

## Introduction

One of the metrics used to indicate a nation's public health and socioeconomic success is maternal mortality. For years research has been conducted and observed this connection between pregnancy and childbirth complications and death rates among women of reproductive age (Zureick-Brown et al., 2013). The passing of a mother during pregnancy or childbirth is a tragedy and shines a light to the gaps in the systems meant to protect society's most vulnerable. Maternal mortality offers a unique understanding of both population health and socioeconomic development (Sajedinejad et al., 2015). A global analysis of various maternal health indicators has revealed an elevated rate of maternal deaths in low-income countries compared to high-income ones. Determining the underlying reasons this gap exists and why there is significant variation across countries can support the development of interventions to mitigate maternal mortality rates.

In this paper, we will be exploring the relationships between six key variables that influence maternal mortality globally. These include the maternal mortality ratio (MMR), the absolute number of maternal deaths, Gross National Income (GNI) per capita, 10 countries with the highest and 10 with the lowest GNI, the percentage of births attended by skilled healthcare workers, and the leading causes of maternal death. With these variables, we were able to create three research questions for our project: *How does the economic status of a country influence how often skilled healthcare workers are in attendance during childbirth?; What are the leading causes of maternal mortality in low-income vs. high-income countries?; How have maternal mortality rates changed over the last two decades?* In the methods section we define the variables and explain their significance in assessing maternal health outcomes. We then move onto describing the datasets we used, sourced from the World Health Organization and the

Institute for Health Metrics and Evaluation, and analyzed patterns across countries and time. We utilized Tableau to visually identify correlations between economic resources, medical support, and regional maternal health outcomes.

Finally, our results section emphasizes long-standing global patterns. Countries with lower GNI per capita have fewer skilled health workers at birth and tend to have both higher MMRs and greater numbers of maternal deaths. Additionally, we found the leading causes of maternal mortality differed by income level. Hemorrhage is the most common cause in low-income countries, while complications such as pre-existing conditions or surgical risks were more prominent in higher-income regions. These findings underline the need for policy solutions tailored not only to national income levels, but also to region-specific barriers in maternal healthcare delivery.

## **Background**

One of the World Health Organization's Sustainable Development Goals is to reduce the global maternal mortality ratio to below 70 per 100,000 live births (WHO, 2025). Most maternal deaths disproportionately occur in lower and low-middle income countries and many of these deaths are preventable. This statistic prompted us to primarily investigate the relationship between GNI and MMR. Major complications like hemorrhage, pre-eclampsia, and infections can occur during childbirth, which is why the presence of skilled health workers during live births is essential in preventing maternal deaths (Nelson et al., 2022).

According to a cross-sectional study examining macrostructural factors as determinants of maternal health and well-being, individual level interventions are not nearly as effective at reducing maternal deaths as population level interventions (Sajedinejad et al., 2015). This suggests that while it is important to examine the role of clinical factors in poor maternal health

outcomes, to gain a more comprehensive picture of structural causes of maternal mortality, policy level interventions must be evaluated. There are many intersecting factors outside of a health system context that influence health outcomes. We hope that by investigating the relationships between economic indicators and health indicators, we can address the reasons why this gap exists and propose strategies to combat them.

## **Data and Methods**

In research for this project, it was found that studying the causes of and differences in maternal mortality across countries requires taking into account multiple variables. As a result, the investigation required the use of five key variables, those being the maternal mortality ratio and the number of maternal deaths, the percentage of skilled health workers present during live births, Gross National Income, and causes of maternal deaths.

The maternal mortality ratio is the number of maternal deaths per 100,000 live births. Essentially, it reflects how many mothers die due to complications of pregnancy or childbirth for every 100,000 babies born alive. This is a vital component for comparison between countries, as larger countries that have more consistent success in their healthcare systems for mothers will likely still see more maternal deaths than smaller countries due to the population differences, and give an inaccurate picture as a result.

This study also recognizes the importance of including the absolute number of maternal deaths as a key variable in our study. MMR, while a valuable indicator, can be misleading when viewing small populations. In such cases, a single maternal death could result in a high MMR for that country due to the limited number of live births to go off of. Moreover, for a larger population country, thousands of maternal deaths can happen, but due to the scale of cases, the MMR could be very low despite the obvious problem of high maternal deaths. By including both

MMR and the number of maternal deaths, this project aims to provide a more balanced and comprehensive analysis.

In aiming to find potential correlating variables, Gross National Income per capita was used as an indicator. GNI is the total amount of money earned by a country's people and businesses, and when viewing this per capita, we are dividing a nation's GNI by its total population to get an idea of the average per-person income of the nation. It can be hypothesized that individuals with higher incomes could have access to resources linked with health and lifestyle. These include the ability to afford better nutrition, medical and health care, and even better living conditions. It's lifestyle differences like this that could be shown through a high-GNI country having lower MMR values than a low-GNI country.

Similarly, the percentage of births that were attended by skilled healthcare workers was looked at due to its potential for correlating with maternal deaths. The presence of skilled healthcare workers, such as doctors and nurses, during labor and delivery is critical in ensuring proper management of health complications that can occur during childbirth. Countries with higher rates of skilled workers in attendance would potentially see lower rates of maternal mortality and fewer deaths overall compared to countries who would operate without skilled medical workers.

Lastly, the causes of maternal death were examined as a final indicator in this study. This analysis allowed for a more in-depth understanding of the underlying factors contributing to maternal mortality in different countries. By identifying the most common and preventable causes, there's room to draw more targeted conclusions and develop informed recommendations. These conclusions are necessary for shaping effective policies that address specific medical, systemic, or infrastructural gaps from country to country.

Each of these variables was looked at by country and by global region at a year-to-year level. The MMR, number of maternal deaths, skilled healthcare workers, and GNI per capita indicators were all gathered by the World Health Organization, an agency of the United Nations, and downloaded from their website. The causes of maternal death variable was collected by the Institute for Health Metrics and Evaluation, an organization based at the University of Washington, and was downloadable for individual countries. This process of downloading individual country datasets and aggregating them into a global one, although time-consuming, would have been possible, however, the size of the dataset was too large to smoothly run in Tableau.

Through this project, we hope to discover relationships between these indicators in relation to Maternal Mortality. By using the GNI and skilled healthcare worker variables, this research aims to discover a possible correlation between the two across countries globally. An increase in GNI could mean there's more available money to be spent on proper healthcare services, and therefore a lower MMR, so a relationship between the two variables is a key point in our study.

Building on this potential correlation and focusing on GNI as a key variable, this study looks to examine the similarities and differences in the leading causes of maternal mortality between high-income and low-income countries. Finding commonalities between countries of similar GNI levels could be valuable in knowing what to allocate monetary and medical resources toward for means of future prevention.

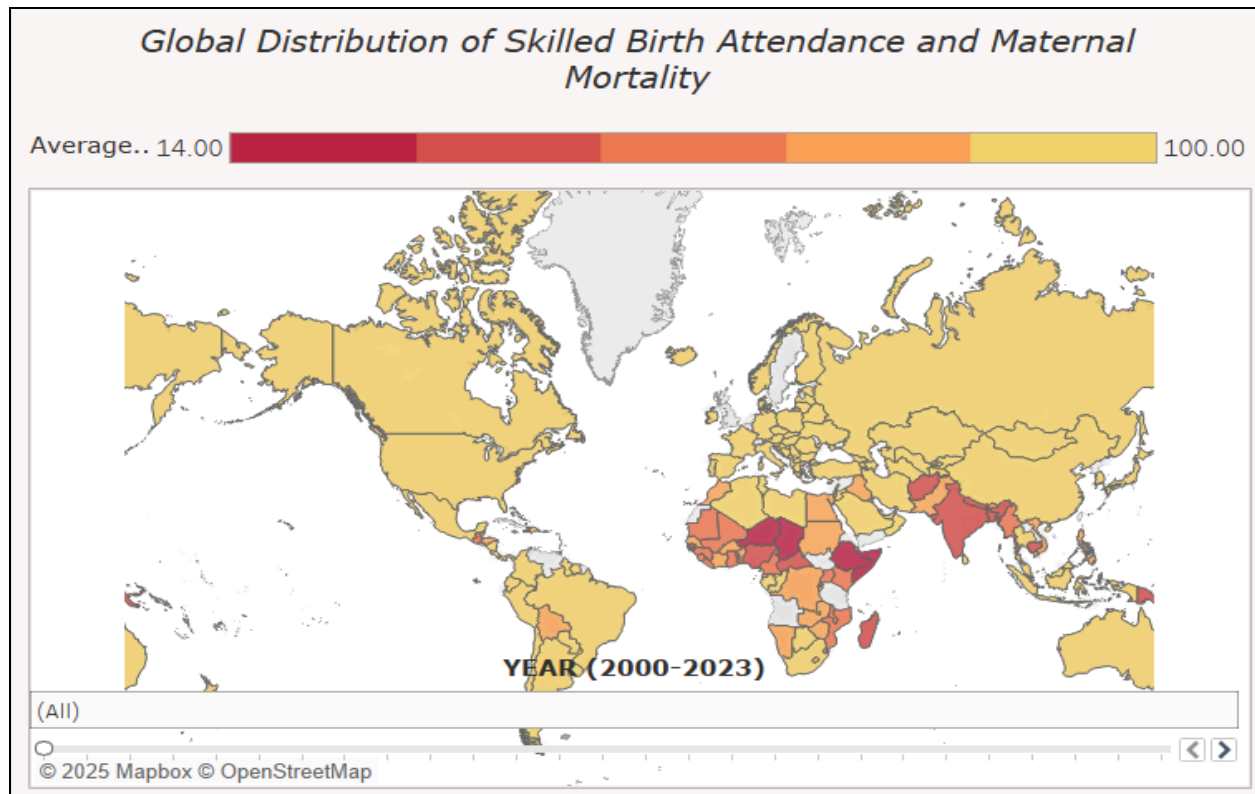
A final means of this study is to uncover how maternal mortality has changed from country to country over the last two decades. An investigation here would show how the issue

has evolved, getting more or less critical depending on the country. For this area, the maternal mortality rate itself, along with the number of maternal deaths, will be the information of use.

With these goals in mind and using the five indicators listed previously, these variables related to maternal death were plotted through Tableau through two distinct dashboards, with distinct models and graphs created from these variables to uncover answers to the pressing research questions.

## **Results**

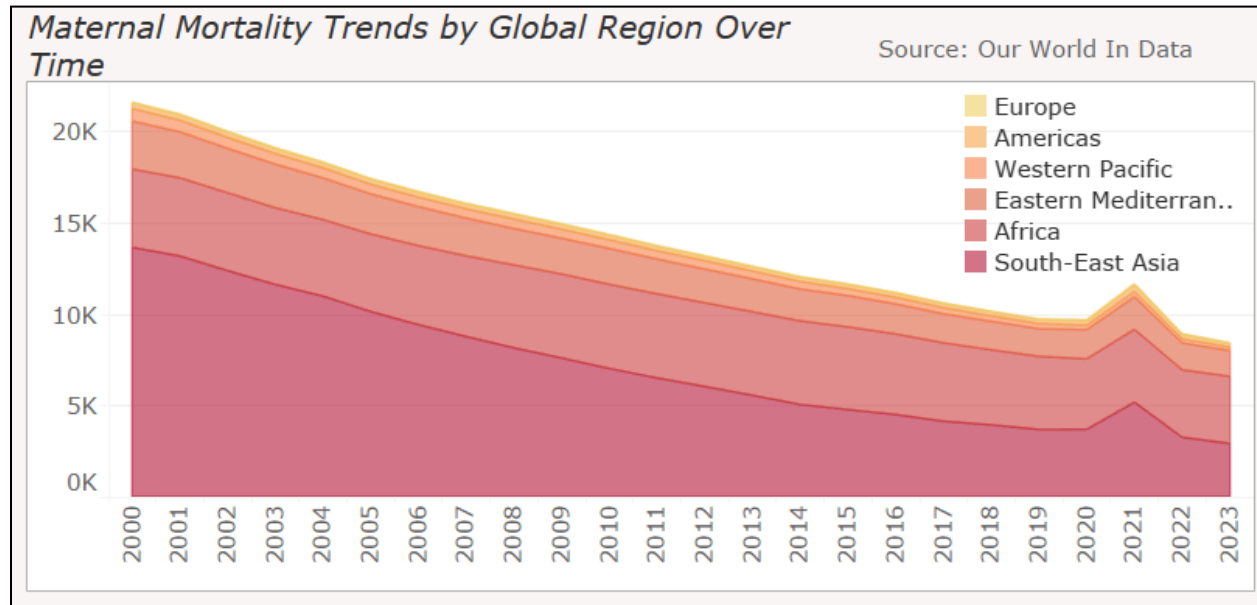
Each of the dashboards created for this project kept a focus on select indicators so as not to become convoluted by too many forms of data. The first dashboard, titled *Maternal Mortality: Global Disparities and Impact of Healthcare Workers (2000 - 2023)*, primarily focuses on the maternal mortality rate and number of deaths, and the percentage of skilled healthcare workers in attendance indicators. To solidify a frame of reference for these variables in relation to each other, below is one such visualization from that dashboard, detailing the relationship between skilled birth attendance and maternal mortality from country to country.



Countries shaded more yellow typically had a higher frequency of births attended by a skilled healthcare worker. Contrasting this, countries shaded more red had a lower frequency of births attended by a skilled healthcare worker. The map is currently set to display the skilled birth attendance variable averaged out across all the years available in the dataset, however, can be filtered by year individually. From the map, it can be seen that on average, skilled healthcare workers are in attendance for births at high rates in many North and South American countries, as well as in many European and Asian countries. What's concerning is the stark difference that can be seen as you move toward the Middle Eastern and African countries, where many countries have fewer than half of their births being attended by health care workers.

These regional issues were investigated further and visualized as well, where it can be seen that the average number of maternal deaths in South-East Asian, African, and Eastern Mediterranean countries experience maternal mortality at rates far higher than other major

regions of the world.

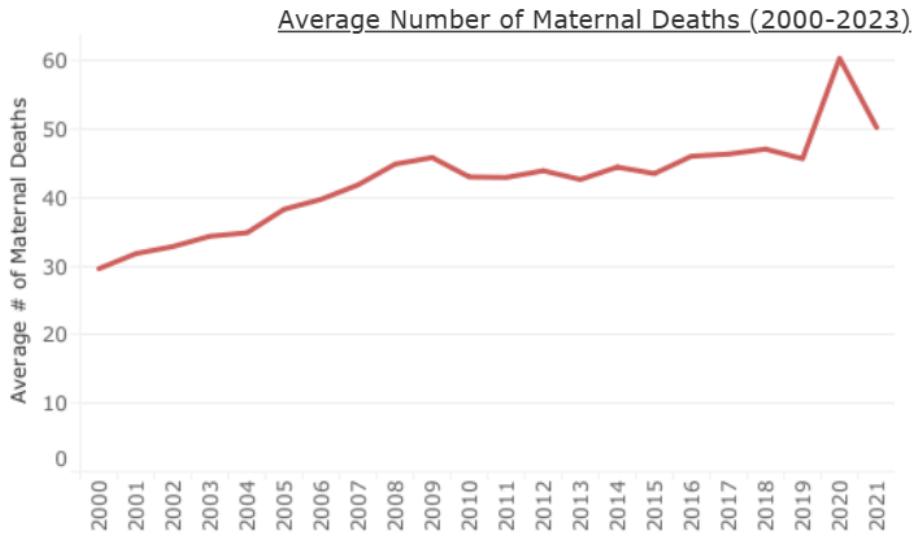


Here the downward trend can be seen in the number of maternal deaths on average over the years globally. An important exception to this downward trend is the sharp spike in 2021, which represents the equivalent of 2,000 additional maternal deaths per country worldwide. This spike in 2021 will be looked at further through other graphs and data in this project later on.

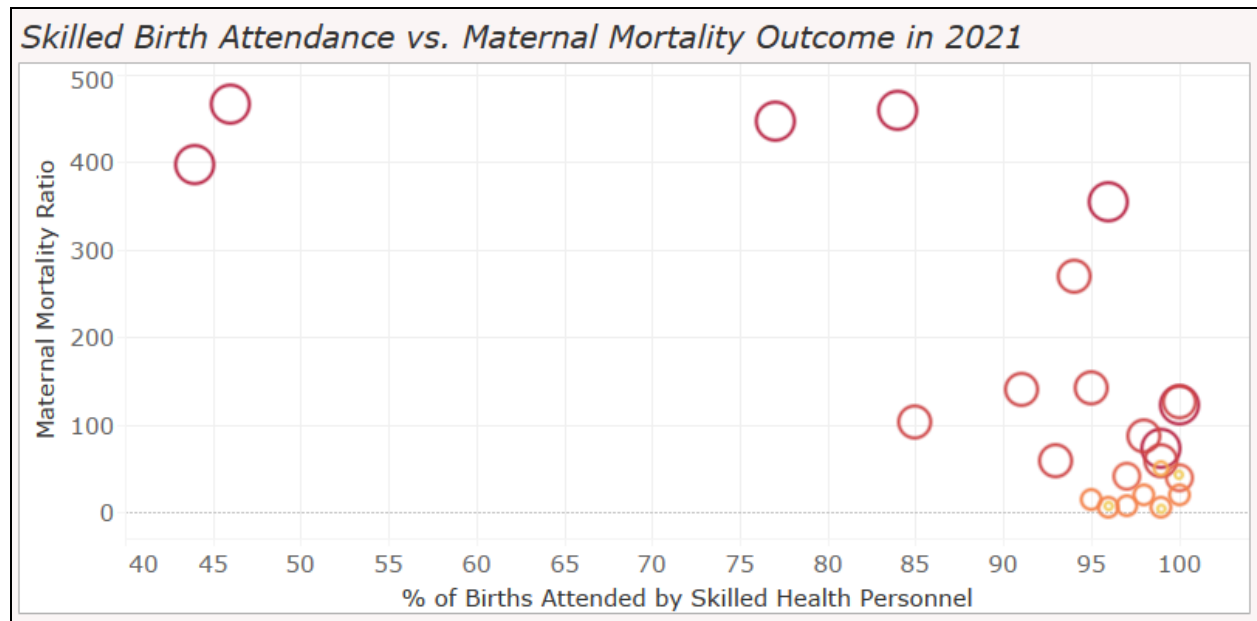
Jumping back to the main map on this dashboard, hovering over each of these countries displays additional year-to-year information as well through the use of a line graph, where it can again be seen that there is a spike in maternal deaths in and around 2021. Pictured is a line graph specific to Canada with one such spike, but similar ones can be seen in many of the other countries as well.



In **Canada**, an average of **99.00%** of births were attended by skilled health personnel, where an average **9** maternal mortality (ratio) occurred *per 100,000 live births*.



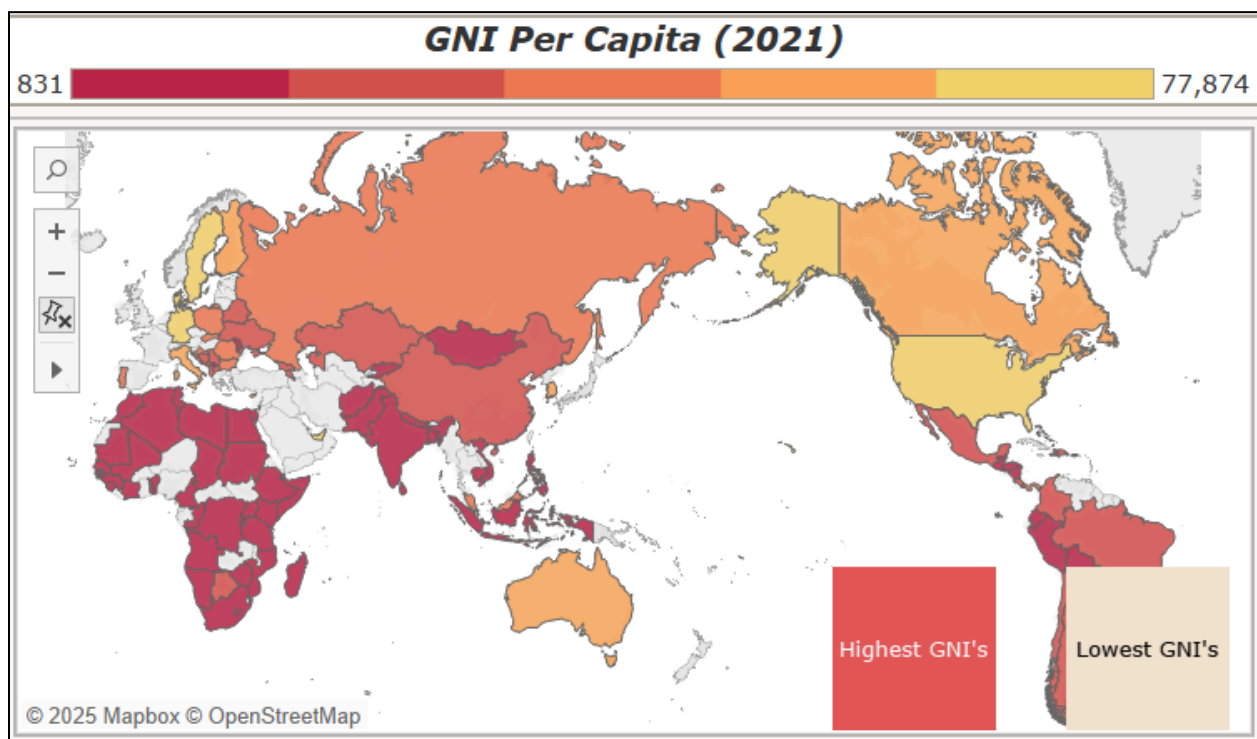
The final visualization from this first dashboard directly compares the skilled birth attendance rate to the maternal mortality ratio. Using the same color coordination system as the area plot graph, this scatterplot is colored depending on the region of the world being represented, with the size of the points changing depending on the region as well for better visual clarity when looking at overlapping points. That scatter plot is shown below.



In this scatterplot graph, the negative correlation between maternal mortality rate and the percentage of births attended by skilled health personnel is evident by the downward trend we see in the graph. As the percentage of skilled workers increases, the maternal mortality ratio tends to decrease. Moreover, the regions with these low MMR and high skilled healthcare worker values tended to be European and American countries, while the regions of high maternal mortality and low skilled healthcare attendance were again composed of those African, Middle Eastern, and South-East Asian countries.

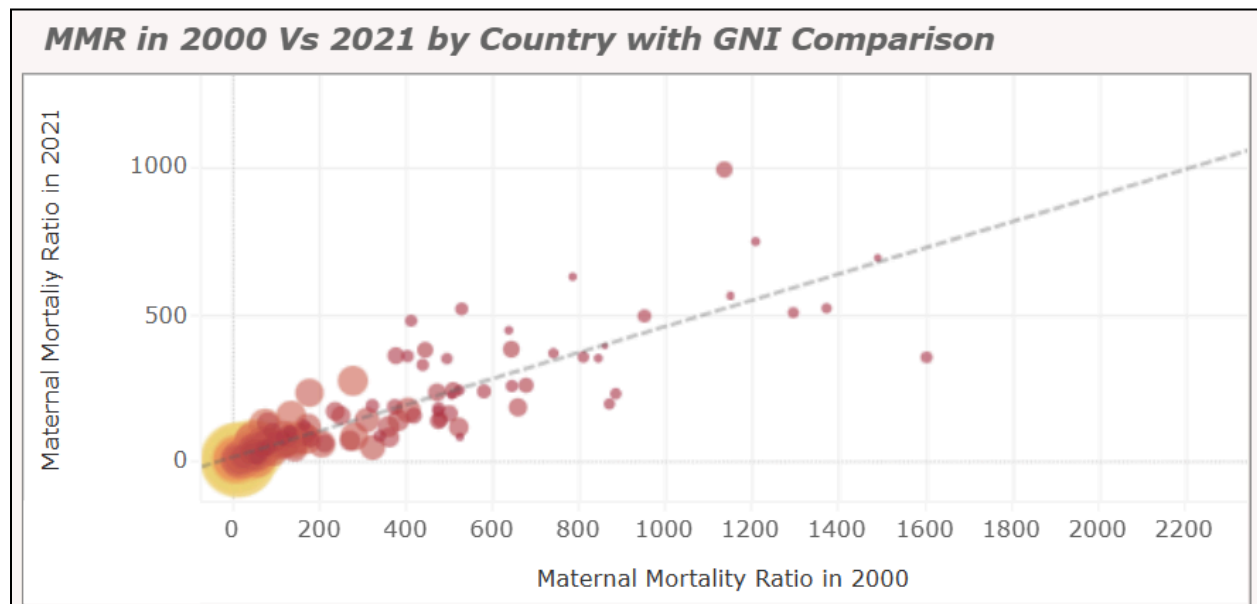
This dashboard effectively highlights the relationship between MMR and having births attended by skilled healthcare workers, while identifying the countries and regions of the world where these indicators are most concerning. It also shows a notable spike in maternal deaths in 2021, an increase that can be noticed across countries globally. This increase gets looked into further through the second dashboard created for this project, which focuses on GNI in relation to causes of maternal death and the maternal mortality ratio over time.

The second dashboard created for this study, titled *Economic Indicators of Risk | GNI as a Predictor of Maternal Mortality*, similarly to the first dashboard, has a central map to it. This map shades countries depending on their average GNI per capita, tinting countries more yellow if they have a higher GNI, and countries being more red when they have a lower GNI. Focusing on the spike noted on the area plot from the previous dashboard, this map uses 2021 GNI data for its shading, allowing for comparisons to be more easily and accurately made between the two visualizations.



While there isn't data available for each and every country specific to 2021, there is a very notable trend that can be pointed out here when comparing the area plot from before to this graph. The same countries with low percentages of skilled healthcare workers and high maternal mortality rates, primarily in the African, Eastern Mediterranean, and South-East Asian regions, also show correspondingly low GNI values.

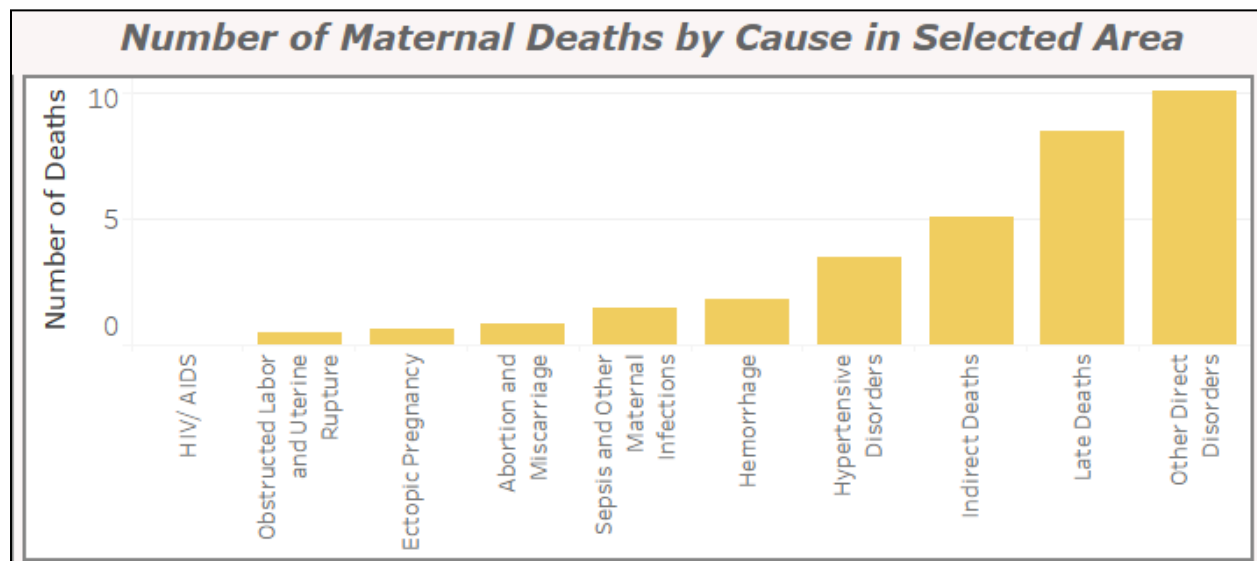
Continuing with investigating the potential correlation between GNI and MMR, while still focusing on the spike found in 2021, this relationship was looked at over time. Below is a scatterplot comparing 2021 MMR values to 2000 MMR values for each country.



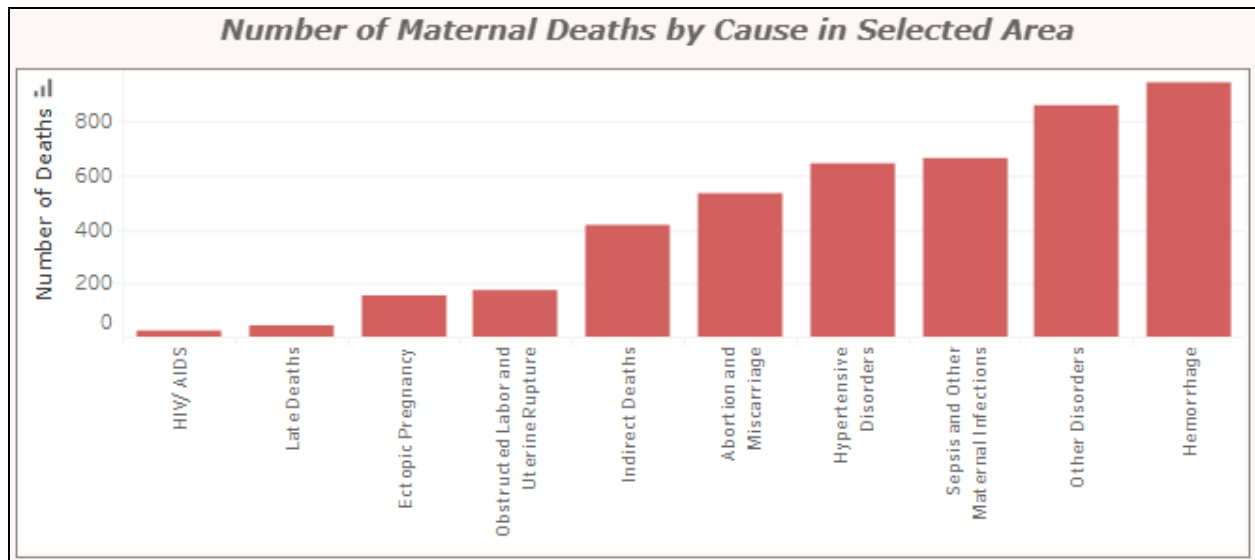
In this model, the points on the graph represent different countries in the dataset, which are colored using the same GNI scale found in the map. The yellow countries have higher average GNI per capita levels while the red countries are lower in GNI per capita. These dots are also sized larger or smaller depending on higher or lower GNI levels respectively for added clarity in viewing. Across the board the MMR of countries in 2000 tended to be much higher than in 2021, showing again that decrease in MMR globally over the years. Almost if not all of the top GNI countries sit toward the lower left corner of the graph, which indicates low MMR values in both 2000 and 2021. Showing the GNI and MMR negative correlation further, as countries decrease in GNI, they tend to increase in MMR.

Looking to attribute causes to these maternal death rates, the final part of this dashboard examines the differences in the causes of maternal deaths for the 10 highest GNI countries, and

compares that to the 10 lowest. This is filterable through the use of a button on the dashboard, which correlates with a graph depicting the number of maternal deaths by either the top 10 or bottom 10 GNI countries, depending on the selection. Shown first is a graph representing the 10 highest GNI countries.



Aside from the other disorders column, which is ultimately a column representing miscellaneous causes of death without a centralizing title, the leading cause of death for many mothers is late deaths. Essentially, a late death is considered a death from old age, which for the countries with high global national incomes, is very common. Compare this to the causes of death for the lowest GNI countries in the following graph.



Late Deaths are among the least common causes of maternal mortality in countries with lower global national income per capita. For these countries, nearly every other cause aside from HIV causes more deaths to mothers than old age does. Before living into their elder years, it's by far most common for a mother to die from a hemorrhage or sepsis.

Another important factor to note is that the number of maternal deaths increases drastically for each cause when going from high GNI to low GNI countries. Where the top causes of maternal mortality in more wealthy countries would result in just over 40 deaths, the top causes in less wealthy countries would result in hundreds of deaths on average.

In summary of both dashboards and their visualizations, there is a long-standing disparity between maternal mortality in countries with a low GNI versus countries with a high GNI. Along with this, countries that had a higher number of skilled health workers present during childbirth tended to have higher GNIs on average and also had a lower maternal mortality rate. Another conclusion was found through the significant differences in the causes of maternal deaths between low-income and high-income countries, with hemorrhage being the leading cause of death in low-income countries, and old age being among the highest for high-income countries.

These visualizations in their totality effectively illustrate the main causes and correlates of maternal mortality, allowing for conclusions like these to be informatively drawn.

## **Conclusions**

Although there has been a steady decrease in global maternal mortality within the last few decades, maternal deaths are occurring at higher rates in low GNI countries. This shows that financing is an important factor in reducing poor health outcomes, to an extent. The presence of skilled healthcare workers during childbirth is significant in reducing maternal mortality and producing better health outcomes.

The general trend shows that countries with a higher GNI have lower maternal mortality, however, there are some outliers in this group. One of the outliers is the United States, highlighting issues happening within high income countries as well. Structural inequities create the conditions for poor health outcomes, regardless of high GNI. Our goal was to center people in our narrative and visualizations since we were primarily working with global and population level data. We hope these findings build on an existing foundation of research and support future investigations that focus on the effects of historical forces such as the International Monetary Fund's structural adjustment programs. These programs were implemented with conditionalities for the borrowing countries that limited funding towards public health services eventually leading to worsening health outcomes. According to an observational review done in 2017, structural adjustment programs were found to have destructive effects on child and maternal health (Thomson et al. 2017). The regions we observed to have consistently high maternal mortality rates overlap with the countries whose operations are governed by these programs.

Several limitations should be acknowledged in this investigation. There are significant differences in the scope and depth of data collection across countries. Standards for data

collection vary regionally and some records may be incomplete due to ongoing conflicts, political instability, or limited surveillance systems. Additionally, privacy laws around healthcare data may offer a limited picture of maternal health outcomes. It is also important to note that the metric for births attended by a skilled healthcare worker is an indicator of system utilization but cannot be used as a measure for the quality of care provided. Findings should be interpreted at a population level and cannot be applied to individual outcomes.



## References

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