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Negative Binomial Regression Modeling in the Analysis of Malnourished Under-Five Children in Central Java in 2023

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Abstract
Toddlers in Indonesia are an age group that is vulnerable to the impacts of malnutrition. Central Java Province is the province with the highest number of cases of malnutrition in toddlers in Java, namely 9525 cases of malnutrition during 2023. This study aims to analyze the variables that influence malnutrition in Central Java Province in 2023. The data used are secondary data in 2023sourced from the Badan Pusat Statistik (BPS), Central Java Provincial Health Service, and Badan Panga Nasional (BPN). The analysis method used is negative binomial regression for modeling enumeration data to overcome the problem of overdispersion in Poisson regression. The results of the analysis show that there is a negative influence of the variables of the percentage of households with access to proper sanitation, the food security index, and the percentage of babies receiving exclusive breastfeeding on the number of cases of malnutrition in toddlers. Meanwhile, the proportion of women aged over 15 years who have a maximum junior high school diploma has an effect on increasing cases of malnutrition in toddlers.

Keywords: *malnutrition, toddler, binomial negative regression*

1. INTRODUCTION

Health is an important factor that determines the sustainability of human life. According to the Undang-Undang Republik Indonesia Nomor 36 Tahun 2009 concerning Health, health is a healthy state, both physically, mentally, and socially so that everyone is able to live productively socially and economically. Nutritional status is one indicator in determining the level of public health. The importance of nutritional status issues can be seen through the second goal of the Sustainable Development Goals (SDGs) related to eliminating hunger. One of the targets contained in the second goal of the SDGs is to reduce all forms of malnutrition. (Katona & Katona-Apte, 2008; Scott et al., 2020) .

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In Indonesia, the problem of nutritional intake is still one of the things that has not been resolved. This can be seen from the many people who still experience stunting, wasting, and other nutritional problems. In developing countries, toddlers or children aged 0-5 years are the age group most often affected by malnutrition, or also called vulnerable communities. Generally, World Health Organization (WHO) stated that around 148.1 million toddlers are stunted with the prevalence of toddler stunting in the world reaching 22.3 percent in 2022. Estimated data for 2022 shows that in the Asian continent, 52 percent of children under the age of five are stunted (UNICEF et al., 2023). In Southeast Asia, Indonesia is the country with the highest percentage of stunting prevalence, namely 31 percent. Meanwhile, based on the results of Survei Status Gizi Indonesia (SSGI) owned by the Ministry of Health of the Republic of Indonesia, the prevalence of stunting in toddlers in Indonesia reached 21.5 percent in 2023 (Kemenkes RI, 2023). This means that there are problems with growth and development that are not yet optimal, which is indicated by around 1 in 3 toddlers experiencing stunting.

Various studies have shown that malnutrition, especially in early life, can have an impact on children's growth and development. Suryawan et al., (2022) stated that malnutrition in early childhood is negatively related to children's cognitive performance. In addition, the research results Soliman et al., (2021) also stated that children who experience severe stunting have a negative impact on their development. Problematic nutritional quality has been shown to significantly affect children's immunity so that the number of infectious diseases increases which causes a high number of deaths (UNICEF et al., 2023) . In addition, poor nutrition can cause decreased productivity so that the income generated decreases and the poverty rate increases so that people are unable to achieve a decent standard of living (Ayala & Meier, 2017) .

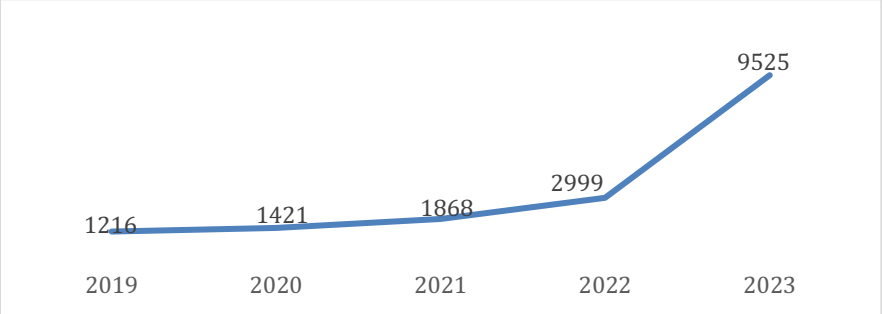


Figure 1. Case Malnourished Under-Five Children in Central Java in 2019-2023

Central Java Province has a fairly high prevalence of malnutrition and undernutrition in toddlers, which are 5.42 and 0.53 percent respectively in 2023. This figure is still quite high considering that the value is quite far above the national average. In addition, data from the Health Office shows that the number of cases of toddlers with malnutrition in Central Java Province continues to increase every year, where in 2029 the number of cases of malnutrition in toddlers recorded was 1216. This figure continues to increase sharply until in 2023 it reached its highest, namely 9525 toddlers who experienced malnutrition (Dinkes Jateng, 2023).

United Nations International Children's Emergency Fund (UNICEF) (1998) in Harris & Nisbett (2021) has developed a framework to explain the causes of

malnutrition. The causes of malnutrition can be divided into direct causes, indirect causes, and basic causes at the community level. Malnutrition in toddlers can be caused directly by food consumption and the presence of infectious diseases. Consumption of food with less balanced nutrition will cause the body's nutritional needs to be less than met. As a result of poor nutritional status, children will be very susceptible to disease, especially infectious diseases such as tuberculosis and others. While indirect causes are low food supplies, inadequate maternal care for children, and poor quality water, sanitation, and health services. Meanwhile, the root of the problem of malnutrition is the economic, political, and social conditions in a region.

Modeling related to malnutrition events has been carried out, including using the Generalized Linear Mixed Model (GLMM) (Dube , 2019; Renzaho et al., 2019) the Spatial Bayes approach (Fenta et al., 2021; Rachmawati & Pusponegoro, 2021) , Generalized Additive Mixed Models (Mullah et al., 2023) , and machine learning (Dhanamjayulu et al., 2022) . Modeling carried out in previous studies has not specifically examined cases of overdispersion in malnutrition cases, so the modeling carried out still contains bias. This study will conduct modeling by considering the occurrence of overdispersion in malnutrition cases in Central Java.

Therefore, based on the background above, the purpose of this study is to determine the general description of the number of toddlers suffering from malnutrition in Central Java Province in 2023 and to determine the variables that influence malnourished under-five children in Central Java Province in 2023 using negative binomial regression modeling.

2. LITERATURE REVIEW

Malnutrition is a serious health disorder that occurs when the body does not get enough nutritional intake. In fact, nutrition has an important role in the formation of healthy and productive human resource quality. Malnutrition is a condition where someone lacks energy and protein due to an imbalance between food consumption and nutritional needs (Allen & Saunders, 2023; Kiani et al., 2022) . According to Kerac et al., (2020) , malnutrition is the most severe form of chronic malnutrition. Malnutrition itself can be recognized by height, weight, and arm circumference below average.

Infants and children are included in the group that is vulnerable to malnutrition problems. This is due to the high nutritional needs of infants and children in the process of growth and development, the ownership of energy reserves, and dependence on others in fulfilling their nutritional needs (Prihastyanti et al., 2021; Youness et al., 2022) . In Indonesia, the measurement of nutritional standards has been stipulated by the Regulation of the Minister of Health Number 2 of 2020 concerning Child Anthropometric Standards (Kemenkes, 2020). The classification of a child's nutritional status is carried out using the body weight index according to body length or height. The results of the index calculation are used to group children according to their nutritional status, namely undernutrition, severe malnutrition, good nutrition, at risk of overnutrition, overnutrition, and obesity. The classification of nutritional status and its thresholds can be seen in Table 1.

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Table 1. Categories and Thresholds for Child Nutritional Status

Category Status Nutrition	Threshold Limit (*Z- score*)
Malnourished	$< -3\ SD$
Undernutrition	$-3\ SD$ up to $< -2\ SD$
Well-nourished (normal)	$-2\ SD$ up to $+1\ SD$
At risk *of* overweight	$> +1\ SD$ up to $+2\ SD$
Overweight	$> +2\ SD$ up to $+3\ SD$
O*bese*	$> +3\ SD$

2.1. Data and Data Sources

This study examines about the number of cases malnourished under-five children aged 0-59 months in Central Java Province in 2023. The data used is secondary data that comes from Badan Pusat Statistik (BPS), Central Java Provincial Health Service, and Badan Pangan Nasional (BPN). Unit research analysis This covers 35 districts in Java Middle. Details data Which used in this study can be seen in Table 2

Table 2. List variable in study

Variables	Notation	Source data
Amount child toddler sufferer malnutrition	Y	Profile Health Java Mid 2023 (Central Java Provincial Health Office)
Percentage House ladder with access to proper sanitation	X_1	Profile Health Java Mid 2023 (Central Java Provincial Health Office)
GRDP districts on base price constant	X_2	Central Java Province BPS
Index Resilience Food	X_3	Index Resilience Indonesian Food 2023 (BPN)
Percentage integrated health service post active	X_4	Profile Health Java Mid 2023 (Central Java Provincial Health Office)
Proportion Woman aged in on 15 year Which have a maximum junior high school diploma	X_5	Statistics Welfare People 2023 (BPS)
Exclusive breastfeeding rate among infants	X_6	Profile Health Java Mid 2023 (Central Java Provincial Health Office)

3. METHODS

The analysis methods used in this study are descriptive analysis and inferential analysis. Descriptive analysis in this study will look at the distribution of malnutrition in toddlers aged 0-59 months in Central Java Province in 2023 and the variables that influence it. Meanwhile, inferential analysis is used to determine the effect of predictor variables on response variables in the form of count data on the number of cases of malnutrition in toddlers in East Java Province in 2023. The following is the poisson regression model on the equation (1) (Hilbe, 2011) :

$$\hat{\mu}_i = exp(\beta_0 + \beta_1 X_{1i} + \cdots + \beta_6 X_{7i}) \quad (1)$$

The stages of inference analysis in this study are as follows:

1. Estimation of Poisson regression parameters.
2. Collinearity check. VIF values greater than 10 indicate multicollinearity.
3. Examination of equidispersion in Poisson regression. Equidispersion is detected through the dispersion ratio, with the following formula (Kenne Pagui et al., 2022) :

   $$\emptyset = \frac{D}{df}$$

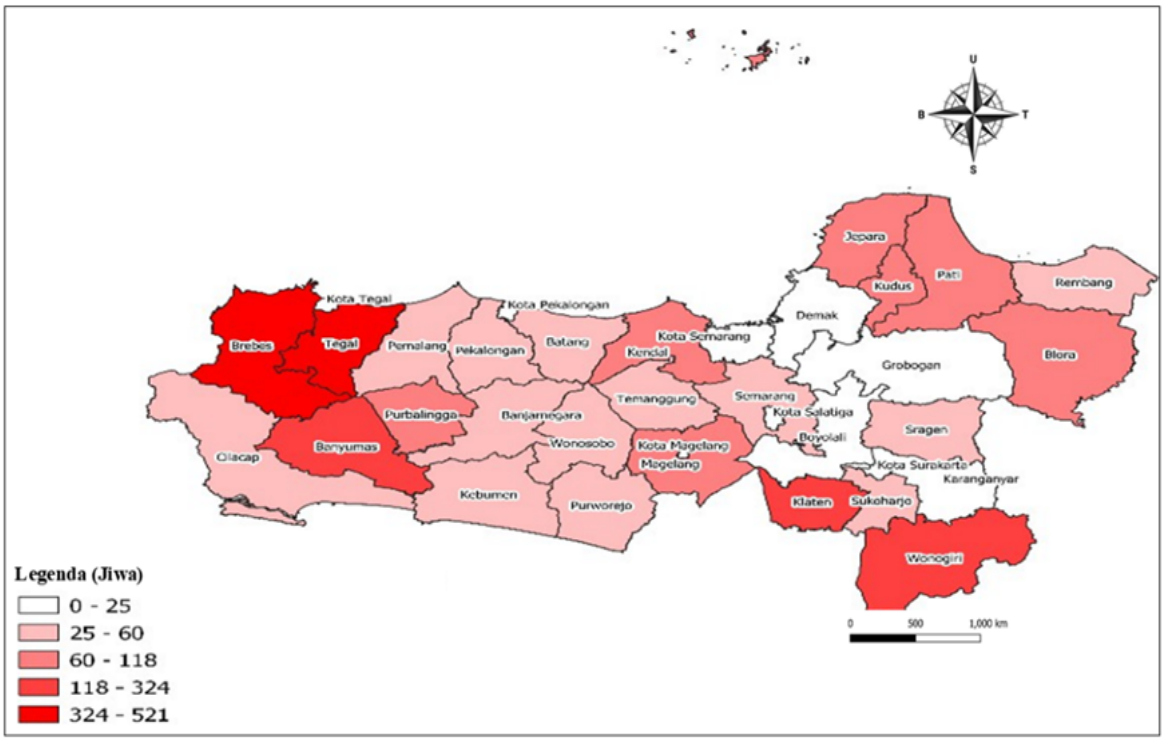
   Where D is the deviance value and df is the degree of freedom. If the dispersion ratio is more than one, the regression results can be said to be overdispersion.
4. Estimation parameter regression binomial negative for overcome overdispersion.
5. Testing significance parameter regression in a way simultaneous with hypothesis:
   $H_0: \beta_1 = \beta_2 = \cdots = \beta_6 = 0$ (all predictor variables have no significant effect on the response variable).
   H_1: Minimal satu $\beta_j \neq 0$ (at least one predictor variable has a significant effect on the response variable), j = 1, 2, …, 6
   Reject H_0 at a significance level of α if $p - value < \alpha$.
6. Partial regression parameter significance testing with the following hypotheses:
   $H_0: \beta_j = 0$ (the j[th] predictor variable has no significant effect on the response variable).
   $H_1: \beta_j \neq 0$ (the j[th] predictor variable has a significant effect on the response variable), j=1, 2, … ,6
   Reject H_0 at a significance level of α if $p - value < \alpha$.
7. Interpretation of the best regression equation produced.

4. RESULTS

4.1 Overview of Malnourished under-five children in Central Java Province in 2023

Figure 2 shows distribution of number of events malnourished under-five children in Central Java Province in 2023. Getting darker color an area indicates a higher number of cases malnourished under-five children. There is four districts with the number of incidents malnourished under-five children with category high, namely Banyumas, Klaten, Wonogiri, Tegal, and Brebes. Temporary That, region with amount case Malnourished under-five children lowest are the cities of Semarang, Surakarta, Demak, Grobogan, Boyolali and Karanganyar regencies.

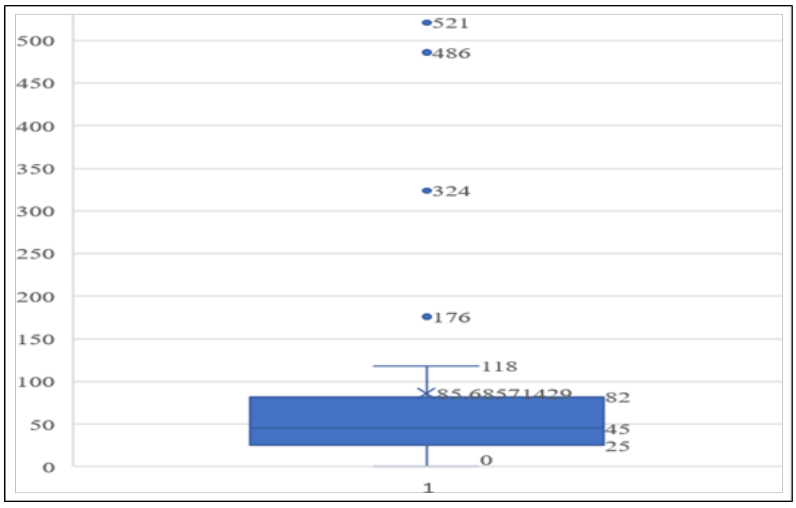
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Source: processing result

Figure 2. Amount Toddler Suffer Malnutrition in Central Java in 2023

Exploration using the boxplot diagram in Figure 3 shows that there are five outliers in the data on the number of toddlers suffering from malnutrition in Central Java. The five outliers are cases of malnutrition in toddlers in Banyumas as many as 180 cases, Klaten as many as 176 cases, Wonogiri as many as 324 cases, Tegal as many as 486 cases, and Brebes as many as 521 cases.



Source: processing result

Figure 3. Ammount Case Malnourished Under-Five Children in Central Java Province in 2023

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4.1 Modeling the Number of Malnutrition Based on Influencing Variables in Central Java Province in 2023

The number of malnutrition cases in toddlers is count data, so the initial model used is the Poisson regression model as in equation (2). The following is the Poisson regression equation that is formed:

$$\hat{\mu} = \exp(1.237 - 0.006X_1 + 0.015X_2 - 0.095X_3 - 0.003X_4 + 0.092X_5 - 0.033X_6) \quad (2)$$

After forming the Poisson regression equation, a collinearity check was performed using the VIF value criteria. Based on Table 3, all predictor variables have VIF values that are much smaller than 10. This indicates that there is no multicollinearity problem.

Table 3. Multicollinearity Check

Variables	X_1	X_2	X_3	X_4	X_5	X_6
VIF	1.119	1,827	1,839	4.099	1,441	1,066

Source: processing result

Next, an equidispersion assumption check was carried out on the Poisson regression equation that was formed. Based on the results of the examination, the deviance value was obtained as much as 1450.795 with a degree of freedom of 27 so that the dispersion ratio value was 81.915 experiencing overdispersion. This causes the estimated parameter results from the Poisson regression to be unusable because they are no longer accurate. To overcome this, it is necessary to form a negative binomial regression model (Hilbe, 2011) . The following equation (3) negative binomial regression is formed:

$$\hat{\mu} = \exp(2.794 - 0.045X_1 + 0.012X_2 - 0.058X_3 - 0.014X_4 + 0.066X_5 - 0.034X_6) \quad (3)$$

In the next stage, simultaneous testing was conducted to determine the effect of all predictor variables on the number of toddler malnutrition. Based on the test results, a likelihood ratio value of 30.139 was obtained. This value is greater than the chi-square value at a significance level of 5 percent ($\chi^2_{0.05;7} = 14.067$) so that the test decision is to reject H_0. This means that all predictor variables together have a significant effect on the number of toddler malnutrition.

After simultaneous testing, partial testing was conducted to determine the effect of each predictor variable on the number of toddler malnutrition cases. Based on Table 4, there are four predictor variables, namely variables $X_1, X_2, X_5,$ and X_6 which has a p-value < 0.05 so that the test decision is to reject H_0. This shows that the four predictor variables partially have a significant effect on the number of cases of malnutrition in toddlers.

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Table 4. Results estimation coefficient parameter regression binomial negative

Variables	Coefficient	*p-value*
Intercept	2,794	0.554
X_1	-0.045	0.009*
X_2	0.058	0.065
X_3	-0.012	0.025*
X_4	-0.014	0.287
X_5	0.066	0.005*
X_6	-0.034	0.000*

Information: * = significant on level 5 percent significance
Source: processing result

Based on the negative binomial regression equation obtained. The variable percentage of households with access to proper sanitation (X_1) has a significant negative effect on the number of malnutrition in toddlers. The coefficient value of 0.045 indicates that an increase in the percentage of households with access to proper sanitation by one percent will reduce the average number of malnourished under-five childrenby (exp (0.045) − exp (0)) × 100 = 4.60 percent assuming ceteris paribus. This indicates that the more households have access to adequate sanitation facilities, the lower the incidence of malnutrition in toddlers. Access to proper sanitation, such as healthy toilets and safe waste disposal systems, plays an important role in preventing the spread of infectious diseases such as diarrhea and worms which can directly interfere with the absorption of nutrients in the child's body. When children live in an environment with poor sanitation, they are more susceptible to recurring diseases that cause growth disorders and decreased nutritional status. The results of this study are in line with research conducted by Hasan et al. (2023) , Bekele et al. (2020) and Islam et al. (2022) .

Furthermore, the food security index variable (X_3) has a significant negative effect on the number of malnutrition in toddlers. The coefficient value of -0.0129 indicates that an increase in the food security index by one unit will reduce the average number of malnourished under-five childrenby (exp (0.012) − exp (0)) × 100 = 1.20 assuming ceteris paribus. This finding confirms that good food security includes the availability, access, utilization, and stability of food, which plays a crucial role in ensuring the fulfillment of children's nutritional needs in a sustainable manner. When a region is able to guarantee the availability of nutritious and affordable food for the entire community, especially vulnerable groups such as mothers and children, the risk of malnutrition can be significantly reduced. This shows that interventions to increase food security, either through food distribution policies, strengthening local agriculture, or nutrition education, are important strategies in supporting child growth and development and reducing malnutrition rates systematically and sustainably. The results of this study are in line with research conducted by Luo et al. (2020) and Harper et al. (2022) .

Then, the variable of proportion of women aged over 15 years who have a maximum junior high school diploma (X_5) has a significant positive effect on the

number of malnutrition in toddlers. The coefficient value of 0.066 indicates that an increase in the proportion of women aged over 15 years with a minimum junior high school diploma by one unit will increase the average number of cases of malnourished under-five childrenby (exp (0.066) − exp (0)) × 100 = 6.82 percent assuming ceteris paribus. This reflects the importance of women's education in determining the quality of care and fulfillment of children's nutritional needs. Women with lower levels of education tend to have limited access to information on health, balanced nutrition, and proper child care practices, potentially increasing the risk of malnutrition in their children. The results of this study are in line with studies conducted by Lukwa et al. (2020) and Luo et al. (2020) .

The last, variable percentage of infants receiving exclusive breastfeeding (X_6) has a significant negative effect on the number of cases of malnutrition in toddlers. The coefficient value of -0.034 indicates that an increase in the percentage of infants receiving exclusive breastfeeding by one unit will reduce the average number of cases of malnourished under-five childrenby (exp (0.034) − exp (0)) × 100 = 3.45 percent assuming ceteris paribus. This finding underlines the importance of the practice of exclusive breastfeeding as the main foundation in developing children's nutritional status from an early age. Exclusive breastfeeding has been shown to contain all the nutrients needed for optimal growth and development of infants during the first six months of life, while increasing immunity and preventing infections that can worsen nutritional status. Therefore, the low coverage of exclusive breastfeeding in a population can be an indicator of weak maternal-child nutrition and health interventions, which ultimately contribute to the high prevalence of malnutrition. The results of this study are in line with research conducted by Ibrahim et al. (2022) and Setyowati et al. (2022) .

5. CONCLUSION

Based on the results and discussion, two important conclusions can be drawn. First, the distribution of the number of toddlers with malnutrition. bad in Central Java Province in 2023 still classified as high in seven district First, the distribution of the number of toddlers with malnutrition in Central Java Province in 2023 is still relatively high in seven districts among them are Kudus, Pati, Klaten, Banyumas, Wonogiri, Tegal, and Brebes. Second, the variables of the percentage of households with access to proper sanitation, the food security index, the proportion of women aged over 15 years who have a maximum junior high school diploma, and the percentage of babies receiving exclusive breastfeeding have an influence on reducing the number of malnourished under-five children.

As a suggestion, the government can focus on specific programs as an effort to overcome malnourished under-five children. The government can increase the number of safe drinking water facilities. increase access to proper household sanitation. Pay special attention to education for women. and conduct socialization of the importance of using access to proper sanitation and safe drinking water for local residents.

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