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The BS$_t$ID Mathematical Model for Prevalence of Stunting

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Abstract

This study aims to propose a new mathematical model for transmitting stunting prevalence in children. This study develops an initial model of stunting prevalence, namely the B.S_tID compartment model, which considers important characteristics of stunting transmission. In this study, the resulting model is $\frac{\partial B}{\partial t} = \alpha - B\beta_t S_t - B\mu, \frac{\partial S_t}{\partial t} = B\beta_t S_t - S_t\gamma D$ dan $\frac{\partial D}{\partial t} = S_t\gamma - D\mu.$ This mathematical model will include the development of difference and differential equations to represent the transmission of stunting prevalence in real life, such as being able to describe the development of stunting in the future. Authorities can use this new initial mathematical model as a prevention strategy to reduce stunting prevalence. The extension of this study will include the application of the proposed BStID mathematical model to stunting data in Indonesia.

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

INTRODUCTION

Children are a valuable asset for a country's development and better future. Quality and superior human resources will create a developed and strong country in various fields; therefore, child protection must be carried out so children can grow and develop properly. One indicator of children's growing and developing well is their nutritional status. The nutritional status of children depends on the amount of food consumed; for this reason, it is necessary to have the ability to fulfill this.

The National Medium Term Development Plan (RPJMN) of 2020 – 2024 is an essential stage in the 2005-2025 National Long Term Development Plan (RPJPN) because it will affect the achievement of development targets in the RPJPN. At that time, Indonesia's per capita income was estimated to have entered the upper middle-income countries with better infrastructure, quality human resources, public services, and people's welfare. Also, by the direction of the 2005-2025 RPJPN, the medium-term development goals for 2020-2024 are to realize an Indonesian society that is independent, advanced, just, and prosperous through accelerated development in various fields with an emphasis on building solid infrastructure an economic structure based on excellence competitive in various fields supported by quality and competitive human resources.

However, the reality is that the goals expected by the Indonesian government are not met. According to WHO data, in 2020, 148.1 million, or 22.3 percent of children under 5, experienced stunting worldwide. Based on the same data, Indonesian children, who are Indonesia's human resources, in 2020 had a stunting.

Prevalence of 31 percent, making Indonesia the second country with the highest stunting rate in Southeast Asia. The highest country is East Leste with a percentage of 45.16 percent; the third country is Laos with 30.2 percent, followed by Cambodia at 29.9 percent, the Philippines at 28.8 percent, Myanmar at 24.1 percent, Malaysia at 21.9 percent, Vietnam at 19.3 percent, Brunei Darussalam at 12.7 percent, Thailand at 11.8 percent. The last country is Singapore at 3 percent.

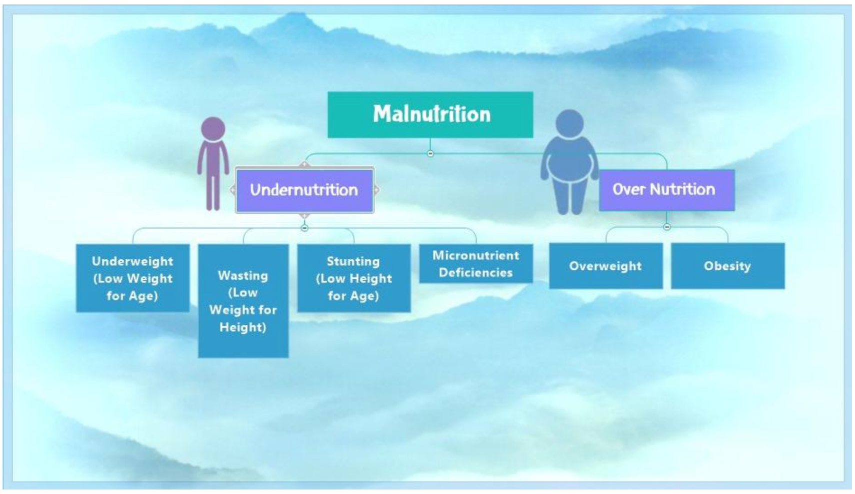

Figure 1 Malnutrition category

Stunting is a disorder of the growth and development of children due to chronic malnutrition and recurrent infections, characterized by the length or height being below standard, especially in the first 1,000 days of life. Stunting affects brain development, so the child's intelligence level is not optimal. This has the risk of reducing productivity as an adult. Stunting also makes children more susceptible to disease. Stunted children are at higher risk of suffering from chronic diseases in adulthood. Stunting and various forms of nutritional problems are estimated to contribute to the loss of 2 % - 3% of the Gross Domestic Product (GDP) each year. [1], [2], [3], [4].

Literature review research conducted by the author found that research on stunting only discusses the factors causing stunting. For example, Log-binomial regression estimates relative risk (RR) with a 95% confidence interval. [5]. The logistic regression method determines the factors causing stunting in a country. The research design used is cross-sectional, which measures several variables at once [6], [7], [8], [9], [10], [11], [12], [13]. So, it can be concluded that no researchers have modeled stunting.

Because of the many risks that the government will face due to stunting, there is no stunting model that has been created. So, the author tries to mathematically describe the problem of stunting by modeling it. A mathematical model represents a phenomenon, system, or process in the form of equations, functions, or other mathematical rules. The purpose of a mathematical model is to understand, predict, or describe the behavior or characteristics of an observed phenomenon. A mathematical model is a relationship between several compartments in a problem and is formulated in a mathematical equation containing several of these components as variables. [14]. In other literature, a mathematical model is the relationship between components in a problem formulated in a mathematical equation containing the components as variables.

The process of obtaining a model of a problem is called mathematical modeling. [15].

Mathematical models can be used in various fields, including physics, biology, economics, engineering, and computer science. In this context, they analyze and understand the relationships between the variables involved and predict outcomes or changes in the system. Also, mathematical models can help us understand the development of the number of infectious and non-communicable disease sufferers. [16]. Compartmental models are a type of mathematical modeling. [16], [17].

The compartment model is also called the box model, a natural process model. [18]. The compartmental model is a model of the spread of infectious diseases. However, the development of compartmental models is beyond limits at this time. The development of compartmental models in the social field can be seen from the dynamics of the spread of rumors, which can be discussed from a mathematical perspective by assuming rumors are a disease that can spread. [17]. The development of compartmental models in the health sector for non-communicable diseases is the spread of diabetes mellitus. Diabetes Mellitus is a genetic disease and is also caused by an unhealthy lifestyle. [16], [19], [20], [21], [22]. Likewise, stunting is not an infectious disease. If we compare the habits that cause stunting, the spread mechanism is the same as the spread of contagious diseases. [23]. These include habits or behaviors involving poor eating and parenting patterns for babies, habits that do not maintain a clean environment, and behaviors that do not make it a habit to take the baby to health care to see its growth and development. The three habits above are behaviors or habits whose spread can be the same as the spread of infectious diseases.

This research aims to build a new compartment model and introduce it as a representation of the stunting prevalence model. This compartmental model is expected to comprehensively describe stunting so the government can optimally overcome it.

METHODS

The first step in modeling stunting prevention is to build a model using a system of differential equations. A system of differential equations contains the derivatives of one or more dependent variables on one or more independent variables. [14], [24], [25]. The following is the general form of a system of first-order equations,

$$\frac{dx_1}{dt} = f_1(t, x_1, x_2, \dots, x_n) \qquad (1.1)$$

$$\frac{dx_2}{dt} = f_2(t, x_1, x_2, \dots, x_n) \qquad (1.2)$$

$$\frac{dx_n}{dt} = f_n(t, x_1, x_2, \dots, x_n) \qquad (1.3)$$

Where $x_1, x_2, \dots, x_n$ are independent variables, and *t* is the dependent variable, then $x_1 = x_1(t),\ x_2 = x_2(t), \dots, x_n = x_n(t)$, $\frac{dx_1}{dt}$ is a derivative of the function x_1 on *t* and f_1 is a function that depends on the variables $x_1, x_2, \dots, x_n$ and *t*.

A Mathematical model is an approach to a real problem with a mathematical formula. A mathematical model is the relationship between components in a problem, formulated in a mathematical equation containing the components as variables. Mathematical models that describe the spread of disease are known as compartmental models. One example of a compartmental model that describes the process of disease spread is the susceptible infected recovered SIR model. According to Kermack and McKendrick (1927), in this model, the population is divided into three compartments, namely:

1. Susceptible (S), namely individual compartments that do not yet have the disease but have the potential to develop the disease after coming into contact with the infected.
2. Infected (I), namely the individual compartment that is infected and can transmit the disease to other individuals,
3. Recovered (R), the individual compartment attacked by the disease, becomes cured and cannot be re-infected.

The parameters β and γ are assumed to be non-negative constants. Parameters are estimated numerically using the obtained data. [26], [27]. The stunting prevalence data used is secondary data. This data was obtained from the Ministry of Health of the Republic of Indonesia, the West Sumatra Health Office, and the Central Statistics Agency. The SIR model can be formulated in the differential equation as follows:

$$\frac{\partial S}{\partial t} = -\frac{\beta SI}{N} \quad (1.4)$$

$$\frac{\partial I}{\partial t} = \frac{\beta SI}{N} - \gamma I \quad (1.5)$$

$$\frac{\partial R}{\partial t} = \gamma I \quad (1.6)$$

The assumption given in the model above is that the population average for transmitting the infection to others is $\frac{\beta}{N}$ Per unit time, where N represents the total population size, $N = S + I + R$ [28]. Infection population compartments will flow or leave infection at a γI Rate per unit of time. There is no increase in population except through deaths from disease.

RESULTS AND DISCUSSION

In this study, researchers focused on the mathematical model of stunting prevalence without intervention, meaning it is not influenced biologically, for example breastfeeding, complete immunization and clean sanitation environment. This compartment model was chosen to describe stunting because the compartments represent the variables and parameters that influence stunting. The process of movement between compartments describes movement between defined populations.

The model developed is newborn (0 months) – stunting (0 months to 59 months) – disease infection (above 59 months) called the model (B.S_tD). This compartment model is a stunting model in children aged 0 months to 59 months without intervention so that at the age of more than 59 months, the toddler will be infected with disease, cognitive decline, and abnormal height. This happens because the optimal stunting healing occurs during the first 1000 days of life (Ministry of Health).

So, the compartments formed consist of three, namely newborns (B) and stunted toddlers aged 0 months to 59 months. (S_t). And stunted toddlers aged over 59 months who are affected by stunting (D). And α is the birth rate, μ is the mortality rate, β_t is the stunting prevalence rate, γ is the stunting prevalence rate that has an impact. The model is formulated with the following assumptions:

1. The population size in the compartment model is constant
2. There are demographic effects, namely births and deaths
3. Each newly born individual will immediately enter the baby population.

This model can be shown in the image below;

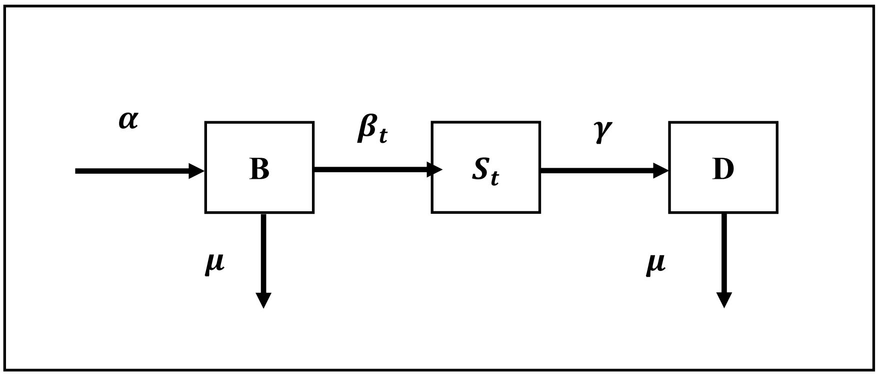

Figure 2 The BS_tD Model Diagram

Figure 2 above illustrates a compartment diagram from B to S_t to D. Each arrow pointing into the compartment represents a positive number in the equation, while the arrow pointing out of the compartment represents a negative number. Still from Figure 2, the movement from one compartment to another can be explained as follows: in equation 1.7, the birth rate is reduced by the number of newborns vulnerable to stunting aged 0 months, multiplied by the stunting prevalence rate multiplied by the number of stunted toddlers aged 0 months to 59 months, then reduced by the number of toddlers vulnerable to stunting aged 0 months to 59 months multiplied by the death rate.

The number of newborns vulnerable to stunting aged 0 months multiplied by the stunting prevalence rate multiplied by the number of stunted toddlers aged 0 months to 59 months minus the number of stunted toddlers aged 0 months to 59 months multiplied by the stunting prevalence rate that has an impact multiplied by the population of toddlers affected by stunting is stated in equation 1.8.
In equation 1.9, the population of stunted toddlers is multiplied by the prevalence rate of stunting that has an impact minus the population of stunted toddlers that has an effect multiplied by the death rate. With three differential equations as follows,

$$\frac{\partial B}{\partial t} = \alpha - B\beta_t S_t - B\mu \qquad (1.7)$$

$$\frac{\partial S_t}{\partial t} = B\beta_t S_t - S_t\gamma D \qquad (1.8)$$

$$\frac{\partial D}{\partial t} = S_t\gamma - D\mu \qquad (1.9\ )$$

with the initial conditions $B(0) > 0, S_t(0) > 0$, and $D(0) > 0$. To calculate the number of individuals in each compartment class or population class, the number of individuals at a time t is expressed as $B(t), S_t(t)$ and $D(t)$. So, the total population at the time t, namely $N(t)$, can be calculated;

$$N(t) = B(t) + S_t(t) + D(t)$$

All parameters α, μ, β_t, and γ 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.

After the model is obtained, in the following study, we will simulate the model using secondary data obtained.

From the Ministry of Health of the Republic of Indonesia, the West Sumatra Health Service, and the Central Statistics Agency. Next, we will compare secondary data with estimated data using the MAPE (Mean Absolute Percentage Error) method. MAPE is calculated to determine the model error so that the model is valid and accurate.

CONCLUSION

Three models were formed to describe the prevalence of stunting without intervention. These models are expected to help the government reduce the prevalence of stunting. This model will describe the growth of stunting if intervention is not carried out by the government. For further research, the author will conduct simulations on the compartment model using stunting prevalence data obtained from the Ministry of Health of the Republic of Indonesia, the West Sumatra Health Office, and the Central Statistics Agency so that the validity and accuracy of the model can be known.

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