A Bayesian Multistate Model to Understand Racial Disparities in the Transitions between Opioid Use, Misuse, and Fatal Overdoses

Supplementary materials

Supplementary materials including simulations, plots, and any codes used for the work are available at

github.com/mjmoon/bmm-opioid

Selected references

National Center for Health Statistics (2023), *Mortality Multiple Cause Files.*

Substance Abuse and Mental Health Services Administration (2023), *National Survey on Drug Use and Health.*

Sweeting, M.J., de Angelis, D., And Aalen O.O (2005), "Bayesian back-calculation using a multi-state model with application to HIV", *Statistics in Medicine,* 24, 3991-4007.

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Summary

Opioid addiction and overdose are ongoing crisis in the United States. The epidemic has evolved over time affecting different communities at different magnitudes. While trends and patterns in opioid-related mortality are well studied, little is known about the transitions that lead to opioid-induced deaths.

We propose a theoretical framework in understanding the transitions incorporating data from multiple sources. We applied the framework to investigate the disparities between non-Hispanic black and non-Hispanic white US residents. The findings allow better understanding of the affected population at different stages and can lead to better-targeted interventions.

Background

- Opioid addiction and overdose are ongoing crisis in the United States fuelled by misuse of prescription opioids and, more recently, proliferation of synthetic opioids.
- Trends in opioid-induced deaths show disparities between different races.
- We propose a framework to model **the transitions** that lead to opioid-induced deaths and understand the disparities in them.

Objectives

- To provide a theoretical framework for estimating the transition probabilities between prescription opioids use, illicit opioids use, and opioid-induced deaths.
- To identify any disparities in the transition probabilities between non-Hispanic black and non-Hispanic white populations.

Data sources

- Opioid-induced and general mortality counts are extracted from Multiple Causes of Deaths Data **(MCD)** based on death certificates of US residents.
- National Survey on Drug Use and Health **(NSDUH)** provides yearly estimates on the population at different stages of opioid use.

Methods

Scope

- 2015 to 2019 indexed by: $i \in \{1, 2, 3, 4, 5\}$
- 12 or older US residents.
- Non-Hispanic black and non-Hispanic white fitted individually and compared.

Bayesian back-calculation

$$W_i \sim \text{Pois}\left(r_i^{(2)} + p_i^{(1)} \sum_{j=1}^{i-1} r_j^{(1)} \left(1 - p_j^{(1)}\right) (1 - u_j)\right)$$

$$Y_i \sim \text{Pois}\left(p_i^{(2)} \sum_{j=1}^{i-1} E\left(W_j\right) \left(1 - p_j^{(2)}\right) \left(1 - p_j^{(3)}\right) (1 - u_j)\right)$$

$$X_i \sim \text{Pois}\left(p_i^{(3)} \sum_{j=1}^{i-1} E\left(W_j\right) \left(1 - p_j^{(2)}\right) \left(1 - p_j^{(3)}\right) (1 - u_j)\right)$$

- Expected counts are derived from the multistate model.

Smoothing rates over time

$\gamma_i \sim \text{N}\left(\gamma_{i-1}, \sigma_\gamma^2\right), \quad \gamma_i = \log\left(r_i^{(\cdot)}\right)$

$\delta_i \sim \text{N}\left(\delta_{i-1}, \sigma_\delta^2\right), \quad \delta_i = \text{logit}\left(p_i^{(\cdot)}\right)$

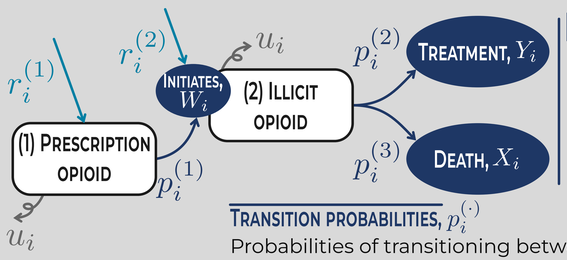
- Smoothed using random walks.

Prior and assumptions

- Weakly informative priors on random walk variances, $\sigma_\cdot^2$, initial rates, $r_0^{(\cdot)}, p_0^{(\cdot)}$, and initial prevalences.
- Known general mortality rates (MCD).

Incidences, $r_i^{(\cdot)}$

Yearly counts of new prescription opioid users (1) and direct initiates of illicit opioids (2).



Observed counts

- W_i, annual illicit opioid initiates (NSDUH)
- Y_i, annual drug treatment initiates (NSDUH)
- X_i, annual opioid-induced deaths (MCD)

Transition probabilities, $p_i^{(\cdot)}$

Probabilities of transitioning between different stages of opioid use in each year.

General mortality rates

Deaths unrelated to opioid misuse.

Opioid use multistate model used to formulate the back-calculation.

Incorporating ratio estimates

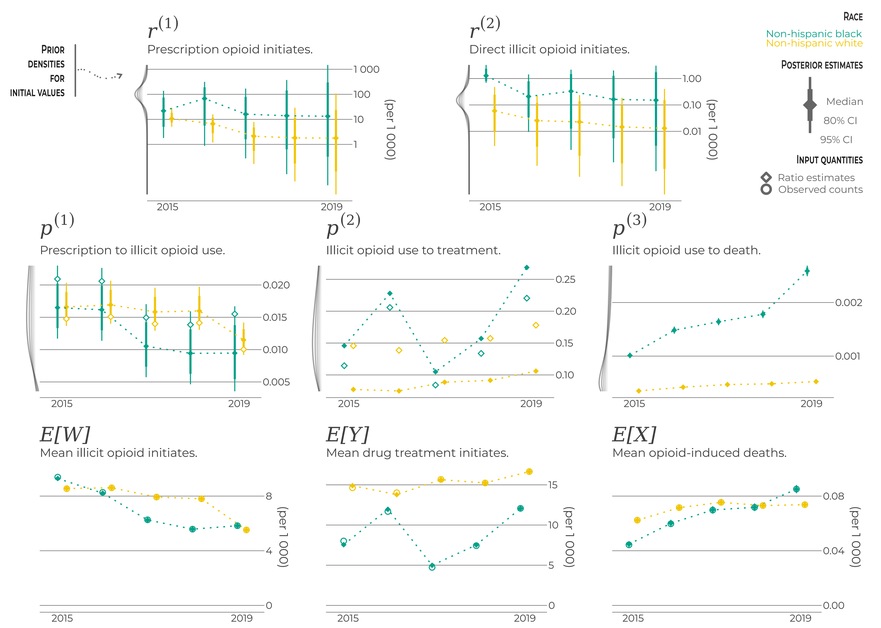
Ratio of prevalence and transition estimates (NSDUH)

$$\frac{s_i^{(m)}}{S_{i-1}^{(m)}} \sim \text{N}\left(p_i^{(m)} + \phi^{(m)}, \frac{p_i^{(m)}\left(1 - p_i^{(m)}\right)}{S_{i-1}^{(m)}}\right), \quad m \in \{1, 2\}$$

Adjusts for biases introduced by the ratio estimator.

Estimates the transition probabilities.

Results



Posterior estimates display different patterns between the two races.

Discussion

- The framework provides a probabilistic understanding of the transitions incorporating data from multiple sources.
- The resulting estimates show that non-Hispanic black opioid users face higher risks of mortality suggesting that they are exposed to different types of opioids and/or different levels of treatments.
- Incorporating more informative priors on the incidences could improve the estimates and computational efficiency.

Future work

- Incorporating demographic attributes including race and age in the framework to provide probabilistic estimates on the discrepancies.
- Capturing opioid users that relapse from treatment in the multistate model while focusing on treatments from specialty facilities.