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THE COMPARTMENT MODEL WITH INTERVENTION FOR STUNTING PREVALENCE

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Abstract: This study aims to propose a new mathematical model to reduce the prevalence of stunting with interventions given to children aged 0 months to less than 24 months. The interventions provided are how often toddlers are checked for health at integrated health centers denoted H, breastfeeding denoted M, complementary feeding denoted C and immunization denoted Z. This study develops a $BSIR$ compartment model that considers the basic characteristics of stunting transmission and interventions that will be given to toddlers diagnosed with stunting. This mathematical model will include the development of difference and differential equations to represent the transmission of stunting prevalence in real life. Authorities can use this newly formed initial mathematical model as a prevention strategy to reduce the prevalence of stunting. The extension of this study will include the application of the proposed $BSIR$ mathematical model to stunting data in Indonesia.

Keywords: Compartment Model, Difference Equation, Differential Equations, Stunting, Intervention

Abstract: Penelitian ini bertujuan untuk mengusulkan model matematika baru untuk menurunkan prevalensi stunting dengan intervensi yang diberikan pada anak usia 0 bulan hingga kurang dari 24 bulan. Intervensi yang diberikan adalah seberapa sering balita diperiksa kesehatannya di Puskesmas terpadu yang diberi lambang H, ASI diberi lambang M, pemberian makanan pendamping ASI diberi lambang C dan imunisasi diberi lambang Z. Penelitian ini mengembangkan model kompartemen BSIR yang mempertimbangkan ciri-ciri dasar penularan stunting dan intervensi yang akan dilakukan. Diberikan kepada balita yang terdiagnosis stunting. Model matematika ini akan mencakup pengembangan persamaan selisih dan persamaan diferensial untuk merepresentasikan transmisi prevalensi stunting di kehidupan nyata. Model matematika awal yang baru terbentuk ini dapat digunakan oleh pihak berwenang sebagai strategi pencegahan untuk mengurangi prevalensi stunting. Perpanjangan penelitian ini akan mencakup penerapan model matematika BSIR yang diusulkan pada data stunting di Indonesia.

Kata Kunci: Model Kompartemen, Persamaan Perbedaan, Persamaan Diferensial, Stunting, Intervensi

INTRODUCTION

Stunting is a disorder of growth and development of children due to chronic malnutrition and repeated infections, with their length or height below the standard, especially in the first 1000 days of life, abbreviated as (HPK). Children are classified as stunted if their length or height according to their age is lower than the applicable national standard. The condition of failure to thrive in toddlers is caused by a lack of nutritional intake for a long time and repeated infections. Both of these causative factors are influenced by inadequate parenting patterns, especially in the first 1,000 (HPK). Other factors causing stunting are health services and environmental sanitation. Good hygiene affects children's growth and development. Food hygiene and safety can increase the risk of disease (Kementerian Kesehatan RI, 2023). Poor environmental sanitation conditions can allow various bacteria to enter the body and cause various diseases such as diarrhoea, intestinal parasites, fever, malaria, and many other diseases (Suek et al., 2024). Infection can interfere with nutrient absorption, causing malnutrition and stunted growth.

In the economic sector, government losses due to stunting range from 3.057 million or two percent to 13.758 million or nine percent. The large losses incurred due to stunting are due to increased government spending, especially national health insurance related to non-communicable diseases such as heart disease, stroke, diabetes, or kidney failure. This is because when they are adults, children who suffer from stunting are easily obese, so they are susceptible to attacks of non-communicable diseases such as heart disease, stroke, or diabetes. Not to mention the threat of a reduction in intelligence levels by 5 - 11 points (Kementerian Kesehatan RI, 2023). There are so many risks faced due to stunting and the government has also made efforts to reduce the prevalence of stunting. Therefore, the author in this study mathematically describes the problem of stunting and the interventions given to toddlers diagnosed with stunting by modeling it.

An equation, function, or other mathematical rule used to describe an event, system, or process is called a mathematical model. A mathematical model is used to interpret, forecast, or characterize the features or actions of an observable phenomenon. A link between many compartments of a problem expressed as a mathematical equation with multiple of these components acting as variables is called a mathematical model (Indah & Maulana, 2022). The growth in the number of people afflicted with infectious and non-communicable diseases may be understood by mathematical models (Effendi et al., 2015).

One kind of mathematical modeling is compartmental modeling (Effendi et al., 2015; Izzati & Kaaffah, 2020). The box model, often known as the compartment model, is essentially a natural process model (Eriksson, 1971). One model used to simulate the spread of infectious illnesses is the compartmental model. However, the advancement of compartmental models is unbounded at this point. Assuming that rumors are contagious diseases, a mathematical discussion of the dynamics of rumor propagation sheds light on the evolution of compartmental models in the social sciences (Izzati & Kaaffah, 2020). Diabetes mellitus is spreading as a result of the health sector's creation of compartmentalized models for non-communicable illnesses (Ashari et al., 2021; Dodi Suryanto et al., 2017; Effendi et al., 2015; Kaya & Ekawati, 2021). Diabetes Mellitus is a hereditary condition that is also brought on by an unhealthy lifestyle. Stunting is also not a contagious illness. If we compare the practices that lead to stunting to the development of infectious illnesses, we find that the mechanisms of dissemination are the same (Li & Guo, 2019). Examples of such behaviors include bad food and parenting habits, failing to keep an environment tidy, and failing to make it a routine to take the infant to the doctor to monitor its development. It is possible to compare the spread of the three aforementioned habits or behaviors to the spread of contagious illnesses.

To suppress the stunting prevalence figure, the research aims to construct a new model and provide it as a representation of a stunting model that includes certain interventions. It is anticipated that this model will offer a thorough explanation of stunting, enabling the government to address stunting as effectively as possible.

METHOD

This research was conducted using a literature review method, namely by studying several references containing materials related to the problems discussed. The stages in this research include determining the problem, formulating the problem, conducting a literature study, transforming the problem into a mathematical model and conclusions.

A mathematical model is a method of using a mathematical formula to solve a real-world issue. The relationship between the variables in a problem expressed as a mathematical equation with the components as variables is called a mathematical model. Compartmental models are mathematical representations of the transmission of illness. The susceptible infected recovered (SIR) model exemplifies a compartmental model that depicts the process of disease dissemination. Gounane et al. (2021) state that this model divides the population into three compartments; (1) Susceptible (S), which refers to certain compartments that are not currently afflicted but may become so if they come into contact with an affected person; (2) Infected (I), or the specific compartment that is contaminated and has the potential to spread the illness to other people; (3)Recovered

(R), denoting the specific compartment that is afflicted with the illness and then recovers to the point where reinfection is impossible.

It is assumed that the parameters β and γ are constants that are not negative. Where β is the rate of spread and γ is the rate of healing. The differential equation may be used to formulate the SIR model in the following way: first equation $\frac{\partial S}{\partial t} = -\frac{\beta SI}{N}$, expressed as the number of susceptible individuals is the negative of the rate of spread multiplied by the number of susceptible individuals multiplied by the number of infected individuals divided by the total population. Second equation $\frac{\partial I}{\partial t} = \frac{\beta SI}{N} - \gamma I$, expressed as the number of infected individuals is the rate of spread multiplied by the number of susceptible individuals multiplied by the number of infected individuals divided by the total population minus the rate of recovery multiplied by the number of infected individuals. And the third equation $\frac{\partial R}{\partial t} = \gamma I$, expressed as the number of individuals who recover from an infection is the rate of recovery multiplied by the number of infected individuals.

The model above assumes that the population average for infecting new people is $\frac{\beta}{N}$ per unit of time, where N is the entire population size, $N = S + I + R$ (Yong & Samat, 2018). Partitions of the infection population will either enter or exit infection at a γI rate per unit of time. The only way the population grows is through disease-related fatalities.

The SIR model above will be used as a reference in building a stunting prevalence model with intervention. In reducing the stunting prevalence rate, the government's efforts are made through two interventions; specific nutritional interventions to address direct causes and sensitive nutritional interventions to address indirect causes. These specific interventions consist of three parts given to new mothers, during pregnancy, and to toddlers. Specific interventions given to toddlers include monitoring toddler growth at the Integrated Healthcare Center or Public Health Center, providing breast milk, providing complementary foods for breast milk, and immunization. Sensitive interventions are various development activities outside the health sector (Rusliani et al., 2022). In this study, the author focuses on specific interventions given to children aged 0 months to less than two years.

RESULTS AND DISCUSSION

This section is divided into two sections; the results section, where the author will explain the findings of this study, and the discussion section, where the researcher will describe the findings that have been obtained.

Results

The model formed in this study is a stunting model for children aged 0 months to less than two years who are diagnosed with stunting and then specific interventions are carried out so that stunting in toddlers disappears. This model is formed using model compartments, namely; babies, stunting (less than 2 years), health centers, and breast milk - complementary foods for breast milk, immunity, and recovery. For Health Centers, Breast Milk, Complementary Food for Breast Milk, and Immunization are combined by replacing the notation with I, then this model is named the BSIR Model. The model can be shown in the figure below:

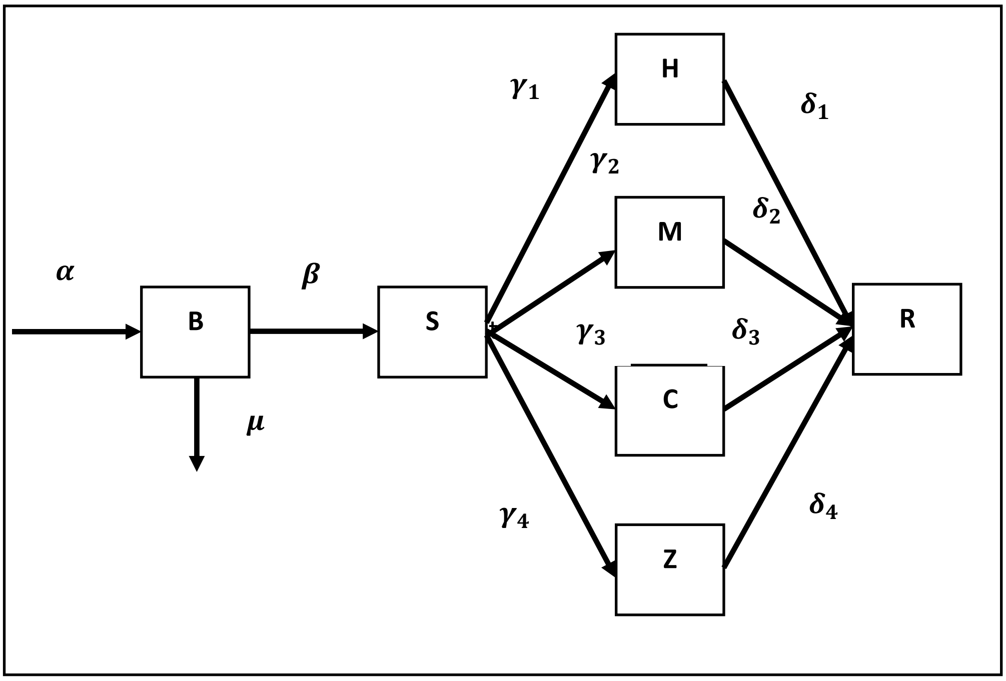

Figure 1. The Model Diagram

From the diagram above, the differential equation is obtained as follows:

$$\frac{\partial B}{\partial t} = \alpha - B\mu - B\beta S \qquad (1.1)$$

$$\frac{\partial S}{\partial t} = B\beta S - S\gamma_1 H - S\gamma_2 M - S\gamma_3 C - S\gamma_4 Z \qquad (1.2)$$

$$\frac{\partial H}{\partial t} = S\gamma_1 H - H\delta_1 R \qquad (1.3)$$

$$\frac{\partial M}{\partial t} = S\gamma_2 M - M\delta_2 R \qquad (1.4)$$
$$\frac{\partial C}{\partial t} = S\gamma_3 C - C\delta_3 R \qquad (1.5)$$
$$\frac{\partial Z}{\partial t} = S\gamma_4 Z - Z\delta_4 R \qquad (1.6)$$
$$\frac{\partial R}{\partial t} = H\delta_1 R + M\delta_2 R + C\delta_3 R + Z\delta_4 R \qquad (1.7)$$

with the initial conditions $B(0) > 0, S(0) > 0, H(0) > 0, M(0) > 0, C(0) > 0, Z(0) > 0$, and $R(0) > 0$.

Discussion

The mathematical model presented is the prevalence of stunting in children under 2 years of age that can be cured with specific interventions given so that they will not contract infectious diseases due to the impact of stunting (De Wilde et al., 2020). This happens because toddlers who are more than or equal to 2 years of age cannot be cured of stunting (Kementerian Kesehatan RI, 2023). The compartments, or populations, formed in this model are; First, group of toddlers but vulnerable to stunting, the age range starts from 0 months to less than 2 years. The number of individuals in this group at time t is denoted by $B(t)$. Second, a group of toddlers aged 0 months to less than 2 years who are diagnosed with stunting. The number of individuals in this group at time t is denoted by $S(t)$. Third, a group of toddlers aged 0 months to less than 2 years who are given intervention, the activeness of parents to the health center to check their child's growth and development. The number of individuals in this group at time t is denoted by $H(t)$. Fourt, a group of toddlers aged 0 months to less than 2 years who are given an intervention by providing breast milk. The number of individuals in this group at time t is denoted by $M(t)$. Fifth, A group of toddlers aged 6 months to less than 2 years who are given intervention, by providing complementary foods to breast milk. The number of individuals in this group at time t is denoted as $C(t)$. Sixth, a group of toddlers aged 0 months to less than 2 years were given intervention by administering immunization. The number of individuals in this group at time t is denoted as $Z(t)$. And seventh, group of toddlers aged 0 months to less than 2 years who have been free from stunting $R(t)$. From the seven groups or compartments, the total population (N) is;

$$N = B(t) + S(t) + H(t) + M(t) + C(t) + Z(t) + R(t)$$

The parameters used in the formation of the SIR compartment model with interventions are as follows: α represents the infant birth rate, μ is expressed as the infant mortality rate, β is the prevalence rate of stunting aged less than 2 years, γ_1 is the rate of intervention by increasing of Integrated Healthcare Center, γ_2 is the rate of intervention with exclusive breastfeeding, γ_3 is the rate of intervention with complementary feeding, γ_4 is the rate of intervention with immunization, δ_1 is the stunting recovery rate from the Integrated Healthcare Center improvement intervention, δ_2 is the stunting recovery rate from the exclusive breastfeeding intervention, δ_3 is the stunting recovery rate from the complementary feeding intervention dan δ_4 is the stunting recovery rate from the immunization intervention.

All parameters $\alpha, \mu, \beta, \gamma_1, \gamma_2, \gamma_3, \gamma_4, \delta_1, \delta_2, \delta_3$, dan δ_4 are assumed to be non-negative constants. An additional assumption from the development of the compartment model is that the baby population B will increase due to the birth rate and decrease due to the death rate. S is the number of stunted babies who are less than or equal to 2 years and the number of babies who have recovered will decrease due to death. The following presumptions are used in the formulation of the model; In the compartment model, the population size is constant. Births and deaths have an impact on the population. And every newborn will instantly become a member of the infant population.

From Figure 1 above, transmission from one compartment to another can be explained as follows: In equation one, the rate of children aged 0 months to less than 24 months who are vulnerable to stunting is the rate of births of babies who enter the population of children aged 0 months to less than 24 months who are vulnerable. Stunting is reduced by the death rate of children aged 0 months to less than 24 months and then reduced by the stunting prevalence rate of children aged 0 months to less than 24 months, as mathematically written in equation 1.1.

The rate of children aged 0 months to less than 24 months who are diagnosed with stunting is the prevalence rate of stunting in children aged 0 months to less than 24 months minus the death rate of children aged 0 months to less than 24 months minus the rate of intervention visits to health centers or children's health posts age 0 months to less than 24 months minus the intervention rate of providing breast milk for children aged 0 months to less than 24 months minus the intervention rate of providing complementary foods for children aged 0 months to less than 24 months minus the intervention rate of providing immunization for children aged 0 months to less than 24 months is in equation 1.2.

In the third equation, the rate of children aged 0 months to less than 24 months who visit the health center or integrated health post to check their growth and development is the rate of intervention visits for children aged 0 months to less than 24 months minus the rate of stunting recovery from intervention visits to health centers or integrated health posts for children aged 0 months to less than 24 months are found in equation 1.3. The rate of children aged 0 months to less than 24 months who are given breast milk is the rate of intervention in giving breast milk to children aged 0 months to less than 24 months minus the rate of recovery from stunting with the intervention in giving breast milk as found in equation 1.4.

Further, the rate of children aged 0 months to less than 24 months who are given complementary foods is the rate of intervention for providing complementary foods for children aged 0 months to less than 24 months minus the rate of recovery from stunting with the intervention of providing complementary foods for children aged 0 months to less than 24 months, found in equation 1.5.

Likewise in the sixth equation, the rate of children aged 0 months to less than 24 months who were given immunization is the rate of intervention for providing immunization to children aged 0 months to less than 24 months minus the rate of recovery from stunting with intervention for providing immunization to children aged 0 months to less than 24 months. This can be found in equation 1.6. And last, the rate of children aged 0 months to less than 24 months who are free from stunting prevalence is the rate of stunting recovery after visiting health centers or integrated health posts plus the rate of stunting recovery with interventions of providing breast milk plus the rate of stunting recovery with interventions of providing complementary foods plus the rate of stunting recovery with immunization interventions for all children aged 0 months to less than 24 months, as found in equation 1.7.

CONCLUSION

The conclusion in this study is seven equations are obtained that will be implemented to reduce the prevalence of stunting. The first equation calculates the rate of children aged 0 months to less than 24 months who are susceptible to stunting; the second equation calculates the rate of children aged 0 months to less than 24 months who are diagnosed with stunting; and the third equation calculates the rate of children aged 0 months to less than 24 months who visit health centers or integrated health posts to check their growth and development. The fourth equation is the rate of children aged 0 months to less than 24 months who are given breast milk. The fifth equation calculates the rate of children aged 0 months to less than 24 months who are given complementary foods. The sixth equation is to calculate the rate of children aged 0 months to less than 24 months who are given immunization and the seventh equation is to calculate the rate of children aged 0 months to less than 24 months who are free from the prevalence of stunting. For further research, the author will calculate the equilibrium point, equilibrium stability point and basic reproduction number. Furthermore, conducting simulations on this compartment model using stunting prevalence data is necessary so that the validity and accuracy of the model can be known.

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