INTRODUCTION

The Meningitis Belt in Africa encompasses the country of Ghana; in this region peaks of infection of bacterial meningitis occur once a year during the dry season. One of the primary vaccines in Ghana, PMC, was modeled in this paper to compare the effects of both vaccination rate and migration rate of the population on the incidence of infection. The graph of incidence of infection in regard to vaccination rate show that there is a negative logarithmic curve between initial peak value and vaccination with no such impact of migration rate on the amplitude of the outbreak. The infection rates at the fifth peaks (5 year mark) of infection showed a negative linear relationship with a lower migration rate having a smaller value at the fifth peak.

Bacterial Meningitis is a bacterial infection of the meninges, or the layers surrounding the brain and the spinal cord. The infection causes the membranes to swell cutting off blood flow and potentially resulting in brain damage or even death. While children under 2 years of age are the most susceptible, adolescents ranging from 0-19 years old have also been found to be the most common victims of the disease (Woods et al.). The bacteria can be found in the nose and respiratory system and is, therefore, transmitted through the air and also through person to person contact. First symptoms of the infection include a high fever, headache, and stiffness of the neck. As the onset of the symptoms is rapid, it is imperative for patients to seek medical treatment immediately. Progression of the infection can result in scarring and can quickly become life threatening if allowed to progress. (Varane et al.). Even those who do not succumb to the illness can be harmed with lifelong impairments, including brain damage and paralysis.

While many of the citizens in the United States have received the meningococcal vaccine and are thus immune to the infection, those in third world nations are still highly susceptible to the infection (Woods et al.). Specifically, the Meningitis Belt across western Africa has been prone to an annual outbreak of the disease correlating with the dry season which begins in mid-February. The dry season decreases the cleanliness and hygiene of the region allowing the bacteria to manifest and spread much more rapidly than it does in the dry season. Additionally, people tend to crowd in the dry season because of the cold weather from the humid region. In this region, there can be up to 1000 cases per 100,000 people per year (Kaburu et al.). The worst epidemic of Meningitis ever seen hit Ghana in 1997, when over 18,000 cases were reported resulting in nearly 1,500 deaths in the population (Varane et al.). The susceptibility of the belt is largely due to the lack of proactive vaccination. There are currently two primary types of vaccines for use in Ghana. The first, a polyvalent meningococcal polysaccharide (PMP), is a cheaper vaccine. However, it only provides immunity for 3 years. Given the annual outbreaks in Ghana, this is not ideal as the person will soon be susceptible once again. Due to cost needs, however, this is the vaccine currently used once an outbreak has occurred. The second vaccine, a polyvalent meningococcal conjugate (PMC), is a more expensive version of the vaccine that guarantees 15 years of immunity; given that you are most susceptible from 0-19 years, this translates to almost complete immunity for all individuals who receive this immunization (Woods et al.). In the United States, the PMC vaccine is what is given as a proactive immunization. However, in Ghana the PM vaccine is almost exclusively used with it being implemented generally 2.3 weeks into an outbreak (Kaburu et al.).

In our model, modeled a Meningitis outbreak in Ghana using a SIR model (Susceptible - Infected - Recovered). This model took into account the potential of migration of people into Ghana as well as a 2015 study of the meningitis belt in Ghana was used. Once the values of the initial peaks at different migration rates, .001 and .003. This figure shows a predominantly inverse linear relationship between vaccination rate and amount of infected individuals at the fifth peak on infection depending on the migration rate into the population. This data shows that a lower migration rate will lead to a lower value at this fifth peak. Figure 2 compares vaccination rates versus the amount of infected individuals at the initial peak of infection for two different migration rates, .001 and .003. This figure shows a predominantly inverse linear relationship between vaccination rate and amount of infected individuals at the fifth peak of infection. This figure also shows that there is an impact on the number of individuals at the fifth peak on infection depending on the migration rate into the population. This data shows that a lower migration rate will lead to a lower value at this fifth peak.

FUTURE DIRECTIONS...

To further understand the most effective vaccination strategy for bacterial meningitis in Ghana, mathematical modeling can be done with other viable vaccines. Specifically, the vaccination efficacy needs to be compared to a cheaper, reactive vaccine for meningitis that provides temporary immunity, PMP. The timing of implementation of PMP as well as the cost effectiveness of PMP could be compared in order to model the most effective and cost efficient way to minimize the meningitis outbreaks in Ghana.

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The five year trajectory of infection in Ghana was modeled on the Big Green Differential Equation Machine to compare the values of the first and fifth peaks of infection based on the rate of vaccination as well as the rate of migration into the population. The equations were derived from the SIR infection model with an alteration to the model to account for the effects of vaccination on the populations of the susceptible, infected, recovered, and vaccinated individuals. The data used for the parameters are from a 2015 study of the meningitis belt in Ghana was used. Once the values of the initial peaks at different vaccination rates were known, the data was entered into excel. The curve of initial peaks for a migration rate with no such impact of migration rate on the amplitude of the outbreak. The infection rate level. While we would still recommend vaccinating as many people as possible, this model suggests that vaccinating just 40% of the population will significantly diminish the infection and that vaccinating over 80% of the population prevents the outbreak almost completely. It appears that at 80% vaccination, the population gains herd immunity meaning that enough people have been vaccinated that the population is almost completely immune to the infection. The migration rate into the population had no effect on amplitude of the initial outbreak, regardless of the vaccination rate. These optimal vaccination rates can be achieved through infant immunization and proactive vaccination of the population. If no proactive distribution of vaccines once an outbreak has already begun. In order to make this a genuine possibility, the availability and cost-accessibility of the PMC would have to be substantially increased, changing the culture around vaccines in Ghana to make them much more normalized.

Since the newborns nature of the attack rate, the infection rate reflected a similar pattern as seen in figure 3. With the addition of the PMC vaccine, fewer members went from the susceptible to infected population and therefore the number of infected individuals went down with each successive outbreak eventually reaching a steady period state in which the infected individuals peaked at the same rate every 365 days. For all runs, the initial peak had the highest value and reached a steady period state around the fifth peak, after five years following an initial outbreak. Figure 1 compares vaccination rates versus amount of infected individuals at the fifth peak for two different migration rates, .001 and .003. This figure shows a predominantly inverse linear relationship between vaccination rate and amount of infected individuals at the fifth peak on infection. This figure also shows that there is an impact on the number of individuals at the fifth peak on infection depending on the migration rate into the population. This data shows that a lower migration rate will lead to a lower value at this fifth peak.

Figure 2 compares vaccination rates versus the amount of infected individuals at the initial peak of infection for two different migration rates as well, .003 and .001. This figure shows that at the first peak, there is no effect on the amount of susceptible in the initial peak from the rate of migration into the population over time. The data for both discovered the optimum rate of vaccination using PMC vaccination in Ghana considering the effects of migration into the population.