Particulate air pollution and health in elementary school students and collegiate distance runners in Carlisle, PA

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ABSTRACT

BACKGROUND: Central Pennsylvania's Cumberland Valley would seem an unlikely location for health-impairing air pollution. However, heavy trucking, regional coal emissions, topography and weather have made this moderately-populated region one of the worst in the country for $PM_{2.5}$. The purpose of this study was to examine the effects of $PM_{2.5}$ on lung health in Carlisle's elementary school students and collegiate distance runners at Dickinson College. METHODS: Elementary schools, in the Carlisle Area School District, record supervised use of inhalers for asthmatic children. We compared this data to hourly $PM_{2.5}$ concentrations starting in September 2009 through March 2010. We also measured peak expiratory flow (PEF) values and collected self-reports of respiratory symptoms from 31 distance runners at Dickinson. We did this right after practice for 25 days throughout the cross country and track seasons. PEF values and changes in symptoms after running were compared to $PM_{2.5}$ concentrations as well. Correlations between $PM_{2.5}$ and the various measures of lung health were calculated through linear regressions and the calculation of p and R^2 values. RESULTS: For the elementary school students there was no correlation of inhaler usage with $PM_{2.5}$ exposure. Similarly, there were no clear trends shared by all the runners. The amount of data that is available is definitely limited, however further study would most likely indicate that local particulate matter is inadequately controlled**.**

INTRODUCTION

PM$_{2.5}$

PM$_{2.5}$ is particulate matter that is 2.5 microns or less in diameter (Kavouras et al. 2001). Each particle is about 1/30 the size of a human hair (Clean Air Board 2008). A study done in six US cities (Boston, St. Louis, Knoxville, Madison, Steubenville, Topeka) found that coal and mobile sources account for a majority of the fine particulate pollution (Laden et al. 2000). The proportion of fine particles that could be accounted for by mobile sources ranged from 5% in Steubenville to 29% in Boston (Laden et al. 2000). Other sources of PM$_{2.5}$ include wood smoke and road dust (Penn Future 2010, Kavouras et al. 2001). 40 known toxins and 3 known carcinogens can be bound to these particles in diesel exhaust (Clean Air Board 2008). These particles can cause exacerbations of lung disease and the carcinogens attached to them can cause lung cancer (Clean Air Board 2008).

PM$_{2.5}$ is smaller than PM$_{10}$ (particulate matter that is 10 microns or less in diameter) and is therefore associated with more health risks than PM$_{10}$. The size of a particle determines where it gets deposited in the respiratory tract. Larger particles get caught in the upper and larger airways. Smaller particles make it past these airways into the alveolar spaces and can be retained by lung tissue (Ling and Eeden 2009).

When the Clean Air Act was last amended in 1990, the Environmental Protection Agency (EPA) was required to set National Ambient Air Quality Standards (NAAQS) for the primary pollutants than can cause damage to human health (Environmental Protection Agency 2010). The NAAQS for PM$_{2.5}$ is 15.0 µg/m^3 for an annual average and 35.0 µg/m^3 for a 24 hour average (Environmental Protection Agency 2010). This means that a county is in nonattainment if the PM$_{2.5}$ averaged over a year exceeds 15.0 µg/m^3 or if more than 2% of the 24 hour PM$_{2.5}$ averages over a three year time period exceed 35.0 µg/m^3 (Environmental Protection Agency 2009). Reaching attainment for the 24 hour standard is important since the health effects of PM$_{2.5}$ can usually be seen on the same day that a person is exposed to PM$_{2.5}$ (Escamilla-Nuñez et al. 2008**).**

Carlisle and PM$_{2.5}$

In 1997, the EPA set 15.0 µg/m^3 as the annual standard (Environmental Protection Agency 2007). In December of 2004, the EPA used this standard to designate nonattainment counties based on annual PM$_{2.5}$ concentration averages (Environmental Protection Agency 2007). Figure 1 below shows the counties within Pennsylvania that were designated as nonattainment counties based on the 1997 annual standard.
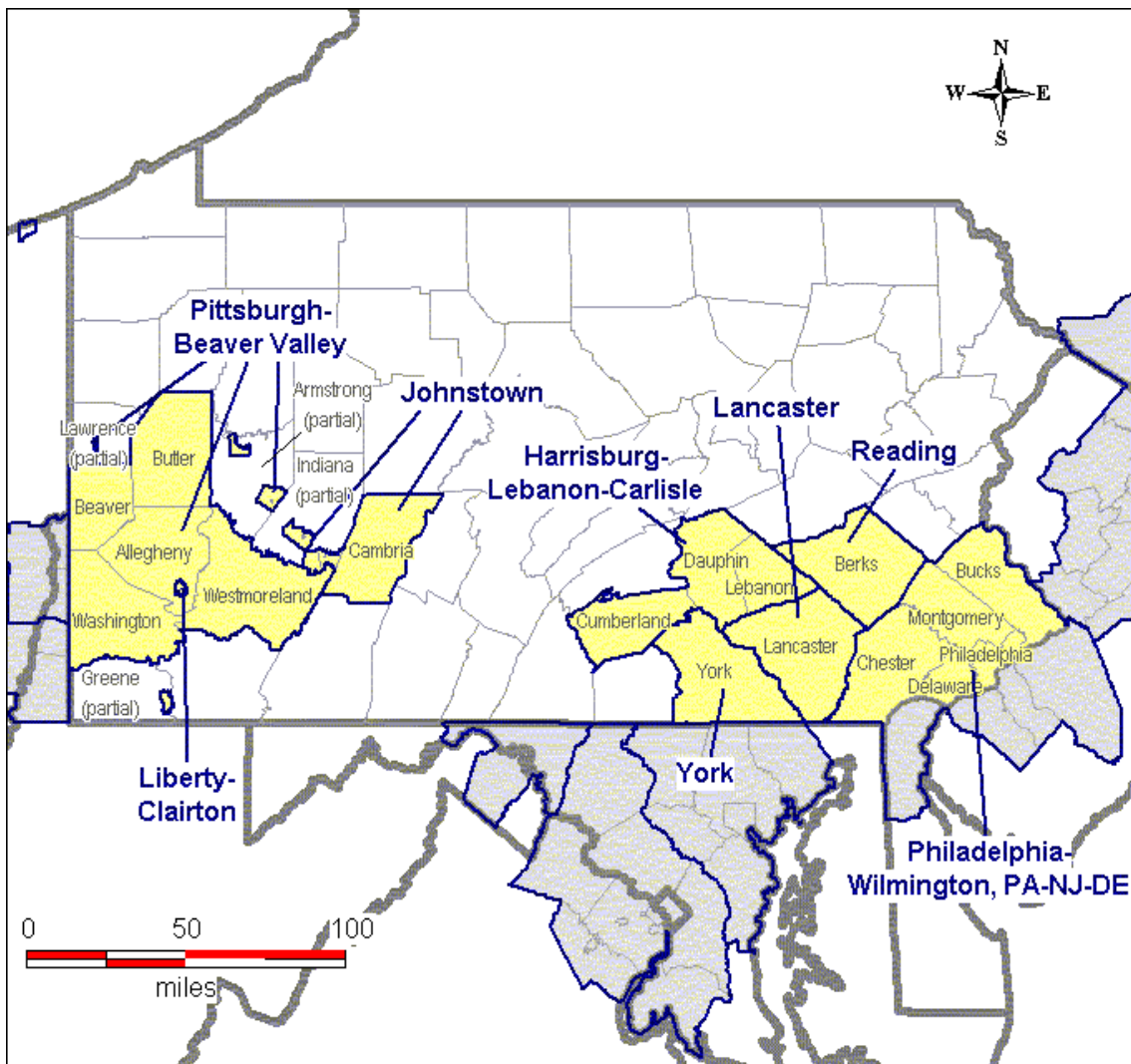

Figure 1 - Pennsylvania PM2.5 designations map (Environmental Protection Agency 2008)

On October 8, 2009 the EPA issued a final Federal Register notice stating the "attainment" and "nonattainment" areas for the 24 hour national air quality standard for

$PM_{2.5}$. Cumberland County, PA was listed as a designated as a "nonattainment" area in the final Federal Register notice (Environmental Protection Agency 2009).

These $PM_{2.5}$ levels are surprisingly high given that in 2009 Cumberland County had a population of 667,425, which is relatively small compared to other counties that are in nonattainment (U.S. Census Bureau 2009). In 2007, the American Lung Association ranked Cumberland County 17th on the list of counties that were "most polluted by short-term particulate pollution"(Clean Air Board 2008).

This study looks specifically at Carlisle, PA which is in Cumberland County. Carlisle is also located in Cumberland Valley and between two major trucking highways, I-76 and I-81. The tendency for air to get trapped in the valley as well as the high volume of truck traffic makes Carlisle subject to excessive $PM_{2.5}$ concentrations. On I-81 alone there are 15,000 to 20,000 trucks per day (Pennsylvania Department of Transportation 2009).

$PM_{2.5}$ and asthma in elementary school students

Asthmatics, the elderly and children are the main groups that are sensitive to air pollution (Environmental Protection Agency 2010). The incidence of asthma has increased the most in the 18 and under age group in the US (Koren 1995). In a past study done in Mexico City, asthmatic children in urban areas were shown to have an increased incidence of daily respiratory symptoms as well as increased use of bronchodilators (Escamilla-Nuñez et al. 2008). Another study done in Atlanta found that pediatric emergency visits related to PM_{10} (particles 10 microns or less in diameter) exposure were higher than those for adults (Lee et al. 2006). As mentioned before, PM_{10} is less harmful to health than $PM_{2.5}$ so an even more exaggerated patten would probably be seen with emergency visits related to $PM_{2.5}$ particles.

For this study, the daily inhaler usage of the elementary school students in the Carlisle Area School District was examined. Mary Franco, the head nurse of the school district, reported that the percent prevalence of asthma in the school district has been constantly increasing in the past few years. During the 1998 to 1999 school year, 8% of the students in the Carlisle Area School District had asthma. During the 2008 to 2009

school year, 10% of the student population had asthma. That is a 2% increase in asthma incidence over a 10 year time period.

As seen in Figure 2, most of the elementary schools in Carlisle are located very close to a highway. Students in Carlisle may suffer from impaired lung development due to constant, longterm exposure to diesel exhaust.
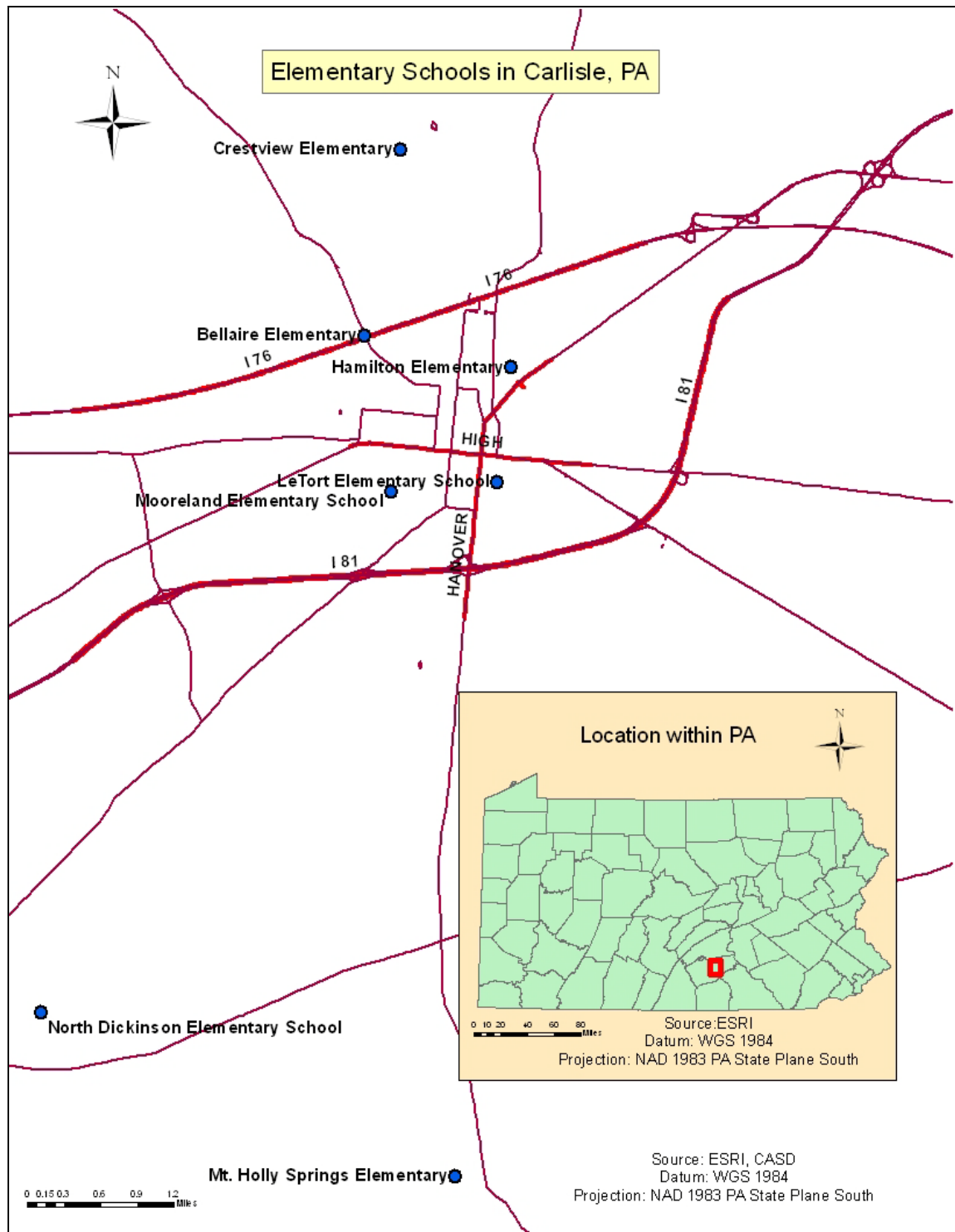
Figure 2 – Location of Elementary schools in the Carlisle Area School District

PM$_{2.5}$ and distance runners

Active individuals, as well as children, are also sensitive to air pollution. During exercise more air is inhaled through the mouth than through the nose, meaning that the normal mechanisms for filtration are bypassed (Carlisle and Sharp 2001). Therefore, vigorous exercise on high PM$_{2.5}$ days can result in airway inflammation (Ferdinands et al. 2008). The cross country and track athletes at Dickinson College participate in an extended amount of vigourous physical exercise almost every day of the week. As the subjects of this study they were tested for indications of impaired lung function after running.

Ozone and PM$_{2.5}$

Ozone, as well as PM$_{2.5}$, has been known to cause airway inflammation. A study done in metropolitan Tokyo found an increase in nighttime primary care visits for asthma attacks when ambient ozone levels were higher (Yamazaki et al. 2009). The correlation between these visits and ozone levels was the strongest for preschool children (Yamazaki et al. 2009). Athletic performance can be impaired at relatively low levels of ozone. In the Los Angeles basin, the ozone level reaches 0.18 ppm for at least 1 hour for about 180 days of the year; statistically significant impairment of exercise has been recorded at this concentration (Adams 1987). The NAAQS for ozone is an average of 0.075 ppm over an 8 hour time period (Environmental Protection Agency 2010). As seen in Figure 3, Carlisle has been above or at the NAAQS from 1990 until 2008. The 4th highest 8-hr average in the calendar year was at just about 0.10 ppm (Figure 3). Along with PM$_{2.5}$, this study will look at the effects of ozone on lung health in Carlisle.
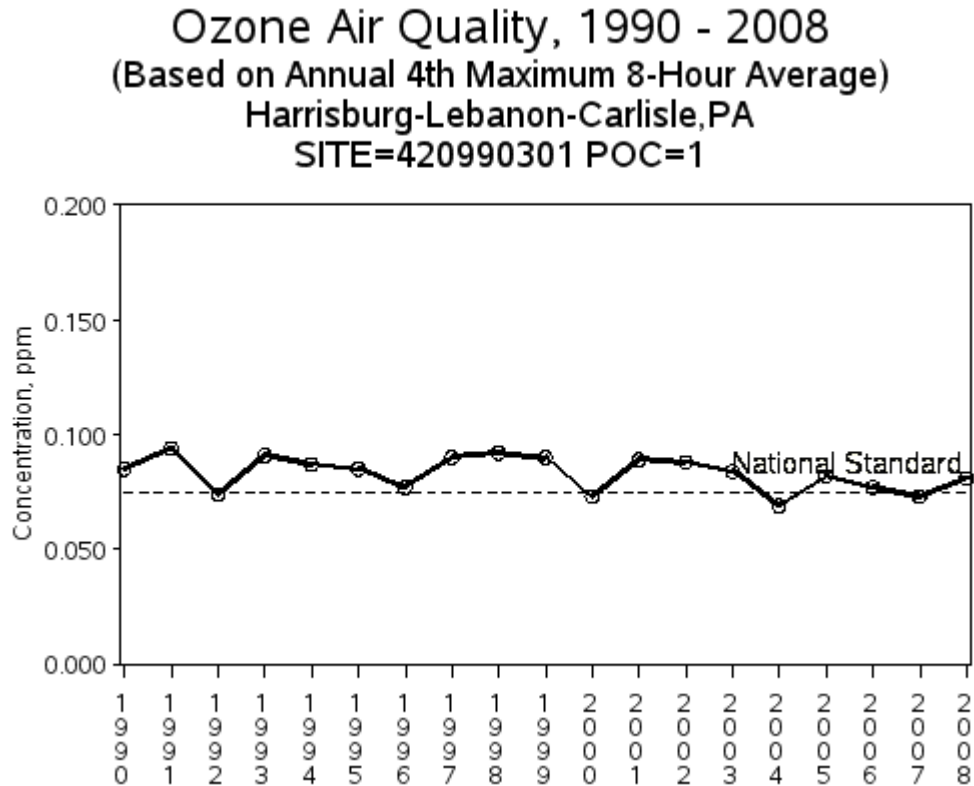
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Figure 3 – (Environmental Protection Agency 2009)

METHODS

PM$_{2.5}$ data collection

The Carlisle PM$_{2.5}$ monitor, a Beta-Attenuation Mass Monitor (BAM), is located on top of the *Sentinel* building. As it collects hourly data of PM$_{2.5}$ concentration, it records this data to the *Sentinel* server which is then transferred online for public use at the end of every hour. The *Sentinel* helps to maintain the data and CAB cleans and maintains the BAM. George Shickler, the web developer at the Sentinel, is in charge of the BAM data collection and was very helpful with forwarding the data via email.

Ozone data collection

There is no air monitor for ozone in Carlisle, but there is one in Harrisburg. A scatter plot (Figure 4) of PM$_{2.5}$ concentrations in Carlisle and PM$_{2.5}$ concentrations in

Harrisburg showed that the two cities had similar air pollution patterns. The R^2 value of 0.9 on the linear trend line indicates that the $PM_{2.5}$ concentrations are almost exactly the same in both cities on a given day.
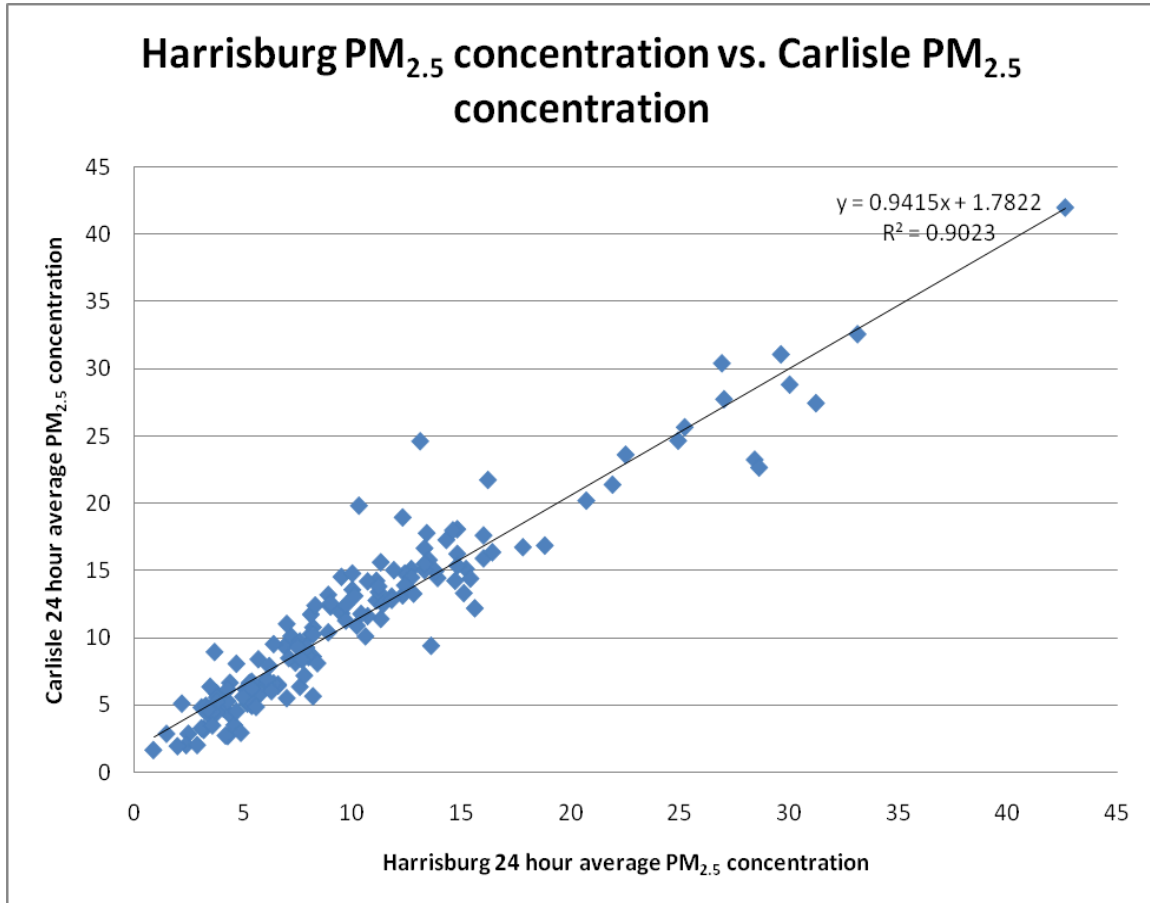

Figure 4 – Comparison of $PM_{2.5}$ concentrations in Harrisburg and Carlisle

Therefore, the assumption was made that the ozone concentrations in Harrisburg are similar to the ozone concentrations in Carlisle, and we used Harrisburg ozone data in our analysis. Harrisburg ozone data came from the Pennsylvania Department for Environmental Protection (PADEP) website (Pennsylvania Department for Environmental Protection 2010).

Inhaler usage data collection

The Carlisle Area School District has put a system in place where each school nurse is required to record the number of students who use inhalers while in school on a daily basis. Mary Franco is the head nurse of the school district and she helped with the collection of this data. The collection of inhaler data began on September 1, 2009 and was used for this study through the end of March 2010.

Middle school and high school students are allowed to carry their own inhalers. Therefore this study only looks at inhaler usage among elementary school students in the Carlisle School District.

Due to the reporting process, there were many errors in the data noted by the school nurses and Mary Franco. Most nurses used the new software to record inhaler uses but some hand-counted the doses. Also, some kids with exercise-induced asthma used their inhalers before every gym class; these inhaler usages did not necessarily reflect the air pollution conditions.

Inhaler usage data analysis

Inhaler usage numbers were summed to get a total number of students who used their inhalers each day for all elementary schools combined. The inhaler usage counts were then compared to $PM_{2.5}$ concentrations in Carlisle and ozone concentrations in Harrisburg. These comparisons were done with multiple regressions on Microsoft Excel.

The amount of time it takes for $PM_{2.5}$ or ozone to have an effect on lung health is still somewhat uncertain. A study conducted in Mexico City stated that the health effects of $PM_{2.5}$ can usually be seen on the same day that a person is exposed to $PM_{2.5}$ (Escamilla-Nuñez et al. 2008). Another study conducted in Rome from 2001 to 2005 found that the effects of $PM_{2.5}$ on hospitalizations for acute coronary syndrome and heart failure were immediate, while effects on lower respiratory tract infections were delayed (Belleudi et al. 2010). For ozone specifically, a study done on adult hikers on Mount Washington in New Hampshire found significant effects of ozone on lung function right after each subject completed his or her hike (Korrick et al. 1998).

We investigated several different lag times by averaging the hourly pollutant concentrations for the following time periods: 7 hours (8:00 AM to 3:00 PM on the

current day), 24 hours (3:00 PM on the previous day to 3:00 PM on the current day) and previous three days (3:00 PM three days earlier to 3:00 PM on the current day). Since the time of inhaler use was not known, all time periods ended at 3:00 pm, the closest time available to the end of the school day.

Peak expiratory flow data collection

Athletes on the Dickinson Cross Country team who expressed interest in the study were asked to sign consent forms, in accordance with the Internal Review Board (IRB) requirements (Appendix A). All consenting participants were then asked to fill out a baseline health survey. This survey included questions about the subject's health background and exercise habits (Appendix B). On selected days, during the cross country and track seasons, we collected peak expiratory flow (PEF) data from runners who had just finished a run outside. PEF (peak expiratory flow) is a simple noninvasive test of lung function that has been show in the past to be affected by PM and other forms of air pollution in athletes (Thaller et al. 2008, Strak et al. 2009). In addition to testing their peak flow, each athlete was asked to self-report any symptoms they had before and/or after running.

Peak expiratory flow data analysis

Peak flow values and symptoms were compiled into an Excel spreadsheet by name of athlete and date. Athletes were then assigned new randomly generated names, in accordance with the confidentiality requirements of the IRB. Three hour $PM_{2.5}$ concentration averages were graphed against PEF values for each athlete and fit with linear trends using the statistical program R (www.r-project.org). In addition, a random-effects multilevel model was used to see if there was an overall trend shared by all the runners.

We also looked at changes in symptoms from before running to after running for each subject. The number of runners with symptoms after running that they did not have prior to running was divided by the total number of runners tested on that day. This ratio was then put into a linear regression with $PM_{2.5}$ concentrations.

RESULTS

Elementary School Students

The data for the inhaler usage of the elementary school students indicated that $PM_{2.5}$ had no impact on inhaler usage totals. Impact was determined through linear regression of $PM_{2.5}$/inhaler usage for each of the time periods. The regression for the seven hour time period (Figure 5a) had a slope = 0.0133, R^2 = 0.0019 and p-value = 0.61 indicating that there was no impact of $PM_{2.5}$ on inhaler usage during the school day. The regression for the 24 hour time period (Figure 5b) had a slope = 0.0007, R^2 = 4e-6 and p-value = 0.9806 indicating that there was no impact of $PM_{2.5}$ on inhaler usage for the 24 hours between the end of the previous school day and the end of the current school day. The regression for the 3 day time period (Figure 5c) had a slope = -0.0226, R^2 = 0.0025 and p-value = 0.5550 indicating that there was no impact of $PM_{2.5}$ on inhaler usage for that current school day as well as the previous two school days.
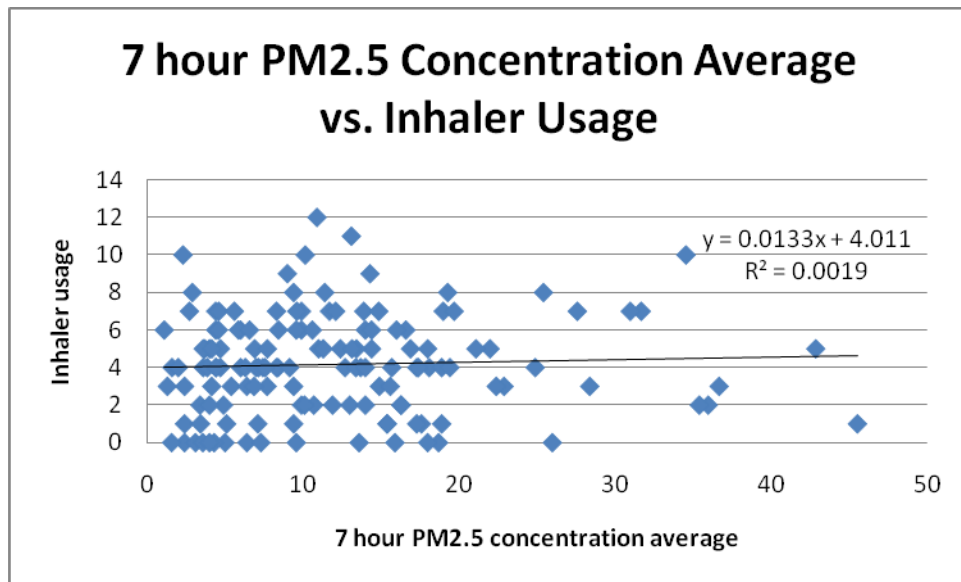

Figure 5a – $PM_{2.5}$ concentration averaged over the school day compared to inhaler usage on the same day
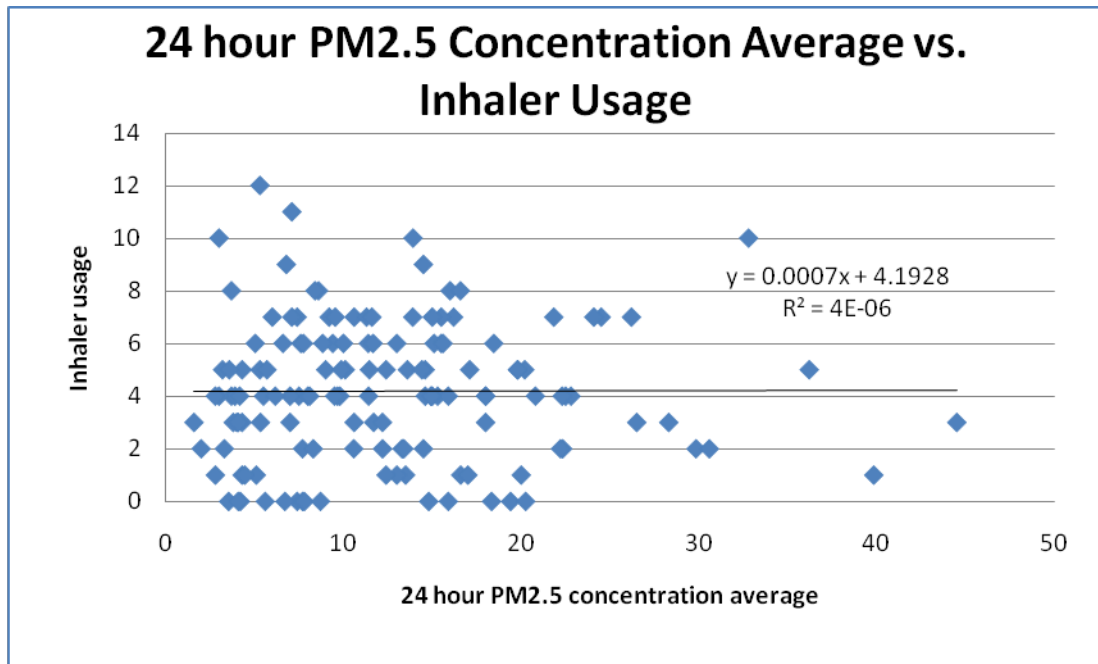
Figure 5b - PM$_{2.5}$ concentration averaged over the 24 hours before the start of practice on a given day compared to inhaler usage on the same day
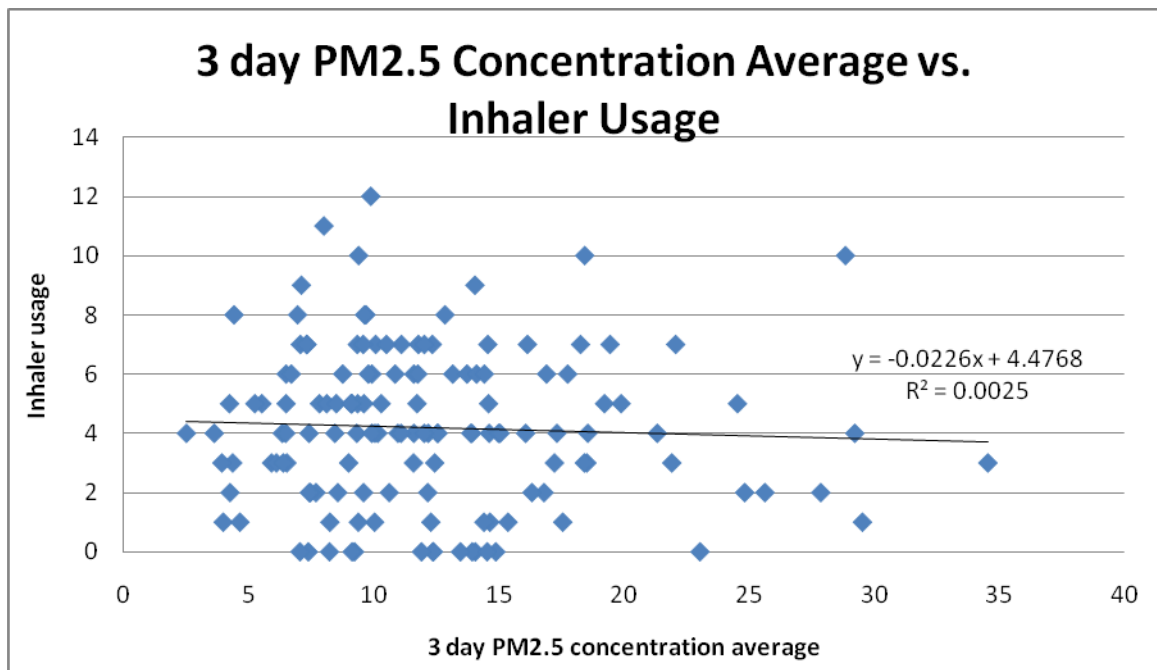

Figure 5c - PM$_{2.5}$ concentration averaged over the current school day and the previous two school days compared to inhaler usage on the current school day

We also looked at ozone since it is possible that it might be a confounding factor. There was no correlation between ozone and inhaler usage totals. Correlation was

determined through linear regression of ozone/inhaler usage for each of the time periods. The regression for the seven hour time period had a slope = -0.0165, R^2 = 0.0046 and *p*-value = 0.4349. The regression for the 24 hour time period had a slope = -0.0176, R^2 = 0.0039 and *p*-value = 0.4690. The regression for the 3 day time period had a slope = -0.0133, R^2 = 0.0016 and *p*-value = 0.6410.

Collegiate Distance Runners

There are a total of 47 runners on the Dickinson College cross country team. 31 of those runners participated in this study. In Table 2 we outlined the demographics of the team as well as the demographics of the study participants. By comparing the team demographics to the participant demographics, we could investigate whether or not our study group was representative of the team as a whole. In terms of each class year, the percentages are not too similar between the team and the participants. Since all of the runners are close in age it is insignificant that the class years are not perfectly represented by the group of participants. However, the whole team is approximately half male and half female and the group of participants was also half male and half female. Since males and females have different body types it was important for us to represent each equally in the study.

		Freshman	Sophomore	Junior	Senior	Total
Team	M	5 (11%)	9 (19%)	6 (13%)	5 (11%)	25 (53%)
	F	8 (17%)	5 (11%)	3 (6%)	6 (13%)	22 (47%)
	Total	13 (28%)	14 (30%)	9 (19%)	11 (23%)	**47**
Study	M	4 (13%)	6 (19%)	3 (10%)	2 (6%)	15 (48%)
	F	8 (26%)	5 (16%)	0 (0%)	3 (10%)	16 (52%)
	Total	12 (39%)	11 (35%)	3 (10%)	5 (16%)	**31**

Table 2 – Team demographics and study participant demographics

Between the cross country and track seasons we tested for a total of 25 days. None of the participants tested on all 25 days. According to Figure 6, only one participant tested on 15 days and the rest of the participants tested somewhere between 4 and 13 days.
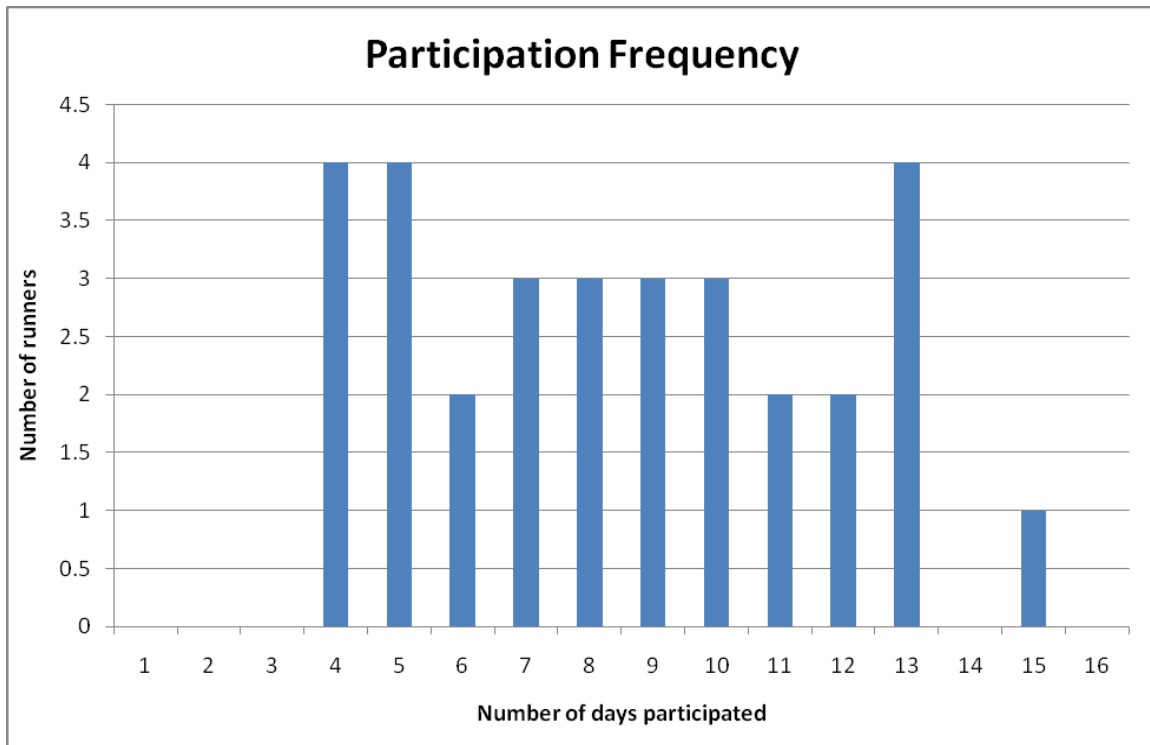
Figure 6 – Participation frequency of runners on the Dickinson College cross country team

The data for the collegiate distance runners indicated that $PM_{2.5}$ had no impact on peak expiratory flow (PEF) values. For each runner, a linear model of $PM_{2.5}$ against PEF was performed (Figure 7a). Although each runner had a different base PEF value, indicated by the high variation in intercept values, the slopes of the regression for most of the runners were relatively close to zero (Figure 7b). A mixed model of the relationship between $PM_{2.5}$ and PEF regression for the group as a whole had a slope that was almost exactly zero (Figure 7c).
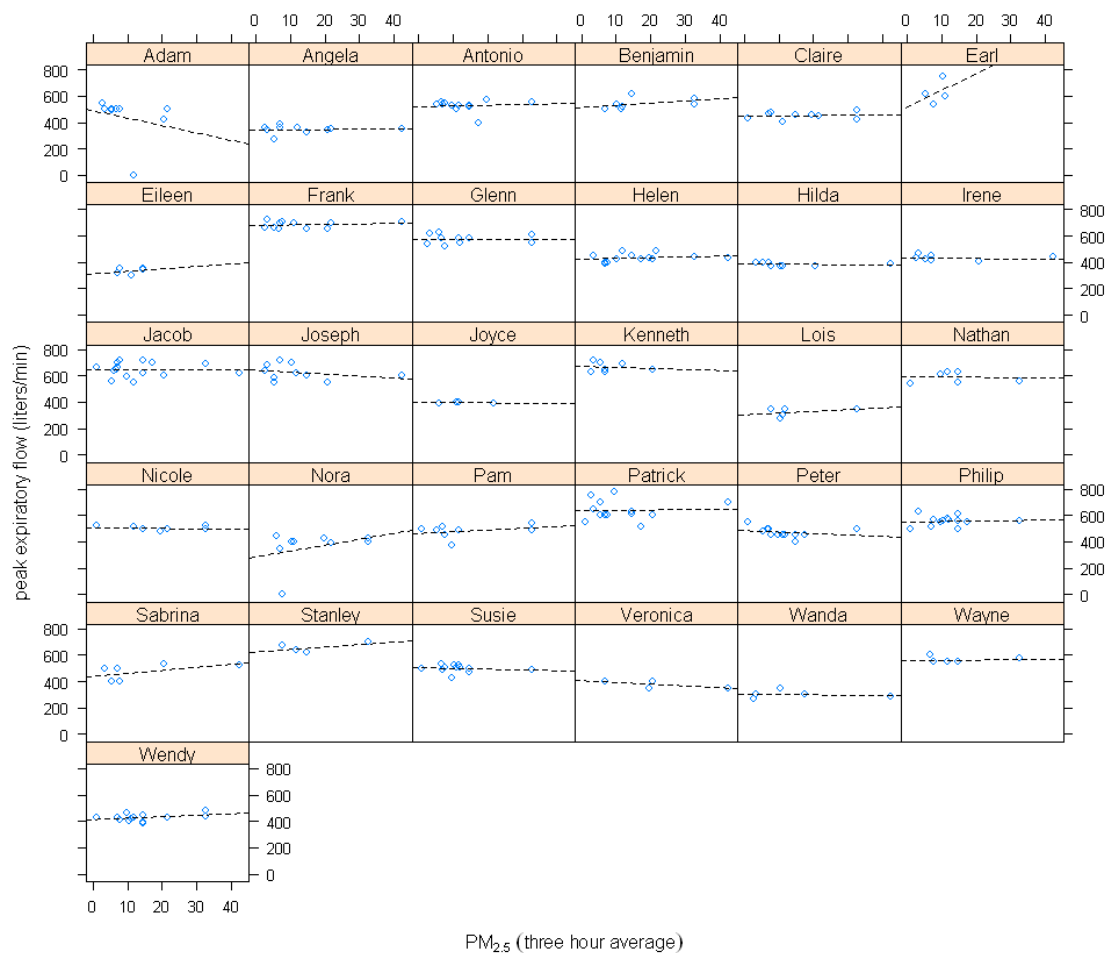
Figure 7a – Three hour PM$_{2.5}$ averages graphed against peak expiratory flow values for each study participant
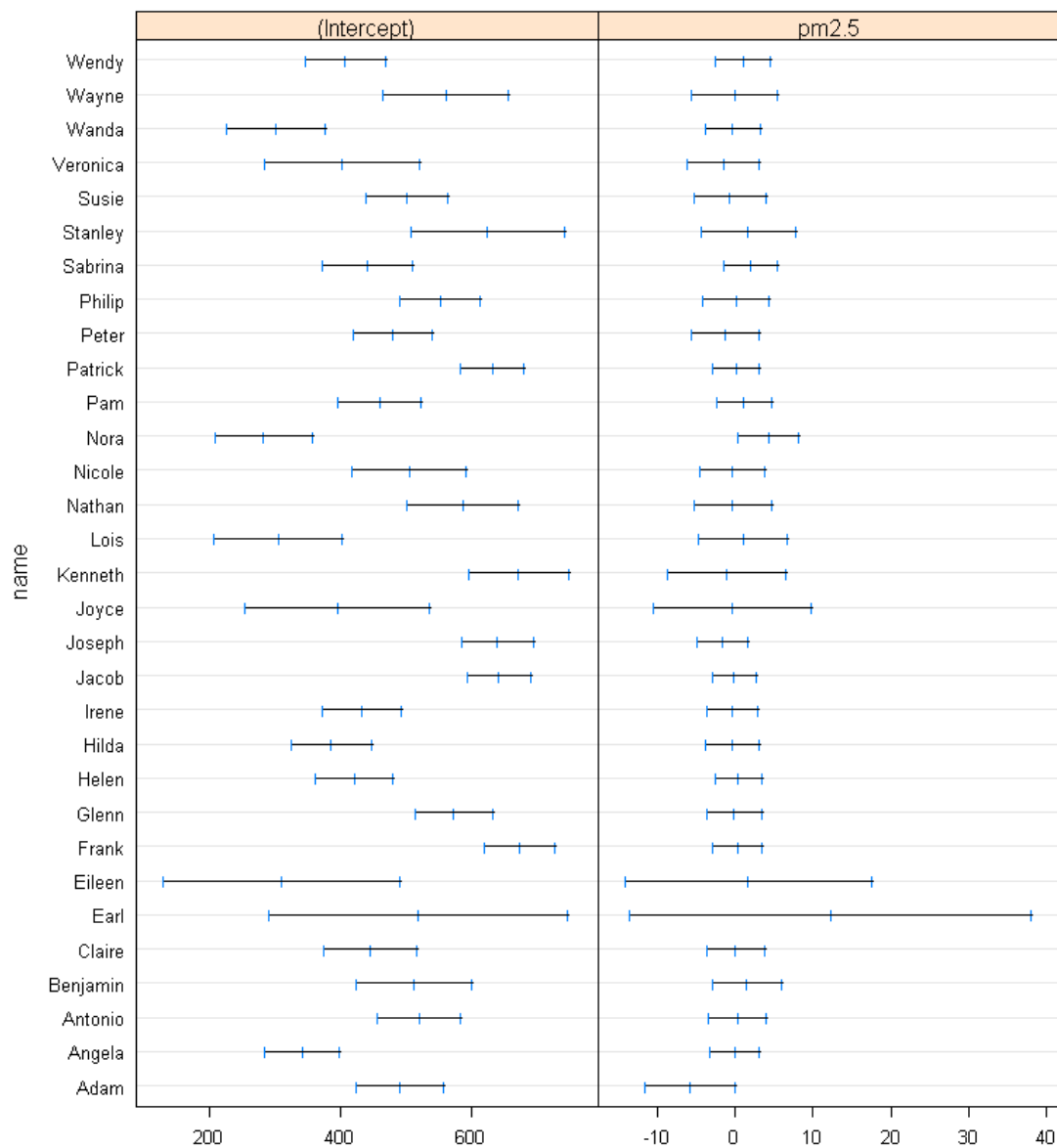
Figure 7b – Confidence intervals of intercept (baseline PEF values) and PM$_{2.5}$ (slope) for each runner participant
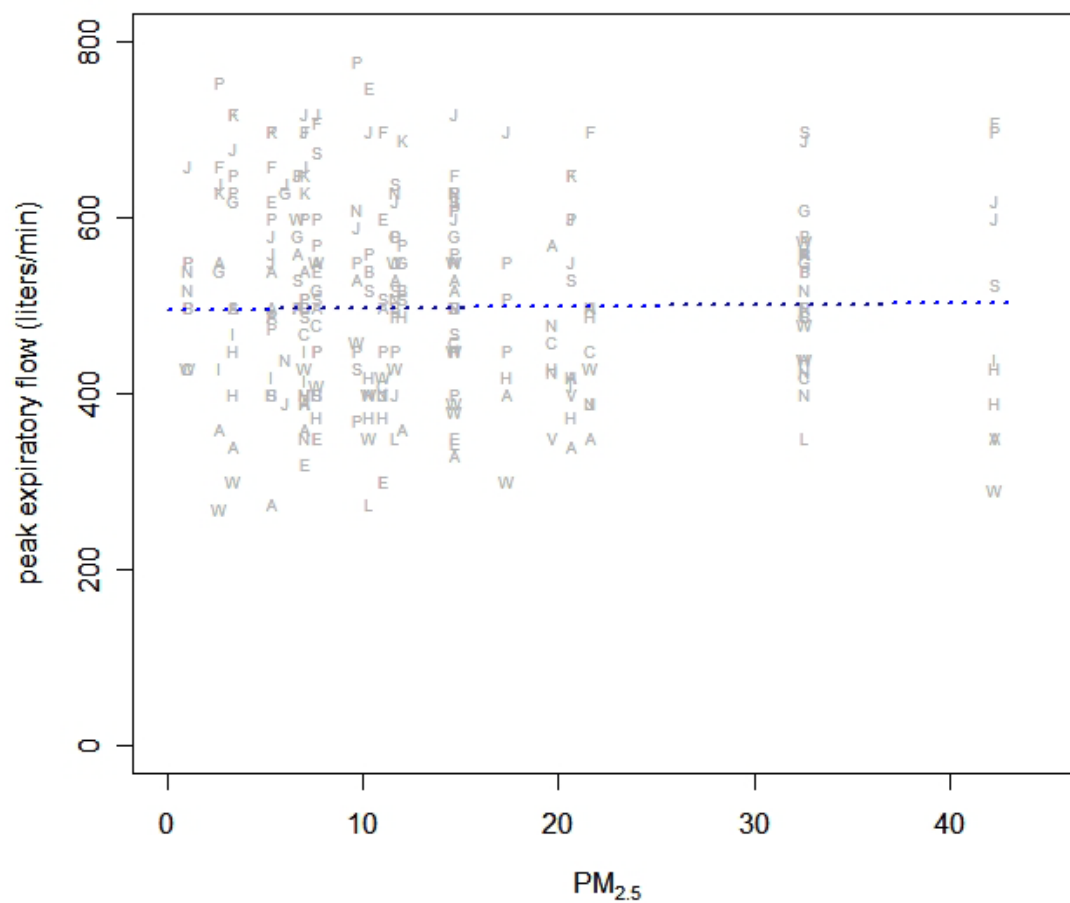
Figure 7c – Linear mixed-effects model of $PM_{2.5}$ vs. PEF for all collegiate distance runners who participated in the study. Letters indicate first-name initials of runners.

We also looked at the ratio of runners who had a change in one or more respiratory symptoms between the start and the end of their run. For each of the time periods, 3 hour (Figure 8a), 10 hour (Figure 8b) and 24 hour (Figure 8c), there was a slightly positive correlation between $PM_{2.5}$ and the ratio of runners with a change in symptoms. However, all three time periods had high p-values indicating that this correlation was not statistically significant.
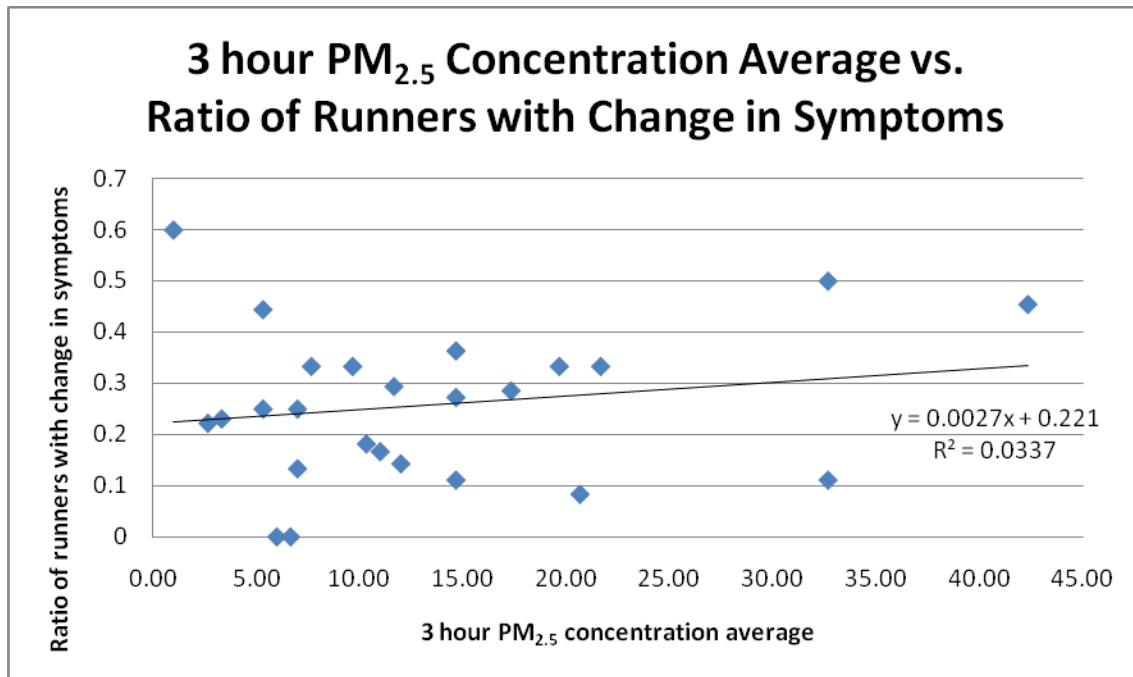

Figure 8a – Three hour $PM_{2.5}$ concentration average graphed against the ratio of runners who had a change in at least one respiratory symptom during their run

Figure 8b - Ten hour PM$_{2.5}$ concentration average graphed against the ratio of runners who had a change in at least one respiratory symptom during their run

Figure 8c - 24 hour PM$_{2.5}$ concentration average graphed against the ratio of runners who had a change in at least one respiratory symptom during their run

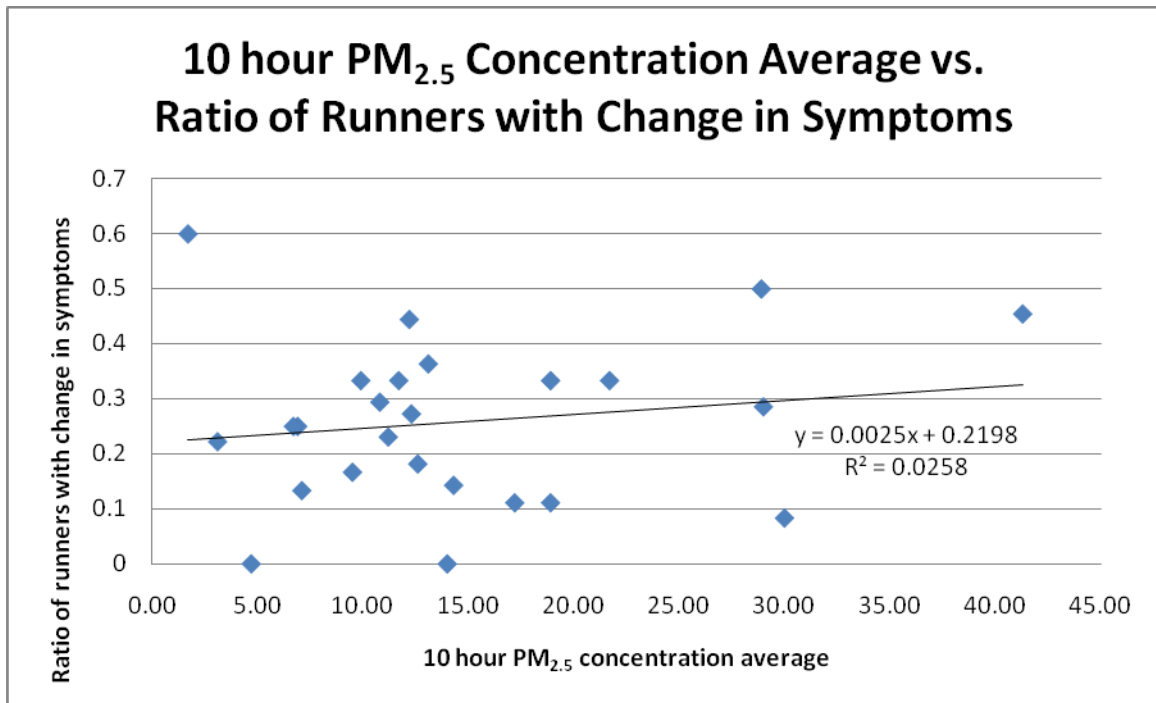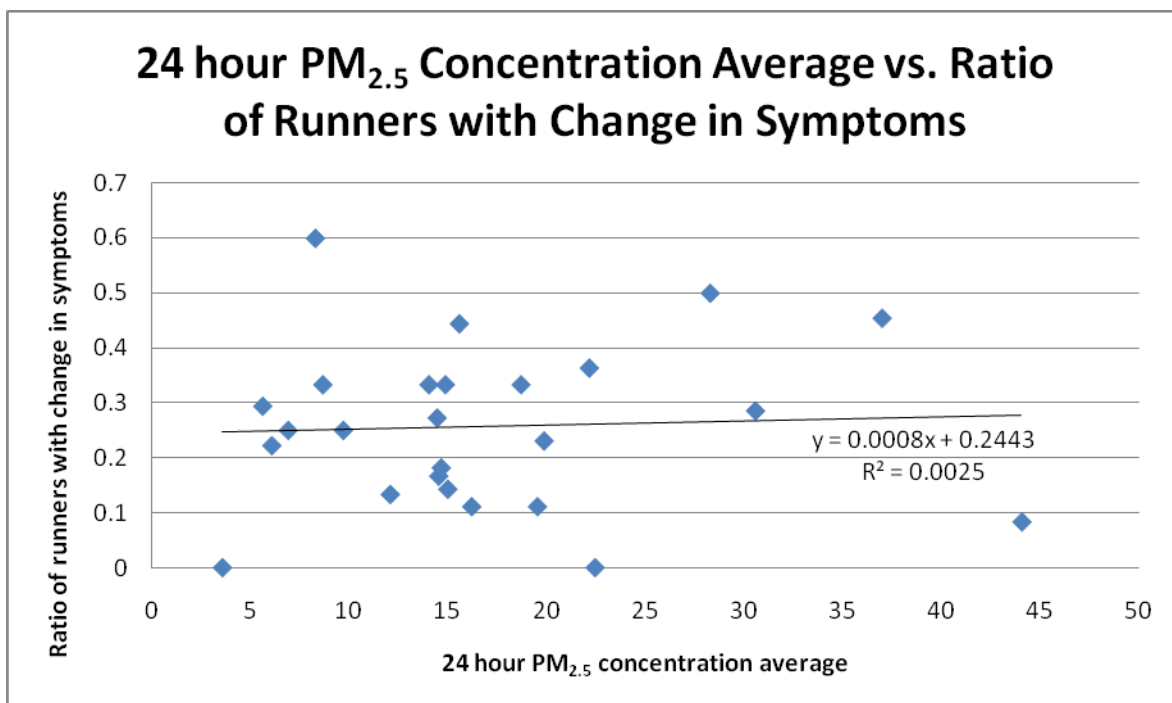## DISCUSSION

This study was definitely very useful to create awareness of the air pollution problem among the Carlisle community and the Dickinson community. The Clean Air Board (CAB) provided a lot of great data on $PM_{2.5}$ and health. Along with using their website frequently, we attended a CAB meeting about the effects of weather on $PM_{2.5}$ concentrations. At the end of that meeting we were interviewed and later quoted in an article in *The Sentinel*, Carlisle's local newspaper (Sentinel 2009).

The role of this study was mainly to educate Dickinson students on the same topics that CAB is trying to educate the Carlisle community on. Talks were given to members of the Dickinson community part way through the study as well as at the conclusion of the study. An article was also published in Dickinson's "Extra", an online newspaper (Klatskin 2010). A student in the "Science Writing" course at Dickinson wrote a public service announcement about our study that was played on the Dickinson College radio station.

Although the results from both the asthmatic elementary school students and the distance runners indicated that we failed to reject the null hypothesis, ultimately educating the public was the most important part of this study. According to our results there was no impact of $PM_{2.5}$ on lung health. However, past studies and research have shown that $PM_{2.5}$ does have detrimental effects on lung function. It would follow that $PM_{2.5}$ would be detrimental to the lung health of Carlisle residents. There were many limitations in this study that may have affected the results.

Elementary School Students

The data in the inhaler usage study of the elementary school students was limited by the precision with which the local nurses recorded the data, and by a lack of indication between routine or emergency use and the varied locations of the elementary schools. The nurses are supposed to use an electronic system to record daily inhaler usage counts. This system was just put in place in September so many nurses were still using their own systems, or recording data by hand. This definitely interfered with the accuracy of some of the inhaler data. Many students also used their inhalers right before PE class as a precaution. Only some nurses indicated the inhaler uses that corresponded to these

students. For the purposes of this study, all inhaler uses were considered equally; it was too hard to differentiate between precautionary and emergency use. In the future, more methodical data collection from the school nurses would be useful to separate emergency inhaler use from routine inhaler use. Finally, some elementary schools were located close to a major highway and some were further away. In a further study it would be nice to have $PM_{2.5}$ air monitors at each elementary school to see if the concentration, and inhaler usage, varied by location.

Collegiate Distance Runners

The data in the distance runner study was limited by practice timing, number of runners willing to participate on a given day and subjective reports of run difficulty and symptoms. Depending on the day of the week, members of the cross country and track teams either finished their run before or after practice. With required team activities and participants rushing off to other obligations is was impossible to test everyone in the study on every day of testing. The PEF test was the only objective part of testing; the subjective reports that each runner provided were only so helpful because there were no standards to base these reports off of.

Although PEF was an objective measure, it may not have been the best measure of lung function. The peak flow meter is a simple instrument and is not very sensitive to the rate at which the air is traveling through it. FEV_1 (Forced Expiratory Volume in one second) may be a better measure since it is used more commonly in pulmonary studies. We could not measure FEV_1 because it required the use of a spirometer. Most spirometers are significantly more expensive than peak flow meters. We did not have the funds to get a spirometer and it also would not have been practical to pass an expensive piece of equipment around to all the participants.

We also could have chosen the test days more carefully so that the $PM_{2.5}$ exposure contrast would be increased for each runner. Most of the test days chosen for this study were on lower $PM_{2.5}$ days. If the number of high $PM_{2.5}$ days included in the study increased than the study may have shown evidence of an impact of $PM_{2.5}$ on lung function.

Confounding factors

Some confounding factors to consider were weather patterns, other air pollutants and sickness in either the elementary school students or the collegiate runners. Temperature and pollen counts can both effect lung functions on a given day. Elevated temperatures have been known to cause respiratory mortality due to "stress placed on the respiratory and circulatory systems to increase heat loss though skin surface blood circulation" (Almeida et al. 2010). Airborne pollen can cause respiratory symptoms in those individuals predisposed to pollen allergies (D'Amato et al. 2005). Ozone, as well as $PM_{2.5}$, has been shown to impact lung health. Increases in ozone levels have been correlated with airway obstruction and asthma attacks (Thaller et al. 2008). For athletes, ozone is one of the most detrimental air pollutants (Carlisle and Sharp 2001). Finally, many sicknesses are accompanied by respiratory symptoms that can be mistaken for respiratory symptoms from air pollution.

Future studies

Data was fairly limited for both the asthmatic elementary school students and the collegiate distance runners. Since the small amount of data was probably one of the main reasons that the results were inconclusive, the first step in expanding this study would be to collect more inhaler usage and PEF data. To figure out exactly how many days of data would need to be collected a power analysis could be conducted.

It would be difficult to continue collecting data from the collegiate distance runners at Dickinson College since the members of the team, and the study participants, will change at the start of each new school year. Even though this study only collected data over part of the school year there were many factors, such as variation in running time for each individual, post-practice meetings, weather, etc., that prevented us from collecting PEF values for all study participants on each testing day. Since the previously mentioned factors cannot be controlled, it does not seem productive to continue to study the distance runners. On the other hand, it would be worthwhile to continue to study the asthmatic elementary school students.

In order to strengthen the study of the asthmatic elementary school students, more inhaler usage data would need to be collected along with ozone data for Carlisle, pollen

levels for Carlisle and weather data for Carlisle. As mentioned before the ozone data was from Harrisburg so although it is probably relatively close to ozone levels in Carlisle it is not exact. Since pollen causes allergies, the pollen levels may have a substantial impact on daily respiratory health. Weather data for Carlisle could be used to see if humidity or temperature had any effects on respiratory health, without consideration of $PM_{2.5}$ levels.

Since particulate matter from diesel exhaust is the most harmful to human health because it comes with toxins and carcinogens, it would be useful to know exactly where the $PM_{2.5}$ in Carlisle is coming from. Since there is a high amount of truck traffic in the area we are assuming that most of the particulate matter is coming from diesel exhaust. However, the only way we can prove where each particle actually came from is through a source apportionment study.

If any sort of hospital data could be obtained for emergency room visits for respiratory illnesses, this would be a great way to expand upon the study. As mentioned previously, past studies have shown that high pollution days can increase the number of respiratory mortalities (Almeida et al. 2010). Of course this means that many individuals who suffer from respiratory mortality, or any other sort of respiratory malfunction, would be admitted to the emergency room.

CONCLUSION

The results of this study failed to demonstrate an impact of $PM_{2.5}$ on lung health. This result is likely due to limitations in the study design rather than to a lack of a real effect. A continuation of study on the collegiate distance runners does not seem to be productive. However, a longer-term study of inhaler usage among the asthmatic elementary school students in the Carlisle Area School District may provide stronger results. Further studies on $PM_{2.5}$ and its impacts on health in Carlisle are definitely warranted. Past studies have shown conclusively that $PM_{2.5}$ has a negative impact on lung health. Carlisle's residents are most likely subject to this negative impact since Carlisle is in a designated "nonattainment" county for $PM_{2.5}$, according to the EPA.

ACKNOWLEDGEMENTS

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Appendix A

Effects of PM2.5 (Fine Particulate Matter) on the Pulmonary Health of Collegiate Distance Runners.

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Emily Lawrence, Environmental Science   303-819-4174

INVITATION TO PARTICIPATE: You are being asked to participate in a research study because you are a collegiate athlete who is exposed to elevated levels of fine particulate matter air pollution ($PM_{2.5}$) in Carlisle. We are interested in studying runners, who exercise at a higher intensity and volume than the average person who is exposed to this type of air pollution. Participation in this study is always voluntary, and you may withdraw at any time. Your choice to participate or not participate in the study will not have any consequences for your participation on the cross country or track teams, your standing at Dickinson College or in courses there, or in any other way.

PURPOSE: To evaluate changes in lung function that may occur due to $PM_{2.5}$ exposure in runners in Carlisle.

PROCEDURES: Before beginning this study you will fill out a baseline health survey which includes questions on age, sex, and race; training load and physical activity other than running; current and past respiratory health; and other relevant exposures like smoking. On each day that data is collected, you will fill out a brief survey after your run. This survey asks about the type of run, amount of exertion felt, and pulmonary symptoms felt before and after running. Along with this brief daily survey, we will ask you to breathe into a peak flow meter in order to rate your lung function on a more quantitative level. These procedures will only take about two minutes per day. This data will be kept strictly confidential, and you may decline to participate at any time.

RISKS: There is a small amount of psychological risk associated with this study. The air pollution situation in Carlisle is fairly well known; however, your participation in this study may make you more conscious than most Carlisle residents of its potential effects on your lungs. You may be concerned with small variations in peak flow measurements and other respiratory symptoms; these are normal, and do not necessarily indicate any respiratory problem. The data collected in this study is not sufficient to diagnose any respiratory condition, and will be used only to look at small variations in performance across the whole team, rather than the health of individuals. If you are concerned about these results, or about other respiratory symptoms, please contact the researchers or your primary care provider.

Use of a peak flow meter does not cause any serious health effects; however, the deep breath or strong exhalation may sometimes cause coughing, wheezing, or tightening within the lungs in some cases. Peak flow meters are noninvasive and easy to use, and are regularly recommended for monitoring of asthma symptoms, including in children. If you have any concerns about use of these meters, you should ask the researchers at any time.

BENEFITS: You will not directly receive any benefit from this study, except general knowledge about air pollution in Carlisle and its effect on respiratory health. You may find your individual results interesting, although they will not be diagnostic of any health

condition. This study will be beneficial to all residents of Carlisle, to the Clean Air Board, and to the many athletes who reside in areas with polluted air.

COMPENSATION: There will be no financial compensation for participation.

CONFIDENTIALITY: Every attempt will be made by the investigators to maintain all information collected in this study strictly confidential. All identifiable information, including completed consent forms, baseline surveys, daily surveys and peak flow results, will be kept in a secure location, and will destroyed at the end of the study. At no time will any member of the coaching staff be allowed to see any of the data. Authorized representatives of the Dickinson College Institutional Review Board (IRB), a board charged with protecting the rights and welfare of research subjects, may be provided access to research records that identify you by name.

If any publications or presentations results from this research, you will not be identified by name. The data you supply will not be analyzed individually, but only along with the entire study group.

YOUR RIGHTS: You should decide on your own whether or not you want to be in this study. Your participation in this study is completely voluntary, and you have the right to refuse to participate as well as to withdraw at any time. For Dickinson College students participating in this research, you understand that your right to refuse to participate or to withdraw will not prejudice your standing within Dickinson College, your athletic team, or within any course.

QUESTIONS: If you have any questions or concerns about being in this study, please contact Professor Greg Howard at 717-245-1527 or howardg@dickinson.edu.

PLEASE READ THE FOLLOWING STATEMENT AND SIGN BELOW IF YOU AGREE.

I have had the chance to read the project description provided to me and ask any questions I have about this study, and my questions have been answered. I have read the information in the project description and consent information page and I agree to be in this study.

| Name of Participant | Signature of Participant | Date |

| Name of Researcher | Signature of Researcher | Date |

Please report any concerns or problems during this research project to the Chair of the Dickinson College Institutional Review Board, Walter Chromiak, Associate Provost, 717.245.1254 (chromiak@dickinson.edu).

Appendix B

Baseline Health Survey

1)Sex

2)Race and Ethnicity

3)Age

4)Where are you from? Is this also where you live while you are not living in Carlisle?

5) Have you been told in the past that you have asthma?

6)Do you smoke? Does anyone in your house smoke? Do any of your roommates smoke? Do you have any friends that smoke?

7)In the past, have you noticed changes in your breathing associated with any of the following: cold air, change in weather, exercise or physical activity, tobacco smoke, sprays and paints, strong odors, cleaning products, air pollution allergies, emotions or stress, hair sprays or perfumes?

8)How many years have you been running?

9)What is the average number of hours you spend running per week?

10)How many miles a week are you running right now? What is the highest number of miles you have run in a week?

11)What other forms of physical activity do you do besides running? How many times during the week do you participate in this activity and for how long? How many years have you been doing this activity?