Quantifying Maternal Mortality Disparities Using Bayesian Implementation Techniques

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***Abstract*—Maternal death rates and racial disparities were explored using publicly available data from the New York City (NYC) Department of Health and Mental Hygiene (DOHMH). Bayesian linear regression was used to quantify maternal mortality disparities between five racial/ethnic groups: Black, White, Asian/Pacific Islander, Latino, and Other. Results suggested that Black women experience the highest average maternal mortality rate within the dataset ranging from the years 2016 to 2021. A time-series forecast model was then created to predict future mortality rates for Black women in NYC and revealed a persistent yet elevated death count until the year 2031. This report casts light on the racial inequities in maternal health outcomes, and the need for targeted public health interventions.**

Keywords—Bayesian modeling, maternal mortality, racial disparities, PyMC, time-series forecasting

I. Introduction

The World Health Organization (WHO) defines maternal death as "the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and the site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes". The United States maternal mortality rate decreased from 18.6 deaths per 100,000 live births in 2023, down from 22.3 in 2022 according to data from the Centers for Disease Control and Prevention (CDC). While the CDC did display a decrease in overall mortality rate, the maternal mortality rate for Black women in 2023 was 50.3 deaths per 100,000 live births, a significantly higher rate than White, Hispanic/Latina and Asian women [1]. Multiple studies have documented the persistent and significant inequity between non-Hispanic Black women and other racial groups, but especially non-Hispanic White women. These disparities can be attributed to a combination of factors: such as quality of healthcare, implicit bias, and systemic racism.

Frequentist methods are commonly used to study these disparities, but this report takes a Bayesian approach. The use of Bayesian methods allows for the incorporation of prior data, and can generate posterior distributions even with limited information, giving us a much more nuanced understanding of maternal mortality trends. This study models maternal mortality trends amongst five racial groups in New York City (NYC), placing a focus on black women due to the disproportionate inequities they face. A time-series forecasting model was also implemented to project future mortality rates amongst pregnant black women, to assess the potential need for public health intervention.

The goal of this study is to build upon already existing research, leveraging Bayesian statistical tools to quantify disparities and highlight the urgency of public health interventions.

II. Description of Data

The data for this study was taken from the NYC Open Data portal, specifically from the Department of Health and Mental Hygiene (DOHMH). The DOHMH is the public health agency of NYC and is responsible for protecting and promoting the health of all New Yorkers by providing critical health services and surveillance.

This dataset was compiled using multiple methods including death certificates, vital records linkage, medical examiner records and hospital discharge data to identify all pregnancy-associated deaths of NYC residents [2].

Variables included in the dataset include year, related (whether the death was pregnancy-related or otherwise), the underlying cause of death, race/ethnicity, borough, and death count. For this study, the data was filtered using Python's pandas library to extract pregnancy-related deaths by race from the years 2016 to 2021.

The dataset was relatively small consisting of only 235 entries. After filtering for race and pregnancy-related deaths, 24 datapoints were used for analysis. There were also very few entries under the "Other" racial/ethnic category, which limited the ability to draw statistically meaningful conclusions for this group.

III. Models Utilized

The models used in this study were implemented using Python's Bayesian statistical library, PyMC. The posterior distributions were then analyzed using the ArviZ package.

A. Bayesian Linear Regression Model

1) A Bayesian linear regression model was created to estimate maternal mortality counts by race over time. The models assumes that the observed number of pregnancy-related deaths per racial group follows a normal distribution modeled directly as the group-specific mean, with no intercept term. All chains converged and posterior diagnostics were within an acceptable range (no divergences, with all r-hat equal to 1). The full model is specified as follows:

$$y_i = N(\mu_i, \sigma) \tag{1}$$

$$\mu_i = \beta_{asian}x_{asian,i} + \beta_{black}x_{black,i} + \beta_{latina}x_{latina,i} + \beta_{other}x_{other,i} + \beta_{white}x_{white,i} \tag{2}$$

$$\beta_{race} = N(0, 10) \tag{3}$$

$$\sigma = HalfNormal(10) \tag{4}$$

To quantify disparities, the posterior difference was calculated between each racial group and black women:

$$\Delta_{Black\ vs.\ race} = \beta_{black} - \beta_{race} \quad (5)$$

These differences were then used to assess whether observed disparities were statistically significant by examining if the 95% highest density intervals (HDIs) excluded zero.

B. Time-Series Forecasting

After results from Bayesian linear regression revealed a high maternal mortality rate amongst Black women, time-series forecasting was implemented to predict future death counts for this demographic. An autoregressive model of order 1 [AR(1)] was used to account for year-to-year dependency. Forecasts were generated for 10 years beyond the observed data range (2022 – 2031). All chains converged and posterior diagnostics were within an acceptable range (no divergences, with all r-hats equal to 1). The full model is specified as follows:

$$y_t = N(\mu_t, \sigma) \quad (1)$$

$$\mu_t = \alpha + \rho \cdot y_{t-1} \quad (2)$$

$$\alpha \sim N(0, 5) \quad (3)$$

$$\rho \sim N(0, 5) \quad (4)$$

$$\sigma = HalfNormal(5) \quad (5)$$

IV. INTERPRETATIONS

Black women had the highest average maternal death count (maternal death count = 10.704) amongst all other racial groups within this dataset. The 2nd highest being Latina women (maternal death count = 7.008). The standard deviation for the two groups, in addition to Whites, and Asians are smaller, with a narrower HDI showing greater certainty for these values.

Women categorized as "Other" had the lowest mean death count (mean death count = 0.957), but this value is not statistically significant due to 95% HDI including zero. This is more than likely due to the low amount of data for women categorized as "Other". The standard deviation for this category is more than twice as big as the other means, emphasizing greater uncertainty due to the small sample size.

	Posterior Mean Summary Statistics		
	Mean	***Standard Deviation***	***95% HDI***
σ	2.649	0.470	(1.859, 3.613)
β_{Black}	10.704	1.113	(8.579, 13.005)
β_{White}	3.290	1.084	(1.089, 5.393)
β_{Asian}	2.966	1.189	(0.644, 5.337)
β_{Latina}	7.088	1.092	(4.946, 9.242)
β_{Other}	0.957	2.540	(-3.965, 6.124)

TABLE I. SUMMARY STATISTICS FOR MATERNAL MORTALITY RATES AMONGST EACH RACIAL/ETHNIC GROUP

As shown in Fig. 1 the posterior distributions for most women are similar in shape, centered, with a relatively narrow HDI. The "Other" category is different in that it is the widest, and overlaps significantly with zero, reflecting a low sample size and high uncertainty. Further reinforcing data shown in Table I.

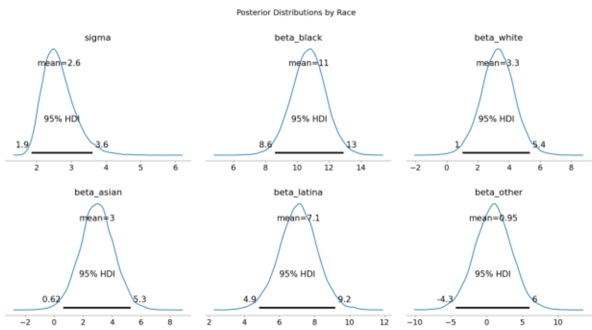

Fig 1. Posterior distributions of each racial group in the dataset.

Disparities were quantified by calculating the posterior difference between the posterior mean of black maternal death count versus every other race in the dataset.

	Posterior Mean Differences		
	Mean	***Standard Deviation***	***95% HDI***
$\beta_{Black\ vs.}\ \beta_{White}$	7.413	1.539	(4.391, 10.371)
$\beta_{Black\ vs.}\ \beta_{Asian}$	7.738	1.628	(4.538, 10.932)
$\beta_{Black\ vs.}\ \beta_{Latina}$	3.616	1.558	(0.499, 6.683)
$\beta_{Black\ vs.}\ \beta_{Other}$	9.746	2.794	(4.403, 15.459)

TABLE II. SUMMARY STATISTICS FOR MATERNAL MORTALITY RATES AMONGST EACH RACIAL/ETHNIC GROUP COMPARED TO BLACK WOMEN

As shown in Table II, the largest difference was observed between Black women and women categorized as "Other" (mean difference = 9.75). But the standard deviation was almost 3, nearly double the standard deviation of all other posterior mean differences. The 95% HDI was wide as well, reflecting significant uncertainty due to a low sample size in the "Other" category. As a result, this comparison should be interpreted with caution.

The next largest difference was between Black and Asian/Pacific Islander women (mean difference = 7.74). This comparison had a narrower HDI and smaller standard deviation, suggesting stronger evidence of disparity between these two racial groups. White and Black women yielded a slightly smaller mean difference (7.41) and standard deviation, reinforcing the well-documented disparity between these two.

The smallest difference was between Black and Latina women, with a mean difference of 3.61 and a similar degree of uncertainty to the posterior mean difference between Black and White women. While the disparity is significantly smaller than other comparisons, it still suggests an elevated risk for Latina women. The outcome indicates a need for this group of women to receive public attention as well, as they are also at a high risk for maternal mortality. All HDIs exclude zero, indicating statistically significant differences between all comparisons.

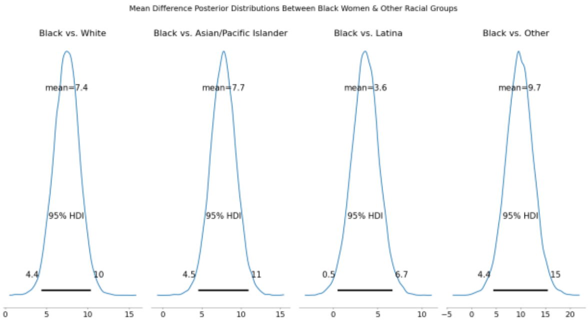

Fig. 2 Posterior distributions of the differences in maternal mortailty rates between black women and other racial/ethnic groups.

Together, these results highlight the disproportionate maternal mortality disparity faced by Black women in NYC, emphasizing the importance for targeted interventions informed by data.

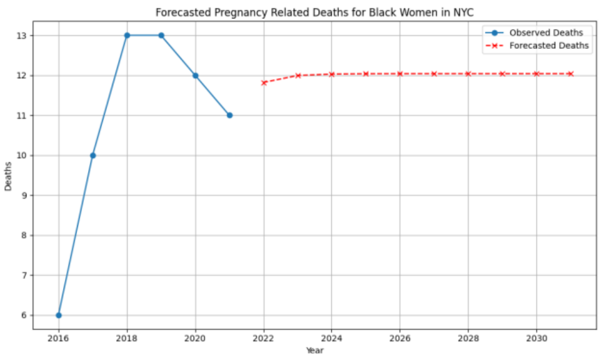

Fig. 3 Time series model line graph forecasting the maternal mortality rate for black women from years 2022 – 2031.

The maternal death count of Black women was then projected using a Bayesian time series forecasting model as seen in Fig. 3. Results suggest a leveling of approximately 12 deaths per year from 2022 to 2031. While that is not as high as the peak values seen in years 2018 and 2019, it suggests that the maternal mortality rate among Black women will likely remain elevated without public health intervention. These findings emphasize the urgent need for targeted and immediate attention to reduce preventable maternal deaths.

V. Future Work

This dataset was narrow in both size and scope, limiting the ability to draw more meaningful conclusions for underrepresented minorities. In the future, I would like to explore a larger and more comprehensive dataset, one that includes individual-level information across multiple cities and states in the US. Adding covariates such as age, salary, community type, and insurance status could provide a much more nuanced understanding of the factors contributing to maternal mortality disparities.

Conclusion

Although the overall maternal mortality rates have slightly improved within the United States, Black women still face a significant and disproportionate disadvantage. Implementing Bayesian frameworks to a maternal mortality dataset helps to provide a much deeper understanding of the existing disparities even with limited data. This study underlines the value of Bayesian modeling in public health and reinforces the need for continued research to reduce inequities in maternal outcomes.

References

[1] World Health Organization, *International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD–10)*, 2008 ed. Geneva, Switzerland: WHO Press, 2009.

[2] New York City Department of Health and Mental Hygiene, “Pregnancy-Associated Mortality,” NYC Open Data, [Online]. Available: https://data.cityofnewyork.us/Health/Pregnancy-Associated-Mortality/27x4-cbi6. [Accessed: Apr. 19, 2025].