Geographic Relationships Between Smoking and Chronic Lower Respiratory Disease in Delaware

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Abstract

Objectives: To determine geographical relationships between smoking prevalence, COPD prevalence, and lower respiratory disease mortality in Delaware by census tract and county. *Methods:* Data about Delaware residents with COPD, who are smokers, and/or have chronic lower respiratory diseases, respectively, were analyzed from publically accessible datasets posted on PolicyMap and Delaware Open Data. Data was linked to shapefiles in order to map prevalence and mortality rates by Delaware census tract and county. Geo-based descriptive analysis was conducted via choropleth maps. *Results:* COPD prevalence was higher in urban areas with high smoking prevalence. The highest proportion of census tracts with high COPD rates occurred in Sussex County and the lowest was in New Castle County. The highest crude and age-adjusted mortality rate due to chronic lower respiratory disease was in Sussex County and the lowest was in New Castle County. Chronic lower respiratory disease mortality was highest among white residents, increased as age increased, and occurred more frequently in females than in males. *Conclusion:* Sussex County had a high proportion of census tracts with high COPD rates and the highest mortality rate due to chronic lower respiratory disease. Urban census tracts displayed high rates of COPD prevalence and smoking prevalence. Identifying geographic focus areas can be used to direct future healthcare programs and public health initiatives. Future research should test statistical relationships between risk factors, geographic areas, and chronic lung disease outcomes.

Introduction

Background

Chronic lower respiratory diseases are chronic diseases of the lower lungs including chronic obstructive pulmonary disease (COPD). COPD is the disease responsible for making chronic lower respiratory disease the third leading cause of death in the nation.[1] COPD is a progressive lung disease that makes breathing difficult as it causes airways to become inflamed and thickened while destroying the tissue where oxygen is exchanged. It can lead to serious long-term disability and early death.[1] While there is no cure, COPD can be treated with medication, rehabilitation, or surgery.[1] The major cause of COPD is tobacco smoke. Other factors that cause COPD are air pollution in the home and workplace, genetic factors, and respiratory infection. In some developing countries, indoor air quality plays a larger role in COPD onset and progression, but in the United States tobacco smoke is, by far, the most prevalent risk factor.[2] Demographic subgroups with higher prevalence of COPD are people ages 65-74, American Indian/Alaskan Natives and multiracial non-Hispanics, women, current or former smokers, and people with history of asthma.[3]

Impact on Delaware

As of 2017, 16 million Americans were diagnosed with COPD - 46,700 of whom live in Delaware (DE).[4] This means that nearly 5% of Delaware's population has a current diagnosis of COPD. While this rate is similar to the national rate, the disease exerts a large public health burden in Delaware, especially since almost 40% of adults in Delaware suffer from multiple chronic conditions.[5]

COPD is more prevalent among women compared to men and much more common among people as they age.[6] In 2014, 10.7% of the Medicare population in Delaware were diagnosed with COPD. According to the Kaiser Family Foundation (KFF), in 2014, 19% of Delaware's population were Medicare beneficiaries.[7] The American Lung Association stratified COPD morbidity by county in Delaware and found that Kent County had the highest percentage of Medicare patients with COPD (13.4%) followed by Sussex (11.5%) and finally New Castle (9.1%).[8]

According to the CDC, in 2017, the overall mortality rate in the U.S. of chronic lower respiratory disease was 44.7 deaths per 100,000 when not age-adjusted, and 40.6 deaths per 100,000 when age-adjusted. The mortality rate of chronic lower respiratory disease in Delaware was 40.5 deaths per 100,000 when including all age groups.[8] While lower than the U.S. mortality rate, the mortality burden in Delaware is higher in comparison to other states in the mid-Atlantic region, including Pennsylvania (36.8 per 100,000), Maryland (30.5 per 100,000) and New Jersey (27.9 per 100,000).[9] In 2016, chronic lower respiratory disease was the third leading cause of death in Delaware, accounting for 6.1% of all deaths.[10]

This study will explore the geographic and demographic relationships between chronic lower respiratory diseases and smoking in Delaware using the most updated publically accessible datasets. Analyzing COPD prevalence and smoking in Delaware by census tract allows for identification of potential geographic disease patterns and reveal the areas with the greatest risk for COPD and other lung illnesses. Additionally, this study will consider mortality rates of chronic lower respiratory disease by Delaware County.

A descriptive study analyzing the geographic relationships of COPD outcomes using maps provides many advantages. By analyzing COPD rates by census tract and mortality rates by county, mapping may be able to identify geographic patterns of disease in Delaware communities. In addition to informing further research into the causes of differences in geographic distribution of chronic lower respiratory disease, this analysis can direct future healthcare programs and public health initiatives to prioritize the populations most in need of lung disease prevention initiatives and treatment.

Methods

Data Sources

Smoking Rates: The prevalence of adult current smoking was obtained from the 2013 Behavioral Risk Factor Surveillance System (BRFSS) for the state of Delaware. BRFSS data alone does not have adequate sample size to produce survey estimates for census tracts in Delaware. Policy Map obtained BRFSS data for Delaware in 2013 and used statistical models to estimate smoking prevalence by census tract by weighting BRFSS responses against U.S. census data from the

American Communities Survey. These small area estimates of smoking by DE census tract were downloaded from PolicyMap.[11]

COPD Rates: Policy Map calculated small area estimates of the crude prevalence of COPD by census tract with BRFSS data using similar methods as those used to determine rates of smoking. CDC researchers have calculated small area estimates using similar methods.[12,13] Small area estimates of rates of COPD by Delaware census tract were downloaded from PolicyMap.[14] The original BRFSS item asked participants if a doctor, nurse, or other health professional has ever told them they had chronic conditions, including COPD.

Chronic Lower Respiratory Disease Mortality: The source of 2013 crude and age-adjusted county-specific mortality rates of chronic lower respiratory disease was the CDC WONDER Online database from the Multiple Cause of Death Files, 1999-2017.[15] The source of chronic lower respiratory disease mortality data presented in tables was death certificates compiled by Delaware's Department of Health and Social Services, Division of Public Health and the Health Statistics Center between 2009 and 2016. This information is publically accessible on Delaware Open Data.[16] This individual-level death data included helpful demographic information such as county of residence, age, race/ethnicity, sex, and place of death.

Sample

Rate estimates of smoking and COPD were identified for 214 of the 218 census tracts in Delaware. For chronic lower respiratory disease mortality there were 3,733 total deaths due to chronic lower respiratory disease reported in Delaware between 2009 and 2016.

Measures

Statistical and Geographical Analysis: Base map TIGER/Line shapefiles were downloaded from the U.S. Census Bureau for counties and census tracts in Delaware from 2010. Risk factor and health outcome data was inspected and prepared via Microsoft Excel to import into ArcGIS version 10.3. The data was then joined to basemaps in ArcGIS to create choropleth maps that employed shading to display differences in smoking prevalence by census tract, differences in COPD prevalence by census tract, and differences in 2013 chronic lower respiratory disease mortality by Delaware county.

Using SPSS,[17] we generated descriptive statistics to summarize the number and proportion of deaths related to chronic lower respiratory disease (2009-2016) in respective counties stratified by race, age range, and sex.

We mapped the data using choropleth maps. Choropleth maps allowed us to visually compare rates by geography between relevant variables. The projected coordinate system was Delaware State Plane (NAD 1983 StatePlane Delaware FIPS 0700 (Meters)).

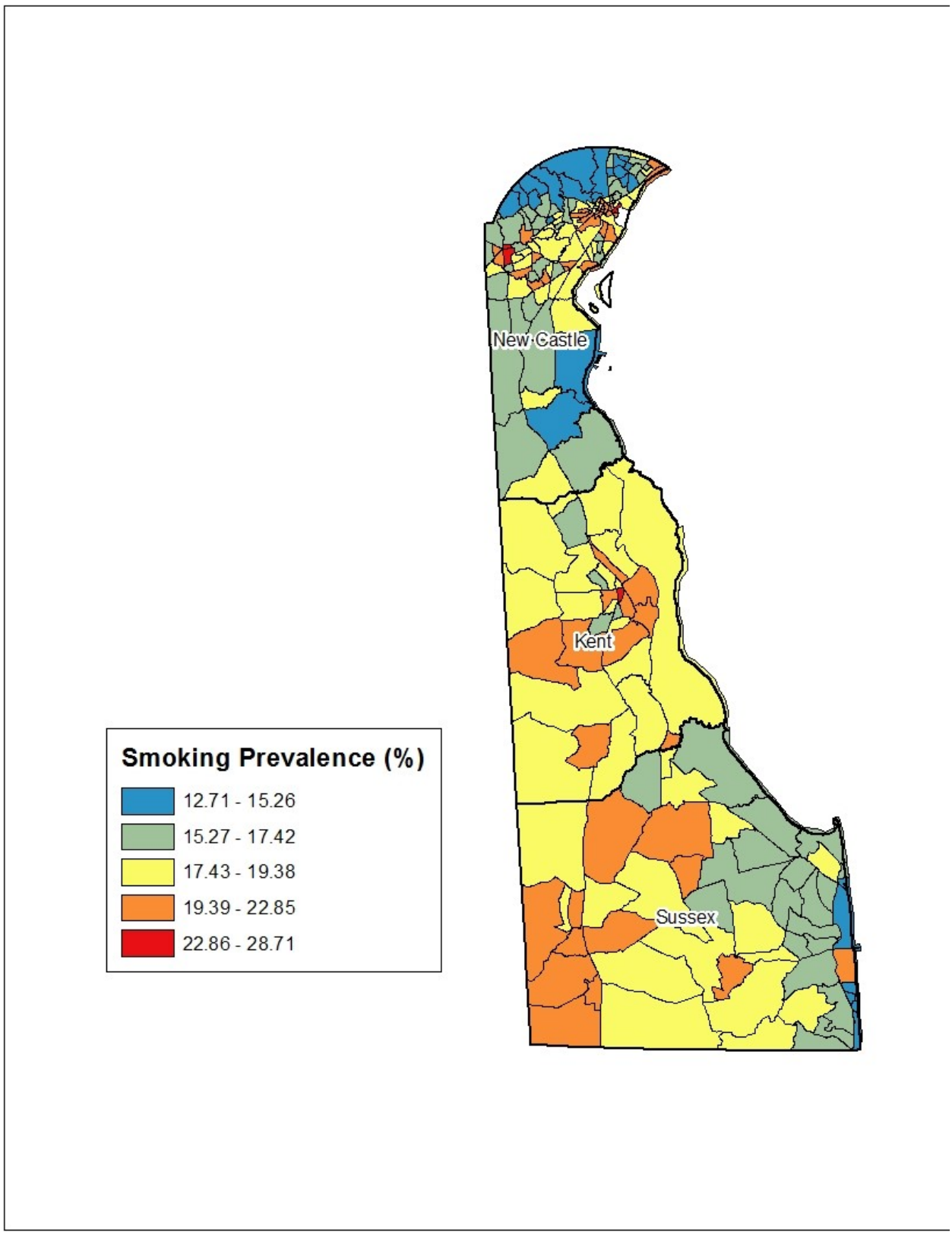
Results

Smoking by Census Tract

The choropleth map of smoking prevalence by census tract shows much variability (see Figure 1). Many of the census with elevated smoking rates cluster around the urban centers of Wilmington, Newark and Dover. The majority of Delaware census tracts with the lowest smoking prevalence (15.26% or below) occurred in New Castle county north of Wilmington, and

along the southeastern coast communities. By county, the highest proportion of census tracts with smoking rates in the two highest categories (orange or red; between 19.39-28.71%) were in Kent County, with 33.3%.

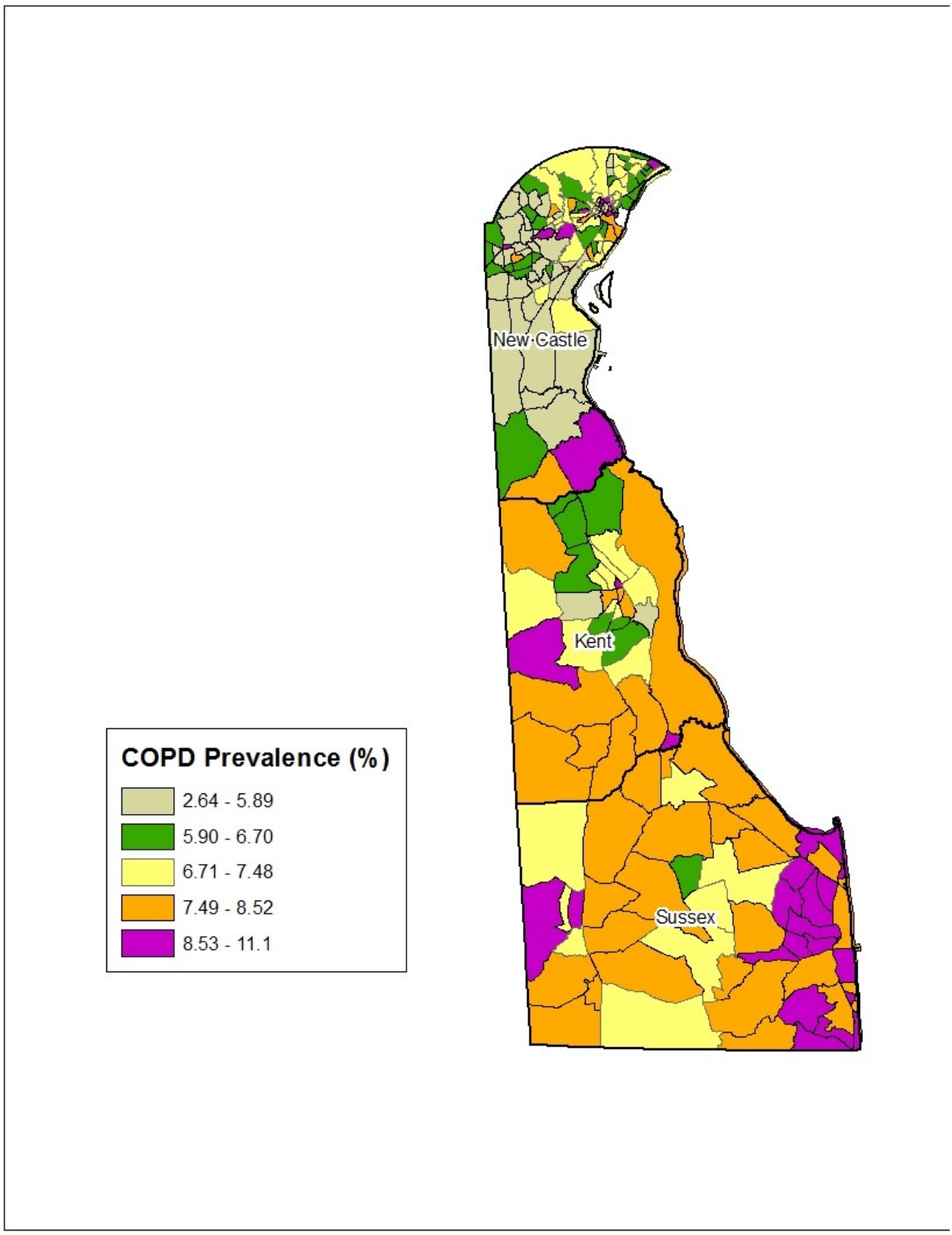
Fig 1. Small-area estimates of the prevalence of smoking by census tract in Delaware in 2013



COPD by Census Tract

The choropleth map of crude COPD prevalence by census tract (see Figure 2) shows a high proportion of census tracts in the highest COPD rate category (8.53-11.1%) in Sussex county. Although, COPD rates noticeably cluster in census tracts the southeastern corner of Delaware, there is also a clear pattern of high prevalence in census tracts in the urban areas of Wilmington, Newark and Dover. The vast majority of census tracts with the lowest COPD prevalences (2.64-5.89%) were located in the New Castle County. No census tracts had a COPD prevalence below 2.65%.

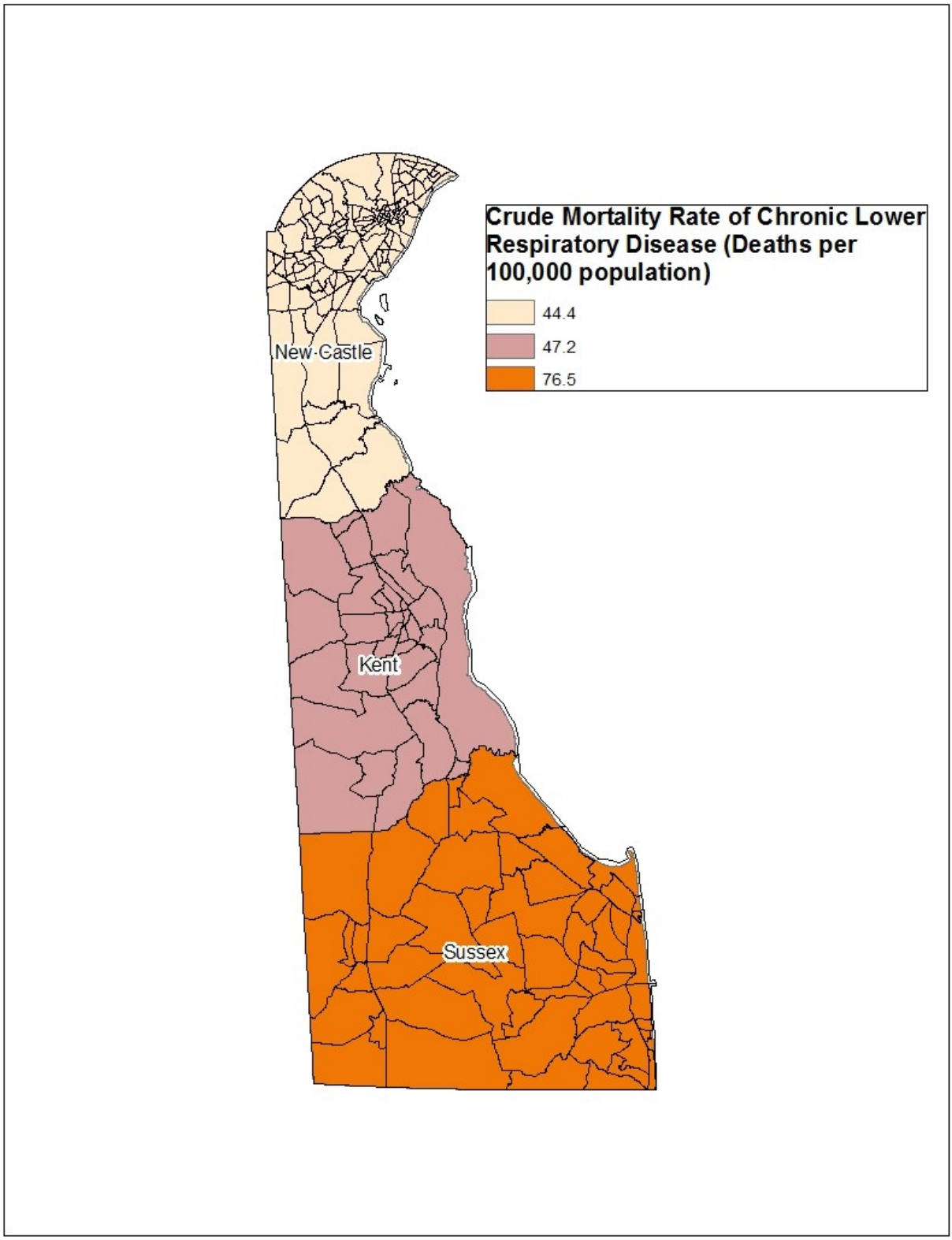
Fig 2. Small-area estimates of the prevalence of COPD by census tract in Delaware in 2013



Chronic Lower Respiratory Disease Mortality by County

The choropleth map of crude chronic lower respiratory disease mortality by county (see Figure 3) displays a clear visual differentiation in mortality rates. In 2013, New Castle County had the lowest mortality rate with 44.4 deaths due to chronic lower respiratory disease per 100,000 population. Kent County had the second highest mortality rate with 47.2 deaths per 100,000, and Sussex County had the highest crude mortality rate due to chronic lower respiratory disease mortality, with 76.5 deaths per 100,000 population.

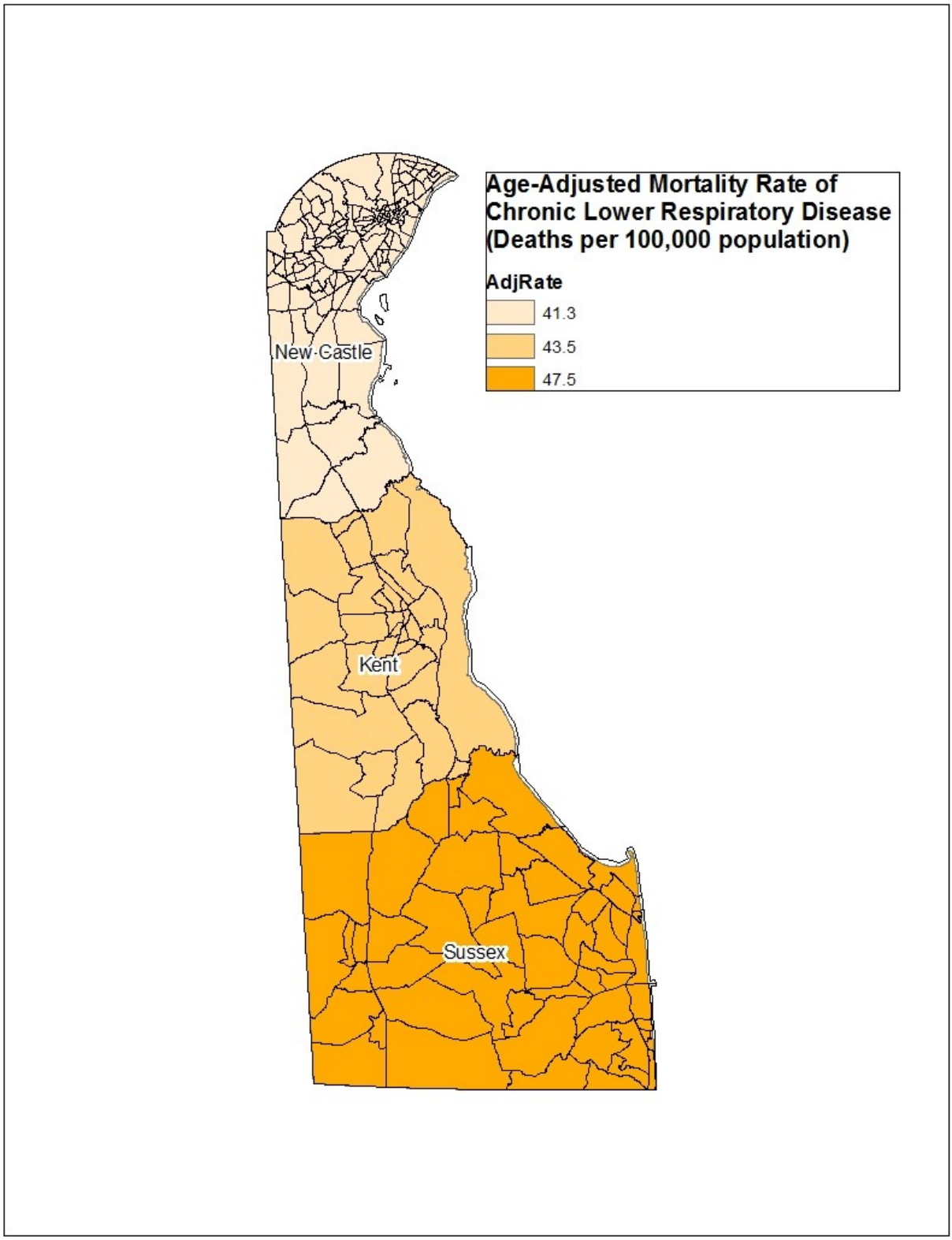
Fig 3. Crude chronic lower respiratory disease mortality by county in Delaware in 2013



These crude rates of mortality due to chronic lower respiratory disease do not take into account differences in the age distribution of people living in the different counties in Delaware,

however. Figure 4 shows the age-adjusted death rate due to chronic lower respiratory disease among Delaware counties. Figure 4 shows that the mortality rate for Sussex County dropped dramatically after age-adjustment. This suggests that Sussex County had a high proportion of older people that would be more likely to die from chronic diseases such as chronic lower respiratory disease.

Fig 4. Age-adjusted chronic lower respiratory disease mortality by county in Delaware in 2013



Chronic Lower Respiratory Disease Mortality in Delaware 2009-2016, by Demographics

Delaware Open Source Data from 2009-2016 showed that 3733 Delawareans died of chronic lower respiratory disease. Among those deaths, 88.5% were White, 10.6% were Black, and 0.9% reported a race as Other or was unknown (see Table 1).[16] During this time period, there was a higher proportion of female deaths due to chronic lower respiratory disease (53.3%) than males (46.7%). The proportion of those who died of chronic lower respiratory disease increase as age increases, with the most cases occurring in people aged 75 and older (63.3%) and the fewest cases occurring in people ages 15 - 54 years old (3.8%). New Castle County has the highest proportion of deaths among all counties (50.2%) compared to Sussex (30.6%) and Kent (19.2%) counties.

Table 1. Chronic lower respiratory disease mortality (2009-2016) by race, age group, sex and county of residence in Delaware[16,18]

County of Residence	Race %, (Count)			Age Group %, (Count)				Sex %, (Count)	
	Black	White	Other/Unknown	15-54	55-64	65-74	75+	Male	Female
Kent (n =715)	10.8 (77)	88.2 (631)	1.0 (7)	5.2 (37)	9.8 (70)	24.9 (178)	60.1 (430)	46.7 (334)	53.3 (381)
New Castle (n=1874)	13.9 (261)	85.3 (1599)	0.80 (14)	3.9 (74)	10.1 (190)	21.1 (395)	64.8 (1215)	41.0 (766)	59.0 (1108)
Sussex (n=1144)	4.9 (56)	94.0 (1075)	1.1 (13)	2.7 (31)	8.7 (100)	25.7 (294)	62.8 (719)	46.7 (534)	53.3 (610)
Total n = 3733	394	3305	34	142	360	867	2364	1634	2099

Discussion

The purpose of this study was to examine geographical relationships between smoking prevalence, COPD prevalence, and chronic lower respiratory disease mortality in Delaware. This study analyzes health data geographically by adding data layers representing adult smoking, COPD prevalence and lower respiratory disease mortality to basemaps for Delaware census tracts and counties. Delaware Open Data describing chronic lower respiratory disease mortality was also analyzed to identify mortality proportions by race, age group, and sex.

Main Findings

Our study showed a visual correlation between high smoking prevalence and COPD prevalence in census tracts surrounding urban areas; however, we found no visual correlation in general

between census tracts regarding smoking and COPD prevalence among all census tracts in Delaware. There are a multitude of risk factors for development of COPD that occur independently of tobacco use or exposure - including respiratory infections, genetics, occupational exposures, socio-economic status, and, perhaps most importantly, age. Our rates of COPD by census tract were not age-adjusted; therefore age distribution between census tracts cannot be discounted as a possible driver in the rate of COPD experienced by people within census tracts in Delaware. Additionally, studies using 2015 BRFSS data found that rural counties had higher rates of COPD, hospitalizations among Medicare patients, and COPD-related deaths, compared to more urban residents.[19] It is possible that the smoking-urban/rural-COPD rate relationships are different in Delaware due to local contextual factors such as access to healthcare, demographics, or smoking norms, or methodological differences such as categories of urbanicity and rurality. A more in-depth study to explore these relationships is warranted.

We also found that the census tracts with the highest COPD rates were located, largely, in the counties with the highest mortality rate, which is not surprising. Sussex County had the highest crude and age adjusted mortality rate (76.5 deaths per 100,000 and 47.5 deaths per 100,000, respectively). It is interesting to see such a dramatic reduction in mortality rate after age-adjustment in Sussex County. Age-adjustment is a common method among descriptive epidemiological studies to remove the confounding effect of age on determination of rates that describe groups. This process allows researchers to make meaningful comparisons of rates between groups, such as counties. After age-adjusting, Sussex, Kent, and New Castle Counties had very similar rates of chronic lung disease mortality, which suggests that a main risk factor for death due to chronic lung disease in Delaware in 2013 was age, and that Sussex county had a very high proportion of older people compared to Kent and New Castle counties. Because age is not a modifiable risk factor, this finding may not change the nature of lung disease interventions, but it does identify that Sussex County has a large amount of people with increased likelihood of mortality due to chronic lower respiratory diseases.

In examining the chronic lower respiratory disease mortality from 2009 - 2016 by demographics, we found similar racial trends between counties; the highest proportion of cases were among whites, followed by blacks, and lowest among individuals in the unknown/other category. These percentages largely mirror the racial demographics contained in the counties.[18] However, the proportion that died of chronic lower respiratory disease (by race) within each county is not the same as the racial distribution within each county. For example, the proportion of whites that died of chronic lower respiratory disease within each county was higher than the proportion of whites that lives within each county. This suggests that whites were more likely to die of chronic lower respiratory disease, compared to other races. In previous studies, white populations were found to have both higher prevalence and higher mortality rates than African Americans and other ethnicities.[20–22] A potential confounder for this relationship could be smoking. However, a study by Gilkes et al., found that in London, blacks were half as likely as whites to have COPD even after adjusting for smoking, suggesting the influence of other demographic, genetic, or behavioral factors.[23] In addition, females had a higher proportion of deaths compared to males. Previous studies have found that female smokers are about 50% more likely to develop COPD than male smokers, and have increased risk of hospitalization and death from respiratory failure and comorbidities.

Another important risk factor for the development and exacerbation of COPD is air quality. According to the American Lung Association Air Report Card for Delaware, which rates

County-level air quality on a letter scale from highest quality (A) to lowest quality (F), air quality varies by Delaware County. New Castle received a D grade in particle pollution whereas Kent and Sussex Counties both received A grades. New Castle scored an F for the number of high ozone days whereas Kent scored a C and Sussex scored D.[8] While these scores do not directly correlate with the COPD outcomes we identified in this study, poor air quality may interact with other risk factors that make individuals more likely to develop COPD and poor outcomes resulting from COPD, such as death.

The CDC emphasizes the importance of COPD surveillance to identify local communities that would benefit from interventions, and evaluate the effectiveness of prevention and treatment of COPD.[24] From the current study, it is clear that many Delaware census tracts in urban areas and in Sussex County as a whole, would benefit from targeted public health interventions related to smoking cessation and/or COPD management. Also, physicians can tailor their treatment plans to be more efficient for the people who live in Sussex County. A randomized controlled trial with over 8,000 participants found that a health management program including health lectures, counseling for smoking cessation, psychological counseling, and regular follow-up is an effective community-based strategy for COPD prevention and management.[25] This study confirmed the results of previous research that found that the INTERdisciplinary COMmunity-based COPD management program (INTERCOM) is effective for patients with COPD without exercise impairment as well as for patients with COPD with exercise impairment and less advanced airflow obstruction.[26]

While this study identified geographic areas with high burdens of chronic lung diseases on which prevention and treatment efforts should be focused, there are limitations. First, this study used only visual comparisons between variables, and did not employ statistical comparative methods. Future studies should identify if the upstream visual associations that we found are statistically significant between variables and geographic units of analysis. Second, the cross sectional nature of the data limits inferences based our results to associations only; no causal relationships can be identified based on our study results. Third, the ecological nature of the variables, as they described data at the group level not the individual level, prevents inferences from applying to individuals. Fourth, there are likely many other confounding factors that contribute to the development of and severity of lung diseases within communities including pollution, population density, access to healthcare, socioeconomic status, and health behaviors aside from smoking such as physical activity, preventive care, and disease management.

Next Steps for Research

In addition to future studies mentioned above, an interesting continuation of this research would be to perform a more focused geographic analysis of mortality. Deaths could be aggregated over time by census tract to identify sub-county areas with the highest and lowest mortality. This information could be important to explore the influence of geographic proximity to healthcare services on lung disease mortality.

There are various potential risk factors related to the development of COPD; some, such as genetics, age, and sex are not modifiable. Air quality is modifiable through a number of quality control strategies.[27] There are many ways of measuring air pollution, for example, by direct air monitoring devices, or by residential proximity to pollutant sources such as manufacturing plants or major highways. Linking information on area or residential-based proximity to pollutants with patient-level data on COPD or mortality data in order to analyze relationship between air

pollution and chronic lung disease outcomes in Delaware could be an important and influential study.

Conclusion

In the study we mapped the prevalence of smoking and COPD by census tract, and explored mortality by county, age, race, and sex in the state of Delaware. We analyzed maps for visual geographic patterns between variables and geographic units of analysis.

We found that Sussex County had a high proportion of census tracts with high COPD rates and the highest chronic lower respiratory disease mortality rate. COPD prevalence was higher in urban areas with high smoking prevalence. This study is useful to health care providers, researchers, and public health professionals working to create programs in Delaware to improve chronic lung disease prevalence and mortality.

References

1. American Lung Association. (2018). Chronic obstructive pulmonary disease (COPD). Retrieved from http://www.lung.org/lung-health-and-diseases/lung-disease-lookup/copd/
2. Centers for Disease Control and Prevention (CDC). (2005, July 1). Annual smoking-attributable mortality, years of potential life lost, and productivity losses—United States, 1997-2001. *MMWR. Morbidity and Mortality Weekly Report*, *54*(25), 625–628. PubMed
3. Mannino, D. M., Gagnon, R. C., Petty, T. L., & Lydick, E. (2000, June 12). Obstructive lung disease and low lung function in adults in the United States: Data from the National Health and Nutrition Examination Survey, 1988-1994. *Archives of Internal Medicine*, *160*(11), 1683–1689. PubMed https://doi.org/10.1001/archinte.160.11.1683
4. National Heart, Lung, and Blood Institute. (2017, May 15). COPD state prevalence cards. Retrieved from https://www.nhlbi.nih.gov/node/83481
5. Gupta, S. (2016, November 23). Burden of multiple chronic conditions in Delaware, 2011–2014. *Preventing Chronic Disease*, *13*, 160264. https://doi.org/10.5888/pcd13.160264 PubMed
6. Ward, B. W., Nugent, C. N., Blumberg, S. J., & Vahratian, A. (2017, March/April). Measuring the prevalence of diagnosed chronic obstructive pulmonary disease in the United States using data from the 2012-2014 National Health Interview Survey. *Public Health Rep*, *132*(2), 149–156. https://doi.org/10.1177/0033354916688197 PubMed
7. Kaiser Family Foundation. (2018). Total number of Medicare beneficiaries. Retrieved from: https://www.kff.org/medicare/state-indicator/total-medicare-beneficiaries/
8. American Lung Association. (2019). State of the air 2019. Retrieved from https://www.lung.org/our-initiatives/healthy-air/sota/city-rankings/states/delaware/
9. National Center for Health Statistics. (2018, January 8). Chronic lower respiratory disease mortality by state. Retrieved from https://www.cdc.gov/nchs/pressroom/sosmap/lung_disease_mortality/lung_disease.htm

10. Delaware Department of Health and Human Services. (2018). Delaware vital statistics executive summary report 2016. Retrieved from: https://www.dhss.delaware.gov/dhss/dph/hp/files/summary16.pdf
11. Centers for Disease Control and Prevention. (n.d.). Behavioral risk factor surveillance system. pct. of adults reporting to smoke cigarettes regularly in 2013. Policy Map. Retrieved from: https://tju-policymap-com.proxy1.lib.tju.edu/maps
12. Zhang, X., Holt, J. B., Lu, H., Wheaton, A. G., Ford, E. S., Greenlund, K. J., & Croft, J. B. (2014). Multilevel regression and poststratification for small area estimation of population health outcomes: A case study of chronic obstructive pulmonary disease prevalence using BRFSS. *American Journal of Epidemiology*, *179*(8), 1025–1033. PubMed https://doi.org/10.1093/aje/kwu018
13. Centers for Disease Control and Prevention. (2018, December 20). Chronic Obstructive Pulmonary Disease (COPD). https://www.cdc.gov/copd/data.html
14. Centers for Disease Control and Prevention. (2018). Behavioral risk factor surveillance system. pct. of adults every diagnosed with chronic obstructive pulmonary disease, emphysema, or chronic bronchitis in 2013. Policy Map. Retrieved from: https://tju-policymap-com.proxy1.lib.tju.edu/maps
15. Centers for Disease Control and Prevention. (2018). Multiple cause of death data. Retrieved from https://wonder.cdc.gov/mcd.html
16. State of Delaware. (n.d.). Delaware open data: deaths. Retrieved from: https://data.delaware.gov/Health/Deaths/nck5-dhqv
17. IBM. (2017). IBM SPSS Statistics for Windows (25). Computer software, Armonk, NY: IBM Corp.
18. United States Census Bureau. (2019). Quick Facts. Retrieved from https://www.census.gov/quickfacts/fact/table/newcastlecountydelaware,sussexcountydelaware,kentcountydelaware,delawarecountypennsylvania/PST045218
19. Croft, J. B., Wheaton, A. G., Liu, Y., Xu, F., Lu, H., Matthews, K. A., . . . Holt, J. B. (2018, February 23). Urban-rural county and state differences in chronic obstructive pulmonary disease— United States, 2015. *MMWR. Morbidity and Mortality Weekly Report*, *67*(7), 205–211. https://doi.org/10.15585/mmwr.mm6707a1 PubMed
20. Mannino, D. M., Homa, D. M., Akinbami, L. J., Ford, E. S., & Redd, S. C. (2002, October). Chronic obstructive pulmonary disease surveillance—United States, 1971-2000. *Respiratory Care*, *47*(10), 1184–1199. PubMed
21. Ford, E. S. (2015, October). Trends in mortality from COPD among adults in the United States. *Chest*, *148*(4), 962–970. https://doi.org/10.1378/chest.14-2311 PubMed
22. Kamil, F., Pinzon, I., & Foreman, M. G. (2013, March). Sex and race factors in early-onset COPD. *Current Opinion in Pulmonary Medicine*, *19*(2), 140–144. https://doi.org/10.1097/MCP.0b013e32835d903b PubMed
23. Gilkes, A., Ashworth, M., Schofield, P., Harries, T. H., Durbaba, S., Weston, C., & White, P. (2016, April 7). Does COPD risk vary by ethnicity? A retrospective cross-sectional study.

International Journal of Chronic Obstructive Pulmonary Disease, *11*, 739–746. https://doi.org/10.2147/COPD.S96391 PubMed

24. Centers for Disease Control and Prevention (CDC). (2012, November 23). Chronic obstructive pulmonary disease among adults—United States, 2011. *MMWR. Morbidity and Mortality Weekly Report*, *61*(46), 938–943. PubMed
25. Lou, P., Chen, P., Zhang, P., Yu, J., Wang, Y., Chen, N., . . . Zhao, J. (2015, January). A COPD health management program in a community-based primary care setting: A randomized controlled trial. *Respiratory Care*, *60*(1), 102–112. https://doi.org/10.4187/respcare.03420 PubMed
26. van Wetering, C. R., Hoogendoorn, M., Mol, S. J. M., Rutten-van Mölken, M. P. M. H., & Schols, A. M. (2010, January). Short- and long-term efficacy of a community-based COPD management programme in less advanced COPD: A randomised controlled trial. *Thorax*, *65*(1), 7–13. https://doi.org/10.1136/thx.2009.118620 PubMed
27. U.S. Environmental Protection Agency. (2018). Quality control strategies. Retrieved from https://www.epa.gov/air-quality-management-process/managing-air-quality-control-strategies-achieve-air-pollution