Bending the Curve: A Mathematical Model to Predict the Impact of a Novel Approach to Mitigate the Opioid Crisis

INTRODUCTION and BACKGROUND

Opioid Crisis and Opioid Use Disorders

This project mathematically modeled the opioid crisis to predict its progress, the effectiveness of current interventions, and ultimately develop a new approach to combat the crisis.

An opioid use disorder occurs when a person physically and mentally depends on opioids to relieve pain. These powerful drugs bind to the 'reward pathway' of the brain to produce pleasurable feelings. Just by taking these drugs puts a person at risk of tolerance, wherein higher doses are needed to produce the same effects over time. Dependence can eventually occur if the urge for the drugs becomes uncontrollable.

The opioid crisis has plagued the United States for the past 20 years, and continues to bring devastation to society. Every day, more than 130 lives are lost due to opioid overdoses caused most commonly by prescription narcotics and heroin. In 2016, 2.1 million Americans suffered from an opioid use disorder. The economy has also taken a huge toll, as the opioid crisis cost $631 billion from 2015-2018, and $188 billion in 2019.

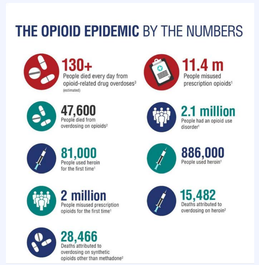


Photo Credit: Department of Health and Human Services

Although initiatives by the medical community, law enforcement, and education fields have recently been taken to address this crisis, the broader context of the effectiveness of these initiatives and the specific extent to which this epidemic has been addressed are still not fully developed. The mathematical models presented in this project have incorporated trend lines based on previous trends from the opioid crisis from 1999 to 2017, the year before major interventions to address the crisis have taken place. These models have addressed the initiatives' effectiveness, as well as highlighting the additional courses of action society needs to take to try to combat the opioid epidemic.

OBJECTIVES

The opioid crisis is a multi-dimensional issue because there is no one optimal solution due to the effects on a significant portion of society. Prevention of increased deaths from opioid overdose include actions such as the reduction of opioid prescriptions and rise in medical treatment and rehabilitation services. However, the crisis has not been eliminated and there are still no clear signs indicating total resolution.

Photo Credit: National Institutes of Health

The focus of this project is to predict how additional intervention can further change the trajectory of the crisis by devising mathematical models to prove and put into perspective the extent to which the current initiatives have affected the opioid crisis.

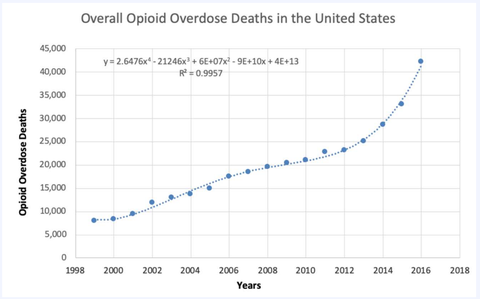
HYPOTHESIS

Teenagers are currently not involved in trying to mitigate the opioid crisis. The hypothesis is that if methods exist for teenagers to actively intervene and help adults try to combat the crisis, our society can bend the curve faster, meaning that more lives can be saved from opioid use disorders. It should be noted that this is not about teenagers avoiding opioids, as there are already sufficient educational resources to address this aspect. *The premise is that society can empower teenagers to assist their friends and family members struggling with opioid use disorders.*

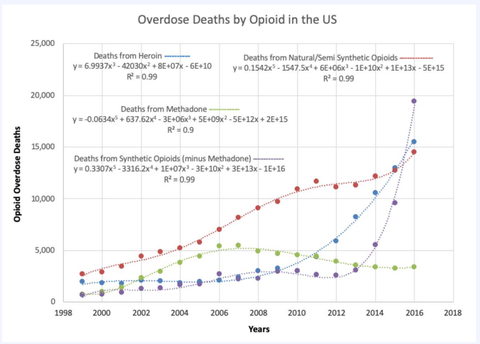
METHODS

Fitting Equations and Trendlines

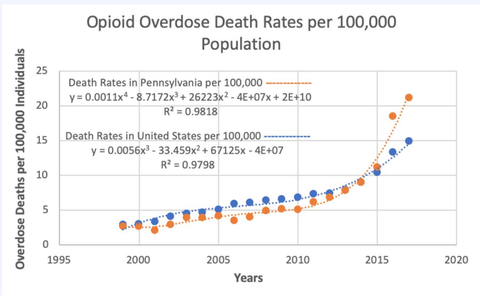
Major initiatives to address the opioid crisis were not taken until after the year 2017. To measure the effectiveness of the solutions, trendlines were formed to best fit the opioid crisis curves, which measure the number of lives lost from opioid overdose from 1999 to 2017. The trendlines are all polynomial equations as they best account for the inflection points found in the data. The R^2 value indicates the relative accuracy of the model (with the value 1.00 as most accurate).



The above graph indicates that the national opioid crisis peaked in more recent years, with a general increasing trend affecting more lives.



The above graph is specific to each opioid. This graph demonstrates that because each opioid had its own peak in the crisis, the graph with the number of overall overdoses takes into account the patterns of each opioid to generate an overall trend.

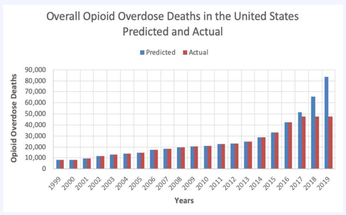


Pennsylvania has the 4th highest rate in the country in terms of opioid use disorders. This graph compares the national rate of deaths from opioid use disorders with Pennsylvania's rate. This graph is per 100,000 individuals in the respective populations.

***Data provided by Centers for Disease and Control (CDC)**

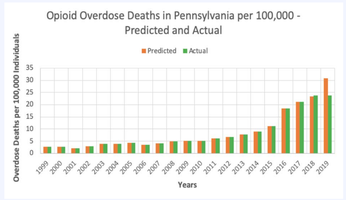
RESULTS

After fitting the equations, the number of opioid overdose deaths for the subsequent years (2018 and 2019) were predicted. These would have been the values had there not been any interventions.



United States Predicted Values
2017: 51,699
2018: 65,443
2019: 83,410

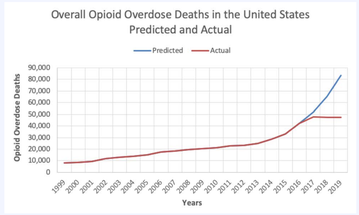
United States Actual Values
2017: 47,600
2018: 47,590
2019: 47,450

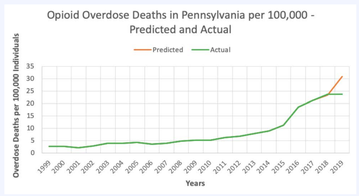


Pennsylvania Predicted Values (per 100,000 individuals)
2017: 21.2
2018: 23.4
2019: 30.8

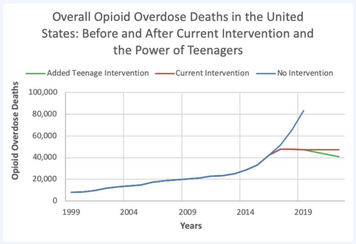
Pennsylvania Actual Values (per 100,000 individuals)
2017: 21.2
2018: 23.8
2019: 23.7

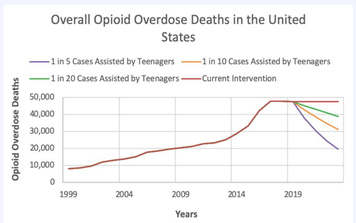
These models indicate that while a significant number of lives from opioid overdoses have been saved since 2017 due to intervention, those numbers have remained at 47,000 individuals in the United States and 2,500 individuals in Pennsylvania every year (or around 23.7 individuals per 100,000 population in PA). Additional intervention is then needed to bend the curve.





Teenage Intervention





These graphs highlight that if teenagers were to intervene by helping a loved one battle an opioid use disorder, more lives would be saved and the opioid crisis curve would be significantly bent. Note that these values already take into account the continual implementation of already existing initiatives.

DISCUSSION

Due to the interventions taken since 2017, the opioid crisis curve has flattened. The projections indicate that teenagers helping loved ones with opioid use disorders can bend the curve. Even if teenagers save 1 out of every 20 individuals, a significant bend is still created. *This is a new angle to the crisis that has not been previously considered.*

Stories with Teenagers

A majority of cases have teenagers who may want to help but do not know how to proceed. The following are real-life stories demonstrating the roles of teenagers and the opioid crisis, where teenagers were passive bystanders.

Photo Credit: Fritz Clinic

Story 1: Certified Recovery Specialist in her 20s
She struggled with an opioid use disorder, but could not control her life. Her teenage friends witnessed her downhill struggle and wanted to prevent her from excessive drug use, but did not quite know how to assist or even approach her. It was only after she experienced an older woman's life being taken away due to a drug overdose did she ultimately decide to enter recovery and turn her life around.

Story 2: Two high school honor students and sisters
One of the sisters seemed extremely tired and drowsy. Only after an overdose occurred did her family realize her condition and jumped into action to help her seek professional care. Luckily, she was able to recover after a couple of dangerous relapses. Her sister helped her mother create a support group to express her experiences as the sister who witnessed the opioid use disorder, and wished that she could have better helped her sister at the time had she known what to do.

How Teenagers Can Help

Changing perception of opioid use disorders: regard them as treatable medical conditions instead of moral issues. This removes the stigma that evokes feelings of fear, shame, and guilt among all of those who experience opioid use disorders. This perception has been rooted in our society, making adults feel less inclined to initiate conversation and assist those with opioid use disorders.

Teenagers are just starting to learn about these issues with a fresh lens clear of such stigmatizing perspectives. This puts them at a more favorable position to assist a loved one.

Photo Credit: National Alliance on Mental Illness (NAMI)

Extend support by initiating conversation: This process includes emphasizing that the individuals can share their stories and receive help as needed. Chances exist that they will not open up immediately, but by demonstrating empathy, the stigmatizing barriers are removed and they will eventually feel more comfortable sharing their stories.

Mirror conversation to guide them to recovery options: The conversation is not providing instructions, but offering supportive statements to help them figure out what they feel is best for them. By following these steps, teenagers are more likely to save a life by helping their loved ones seek the professional care they need.

SUMMARY

Trendlines were formed to model the path of the opioid crisis from the time period before intervention (1999-2017) to demonstrate the extent to which initiatives taken after 2017 bent the otherwise increasing curve. In order to further bend the curve, a novel approach was proposed, which utilized teenagers to assist loved ones. This solution was proven by the graphs indicating the degree of the bends. Methods by which teenagers could help were discussed.

Photo Credit: Physician's Briefing