ORIGINAL ARTICLE

Analysis of determinants of stunting among children under five years using curve analysis of receiver operating characteristics

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ABSTRACT

Stunting in children is still a global public health issue. Compared to other middle-income nations, Indonesia has one of the highest rates of stunting, and Bandung City is one of the worst affected areas in the country. The purpose of this study is to analyze the determinants of stunting and identify predictive indices of stunting incidence in children aged 12-59 months using curve analysis of receiver operating characteristics. In Bandung City, 400 participants (200 cases and 200 controls) participated in a case-control study. Simple random sampling and proportional sampling methods were used to draw samples. Data were gathered by anthropometric measurements and interviews using structured questionnaires. Predictive indices were determined using receiver operating characteristic analysis and the multiple logistic regression test. A history of infectious disease (p=0.003, OR=2.524, 95% CI=1.361-4.683), not being exclusively breastfed (p=0.020, OR=1.929, 95% CI=1.109-3.356), incomplete immunization history (p=0.0001, OR=4.703, 95% CI=2.747-8.052), inadequate drinking water source (p=0.0001, OR=2.587, 95% CI=1.543-4.337), and birth spacing < 24 months were all associated with stunting. According to the receiver operating characteristics study, the stunting prediction index may identify toddlers who are actually stunted by 31.0% of the stunted population, with a Sensitivity (0.31) and Specificity (0.31) value. The risk of stunting is 93.2% if the child is born less than 24 months apart from a sibling, is not breastfed exclusively, has an incomplete immunization history, has a history of infectious diseases, and the drinking water source does not satisfy the necessary standards. Therefore, in order to combat malnutrition, policymakers and stakeholders are advised to enhance prevention and promotion strategies during the prenatal, antenatal, and postnatal phases.

Keywords:
stunting; children under five; immunization history; determinants of stunting

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INTRODUCTION

The prevalence of undernutrition in children is determined by stunting, wasting, and underweight. Children who suffer from stunting have delayed growth and development as a result of inadequate nutrition.[1] If the length/height-for-age ratio is less than -2 standard deviations (SD) on the WHO growth curve, the child is considered stunted.[2,3] Stunting raises a child's risk of morbidity and death, in addition to preventing mental growth and affecting cognitive capacities.[4,5] A physical sign of chronic undernutrition in children that is simple to observe and quantify is stunting.[3] There are several chronic health issues that stunting might exacerbate. Stunted children typically have inferior cognitive capacities, which can have an impact on both their future academic success and capacity to contribute positively to society.[6] In addition to diseases and health issues, stunting is a major cause of child illness and mortality, contributing to an estimated 3.1 million or 45% of child fatalities globally each year.[7] When compared to other middle-income nations, Indonesia has one of the highest rates of stunting.[8] Despite being lower than Myanmar (35%), Indonesia (24.4%) nevertheless has a higher stunting rate than Vietnam (23%), Malaysia (17%), Thailand (16%), and Singapore (4%).[9]

By 2022, Indonesia's stunting rate had dropped from 24.4% to 21.6%.[10] In West Sulawesi, the greatest stunting rate is 35%. The province of West Java has a stunting percentage that is lower than the 20.2% national average. In Bandung, the percentage of stunted children decreased from 7.59% to 6.43% in 2022, from 7,568 children in 2021 to 6,518 newborns in 2022. While the stunting rate is trending downward, a modest increase of about 6.50% can be seen if we look at the data from 2017.[11] The government's rapid stunting prevention program is one of its main goals. The Indonesian government has taken a variety of steps to lower the incidence of stunting and the resulting burden of malnutrition. Among these are the Sustainable Development Goals (SDGs), which seek to end hunger, increase nutrition and food security, establish sustainable agriculture, and prevent childhood stunting. By improving the efficacy of focused and tailored nutrition interventions, this strategy also speeds up the decrease in stunting.[12]

Research findings indicate that stunting is associated with certain home, parent, and child variables. Stunting has been linked to a number of household variables, such as the number of children in the family, the size of the house, and the socioeconomic status of the family, according to research done in Bangladesh, Ethiopia, and Nepal. According to the study's findings, children from higher socioeconomic groups had a reduced risk of stunting than those from lower socioeconomic groups.[13–15] According to research from Bangladesh, Pakistan, and Ethiopia, stunting has been linked to maternal traits like height and schooling.[14–16] Biological variables include factors like breastfeeding, low birth weight, infections (such as diarrhea), child's age, and gender.[17,18] Moreover, the elevated incidence of stunting is also linked to environmental variables. Numerous studies have found a variety of environmental factors that contribute to stunting in children, such as the availability and upkeep of facilities for disposing of waste, the quality of drinking water sources, wastewater treatment, and the availability of latrines.[19,20] However, this study brings novelty by integrating these determinants into a predictive index using Receiver Operating Characteristics (ROC) curve analysis. This approach not only maps the determinants of stunting, but also provides a predictive model that can be used to support evidence-based interventions. Since stunting is quite common in Bandung City, Indonesia, where this study was carried out, it offers locally relevant support for national initiatives aimed at lowering the prevalence of stunting. Finding predictive indices of the factors that contribute to stunting in children under five is crucial for prevention initiatives to be successful in lowering the prevalence of stunting in this age group. Finding predictive indices of the factors that contribute to stunting in children under five is crucial for prevention initiatives to be successful in lowering the prevalence of stunting in this age group. The objective of this study was to analyze the determinants of stunting and identify predictive indices of stunting incidence in children aged 12-59 months using curve analysis of receiver operating characteristics.

METHODS

Study Design and Location

From March to May 2024, a case-control design was used in Bandung City, Indonesia. Due to its high prevalence of stunting and status as Indonesia's third largest city, Bandung was selected as the research site. There were 129,609 children under the age of five in the population. This study has been approved by the Bhakti Kencana University health research ethics committee with the number 035/09.KEPK/UBK/VII/2024. Each respondent has given their permission to participate in voluntary research. Each participant filled out and signed a consent form before the interview.

Population and study sample

All mothers and children living in Bandung City between the ages of 12 and 59 months made up the data source population. However, all Bandung City children between the ages of 12 and 59 months made up the study population. Children having a Z-score of less than -2.0 SD, ranging in age from 12 to 59 months, made up the case group. Conversely, the control group included kids aged 12 to 59 months who had a Z-score of 2.0 SD or above.

Sample criteria

Children aged 12 to 59 months and their mothers who have been in Bandung City for a year and are able to converse in Bahasa Indonesia are eligible to participate. All children between the ages of 12 and 59 months as well as their mothers who were in severe health conditions and thus unable to submit information during data collection were excluded.

Sample Size

The formula for the 2-proportion difference hypothesis test was used to determine the minimal sample size. The odds ratio (OR) value from earlier research was taken into account while determining the sample size. Next, the sample was computed using a power of test (β) of 80% ($Z\beta$=0,842) and a significance level (α) of 5% ($Z\alpha$=1,960). In the case group, a minimum sample size of 200 was required. We utilized a ratio of 1:1 to calculate the sample size in the control group, which came out to be 200. This meant that there were 400 respondents in the study overall.

Sampling procedure

Ten of the thirty subdistricts that make up Bandung City were chosen by random sampling. The number of samples from each sub-district was calculated using proportional sampling. After that, a survey was conducted in each of the ten subdistricts to create a list of homes from which all children between the ages of 12 and 59 months would be randomly picked. All 12- to 59-month-old children who satisfied the requirements and had resided in Bandung City for more than a year were chosen at random to be part of the study sample. Following anthropometric measurements of all the children aged 12-59 months who were chosen as the research sample, the z-score for height was determined based on the age of the children. The anthropometric measurements were categorized as a case group (stunted young children) if the Z-score was less than -2 SD. The child is placed in the control group (young children who are not stunted) if the Z-score from the anthropometric measurements is -2SD. Using a straightforward random sample procedure, mothers and children ages 12 to 59 months from each sub-district were chosen and enrolled in the study's second phase. The selection of households was conducted through the utilisation of the lottery method. In instances where there were multiple eligible children present within a single household, only one child was selected into the sample through the lottery method.

Research Variables

The dependent variable is the incidence of stunting. The independent variables were maternal characteristics (maternal age was categorized into < 20 and > 35 years and 20-35 years, maternal education was categorized into Low, if the mother had no schooling/Primary school/Middle School and High, if the mother's education was High School/College. Maternal occupation was categorized into Unemployed and Permanently employed, birth spacing was categorized into < 24 months and ≥ 24 months), child characteristics (child age was categorized into ≥ 24 months and < 24 months, child sex was categorized into male and female, birth weight was categorized into low birth weight and normal, exclusive breastfeeding history was categorized into no and yes, immunization history was categorized into incomplete and complete, infectious disease history was categorized into available and unavailable), and environmental factors (drinking water source, waste disposal facilities, wastewater disposal facilities, and family latrine facilities) were categorized into ineligible and eligible.

Data collection

The data collection was conducted by four midwives who had received training in the relevant techniques. Prior to the commencement of data collection, the midwives underwent a one-day training programme which encompassed the following areas: anthropometric measurements, data collection techniques, household selection criteria, and techniques for approaching respondents. Data collection was conducted via house-to-house visits. The questionnaire was adapted from existing literature and guidelines. Anthropometric measurements (child height) and direct interviews with rigorously selected respondents were conducted using a previously tested structured questionnaire. The questionnaire comprised questions on maternal characteristics, child characteristics, and environmental factors.

Anthropometric measurements

Using a standard length measuring board and with no shoes, children aged 12 to 23 months had their body length measured in a supine posture with an accuracy of 0.1 cm. Children between the ages of 24 and 59 months were measured for height by standing up straight in the center of the board, dressed in loose-fitting clothing, and without shoes. To guarantee the study's reliability, the head, shoulders, buttocks, knees, and heels were all positioned in relation to the board, and each measurement was made twice.

Statistical Analysis

WHO Anthro software version 3.1.0 was used to calculate anthropometric data, and the 2006 WHO reference population median (child growth standards) was used to generate height-for-age Z scores. The analyses used in this study were univariate to determine maternal characteristics, child characteristics, and environmental factors, and were then presented using frequency distribution data. Bivariate analysis using the chi square (X^2) test, to determine the relationship of each independent variable with the dependent variable. Further analysis was carried out using simple logistic regression; this test was used to determine which variables would be selected as candidates for further analysis. Variables were considered candidates for multivariate analysis if the simple logistic regression results showed a p value <0.25. The multiple logistic regression test was used to model the multiple logistic regression equation, which aims to determine the probability of stunting from the selected determinant factors. Analyzing a test's performance (specificity and sensitivity) within a certain range of values is the goal of receiver operating characteristic (ROC) analysis. An ROC curve was also generated from the ROC analysis results, and this ROC curve was used to calculate the cut level value.

RESULTS

There were 400 mothers and children included in this study (200 cases and 200 controls). Based on maternal characteristics, most mothers were 20-35 years (58.3%), highly educated (54.8%), not working (57.5%), and had birth spacing ≥ 24 months (66.5%). The majority of children were < 24 months (62.0%), half of the children under five were male (50%), and only a small proportion of children under five were low birth weight (37.5%). The majority of children under five were not exclusively breastfed (69.3%), fully immunized (73.0%) and had a history of infectious disease (75.8%) (Table 1).

Table 1. Characteristics of mothers and children less than five years old

Characteristics	n (case=200, control=200)	Percentage
Mother’s Age		
< 20 and > 35 years	167	41.8
20-35 years	233	58.3
Mother's education		
Low (< High School)	181	45.3
High (≥ High School)	219	54.8
Mother’s occupation		
Unemployed	230	57.5
Permanently employed	170	42.5
Birth spacing		
< 24 months	134	33.5
≥ 24 months	266	66.5
Child’s age		
≥ 24 months	152	38.0
< 24 months	248	62.0
Child’s age		
Male	200	50.0
Female	200	50.0
Birthweight		
Low birth weight	150	37.5
Normal	250	62.5

Characteristics	n (case=200, control=200)	Percentage
Exclusive breastfeeding history		
No	277	69.3
Yes	123	30.8
Immunization history		
Incomplete	108	27.0
Complete	292	73.0
History of infectious disease		
Available	303	75.8
Unavailable	97	24.3

Of the environmental factors observed (**Table 2),** the majority of mothers and children used safe drinking water sources (75.5%). Additionally, over half of the mothers had inadequate waste disposal practices (58.3%). Furthermore, the majority of observed houses had improper wastewater disposal (60.8%), and the majority of respondents' houses had functional family latrines (66.5%).

Table 2. Condition of Environmental Factors

Environmental Factors	n (case=200, control=200)	Percentage
Source of drinking water		
Ineligible	98	24.5
Eligible	302	75.5
Waste disposal facilities		
Ineligible	233	58.3
Eligible	167	41.8
Wastewater disposal facilities		
Ineligible	243	60.8
Eligible	157	39.3
Family latrine facilities		
Ineligible	134	33.5
Eligible	266	66.5

The results of the chi-square test, as presented in **Table 3**, indicate that maternal characteristics associated with the incidence of stunting in children under five years of age are education (p=0.005, OR=1.803, 95% CI=1.211-2.685) and birth spacing (p=0.0001, OR=2.073, 95% CI=1.356-3.169). No significant association was found between maternal age (p=0.839) and employment status (p=0.613) and the incidence of stunting in children under five years of age.

Table 3. Chi Square test for Maternal characteristics and the incidence of stunting

Maternal Characteristics	Cases (%)	Control (%)	P-value	OR	95% CI
Mother's age					
< 20 and > 35 years	85 (42.5)	82 (41.0)	0.839	1.064	0.715-1.583
20-35 years	115 (57.5)	118 (59.0)			
Mothers' education					
Low (< SMA)	105 (52.5)	76 (38.0)	0.005	1.803	1.211-2.685
High (≥ SMA)	95 (47.5)	124 (62.0)			

Maternal Characteristics	Cases (%)	Control (%)	P-value	OR	95% CI
Mother's Occupation					
Unemployed	112 (56.0)	118 (59.0)	0.613	0.884	0.595-1.315
Permanently employed	88 (44.0)	82 (41.0)			
Pregnancy Spacing					
< 24 months	83 (41.5)	51 (25.5)	0.0001	2.073	1.356-3.169
≥ 24 months	117 (58.5)	149 (74.5)			

The association of toddler characteristics in **Table 4** shows that birth weight (p=0.0001, OR=3.296, 95% CI=2.151-5.051), exclusive breastfeeding history (p=0.0001, OR=2.989, 95% CI=1.909-4. 682), immunization history (p=0.0001, OR=3.623, 95% CI=2.240-5.861), and history of infectious disease (p=0.0001, OR=3.236, 95% CI=1.973-5.305) were associated with stunting in children under five years old.

Table 4. Features of children under five and the prevalence of stunting

Characteristics of children less than five years old	Cases (%)	Control (%)	P-value	OR	95% CI
Child's age					
≥ 24 months	81 (40.5)	71 (35.5)	0.354	1.237	0.825-1.853
< 24 months	119 (59.5)	129 (64.5)			
Child's sex					
Male	105 (52.5)	95 (47.5)	0.368	1.222	0.825-1.809
Female	95 (47.5)	105 (52.5)			
Birthweight					
Low birth weight	102 (51.0)	48 (24.0)	0.0001	3.296	2.151-5.051
Normal	98 (49.0)	153 (76.0)			
Exclusive breastfeeding history			0.0001	2.989	1.909-4.682
No	161 (80.5)	116 (58.0)			
Yes	39 (19.5)	84 (42.0)			
Immunization history					
Incomplete	78 (39.0)	30 (15.0)	0.0001	3.623	2.240-5.861
Complete	122 (61.0)	170 (85.0)			
History of infectious disease			0.0001	3.236	1.973-5.305
Available	172 (86.0)	131 (65.5)			
Unavailable	28 (14.0)	69 (34.5)			

The relationship between environmental factors in **Table 5** shows that drinking water sources (p=0.002, OR=2.168, 95% CI=1.353-3.473), and family latrine facilities (p=0.002, OR=1.978, 95% CI=1.295-3.020) are associated with the incidence of stunting in children under five years of age. Meanwhile, waste disposal facilities and wastewater disposal facilities are not associated with stunting.

Table 5. Stunting incidence and environmental factors

Enviromental Factors	Cases (%)	Control (%)	P-value	OR	95% CI
Source of drinking water					
Ineligible	63 (31.5)	35 (17.5)	0.002	2.168	1.353-3.473
Eligible	137 (68.5)	165 (82.5)			
Waste disposal facilities					
Ineligible	115 (57.5)	118 (59.0)	0.839	0.940	0.632-1.399
Eligible	85 (42.5)	82 (41.0)			
Wastewater disposal facilities					
Ineligible	125 (62.5)	118 (59.0)	0.539	1.158	0.775-1.731
Eligible	75 (37.5)	82 (41.0)			
Family latrine facilities					
Ineligible	82 (41.0)	52 (26.0)	0.002	1.978	1.295-3.020
Eligible	118 (59.0)	148 (74.0)			

The final model of the determinants of stunting in underage children found that the factors that had an impact on causing stunting were birth spacing, exclusive breastfeeding history, immunization history, infectious disease history, and drinking water source. Based on **Table 6**, the main factor causing stunting in underage children was immunization history (OR=4.703, 95% CI=2.747-8.052, P=0.0001).

Table 6. Modeling factors that contribute to stunting in children under five

Variable		B	SE	P-value	OR	95% CI
Birth spacing	< 24 months ≥ 24 months	0.521	0.237	0.028	1.683	1.058-2.679
Exclusive Breastfeeding History	Tidak Iya	0.657	0.282	0.020	1.929	1.109-3.356
Immunization History	Incomplete Complete	1.548	0.274	0.0001	4.703	2.747-8.052
History of Infectious Disease	Available Unavailable	0.926	0.315	0.003	2.524	1.361-4.683
Source of Drinking Water	Ineligible Eligible	0.950	0.264	0.0001	2.587	1.543-4.337
Constant		-7.221	0.939	0.0001	0.001	

Multiple logistic regression model to determine the probability of stunting from the variables of birth spacing, exclusive breastfeeding history, immunization history, infectious disease history, and drinking water source:

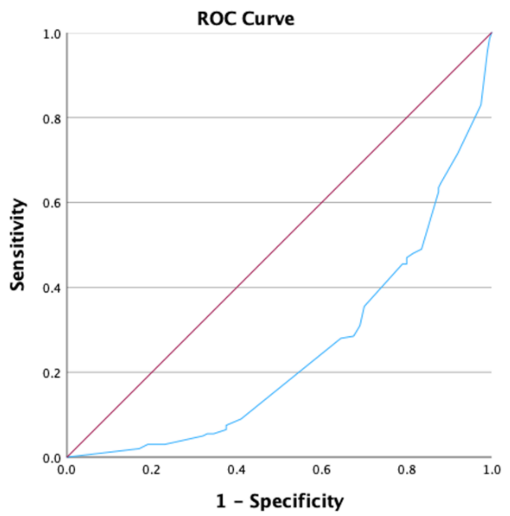
$$P = \frac{1}{1+2{,}718^{-(-7.221 + (0.521x1+0.657x1+1.548x1+0.926x1+0.950x1)}}$$

$$P = \frac{1}{1+0.073}$$

$$P = \frac{1}{1.073}$$

$$P = 0{,}932 = 93{,}2\%$$

From the equation, it is known that if birth spacing is less than 24 months, the child is not exclusively breastfed, has an incomplete immunisation history, has a history of infectious disease, and the source of drinking water does not meet the requirements, the child is likely to experience stunting by 93.2% and 6.8% is caused by other factors. The formula for the stunting toddler index in this study has a sensitivity value (0.31) and specificity (0.31), according to the results of the receiver operating characteristic analysis (**Figure 1**), which focuses on the middle of the cut-off point on the curve. This means that the predictive index of stunting toddlers can predict toddlers who are actually stunted among the population who are not stunted by 31.0%, and it can predict children who are actually not stunted among the population who are not stunted by 31.0%.



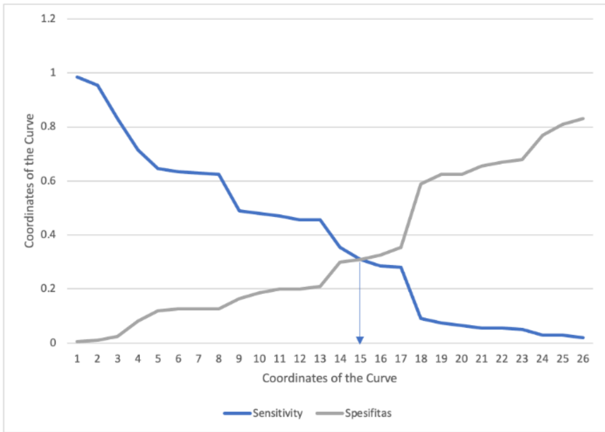


Figure 1. shows the sensitivity and specificity cut-off points as well as the ROC curve for stunted children

DISCUSSION

A history of incomplete immunization, a history of infectious infections, a history of non-exclusive breastfeeding, a history of birth spacing less than 24 months, and insufficient drinking water sources can all contribute to the occurrence of stunting in children under five. If a toddler born to a mother with a birth spacing of less than 24 months, does not get exclusive breastfeeding, does not get complete immunization, has experienced an infectious disease, and the family's drinking water source does not meet the requirements, the toddler has a 93.2% chance of being stunted. One of the factors contributing to childhood stunting is a birth spacing of less than 24 months. This finding aligns with research conducted in Indonesia, which indicates that 30.3% of stunting cases are caused by maternal variables, including birth spacing, nutritional status, weight increase during pregnancy, and infections during pregnancy.[21] The occurrence of stunting at non-ideal birth spacing is caused by an imbalance in food supply within the household. If family members increase, the family will find it difficult to fulfil the family's food needs, especially in low-income families.[22] The incidence of stunting is correlated with the number of family members; a child is more likely to be stunted if the interval between births is shorter than 24 months.[23] There is a strong correlation between stunting and children from large families. Studies carried out in Northern Sudan and Armenia have demonstrated the same.[24,25]

A history of exclusive breastfeeding is often associated with stunting. The findings in our study showed that 80.5% of stunted infants were not exclusively breastfed. WHO recommends that infants begin breastfeeding within the first hour after birth, and continue exclusive breastfeeding for the first 6 months of life. Findings from Pakistan highlight the importance of reinforcing exclusive breastfeeding messages for the first 6 months.[26] Among child features, stunting was found to be linked with exclusive breastfeeding for six months. Compared to children who were exclusively breastfed for six months, children who were not breastfed for six months had a 1.9-fold higher risk of stunting. Accordingly, a study carried out in Indonesia revealed that children who began breastfeeding before the age of six months were 1.2 times more likely to suffer from stunting than those who began breastfeeding at six months.

Other findings supporting the findings of this study reported from studies conducted in Bangladesh and Mexico also showed that children who were not exclusively breastfed were more likely to be stunted compared to those who were exclusively breastfed.[27,28] When complementary foods are started, there is a decrease in breastmilk consumption, which can lead to loss of immunity. This leads to higher morbidity when unhygienic food is used, leading to diarrheal disease. In addition, inadequate weaning practices and poor infant feeding practices lead to low protein and energy intake.[29]

Infectious disease history showed a statistically significant association with the incidence of stunting. Children who had suffered from infectious diseases such as diarrhea and acute respiratory infections were more likely to be stunted. In line with the findings of this study, another study in Indonesia stated that toddlers who have a history of infectious diseases are at a 5.9 times greater risk of stunting compared to toddlers who have never experienced infectious diseases.[30] Toddlers under 5 years old who suffer from acute diarrhea for more than 2 weeks are more at risk of stunting, and toddlers who experience acute respiratory infections for up to 14 days are also at risk of stunting.[31] Acute respiratory infections are a major factor in underweight and stunting, while diarrhea causes stunting. The relationship between these two infectious diseases and underweight is inseparable.[32]

The source of drinking water has been identified as a significant factor influencing the incidence of stunting. The results of this study indicate that 31.5% of stunted toddlers have an unqualified drinking water source. Families that utilise an inadequate drinking water source are 2.5 times more likely to have stunted children. This finding is consistent with research conducted in different regions in Indonesia, which demonstrates that environmental factors such as clean water sources play a significant role in the incidence of stunting in children.[19,33,34] A further analogous study conducted in rural Ethiopia demonstrated that when access to clean drinking water sources is unavailable, the advantages of soap may not be realised. This may indicate the additional value of access to clean water and hygiene and handwashing practices in communities with unsafe sanitation facilities.[35]

The results of the Receiver Operating Characteristics (ROC) analysis in this study show that the predictive index of stunting has a sensitivity and specificity of 31%, which means that the ability of this model to identify children under five who are truly stunted among the stunted population and those who are not stunted among the non-stunted population is 31%. Despite these low sensitivity and specificity values, this approach remains relevant as a first step in understanding the determinants of stunting at the local level. Previous studies support the importance of using ROC analysis in predicting stunting risk. Research in Africa shows that the use of appropriate variable selection methods can improve the discrimination ability of the model, as indicated by Area Under the Curve (AUC) values of up to 64% in stunting risk prediction.[36] In addition, research in China confirmed that the combination of LASSO regression and binary logistic analysis can produce a more robust prediction model with external validation showing an AUC of 73.4%, especially when involving multidimensional predictor variables such as parenting and environmental factors.[37] This combination of approaches can serve as a reference for developing more accurate models in the future.

This study has several strengths and limitations. The strengths of this study are that the use of Receiver Operating Characteristics (ROC) curve analysis provides an accurate quantitative approach to evaluate the sensitivity and specificity of stunting predictors, while enabling the development of applicable predictive indices. In addition, the multidimensional approach integrating maternal, child and environmental factors provides a comprehensive picture of the determinants of stunting. However, the low sensitivity and specificity (31%) observed in the ROC analysis suggest that the model's ability to correctly classify stunted and non-stunted children is limited. This could be due to several factors, including the complexity of stunting as a multifactorial condition that may not be fully captured by the selected variables.[38] Additionally, factors such as sample size, data quality, or even the homogeneity of the study population could influence the model's performance.[39] Previous studies have also reported similar challenges in predictive modeling for stunting, where the inclusion of more diverse variables or the application of alternative methodologies could potentially improve predictive accuracy.[40]

This study also has limitations: firstly, the findings may be less generalizable because the study was conducted in one specific location and over a limited period of time; secondly, this study also focused more on identifying determinants rather than exploring causal relationships, so the analysis is still descriptive. Nonetheless, this study is a strong first step to support stunting control efforts at the local and national levels.

CONCLUSION

The incidence of stunting in children under five years old is caused by birth spacing < 24 months, a history of non-exclusive breastfeeding, a history of incomplete immunization, a history of infectious disease, and an inadequate drinking water source, where the probability of the child experiencing stunting is 93.2%. It is therefore recommended that policy makers and stakeholders strengthen prevention and promotion strategies during prenatal, antenatal and postnatal periods so that malnutrition can be addressed. Specifically, policies should focus on: (1) expanding access to family planning services to ensure optimal birth spacing, (2) integrating exclusive breastfeeding education into maternal and child health programs, (3) strengthening immunization coverage through community-based outreach programs, and (4) improving access to clean water and sanitation infrastructure in high-risk areas. In addition, the public health sector also needs to increase public awareness of early detection of malnutrition in the first two years of life.

AUTHOR CONTRIBUTIONS

Ade Elvina: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft. **Sari Widyaningsih**: Methodology, Investigation, Data curation, Writing – review & editing. **Rismayani Rismayani**: Investigation, Data curation, Validation, Writing – review & editing. **Herlinda Herlinda**: Investigation, Resources, Data curation, Writing – review & editing. **Dita Selvianti**: Formal analysis, Visualization, Validation, Writing – review & editing. **Ismirati Ismirati**: Investigation, Resources, Writing – review & editing. **Agung Sutriyawan**: Supervision, Conceptualization, Methodology, Project administration, Writing – review & editing.

ETHICAL CONSIDERATION

This study received ethical approval from the Health Research Ethics Committee, Bhakti Kencana University, with protocol/approval number 035/09.KEPK/UBK/VII/2024, approved on 17 February 2024.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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