Research Proposal

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Introduction

Measles is one of Vaccine-Preventable Diseases (VPDs) that can cause serious disease and complications of disease. Measles is a highly contagious aerial viral infection.Measles is an infection that causes fever, rash, cough, and redness of the eyes. It causes serious complications like encephalitis and can even lead to deafness[1]. Transmission occurs through direct contact with infectious droplets or by airborne spread when an infected person breathes, coughs, or sneezes[2]. About 90% of exposed susceptible individuals have measles. Clinically, the incubation period from exposure to an early symptom indicating the onset of a disease averages 10-12 and 14 days from exposure to the rash. The serious complications caused by measles can occur approximately 30% of measles cases, especially children under 5 years of age or adults [3].

Prior to the development of the measles vaccine in the 1960s, measles was a major cause of morbidity and mortality [4]. Childhood measles infections have become practically universal since the development of safe and effective vaccines in 1963, killing an estimated every year, 2.6 million people are affected. [5]. Despite the availability of vaccines, measles continues to be the leading cause of death in children under the age of five [6]. Measles outbreaks are still occurring in countries where vaccination coverage is low [7]. According to the WHO, global efforts to increase vaccination coverage lowered deaths by 73% in 2018, with Africa accounting for the majority of deaths saved. In 2012, WHO updated the Measles Eradication Initiative with the goal of eradicating measles in at least five of the six regions of the world by 2020 [8].Measles elimination is defined by the World Health Organization as the absence of indigenous measles cases in a certain area for up to 12 months in the presence of high-quality surveillance systems. WHO also requires a national measles vaccination rate of 95% in all districts with two vaccinations per child. Within a year, at least 80% of districts should examine at least one suspicious case and report a nationwide non-measles case rate of at least 2 cases per 100,000 people. [9].

Vaccination is the most effective way to avoid measles. Single-dose measles vaccine became available in South Africa in 1975 as part of the Expanded Programme on Immunization (EPI). Single dose vaccination against measles was started in South Africa in 1975 as part of the Expanded Program on Immunization (EPI). Then, in 1995, a two-dose strategy was introduced in 9 and 18 months, with additional vaccination campaigns every 3-4 years. The two vaccination schedules for measles were altered to 6 months and 12 months in 2016. The first dose at 6 months is intended to prevent the high morbidity and mortality associated with infant illness [10-12]. To prevent the outbreak of measles, the immunity rate of the population is estimated to be about 95% [13]. In 2016, the World Health Organization (WHO) found that only 85% of children worldwide received the first dose of measles vaccine through regular medical services by the first birthday, and 64% received the second dose [14]..

World Health Organization (WHO) strongly encouraged the usage of MMR vaccines to get rid of measles virus with inside the nations enforcing large-scale immunization program[15]. The National Institute Communicable Diseases recommends that all children be vaccinated twice with the MMR (Measles and Mumps Rubella) vaccine. The first vaccination is 12 to 15 months and the second vaccination is 4 to 6 years old. Children can receive a second dose earlier if at least 28 days have passed since the first dose [22].

One of the most important contributors to population heterogeneity is age distribution, which has a significant impact on the timing and outcome of infectious illness transmission and spread. Most crucially, there is a considerable degree of non-uniformity in transmission rates due to the patterns and frequency of individual encounters, which can range dramatically between age groups. Age-related differences in immunity to infections are another possibility. Age-specific mortality and infection-related recovery may be impacted by these variations. Understanding the complexity of disease dynamics and implementing effective disease control and prevention depend on modeling the effect of population age composition on the spread of infectious diseases.

The age structure of epidemiological models has been studied in the literature using both discrete and continuous approaches. Partially differential equation (PDE) models with a continuous age structure are used in these research [23].

Mathematical Model

An application to vaccination strategies for measles

Measles is a disease that can be prevented with a vaccine. When given as part of the measles, mumps, rubella (MMR) vaccine, the measles vaccine usually needs to be given twice. The measles vaccine (MMR1) is normally administered to infants 12 to 15 months of age. It is effective for 85% to 93% of infants at this age. A second dose (MMR2) should be given before the child starts school. Efficacy with 2 doses can reach 97% of MMR [16,17]. World Health Organization recommends that children between 15 and 18 months of age or at admission receive MMR2 for high immunity, either to prevent measles or as a part of admission for better immunity. [18].

In this section, we develop a two-dose vaccination version with two age corporations to observe the vaccination strategies for measles epidemics.

Measles vaccination model

Measles can be prevented with the MMR vaccine. The CDC recommends that children receive the MMR vaccine twice. The first dose is 12 to 15 months old and the second dose is 4 to 6 years old [19]. One dose of MMR vaccine is 93% effective against measles while two doses of MMR vaccine are 97% effective against measles. A small number of vaccinated individuals can get measles, but the disease is milder than unvaccinated individuals [20].

Subdivide the host population into two age groups, taking into account age-specific differences in vaccination schedules, case fatality rates, and contact patterns.

The model structure is shown in the transmission diagram in Figure 1. Two doses of measles vaccine were incorporated: MMR1 for age group 1 (12-15 months), MMR2 for age group 2 (4-6 years). The model is described by the following system of differential equations.

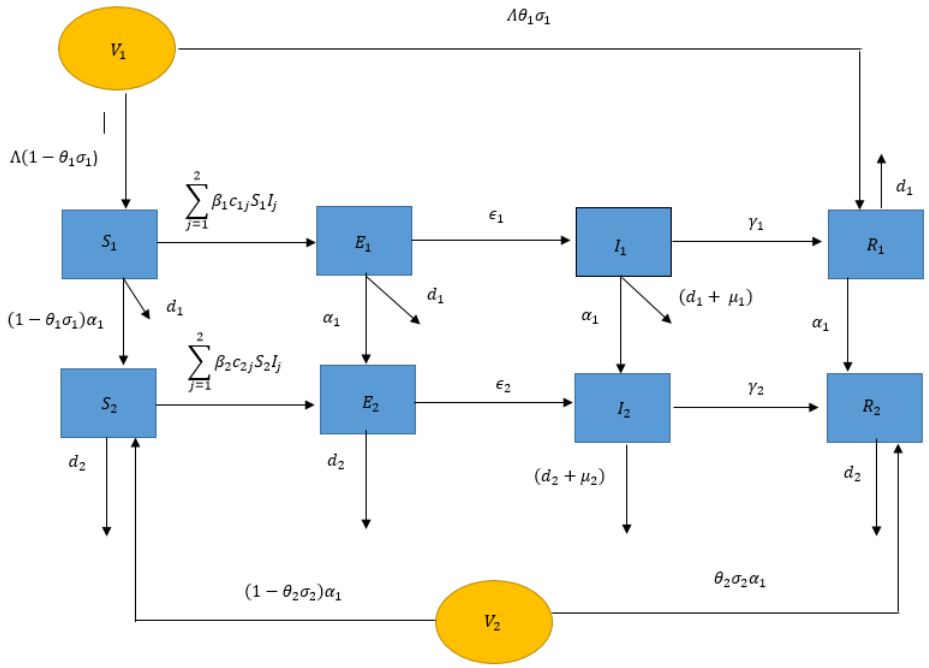

Figure 1: Transfer diagram for a vaccination model with four age groups.

Differential equations for age group 1:

$$\frac{dS_1}{dt} = \Lambda(1-\theta_1\sigma_1)V_1 - \sum_{j=1}^{2}\beta_1 c_{1J} S_1 I_J - (1-\theta_1\sigma_1)\alpha_1 S_1 - d_1 S_1$$
$$\frac{dV_1}{dt} = -(\Lambda(1-\theta_1\sigma_1) + \Lambda\theta_1\sigma_1)V_1$$
$$\frac{dE_1}{dt} = \sum_{j=1}^{2}\beta_1 c_1 J S_1 I_J - (\alpha_1 + d_1 + \epsilon_1)E_1$$
$$\frac{dI_1}{dt} = \epsilon_1 E_1 - (\alpha_1 + \gamma_1)I_1 + (d_1 + \mu_1)I_1$$
$$\frac{dR_1}{dt} = \gamma_1 I_1 + \Lambda\theta_1\sigma_1 V_1 - d_1 R_1$$

Differential equations for age group 2:

$$\frac{dS_2}{dt} = (1-\theta_2\sigma_2)\alpha_1 V_2 + (1-\theta_1\sigma_1)\alpha_1 S_1 - \sum_{j=1}^{2}\beta_2 c_2 J S_2 I_J - d_2 S_2$$
$$\frac{dV_2}{dt} = -((1-\theta_2\sigma_2)\alpha_1 V_2 + \theta_2\sigma_2\alpha_1)V_2$$
$$\frac{dE_2}{dt} = \sum_{j=1}^{2}\beta_2 c_2 J S_2 I_J + \alpha_1 E_1 - (d_2 + \epsilon_2)E_2$$
$$\frac{dI_2}{dt} = \epsilon_1 E_2 + \alpha_1 I_1 - \gamma_2 I_2 + (d_2 + \mu_2)I_2$$
$$\frac{dR_2}{dt} = \gamma_2 I_2 + \theta_2\sigma_2\alpha_1 - \alpha_1 R_1 - d_2 R_2$$

The model parameters are shown in Table 1 along with their description and parameters. Specifically, θ_1 and θ_2 are the vaccination rates of MMR1 and MMR2, respectively, σ_1 and σ_2 are the effects of MMR1 and MMR2, respectively, and $\theta_1\sigma_1$ and $\theta_1\sigma_1$ are the effective ranges of MMR1 and MMR2, respectively. The transmission coefficient β_{kj} between S_k and I_j is decomposed into two factors $\beta_{kj} = c_{kj}$ where β_k k is the probability of transmission for an average contact between a susceptible individual in age group k S_k, and c_{kj} is the mean. Number of contacts between people in age group and people in age group k.Note that c_{kj} and c_{jk} are not the same and the contact matrix (c_{jj}) may not be symmetric because of different ages. Other parameters have the same meaning as the general model[21].

Table 1: Parameters and their estimated values for model

Parameters	Values/Range	Unit	Description	Reference
Λ_k	650	10^3/week	Influx of susceptible	
d_k		week^{-1}	Natural mortality rate of age group k	
α_k		week^{-1}	Aging rate of age group k	
γ_k		week^{-1}	Recovery rate of age group k	
ϵ_k		week^{-1}	Exposed rate of age group	
μ_k			Case fatality rate of age group k	
θ_k			Immunization rate of Measles vaccine	
σ_1			Efficacy of MCV1	
σ_2			Efficacy of MCV2	
β_1			Probability of transmission per contact for age group 1	
β_2			Probability of transmission per contact for age group 2	
c_{kj}		week^{-1}	Average number of contacts from age group j to age group k	

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