

Multifactorial Predictors of Stunting Among Children Under Five Years: Evidence from Batanghari District, Jambi, Indonesia

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ABSTRACT

Stunting is a public health problem with a high prevalence in Indonesia. The Batanghari District has a stunting rate of 26.3%, exceeding the national target; however, specific regional determinants have not been comprehensively identified. This study aimed to identify multifactorial predictors of stunting in children under five years in Batanghari District. A cross-sectional study was conducted in Batanghari District from August to October 2024, involving 64 children aged 0–60 months selected through purposive sampling. Data were collected via structured questionnaires, anthropometric measurements via WHO standards, and 24 h dietary assessment food recall. Stunting was defined as a height-for-age z score < -2 SD. For statistical analysis, binary logistic regression was used to calculate odds ratios (ORs) and 95% confidence intervals (CIs). The prevalence of stunting was 70.3% (n=45). Inadequate energy density was the strongest predictor (OR = 11.389; 95% CI: 2.906–44.627; p < 0.001), followed by poor drinking water quality (OR = 8.705; 95% CI: 1.668–45.445; p = 0.004), history of problematic pregnancy (OR = 8.250; 95% CI: 0.799–85.165; p = 0.041), poor type of food (OR = 5.123; 95% CI: 1.449–18.110; p = 0.011), calcium density (OR = 4.242; 95% CI: 1.181–15.234; p = 0.021), income below the regional minimum wage (OR = 3.681; 95% CI: 1.146–11.832; p = 0.025), and authoritarian parenting (OR = 3.523; 95% CI: 1.056–11.762; p = 0.036). These findings suggest that stunting in Batanghari District is associated with a complex interplay of nutritional deficiencies, socioeconomic factors, environmental conditions, maternal health, and behavioral factors.

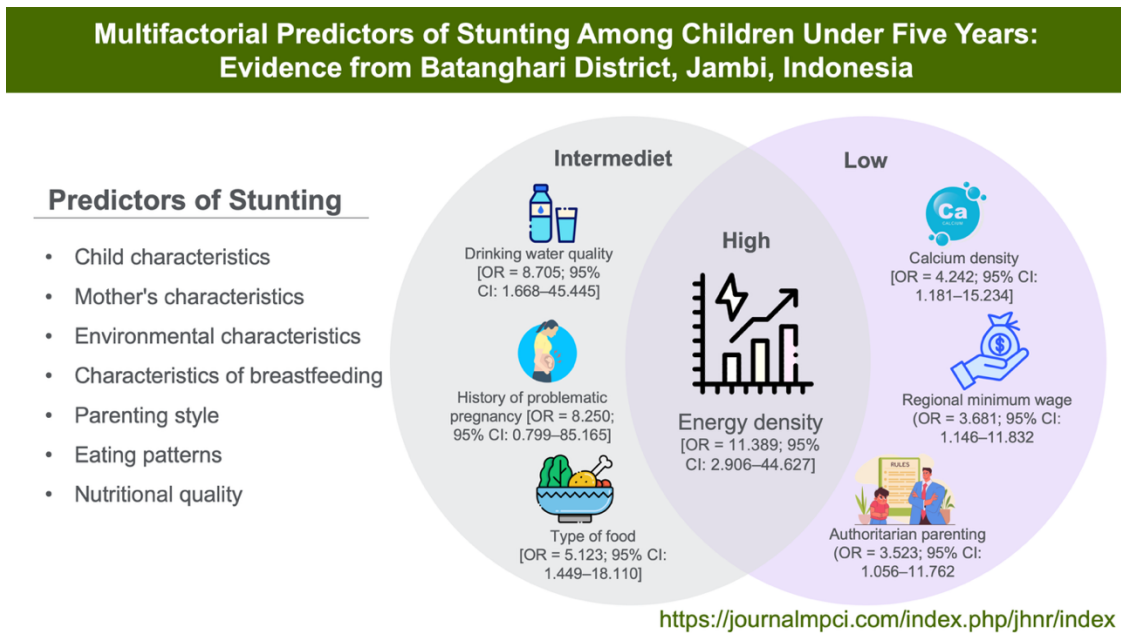
Key Messages:

- The high prevalence of stunting in Batanghari District is a complex, multifactorial issue primarily driven by inadequate dietary energy density and poor water quality, demanding comprehensive interventions that address not only nutrition but also environmental sanitation, maternal health, parenting behaviors, and socioeconomic conditions

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GRAPHICAL ABSTRACT



INTRODUCTION

Stunting is characterized by chronic linear growth impairment caused by a complex interaction between nutritional deficiencies, recurrent infections, and inadequate psychosocial stimulation during critical periods of child growth, making it a global problem, including in Indonesia (1). Global data show that 149.2 million children under the age of five were stunted in 2020, with 55% of cases distributed in Asia and 39% in Africa (2). Indonesia faces a significant burden of stunting, with a prevalence of 21.6% according to the 2022 Indonesian Nutrition Status Survey (SSGI), placing the country in the category of serious public health problems according to WHO standards (3). The province of Jambi recorded a stunting prevalence of 18%, with Batanghari Regency having the highest rate of 26.3%, indicating geographical disparities that require an in-depth investigation of specific regional determinants (4).

The etiology of stunting involves a multifactorial pathway that includes proximal determinants, such as inadequate nutritional intake and infectious morbidity, as well as distal determinants, including socioeconomic factors, the environment, and parenting practices (5,6). The UNICEF conceptual framework identifies three levels of causation: immediate (dietary intake and health status), underlying (household food security, care practices, health services, and a healthy environment), and basic (economic, political, and social factors) (7). Longitudinal studies have shown that the first 1000 days of life are a window of opportunity for stunting prevention, where maternal nutritional quality and infant feeding practices play a determining role (8–11). Due to poor sanitation and drinking water contamination, environmental enteropathy contributes to chronic intestinal inflammation that interferes with nutrient absorption and increases metabolic needs (12–14).

Previous studies have identified variability in the predictors of stunting across different settings, with consistent findings on family income (15), water quality and sanitation (16), and feeding practices (17). Research in Indonesia shows that the proportion of stunting variance is explained by socioeconomic factors (15–25%), the environment (8–18%), and nutrition (20–35%) (18). However, there is a knowledge gap regarding the interaction effects and relative contribution of each predictor in specific geographical contexts. A meta-analysis of Southeast Asia revealed significant heterogeneity in effect size, indicating the need for context-specific analysis to identify local determinants (19–21). The limitations of existing research include a focus on single-factor analysis, inadequate sample size for multivariable modeling, and limited assessment of dietary quality using objective nutritional indicators (22).

This study aimed to identify the multifactorial predictors of stunting in children aged 0–60 months

in the Batanghari District through a comprehensive assessment of socioeconomic determinants, drinking water quality, and nutritional status using binary logistic regression analysis. The significance of this study lies in its evidence-based contribution to the development of targeted intervention strategies that are appropriate for local characteristics, as well as its advancement in understanding the complex interactions between multiple risk factors in rural Jambi, Indonesia. The findings of this study are expected to provide a foundation for policy formulation related to cost-effective and sustainable stunting prevention programs, with implications for health system strengthening and resource allocation optimization at the district and national levels.

METHODS

Study design and setting

This study used an analytical observational cross-sectional design to identify the multifactorial predictors of stunting in children aged 0–60 months (23). The study was conducted in the Batanghari District, Jambi Province, over three months (August–October 2024). Data were collected through the Mersam Public Health Center (PHC) using a door-to-door approach involving local *posyandu* cadres as community access facilitators. The location was selected based on the 2018 Riskesdas data, which showed a stunting prevalence of 36.2% in Jambi, and the 2022 Indonesian Nutrition Status Survey (SSGI), which showed a prevalence of 18%. The number of stunted cases in this region is relatively high and has not met the expected target values.

Population and sampling

The target population for this study was children aged 0–60 months residing in Batanghari Regency and their mothers/primary caregivers. Purposive sampling was used, considering geographical accessibility and socioeconomic characteristics (24). The sample size was calculated using the Lemeshow formula for cross-sectional studies, with a 95% confidence level and a 5% margin of error, resulting in a minimum sample size of 64 respondents ($n=64$).

Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) children aged 0–60 months based on birth certificates or child identity cards; (2) permanent residence in Batanghari Regency for at least the last 6 months; (3) mothers/primary caregivers willing to participate and sign informed consent; and (4) children in good health at the time of the anthropometric measurements. The exclusion criteria were as follows: (1) children with congenital abnormalities or chronic diseases that affect growth; (2) children with a history of major surgery in the last 3 months; and (3) families who refused to undergo complete anthropometric measurements and refused to participate in interviews and/or the research process.

Research procedure

Data collection was carried out by involving the Mersam Community Health Center *posyandu* cadres during integrated service post activities and/or mothers who did not attend the *posyandu* by visiting the community health center. The process began with socialization to the village head, community leaders, and subdistrict health workers, followed by the identification of potential respondents through postevent data. Each respondent received an explanation of the research objectives and signed an informed consent form before the interview. The enumerator team comprised certified nutritionists and trained midwives who had undergone training in a standardized research protocol.

Research instruments

The research instrument used a structured questionnaire that was adapted to the research needs based on the available literature. All elements of the questions underwent validity and reliability tests to confirm the accuracy of each item. The questionnaire covered seven domains: (1) child characteristics (child's age (months), height (cm), weight (kg), upper arm circumference (cm), birth weight (kg or grams converted)); (2) mother characteristics (mother's age (years), number of children (persons), highest level

of education, occupation, pregnancy history (problems or no problems), socioeconomic status including family income (above or below the regional minimum wage in Batanghari district), and working hours); (3) environmental conditions (drinking water sources and sanitation. Drinking water sources were categorized as follows: (1) self-processed water, defined as water obtained from wells, municipal water supplies (PAM), or other sources and subsequently treated within the household through boiling, filtering, or other purification methods; and (2) refillable drinking water, defined as commercially packaged drinking water purchased in refillable containers from certified water depot facilities.); (4) parenting patterns (using the Parenting Style Questionnaire-short form with the results converted to a 4-point scale of always, often, sometimes, and never); (5) dietary patterns (dietary diversity score based on WHO/UNICEF guidelines); and (6) nutritional quality (energy, protein, and calcium density) using a 24 h food recall.

Parenting style was assessed using the Parenting Style Questionnaire-Short Form (PSQ-SF) developed by Robinson et al. (25), which has been validated in multiple cultural contexts, including Southeast Asian populations ($A = 0.78-0.82$) (25,26). The instrument comprises 32 items across three domains: democratic (11 items), authoritarian (12 items), and permissive (9 items), scored on a 4-point Likert scale (1 = never, 2 = sometimes, 3 = often, and 4 = always). Total scores for each parenting style were calculated and dichotomized based on established normative cut-offs: scores $\geq 76\%$ of the maximum possible score were classified as 'good', while scores $< 76\%$ were classified as 'insufficient', consistent with the classification thresholds used in previous Indonesian child nutrition studies (27,28).

Data collected

Anthropometric measurements included height using a SECA 416 infantometer (0.1 cm precision) for children < 24 months, a SECA 213 portable stadiometer for children ≥ 24 months, and weight using a SECA 874 digital scale (0.1 kg precision). The mid-upper arm circumference was measured using a non-stretchable MUAC tape at the midpoint between the acromion and olecranon. Dietary assessment data were collected through 24-hour food recall using food models and household measurements for accurate portion estimation. Food composition analysis was performed using the 2017 Indonesian Food Composition Table (TKPI) and the USDA Food Composition database for foods not listed in the TKPI.

Data extraction and statistical analysis

Continuous variables were dichotomized using clinically relevant and literature-based cut-off values. Maternal age was categorized as ≤ 30 years versus > 30 years based on the WHO classification of reproductive age and previous studies identifying increased nutritional risk in younger mothers (1). Energy density thresholds followed the WHO complementary feeding guidelines (≥ 1.6 kcal/g for adequate density) (29). Calcium density cut-offs (< 500 mg versus $\geq 500-800$ mg) were established according to the recommended dietary allowances for children aged 0-60 months (30). Income categorization used the 2024 Batanghari District Regional Minimum Wage (IDR 3,234,535) as the reference threshold, consistent with the Indonesian national poverty assessment methodology.

Children's nutritional status was classified based on the 2006 WHO Child Growth Standards using height-for-age z scores, with stunting defined as $HAZ < -2$ SD. All data were tabulated and converted into 2×2 categories for further analysis. For the univariate analysis, descriptive statistics were used to characterize the sample, whereas for the bivariate analysis, the chi-square test was used for categorical variables. For multivariate analysis, binary logistic regression with the backward likelihood ratio method was used, and odds ratios (ORs) and 95% confidence intervals (CIs) were reported. The analysis was performed using IBM SPSS Statistics version 29.0, with a significance level of $\alpha = 0.05$. Missing data were handled via pairwise deletion to minimize selection bias, with a proportion of missing data of $< 5\%$ for all key variables. All data are presented in tables and narratives.

Ethical considerations

This study was approved and met the ethical requirements of number 1293/UN.21.8/PT.01.04/2025 issued by the Health Research Ethics Committee (KEPK) of the Faculty of Medicine and Health Sciences, Universitas Jambi. All respondents who participated in this study signed a

letter of consent for the limited use of their data through informed consent.

RESULTS

Profile of the participants

This study involved 64 respondents from the Batanghari District in Jambi City (**Table 1**). The findings revealed that most of the respondents were > 12 months old (73.4%), with a height of ≥50 cm (70.3%) and a weight of ≤12 kg (78.1%). Upper arm circumference >12.5 cm was found in 67.2% of the children, and birth weight >2.5 kg was recorded in 70.3% of the respondents. The age distributions of the children in the stunted and non-stunted groups differed, with a greater proportion of children >12 months of age in the stunted group (77.8%) than in the non-stunted group (63.2%). The profile of maternal characteristics revealed that 60.9% were aged ≤30 years, with ≤3 children in 93.8% of cases. The educational level of mothers was dominated by elementary and secondary school graduates (71.9%), with 75% of them being unemployed. Most families worked ≤8 h/day (84.4%) with incomes below the regional minimum wage (73.4%) in the Batanghari district. A history of problematic pregnancies was reported by 6.3% of the respondents, with a greater distribution in the non-stunted group (15.8%) than in the stunted group (2.2%).

The environmental conditions provided adequate sanitation access, with 96.9% of the population using toilets and septic tanks for fecal disposal and waste management. Drinking water sources were dominated by self-processed water (84.4%), boiled or filtered via machines, although 15.6% of the participants relied on refillable water. Breastfeeding practices were associated with a high rate of exclusive breastfeeding (84.4%), with an almost equal distribution between the stunted and non-stunted groups. A breastfeeding duration of ≤12 months was recorded for 51.6% of respondents. Iron supplementation during breastfeeding was practiced by 37.5% of mothers, whereas iron tablet consumption by children reached 56.3%, with a greater proportion in the non-stunted group (73.7%) than in the stunted group (48.9%). The majority of parents applied parenting styles that were categorized as inadequate for all types: democratic (75%), authoritarian (76.6%), and permissive (60.9%). The distribution of parenting styles between the stunted and non-stunted groups was relatively uniform. In terms of children's eating patterns, 65.6% consumed poor food types, and 67.2% had irregular eating schedules. Nutritional quality showed widespread deficiencies, with low energy, protein, and calcium densities of 70.3%, 59.4%, and 71.8%, respectively.

Table 1. Characteristics of respondents based on predictors of stunting (n=64)

Variable	Nutritional Status		Total (n=64) n (%)
	Stunting (n=45) n (%)	Not Stunting (n=19) n (%)	
Child characteristics			
Child's age			
≤ 12 months	10 (22.2)	7 (36.8)	17 (26.6)
> 12 months	35 (77.8)	12 (63.2)	47 (73.4)
Height			
< 50 cm	14 (31.1)	5 (26.3)	19 (29.7)
≥ 50 cm	31 (68.9)	14 (73.7)	45 (70.3)
Body Weight			
≤ 12 kg	34 (75.6)	16 (84.2)	50 (78.1)
> 12 kg	11 (24.4)	3 (15.8)	14 (21.9)
Upper arm circumference			
≤ 12.5 cm	15 (33.3)	6 (31.6)	21 (32.8)
> 12.5 cm	30 (66.7)	13 (68.4)	43 (67.2)
Birth Weight			
≤ 2.5 kg	12 (26.7)	7 (36.8)	19 (29.7)
> 2.5 kg	33 (73.3)	12 (63.2)	45 (70.3)
Mother's characteristics			
Mother's age			
≤ 30 years old	26 (57.8)	13 (68.4)	39 (60.9)
> 30 years old	19 (42.2)	6 (31.6)	25 (39.1)

Number of children			
≤ 3 person	43 (95.6)	17 (89.5)	60 (93.8)
> 3 person	2 (4.4)	2 (10.5)	4 (6.3)
Mother's education			
Elementary and Secondary School	34 (75.6)	12 (63.2)	46 (71.9)
College	11 (24.4)	7 (36.8)	18 (28.1)
Mother's occupation			
Unemployed	34 (75.6)	14 (73.7)	48 (75.0)
Employed	11 (24.4)	5 (26.3)	16 (25.0)
Length of employment			
≤ 8 h	36 (80.0)	18 (94.7)	54 (84.4)
> 8 h	9 (20.0)	1 (5.3)	10 (15.6)
Income			
< Regional Minimum Wage (IDR 3,234,535)	36 (80.0)	11 (57.9)	47 (73.4)
≥ Regional Minimum Wage (IDR 3,234,535)	8 (17.8)	9 (47.4)	17 (26.6)
History of complicated pregnancy			
No	44 (97.8)	16 (84.2)	60 (93.8)
Yes	1 (2.2)	3 (15.8)	4 (6.3)
Environmental characteristics			
Drinking Water Source			
Self-processed water	37 (82.2)	17 (89.5)	54 (84.4)
Refillable Drinking Water	2 (4.44)	8 (42.1)	10 (15.6)
Sewage Disposal Site			
Toilet	43 (95.6)	19 (100.0)	62 (96.9)
Outhouse	2 (4.4)	0 (0.0)	2 (3.1)
Final Waste Source			
Septic Tank	44 (97.8)	18 (94.7)	62 (96.9)
River	1 (2.2)	1 (5.3)	2 (3.1)
Characteristics of breastfeeding			
Exclusive breastfeeding			
No	7 (15.6)	3 (15.8)	10 (15.6)
Yes	38 (84.4)	16 (84.2)	54 (84.4)
Breastfeeding duration			
≤ 12 months	22 (48.9)	11 (57.9)	33 (51.6)
> 12 months	23 (51.1)	8 (42.1)	31 (48.4)
Iron supplementation during breastfeeding			
No	28 (62.2)	12 (63.2)	40 (62.5)
Yes	17 (37.8)	7 (36.8)	24 (37.5)
Iron tablet consumption			
No	23 (51.1)	5 (26.3)	28 (43.8)
Yes	22 (48.9)	14 (73.7)	36 (56.3)
Parenting style			
Democratic parenting style			
Insufficient (< 56-75%)	34 (75.6)	14 (73.7)	48 (75.0)
Good (76-100%)	11 (24.4)	5 (26.3)	16 (25.0)
Authoritarian parenting style			
Insufficient (<56-75%)	37 (82.2)	12 (63.1)	49 (76.6)
Good (76-100%)	7 (15.6)	8 (42.1)	15 (23.4)
Permissive parenting style			
Insufficient (<56-75%)	28 (62.2)	11 (57.9)	39 (60.9)
Good (76-100%)	17 (37.8)	8 (42.1)	25 (39.1)
Eating patterns			
Type of Food			
Insufficient (<56-75%)	37 (82.2)	5 (23.3)	42 (65.6)
Good (76-100%)	13 (28.9)	9 (47.7)	22 (34.4)
Meal Schedule			
Insufficient (<56-75%)	30 (66.7)	13 (68.4)	43 (67.2)
Good (76-100%)	15 (33.3)	6 (31.6)	21 (32.8)
Nutritional quality			
Energy Density			
Low (< 1.6 kcal/g)	41 (91.1)	4 (21.0)	45 (70.3)
Adequate (≥ 1.6 kcal/g)	9 (20.0)	10 (52.6)	19 (29.7)
Protein Density			
Low (<20 g)	25 (55.6)	13 (68.4)	38 (59.4)
Adequate (≥ 20 g)	20 (44.4)	6 (31.6)	26 (40.6)

Calcium density			
Low (<500 mg)	40 (88.9)	6 (31.6)	46 (71.8)
Adequate (≥ 500–800 mg)	11 (24.4)	7 (36.8)	18 (28.2)

Remarks: All variables are presented as frequencies and percentages. Continuous variables were dichotomized using clinically relevant cut-off points, as described in the Methods section.

Correlation of predictors of stunting with binary logistic regression

The study findings revealed that of all the respondents who met the inclusion criteria ($n = 64$), 70.3% ($n = 45$) were at risk of stunting, and 29.7% ($n = 19$) did not meet the WHO criteria for stunting (comparison of z -score values (IMT/U) ≥ -2 standard deviation (SD)) (**Table 2**). Based on these findings, the distribution of children's ages was dominated by children aged >12 months (73.4%), with a stunting prevalence of 77.8% in this group compared with 22.2% in the ≤ 12 -month group. However, this difference was not statistically significant ($P = 0.226$). A similar pattern was observed for other anthropometric parameters, such as height, weight, upper arm circumference, and birth weight, which showed an almost even distribution between the two groups without any significant differences. Furthermore, the identification of maternal factors has yielded mixed results. Maternal age, number of children, education, and occupation did not differ significantly between the stunted and non-stunted groups. However, maternal working hours showed an interesting pattern, with 94.7% of mothers working ≤ 8 h having non-stunted children, whereas only 5.3% of mothers working >8 h had non-stunted children ($p = 0.138$).

Family income was a predictor of stunting in this region (OR 3.681, 95% CI 1.146–11.832, $p = 0.025$). Families with incomes below the minimum wage (IDR 3,234,535) had a 3.68 times greater risk of stunting. The data distribution revealed that 80% of the stunted children were from low-income families, whereas 57.9% of the nonstunted children were from low-income families. In addition, a history of problematic pregnancies, such as recurrent illness, vomiting, shortness of breath, and other infectious diseases, was significantly associated with the outcomes (OR = 8.250; 95% CI: 0.799–85.165; $p = 0.041$). Despite the low prevalence (6.3%), mothers with a history of problematic pregnancies had an 8.25-fold higher risk of giving birth to children at risk of stunting.

This finding is supported by the provision of drinking water for children, which was significantly associated with stunting (OR = 8.705; 95% CI: 1.668–45.445; $P = 0.004$). The use of refillable drinking water provided protection against stunting, with 42.1% of non-stunted children using refillable water compared with only 4.4% in the stunted group. Conversely, 82.2% of the stunted children used self-processed water, which was likely processed in an unclean and inappropriate manner and contained contaminants and other pollutants. Drinking water from drinking water companies (PAM) and contaminated wells was 8.70 times more likely to cause stunting. Sanitation facilities, such as fecal disposal facilities and final waste sources, showed no significant differences, with the majority of respondents ($>95\%$) having access to proper toilets and septic systems.

Breastfeeding practices showed satisfactory results, with 84.4% of mothers practising exclusive breastfeeding. However, no significant differences were observed in exclusive breastfeeding practices, duration of breastfeeding, iron supplementation, or iron tablet consumption between the two groups. These findings indicate that mothers are consciously capable of providing breast milk to support their children's growth and development through breastfeeding. In addition, parenting styles influence stunting in children. Authoritarian parenting styles were significantly associated with stunting (OR = 3.523; 95% CI: 1.056–11.762; $P = 0.036$). Children with poor authoritarian parenting (<56 –75%) had a 3.5-fold greater risk of stunting. The data revealed that 82.2% of the children at risk of stunting had authoritarian parenting, whereas only 42.1% in the non-stunted group had good authoritarian parenting. Democratic and permissive parenting styles did not differ significantly between the two groups of parents. Poor parenting styles involving coercion and punishment, both physical and verbal, increase the incidence of child stunting.

Diet and nutritional quality are also a focus of attention for caregivers and parents of children with ASD. In this case, the type of food was significantly correlated with the incidence and risk of stunting (OR = 5.123; 95% CI: 1.449–18.110; $P = 0.011$). A good variety of food types had a protective effect, with 47.7% of non-stunted children consuming a variety of food types compared with 28.9% in the stunted group. Children at risk of stunting predominantly consume foods that are less healthy (82.2%) than non-stunted

children. Meal schedules showed no significant differences, with almost equal distribution between the two groups. The foods consumed by children are strongly associated with their nutritional quality. Our findings showed that food energy density had the strongest association with stunting (OR = 11.389; 95% CI: 2.906–44.627; $P < 0.001$).

Children with inadequate energy density (< 1.6 kcal/g) had an 11.4-fold greater risk of stunting. The data showed a sharp contrast: 91.1% of the stunted children consumed foods with low energy density, whereas 52.6% of the non-stunted children had adequate energy density. In addition, this affects calcium density, which is also significant (OR 4.242; 95% CI: 1.181–15.234; $p = 0.021$). Low calcium intake (<1500 mg) had a 4.2-fold positive effect on stunting incidence. A total of 88.9% of the stunted children and 31.6% of the non-stunted children had low calcium intake. Protein density did not significantly differ, although there was a tendency for non-stunted children to have better protein intake.

Table 2. Correlation of predictors with stunting based on binary logistic regression (n=64)

Variable	Total (n=64) n (%)	Nutritional Status		χ^2	r	p-value	OR	95% CI
		Stunting (n=45) n (%)	Not stunted (n=19) n (%)					
Child Characteristics								
Child's age								
≤ 12 months	17 (26.6)	10 (22.2)	7 (36.8)	1,464	-0.151	Ref.	0.490	0.152–1.574
> 12 months	47 (73.4)	35 (77.8)	12 (63.2)					
Height								
< 50 cm	19 (29.7)	14 (31.1)	5 (26.3)	0.147	0.048	0.701	1.265	0.381–4.200
≥ 50 cm	45 (70.3)	31 (68.9)	14 (73.7)					
Body Weight								
≤ 12 kg	50 (78.1)	34 (75.6)	16 (84.2)	0.586	-0.096	0.444	0.580	0.142–2.369
> 12 kg	14 (21.9)	11 (24.4)	3 (15.8)					
Upper Arm Circumference								
≤ 12.5 cm	21 (32.8)	15 (33.3)	6 (31.6)	0.019	0.017	0.891	1.083	0.343–3.417
> 12.5 cm	43 (67.2)	30 (66.7)	13 (68.4)					
Birth Weight								
≤ 2.5 kg	19 (29.7)	12 (26.7)	7 (36.8)	0.663	-0.102	0.416	0.623	0.199–1.954
> 2.5 kg	45 (70.3)	33 (73.3)	12 (63.2)					
Mother's Characteristics								
Mother's age								
≤ 30 years old	39 (60.9)	26 (57.8)	13 (68.4)	0.636	-0.100	0.425	0.632	0.203–1.963
> 30 years old	25 (39.1)	19 (42.2)	6 (31.6)					
Number of Children								
≤ 3 person	60 (93.8)	43 (95.6)	17 (89.5)	0.843	0.115	0.358	2.529	0.329–19.430
> 3 person	4 (6.3)	2 (4.4)	2 (10.5)					
Mother's Education								
Elementary and Secondary School	46 (71.9)	34 (75.6)	12 (63.2)	1.016	0.126	0.314	1.803	0.569–5.716
College	18 (28.1)	11 (24.4)	7 (36.8)					
Mother's occupation								
Unemployed	48 (75.0)	34 (75.6)	14 (73.7)	0.025	0.020	0.874	1.104	0.324–3.764
Employed	16 (25.0)	11 (24.4)	5 (26.3)					
Length of employment								
≤ 8 h	54 (84.4)	36 (80.0)	18 (94.7)	2,201	-0.185	Ref.	0.222	0.026–1.893
> 8 h	10 (15.6)	9 (20.0)	1 (5.3)					
Income								
< Regional Minimum Wage (IDR 3,234,535)	47 (73.4)	36 (80.0)	11 (57.9)	0.876	0.106	Ref.	3.681	1.146–11.832
≥ Regional Minimum Wage (IDR 3,234,535)	17 (26.6)	8 (17.8)	9 (47.4)					
History of Complicated Pregnancy								

No	60 (93.8)	44 (97.8)	16 (84.2)	4,197	0.256	Ref.		0.799-
Yes	4 (6.3)	1 (2.2)	3 (15.8)			0.041*	8.250	85.165
Environmental Characteristics								
Drinking water source								
Self-processed water	54 (84.4)	37 (82.2)	17 (89.5)	8,213	0.191	0.004**	8.705	1.668-45.445
Refillable Drinking Water	10 (15.6)	2 (4.44)	8 (42.1)					
Sewage disposal site								
Toilet	62 (96.9)	43 (95.6)	19 (100.0)	0.872	-0.117	Ref.		
Outhouse	2 (3.1)	2 (4.4)	0 (0.0)			0.350	-	-
Final waste source								
Septic Tank	62 (96.9)	44 (97.8)	18 (94.7)	0.408	0.080	Ref.		0.145-
River	2 (3.1)	1 (2.2)	1 (5.3)			0.523	2.444	41.238
Characteristics of Breastfeeding								
Exclusive breastfeeding								
No	10 (15.6)	7 (15.6)	3 (15.8)	0.001	-0.003	0.981	0.982	0.225-
Yes	54 (84.4)	38 (84.4)	16 (84.2)			Ref.		4.287
Duration of breastfeeding								
≤ 12 months	33 (51.6)	22 (48.9)	11 (57.9)	0.434	-0.082	0.510	0.696	0.236-
> 12 months	31 (48.4)	23 (51.1)	8 (42.1)			Ref.		2.053
Iron supplementation during breastfeeding								
No	40 (62.5)	28 (62.2)	12 (63.2)	0.005	-0.009	0.944	0.961	0.317-
Yes	24 (37.5)	17 (37.8)	7 (36.8)			Ref.		2.915
Iron tablet consumption								
No	28 (43.8)	23 (51.1)	5 (26.3)	3,338	0.228	0.068	2.927	0.903-
Yes	36 (56.3)	22 (48.9)	14 (73.7)			Ref.		9.494
Parenting Style								
Democratic parenting style								
Insufficient (< 56-75%)	48 (75.0)	34 (75.6)	14 (73.7)	0.025	0.020	0.874	1.104	0.324-
Good (76-100%)	16 (25.0)	11 (24.4)	5 (26.3)			Ref.		3.764
Authoritarian parenting style								
Insufficient (<56-75%)	49 (76.6)	37 (82.2)	12 (63.1)	4.377	0.213	0.036*	3.523	1.056-
Good (76-100%)	15 (23.4)	7 (15.6)	8 (42.1)			Ref.		11.762
Permissive parenting style								
Insufficient (<56-75%)	39 (60.9)	28 (62.2)	11 (57.9)	0.105	0.041	0.746	1.198	0.402-
Good (76-100%)	25 (39.1)	17 (37.8)	8 (42.1)			Ref.		3.570
Eating Patterns								
Type of food								
Insufficient (<56-75%)	42 (65.6)	37 (82.2)	5 (23.3)	5.770	0.304	0.011*	5.123	1.449-
Good (76-100%)	22 (34.4)	13 (28.9)	9 (47.7)			Ref.		18.110
Meal Schedule								
Insufficient (<56-75%)	43 (67.2)	30 (66.7)	13 (68.4)	0.019	-0.017	0.891	0.923	0.293-
Good (76-100%)	21 (32.8)	15 (33.3)	6 (31.6)			Ref.		2.912
Nutritional Quality								
Energy density								
Low (< 1.6 kcal/g)	45 (70.3)	41 (91.1)	4 (21.0)	14.723	0.309	<0.001**	11.389	2.906-
Adequate (≥ 1.6 kcal/g)	19 (29.7)	9 (20.0)	10 (52.6)					44.627
Protein Density								
Low (< 20 g)	38 (59.4)	25 (55.6)	13 (68.4)	0.917	0.125	0.338	0.577	0.186-
Adequate (≥ 20 g)	26 (40.6)	20 (44.4)	6 (31.6)			Ref.		1.790
Calcium density								

Low (< 500 mg)	46 (71.8)	40 (88.9)	6 (31.6)	5.255	0.192	0.021*	4.242	1.181-
Adequate (≥ 500-800 mg)	18 (28.2)	11 (24.4)	7 (36.8)			Ref.		15.234

Remarks: * (significant level $p < 0.05$), ** (significant level $p < 0.01$), ²: chi-square test, r: Pearson correlation coefficient, OR: odds ratio, CI: confidence interval, (-): cannot be calculated because one cell has a value of 0, ref.: reference category.

DISCUSSION

This study identified several predictors associated with the high prevalence of stunting, which reached 70.3% in Batanghari District, Jambi, Indonesia, above the national average. The binary logistic regression analysis revealed that family income, history of problematic pregnancies, quality of drinking water sources, authoritarian parenting, diet, and nutritional quality, including energy density and calcium, were significantly associated with the risk of stunting in children in this region.

The finding that family income below the regional minimum wage (UMR) increases the risk of stunting by 3.68 times is in line with global research confirming that poverty and food insecurity are associated with chronic malnutrition (31–35). Socioeconomic determinants are consistent with recent studies reporting economic disparities, including poverty, as a major risk factor for stunting, with an odds ratio of 1.23 (95% CI 1.04–1.47) in the Indonesian population (36) and Southeast Asia (37–39). Low family income indirectly limits access to nutritious food, especially the purchase of food with adequate energy and nutrient density, thus directly impacting children's nutritional status, quality health services, and an environment that supports optimal child growth. This is in line with findings in populations in Kenya, the UK, Ethiopia, and regions with limited and underdeveloped resources, where poor economic conditions limit adequate nutritional intake, ultimately hindering child growth and development (40–43).

A history of problematic pregnancies was associated with a high risk of stunting (OR = 8.250). Mothers with a history of recurrent illness, vomiting, shortness of breath, or infection during pregnancy had an 8.25-fold greater risk of giving birth to a stunted child. This finding indicates that maternal health during pregnancy is an important predictor of stunting, even more so than other demographic factors, such as maternal age, education level, and occupation, which were not significantly related in this study. Poor maternal health during pregnancy can cause IUGR (intrauterine growth restriction), which is associated with impaired fetal growth and continues to stunt during the postnatal period. This finding is in line with longitudinal studies in Indonesia that identified pregnancy complications as strong predictors of stunting through the mechanisms of intrauterine growth restriction and maternal nutritional deficiency (15,44–46). Maternal factors, particularly a history of problematic pregnancies, although low in prevalence (6.3%), have a significant association, reinforcing the literature that suboptimal maternal health, including infectious diseases, shortness of breath, and other comorbidities during pregnancy, can affect fetal growth and increase susceptibility to postnatal stunting (47–49).

In addition to child and maternal predictors, environmental predictors also play a role in influence stunting. This study revealed a strong association between poor-quality drinking water and self-processed water, which increased the risk of stunting by 8.70 times. Although most respondents had access to good sanitation, the use of self-processed water, which is likely to be contaminated, was associated with an increased stunting risk, whereas refillable water had a protective effect. These findings challenge the assumption that access to basic sanitation alone is sufficient; instead, the quality of the water consumed plays a critical role. This is in line with studies in Southeast Asia by Rizaldi et al. (50) Indonesia by Yuniarti et al. (51) and Nizaruddin et al. (52), Ethiopia by Kwami et al. (53) and Biruk et al. (54), and Nepal by Shrestha et al. (55), which reported that even with adequate basic sanitation, water contamination can increase the risk of developing stunting. Microbial contamination of water can cause recurrent diarrheal diseases that directly interfere with nutrient absorption in the intestines, leading to chronic malnutrition, even when food intake is adequate (56). This link between water and stunting highlights the need for interventions that focus not only on sanitation but also on clean water treatment practices at the household level, including source management and water storage.

The incidence of stunting is also influenced by parenting style, type of food consumed, and nutritional quality of the food consumed. Our findings related to authoritarian parenting styles revealed a

3.5-fold greater risk of stunting in children than those related to democratic and permissive parenting styles, which were not significantly related. Unresponsive parenting may contribute to impaired child development. Parenting patterns that tend to be coercive, with an orientation toward physical or verbal punishment, can create a stressful environment that hinders responsive feeding and reduces children's appetite (6,27,57). This finding is in line with other studies showing that chronic stress in children is linked to alterations in growth hormone regulation, which may influence linear growth trajectories (58,59). The interaction between parenting and nutrition shows that interventions for stunting must include educating parents about positive feeding practices rather than focusing solely on the type of food (27,28,60).

In terms of food type, 82.2% of the children consumed unhealthy foods and were 5.12 times more likely to experience stunting as a result of nutritional deficiencies, although this did not directly indicate a significant relationship between them. However, this was evident in the quality of nutrition received by the children. Our findings revealed that low energy density (OR = 11.389; $P < 0.001$) and calcium density (OR = 4.242; $P = 0.021$) were strong predictors of stunting, whereas protein density was not significantly different.

These findings confirm that low energy density (<1.6 kcal/g) and low calcium density (<500 mg) are the strongest predictors of stunting in the Batanghari District of Jambi Province. This is likely due to parents or caregivers prioritizing the quantity of food (e.g., carbohydrates, fats, and proteins) over its quality, resulting in children experiencing energy and micronutrient deficiencies (61,62). An unbalanced and poor-quality diet results in low energy and calcium absorption, which is required to increase immunity and support children's growth and development, leading to the risk of stunting (38,63,64).

This finding is in line with previous studies confirming that food serves as a source of specific micronutrients for preventing stunting (65–67). This finding indicates that nutritional interventions cannot focus solely on food quantity and must prioritize nutritional quality and energy density. Furthermore, although exclusive breastfeeding practices and breastfeeding duration showed good results, these findings indicate that the transition to complementary foods is not optimal and does not meet children's nutritional needs (68,69). This is in line with research in Ethiopia that reported similar results in Ethiopia (70) and sub-Saharan Africa (71).

The multifactorial determinants identified in this study operate through interconnected pathways that align with the UNICEF conceptual framework of malnutrition (2). Low family income, a distal determinant, may mediate its effect on stunting through multiple proximal pathways. Economic constraints limit household purchasing power, restricting access to nutrient-dense foods and resulting in diets characterized by low energy density (<1.6 kcal/g) and inadequate calcium intake (<500 mg/day), as demonstrated by the strong associations observed in our regression analysis (OR = 11.389 for energy density and OR = 4.242 for calcium density). Financial limitations further constrain investments in improved water infrastructure, compelling families to rely on self-processed water sources that may harbor microbiological contamination despite household treatment efforts (OR = 8.705). This environmental exposure pathway contributes to subclinical environmental enteropathy, which is characterized by chronic intestinal inflammation that impairs nutrient absorption and increases metabolic demands (14,72).

Stress associated with economic hardship may also influence parenting behaviors, potentially contributing to authoritarian parenting styles (OR = 3.523) that create feeding environments characterized by coercion rather than responsive feeding practices (6,73). Maternal health during pregnancy represents another pathway, where inadequate prenatal nutrition and infection burden in low-income settings increase the risk of problematic pregnancies (OR = 8.250), leading to intrauterine growth restriction and establishing a trajectory toward postnatal stunting (46,74). These interconnected pathways demonstrate that stunting prevention requires integrated interventions addressing both structural determinants (poverty alleviation and water infrastructure) and proximal determinants (dietary quality improvement and responsive feeding practices) simultaneously rather than isolated single-factor approaches.

Public health and clinical implications

The findings of this study have strategic implications for the development of evidence-based

stunting intervention programs in Indonesia. The magnitude of the effect of high energy density indicates the need to revise complementary feeding guidelines, with an emphasis on energy and calcium fortification through lipid-based nutrient supplements and locally fortified products. The Supplementary Feeding Program (PMT) needs to be modified with a specific target of at least 1.6 kcal/g and 500–800 mg calcium/day to achieve optimal effectiveness in preventing stunting. Determinants of drinking water quality require the integration of WASH programs with nutritional interventions through the development of cost-effective household water treatment technologies and implementation of water quality monitoring systems at the community level. The finding that authoritarian parenting is a predictor of stunting necessitates the integration of responsive feeding and positive parenting components into nutrition education programs and the development of screening tools to identify early warning signs of risky parenting practices. Clinically, the results of this study support the use of a multisectoral screening approach that integrates socioeconomic, environmental, and nutritional quality assessments into early stunting detection protocols. Healthcare providers must develop a risk stratification model based on the identified predictors to optimize resource allocation and targeted interventions in high-risk populations.

Limitations

This study has several limitations, including its cross-sectional design, which limits the ability to establish causal relationships between variables and cannot capture the temporal relationship between exposure and outcomes. The relatively small sample size (n=64) with a low prevalence of several exposures resulted in wide confidence intervals, especially for the variables of problematic pregnancy history and drinking water sources, thereby reducing the precision of the effect estimates. The method of data collection for dietary assessment through 24 h food recall has the potential for recall bias and does not reflect long-term intake variability. The measurement of parenting patterns via self-report questionnaires may be subject to social desirability bias, which affects the internal validity. This study did not measure specific micronutrient deficiency biomarkers, such as serum zinc, iron status, or vitamin D, which could provide more comprehensive information about the nutritional status of children. The analysis did not control for potential confounding variables such as birth spacing, infectious disease history, or genetic factors that could affect the growth trajectory. The generalizability of the findings is limited to rural populations with similar socioeconomic and geographic characteristics; therefore, the external validity for urban populations or other regions requires further validation.

CONCLUSION

This study identified seven independent predictors of stunting in children aged 0–60 months in Batanghari District, where the prevalence of stunting was 70.3%, exceeding the national average. Inadequate energy density was the strongest predictor, followed by poor drinking water quality and difficult pregnancy history. Socioeconomic determinants, such as income below the regional minimum wage, authoritarian parenting, poor diet, and calcium deficiency, significantly contributed to the risk of stunting. These findings confirm the multifactorial etiology of stunting, involving complex pathways between poverty and nutrition, environmental enteropathy, and stress-induced growth hormone suppression. Stunting interventions require an integrated approach that simultaneously addresses proximate and distal determinants by strengthening social safety nets, improving water sanitation infrastructure, enhancing complementary feeding quality, and promoting responsive care-giving practices. Longitudinal studies with larger sample sizes are needed to validate temporal relationships and develop more robust prediction models for implementing risk-based stunting prevention programs in Indonesia.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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