Environmental Indicators of Heavy Traffic on Cardiovascular Mortality Rate in King County, WA

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Executive Summary

King County, WA encompasses the cities of Seattle and Bellevue, and has a long history of dense traffic conditions. Proximity to and air pollution from heavy traffic have both been associated with higher rates of cardiovascular disease in previous literature. This study specifically examines if living close to heavy traffic highways is associated with higher rates of cardiovascular mortality in King County. While this hypothesis is disconfirmed in a bivariate and multivariate linear regression model, the multivariate model shows a positive statistically significant relationship between cardiovascular mortality rate and both PM2.5 concentration and ozone concentration.

Topic and Research Questions

Environmental conditions have long been shown to impact public health, thus increasing existing health disparities. Cardiovascular disease specifically has been a primary topic in population health research due to the stead global rise in people affected by it. Cardiovascular disease has long been associated with short-term and long-term air pollution, with indication that elderly populations and populations without a high school diploma may have increased risk of cardiovascular disease. [1] Already vulnerable populations can be placed at higher risk for cardiovascular disease due to the environmental conditions they are living in. A study conducted in Vancouver, CA linked proximity to major highways or roadways to increased risk of mortality from coronary heart disease a type of cardiovascular disease.[2] As research continues to examine global health disparities, the relationship between the environment and population health needs thoroughly examined.

King County, WA, with two major cities, Seattle and Bellevue, has faced long standing urban issues with traffic, that has only been impacted more by recent rapid population growth, and long-standing issues with the limited public transportation available. In 2013, the US Census Bureau had a press release to announce that over 240,000 people commute into King County from neighboring counties daily.[3] The lack of diverse public transportation options in the area makes it difficult for individuals living outside of the cities of Seattle and Bellevue to commute into the city via public transportation in a reasonable amount of time, influencing more people to use passenger cars as their primary mode of transportation.

This analysis seeks to examine the relationship between heavy traffic patterns and cardiovascular mortality rate in King County, WA. Exploring this relationship between the environmental impact of highway infrastructure on public health could help guide future environmental and public health policy, as well as ensure funding is used in the most effective way. Future road infrastructure projects and funding for public transportation could be guided by exploratory research. Local city and county leaders can use scientific conclusions examining data that is already being collected to inform environmental policy changes. Public health leaders and non-profit organizations can use data analysis on the intersection of environmental conditions and public health to advocate for more funding and outreach to combat health inequalities.

Key Concepts and Variables

A needed area of thorough research is where environmental risk factors from transportation interacts and impacts public health. This analysis focuses on environmental indicators of heavy traffic, that is, do individuals exposed to heavy traffic conditions and higher pollution from traffic experience health disparities than their counterparts in low traffic density areas? To explore this question, cardiovascular mortality rate was selected as the primary dependent variable given previous academic research showing association between traffic conditions increasing risk for cardiovascular disease morbidity and mortality. This variable is the age-adjusted rate of individual deaths from cardiovascular disease per 100,000 people; both a valid and reliable variable. This variable is collected by the Washington State Department of Health and are 5-year estimates of cardiovascular mortality rate. Being a 5-year estimate and reported per 100,000 people, this variable is less impacted by year-to-year fluctuations in mortality rate and is standardized for varying population sizes.

In order to examine the impact of heavy traffic, three environmental indicators of traffic have been included in this study; proximity to heavy traffic highways, PM2.5 concentration, and ozone concentration. The primary independent variable of interest is proximity to heavy traffic roadways. This variable is calculated by determining the maximum number of vehicles per day on highways and dividing by the number of kilometers to the nearest highway. This variable is limited by the trade-off of granularity; each census tract has one representative value of vehicles/day/km even though distance to the nearest highway can vary within a census tract. Additionally, this variable only accounts for the number of vehicles on the highway and the distance to the nearest highway and is limited in regard to roadways with high commuting traffic that are not designated as highways. PM2.5 concentration and ozone concentration are included to examine the air pollutants that are higher in heavy traffic areas. Particulate matter 2.5 is defined as chemical particles which are equal to 2.5 micrometers or smaller. These chemical particles are released from combustion, industry, motor vehicles and secondary chemical reactions and are dependent on regional geography and weather patterns. PM2.5 concentrations are collected in the field, and spatially mapped by the Air-quality forecasting for the Pacific Northwest (AIRPACT) modeling system. The AIRPACT system accounts for weather patterns and maps 4km squares. Each census tract was assigned the maximum emission estimate of any 4km square that was located within each census tract. Ozone concentrations are also mapped in 4km squares, with each census tract being assigned the ozone concentration of the most populated 4km square within that census tract. Similar to the proximity to heavy traffic variable, PM2.5 and ozone concentrations are limited due to varying at a finer scale than 4km squares.

Socioeconomic variables including education rate, unemployment rate, and median household income were included as socioeconomic control variables. Education rate is represented by the percentage of individuals over the age of 25 years without a high school diploma. The unemployment rate is the percentage of individuals over the age of 16 years that are eligible members of the labor force that are unemployed. Median household income represents the median household income in US dollars for all households in each census tract.

Hypothesis and Theoretical Rationale

With the unique traffic conditions in King County and the density of commuting traffic, previous literature suggests that individuals living in areas of high-density traffic will be at greater risk for cardiovascular disease and mortality. In this analysis, I hypothesize that across the census tracts in King County, as proximity to high traffic highways increases, cardiovascular mortality rate will also increase. Examining this relationship will be particularly useful with data from census tracts in King County as traffic widely varies across King County, with higher densities of traffic following around the cities of Seattle and Bellevue, and minimal traffic densities in census tracts geographical located far away from neighboring cities.

This hypothesis operates under a few assumptions, mainly that the health measures not included in this study do not outweigh the impact that environmental indicators of heavy traffic have on cardiovascular mortality rate. That is, a model of proximity to high traffic highways and cardiovascular mortality rate would show a statistically significant relationship when other health variables are not included and a null relationship when they are included. While it is possible that any explanation that these environmental indicators have on the variance of cardiovascular mortality rate may suffer from omitted variable bias, previous extensive literature demonstrates that cardiovascular disease and mortality is impacted by poor environmental conditions.

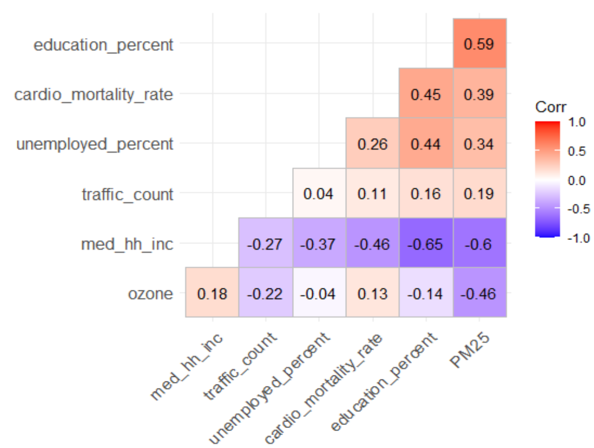
Methods and Data Sources

In order to address some of the previously discussed limitations of the variables available, a correlation matrix will be created to determine how highly the variables are correlated with each other. This will be examined along with both a bivariate and a multivariate linear regression model will be created to explore the relationship between proximity to high traffic highways and cardiovascular mortality rate.

Cardiovascular disease mortality rate was gathered from the Department of Health's Center for Health Statistics, community Health Assessment Tool (CHAT) 2015-2019, 5-year estimates. Proximity to heavy traffic roadways was calculated from 2019 data collected by the Washington State Department of Transportation. PM2.5 concentrations are estimated by the Washington State Department of Ecology from the years 2014-2017, and air quality was then forecasted by Washington State University's AIRPACT modeling. Ozone concentrations are retrieved from NW-AIRQUEST Regional Background Design Values, 2014-2017 estimates. Percentage of individuals without a high school diploma, unemployment rate, and median household income were collected from the US Census Bureau's American Community Survey (ACS) from 2015-2019, providing a 5-year estimate of these measures.

Findings

Figure 1: Correlation Matrix of Cardiovascular Mortality Rate, Environmental Indicators, and Control Variables



The correlation matrix displays that the percentage of individuals without a high school diploma is highly negatively correlated with median household income and highly positively correlated with overall PM2.5 concentrations (Fig. 1). The correlation between percentage of individuals without high school diploma and median household income confirms previous literature, as high school incompletion rate increases, median household income decreases.

The large positive correlation between high school incompletion rate and PM2.5 concentration is noteworthy, as high school incompletion rate increases, so does PM2.5 concentration.

Table 1: Summary Statistics for Environmental Indicators of Cardiovascular Mortality Rate

Summary Statistics for Cardiovascular Mortality Rate Indicators

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
cardio_mortality_rate	360	188.616	65.349	84.420	140.372	224.313	492.040
education_percent	387	7.913	7.048	0.540	2.495	11.415	36.900
unemployed_percent	395	5.099	2.618	1.000	3.350	6.460	24.400
traffic_count	397	868.406	1,292.847	0.000	0.000	1,385.000	8,103.000
ozone	397	50.623	2.762	46.731	48.906	51.278	62.885
PM25	397	6.186	0.841	3.787	5.642	6.872	7.897
med_hh_inc	397	101,201.400	38,295.320	17,188.000	73,180.000	121,478.000	250,000.000

Cardiovascular mortality rate and proximity to heavy traffic highways varies greatly across King County (Table 1). For all census tracts in King County the average 5-year estimate of cardiovascular deaths is approximately 189 deaths per 100,000 people. King County census tracts vary in cardiovascular disease deaths from 84 to 492 deaths per 100,000 people. Across King County, the proximity to heavy traffic highways averages at 868 vehicles/day/km; with the census tract with the highest traffic density being 8,103 vehicles/day/km.

In both the univariate and multivariate analyses, the primary independent variable of interest is not a statistically significant predictor of cardiovascular mortality rate in King County, WA (Table 2). Proximity to high traffic highways has a positive coefficient with a small magnitude. This magnitude decreases in the multivariate model as well. Both models disconfirm the hypothesis. Contrarily, both ozone concentration and PM2.5 concentration are positive, statistically significant predictors of cardiovascular mortality rate. As either of these concentrations increase, cardiovascular mortality rate increases. High school incompletion rate is also a statically significant predictor; as the percentage of individuals who did not complete their high school diploma increases, so does cardiovascular mortality rate. Median household income has a negative, statistically significant association with cardiovascular mortality rate, as income increases, mortality rate decreases. Unemployment percentage was not a statistically significant predictor of cardiovascular mortality rate.

Table 2: Bivariate and Multivariate Linear Regression Models for Cardiovascular Mortality Rate, Proximity to Heavy Traffic Highways, & PM2.5 Concentration

Cardiovascular Mortality Rate & Environmental Indicators

	Dependent variable:		
	cardio_mortality_rate		
	Bivariate	MV - Traffic Prox	MV - PM2.5
traffic_count	0.005	0.002	
	(0.003)	(0.003)	
education_percent		1.489^{**}	1.494^{**}
		(0.732)	(0.732)
unemployed_percent		0.578	0.501
		(1.528)	(1.535)
ozone		8.360^{***}	8.117^{***}
		(1.543)	(1.543)
PM25		24.948^{***}	24.698^{***}
		(5.263)	(5.259)
med_hh_inc		-0.0004^{***}	-0.0004^{***}
		(0.0001)	(0.0001)
Constant	183.865^{***}	-370.329^{***}	-351.395^{***}
	(4.181)	(99.949)	(100.002)
Observations	360	349	349
R^2	0.011	0.342	0.340
Adjusted R^2	0.009	0.331	0.330
Residual Std. Error	65.065 (df = 358)	53.794 (df = 342)	53.804 (df = 343)
F Statistic	4.146^{**} (df = 1; 358)	29.655^{***} (df = 6; 342)	35.349^{***} (df = 5; 343)
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Discussion

The linear regression results disconfirmed the hypothesis, the relationship between proximity to heavy traffic and cardiovascular mortality rate is not statistically different than zero in King County at the census tract level. The air pollutants associated with heavy traffic conditions including particulate matter and ozone are statistically significant predictors of cardiovascular mortality rate. These findings indicate, that while challenging to measure on a neighborhood scale, PM2.5 and ozone concentration are better environmental indicators of cardiovascular mortality rate than proximity to heavy traffic highways. Removing proximity to heavy traffic from the multivariate model, shows a small, inconsequential decrease in Adjusted R^2 value (Table 2), confirming this conclusion. As previously discussed, proximity to heavy traffic highways may be limited in the fact that this has been estimated at the census tract level. As census tracts are designed to include approximately 4,000 individuals, they are not geographically equivalent areas. Thus, proximity to heavy traffic highways can vary greatly both within a census tract, and across multiple neighboring census tracts as they move away from urban centers where populations decrease. This study is additionally limited to in that PM2.5 and ozone concentration a likely covary, making it difficult to separate the association between these two variables.

The main limitation of this study was exclusively examining only a few control variables that could have a confounding effect on cardiovascular mortality rates. Distance to the nearest hospital, access to affordable healthcare, and neighborhood walkability could all be collinear with proximity to heavy traffic. Future time-series analysis and longitudinal studies of cardiovascular disease and mortality rates could draw conclusions about how changes in environmental indicators of heavy traffic impact public health. The COVID-19 pandemic has changed the expectation to commute to work and encourages increased remote work positions. The Seattle area specifically, has recent work towards expansion of the lightrail system to the smaller cities surrounding Seattle, and into the neighboring Pierce County. These recent changes make excellent opportunities for quasi-studies and will likely show a decrease in common air pollutants, and thus a long-term decrease in cardiovascular mortality rates.

Appendices

Endnotes

1 Brook, R. D., B. Franklin, W. Cascio, Y. Hong, G. Howard, M. Lipsett, R. Luepker et al. "A statement for healthcare professionals from the expert panel on population and prevention science of the American Heart Association." *Circulation* 109, no. 21 (2004): 2655-2671.

2 Gan, Wen Qi, Lillian Tamburic, Hugh W. Davies, Paul A. Demers, Mieke Koehoorn, and Michael Brauer. "Changes in Residential Proximity to Road Traffic and the Risk of Death From Coronary Heart Disease." *Epidemiology* 21, no. 5 (2010): 642–49. http://www.jstor.org/stable/20788202.

3 Census Bureau reports 240,000 workers commute into King County, Wash., each day. Census.gov. (2013, March 5). Retrieved from https://www.census.gov/newsroom/archives/2013-pr/cb13-r12.html