Analyzing Geospatial Inequalities Through Survey Data for Improved Prediction of Access to Maternal Healthcare in Sub-Saharan Africa

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Introduction

The purpose of this research is to determine spatially unequal maternal access to healthcare in sub-Saharan Africa in order to decrease regional maternal mortality. To determine geospatial inequalities and how maternal healthcare in this region is affected, several methodologies are executed. Civil registration vital statistics are made publicly available by the UN Maternal Mortality Estimation Inter-Agency Group. Surveillance and special inquiries are conducted to compensate for under-reporting in the population-based surveys that are administered through the sisterhood method. The data that is used is from Leontine Alkema's study [1], where statistics of maternal mortalities, causes of death, and family histories were synthesized to predict maternal mortalities by country. This work will build on previous research by narrowing in on the geospatial access to maternal healthcare facilities in sub-Saharan Africa and will incorporate new methods to implement plans to source more accessible healthcare for expecting mothers in this region as well as recent advances towards inferring preventable complications that increase the maternal mortality rate (MMR) [2].

Human Development Topic

Maternal mortality is one of the leading causes of mortality in developing regions. Between 1988 and 2015, the maternal mortality rate was decreased by 44 percent globally; however, this reduction was not enough to satisfy the Millennium Development Goal of 75 percent. Approximately 800 women die every day due to pregnancy-related complications. It was estimated that in 2015, 63.5 percent of these deaths could have been easily prevented had these women received treatment for these complications [6]. According to the World Health Organization, 75 percent of fatalities related to pregnancies were from the following five major complications: severe bleeding, infections, high blood pressure during pregnancy, complications from delivery, and unsafe abortions [8]. Although this issue prevails throughout the globe, it is most prevalent in developing countries. A census conducted in 2015 [8] determined that 99 percent of annual global deaths related to pregnancy occurred in developing countries. Over half of these mortalities were in sub-Saharan Africa, with a regional rate of 546 maternal deaths for every 100,000 live births [9]. There are several factors that account for this high rate: poverty, distance, lack of services and information, and cultural practices. This rate is higher in urban areas and in poor populations [5]. To help reduce this rate, solving the spatial inequality of access to maternal healthcare in sub-Saharan Africa would allow pregnant women to identify and prevent complications related to pregnancy.

In his book Development as Freedom, Amartya Sen claims that the underlying key to human development is individual freedom. This freedom, he argues, stems from capability. Maternal access to healthcare revolves around this concept; many of the pregnancy-related deaths that occur every day could have been prevented had these women been granted the capability of accessing proper healthcare. The reduction of maternal mortality is addressed in the Sustainable Development Goal (SDG) 3, which is good health and well-being. This goal calls for the global

maternal mortality rate to be reduced to under 70 deaths per 100,000 live births, with each country reducing its rate by at least 66 percent.

Human Development Process

Maternal health heavily depends on accessibility of healthcare services in an area. In sub-Saharan Africa, accessibility of these services is variable depending on the population density of an area, socioeconomic statuses of the average woman, and how educated the people in an area generally are. Wealthier countries generally provide more physical infrastructures to service healthcare for its residents. In some countries, it has been estimated that 75 percent of the health budget is used to fund hospitals near rural areas, whereas the other 25 percent is used to fund primary healthcare centers in more rural areas [5]. The average woman from a rural area has less access to maternal healthcare than the average woman from an urban area. While there is greater proximal access in urban settings, in general, the urban poor have worse maternal healthcare than the typical rural resident. As the average per capita income increases, particularly in urban areas, so does the cost of living. This includes antenatal and postnatal healthcare, which women of low socioeconomic status in these regions cannot afford. In addition, women in urban areas who lack a stable source of income often must work during the regular hours of these hospitals. Further inhibiting their accessibility to proper healthcare is the fact that many of these women cannot afford to lose an hour's pay in a city with a high cost of living [5].

Sub-Saharan Africa accounts for 11 percent of the global population, but disproportionately accounts for many of the world's health burdens. 24 percent of disease cases around the world are from this region, yet it is only home to 3 percent of the world's healthcare workers [4]. In 2010, more than half the maternal deaths in sub-Saharan Africa were due to preventable complications. Hemorrhage took the lead with 34 percent of all maternal deaths, followed by sepsis and infection with 10 percent, and hypertensive disorders with 9 percent. All of these obstetric complications could have been prevented had these women had proper access to healthcare [4]. In developing countries, maternal mortality is 1 in 180 women during their lifetimes and are as low as 1 in 54 women in fragile states. This can be compared to the 1 in 4900 proportion in developed countries [who17]. Most of the countries in sub-Saharan Africa have weak health systems and unstable institutions, often caused by conflict. The rate of maternal mortality is 1,174 per 100,000 live births on the eastern side of the Democratic Republic of the Congo but is only 811 per 100,000 live births on the western side [4]. Stable political systems are correlated with good maternal healthcare, which is lacking throughout the region.

Maternal healthcare is highly dependent on gender equality, female education, and empowerment of women to seek care [4]. In sub-Saharan Africa, women often lack the autonomy to make decisions for themselves, which prevents them from seeking proper assistance when they believe something is wrong. In addition, many of these women are not properly educated and do not know what signs to look for during pregnancy. This prevents them from knowing when to get professional help when a problem is occurring, as well as knowing what is normal and what is not normal during a pregnancy. As a result, many women either seek assistance when it is too late for them to fully recover or do not attempt to get help at all [4].

All of these factors play a role in the spatial inequities seen in maternal healthcare in sub-Saharan

Africa. According to Amartya Sen, human development revolves around expanding the freedoms of the individual. In many parts sub-Saharan Africa, women are not culturally celebrated as equals in society; this results in maternal health needs often being overlooked. Politically, corrupt and conflicted states in this area do not dedicate an adequate amount of funding for women across each nation to receive proper healthcare. Many women are not educated enough to know that they need better access to these centers, and women are often discouraged to reach out to get help. In many villages, strong family networks are highly valued, so pregnancy complications may be solved by driving hours away to receive help. In urban settings, however, this is oftentimes not as prioritized, so these complications (if recognized) are considered to be too costly for some women to afford. As countries become more developed, gender equality is generally more prevalent. This influences more funds to be allocated to female healthcare, including maternal healthcare.

Maternal healthcare is not equally distributed across sub-Saharan Africa. Spatial accessibility to healthcare is favors urban areas due to their higher population densities. A study conducted in 2011 found that expecting mothers that live 2 or more hours away (either walking or driving) have a much higher mortality rate than women within 2 hours of health facilities [7]. Women who have other children at home are also more likely to stay at home, which is directly correlated with maternal mortality. However, due to somewhat limited access in urban areas subject to high demand, there is an unfavorable proportion of healthcare facilities to pregnant women. This drastically increases the costs, which in turn decreases the accessibility to expecting mothers.

The proportion of healthcare facilities to population density should theoretically scale sub-linearly. In Geoff West's book Scale, he writes that data from urban and rural towns and cities has found that gas stations and other necessary services all scale sub-linearly, including healthcare services. As population density increases, the demand for such services increases as a lower rate. However, the current proportion of maternal health services falls short of the optimal number of services that should be available in the region. When a population is spread out, more healthcare centers are necessary for women to have access to these services. When the population has a higher density, one facility is within proximity of many more women.

Geospatial Data Science Methods

There are many geospatial data science methods that are used to collect this data. Surveillance and surveys are used to identify regions that have lower accessibility to health services. Data from the UN Maternal Mortality Estimation Inter-Agency Group is used to determine national morality rates and causes of deaths per area. A Bayesian spatial model was created for almost all of the data sets to determine what was statistically significant. To spatially analyze inequalities in the context of transportation time, geographical characteristics were factored in by grouping the areas into ecological zones. Based on the ecological zones, researchers were then able to estimate how developed each area was and how the travel time would be affected [3].

To determine the effects of spatial inequalities on the mortality rate of mothers in Ghana, researchers used two different rounds of Ghana Demographic and Health Surveys, in 1998 and 2003 [3]. They surveyed women solely on their most recent birth, as nearly 80 percent successive births are conducted in the same manner as the first birth. The surveyed women were then divided until

urban and rural areas and then split into three distinct ecological zones: Savannah, Coastal and Forest zones. Each of these zones have different geographical barriers that affect transportation time as well as different characteristics that determine general socioeconomic statuses of their inhabitants. To determine spatial inequalities in Ghana using this data, researchers conducted a multinomial random area intercept model, which calculated the differences in each area. These differences represented the spatial inequalities in access to maternal healthcare [3].

The results from this particular study found that more than one half (54 percent) of all births in 2003 occurred outside of an institution with the absence of a skilled practitioner. The Savannah ecological zone, which was the least developed, had the greatest amount of poverty, and the least accessibility to healthcare saw over 80 percent of its annual births at home, according to the data. Overtime, the random area intercept model showed that the spatial inequalities increased as urbanization in the Coastal and Forest ecological zones increased. However, the migration of people from rural areas to urban areas directly correlated with the maternal mortality rate, which increased by 60 percent between 1998 and 2003 in urban areas as opposed to 20 percent in rural areas [3]. This suggests that even though physical access to maternal health services plays a role in the maternal mortality rate, poverty and cost of living may be a bigger influence.

Discussion

The maternal mortality rate is unnecessarily high in developing regions, particularly in sub-Saharan Africa. Many of the public health, political and socioeconomic issues in this region are both interconnected and involved in a positive feedback loop; maternal mortality is no exception to this. As political tension increases, the socioeconomic status of many people is negatively affected, and public health declines. Maternal fatalities often send their families into a downward spiral, as father figures or other hired help often must then step in to support their families. Oftentimes, maternal mortalities occur post-birth, and working fathers are unable to devote adequate attention to these newborns to monitor their health, resulting in infant mortalities later on.

Increasing the spatial accessibility of proper maternal healthcare services will increase the amount of women who attend these facilities to give birth. Currently, the women with the least access have the lowest rate of attendance. It is statistically proven that women who have access and choose to attend these facilities have a lower likelihood of dying from pregnancy-related complications than women who do not attend these facilities [7]. Approximately 75 percent of each countries' health budgets are dedicated to urban settings, while only 25 percent are for small family health centers in rural areas [8]. This is consistent with other aspects of human development, as it generates a fractal dimension by heavily concentrating on centers, which represent urban areas, and branching out into smaller areas. However, there is simply not enough access anywhere in the region, regardless of whether the setting is urban or rural. The demand in urban areas drives up the cost of maternal healthcare, and the physical accessibility is too low in rural areas.

There are many different factors that need to be addressed in order to lower the maternal mortality rate. A further investigation could involve finding more effective ways to spend their budget in order to increase the amount of facilities that women have access to in both urban and rural settings. Another area that needs to be addressed is the education of the mothers. In 2003, 74 percent of the total number of surveyed mothers who had no formal education gave birth at home

[3]. In comparison, 68 percent of women who had a secondary education or higher gave birth at a health facility. A research gap that currently exists is data on skilled health practitioners and their spatial distributions. It is currently known that only 3 percent of the world's skilled health practitioners live in sub-Saharan Africa, yet over half of the global pregnancy-related deaths occur here [4]. A question that encapsulate this issue is "why is maternal healthcare overlooked?". Investigating the causes of this issue will be the answer to solving the hundreds of preventable deaths that occur every day.

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