Analysis of the Relationship Between Demographic Values, Opiate Treatment Programs, Opiate Related Deaths, and Population using Geographic Information Systems and Exploratory Regression for the Year 2015

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Abstract

Opiate addiction is an ever-growing issue in the United States, including the state of Minnesota. This study analyzed opiate related death occurrences by county in Minnesota for the year 2015 to inform efforts to improve Minnesota's response to the opiate epidemic. The number of deaths by opiate per county in Minnesota varies greatly. Opiate treatment program clinics are a method of harm reduction that allow addicts to safely reduce the use of drugs in an innocuous environment with control of the substances. This study explored the possible relationships between deaths by opiates and opiate treatment programs and other demographic data in Minnesota. Exploratory regression was used to analyze income, age, sex, race, employment, prescription rates, and death data obtained at the county level. Scatterplot graphs were also created in Microsoft Excel to find possible explanatory variables. The purpose of this study was to find trends that can lead to future planning of harm reduction strategies and introduce the strategies to areas that are most in need. The findings determined no passing regression models and no conclusive correlation.

Introduction

Background for Study

Opiate addiction in Minnesota has been on the rise. According to the Minnesota Department of Health (2015), the number of deaths from opiates increased from 145 in 2005 to a record 336 deaths in 2015. From 2015 to 2016, the number increased by roughly 18%. The alarming and continual rise in the number of opiate related deaths is part of a larger national health crisis.

Minnesota declared the opiate crisis in 2007, but there has not been a fall in the number of deaths since 2010, when there was a 17% decrease. The reason for the decrease in 2010 is truly unknown, but some medical experts from the Minnesota Board of Pharmacy and the Department of Health believe the initiation of a prescription drug monitoring program (PDMP), which is essentially a reporting tool that collects and saves patient-specific prescription information, had an impact on the lowered death count during that time. The incentive for the program was to reduce prescription drug abuse. According to Cody Wiberg, the Executive Director for the Minnesota

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Board of Pharmacy, Minnesota introduced a PDMP in 2010. “We began collecting data from dispensers in January, 2010 and started making the data available to prescribers and pharmacists on April 15, 2010. I suppose it is possible that the PDMP had some impact on deaths for 2010 – but I do not know if that is true. We had a gradual increase in the number of prescribers and pharmacists who signed up for an account” (Wiberg, 2018).

Wiberg continued to explain how many states have implemented PDMPs to reduce the abuse of prescription opiates and are implementing guidelines for prescribing, such as quantity limits and requirements of checking a patient’s history in the PDMP database.

Heroin drug abuse has been on the rise since 2010 in the United States and the explanation provided for this is drug cartels have flooded the nation with cheap and somewhat pure heroin (Wiberg, 2018). See Figure 1 for a visual representation of different kinds of opioid overdoses in the United States and Figure 2 for opioid involved deaths in Minnesota. The opioid drugs, when abused, can hurt the mental and physical parts of the body and cause infectious disease. Side effects also include distress on not only the individual abuser, but also families and other relationships with friends, work, hobbies, school, and finances.

Opioid Treatment Program

An opiate treatment program (OTP) is a government accredited program where medication assisted treatment (MAT) is used. A person who is addicted to opioid-based drugs, such as heroin or prescription painkillers, can receive medication-based therapy, such as methadone. An OTP is part of the harm reduction process for most states because they provide a sanitary and controlled environment for the patients receiving treatment. It is one of the most common options for addicts to start the rehabilitation process. The accreditation is given to programs that pass a number of criteria, such as site visits from specialists with experience in opioid treatment medications to ensure proper treatments for patients (Substance Abuse and Mental Health Services Administration (SAMHSA, 2015a).

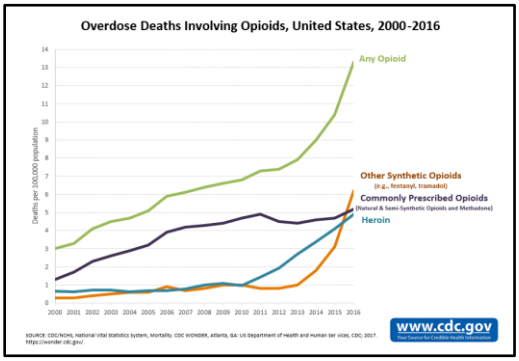

Figure 1. Graph created by the Centers for Disease Control (CDC) shows opiate related deaths in the United States by different types of opiates from 2000-2016. Green – any opiate. Orange – synthetic opiates. Purple – popular prescribed opiates. Blue – heroin.

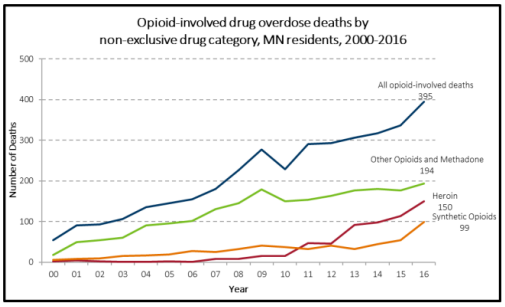

Figure 2. This graph created by the Minnesota Department of Health shows opiate related deaths in the United States by different types of opiates from 2000-2016. Blue – all opiate related deaths. Green – methadone and other opiates. Orange – synthetic opiates. Magenta – heroin.

Purpose of Study

A common question occurring in the realm of drug abuse treatment is whether having available opioid treatment programs reduces the amount of deaths that occur from opioids. For this study, the question is: Does a correlation exist between the presence of an accredited OTP clinic in a county and the number of deaths by opioids in that county or are there other demographic variables that can explain the number of deaths by opioids? According to literature review findings, supporting evidence has been found in harm reduction post-treatment for opioid use disorders. According to the Journal of Substance Abuse Treatment (Leece *et al.*, 2015), methadone therapy is associated with several improved outcomes, including retention in drug treatment as well as reduced opioid use, and some observational studies have observed reductions in all-cause mortality and risk of death from overdose. A study conducted in Taiwan stated that after thoroughly investigating methadone treatment, continuing with the Methadone Maintenance Treatment (MMT, similar to a MAT) program is still an important predictor for survival (Huang and Chung, 2013). Another study done in 2009 stated that a methadone treatment program is more effective for heroin addiction than other treatment programs that do not use opioid replacement treatment (Mattick, Breen, Kimber, and Davoli, 2009).

Although there have been positive outcomes observed in studies of OTPs, there is still much that is unknown because OTPs are not common. The state of Minnesota has 15 accredited OTPs, and according to SAMHSA (2015a), MAT is underused; controversy causes skepticism because of the misconceptions related to trading in one drug for another for the purpose of drug addiction treatment. Suggestions for implementing more OTPs include adequate training for doctors and other medical professionals.

Judgement is another problem opioid treatment programs face. In 2015, SAMHSA stated that the problems faced are rooted in illegal judgment from professionals. "Discrimination against MAT patients is also a factor, despite state and federal laws clearly prohibiting it" (SAMHSA, 2015a).

OTPs offering methadone have been the topic of some academic journals because it is the most popular form of MAT-OTP. Although methadone is a common method of treatment, many stigmas are attached to the word. This could be because methadone is a controlled opioid substance and is sometimes considered a trap rather than a treatment program. According to Harvard's Medical School, people who are taking methadone simply cannot or will not stop taking the drug. The time of the treatment process can be indefinite (Harvard Health Publications, 2005).

SAMHSA recognizes alcohol within MAT, but this study will simply focus on opioids, opioid addiction, opiate related deaths, and opioid treatment programs. An opiate is a drug naturally derived from the flowering opium poppy plant and an opioid is a broader term that includes opiates and refers to any substance, natural or synthetic, that binds to the brain's opioid receptors (Freedman, 2017).

Study Area

This study focused on the eighty-seven (87) counties in the State of Minnesota because of its ongoing opioid crisis, which was declared as a public health crisis by the federal government in October of 2017. The continuous rise of opioid use, addiction, and opioid related deaths in the state of Minnesota has grabbed the attention of everyone, including students, parents, educators, health specialists, and the government. Below is a map of all fifteen (15) opioid treatment programs in Minnesota (Figure 3).

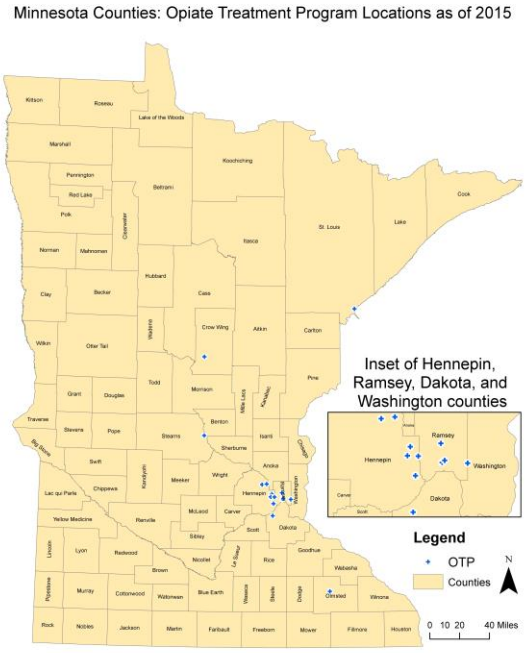

Figure 3. Minnesota counties and OTP locations as of 2015. Inset map shows Hennepin, Ramsey, Dakota, and Washington counties that host 11 of the 15 OTPS in Minnesota.

Data Sources

The data for opioid related deaths by county was collected from a document authored by the Minnesota Department of Health (2015) titled Drug Overdose Deaths among Minnesota Residents Annual Report, which reported the number of deaths per county from years 2000-2016, but only 2015 was used for this research. Other demographic data used for exploratory variables, such as income, age, sex, race, and employment, were obtained from the United States Census Bureau (2015). Prescription rates were found from the Minnesota Board of Pharmacy 2015 Annual Report (2017) and county boundary data was collected from the Minnesota Geospatial Commons (2013). The addresses of existing opioid treatment program were obtained from SAMHSA's OTP directory (2015b).

Data Manipulation

The data used for this study is from 2015 because of the availability for all variables. The estimated values for 2015 were obtained at the county level for race (White, African American, American Indian or Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander), median income, median male and female age, and employment from the U.S. Census Bureau. Prescription rates, opioid treatment program sites, and other facility data used for this study was available in PDF format; therefore, the data was manually entered into Excel.

The final table that was used with the Join tool in ArcMap was a compilation of all the variables and data for each county in Minnesota. The Join tool, as defined by Esri, allows one layer to be joined to another layer based on a common field. The county boundary layer had a unique identifier for each county and that unique identifier was maintained when creating the completed variable table in

Microsoft Excel. This allowed for a smooth table join process to use for analysis in ArcMap. Since joins are not permanent, the records were exported into a new feature class and the joined attributes were made permanent.

The population data used for this study did not have to be converted into an Excel spreadsheet because it was available from the United States Census American Fact Finder and could be exported to Excel from the United States Census American Fact Finder website without manual input. An Excel table was created showing the raw numbers of opioid related deaths for 2015 by county, which was used in the analysis of deaths per 1,000 people per county.

Methods

The main objective of this study was to collect primary data about existing opioid treatment programs and the opioid related deaths that occurred in each county in Minnesota and to determine if there was statistical correlation between selected variables and opioid related deaths. To normalize the opioid related death data, the number of deaths was divided by the population of the county and then multiplied by 1,000, because the number of opioid related deaths divided by population for some counties was extremely low.

The number of deaths per 1000 people was used as the dependent variable to explore possible explanatory variables. The explanatory variables accounting for population by race were also divided by the county's population and multiplied by 1,000 for the same reason; some racial populations were extremely small in some counties. See Figure 4 for a visual of the ratio of deaths and population by county.

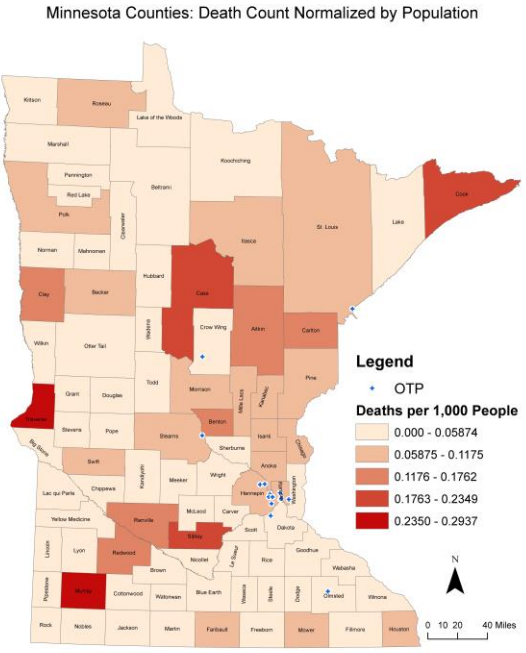

Figure 4. Map displaying the number of deaths per 1,000 people per county. The darker red indicates a county with a higher death count relative to its population.

Data Analysis

To analyze the variables that may explain the dependent variable, the Exploratory Regression tool was used in ArcMap. The Exploratory Regression tool combines all variables in every possible way to see which models will pass. A passing model meets various parameters related to significance of coefficients, multicollinearity (variance inflation factor), bias (Jarque-Bera statistic), and spatial autocorrelation (Esri, 2016). The user sets the maximum acceptable values for each parameter. There are guidelines for appropriate threshold values that are defaults in the tools from Esri. The default threshold values were used for this study.

This study used exploratory regression with multiple combinations of variables. The variables chosen were uncomplicated demographic variables because opioid related deaths are unbiased. According to Hedegaard, Warner, and Minino (as cited by the CDC, 2017a), "Deaths from drug overdose are up among both men and women, all races, and adults of nearly all ages." The variables used in this study were chosen to explore any correlation among the deaths in Minnesota counties and race, age, and sex. Figure 5 provides statistical criteria values used for this study within the Exploratory Regression tool.

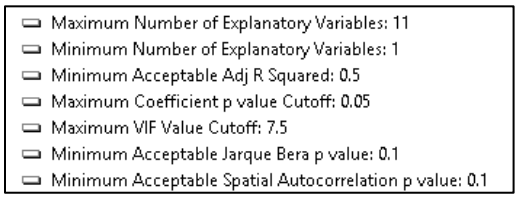

Figure 5. Showing the Exploratory Regression tool Criteria used in this study.

After running the tool with demographic data, OTP data, and prescription rate data, zero models passed. The combination of only demographic data was used to see if a model could pass, but no models passed.

Results

Since exploratory regression did not return any passing models, scatterplots were used to explore possible linear regression patterns. After plotting each independent variable versus the number of deaths per 1,000 people on a scatterplot in Excel, the R-squared value was found. The highest R-squared result was from the Median Age of Male variable at .0257. This value means that the Median Age of Males explains almost 3% of the variation in reported opioid related deaths. Table 1 shows the R-squared Values produced by Excel. Appendix A displays each variable in a scatterplot graph with Y being the explanatory variable used and X being the dependent variable of opioid related deaths per 1,000 people.

Table 1. The variable and R-squared value produced by Excel using the Insert Graph function.

Variable	R-squared Value
Age Male	0.025700
Age Female	0.019000
Asian	0.000003
African Amer.	0.003500
Islander	0.000050
Native	0.004300
White	0.003900
Income	0.000030
Employment	0.019700
Prescription	0.018400
OTP	0.010000

After looking at the low R-squared values above, exploratory regression was conducted again with the subset of Minnesota counties with less than 10 deaths in 2015 to analyze the variables further to see if there is a relationship or correlation between the variables and counties with the least amount of deaths (Table 2).

Another exploratory regression analysis was conducted on all counties that have more than one (>1) deaths in the county in 2015. The R-squared values that were returned were higher than the R-squared results that were returned from the analysis on all counties and all counties with less than 10 deaths in the county (Table 3).

An outlier within the data influenced the decision to test a subset of data for exploratory regression. Hennepin County had more than double the number of deaths (101) than the next leading county (Ramsey with 35). Exploratory

regression analysis was conducted on the data without Hennepin County to see if the results would return a higher R-squared value. Table 4 shows the exploratory regression results for all counties, excluding Hennepin.

Table 2. Highest adjusted R-squared results from the Exploratory Regression tool ran in ArcMap for all Minnesota counties that contained less than 10 deaths in 2015. The Model Variable Sign (+/-) indicates whether the variable is negatively or positively correlated and the amount of significance is marked by the asterisk, which indicates the Model Variable Significance p-value (* = 0.10, ** = 0.05, *** = 0.01).

Variable	R-squared Value
-White +Median Age Male* +OTP Count	0.04
+Median Age Male +Native +OTP Count	0.03
+Median Age Male +OTP Count +Prescription Rate	0.03

Table 3. Highest adjusted R-squared results from the Exploratory Regression tool ran in ArcMap for all Minnesota counties that contained more than one death in 2015.

Variable	R-squared Value
-Income*** +Islander*** +Native*	0.40
-Income** +Islander** +Median Age Male	0.38
-Asian -Income*** +Islander**	0.37

The results identified no passing models. A possibility of this could be the numbers were too small. The number of deaths per county compared to the population resulted in very small value. To look at a bigger picture, the same methodology could be conducted for data that included all kinds of drug overdoses, not just opiates. In addition, the data could be biased per the Jarque-Bera (JB) statistic. JB indicates whether the observed/known dependent variable values minus the predicted/estimated values are normally distributed (Esri, 2016). Model bias can be a result of an outlier. Hennepin County was considered an outlier for this study and that is why the Regression tool was applied without Hennepin County.

Table 4. Highest adjusted R-squared results from the Exploratory Regression tool ran in ArcMap for Minnesota counties excluding outlier, Hennepin County.

Variable	R-squared Value
+Income +Median Age Male* +Native +OTP Count*	0.02
-White -Asian +Median Age Male +OTP Count	0.02
-White +Median Age Male +OTP Count +Prescription Rate	0.02

Discussion

Data Limitations

A limitation of this study was finding data on opioid addiction and accurate opioid related deaths. In Minnesota, the resources available did not give a reliable number for the count of opioid related deaths in a county because many overdoses go unlabeled. Per the CDC (2017b), “Drug overdose deaths can be hard to categorize. In approximately 1

in 5 drug overdose deaths, no specific drug is listed on the death certificate. In many deaths, multiple drugs are present, and it is difficult to identify which drug or drugs caused the death." Since the number of deaths per county is comparatively small to the population number, the resulting numbers are very small when calculating the dependent variable. Although opioid addiction has seen a rise and fall in certain demographics, overall the increase in opioid addiction covers many demographic areas. This made finding possible explanatory variables difficult. Despite an abundance of demographic data, finding patterns within the demographics could be hard because of opioids' non-discriminatory addictive properties. The combinations of possible explanatory variables is ultimately vast.

The CDC states that drug overdose deaths and opioid-involved deaths continue to increase in the United States. "Heroin use has increased across the United States among men and women, most age groups, and all income levels. The greatest increases have occurred in groups with historically low rates of heroin use, including women and people with private insurance and higher incomes" (CDC, 2017c). These variables such as women, private insurance holders, and people with higher incomes could be furthered researched for counties in Minnesota.

Indiana University (n.d.) states even the slightest change in the numerator can lead to a large change in the rate from one year to the next. Unstable rates do not lend themselves to being used to make decisions. At the beginning of this study's research in 2016, opioid data in general was not readily available. In 2018, the CDC and the Minnesota Department of Health conducted thorough research and studies on the opioid crisis. The study promotes continued efforts for overdose prevention and harm reduction plans.

Possibilities for Future Research

The Minnesota Department of Health completed the 2016 report, Drug Overdose Deaths among Minnesota Residents. This is the latest, most thorough research completed for drug overdose deaths in Minnesota. It was published in August of 2017 after the beginning of this research thesis. It would be interesting to take the information from the 2016 Annual Drug Overdose Deaths report and do the same analysis with the same variables for 2016, if they are available. Conducting this research with updated variables and localized block group data could give precise outcomes for explaining the dependent variable. This could be good for future rehabilitation programs to see if hotspots occur for opioid related deaths.

Some research suggests that having low R-squared values when running exploratory regression on human behavior can be accepted and pushing for high R-squared values is not entirely dependable because people are unpredictable and adding more variables to try to predict the dependent variable can be overly aggressive in trying to explain the unexplainable (Minitab, 2014).

Conclusion

The results in this study did not find substantial correlation between income, age, sex, race, employment, prescription rates and deaths at the county level. From this study, the strongest correlation was found between males and employment

rate. These variables could be further researched as the opioid crisis is still in need of harm reduction strategies to reduce the continual rise in the amount of deaths and overdoses in the State of Minnesota.

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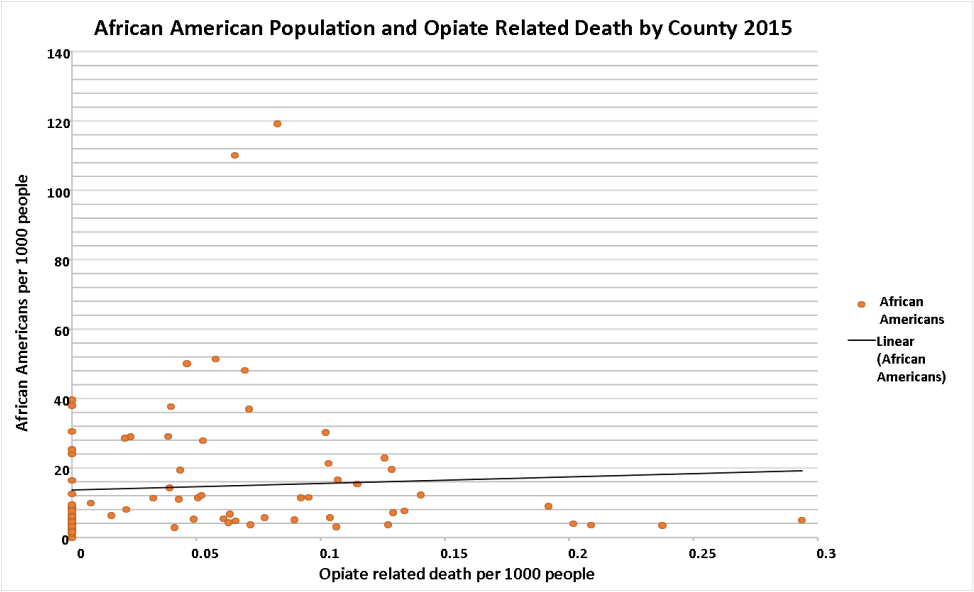
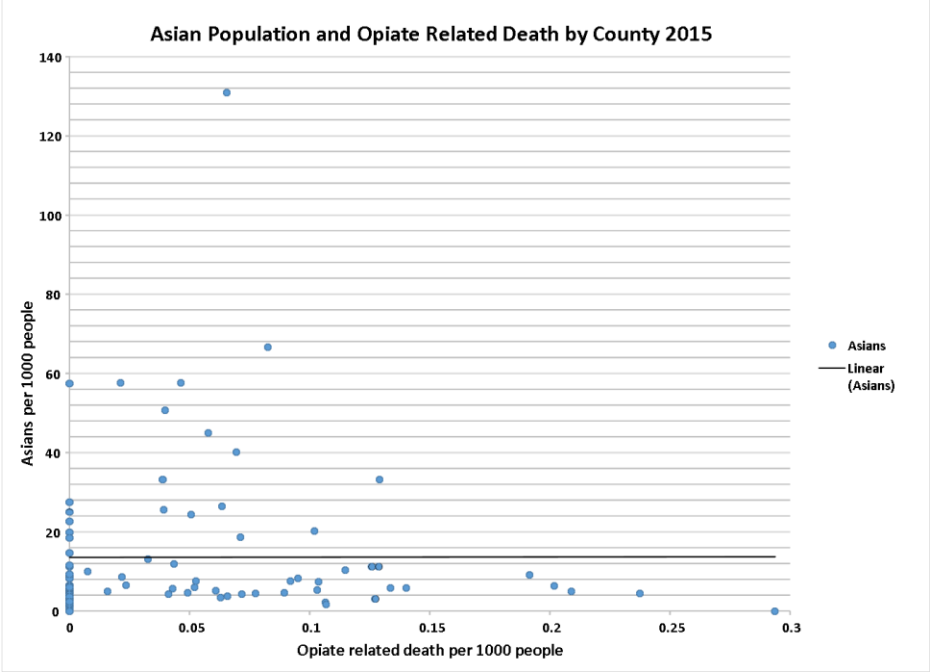
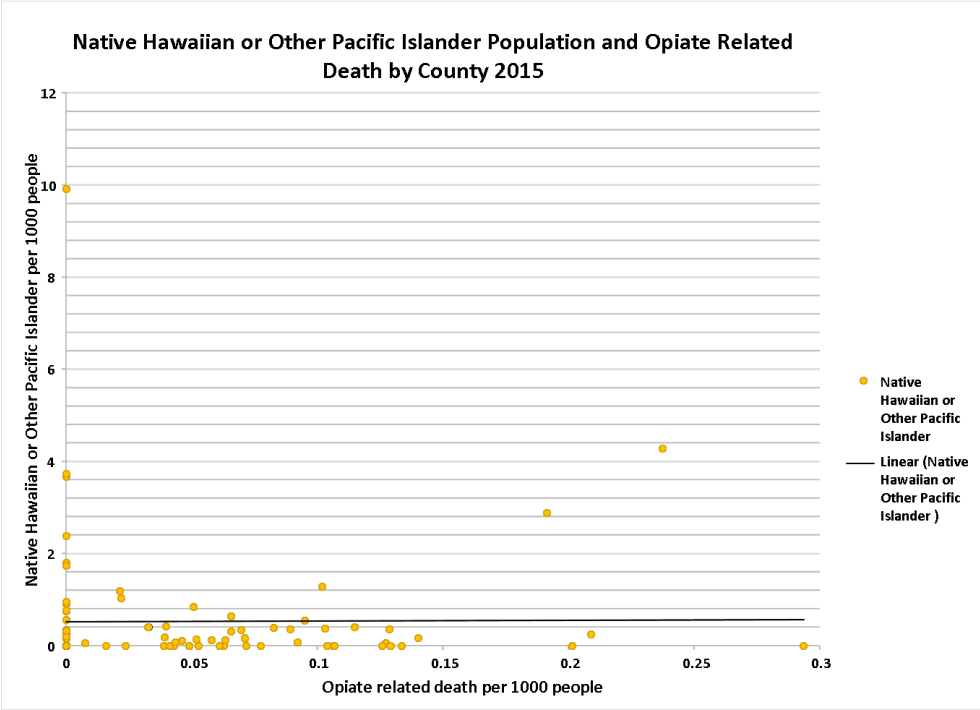
Appendix A. Scatterplot graphs displaying the relationships between the dependent variable, number of opioid related deaths per 1,000 people, and existing OTP clinics, race, income, employment, age, and prescription rate.



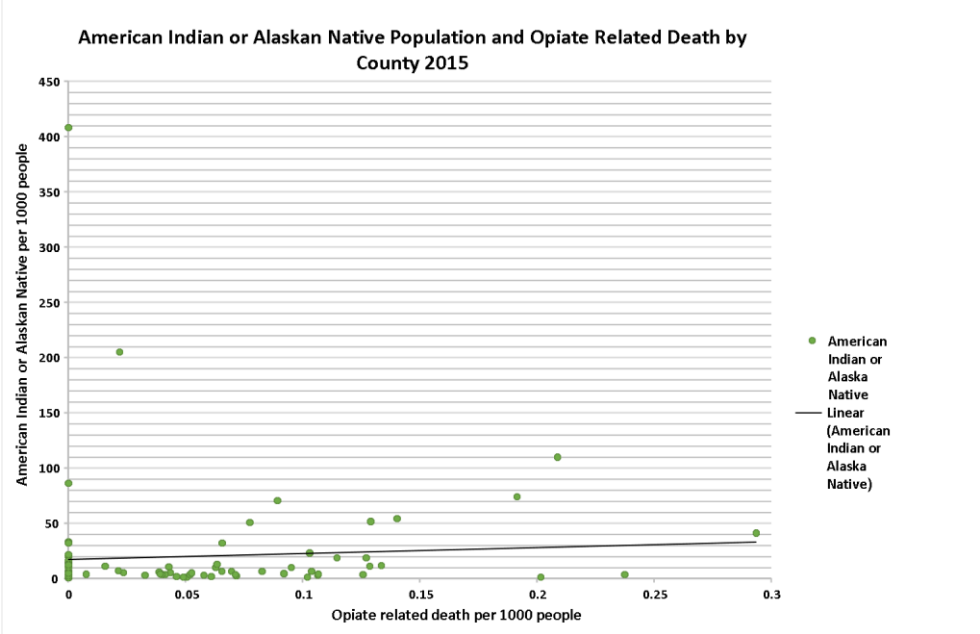
Graph representing African American population and opioid related deaths by county. Formula: y = 18.452x + 13.739. R-squared = 0.0035.



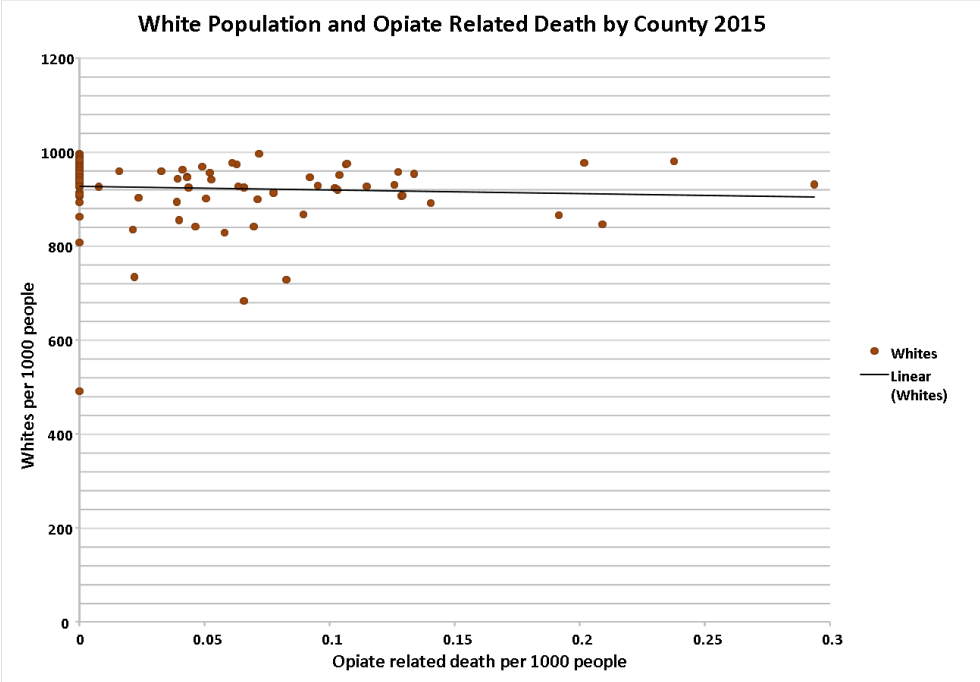
Graph representing Asian population and opioid related deaths by county. Formula: y = 0.532x +13.586. R-squared < 0.01.



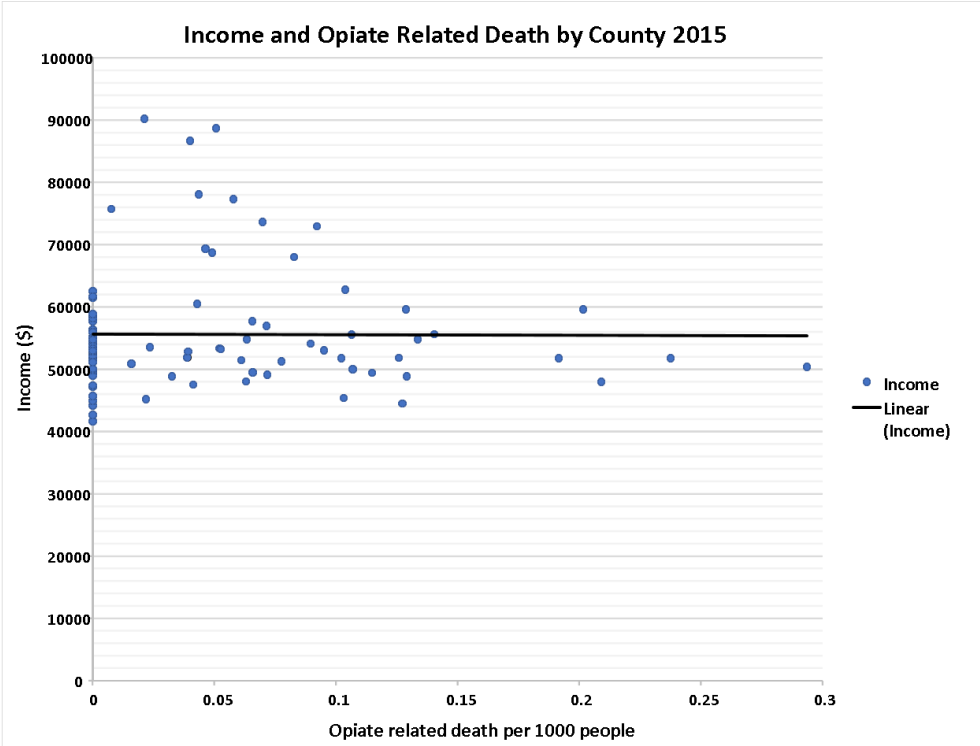
Graph representing Native Hawaiian or Other Pacific Islander population and opioid related deaths by county. Formula: y = 0.1428x + 0.5263. R-squared < 0.01.



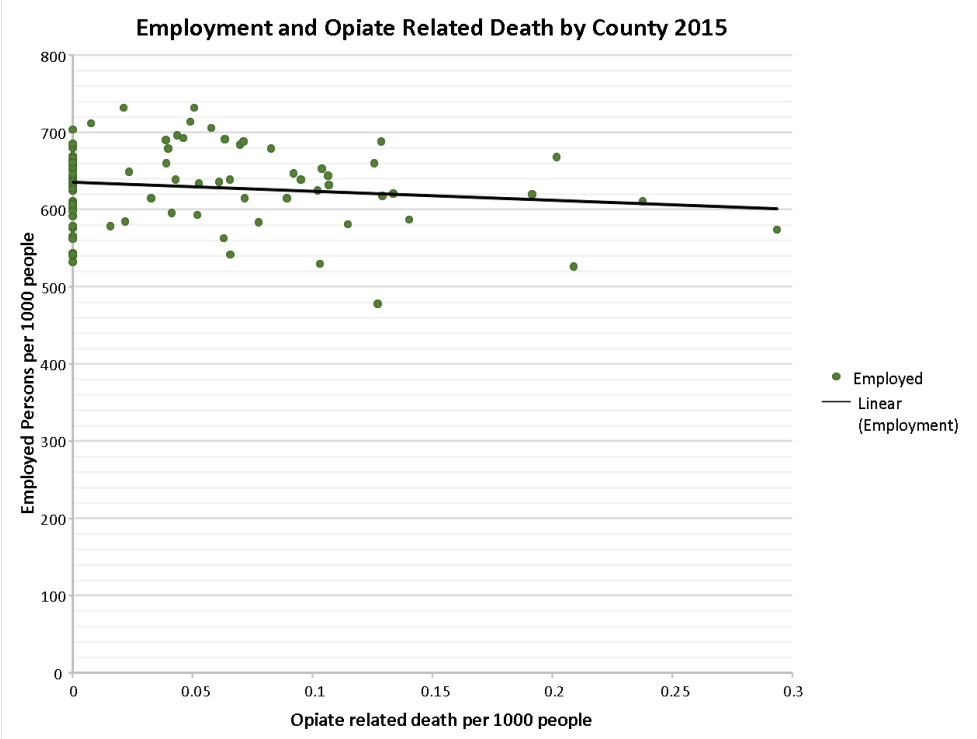
Graph representing American Indian or Alaskan Native population and opioid related deaths by county. Formula: y = 53.836x + 17.199. R-squared = 0.0043.



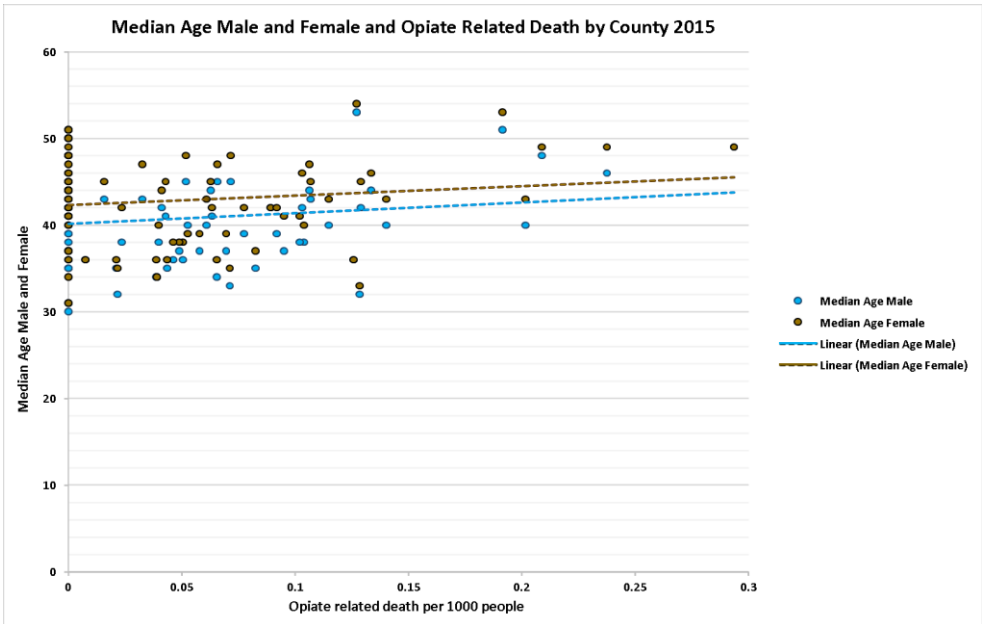
Graph representing White population and opioid related deaths by county.
Formula = -75.609x + 926.56. R-squared = 0.0039.



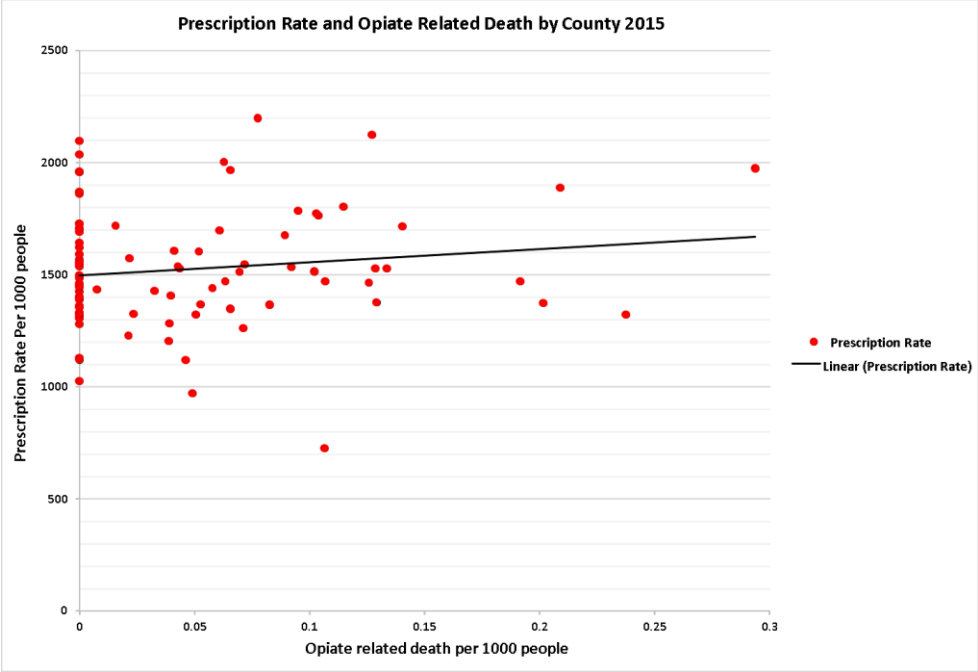
Graph representing income and opioid related deaths by county.
Formula: y = -875.48x + 55602. R-squared < 0.01.



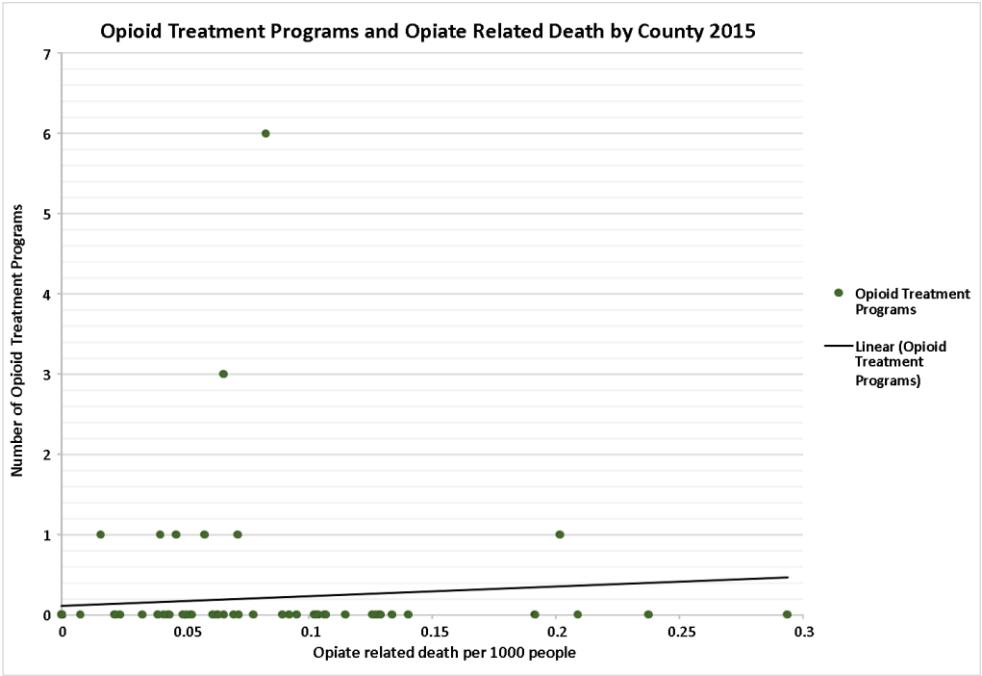
Graph representing employed population and opiate related deaths by county.
Formula: y = -114.39x + 365.14. R-squared = 0.0197.



Graph representing male and female median ages and opiate related deaths by county.
Formula Male: y = 12.488x + 40.121. R-squared = 0.0257.
Formula Female: y = 10.984x + 42.32. R-squared = 0.019.



Graph representing prescription rate and opiate related deaths by county. (Rx Count 2015 / Population 2015 = Prescription Rate)
Formula: y = 581.3x + 1498.6. R-squared = 0.0184.



Graph representing opiate treatment programs and opiate related deaths by county.
Formula: y = 1.201x + 0.1144. R-squared = 0.01.