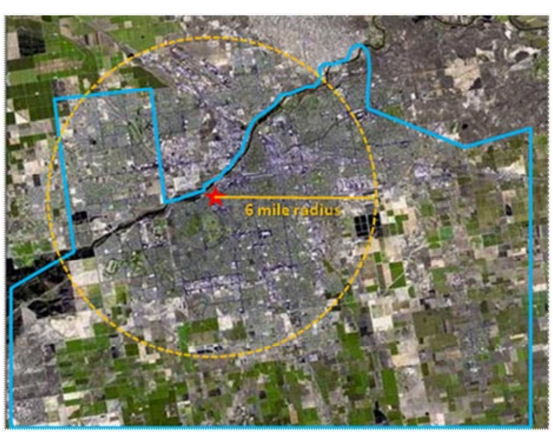
Figure 1: Geographic Study Area

Modesto

Fresno



Bakersfield



The three study communities, like all of the San Joaquin Valley, were generally younger, more Latino, and lower income than California as a whole. As shown in Table 1, there were also differences between communities, with Fresno having a lower median income, Modesto a lower proportion Latino and Bakersfield a lower proportion of elderly (over 55) compared to the other two communities.

C. Measuring exposure and meteorological conditions: We used data from the SJVAPCD monitors in Fresno, Bakersfield and Modesto to assess PM2.5 and ozone. We examined daily PM2.5 measured in micrograms per cubic meter (ug/m3) and 8 hour max ozone in parts per billion. We also included as covariates, daily maximum levels of two other pollutants, carbon monoxide (CO) and nitrogen dioxide (NO2).

We obtained data on daily meteorological conditions from The California Irrigation Management Information System (CIMIS). We included daily maximum temperature and daily average relative humidity.

D. Measuring Hospital Emergency Department and In-Patient Utilization: While we do not have a direct measure of the health burden associated with air pollution, indicators of emergency department (ER) and in-patient hospital admissions offer a strong proxy measure. In a sense, these utilization measures reflect the most extreme indications of health effects: individuals with less severe responses to short-term changes in air quality may successfully manage a disease exacerbation on their own or be able to use primary care resources. We obtained individual level ER (2005-2007) and in-patient admissions (2002-2007) records from the California Office of Statewide Health Planning and Development (OSHPD) with all individual identifiers masked. We developed for the region and each of the three study areas, daily counts of admissions within diagnostic codes and age group, including each of the dependent measures shown below. Note that we did not examine ER admissions for acute myocardial infarction or congestive heart failure, since almost all result in hospitalization and the hospital data represented more years and were thus more reliable. Similarly, we did not examine chronic obstructive pulmonary disease (COPD), acute myocardial infarction (AMI), or congestive heart failure (CHF) for 0-19 age group since these are almost exclusively adult events.

OSHPD ICD-9 Categories

ER Admissions (2005-2007)	**Hospital Admissions (2002-2007)**
RESPIRATORY	
Asthma (ICD-9: 493) (Ages: 1-19, 20+) Pneumonia (ICD-9: 480-486) (Ages: 1-19, 20+) Acute Bronchitis (ICD-9: 466) (Ages: 1-19, 20+)	Asthma (ICD-9: 493) (Ages: 0-19, 20-54, 55+) Pneumonia (Ages: 0-19, 20-54, 55+) COPD (ICD-9: 490-496 w/o 493) (Ages: 20+)
CARDIOVASCULAR	
	Acute Myocardial Infarction (ICD-9: 410) (Ages: 20+) Congestive Heart Failure (ICD-9: 428) (Ages: 20+)

E. Analysis: Data were initially divided into cool season (Oct-Mar) for PM2.5 analysis and warm season (Apr-Sep) for ozone analysis. Descriptive analyses were conducted first to examine regional patterns and how the three urban areas differ in patterns of exposure and utilization, as well as the relationships between PM2.5 or ozone and other pollutants and meteorological indicators. For the primary regional analyses, we used Poisson regression general linear modeling (the most appropriate multivariate method for event or count dependent measures) to examine how quintiles of increasing PM2.5 or ozone were linked to health care use outcomes, controlling for other factors, including co-pollutants (carbon monoxide and nitrogen dioxide), meteorological variables (temperature and relative humidity) and temporal factors (day of week and holidays). We compared counts of events between days falling in each quintile in relation to days in the lowest (or baseline) quintile and linear trends across quintiles of exposure in each city. We evaluated models for each dependent measure for the same day and 1, 2, and 3 day exposure lags.

In preliminary analyses, we examined whether or not regional analyses could be justified. Even if overall levels of exposure and use differed among the three study communities, it is possible that the relationships between exposure and health care use (what is sometime called the “concentration-response function” or “health impact function”) do not and thus, the three cities might be combined for analysis. We tested this by introducing measures of city and the interaction of city and exposure quintiles into the same models described above. In every case, although we did find main effects for city, we did not find statistically significant interactions between city and exposure quintile, indicating that there were no significant city differences in the concentration-response functions (results of these analyses are available upon request). These analyses, however, also confirmed that rates of health care use and exposure were higher in Fresno for most conditions. Acknowledging differences in exposure patterns and demographics among the three urban areas, we also conducted analyses just as those described for the region for the three urban areas separately. Some caution should be exercised in interpreting the individual cities analyses, however, because of smaller sample sizes and thus less statistical power in assessing the relationships between exposure and short-term morbidity.

During our ozone analysis (warm season), we discovered what we interpreted to be a data artifact resulting in a significant association between temperature and asthma ER visits. We hypothesized that environmental factors (e.g. bioallergens) thought to strongly influence asthma ER visit rates during the spring months (April and May) were in part responsible for this artificial relationship between temperature and asthma ER visits (see Section III.B.3). As ozone and temperature are highly correlated during the warm season, the artificial relationship between temperature and asthma ER visits drastically confounded the ozone findings. In an effort to correct for this inaccuracy, we reduced our ozone season to only three months (June-August), which effectively eliminated the relationship between temperature and asthma ER visits, but did not significantly reduce the variability in daily ozone levels. The relative risk findings for ozone are thus representative of the three summer months (hot season) and not the six-month warm season.

Findings

We first present findings on the health effects for the region and then for the individual cities for PM2.5 and ozone, separately.

In general, our findings show that asthma ER admissions are strongly linked to increasing PM2.5 across the region, with a higher risk in children. ER admissions for asthma in children are also associated with PM2.5 in each of the three cities, but associations in adults were only seen in Fresno. Risk for asthma hospitalizations also increased with PM2.5 in children and adults across the region, but the city analysis revealed associations only for children in Fresno and for adults in Bakersfield. While risk for acute MI hospital admissions were also linked to PM2.5 levels regionally, no associations were found at the city level. Weaker associations with PM2.5 were found for regional pneumonia ER visits in children, with the strongest correlation in Bakersfield and to a lesser degree in Modesto. Acute bronchitis ER visits in adults were also moderately linked to PM2.5 at the regional level, while city analysis showed significant correlations only for children in Bakersfield. Hospital admissions for other respiratory and cardiovascular conditions were not linked to PM2.5 levels in consistent ways across the region or within individual cities.

Regionally, ozone was found to be strongly linked to increased risk for asthma ER visits in children, but only mildly so in adults. A mild association between ozone and asthma ER visits in children was also seen in Fresno and Modesto but not Bakersfield. City-level ozone findings, however, were less reliable due to the smaller sample size, resulting from both the geographic (city only) and temporal (June-August) restrictions. No associations were found between ozone and hospital admissions for COPD, pneumonia or acute MI either regionally or at the city level.

FINE PARTICULATE MATTER AND COOL SEASON HEALTH EFFECTS

A: Patterns of PM2.5 Exposure: Tables 2-3 and Figure 2 present information on PM2.5, other pollutants and meteorological conditions for the three cities and the region. Figure 2 shows the distribution of PM2.5 across the three cities and the range of concentrations within each of the quintiles. These quintiles were used for regional and city analyses of PM2.5 health effects. As shown in Table 2, for the region as a whole, 45.1% of the days exceeded the 2006 PM2.5 National Ambient Air Quality Standard (NAAQS). While Fresno and Bakersfield have similar mean daily PM2.5 across the 6-year study period, the mean level is lower in Modesto. Because of the higher average PM2.5 concentrations, Fresno and Bakersfield also have more days that exceed the NAAQS (34.8% and 33.9%, respectively) than does Modesto (19.4%). Similarly, in Table 3, while the lowest or baseline quintile PM2.5 concentrations in Fresno and Bakersfield are up to 14.5 (ug/m3) and 13.9 (ug/m3), respectively, the baseline in Modesto is at 9.6 (ug/m3) and below.

Table 2: Mean Daily Concentrations and NAAQS Exceedances of Environmental Covariates by City and Region

COOL SEASON 2002 - 2007 mean (stdev)	PM2.5 (daily avg)	% days over federal PM2.5 health std (35 ug/m3)	NO2 (daily max)	CO (daily max)	Temperature (daily max)	Relative Humidity (daily avg)
Modesto	23.4 (6.9 - 39.9)	19.4%	.031 (.020 - .042)	1.42 (0.40 - 2.45)	63.1 (53.5 - 72.7)	78.3 (65.6 - 91.0)
Fresno	31.0 (12.7 - 49.2)	34.8%	.040 (.026 - .053)	1.57 (0.52 - 2.62)	64.4 (54.0 - 74.8)	71.7 (59.0 - 84.4)
Bakersfield	30.8 (11.3 - 50.4)	33.9%	.040 (.028 - .053)	1.43 (0.78 - 2.09)	66.4 (55.9 - 76.9)	76.2 (62.2 - 90.3)
REGIONAL	28.5 (10.0 - 47.1)	45.1%	.037 (.024 - .050)	1.48 (0.54 - 2.41)	64.6 (54.4 - 74.9)	75.4 (62.0 - 88.9)
WARM SEASON 2002 - 2007 mean (stdev)	**OZONE (8 hr max)**	**% days over federal O3 health std (75 ppb)**	**NO2 (daily max)**	**CO (daily max)**	**Temperature (daily max)**	**Relative Humidity (daily avg)**
Modesto	53.0 (39.2 - 66.9)	6.9%	.024 (.012 - .035)	0.47 (0.13 - 0.82)	83.3 (73.8 - 92.9)	59.8 (49.6 - 69.9)
Fresno	67.6 (51.0 - 84.2)	31.7%	.027 (.014 - .039)	0.48 (0.16 - 0.81)	87.4 (76.5 - 98.4)	46.1 (35.4 - 56.7)
Bakersfield	68.6 (52.7 - 84.4)	33.5%	.038 (.022 - .054)	0.72 (0.31 - 1.14)	88.8 (78.9 - 98.6)	54.9 (45.6 - 64.2)
REGIONAL	63.0 (46.0 - 80.1)	38.8%	.031 (.016 - .046)	0.55 (0.18 - 0.91)	86.5 (76.1 - 96.9)	53.6 (42.0 - 65.1)

Figure 2: Frequency of Days per PM2.5 Quintile Range During Cool Season (2002 – 2007)

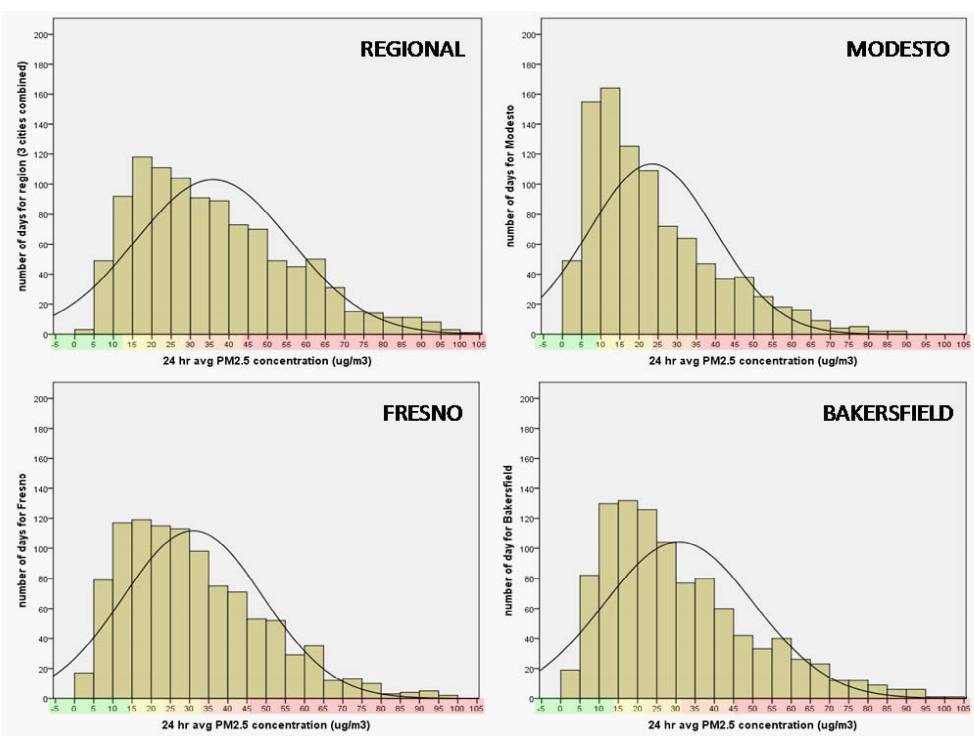


Table 3: PM2.5 Quintile Concentration Range (ppb) by City and Region During Cool Season (2002-2007)

PM2.5 Quintiles	Regional	Modesto	Fresno	Bakersfield
Q5	43.4+	36.3+	46.3+	45.6+
Q4	29.1 - 43.3	23.0 - 36.2	32.6 - 46.2	31.9 - 45.5
Q3	20.1 - 29.0	15.3 - 22.9	22.8 - 32.5	21.9 - 31.8
Q2	12.4 - 20.0	9.6 - 15.2	14.6 - 22.7	14.0 - 21.8
Q1	<= 12.3	<= 9.5	<= 14.5	<= 13.9

B: Emergency Room and Hospital Admissions for Respiratory and Cardiovascular Conditions During the Cool Season: Table 4 shows the average daily ER admissions for asthma, pneumonia, and acute bronchitis, highlighting the smaller daily rates and larger standard deviations for the three separate cities relative to the combined regional values. Differences between the cities in population size and, as shown in Table 5, utilization rates/100,000, help explain these differences. Table 5 also points to differences by disease, age group and city in ER use for respiratory conditions. Tables 6 and 7 examine average daily hospital admissions for respiratory and cardiovascular conditions. Mean daily admissions again suggest city, condition, and age group variations. Children overall are at higher risk for asthma hospitalization, especially in Fresno. Fresno adult ER asthma admissions are also higher than for the other cities. Fresno also has higher rates of acute MI (heart attack). Modesto residents are at greater risk for pneumonia ER and hospital use at each age level and for higher acute bronchitis ER admissions for both children and adults. COPD rates are also highest in Modesto.

Table 4: Mean Daily Respiratory ER Visits During Cool Season by City and Region for 1-19 and 20+ yrs old

ER Visits	1-19 yrs		20+ yrs	
asthma	mean	stdev	mean	stdev
MODESTO	1.16	0.08 - 2.24	1.67	0.38 - 2.97
FRESNO	3.09	1.23 - 4.95	3.21	1.30 - 5.12
BAKERSFIELD	2.51	0.81 - 4.20	1.86	0.46 - 3.25
REGIONAL	6.76	3.94 - 9.58	6.74	3.94 - 9.54
pneumonia				
MODESTO	1.40	0.05 - 2.76	1.49	0.15 - 2.82
FRESNO	1.60	0.00 - 3.19	1.26	0.11 - 2.40
BAKERSFIELD	1.72	0.23 - 3.21	1.87	0.37 - 3.38
REGIONAL	4.72	1.67 - 7.77	4.61	2.11 - 7.12
acute bronchitis				
MODESTO	1.09	0.00 - 2.40	1.56	0.00 - 3.16
FRESNO	0.87	0.00 - 1.95	2.13	0.50 - 3.75
BAKERSFIELD	1.16	0.00 - 2.38	1.06	0.00 - 2.20
REGIONAL	3.11	0.85 - 5.37	4.74	2.02 - 7.46

Table 5: Daily Respiratory ER Visit Rates (mean visits/100,000) During Cool Season by City for 1-19 and 20+ yrs old

Average Number of ER Visits per Day During "Cool Season" from 2005-2007 mean (stdev) per 100,000 total population (not age adjusted)				
Age Group	**Zip code communities**	**asthma**	**pneumonia**	**acute bronchitis**
1-19 yrs old	Modesto	0.55 (0.04-1.06)	0.66 (0.02-1.30)	0.51 (-0.11-1.13)
	Fresno	0.96 (0.38-1.54)	0.50 (0.00-0.99)	0.27 (-0.07-0.61)
	Bakersfield	0.78 (0.25-1.30)	0.53 (0.07-0.99)	0.36 (-0.02-0.74)
20+ yrs old	Modesto	0.79 (0.18-1.40)	0.70 (0.07-1.33)	0.74 (-0.02-1.49)
	Fresno	1.00 (0.40-1.60)	0.39 (0.04-0.75)	0.66 (0.16-1.17)
	Bakersfield	0.57 (0.14-1.01)	0.58 (0.11-1.05)	0.33 (-0.03-0.68)

Table 6: Mean Daily Respiratory and Cardiovascular Hospitalizations During Cool Season by City, Region, Age Group and Payer

HOSPITALIZATIONS	ALL		PUBLIC PAYERS		PRIVATE PAYERS		0-19 YRS OLD		20-54 YRS OLD		55+ YRS OLD	
asthma	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev
MODESTO	0.86	0.94	0.38	0.60	0.48	0.72	0.34	0.61	0.23	0.48	0.28	0.54
FRESNO	1.51	1.27	0.98	1.03	0.53	0.73	0.89	1.00	0.33	0.59	0.30	0.54
BAKERSFIELD	1.10	1.12	0.50	0.72	0.59	0.80	0.44	0.69	0.33	0.61	0.33	0.59
REGIONAL	3.46	2.02	1.87	1.46	1.60	1.31	1.66	1.41	0.90	0.98	0.91	1.00
pneumonia												
MODESTO	3.44	2.12	1.03	1.09	2.41	1.68	0.79	0.98	0.53	0.75	2.12	1.54
FRESNO	3.96	2.43	1.22	1.27	2.74	1.85	0.71	1.00	0.77	0.89	2.49	1.78
BAKERSFIELD	4.33	2.55	1.28	1.34	3.05	1.94	1.17	1.33	0.76	0.88	2.41	1.72
REGIONAL	11.73	5.02	3.53	2.49	8.20	3.56	2.68	2.31	2.06	1.52	7.02	3.24
COPD												
MODESTO	1.13	1.08	0.24	0.51	0.88	0.95						
FRESNO	1.14	1.16	0.25	0.50	0.90	1.03						
BAKERSFIELD	1.17	1.13	0.25	0.52	0.92	0.96						
REGIONAL	3.44	2.04	0.74	0.89	2.70	1.77						
acute MI												
MODESTO	1.00	1.02	0.16	0.39	0.84	0.94						
FRESNO	1.83	1.37	0.23	0.47	1.61	1.28						
BAKERSFIELD	1.39	1.19	0.14	0.36	1.25	1.12						
REGIONAL	4.22	2.10	0.52	0.70	3.70	1.99						
CHF												
MODESTO	1.83	1.42	0.35	0.61	1.49	1.26						
FRESNO	2.65	1.70	0.49	0.71	2.16	1.51						
BAKERSFIELD	2.55	1.60	0.49	0.70	2.06	1.46						
REGIONAL	7.03	2.82	1.32	1.13	5.71	2.55						

Table 7: Daily Hospitalization Rates (per 100,000) for Respiratory and Cardiovascular Disease During Cool Season by City and Age Group

Average Number of Hospitalizations per Day During "Cool Season" from 2002 - 2007 mean (stdev) per 100,000 total population (not age adjusted)						
age group	zip code community	asthma	pneumonia	COPD	MI	CHF
0-19 yrs old	Modesto	0.16 (0.00 - 0.45)	0.37 (0.00 - 0.84)			
	Fresno	0.28 (0.00 - 0.59)	0.22 (0.00 - 0.53)			
	Bakersfield	0.14 (0.00 - 0.35)	0.36 (0.00 - 0.78)			
20-54 yrs old	Modesto	0.11 (0.00 - 0.33)	0.25 (0.00 - 0.60)			
	Fresno	0.10 (0.00 - 0.29)	0.24 (0.00 - 0.52)			
	Bakersfield	0.10 (0.00 - 0.29)	0.24 (0.00 - 0.51)			
55+ yrs old	Modesto	0.13 (0.00 - 0.39)	1.00 (0.27 - 1.72)			
	Fresno	0.09 (0.00 - 0.26)	0.78 (0.22 - 1.33)			
	Bakersfield	0.10 (0.00 - 0.28)	0.74 (0.21 - 1.28)			
all ages	Modesto	0.40 (0.00 - 0.85)	1.62 (0.62 - 2.62)	0.53 (0.02 - 1.04)	0.47 (0.00 - 0.95)	0.87 (0.20 - 1.53)
	Fresno	0.47 (0.07 - 0.87)	1.23 (0.48 - 1.99)	0.36 (0.00 - 0.72)	0.57 (0.15 - 1.00)	0.83 (0.30 - 1.35)
	Bakersfield	0.34 (0.00 - 0.69)	1.34 (0.55 - 2.13)	0.36 (0.01 - 0.71)	0.43 (0.06 - 0.80)	0.79 (0.29 - 1.28)

C: PM2.5-Associated Respiratory Condition Emergency Room Admissions: Table 8 examines regional patterns relating increasing PM2.5 to asthma, pneumonia and acute bronchitis ER admissions. The table shows for each ER diagnostic condition and age group (1-19 and 20+ yrs old) the relative risk (RR) of an ER admission for each exposure quintile relative to the lowest (baseline) quintile. Also included in the table is the 95% confidence interval for the relative risk, the significance (p value) of the difference between each quintile and the baseline, and the linear trend in relative risk of ER admission with increasing PM2.5 (shown vertically). The test of the linear trend in the relationships between ambient PM2.5 concentrations (controlling for other pollutants, weather and holidays) and health events is the most clear assessment of the health effects of increasing exposure, with statistically significant linear trends indicating a strong concentration-response (CR) function.

As shown in Table 8, for asthma in both children and adults, there are significant differences between quintiles of increasing exposure, as well as significant linear trends in asthma ER admissions on the same day as the PM2.5 exposure and for 1, 2, and 3 day lags. Further, for those 1-19 years old, there are increasing pneumonia admissions associated with elevated PM2.5. Conversely, only adults appear to experience increased risks for acute bronchitis admissions in relation to increasing PM2.5 concentrations. Figures 3a – 3f graphically present these respiratory ER/PM2.5 relationships for both children and adults, further highlighting the correlation between asthma and PM2.5 across the region, particularly among children.

Findings from the analysis of respiratory ER admissions by city are available in Appendix Tables I-1 through I-4. In the smaller populations available for the individual city analyses, there is still evidence for PM2.5 short-term health effects. The analyses show that child asthma

Table 8: Relative Risk for PM2.5-Associated Respiratory ER Visit by Disease and Age Group for the Region

REGIONAL ER		ASTHMA_1-19 yrs				ASTHMA_20+ yrs				PNEUMONIA_1-19 yrs				PNEUMONIA_20+ yrs				ACUTE BRONCHITIS_1-19 yrs				ACUTE BRONCHITIS_20+ yrs			
LAG	Q	RR	95% CI	SIG	linear sig	RR	95% CI	SIG	linear sig	RR	95% CI	SIG	linear sig	RR	95% CI	SIG	linear sig	RR	95% CI	SIG	linear sig	RR	95% CI	SIG	linear sig
LAG 0	Q5	1.47	1.28 - 1.68	.000	0.000000	1.16	1.02 - 1.32	.025	0.007228	1.19	1.02 - 1.39	.026	0.003418	0.85	0.72 - 0.99	.039	0.229934	1.13	0.94 - 1.37	.190	0.567933	1.06	0.91 - 1.24	.426	0.378914
	Q4	1.41	1.25 - 1.59	.000		1.10	0.98 - 1.24	.120		1.18	1.03 - 1.35	.021		1.00	0.87 - 1.15	.997		0.97	0.81 - 1.15	.688		1.00	0.87 - 1.15	.990	
	Q3	1.22	1.08 - 1.37	.001		1.04	0.93 - 1.16	.491		1.03	0.90 - 1.18	.625		0.97	0.85 - 1.10	.610		1.02	0.86 - 1.20	.851		1.01	0.89 - 1.15	.870	
	Q2	1.15	1.02 - 1.29	.020		0.98	0.88 - 1.09	.726		0.99	0.86 - 1.12	.825		0.89	0.97 - 1.02	.085		1.09	0.84 - 1.28	251		0.97	0.85 - 1.10	.593	
	Q1	1.00				1.00				1.00				1.00				1.00				1.00			
LAG 1	Q5	1.45	1.26 - 1.66	.000	0.000000	1.30	1.15 - 1.49	.000	0.000026	1.20	1.03 - 1.40	.017	0.020391	0.89	0.76 - 1.04	.133	0.325486	1.05	0.87 - 1.26	.633	0.889078	1.13	0.97 - 1.31	.115	0.119200
	Q4	1.38	1.22 - 1.56	.000		1.17	1.04 - 1.32	.008		1.14	0.99 - 1.31	.069		1.02	0.89 - 1.17	.784		0.86	0.73 - 1.02	.088		0.99	0.86 - 1.13	.874	
	Q3	1.27	1.13 - 1.43	.000		1.17	1.05 - 1.31	.006		1.00	0.88 - 1.15	.951		1.00	0.87 - 1.14	.971		0.88	0.75 - 1.03	.115		0.91	0.80 - 1.04	.148	
	Q2	1.10	0.98 - 1.24	.106		1.05	0.94 - 1.18	.349		1.09	0.96 - 1.24	.183		0.96	0.84 - 1.09	.522		0.97	0.83 - 1.13	.710		0.96	0.84 - 1.08	.482	
	Q1	1.00				1.00				1.00				1.00				1.00				1.00			
LAG 2	Q5	1.49	1.30 - .171	.000	0.000000	1.28	1.13 - 1.46	.000	0.000498	1.07	0.92 - 1.25	.370	0.729568	0.98	0.84 - 1.14	.809	0.533831	1.17	0.98 - 1.41	.090	0.044104	1.28	1.10 - 1.49	.001	0.001912
	Q4	1.41	1.25 - 1.59	.000		1.08	0.96 - 1.22	.205		1.05	0.91 - 1.21	.507		0.90	0.78 - 1.03	.132		1.02	0.86 - 1.21	.792		1.13	0.99 - 1.30	.078	
	Q3	1.27	1.13 - 1.43	.000		1.11	0.99 - 1.25	.064		1.06	0.93 - 1.22	.359		0.96	0.84 - 1.10	.552		0.96	0.82 - 1.13	.621		1.15	1.01 - 1.31	.041	
	Q2	1.09	0.97 - 1.22	.168		1.05	0.94 - 1.17	.373		1.13	1.00 - 1.29	.053		0.97	0.85 - 1.10	.597		0.91	0.78 - 1.07	240		1.08	0.95 - 1.22	.262	
	Q1	1.00				1.00				1.00				1.00				1.00				1.00			
LAG 3	Q5	1.47	1.29 - 1.68	.000	0.000000	1.29	1.14 - 1.47	.000	0.000079	1.20	1.03 - 1.40	.017	0.011161	0.81	0.70 - 0.95	.008	0.040684	1.09	0.90 - 1.31	.375	0.387801	1.25	1.08 - 1.45	.004	0.003417
	Q4	1.51	1.34 - 1.71	.000		1.19	1.05 - 1.34	.005		1.17	1.02 - 1.34	.029		0.84	0.73 - 0.96	.012		1.03	0.87 - 1.23	.706		1.13	0.99 - 1.30	.081	
	Q3	1.23	1.09 - 1.38	.001		1.14	1.02 - 1.28	.022		1.14	1.00 - 1.30	.057		0.89	0.78 - 1.01	.079		1.05	0.89 - 1.23	.571		1.03	0.90 - 1.18	.704	
	Q2	1.11	0.99 - 1.25	.079		1.09	0.98 - 1.22	.126		1.08	0.95 - 1.23	.261		0.80	0.71 - 0.91	.001		1.01	0.86 - 1.19	.872		1.06	0.93 - 1.20	.401	
	Q1	1.00				1.00				1.00				1.00				1.00				1.00			

Figure 3a: Relative Risk for PM2.5-Associated Asthma ER a Visit for 1-19 yrs old for the Region

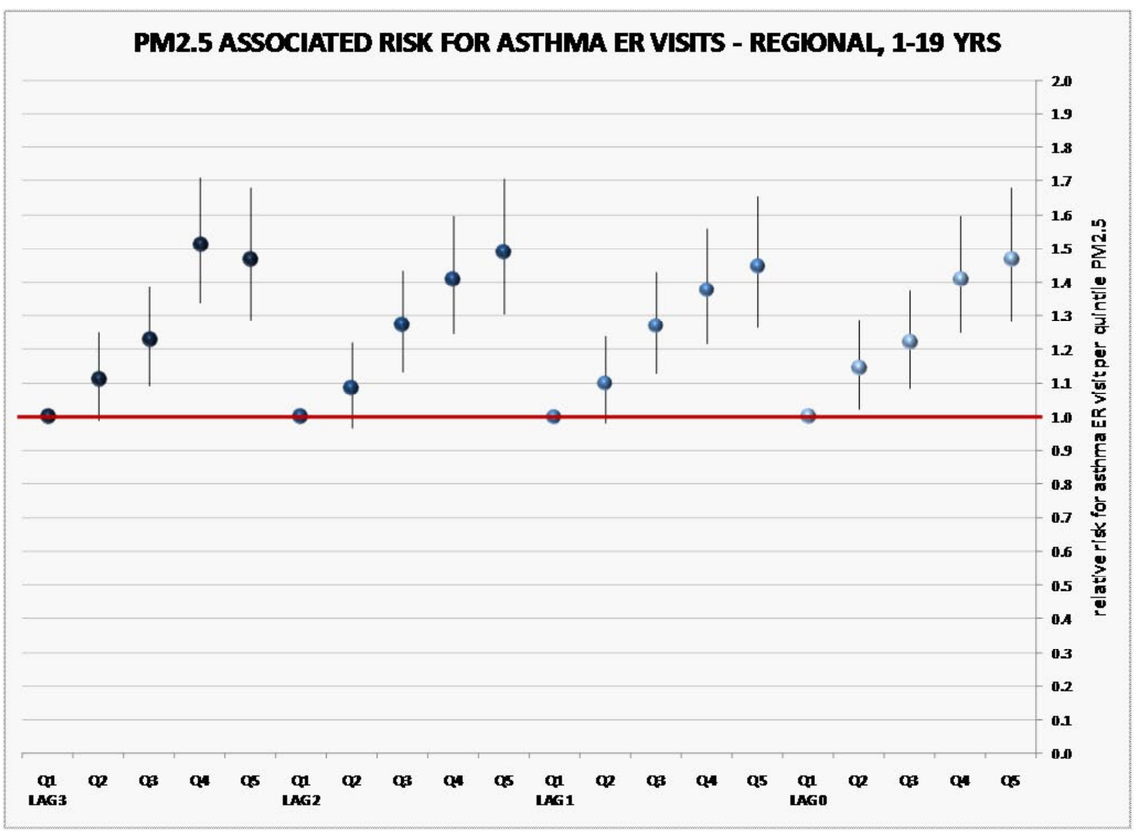


Figure 3b: Relative Risk for PM2.5-Associated Asthma ER Visit for 20+ yrs old for the Region

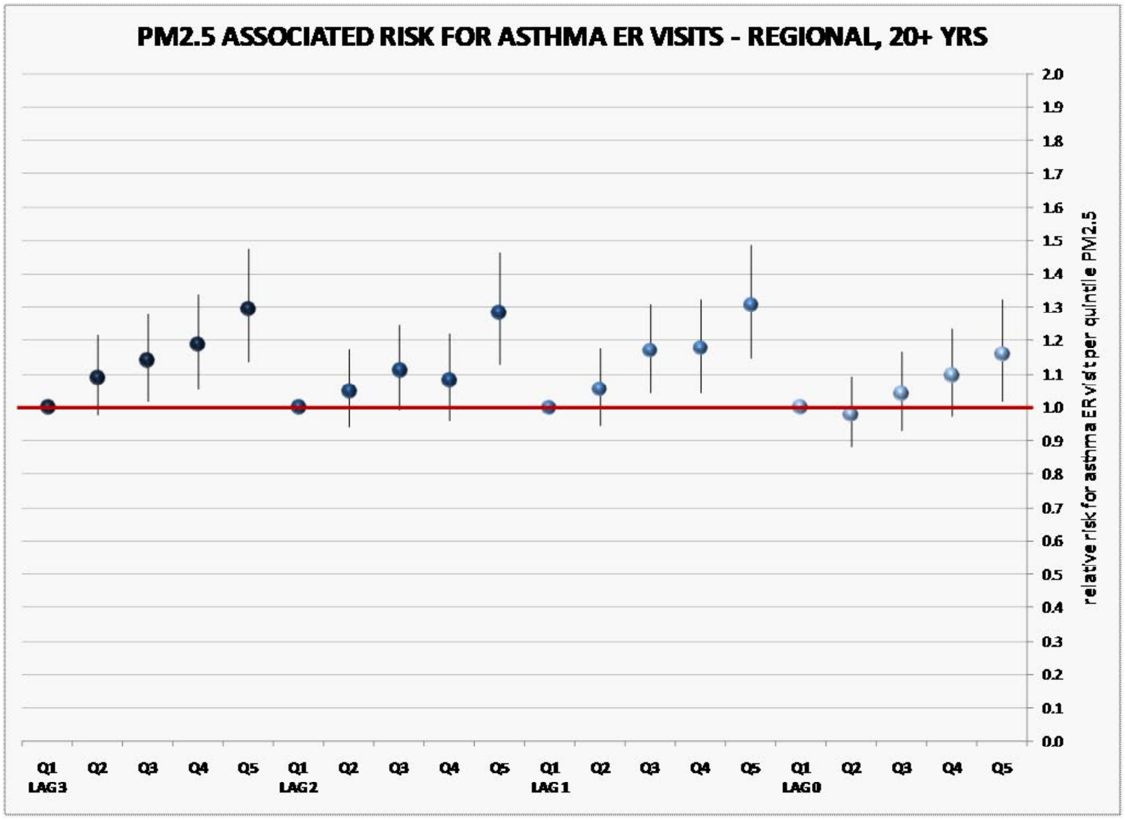


Figure 3c: Relative Risk for PM2.5-Associated Pneumonia ER Visit for 1-19 yrs old for the Region

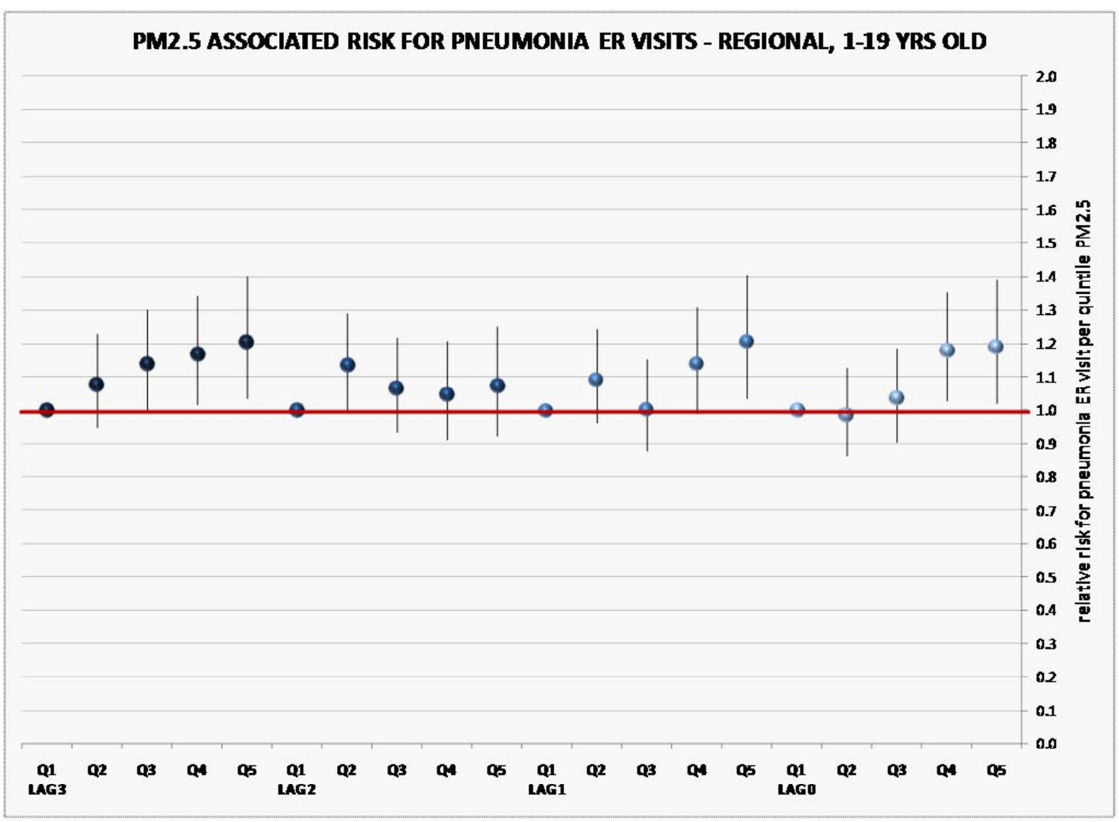


Figure 3d: Relative Risk for PM2.5-Associated Pneumonia ER Visit for 20+ yrs old for the Region

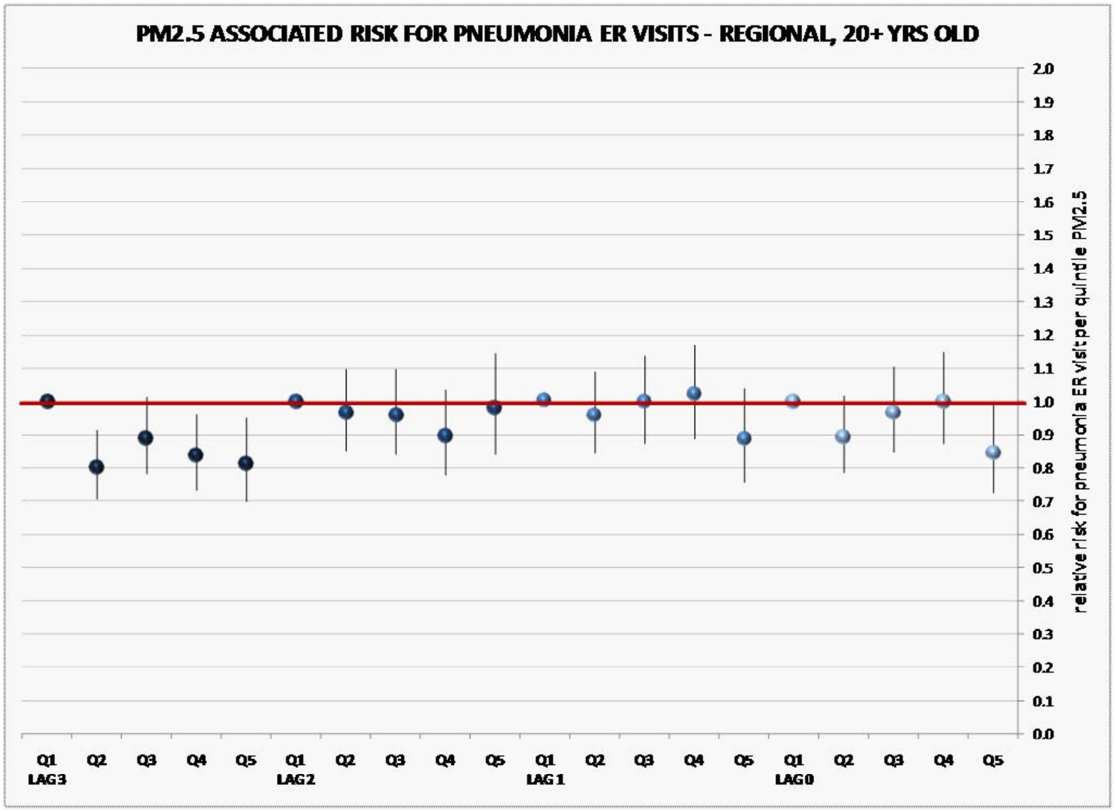


Figure 3e: Relative Risk for PM2.5-Associated Acute Bronchitis ER Visit for 1-19 yrs old for the Region

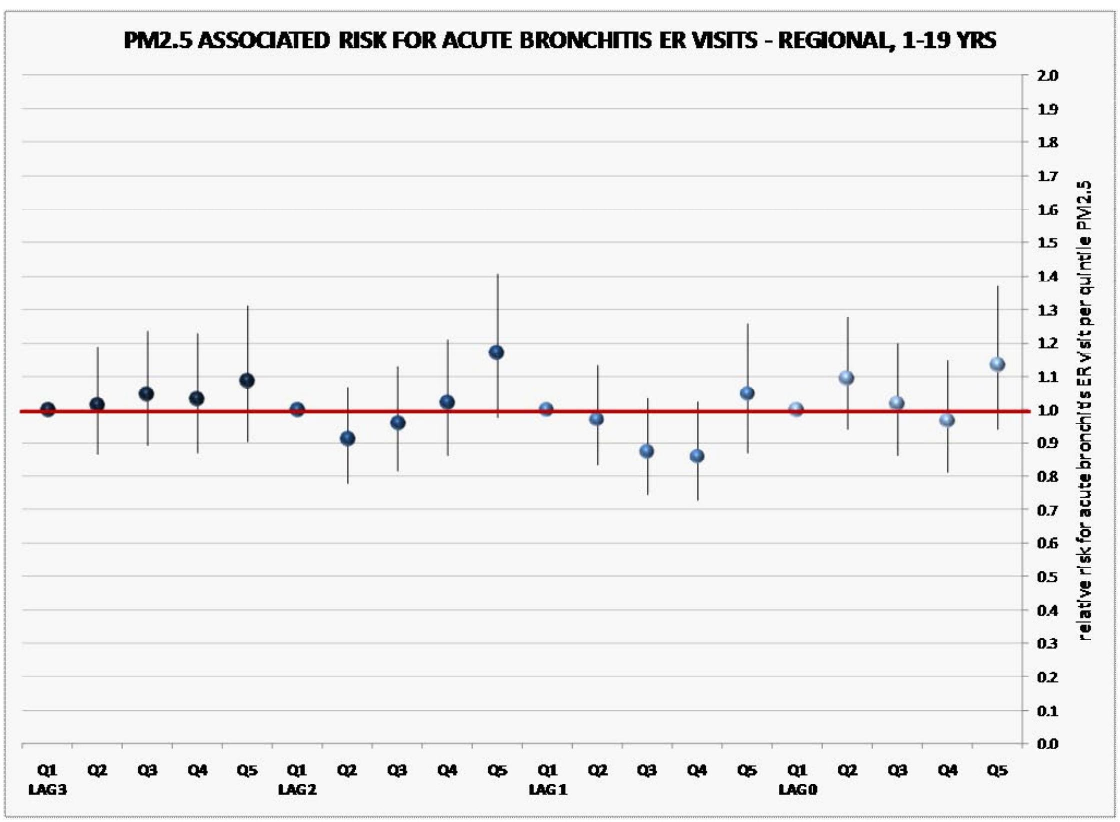
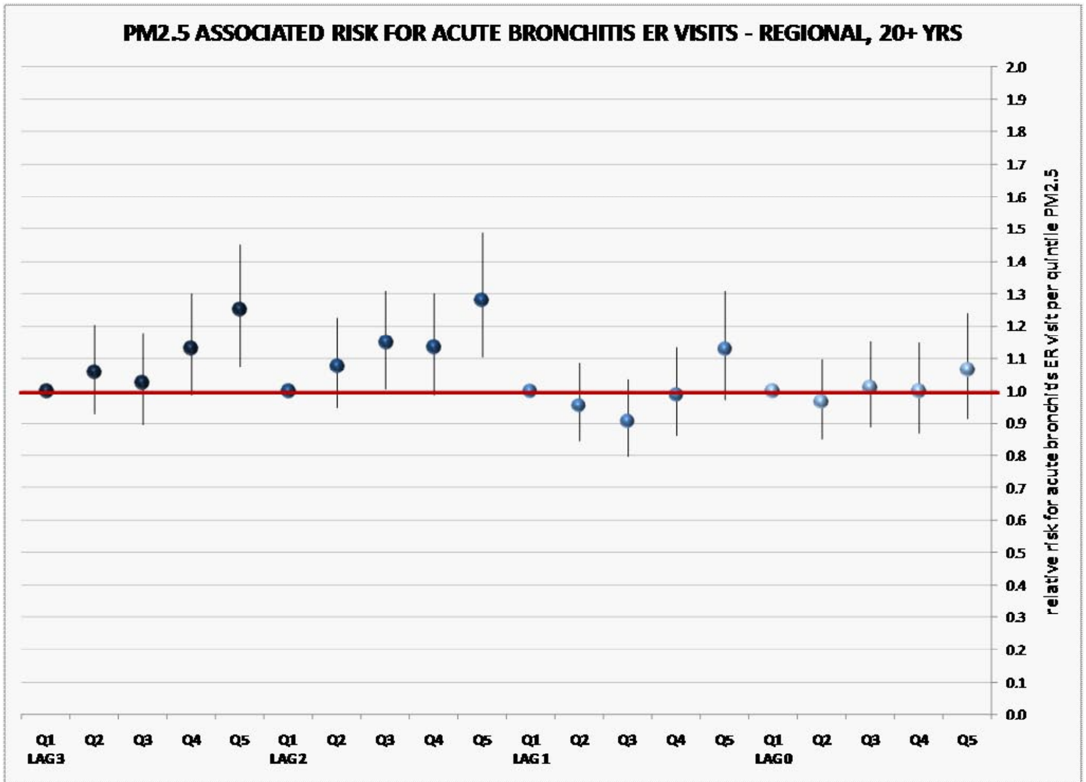


Figure 3f: Relative Risk for PM2.5-Associated Acute Bronchitis ER Visit for 20+ yrs old for the Region



admissions increase with PM2.5 in all three cities, as shown in Appendix Table I-1. For Fresno, there is a significant linear trend with increasing PM2.5 for the same day and 1, 2, and 3 days after the elevation of PM2.5, with the most pronounced effect on the same day or 1 day lag. For Bakersfield and Modesto, significant linear increases in ER admissions for children are not immediately seen following elevated PM2.5 levels, but become pronounced after 2 and 3 day lags. As shown in Appendix Table I-2, only Fresno demonstrates an increase in adult asthma admissions with increasing PM2.5 (1 day lag).

The consistent relationship between asthma ER admissions and increasing PM2.5 was not observed for pneumonia or acute bronchitis in the individual cities analyses, as shown in Appendix Tables I-3 and I-4. However, children in Bakersfield at 2 and 3 day lags did demonstrate a significant correlation between acute bronchitis ER visits and increasing PM2.5 (Appendix Table I-3). Similarly, risk for pneumonia ER admissions for children was significantly elevated in Bakersfield at 0 and 3 day exposure lags, and was moderately increased in children in Modesto (Appendix Table I-4). These findings are addressed further in section E below. Neither pneumonia nor acute bronchitis admissions in adults were related to PM2.5 concentrations at the city level.

D: PM2.5-Associated Respiratory and Cardiovascular Hospital Admissions: Following the trend for ER admissions, hospital admissions for asthma show a strong relationship with increasing PM2.5 in the regional analysis. Table 9 shows the effects of increasing PM2.5 on risk of respiratory and cardiovascular hospitalizations for all age groups across the region. While asthma hospitalizations show the strongest correlation, a significant association is also seen between acute MI and increasing PM2.5. No correlations were found for pneumonia, COPD or CHF. Table 10 shows the effects of increasing PM2.5 on asthma hospitalizations by age group. Increasing PM2.5 exposure is associated with increased asthma hospitalizations for children on the same day and each subsequent day, while adults experience significant increases in asthma hospitalizations 2 and 3 days after the elevation in fine particulates. Risk of asthma hospitalization for individuals over 55 was not significantly linked with elevated PM2.5, though a similar trend was seen at a 3 day lag.

Figures 4a- 4c graphically display the relationships between increasing PM2.5 quintiles and asthma hospitalization risk by age group for the region, while Figure 4d displays the associated risk for acute MI hospitalization in adults.

The strong findings on asthma hospitalizations and PM2.5 are also supported by the individual city analyses, available as Appendix Tables I-5 through I-8. For Fresno, risk of asthma hospital admissions increase with PM2.5 quintiles for the same day and 1 and 2 day lags, while significant increases in Bakersfield are seen 3 days after the elevation in PM2.5. When the PM2.5/ asthma hospitalization relationship is examined by age groups, the elevated risk of asthma hospitalizations is most pronounced for children in Fresno and to a lesser degree in Modesto. In contrast, correlations in Bakersfield were found in adults and elderly, but not children.

The relationship between increasing fine particulate exposure and acute MI hospitalizations found in the regional analysis was not found in the individual cities analyses, as shown in Appendix Table I-9. In contrast, while no correlation was seen between increasing quintiles of PM2.5and risk for COPD or CHF hospitalization in the regional analyses, a moderate association in PM2.5 and COPD hospitalization risk was identified for Bakersfield (1 day lag), as shown in Appendix Table I-10. Interestingly, risk for CHF hospitalization in Bakersfield was strongly correlated with increasing PM2.5, but was inverse, resulting in significanlty decreased risk per quintile of PM2.5 (Appendix Table I-11). This surprising finding may be a reflection of smaller sample sizes, as we are currently unable to provide a mechanistic explanation.

E. PM2.5-Associated Risk and Potential Covariate Collinearity: Appendix Table I-12 shows the Pearson correlations for the pollutant and meteorological variables included in the PM2.5 health analyses. Carbon monoxide is most strongly correlated with PM2.5 in each city (R2 = 0.47 - 0.57). To confirm that other environmental factors in our model, CO in particular, are not influencing the PM2.5 demonstrated health effects, Poisson regression models were re-run and individual covariates were excluded from the model. The results for regional asthma ER visits in 1-19 year olds are shown in Appendix Figure 1-1. As seen in this example, removal of individual co-factors from the model did not influence the relationship between PM2.5 quintiles and risk for asthma ER visit. Similar results were obtained for other health endpoints.

Table 9: Relative Risk for PM2.5-Associated Cardiopulmonary Hospitalization for the Region

Hospital		ASTHMA				PNEUMONIA				COPD				AMI				CHF			
lag	Quintile	RR	95% CI	sig	linear sig	RR	95% CI	sig	linear sig	RR	95% CI	sig	linear sig	RR	95% CI	sig	linear sig	RR	95% CI	sig	linear sig
Lag 0	Q5	1.21	1.06 - 1.37	.005	0.002807	0.96	0.89 - 1.03	.293	0.282836	0.99	0.87 - 1.13	.898	0.626330	1.09	0.97 - 1.22	.159	0.033634	0.93	0.85 - 1.01	.093	0.123719
	Q4	1.14	1.01 - 1.28	.039		0.99	0.93 - 1.06	.869		0.95	0.84 - 1.07	.408		1.03	0.93 - 1.15	.552		0.95	0.88 - 1.03	.249	
	Q3	1.20	1.07 - 1.35	.001		0.98	0.92 - 1.04	.539		1.01	0.90 - 1.13	.885		0.99	0.89 - 1.09	.828		0.97	0.90 - 1.05	.494	
	Q2	1.04	0.93 - 1.16	.500		1.01	0.95 - 1.07	.788		1.03	0.93 - 1.15	.579		0.91	0.82 - 1.00	.059		0.96	0.89 - 1.04	.298	
	Q1	1.00				1.00				1.00				1.00				1.00			
Lag 1	Q5	1.30	1.14 - 1.49	.000	0.000003	1.00	0.93 - 1.07	.961	0.647049	1.01	0.89 - 1.15	.890	0.929606	1.14	1.02 - 1.29	.025	0.009088	0.93	0.85 - 1.01	.093	0.131609
	Q4	1.30	1.15 - 1.47	.000		0.95	0.89 - 1.02	.138		1.00	0.89 - 1.12	.992		1.07	0.96 - 1.19	.220		0.94	0.87 - 1.02	.165	
	Q3	1.19	1.06 - 1.33	.004		1.01	0.94 - 1.07	.864		0.96	0.86 - 1.07	.473		1.02	0.92 - 1.14	.648		0.94	0.87 - 1.02	.150	
	Q2	1.08	0.96 - 1.21	.194		0.98	0.93 - 1.05	.622		1.00	0.90 - 1.12	.943		0.97	0.88 - 1.07	.597		0.95	0.88 - 1.02	.163	
	Q1	1.00				1.00				1.00				1.00				1.00			
Lag 2	Q5	1.52	1.33 - 1.73	.000	0.000000	0.99	0.92 - 1.07	.884	0.828064	0.97	0.85 - 1.10	.645	0.962609	1.11	0.99 - 1.25	.083	0.035958	0.96	0.88 - 1.05	.352	0.724208
	Q4	1.32	1.16 - 1.50	.000		1.01	0.94 - 1.08	.858		1.03	0.91 - 1.15	.663		1.06	0.95 - 1.18	.295		1.01	0.93 - 1.09	.886	
	Q3	1.34	1.19 - 1.50	.000		1.00	0.94 - 1.06	.954		0.97	0.87 - 1.09	.626		1.07	0.96 - 1.18	.210		1.00	0.92 - 1.08	.976	
	Q2	1.21	1.08 - 1.36	.001		0.98	0.92 - 1.04	.449		0.96	0.86 - 1.06	.419		0.97	0.97 - 1.08	.606		0.96	0.89 - 1.03	.261	
	Q1	1.00				1.00				1.00				1.00				1.00			
Lag 3	Q5	1.37	1.20 - 1.57	.000	0.000001	1.03	0.95 - 1.10	.475	0.343401	0.93	0.82 - 106	.268	0.289603	1.08	0.96 - 1.21	.224	0.349076	0.94	0.86 - 1.03	.210	0.499128
	Q4	1.32	1.16 - 1.49	.000		1.02	0.95 - 1.09	.629		0.97	0.86 - 1.09	.625		1.03	0.92 - 1.15	.621		0.98	0.90 - 1.06	.646	
	Q3	1.31	1.16 - 1.47	.000		1.05	0.99 - 1.12	.128		0.99	0.89 - 1.11	.916		1.04	0.94 - 1.16	.419		1.00	0.93 - 1.08	.941	
	Q2	1.15	1.03 - 1.29	.016		0.99	0.93 - 1.05	.708		0.99	0.89 - 1.10	.793		1.04	0.95 - 1.15	.383		0.94	0.87 - 1.01	.099	
	Q1	1.00				1.00				1.00				1.00				1.00			

Table 10: Relative Risk for PM2.5-Associated Asthma Hospitalization by Age Group for the Region

Hospital		Asthma: 0-19 yrs old				Asthma: 20-54 yrs old				Asthma: 55+ yrs old			
lag	Quintile	RR	95% CI	sig	linear sig	RR	95% CI	sig	linear sig	RR	95% CI	sig	linear sig
Lag 0	Q5	1.47	1.22 - 1.79	.000	0.000027	1.25	0.96 - 1.62	.103	0.146551	0.85	0.65 - 1.10	.222	0.413068
	Q4	1.23	1.02 - 1.47	.026		1.18	0.93 - 1.51	.175		1.00	0.79 - 1.26	.997	
	Q3	1.35	1.14 - 1.60	.000		1.25	0.99 - 1.57	.058		0.99	0.80 - 1.23	.926	
	Q2	1.03	0.87 - 1.22	.728		1.17	0.94 - 1.47	.162		0.93	0.75 - 1.14	.478	
	Q1	1.00				1.00				1.00			
Lag 1	Q5	1.58	1.30 - 1.91	.000	0.000000	1.27	0.98 - 1.66	.072	0.034044	1.07	0.83 - 1.39	.612	0.798213
	Q4	1.48	1.24 - 1.78	.000		1.38	1.08 - 1.75	.009		1.05	0.83 - 1.33	.697	
	Q3	1.28	1.08 - 1.53	.005		1.24	0.98 - 1.56	.074		1.07	0.86 - 1.34	.536	
	Q2	1.04	0.88 - 1.24	.629		1.16	0.93 - 1.45	.190		1.11	0.90 - 1.37	.332	
	Q1	1.00				1.00				1.00			
Lag 2	Q5	1.66	1.37 - 2.02	.000	0.000000	1.79	1.36 - 2.36	.000	0.000012	1.14	0.88 - 1.48	.324	0.634914
	Q4	1.35	1.12 - 1.63	.001		1.70	1.32 - 2.20	.000		1.07	0.84 - 1.36	.588	
	Q3	1.37	1.15 - 1.63	.000		1.66	1.30 - 2.11	.000		1.05	0.83 - 1.32	.670	
	Q2	1.14	0.95 - 1.35	.153		1.35	1.06 - 1.71	.013		1.20	0.97 - 1.49	.087	
	Q1	1.00				1.00				1.00			
Lag 3	Q5	1.44	1.19 - 1.75	.000	0.000381	1.42	1.09 - 1.86	.010	0.000730	1.25	0.97 - 1.63	.087	0.062508
	Q4	1.29	1.07 - 1.55	.006		1.52	1.19 - 1.94	.001		1.24	0.98 - 1.57	.074	
	Q3	1.22	1.02 - 1.45	.029		1.48	1.18 - 1.87	.001		1.28	1.02 - 1.60	.031	
	Q2	1.19	1.01 - 1.41	.040		1.07	0.85 - 1.35	.578		1.11	0.89 - 1.37	.358	
	Q1	1.00				1.00				1.00			

Figure 4a: Relative Risk for PM2.5-Associated Asthma Hospitalization for 0-19 yrs old for the Region

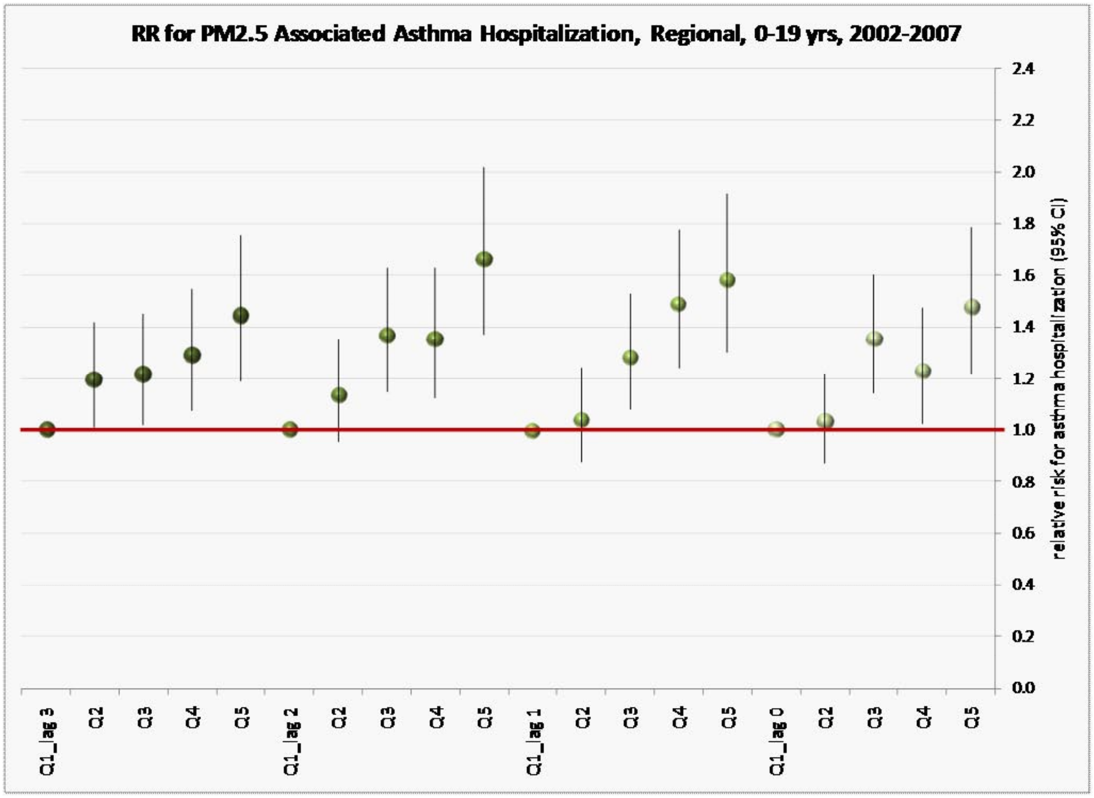


Figure 4b: Relative Risk for PM2.5-Associated Asthma Hospitalization for 20-54 yrs old for the Region

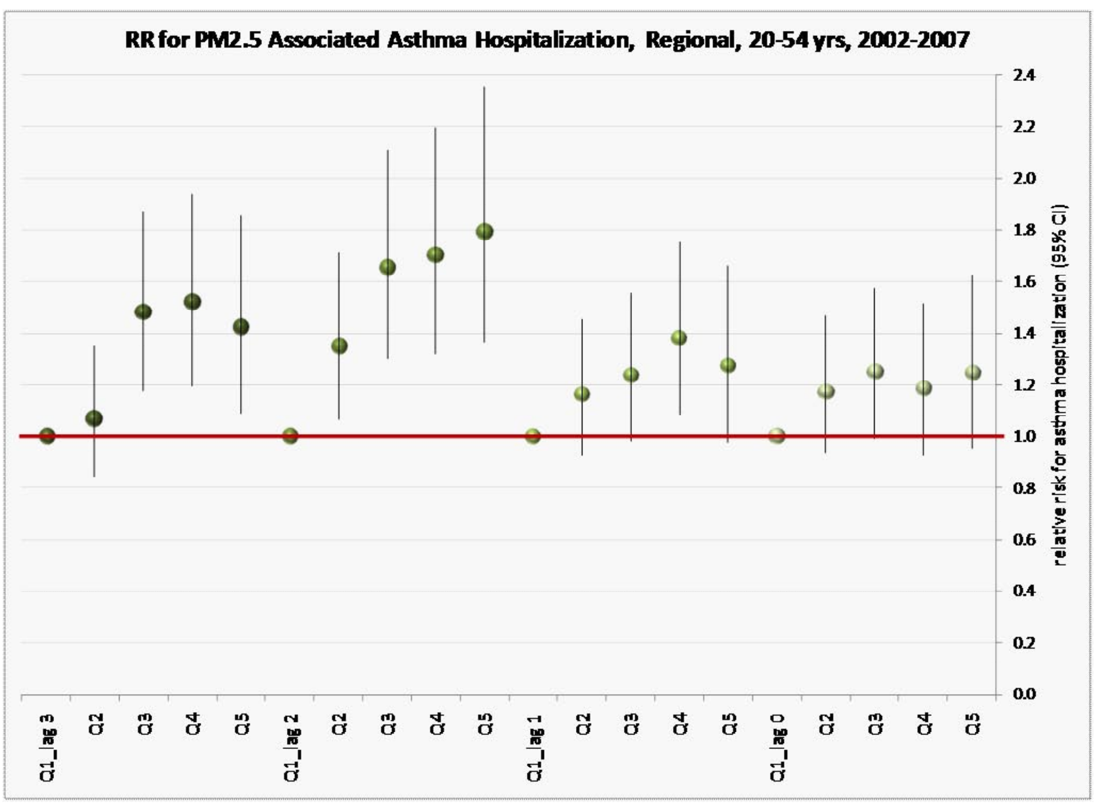


Figure 4c: Relative Risk for PM2.5-Associated Asthma Hospitalization for 55+ yrs old for the Region

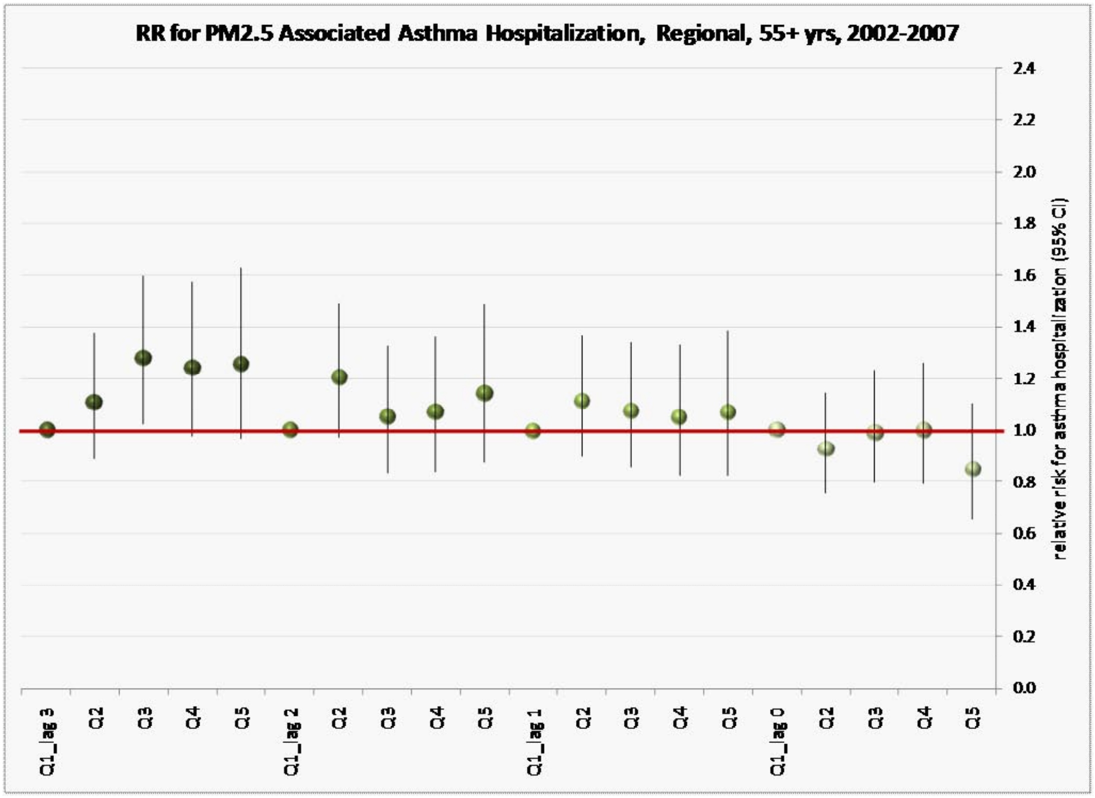
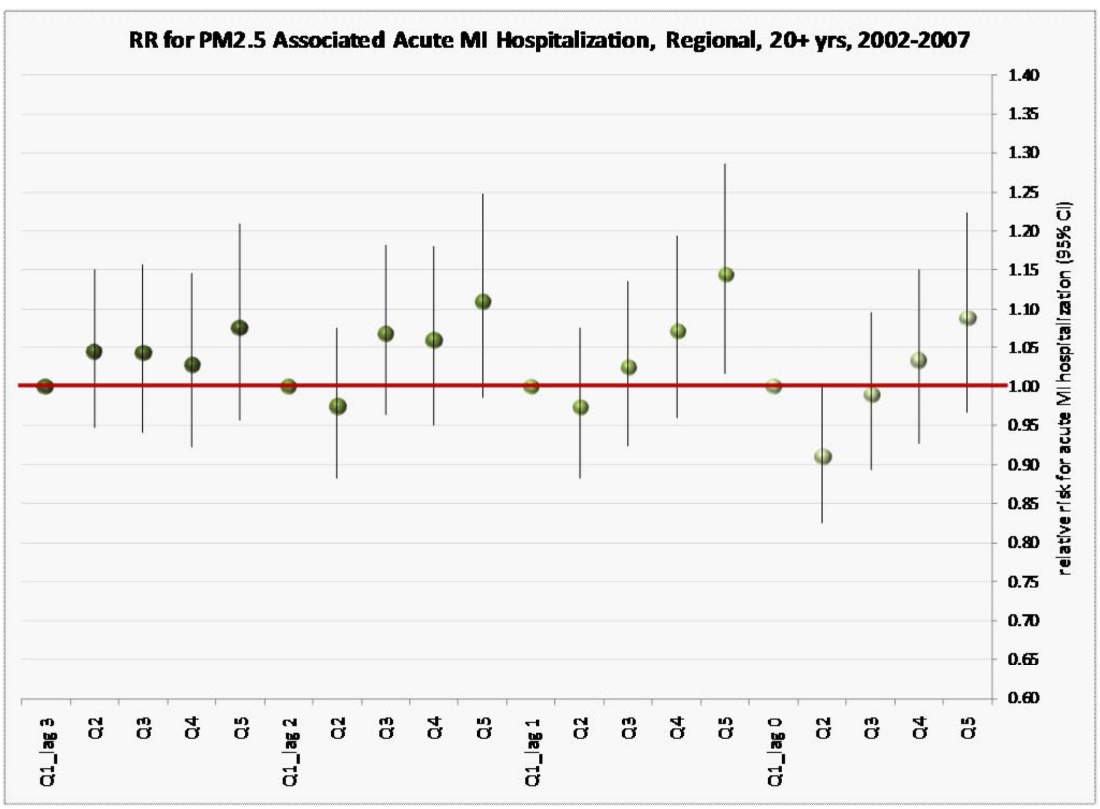


Figure 4d: Relative Risk for PM2.5-Associated Acute MI Hospitalization for 20+ yrs old for the Region



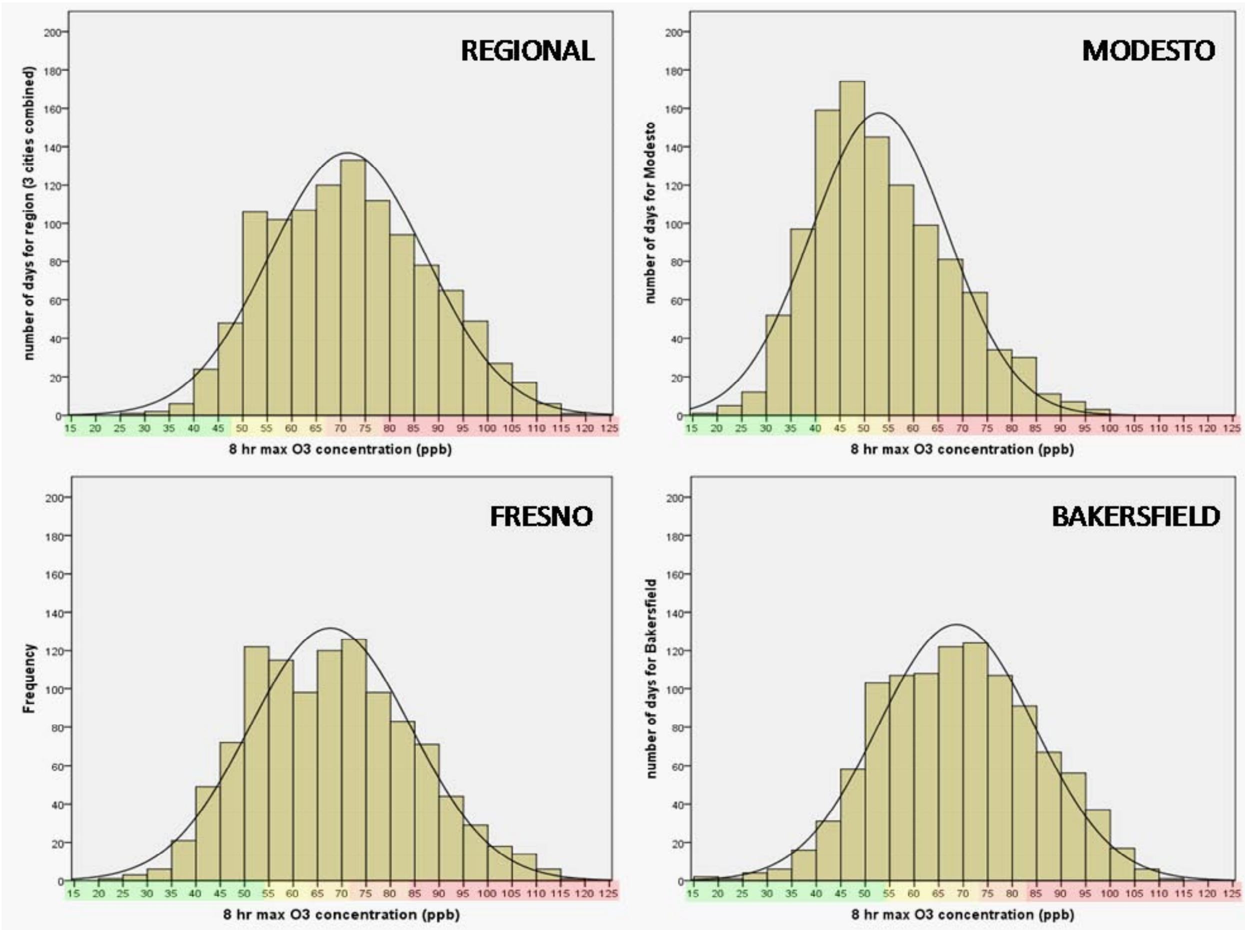
OZONE AND WARM SEASON HEALTH EFFECTS

A: Patterns of Ozone Exposure: Table 2 shows the pattern of ozone exposure, other pollutants and meteorological conditions during the warm season for 2002-2007 for the region and the three study cities. While the 8 hour maximum ozone concentration did not differ notably by city, Fresno and Bakersfield experienced much higher proportions of warm season days that exceeded the Federal ozone standard than did Modesto (32% vs 7%). As shown in Table 3, Bakersfield also experienced higher concentrations of NO2 and CO during warm months, while Fresno had lower humidity. Table 11 and Figure 5 show quintiles of ozone for the region and each city during the warm season. Also, as shown in Appendix Table I-13, the relationships between ozone and other ambient conditions were not the same across cities. In Bakersfield, ozone and relative humidity were positively correlated, while this relationship was negative in the two other cities. Further, elevated ozone was correlated with CO in Bakersfield but the relationship was much less pronounced in the other cities.

Table 11: Ozone Quintile Concentration Range (ppb) by City and Region During Warm Season (2002-2007)

PM2.5 Ozone	Regional	Modesto	Fresno	Bakersfield
Q5	79+	66+	84+	84+
Q4	68 - 78	56 - 65	72 - 83	74 - 83
Q3	58 - 67	49 - 55	63 - 71	65 - 73
Q2	49 - 57	42 - 48	54 - 62	55 - 64
Q1	<= 48	<= 41	<= 53	<= 54

Figure 5: Frequency of Days per Ozone Quintile Range During Warm Season (2002 – 2007)



B: Emergency Room and Hospital Admissions During Warm Season: Tables 12-15 show average daily admissions during the warm season for the region and the three cities. Asthma ER admissions are slightly higher for both children and adults in Fresno. Hospitalization rates for asthma do not differ notably by age or community, and overall hospital admission rates for acute MI, COPD, and pneumonia are relatively similar across cities. Modesto has higher rates for pneumonia and COPD, and Fresno has higher rates for acute MI compared to the other cities during the warm season.

Table 12: Mean Daily Respiratory ER Visits During Warm Season by City and Region for 1-19 and 20+ yrs old

ER Visits	1-19 yrs		20+ yrs	
Asthma	mean	stdev	mean	stdev
MODESTO	0.82	0.98	1.29	1.36
FRESNO	1.94	1.55	2.64	1.75
BAKERSFIELD	1.42	1.32	1.38	1.22
REGIONAL	4.17	2.58	5.30	2.76

Table 13: Daily Asthma ER Visit Rates (per 100,000) During Warm Season by City for 1-19 and 20+ yrs old

AGE GROUP	CITY	ASTHMA
1-19 yrs old	Modesto	0.39 (0.00 - 0.85)
	Fresno	0.60 (0.12 - 1.09)
	Bakersfield	0.44 (0.03 - 0.85)
20+ yrs old	Modesto	0.61 (0.00 - 1.25)
	Fresno	0.82 (0.28 - 1.37)
	Bakersfield	0.43 (0.05 - 0.80)

Table 14: Mean Daily Respiratory and Cardiovascular Hospitalizations During Warm Season by City and Region and Age Group

Hospitalizations	ALL		0-19 yrs		20-54 yrs		55+ yrs	
Asthma	mean	stdev	mean	stdev	mean	stdev	mean	stdev
MODESTO	0.50	0.73	0.18	0.46	0.16	0.40	0.16	0.39
FRESNO	0.87	0.97	0.44	0.68	0.22	0.48	0.20	0.45
BAKERSFIELD	0.69	0.86	0.24	0.50	0.22	0.47	0.24	0.49
REGIONAL	2.06	1.57	0.87	1.00	0.59	0.80	0.60	0.77
Pneumonia								
MODESTO	2.16	1.58						
FRESNO	2.62	1.80						
BAKERSFIELD	2.55	1.67						
REGIONAL	7.33	3.18						
COPD								
MODESTO	0.79	0.90						
FRESNO	0.82	0.93						
BAKERSFIELD	0.86	0.97						
REGIONAL	2.48	1.59						
Acute MI								
MODESTO	0.94	0.97						
FRESNO	1.77	1.32						
BAKERSFIELD	1.25	1.14						
REGIONAL	3.96	2.04						

Table 15: Mean Daily Respiratory and Cardiovascular Hospital Rates (per 100,000) During Warm Season by City and Age Group

age group	city	asthma	pneumonia	COPD	AMI
0-19 yrs old	Modesto	0.09 (0.00 - 0.30)			
	Fresno	0.14 (0.00 - 0.35)			
	Bakersfield	0.07 (0.00 - 0.23)			
20-54 yrs old	Modesto	0.07 (0.00 - 0.26)			
	Fresno	0.07 (0.00 - 0.22)			
	Bakersfield	0.07 (0.00 - 0.21)			
55+ yrs old	Modesto	0.07 (0.00 - 0.26)			
	Fresno	0.06 (0.00 - 0.20)			
	Bakersfield	0.07 (0.00 - 0.23)			
all ages	Modesto	0.23 (0.00 - 0.58)	1.02 (0.27 - 1.76)	0.37 (0.00 - 0.80)	0.44 (0.00 - 0.90)
	Fresno	0.27 (0.00 - 0.57)	0.82 (0.26 - 1.38)	0.26 (0.00 - 0.54)	0.55 (0.14 - 0.96)
	Bakersfield	0.22 (0.00 - 0.48)	0.79 (0.27 - 1.31)	0.27 (0.00 - 0.57)	0.39 (0.03 - 0.74)

C: Relationship Between Temperature, Ozone and Asthma ER Visits: Figure 6 shows the mean monthly values for regional ozone, temperature and asthma ER visits for the region. The strong correlation between temperature and ozone is apparent, and is evidenced further in Figure 8 and Appendix Table 13. On the monthly scale, temperature and ozone both appear to be inversely correlated with asthma ER visits. Previous unpublished research by Tyner and colleagues has shown a strong link between asthma ER visits during spring months (April and May) and bioallergens levels (especially grass pollen). Similarly, FACES invesitgators identified September as the peak month for airborne endotoxin exposure in the Valley (personal communique). The coinciding of high bioallergens and endotoxin with relatively cooler temperatures during the warm season months (April, May, September) likely contributes to the apparent inverse correlation between temperature and asthma ER visits. Similarly, the lower rates of asthma ER visits during the hottest months (June–August) may be related to summer vacation and the reduced circulation of infectious respiratory agents (like rhinovirus) between children when schools are not in session.

As the relationship between temperature and asthma ER visits is likely representative of these types of factors which are unaccounted in our environmental exposure model, the potential confounding of temperature on the relationship between ozone and asthma ER visits is of particular concern and cannot be corrected by simply removing temperature from the model. Figure 7 compares the relative risk for asthma ER visits (1-19 yrs old) per quintile of ambient temperature during the warm season (April–September) and the hot season (June–August). The strong inverse relationship between temperature and asthma ER visits observed during the warm season (right side) was not seen during the hot season (left side). We therefore considered restricting our ozone analysis to the summer months of June – August (Hot Season).

One concern of restricting the time period to the three summer months, in addition to cutting our sample size in half, was the potential to significantly decrease the variability of our main independent variable (ozone), thus reducing our capacity to assess changes in health outcomes associated with variations in ambient ozone. However, as shown in Figure 8, while the variation in temperature in significantly reduced, the variation in ozone remains similar to the six month warm season range. The relationship between ozone and temperature also remains unchanged (warm, R2 = 0.54; hot, R2 = 0.52), so we still faced the issue of collinearity. As shown in Figures 9 and 10, the relative risk for asthma ER visits per quintile of ozone is strongly dependent on temperature in the warm season analysis (Figure 9), but is only slightly affected by temperature in the hot season analysis (Figure 10). We therefore chose to analyze all ozone-related health effects during the three-month hot season, excluding temperature as a co-variate.

Figure 6: Regional Monthly Means for Asthma ER Visits (upper panels), Ozone (bottom left) and Temperature (bottom right)

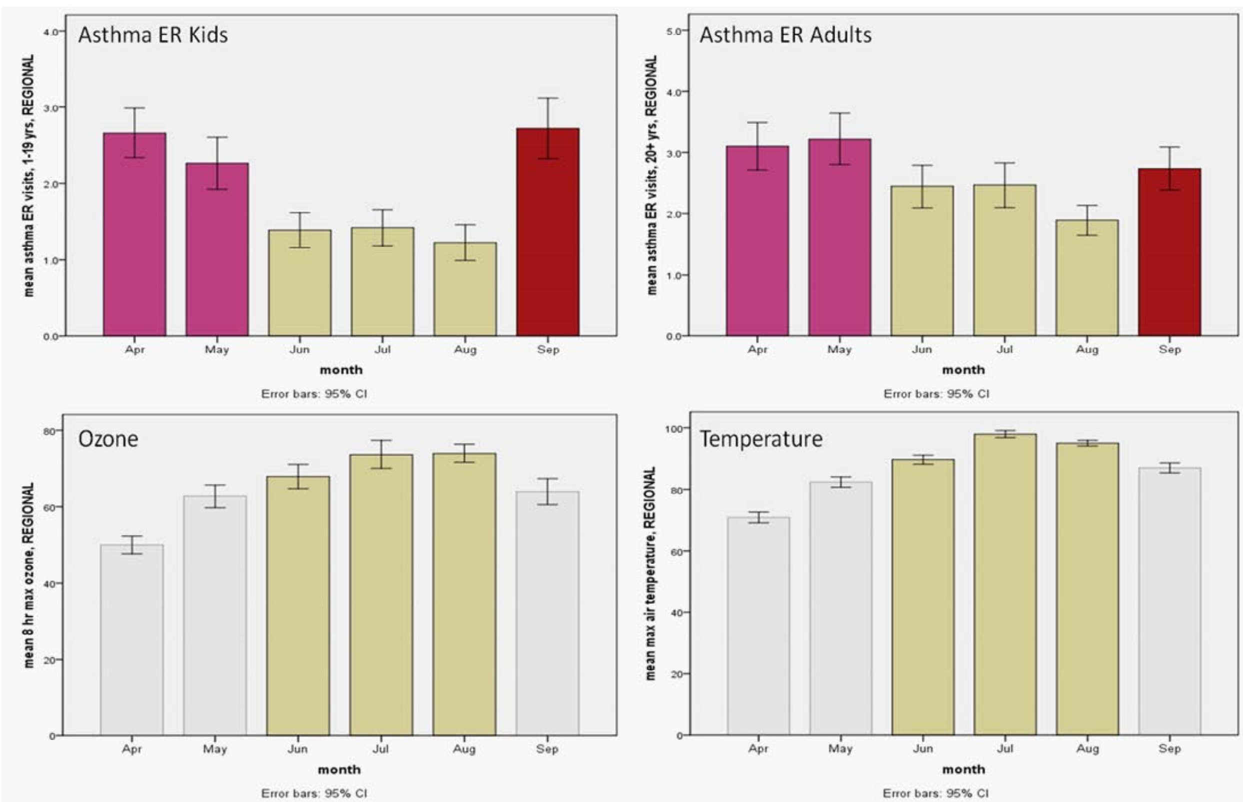


Figure 7: Relative Risk for Temperature-Associated Asthma ER Visits for 1-19 yrs old for the Region

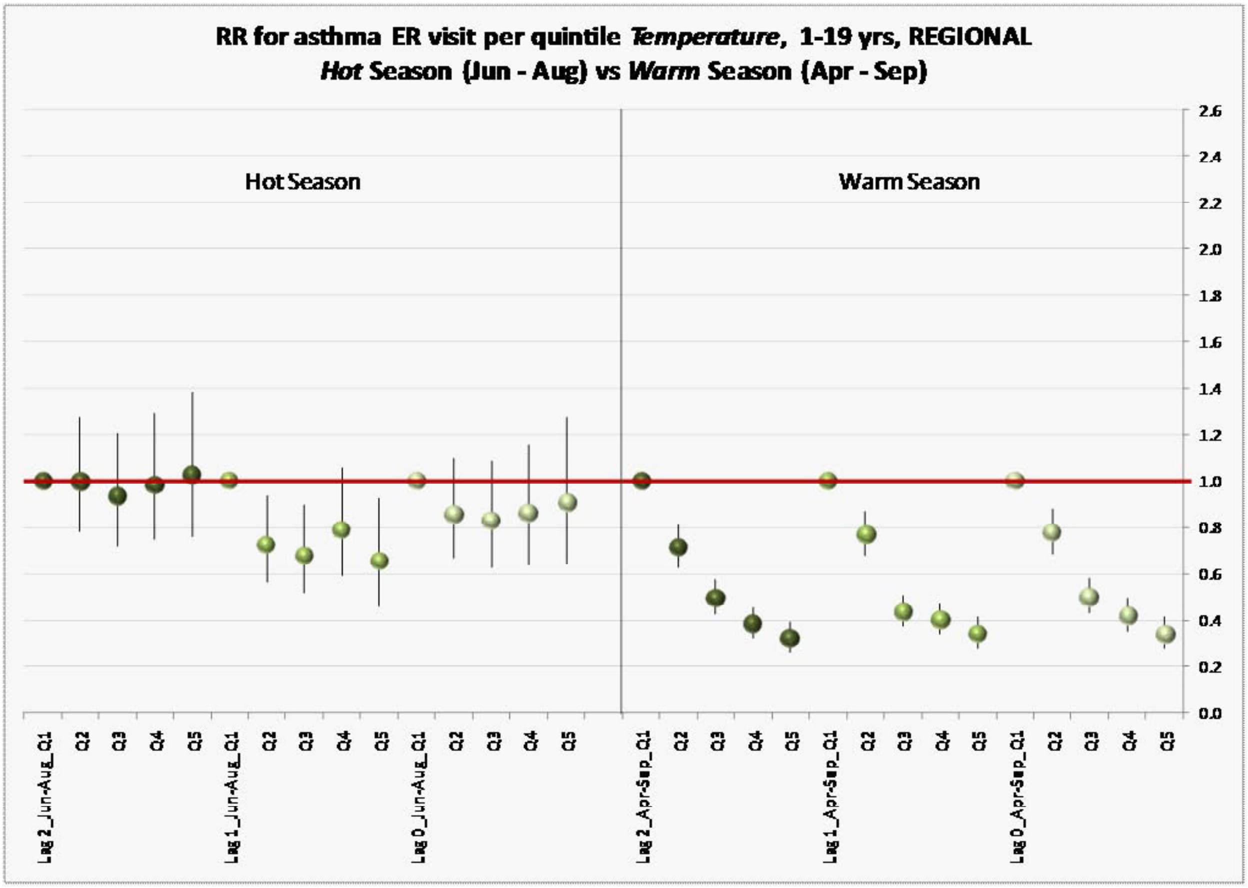


Figure 8: Ozone Variation and Correlations with Temperature During Hot Season (left) and Warm Season (right)

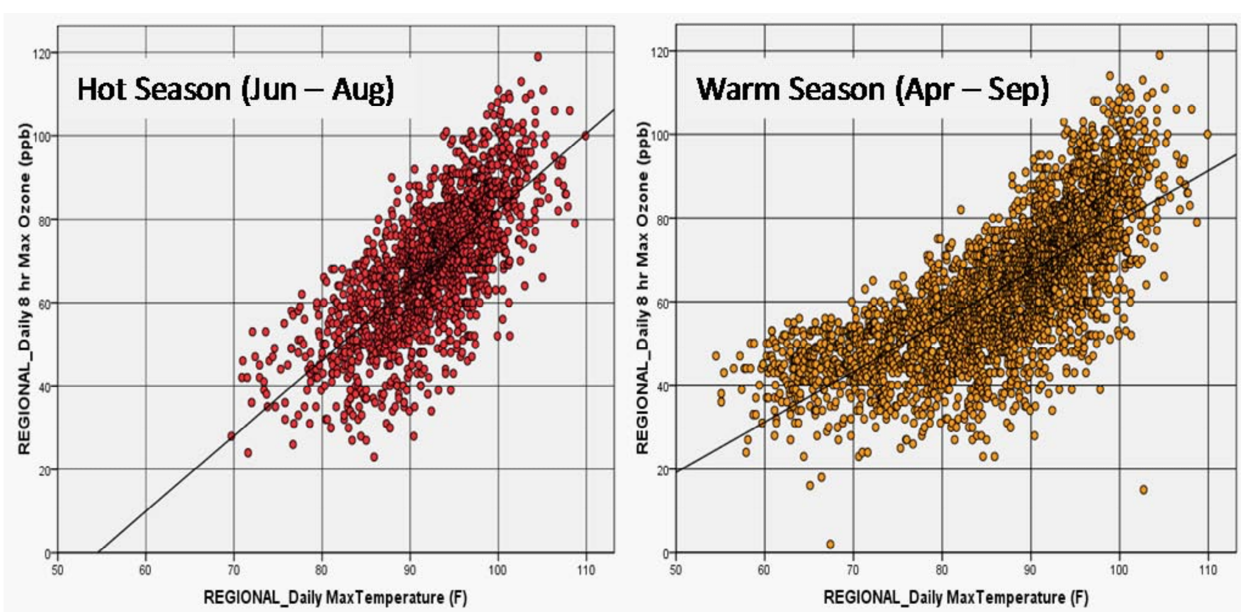


Figure 9: Relative Risk for Ozone-Associated Asthma ER Visits for 1-19 yrs old During Warm Sseason

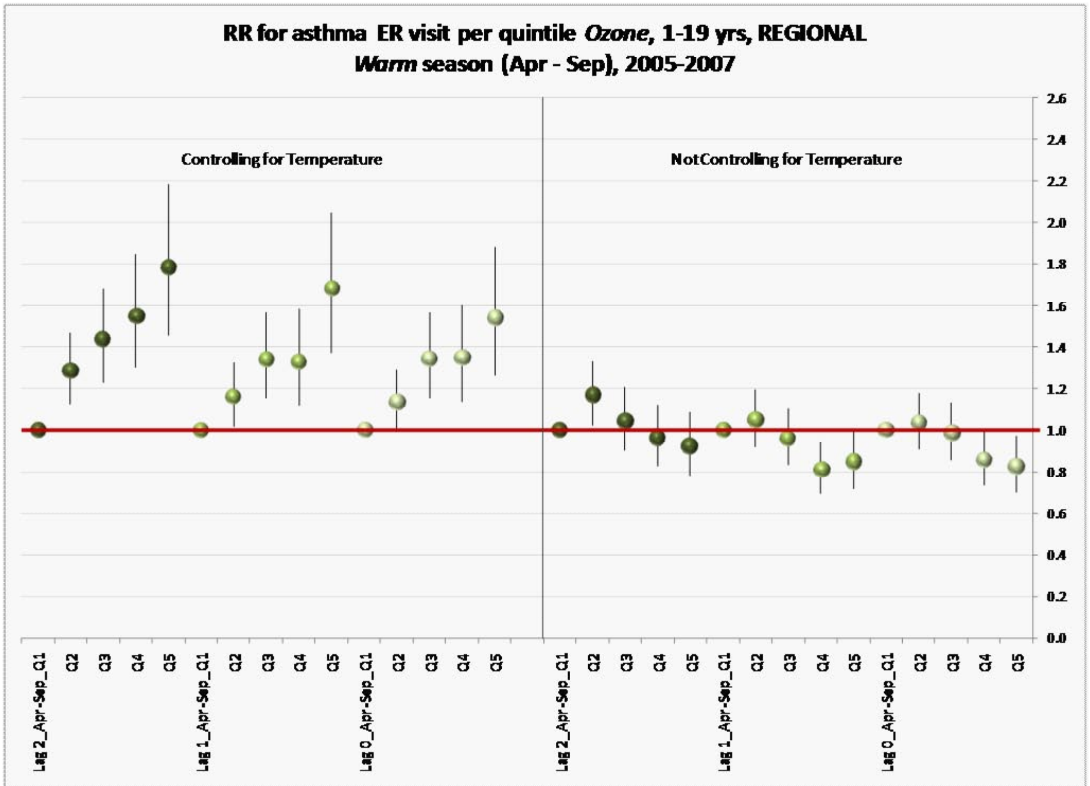
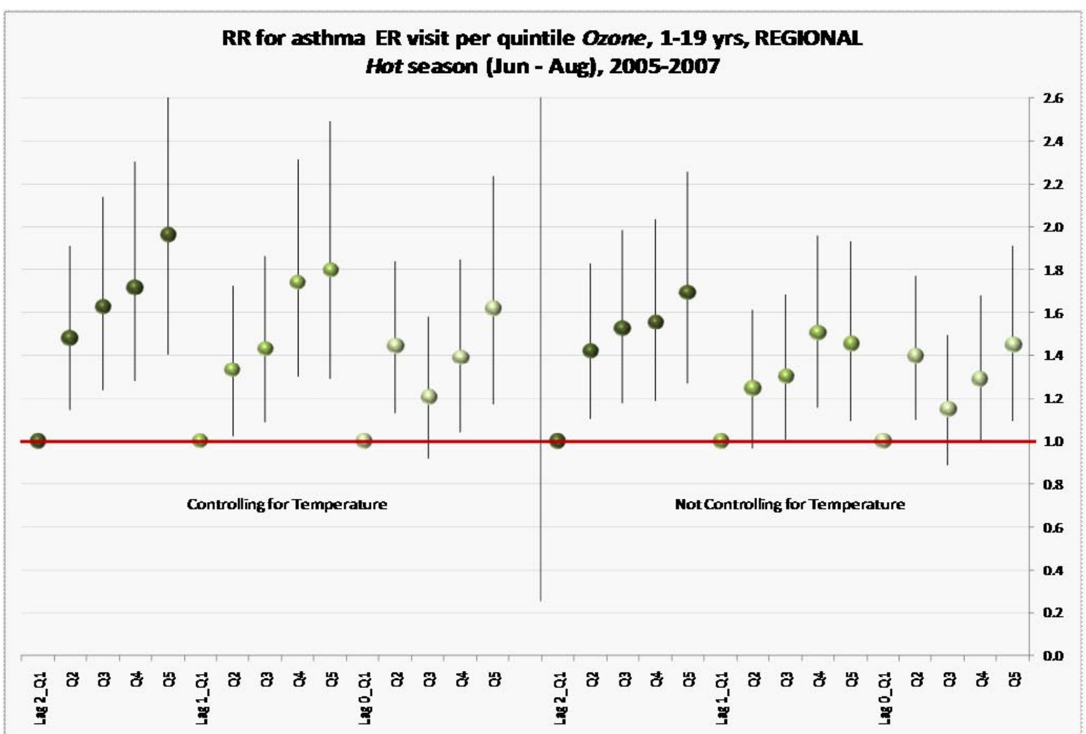


Figure 10: Relative Risk for Ozone-Aassociated Asthma ER Visits for 1-19 yrs old During Hot Season



D: Ozone-related Emergency Room and Hospital Admissions During Hot Season: Table 16 shows regional findings in which increasing levels of ambient ozone are strongly associated with increasing risk for asthma ER visits in children, but only slightly in adults. Table 17 shows ozone quintiles and relative risk for asthma hospitalization. Unlike ER visits, ozone levels were not found to be significantly correlated with asthma hospitalizations in children or adults. Table 18 shows the relative risk for COPD, pneumonia and acute MI hospitalization for the region per ozone quintile. No significant association was observed between elevated ozone and increased hospitalization risk for any of these morbidities.

Similar regression models were run for the individual communities revealing no significant correlations between ozone levels and ER or hospital admissions for any of the above mentioned morbidities. Trends were observed for increased risk of asthma ER visits in children relative to increasing ozone levels in Fresno, but not Modesto or Bakersfield (Appendix Table I-13), however, the limited sample size in these analyses due to the smaller time period (Jun-Aug) resulted in larger standard deviations than observed in the PM2.5 analysis and subsequently no significant correlations were obtained.

Table 16: Relative Risk for Ozone-Associated Asthma ER Visits for 1-19 and 20+ yrs old for the Region

Asthma ER		1-19 yrs old				20+ yrs old			
Lag	Quintile	RR	95% CI	sig	linear sig	RR	95% CI	sig	linear sig
Lag 0	Q5	1.45	1.10 - 1.91	.009	0.040515	1.28	1.04 - 1.58	.020	0.026454
	Q4	1.29	0.99 - 1.68	.058		1.16	0.95 - 0.41	.135	
	Q3	1.15	0.89 - 1.49	.291		0.95	0.78 - 1.16	.616	
	Q2	1.40	1.10 - 1.10	.006		1.10	0.92 - 1.32	.278	
	Q1	1.00				1.00			
Lag 1	Q5	1.46	1.10 - 1.93	.009	0.004279	1.25	1.01 - 1.54	.041	0.052806
	Q4	1.51	1.16 - 1.96	.002		1.13	0.93 - 1.37	.226	
	Q3	1.30	1.01 - 1.68	.043		1.01	0.83 - 1.21	.948	
	Q2	1.25	0.97 - 1.61	.088		1.08	0.90 - 1.29	.388	
	Q1	1.00				1.00			
Lag 2	Q5	1.69	1.27 - 2.26	.000	0.000600	1.12	0.91 - 1.39	.271	0.296069
	Q4	1.56	1.19 - 2.04	.001		1.01	0.83 - 1.23	.918	
	Q3	1.53	1.18 - 1.98	.001		0.87	0.72 - 1.05	.155	
	Q2	1.42	1.11 - 1.83	.006		0.99	0.83 - 1.18	.886	
	Q1	1.00				1.00			

Table 17: Relative Risk for Ozone-Associated Asthma Hospitalizations for 0-19 and 20+ yrs old for the Region

Hospitalizations		ASTHMA_0-19 YRS				ASTHMA_20+ YRS			
LAG	Quintile	RR	95% CI	SIG	linear sig	RR	95% CI	SIG	linear sig
Lag 0	Q5	0.83	0.49 - 1.40	.487	0.783407	1.18	0.79 - 1.78	.418	0.437173
	Q4	1.23	0.79 - 1.91	.349		1.17	0.82 - 1.68	.392	
	Q3	1.30	0.84 - 2.00	.240		1.27	0.89 - 1.80	.189	
	Q2	1.00	0.65 - 1.55	.991		1.14	0.81 - 1.61	.456	
	Q1	1.00				1.00			
Lag 1	Q5	1.09	0.66 - 1.81	.724	0.284239	0.95	0.63 - 1.41	.791	0.436281
	Q4	1.18	0.75 - 1.87	.476		0.91	0.62 - 1.31	.600	
	Q3	1.64	1.07 - 2.51	.023		1.34	0.95 - 1.88	.094	
	Q2	0.76	0.47 - 1.23	.259		1.16	0.83 - 1.63	.374	
	Q1	1.00				1.00			
Lag 2	Q5	1.01	0.63 - 1.62	.976	0.728780	0.89	0.61 - 1.31	.561	0.647027
	Q4	0.91	0.59 - 1.42	.681		0.91	0.64 - 1.29	.601	
	Q3	0.98	0.64 - 1.550	.934		0.90	0.64 - 1.27	.553	
	Q2	0.76	0.49 - 1.18	.221		0.89	0.64 - 1.24	.486	
	Q1	1.00				1.00			

Table 18: Relative Risk for Ozone-Associated Respiratory/Cardiovascular Hospitalizations for the Region

Hospitalizations		COPD				PNEUMONIA				AMI			
LAG	Quintile	RR	95% CI	SIG	linear sig	RR	95% CI	SIG	linear sig	RR	95% CI	SIG	linear sig
Lag 0	Q5	1.18	0.93 - 1.50	.180	0.471600	1.03	0.89 - 1.19	.704	0.653462	1.04	0.87 - 1.25	.657	0.452169
	Q4	0.95	0.76 - 1.18	.619		0.97	0.86 - 1.11	.689		0.96	0.82 - 1.13	.666	
	Q3	0.97	0.79 - 1.20	.806		1.03	0.90 - 1.16	.693		0.94	0.80 - 1.10	.439	
	Q2	1.08	0.89 - 1.31	.457		1.11	0.99 - 1.25	.080		0.89	0.76 - 1.05	.161	
	Q1	1.00				1.00				1.00			
Lag 1	Q5	0.94	0.74 - 1.20	.635	0.486496	0.89	0.77 - 1.02	.100	0.123397	1.05	0.88 - 1.26	.598	0.295504
	Q4	0.88	0.71 - 1.09	.236		0.93	0.82 - 1.06	.283		1.05	0.89 - 1.23	.580	
	Q3	0.93	0.75 - 1.14	.466		0.89	0.79 - 1.01	.076		0.95	0.81 - 1.12	.532	
	Q2	0.95	0.78 - 1.15	.599		0.95	0.85 - 1.07	.374		0.93	0.79 - 1.08	.342	
	Q1	1.00				1.00				1.00			
Lag 2	Q5	1.09	0.85 - 1.39	.494	0.516674	0.96	0.84 - 1.11	.580	0.991675	1.03	0.86 - 1.24	.724	0.659657
	Q4	1.06	0.85 - 1.32	.599		1.00	0.88 - 1.14	.985		1.01	0.86 - 1.20	.881	
	Q3	1.06	0.86 - 1.31	.574		0.95	0.84 - 1.07	.390		1.15	0.98 - 1.35	.097	
	Q2	1.05	0.86 - 1.28	.659		0.92	0.82 - 1.04	.184		0.99	0.84 - 1.16	.858	
	Q1	1.00				1.00				1.00			

Discussion

This study offers the first local evidence of short-term population-level health effects associated with elevations in PM2.5 and ozone for the San Joaquin Valley. While the study examined these relationships both regionally and within three individual cities, the number of observations available within each quintile of exposure in the regional analyses provides more stable measurements. We find linear increases in rates of asthma ER and hospital admissions with increasing exposure to fine particulate matter, with effects more pronounced for children. Further, hospital admissions for acute MI also increased in a linear fashion with increasing exposure.

Further analysis of relationships among the pollutants and contextual variables supported the validity of the identified health risks associated with elevated PM2.5. By contrast, some degree of uncertainty about the ozone-related health effects demonstrated in the regional analysis is warranted because of significant differences between communities in the other pollutant and weather conditions, as well as the strong inverse correlations between health outcomes and meteorological variables.

While precise comparisons to other studies are made difficult by differences in the pollutants and meteorological co-variates, the age, racial/ethnic, and social class distributions of study populations, as well as the lag times considered, our observed relationships are of similar magnitudes to what has been observed elsewhere. For example, using the methods in BenMap, we found a concentration-response function for the relationships between PM2.5 elevation and asthma ER admissions for children of .0949 (.023), somewhat larger than the BenMap report, but in the same range. While these findings leave little doubt that there are short-term health effects of PM2.5 and possibly ozone in the Valley, they also raise a number of additional points for consideration.

1) **PM2.5 Standard and Health Effect:** Our findings clearly show a linearly increasing burden of short-term health effects associated with increasing PM2.5 for asthma ER and hospital admissions, as well as AMI hospital admissions. While these linear effects suggest that increasing exposure is associated with increasing health effects, they do not pinpoint an exposure threshold at which health effects appear consistently. Yet as demonstrated in Appendix Figure I-2, days with PM2.5 levels that exceed the NAAQS are associated with significantly higher hospitalizations for asthma.

2) **City Level Difference:** Our preliminary analysis of the interactions between city and the PM2.5 and ozone concentration-response functions for ER and hospital admissions demonstrated that regional analyses could be undertaken because the exposure-morbidity relationships were constant across the cities. Nonetheless, broad differences between the cities in both exposure and health care utilization patterns also justified assessing short-term health impacts at the city level while being cautious that smaller sample sizes might produce anomalous findings. Individual city differences were found in the overall strength of the PM2.5 exposure/health care use relationship and the sub-populations and lag times most associated with health impacts. Nonetheless, we found one instance across numerous comparisons where a significant finding at the city level contradicted the regional results (PM2.5-associated CHF hospital risk in Bakersfield).

However, our findings do suggest the need for further analysis at the city level because of 1) overall health care utilization and exposure differences between the cities, and 2) disparate patterns of correlation between ozone, other pollutants and weather conditions in Bakersfield relative to the two other cities. More analysis of how PM2.5, ozone, other pollutants and health effects are shaped at the individual city level is warranted. Characterization of PM2.5 component differences at the city level is needed and the possible associations of those differing components on health endpoints will need to be investigated. It is also possible that relative to Fresno, more individuals experiencing short-term asthma or other condition exacerbations in response to PM2.5 or ozone elevations in Bakersfield and Modesto are able to handle their care needs on an outpatient basis. Adding data on primary care use daily variations would greatly extend our capacity to understand within region variations in the burden of poor air quality. Adding additional years of exposure and utilization data could facilitate such analysis by increasing statistical power and allowing further examination of city, age group, and payer type differences.

3) **Additional Health Effects:** Our findings at the regional and individual city level did not find significanly increased risk associated with elevated PM2.5 for pnumonia ER visits in adults, or hospitalization for pneumonia, CHF or COPD. We did not find associations between ozone and any hospital-related morbidity. While some of these impacts have been found in one or more prior studies, they have been in larger samples, longer periods of observation, or focused on populations with known risk factors or co-morbidities.[xix] For example, there is an ongoing debate about whether or not co-morbidities need to be included in modeling the relationships between PM2.5 exposure and COPD.[xx] It is also possible that our failure to find other correlations between elevated ozone levels and health effects (other than asthma) may reflect the reduced timeframe (focusing on the 3 hottest months) and therefore reduced sample size we adopted to account for collinearity between ozone and temperature or increased bioallergen presence during the Spring and early Fall.

One possibility is that the San Joaquin Valley region, unlike other air basins, does not experience short-term health risks for pneumonia, CHF, and COPD from elevated levels of ozone or PM2.5, in which case we need a better understanding of the mechanisms by which such impacts are created in other places, but not here. For example, the specific chemical composition of PM2.5 has been linked to the extent of short-term impacts on cardiovascular admissions. Speciation of PM2.5 and exploration of whether particular components are associated with COPD and CHF morbidity would allow a better understanding of this alternative. From a different perspective, it may be that patients with COPD, CHF and other relevant conditions are already engaging in health behaviors in our region that respond to air quality concerns and thus lessen the observable impact. Studies that include data on daily primary care use, that include more co-morbidity or prior diagnostic data, and that better model the impacts of meteorological conditions might further elucidate this concern.

4) Temporal Analysis and Policy Implications: The observation period for this analysis did not include the years subsequent to the tightening of wood burning restrictions and other recent policy initiatives. Further, our analytic approach used Poisson regression to assess relative risk of utilization across exposure quintiles, and associated assumptions about the underlying statistical properties of the concentration-response relationships for both pollutants and meteorological conditions. Further, our analytic approach allows us to estimate the impacts of elevated PM2.5 and ozone on relative risk of utilization at each day subsequent to the elevation, but does not produce a combined estimate of the additional use associated with multi-day episodes of elevated pollution. As a result, it is difficult to assess the full impact of air quality improvements on short-term health effects of PM2.5 and ozone exposure.

We cannot establish from the present study how long-term exposure influences sensitivity to short-term elevations in pollutants. We cannot draw conclusions about how short-term spikes in PM2.5 or ozone would have impacted morbidity and short-term health care use if there was less long-term exposure. Extending the analysis to more years could allow for greater clarity about whether the reductions in overall, annual exposure seen in recent years have also influenced the relationship between short-term elevations in pollution and health outcomes.

Widely used modeling techniques may also be less than helpful in drawing possible conclusions about the effects of recent policy choices because modeler's have tended to base concentration response functions on differing levels of concentration variation and selection of effects at varying time lags and with varying assumptions about the underlying functional form of the relationship. Policy analyses would be strengthened by further analyses of the data from this project that test alternative methods for deriving the concentration-response function, consider alternative functional forms for the underlying relationship and treatment of co-pollutants and meteorological impacts, and consider alternative analytic techniques.

References

[i] Jerrett M, Burnett RT, Ma R, Pope CA 3rd, Krewski D, Newbold KB, Thurston G, Shi Y, Finkelstein N, Calle EE, Thun MJ. Spatial analysis of air pollution and mortality in Los Angeles. Epidemiology. 2005 Nov;16(6):727-36; Jerrett M, Burnett RT, Pope CA 3rd, Ito K, Thurston G, Krewski D, Shi Y, Calle E, Thun M. Long-term ozone exposure and mortality. N Engl J Med. 2009 Mar 12;360(11):1085-95.

[ii] Mann JK, Tager IB, Lurmann F, Segal M, Quesenberry CP Jr, Lugg MM, Shan J, Van Den Eeden SK. Air pollution and hospital admissions for ischemic heart disease in persons with congestive heart failure or arrhythmia. Environ Health Perspect. 2002 Dec;110(12):1247-52; Pope CA 3rd, Muhlestein JB, May HT, Renlund DG, Anderson JL, Horne BD. Ischemic heart disease events triggered by short-term exposure to fine particulate air pollution. Circulation. 2006 Dec 5;114(23):2443-8. Epub 2006 Nov 13.

[iii] Pope CA 3rd, Ezzati M, Dockery DW. Fine-particulate air pollution and life expectancy in the United States. N Engl J Med. 2009 Jan 22;360(4):376-86.

[iv] Kappos AD, Bruckmann P, Eikmann T, Englert N, Heinrich U, Höppe P, Koch E, Krause GH, Kreyling WG, Rauchfuss K, Rombout P, Schulz-Klemp V, Thiel WR, Wichmann HE. Health effects of particles in ambient air. .Int J Hyg Environ Health. 2004 Sep;207(4):399-407. Kappos AD, Bruckmann P, Eikmann T, Englert N, Heinrich U, Höppe P, Koch E, Krause GH, Kreyling WG, Rauchfuss K, Rombout P, Schulz-Klemp V, Thiel WR, Wichmann HE. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. Circulation. 2010 Jun 1;121(21):2331-78. Epub 2010 May 10.

[v] Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD; Impact of fine and ultrafine particles on emergency hospital admissions for cardiac and respiratory diseases. Epidemiology. 2010 May;21(3):414-23.

[vi] Belleudi V, Faustini A, Stafoggia M, Cattani G, Marconi A, Perucci CA, Forastiere F. mpact of fine and ultrafine particles on emergency hospital admissions for cardiac and respiratory diseases. Epidemiology. 2010 May; 21(3):414-23.

[vii] Samoli E, Nastos PT, Paliatsos AG, Katsouyanni K, Priftis KN. Acute effects of air pollution on pediatric asthma exacerbation: Evidence of association and effect modification. Environ Res. 2011 Feb 4.

[viii] Haley VB, Talbot TO, Felton HD. Surveillance of the short-term impact of fine particle air pollution on cardiovascular disease hospitalizations in New York State. Environ Health. 2009 Sep 22;8:42.

[ix] Peng RD, Bell ML, Geyh AS, McDermott A, Zeger SL, Samet JM, Dominici F. Emergency admissions for cardiovascular and respiratory diseases and the chemical composition of fine particle air pollution.Environ Health Perspect. 2009 Jun;117(6):957-63. Epub 2009 Feb 11.

[x] Schwela D Air pollution and health in urban areas. Rev Environ Health. 2000 Jan-Jun;15(1-2):13-42.

[xi] Moore K, Neugebauer R, Lurmann F, Hall J, Brajer V, Alcorn S, Tager I. Ambient ozone concentrations cause increased hospitalizations for asthma in children: an 18-year study in Southern California.Environ Health Perspect. 2008 Aug;116(8):1063-70.

[xii] Lin S, Bell EM, Liu W, Walker RJ, Kim NK, Hwang SA. Ambient ozone concentration and hospital admissions due to childhood respiratory diseases in New York State, 1991-2001.Environ Res. 2008 Sep;108(1):42-7. Epub 2008 Jul 25.

[xiii] Stieb DM, Szyszkowicz M, Rowe BH, Leech JA. Air pollution and emergency department visits for cardiac and respiratory conditions: a multi-city time-series analysis. Environ Health. 2009 Jun 10; 8:25.

[xiv] Yang Q, Chen Y, Krewski D, Burnett RT, Shi Y, McGrail KMEnviron Res. Effect of short-term exposure to low levels of gaseous pollutants on chronic obstructive pulmonary disease hospitalizations.2005 Sep;99(1):99-105. Epub 2004 Nov 21; Medina-Ramón M, Zanobetti A, Schwartz J. The effect of ozone and PM10 on hospital admissions for pneumonia and chronic obstructive pulmonary disease: a national multicity study. Am J Epidemiol. 2006 Mar 15;163(6):579-88. Epub 2006 Jan 27.

[xv] Chiu HF, Yang CY. Air pollution and emergency room visits for arrhythmias: are there potentially sensitive groups? J Toxicol Environ Health A. 2009;72(13):817-23.

[xvi] Lighthall, D. Environmental Health Evaluation of Rule 4901: Domestic Wood Burning in the San Joaquin Valley. November 7, 2008. California State University, Fresno.

[xvii] Short-term effects of air pollution on wheeze in asthmatic children in Fresno, California. Mann JK, Balmes JR, Bruckner TA, Mortimer KM, Margolis HG, Pratt B, Hammond SK, Lurmann FW, Tager IB. Environ Health Perspect. 2010 Oct;118(10):1497-502. Epub 2010 Jun 22.

[xviii] Joseph JV, Hasson A, Vu K,Ikeda A, Aulack G, Gushiken M, Rawat M and Tyner TR Airway Function, Rhinovirus infection and Urinary Quinones in the Evaluation of Exposure to Ambient PM2.5: A Preliminary Case-Control Study from the San Joaquin Valley.. CHEST. 2011 (submitted).

[xix] Belleudi V, Faustini A, Stafoggia M, Cattani G, Marconi A, Perucci CA, Forastiere F. Impact of fine and ultrafine particles on emergency hospital admissions for cardiac and respiratory diseases. Epidemiology. 2010 May;21(3):414-23.

[xx] Zanobetti A, Franklin M, Koutrakis P, Schwartz J. Fine particulate air pollution and its components in association with cause-specific emergency admissions. Environ Health. 2009 Dec 21;8:58.

Appendix:

ADDITIONAL TABLES AND FIGURES

Table I-1: Relative risk for PM 2.5-associated asthma ER visit by city for 0-19 yrs old

	PM2.5 Quintiles	Modesto (1-19 yrs old) RR	Modesto 95% CI	Modesto linear trend	Fresno (1-19 yrs old) RR	Fresno 95% CI	Fresno linear trend	Bakersfield (1-19 yrs old) RR	Bakersfield 95% CI	Bakersfield linear trend
asthma - LAG 0	Q5	1.41	0.977 - 2.030	p = 0.07699	1.45**	1.204 - 1.757	p = 0.00007**	1.18	0.931 - 1.494	p = 0.13280
	Q4	1.34	0.972 - 1.837		1.32**	1.110 - 1.596		1.20	0.978 - 1.474	
	Q3	1.26	0.944 - 1.692		1.25*	1.050 - 1.482		1.10	0.900 - 1.341	
	Q2	1.24	0.943 - 1.641		1.15	0.969 - 1.362		1.11	0.917 - 1.354	
	Q1	1.00			1.00			1.00		
asthma - LAG 1	Q5	1.22	0.851 - 1.756	p = 0.25510	1.52**	1.260 - 1.835	p = 0.00003**	1.19	0.944 - 1.511	p=0.05872
	Q4	1.31	0.960 - 1.781		1.24*	1.027 - 1.495		1.15	0.941 - 1.411	
	Q3	1.22	0.908 - 1.625		1.36**	1.151 - 1.620		1.11	0.913 - 1.355	
	Q2	1.21	0.917 - 1.596		1.14	0.956 - 1.352		0.99	0.815 - 1.208	
	Q1	1.00			1.00			1.00		
asthma - LAG 2	Q5	1.53*	1.068 - 2.202	p = 0.01049*	1.23*	1.022 - 1.481	p = 0.00111**	1.38**	1.093 - 1.745	p=0.00450**
	Q4	1.47*	1.078 - 2.015		1.26**	1.062 - 1.518		1.26*	1.026 - 1.541	
	Q3	1.41*	1.050 - 1.881		1.12	0.947 - 1.327		1.17	0.954 - 1.428	
	Q2	1.18	0.880 - 1.571		0.94	0.792 - 1.114		1.13	0.928 - 1.381	
	Q1	1.00			1.00			1.00		
asthma - LAG 3	Q5	1.91**	1.342 - 2.722	p = 0.00005**	1.23*	1.017 - 1.482	p = 0.01484*	1.51**	1.191 - 1.914	p=0.00054**
	Q4	1.67**	1.228 - 2.280		1.20	0.998 - 1.436		1.41**	1.151 - 1.736	
	Q3	1.42*	1.053 - 1.902		1.13	0.952 - 1.343		1.31**	1.071 - 1.606	
	Q2	1.15	0.860 - 1.541		1.05	0.889 - 1.250		1.28*	1.048 - 1.553	
	Q1	1.00			1.00			1.00		

Table I-2: Relative risk for PM 2.5-associated asthma ER visit by city for 20+ yrs old

	PM2.5 Quintiles	Modesto (20+ yrs old)			Fresno (20+ yrs old)			Bakersfield (20+ yrs old)		
		RR	95% CI	linear trend	RR	95% CI	linear trend	RR	95% CI	linear trend
asthma - LAG 0	Q5	1.00	0.733 - 1.354		1.16	0.962 - 1.387		1.10	0.843 - 1.435	
	Q4	1.20	0.931 - 1.547		1.05	0.881 - 1.262		0.79	0.621 - 1.012	
	Q3	0.82	0.640 - 1.055	p = 0.68146	1.07	0.911 - 1.263	p = 0.09024	1.06	0.848 - 1.314	p = 0.93587
	Q2	1.03	0.821 - 1.285		1.00	0.851 - 1.174		0.98	0.791 - 1.223	
	Q1	1.00			1.00			1.00		
asthma - LAG 1	Q5	0.91	0.677 - 1.224		1.23*	1.024 - 1.473		1.09	0.828 - 1.432	
	Q4	0.97	0.754 - 1.245		1.21*	1.012 - 1.442		0.97	0.765 - 1.231	
	Q3	1.04	0.824 - 1.310	p = 0.86732	1.11	0.943 - 1.312	p = 0.00294**	1.02	0.815 - 1.287	p = 0.98708
	Q2	0.85	0.677 - 1.070		1.02	0.863 - 1.197		1.16	0.931 - 1.437	
	Q1	1.00			1.00			1.00		
asthma - LAG 2	Q5	1.30	0.972 - 1.747		1.11	0.932 - 1.333		1.03	0.791 - 1.354	
	Q4	1.16	0.895 - 1.493		0.95	0.799 - 1.137		0.88	0.698 - 1.118	
	Q3	1.06	0.838 - 1.353	p = 0.09199	0.96	0.811 - 1.128	p = 0.26623	0.94	0.751 - 1.181	p = 0.91477
	Q2	1.10	0.876 - 1.377		0.95	0.805 - 1.112		0.98	0.786 - 1.216	
	Q1	1.00			1.00			1.00		
asthma - LAG 3	Q5	1.15	0.862 - 1.539		1.24*	1.031 - 1.493		1.02	0.778 - 1.346	
	Q4	1.05	0.814 - 1.349		1.17	0.979 - 1.402		0.96	0.759 - 1.222	
	Q3	1.01	0.795 - 1.280	p = 0.22412	1.06	0.889 - 1.256	p = 0.06852	0.94	0.748 - 1.193	p = 0.83422
	Q2	0.92	0.729 - 1.155		1.20	1.022 - 1.419		1.08	0.865 - 1.340	
	Q1	1.00			1.00			1.00		

Table I-3: Relative risk for PM 2.5-associated acute bronchitis ER visit by city for 1-19 and 20+ yrs old

	Quintile	Modesto (1-19 yrs old)			Modesto (20+ yrs old)			Fresno (1-19 yrs old)			Fresno (20+ yrs old)			Bakersfield (1-19 yrs old)			Bakersfield (20+ yrs old)		
		RR	95% CI	linear trend	RR	95% CI	linear trend	RR	95% CI	linear trend	RR	95% CI	linear trend	RR	95% CI	linear trend	RR	95% CI	linear trend
acute bronchitis - LAG 0	Q5	1.24	0.856 - 1.794		1.09	0.799 - 1.486		0.97	0.676 - 1.385		0.93	0.739 - 1.158		1.53*	1.097 - 2.143		1.27	0.895 - 1.814	
	Q4	1.02	0.740 - 1.418		0.94	0.718 - 1.236		1.10	0.785 - 1.548		0.89	0.719 - 1.107		1.14	0.838 - 1.539		1.06	0.777 - 1.459	
	Q3	1.07	0.788 - 1.440	p = 0.52518	0.94	0.724 - 1.217	p = 0.88098	0.97	0.699 - 1.341	p = 0.78494	1.00	0.821 - 1.215	p = 0.89952	1.14	0.849 - 1.524	p = 0.02828*	0.97	0.715 - 1.327	p = 0.33550
	Q2	1.19	0.905 - 1.576		1.06	0.834 - 1.346		1.16	0.852 - 1.571		0.85	0.694 - 1.033		1.14	0.856 - 1.528		1.18	0.878 - 1.575	
	Q1	1.00			1.00			1.00			1.00			1.00			1.00		
acute bronchitis - LAG 1	Q5	1.07	0.738 - 1.542		1.07	0.795 - 1.450		0.88	0.632 - 1.233		1.02	0.823 - 1.270		1.33	0.949 - 1.858		1.55*	1.094 - 2.192	
	Q4	0.91	0.652 - 1.263		0.89	0.680 - 1.168		0.86	0.625 - 1.196		0.87	0.703 - 1.080		1.09	0.811 - 1.457		0.97	0.708 - 1.332	
	Q3	1.21	0.906 - 1.630	p = 0.88432	0.84	0.642 - 1.091	p = 0.80080	0.87	0.641 - 1.173	p = 0.98840	1.01	0.834 - 1.229	p = 0.87701	0.89	0.659 - 1.197	p = 0.07432	1.06	0.787 - 1.436	p = 0.04169*
	Q2	1.23	0.930 - 1.630		1.24	0.978 - 1.560		0.68	0.496 - 0.927		0.82	0.670 - 0.997		0.97	0.730 - 1.295		1.03	0.772 - 1.384	
	Q1	1.00			1.00			1.00			1.00			1.00			1.00		
acute bronchitis - LAG 2	Q5	1.19	0.833 - 1.702		1.19	0.887 - 1.603		0.96	0.690 - 1.343		1.23	0.987 - 1.535		1.93**	1.378 - 2.690		1.26	0.878 - 1.812	
	Q4	1.14	0.835 - 1.556		0.94	0.722 - 1.232		0.81	0.581 - 1.122		0.97	0.777 - 1.209		1.45*	1.080 - 1.940		1.36*	1.004 - 1.851	
	Q3	1.00	0.745 - 1.350	p = 0.43991	0.87	0.671 - 1.132	p = 0.71338	0.78	0.574 - 1.071	p = 0.88083	1.10	0.900 - 1.353	p = 0.28337	1.11	0.817 - 1.499	p = 0.00004**	1.29	0.951 - 1.744	p = 0.05882
	Q2	1.17	0.886 - 1.538		1.18	0.932 - 1.492		0.79	0.585 - 1.078		1.10	0.899 - 1.336		1.13	0.839 - 1.519		1.00	0.729 - 1.366	
	Q1	1.00			1.00			1.00			1.00			1.00			1.00		
acute bronchitis - LAG 3	Q5	1.13	0.786 - 1.635		0.83	0.613 - 1.116		1.06	0.746 - 1.503		1.24	0.994 - 1.539		1.99**	1.410 - 2.797		1.31	0.902 - 1.894	
	Q4	1.08	0.783 - 1.483		0.77	0.594 - 1.007		1.13	0.813 - 1.579		0.98	0.787 - 1.216		1.43*	1.050 - 1.937		1.26	0.910 - 1.748	
	Q3	1.08	0.797 - 1.454	p = 0.70968	0.84	0.652 - 1.085	p = 0.12326	1.02	0.745 - 1.410	p = 0.33989	0.97	0.786 - 1.188	p = 0.10288	1.49**	1.107 - 2.015	p = 0.00003**	1.31	0.950 - 1.801	p = 0.21928
	Q2	1.18	0.892 - 1.565		0.91	0.715 - 1.159		0.85	0.617 - 1.185		0.98	0.804 - 1.200		1.12	0.822 - 1.517		1.29	0.947 - 1.767	
	Q1	1.00			1.00			1.00			1.00			1.00			1.00		

Table I-4: Relative risk for PM 2.5-associated pneumonia ER visit by city for 1-19 and 20+ yrs old

*p < 0.05; **p < 0.01

	Quintile	Modesto (1-19 yrs old) RR	95% CI	linear trend	Modesto (20+ yrs old) RR	95% CI	linear trend
pneumonia - LAG 0	Q5	1.18	0.864 - 1.621	p = 0.19252	1.10	0.803 - 1.519	p = 0.44198
	Q4	0.91	0.689 - 1.205		1.17	0.893 - 1.531	
	Q3	0.99	0.770 - 1.285		0.96	0.741 - 1.250	
	Q2	0.78	0.607 - 1.012		1.07	0.843 - 1.364	
	Q1	1.00			1.00		
pneumonia - LAG 1	Q5	1.55**	1.145 - 2.100	p = 0.02938*	0.91	0.670 - 1.245	p = 0.74920
	Q4	0.88	0.656 - 1.170		1.05	0.809 - 1.370	
	Q3	1.22	0.943 - 1.574		1.00	0.779 - 1.282	
	Q2	0.96	0.741 - 1.235		0.99	0.776 - 1.254	
	Q1	1.00			1.00		
pneumonia - LAG 2	Q5	1.24	0.912 - 1.698	p = 0.28118	0.87	0.649 - 1.176	p = 0.18739
	Q4	1.06	0.805 - 1.406		0.73*	0.562 - 0.956	
	Q3	1.11	0.853 - 1.438		0.86	0.679 - 1.100	
	Q2	1.11	0.862 - 1.431		0.89	0.706 - 1.120	
	Q1	1.00			1.00		
pneumonia - LAG 3	Q5	1.49*	1.089 - 2.032	p = 0.01032*	0.86	0.630 - 1.165	p = 0.35699
	Q4	1.27	0.963 - 1.682		0.93	0.713 - 1.206	
	Q3	1.21	0.928 - 1.580		0.92	0.714 - 1.174	
	Q2	1.10	0.850 - 1.430		0.94	0.742 - 1.191	
	Q1	1.00			1.00		

	Quintile	Fresno (1-19 yrs old) RR	95% CI	linear trend	Fresno (20+ yrs old) RR	95% CI	linear trend
pneumonia - LAG 0	Q5	1.06	0.807 - 1.386	p = 0.19381	0.87	0.645 - 1.175	p = 0.18754
	Q4	1.27	0.989 - 1.639		0.91	0.684 - 1.211	
	Q3	1.37*	1.088 - 1.734		1.05	0.813 - 1.360	
	Q2	0.94	0.737 - 1.207		1.10	0.856 - 1.406	
	Q1	1.00			1.00		
pneumonia - LAG 1	Q5	0.91	0.705 - 1.187	p = 0.77882	0.83	0.622 - 1.108	p = 0.17483
	Q4	1.08	0.843 - 1.375		0.83	0.629 - 1.096	
	Q3	0.93	0.738 - 1.183		0.91	0.703 - 1.168	
	Q2	0.98	0.782 - 1.234		0.91	0.711 - 1.165	
	Q1	1.00			1.00		
pneumonia - LAG 2	Q5	0.78	0.604 - 1.018	p = 0.01006*	1.00	0.758 - 1.330	p = 0.61381
	Q4	0.83	0.647 - 1.065		0.77	0.582 - 1.029	
	Q3	0.91	0.722 - 1.149		0.96	0.742 - 1.236	
	Q2	1.12	0.898 - 1.391		0.97	0.758 - 1.243	
	Q1	1.00			1.00		
pneumonia - LAG 3	Q5	0.81	0.626 - 1.044	p = 0.14530	0.82	0.620 - 1.091	p = 0.27938
	Q4	0.86	0.673 - 1.097		0.81	0.613 - 1.058	
	Q3	0.93	0.744 - 1.171		0.79	0.609 - 1.016	
	Q2	0.87	0.695 - 1.090		0.78	0.610 - 1.003	
	Q1	1.00			1.00		

	Quintile	Bakersfield (1-19 yrs old) RR	95% CI	linear trend	Bakersfield (20+ yrs old) RR	95% CI	linear trend
pneumonia - LAG 0	Q5	1.54**	1.164 - 2.040	p = 0.00172**	1.10	0.840 - 1.435	p = 0.38729
	Q4	1.42**	1.115 - 1.818		1.14	0.908 - 1.435	
	Q3	1.34*	1.060 - 1.701		1.13	0.910 - 1.409	
	Q2	1.25	0.984 - 1.582		1.05	0.840 - 1.302	
	Q1	1.00			1.00		
pneumonia - LAG 1	Q5	1.30	0.986 - 1.709	p = 0.05308	1.13	0.860 - 1.483	p = 0.25454
	Q4	1.19	0.941 - 1.509		1.18	0.942 - 1.489	
	Q3	1.16	0.923 - 1.469		1.11	0.888 - 1.393	
	Q2	1.10	0.872 - 1.383		1.06	0.852 - 1.330	
	Q1	1.00			1.00		
pneumonia - LAG 2	Q5	1.46**	1.102 - 1.927	p = 0.01484*	1.06	0.810 - 1.391	p 0.70923
	Q4	1.27	0.997 - 1.608		1.08	0.858 - 1.361	
	Q3	1.22	0.962 - 1.549		1.06	0.847 - 1.333	
	Q2	1.25	0.995 - 1.579		1.09	0.870 - 1.359	
	Q1	1.00			1.00		
pneumonia - LAG 3	Q5	1.27	0.964 - 1.684	p = 0.00603**	0.85	0.650 - 1.111	p 0.38590
	Q4	1.31*	1.038 - 1.658		0.88	0.697 - 1.103	
	Q3	1.22	0.964 - 1.532		1.04	0.835 - 1.291	
	Q2	0.89	0.702 - 1.137		0.82	0.660 - 1.029	
	Q1	1.00			1.00		

Table I-5: Relative risk for PM2.5-associated asthma hospitalization by city for all ages

*p < 0.05 / **p < 0.01	PM 2.5 Quintile	Modesto RR	95% CI	linear trend	Fresno RR	95% CI	linear trend	Bakersfield RR	95% CI	linear trend
ASTHMA (all ages) - LAG 0	Q5	1.02	0.75 - 1.37	p = 0.72108	1.37**	1.15 - 1.70	p = 0.00062**	0.82	0.65 - 1.04	p = 0.33678
	Q4	1.06	0.82 - 1.38		1.18	0.98 - 1.43		0.95	0.77 - 1.17	
	Q3	0.99	0.77 - 1.26		1.41**	1.18 - 1.67		0.84	0.69 - 1.03	
	Q2	0.97	0.77 - 1.22		1.05	0.88 - 1.25		0.84	0.69 - 1.02	
	Q1	1.00			1.00			1.00		
ASTHMA (all ages) - LAG 1	Q5	1.04	0.77 - 1.39	p = 0.70592	1.48**	1.21 - 1.80	p = 0.00003**	1.20	0.94 - 1.52	p = 0.06198
	Q4	1.00	0.77 - 1.31		1.41**	1.17 - 1.71		1.25	1.01 - 1.55	
	Q3	0.99	0.77 - 1.27		1.32**	1.10 - 1.58		1.02	0.83 - 1.26	
	Q2	1.23	0.98 - 1.55		1.17	0.98 - 1.39		1.06	0.87 - 1.29	
	Q1	1.00			1.00			1.00		
ASTHMA (all ages) - LAG 2	Q5	1.27	0.94 - 1.72	p = 0.11323	1.37**	1.12 - 1.67	p = 0.00034**	1.40**	1.10 - 1.78	p = 0.03711*
	Q4	1.38*	1.06 - 1.81		1.30**	1.08 - 1.57		1.11	0.89 - 1.39	
	Q3	1.22	0.94 - 1.57		1.38**	1.16 - 1.66		1.26	1.03 - 1.54	
	Q2	1.28	1.00 - 1.63		1.05	0.87 - 1.26		1.21	0.99 - 1.47	
	Q1	1.00			1.00			1.00		
ASTHMA (all ages) - LAG 3	Q5	1.01	0.75 - 1.35	p = 0.30714	1.18	0.97 - 1.44	p = 0.03525*	1.48**	1.16 - 1.88	p = 0.00283**
	Q4	1.26	0.98 - 1.64		1.20	1.00 - 1.44		1.23	0.99 - 1.53	
	Q3	1.16	0.91 - 1.48		1.13	0.94 - 1.35		1.28*	1.04 - 1.57	
	Q2	0.90	0.70 - 1.15		1.03	0.86 - 1.23		1.16	0.95 - 1.41	
	Q1	1.00			1.00			1.00		

Table I-6: Relative risk for PM2.5-associated asthma hospitalization by city for 0-19 yrs old

*p < 0.05	PM 2.5 Quintile	Modesto			Fresno			Bakersfield		
**p < 0.01		RR	95% CI	linear trend	RR	95% CI	linear trend	RR	95% CI	linear trend
ASTHMA (0-19 yrs) - LAG 0	Q5	1.02	0.64 - 1.64	p = 0.49143	1.40*	1.08 - 1.81	p = 0.01530*	0.80	0.56 - 1.15	p = 0.63385
	Q4	1.08	0.72 - 1.62		1.19	0.93 - 1.52		0.91	0.66 - 1.25	
	Q3	0.93	0.64 - 1.36		1.42**	1.13 - 1.79		0.73	0.53 - 1.00	
	Q2	0.76	0.52 - 1.12		1.11	0.88 - 1.40		0.71*	0.52 - 0.98	
	Q1	1.00			1.00			1.00		
ASTHMA (0-19 yrs) - LAG 1	Q5	1.06	0.66 - 1.68	p = 0.79025	1.58**	1.21 - 2.07	p = 0.00005**	1.13	0.78 - 1.63	p = 0.35374
	Q4	0.81	0.53 - 1.25		1.64**	1.28 - 2.10		1.18	0.85 - 1.65	
	Q3	0.84	0.56 - 1.25		1.53**	1.20 - 1.95		0.81	0.58 - 1.14	
	Q2	1.05	0.73 - 1.51		1.17	0.92 - 1.50		1.00	0.73 - 1.36	
	Q1	1.00			1.00			1.00		
ASTHMA (0-19 yrs) - LAG 2	Q5	1.59	0.98 - 2.58	p = 0.02557*	1.38*	1.06 - 1.79	p = 0.00549**	1.25	0.86 - 1.80	p = 0.49709
	Q4	1.65*	1.08 - 2.52		1.27	0.99 - 1.63		0.93	0.66 - 1.32	
	Q3	1.19	0.78 - 1.80		1.32*	1.04 - 1.68		1.05	0.76 - 1.44	
	Q2	1.18	0.79 - 1.75		1.03	0.80 - 1.31		1.07	0.79 - 1.47	
	Q1	1.00			1.00			1.00		
ASTHMA (0-19 yrs) - LAG 3	Q5	1.20	0.74 - 1.96	p = 0.31697	1.07	0.83 - 1.38	p = 0.29009	1.25	0.87 - 1.81	p = 0.56642
	Q4	1.50	0.98 - 2.30		1.12	0.88 - 1.43		0.90	0.64 - 1.28	
	Q3	1.24	0.82 - 1.87		0.98	0.77 - 1.24		0.85	0.61 - 1.18	
	Q2	1.23	0.83 - 1.82		0.93	0.74 - 1.18		1.10	0.81 - 1.49	
	Q1	1.00			1.00			1.00		

Table 1-7: Relative risk for PM2.5-associated asthma hospitalizations by city for 20-54 yrs old

*p < 0.05	PM 2.5 Quintile	Modesto			Fresno			Bakersfield		
**p < 0.01		RR	95% CI	linear trend	RR	95% CI	linear trend	RR	95% CI	linear trend
ASTHMA (20-54 yrs) - LAG 0	Q5	1.39	0.79 - 2.43	p = 0.34137	1.33	0.88 - 2.02	p = 0.07123	0.97	064 - 1.46	p = 0.59534
	Q4	1.19	0.71 - 1.99		1.26	0.85 - 1.86		0.83	0.56 - 1.22	
	Q3	1.11	0.68 - 1.82		1.52*	1.06 - 2.19		0.85	0.59 - 1.22	
	Q2	1.22	0.77 - 1.94		0.91	0.62 - 1.34		1.00	0.71 - 1.41	
	Q1	1.00			1.00			1.00		
ASTHMA (20-54 yrs) - LAG 1	Q5	1.09	0.63 - 1.89	p = 0.60024	1.31	0.86 - 1.99	p = 0.14840	1.31	0.84 - 2.02	p = 0.23507
	Q4	1.16	0.71 - 1.89		1.30	0.88 - 1.92		1.26	0.85 - 1.87	
	Q3	1.11	0.69 - 1.78		1.19	0.81 - 1.74		0.99	0.68 - 1.45	
	Q2	0.98	0.62 - 1.56		1.10	0.76 - 1.59		1.17	0.83 - 1.65	
	Q1	1.00			1.00			1.00		
ASTHMA (20-54 yrs) - LAG 2	Q5	1.29	0.72 - 2.30	p = 0.25385	1.51	0.98 - 2.34	p = 0.04170*	1.74*	1.10 - 2.74	p = 0.02085*
	Q4	1.61	0.97 - 2.69		1.49	0.99 - 2.25		1.56*	1.04 - 2.36	
	Q3	1.20	0.72 - 1.99		1.71**	1.17 - 2.51		1.65**	1.13 - 2.40	
	Q2	1.23	0.76 - 2.00		1.22	0.83 - 1.81		1.39	0.96 - 2.01	
	Q1	1.00			1.00			1.00		
ASTHMA (20-54 yrs) - LAG 3	Q5	1.08	0.62 - 1.86	p = 0.36765	1.30	0.85 - 1.98	p = 0.15698	1.70*	1.08 - 2.69	p = 0.01456*
	Q4	1.14	0.69 - 1.87		1.43	0.97 - 2.12		1.62*	1.08 - 2.45	
	Q3	1.15	0.72 - 1.84		1.22	0.83 - 1.80		1.77**	1.22 - 2.57	
	Q2	0.73	0.44 - 1.20		1.20	0.83 - 1.74		1.28	0.88 - 1.87	
	Q1	1.00			1.00			1.00		

Table 1-8: Relative risk for PM2.5-associated asthma hospitalization by city for 55+ yrs old

*p ≤ 0.05 / **p ≤ 0.01	PM 2.5 Quintile	Modesto RR	Modesto 95% CI	Modesto linear trend	Fresno RR	Fresno 95% CI	Fresno linear trend	Bakersfield RR	Bakersfield 95% CI	Bakersfield linear trend
ASTHMA (55+ yrs) - LAG 0	Q5	0.76	0.44 - 1.28	p = 0.28476	1.40	0.91 - 2.17	p = 0.18298	0.71	0.45 - 1.10	p = 0.40326
	Q4	0.96	0.61 - 1.50		1.06	0.70 - 1.63		1.12	0.77 - 1.62	
	Q3	0.97	0.64 - 1.47		1.25	0.85 - 1.85		0.99	0.69 - 1.41	
	Q2	1.06	0.72 - 1.56		1.05	0.72 - 1.54		0.86	0.61 - 1.23	
	Q1	1.00			1.00			1.00		
ASTHMA (55+ yrs) - LAG 1	Q5	0.93	0.55 - 1.59	p = 0.35145	1.40	0.91 - 2.15	p = 0.37061	1.19	0.77 - 1.85	p = 0.25969
	Q4	1.10	0.69 - 1.76		0.96	0.63 - 1.48		1.33	0.90 - 1.97	
	Q3	1.07	0.69 - 1.67		0.92	0.61 - 1.39		1.36	0.94 - 1.96	
	Q2	1.70	1.16 - 2.49		1.19	0.82 - 1.71		1.05	0.73 - 1.52	
	Q1	1.00			1.00			1.00		
ASTHMA (55+ yrs) - LAG 2	Q5	0.96	0.56 - 1.64	p = 0.43867	1.20	0.77 - 1.87	p = 0.26473	1.32	0.85 - 2.05	p = 0.46145
	Q4	0.93	0.58 - 1.52		1.20	0.79 - 1.82		1.04	0.69 - 1.57	
	Q3	1.25	0.81 - 1.94		1.25	0.84 - 1.84		1.24	0.85 - 1.79	
	Q2	1.40	0.92 - 2.12		0.97	0.65 - 1.43		1.25	0.88 - 1.77	
	Q1	1.00			1.00			1.00		
ASTHMA (55+ yrs) - LAG 3	Q5	0.77	0.47 - 1.28	p = 0.95555	1.44	0.92 - 2.26	p = 0.15010	1.67*	1.07 - 2.60	p = 0.01517*
	Q4	1.16	0.76 - 1.78		1.18	0.77 - 1.83		1.43	0.96 - 2.14	
	Q3	1.10	0.73 - 1.65		1.56*	1.06 - 2.31		1.52*	1.06 - 2.20	
	Q2	0.72	0.47 - 1.10		1.15	0.78 - 1.71		1.13	0.78 - 1.64	
	Q1	1.00			1.00			1.00		

Table I-9: Relative risk for PM2.5-associated acute MI hospitalization by city for 20+ yrs old

*p < 0.05 / **p < 0.01	PM 2.5 Quintile	Modesto RR	Modesto 95% CI	Modesto linear trend	Fresno RR	Fresno 95% CI	Fresno linear trend	Bakersfield RR	Bakersfield 95% CI	Bakersfield linear trend
acute MI - LAG 0	Q5	1.11	0.85 - 1.46	p = 0.61067	1.12	0.94 - 1.34	p = 0.15224	1.08	0.88 - 1.32	p = 0.80569
	Q4	0.96	0.75 - 1.22		1.06	0.90 - 1.26		0.96	0.79 - 1.16	
	Q3	0.91	0.73 - 1.13		1.08	0.92 - 1.27		1.00	0.83 - 1.20	
	Q2	1.01	0.83 - 1.24		0.99	0.85 - 1.16		1.05	0.88 - 1.25	
	Q1	1.00			1.00			1.00		
acute MI - LAG 1	Q5	0.96	0.73 - 1.25	p = 0.60540	1.12	0.94 - 1.34	p = 0.29173	1.14	0.93 - 1.40	p = 0.14296
	Q4	0.92	0.72 - 1.16		1.07	0.91 - 1.27		1.04	0.86 - 1.26	
	Q3	0.86	0.69 - 1.08		1.08	0.92 - 1.26		0.93	0.77 - 1.11	
	Q2	0.99	0.81 - 1.22		1.08	0.93 - 1.26		0.95	0.79 - 1.13	
	Q1	1.00			1.00			1.00		
acute MI - LAG 2	Q5	0.91	0.70 - 1.19	p = 0.39845	1.08	0.90 - 1.30	p = 0.22609	1.10	0.89 - 1.35	p = 0.35556
	Q4	0.92	0.73 - 1.17		1.12	0.94 - 1.32		1.06	0.87 - 1.28	
	Q3	1.05	0.84 - 1.30		1.19	1.02 - 1.39		1.02	0.85 - 1.23	
	Q2	1.00	0.81 - 1.23		1.01	0.86 - 1.18		1.01	0.85 - 1.21	
	Q1	1.00			1.00			1.00		
acute MI - LAG 3	Q5	0.87	0.66 - 1.13	p = 0.30618	1.00	0.83 - 1.19	p = 0.97669	1.06	0.86 - 1.31	p = 0.86030
	Q4	0.94	0.74 - 1.20		0.99	0.84 - 1.17		1.00	0.82 - 1.21	
	Q3	0.99	0.80 - 1.24		1.03	0.88 - 1.21		1.11	0.93 - 1.33	
	Q2	0.98	0.79 - 1.20		0.98	0.84 - 1.14		1.08	0.91 - 1.29	
	Q1	1.00			1.00			1.00		

Table I-10: Relative risk for PM2.5-associated COPD hospitalization by city for 20+ yrs old

*p < 0.05	PM 2.5 Quintile	Modesto			Fresno			Bakersfield		
**p < 0.01		RR	95% CI	linear trend	RR	95% CI	linear trend	RR	95% CI	linear trend
COPD - LAG 0	Q5	0.98	0.76 - 1.27	p = 0.74202	1.08	0.86 - 1.36	p = 0.71623	0.97	0.78 - 1.21	p = 0.79394
	Q4	0.92	0.73 - 1.16		1.09	0.88 - 1.35		0.87	0.71 - 1.07	
	Q3	0.97	0.78 - 1.20		1.09	0.89 - 1.34		0.96	0.80 - 1.16	
	Q2	0.98	0.80 - 1.20		1.15	0.95 - 1.39		0.88	0.73 - 1.06	
	Q1	1.00			1.00			1.00		
COPD - LAG 1	Q5	0.90	0.70 - 1.15	p = 0.29221	1.09	0.87 - 1.36	p = 0.36615	1.27*	1.01 - 1.60	p = 0.03453*
	Q4	0.92	0.74 - 1.16		1.05	0.85 - 1.29		1.22	0.99 - 1.50	
	Q3	0.93	0.75 - 1.15		1.02	0.84 - 1.25		1.13	0.93 - 1.38	
	Q2	1.01	0.83 - 1.24		0.98	0.81 - 1.19		1.12	0.92 - 1.35	
	Q1	1.00			1.00			1.00		
COPD - LAG 2	Q5	0.89	0.70 - 1.14	p = 0.21602	1.13	0.90 - 1.42	p = 0.23687	1.16	0.92 - 1.46	p = 0.09450
	Q4	0.88	0.70 - 1.10		1.24*	1.00 - 1.53		1.17	0.96 - 1.44	
	Q3	0.89	0.72 - 1.10		1.05	0.86 - 1.30		1.15	0.95 - 1.40	
	Q2	1.01	0.83 - 1.22		1.15	0.95 - 1.40		1.00	0.83 - 1.21	
	Q1	1.00			1.00			1.00		
COPD - LAG 3	Q5	0.93	0.72 - 1.19	p = 0.49050	0.88	0.70 - 1.11	p = 0.52726	1.27*	1.01 - 1.60	p = 0.05294
	Q4	0.93	0.74 - 1.17		1.04	0.85 - 1.28		1.10	0.89 - 1.36	
	Q3	1.04	0.85 - 1.28		0.92	0.75 - 1.13		1.29*	1.06 - 1.56	
	Q2	0.99	0.81 - 1.21		0.96	0.79 - 1.16		1.05	0.87 - 1.28	
	Q1	1.00			1.00			1.00		

Table I-11: Relative risk for PM2.5-associated CHF hospitalization by city for 20+ yrs old

*p < 0.05	PM 2.5 Quintile	Modesto			Fresno			Bakersfield		
**p < 0.01		RR	95% CI	linear trend	RR	95% CI	linear trend	RR	95% CI	linear trend
CHF - LAG 0	Q5	0.99	0.81 - 1.21	p = 0.72613	0.91	0.78 - 1.05	p = 0.15599	0.81**	0.70 - 0.95	p = 0.01017*
	Q4	1.00	0.84 - 1.19		0.92	0.81 - 1.06		0.84*	0.74 - 0.97	
	Q3	0.92	0.78 - 1.08		0.97	0.85 - 1.10		0.92	0.81 - 1.04	
	Q2	0.91	0.77 - 1.06		0.97	0.86 - 1.10		0.89	0.78 - 1.01	
	Q1	1.00			1.00			1.00	negative	
CHF - LAG 1	Q5	0.94	0.77 - 1.14	p = 0.49737	0.96	0.82 - 1.11	p = 0.63631	0.78**	0.67 - 0.91	p = 0.00151**
	Q4	0.96	0.80 - 1.14		0.99	0.86 - 1.14		0.80**	0.70 - 0.92	
	Q3	0.90	0.76 - 1.06		1.03	0.90 - 1.18		0.87*	0.77 - 0.99	
	Q2	0.98	0.84 - 1.15		0.98	0.87 - 1.12		0.86*	0.76 - 0.97	
	Q1	1.00			1.00			1.00	NEGATIVE	
CHF - LAG 2	Q5	0.97	0.79 - 1.18	p = 0.75012	0.97	0.83 - 1.12	p = 0.82260	0.92	0.79 - 1.07	p = 0.60373
	Q4	1.03	0.87 - 1.23		0.97	0.85 - 1.12		1.01	0.88 - 1.16	
	Q3	1.06	0.90 - 1.25		0.99	0.87 - 1.13		1.00	0.88 - 1.13	
	Q2	1.04	0.89 - 1.21		0.95	0.83 - 1.07		0.93	0.82 - 1.06	
	Q1	1.00			1.00			1.00		
CHF - LAG 3	Q5	0.94	0.78 - 1.15	p = 0.88147	1.00	0.86 - 1.16	p = 0.61612	0.94	0.80 - 1.10	p = 0.39545
	Q4	1.04	0.88 - 1.24		1.06	0.92 - 1.22		0.95	0.83 - 1.10	
	Q3	1.01	0.86 - 1.19		1.04	0.91 - 1.18		0.98	0.86 - 1.11	
	Q2	0.96	0.82 - 1.12		0.97	0.85 - 1.10		0.98	0.87 - 1.12	
	Q1	1.00			1.00			1.00		

Table I-12: Pearson correlations for cool season co-variates by city

Pearson Correlations	Carbon Monoxide	Nitrogen Dioxide	Ambient Temperature	Relative Humidity
FRE_NO2	.514			
FRE_Temperature	-.005	.465		
FRE_RelHum	.021	-.487	-.697	
FRE_PM2.5 (24 hr avg)	**.574**	**.376**	**-.112**	**.199**
BAK_NO2	.493			
BAK_Temperature	.064	.568		
BAK_RelHum	-.116	-.523	-.686	
BAK_PM2.5 (24 hr avg)	**.474**	**.236**	**-.095**	**.291**
MOD_NO2	.582			
MOD_Temperature	.040	.443		
MOD_RelHum	-.014	-.332	-.579	
MOD_PM2.5 (24 hr avg)	**.540**	**.316**	**-.228**	**.341**

Figure I-1: Relative risk for asthma ER visit per quintile of regional PM2.5 for 1-19 yrs old with and without environmental covariates

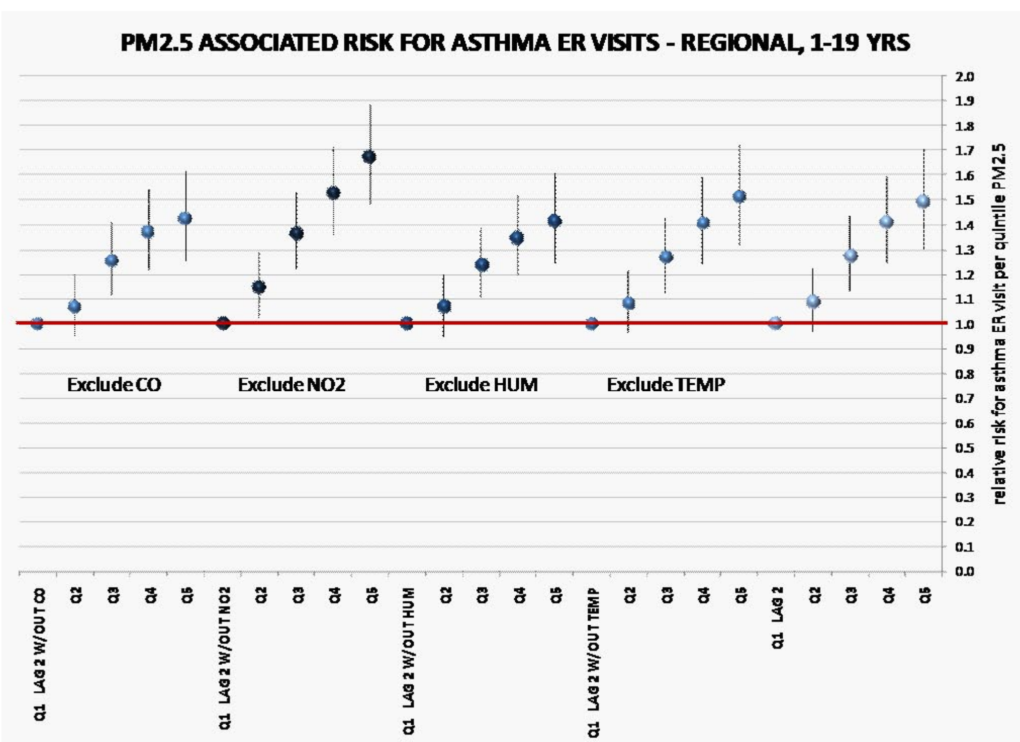


Table I-13: Pearson correlations for warm season co-variates by city

MODESTO	MOD_temp	MOD_relhum	MOD_NO2	MOD_CO	MOD_O3
MOD_temperature					
MOD_relative humidity	-.557				
MOD_NO2	.314	-.157			
MOD_CO	.011	.067	.521		
MOD_O3	**.718**	**-.358**	**.426**	**.093**	
FRESNO	FRE_temp	FRE_relhum	FRE_NO2	FRE_CO	FRE_O3
FRE_temperature					
FRE_relative humidity	-.807				
FRE_NO2	.119	.019			
FRE_CO	-.016	.130	.617		
FRE_O3	**.780**	**-.610**	**.273**	**.059**	
BAKERSFIELD	BAK_temp	BAK_relhum	BAK_NO2	BAK_CO	BAK_O3
BAK_temperature					
BAK_relative humidity	.168				
BAK_NO2	.403	.089			
BAK_CO	.277	-.014	.734		
BAK_O3	**.771**	**.188**	**.482**	**.301**	

Table I-14: Relative risk for ozone-associated asthma ER visit by city for 1-19 and 20+ yrs old

MODESTO

ER	ozone quintile	1-19 yrs old RR	STDEV	SIG	linear trend	20+ yrs old RR	STDEV	SIG	linear trend
asthma ER - lag 0	71+	1.69	0.89 - 3.23	.109	0.08359	1.06	0.70 - 1.64	.737	0.76893
	63 - 70	2.03	1.10 - 3.77	.024		0.89	0.57 - 1.38	.597	
	54 - 62	1.47	0.85 - 2.56	.168		0.91	0.62 - 1.31	.604	
	46 - 53	1.37	0.79 - 2.36	.258		0.88	0.61 - 1.28	.497	
	<=45	1.00				1.00			
asthma ER - lag 1	71+	1.44	0.77 - 2.69	.248	0.48432	1.62	1.04 - 2.53	.034	0.10700
	63 - 70	1.02	0.53 - 1.96	.948		1.21	1.90 - 0.77	.407	
	54 - 62	1.47	0.86 - 2.52	.156		1.28	0.87 - 1.88	.207	
	46 - 53	1.24	0.71 - 2.18	.442		1.31	0.90 - 1.91	.160	
	<=45	1.00				1.00			
asthma ER - lag 2	71+	1.19	0.62 - 2.29	.593	0.39182	0.90	0.58 - 1.39	.631	0.60843
	63 - 70	1.42	0.76 - 2.63	.271		0.78	0.50 - 1.22	.279	
	54 - 62	1.53	0.91 - 2.56	.108		0.90	0.62 - 1.31	.586	
	46 - 53	1.01	0.58 - 1.78	.965		0.91	0.63 - 1.33	.633	
	<=45	1.00				1.00			

FRESNO

ER	ozone quintile	1-19 yrs old RR	STDEV	SIG	linear trend	20+ yrs old RR	STDEV	SIG	linear trend
asthma ER - lag 0	86+	1.42	0.94 - 2.12	.092	0.09423	1.00	0.74 - 1.35	.997	0.94408
	77 - 85	1.34	0.92 - 1.94	.127		0.88	0.67 - 1.17	.383	
	70 - 76	1.22	0.84 - 1.78	.294		0.83	0.63 - 1.10	.190	
	59 - 69	1.23	0.88 - 1.74	.230		0.91	0.71 - 1.16	.433	
	<=58	1.00				1.00			
asthma ER - lag 1	86+	1.30	0.86 - 1.98	.216	0.16932	1.15	0.85 - 1.55	.375	0.16107
	77 - 85	1.60	1.11 - 2.32	.012		1.12	0.85 - 1.47	.420	
	70 - 76	1.25	0.85 - 1.85	.262		0.92	0.70 - 1.22	.576	
	59 - 69	1.40	0.98 - 1.99	.062		0.92	0.72 - 1.19	.528	
	<=58	1.00				1.00			
asthma ER - lag 2	86+	1.48	0.98 - 2.25	.062	0.02975	1.17	0.87 - 1.57	.289	0.18488
	77 - 85	1.73	1.20 - 2.48	.003		0.99	0.75 - 1.30	.948	
	70 - 76	1.31	0.90 - 1.91	.166		0.92	0.70 - 1.21	.548	
	59 - 69	1.37	0.97 - 1.93	.076		0.86	0.67 - 1.11	.256	
	<=58	1.00				1.00			

BAKERSFIELD

ER	ozone quintile	1-19 yrs old RR	STDEV	SIG	linear trend	20+ yrs old RR	STDEV	SIG	linear trend
asthma ER - lag 0	89+	0.94	0.61 - 1.46	.783	0.98775	1.27	0.85 - 1.91	.239	0.18284
	78 - 88	0.71	0.47 - 1.07	.104		1.11	0.77 - 1.62	.577	
	70 - 77	0.67	0.45 - 0.99	.043		1.04	0.73 - 1.49	.820	
	62 - 69	0.62	0.42 - 0.92	.018		0.97	0.68 - 1.39	.878	
	<=61	1.00				1.00			
asthma ER - lag 1	89+	0.97	0.59 - 1.62	.919	0.79183	1.05	0.70 - 1.56	.827	0.94554
	78 - 88	1.45	0.95 - 2.21	.083		0.84	0.58 - 1.22	.367	
	70 - 77	1.11	0.73 - 1.70	.615		0.82	0.58 - 1.17	.272	
	62 - 69	1.18	0.78 - 1.79	.423		0.95	0.68 - 1.33	.771	
	<=61	1.00				1.00			
asthma ER - lag 2	89+	1.18	0.73 - 1.91	.502	0.30454	0.88	0.58 - 1.35	.569	0.98221
	78 - 88	1.28	0.84 - 1.95	.253		1.10	0.77 - 1.57	.604	
	70 - 77	1.15	0.75 - 1.76	.531		0.93	0.64 - 1.34	.686	
	62 - 69	1.01	0.68 - 1.51	.943		0.85	0.61 - 1.19	.351	
	<=61	1.00				1.00			

Figure I-2: Mean daily asthma hospitalizations (all ages) associated with PM2.5 levels above or below the NAAQScovariates