ORIGINAL ARTICLE

Identifying determinant risk factors for stunting in children under five years of age in Aceh, Indonesia: Structural equation modeling

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ABSTRACT

Background and Aim: Stunting is a major public health issue that undermines the quality of human resources. Aceh is a province with diverse community demographics, susceptibility to natural disasters, and a history of social conflict. These conditions complicate health service delivery and contribute to the persistence of stunting. However, the determinants of stunting in Aceh remain insufficiently understood. This study aims to identify effective intervention priorities for reducing stunting in Aceh.

Methods: A cross-sectional analysis was conducted using secondary data from the Indonesian Nutritional Status Survey (SSGI) in Aceh Province. The UNICEF conceptual framework guided variable selection. Structural Equation Modeling using Partial Least Squares (SEM-PLS) was applied for multivariate and hypothesis testing. The final dataset comprised 15,865 children under five years of age.

Results: SEM analysis identified six statistically significant determinants of stunting ($p < 0.001$). Birth condition was the most dominant predictor, with the highest t-statistic (t = 10,541). Strong determinants included sick condition (t = 5,887), exclusive breastfeeding (t = 5,074), pregnancy (t = 4,061), and infection (t = 3,873). The model showed an R Square ($R^2 = 0.000$ to 0.056) value, and Q Square ($Q^2 = 0.000$ to 0.032) that were very low. The Standardized Root Mean Square Residual (SRMR = 0.084) indicated good model fit, while the Goodness of Fit Index (GoF Index = 0.123) showed a low level of fit.

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Conclusions: Efforts to accelerate stunting reduction in Aceh should emphasize preventing low birth weight, strengthening early and high-quality antenatal care, reducing infectious diseases in children, promoting exclusive breastfeeding, and implementing targeted strategies to reduce stunting. (www.actabiomedica.it)

Key words: stunting, determinants, structural equation modeling, intervention priorities

Introduction

Stunting is a growth disorder in children under five, characterized by impaired height growth. It results from chronic malnutrition and recurrent disease. Malnutrition in pregnant women, especially in the first 1,000 days of life, from conception to the child's second year (1), plays a significant role. The 2022 Indonesia Nutritional Status Survey (SSGI) reported a stunting prevalence of 31.2%, which is higher than the national prevalence of 24.3% (2). UNICEF's conceptual framework categorizes the determinants of stunting into three categories: immediate determinants, underlying determinants, and enabling determinants, which encompass various factors. This framework is widely used as a guideline for addressing stunting in many countries, including its implementation in Indonesia (3). Presidential Regulation No. 72 of 2021 mandates two intervention strategies to accelerate stunting reduction, aimed at decreasing its prevalence. These include eleven specific intervention strategies for direct causes and fourteen sensitive methods for indirect causes. Numerous program performance indicators and related sectors are associated with stunting incidence (4). A study analyzed the relationship between the achievement of specific and sensitive interventions for stunting reduction in Aceh. The provision of food to pregnant women, the provision of zinc supplementation, and the implementation of health insurance were associated with stunting in 13 districts/cities in Aceh. Qualitative analysis through interviews and focus group discussions on stunting intervention policies in Aceh showed that several challenges in stunting management persist, including limited knowledge among pregnant women and their reluctance to consume iron tablets, inadequate dietary patterns during pregnancy, and insufficient support from husbands. Routine education on anemia in pregnant women is associated with reduced stunting in children (5–7). However, several studies have analyzed the relationship using a standard regression model with small sample sizes without including all districts in Aceh, limiting the examination of variable relationships. The use of structural equation modeling (SEM) enables simultaneous analysis of multiple variables by testing their relationships and combining path and regression analysis within a single model. This analysis aims to identify variables that need to be accelerated and maintained to support the stunting reduction program (8). Limited budgets for interventions necessitate the government's efforts to identify effective interventions for reducing stunting. An analysis of dominant determinant factors is essential for planning intervention activities that address root causes based on empirical evidence. We hope this study provides recommendations for policy development and strengthens specific interventions to reduce stunting in Aceh.

Participants and Methods

Study site and participants

The sample for this study was selected using stratified random sampling, targeting all households with children under 5 years old. The 2020 Population Census (SP2020) census block list served as the sampling frame. Within each selected census block, 10 households with children under 5 were selected through systematic random sampling, using random numbers generated by the Central Bureau of Statistics (BPS). The final dataset included all eligible children

under five years of age, totalling 15,865 individuals. Respondents were typically the children's mothers; however, if the mother was unavailable, another household member over the age of 17 who could represent the family was interviewed. Exclusion criteria encompassed children with physical abnormalities or conditions that could affect reliable anthropometric measurement, such as congenital malformations, disabilities, Down syndrome, tumours, or spinal deformities. Additionally, cases with incomplete interviews or inaccurate data were excluded from the analysis.

Measurement of variables

The variables measuring and operationalizing endogenous and exogenous/latent variables were analyzed using formative models (Table 1).

Adaptation of UNICEF's conceptual framework suggests that various determinants contribute to stunting. These Immediate determinants include: breastfeeding, feeding, pregnancy, birth, illness, and infection. Underlying determinants include: sanitation, health service, family condition, and health insurance (9). Ethical research approval for this study was obtained by the Health Research Ethics Committee at the Faculty of Medicine, the University of Syiah Kuala, Registration Number: 063/EA/FK/2024.

Statistical analysis

Statistical data processing and analysis were performed using SmartPLS version 4.1.0.3. SmartPLS was employed to assess complex relationships among multiple variables, allowing the simultaneous examination of immediate, underlying, and enabling determinants. This multivariate approach enabled the estimation of both direct and indirect effects within a predictive and exploratory structural model. Using secondary data and adapting the UNICEF conceptual framework with many variable selections may have reduced the model's predictive capability. The study describes model associations rather than causal determinants of stunting.

Model evaluation in PLS included assessments of model fit, structural model fit, and overall goodness-of-fit. The outer model evaluation focused on formative measurement models, with sample adequacy confirmed using the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests. The cut-off values applied in this study were Outer Loading (OL) ≥ 0.50, Composite Reliability (CR) ≥ 0.60, and Average Variance Extracted (AVE) ≥ 0.50. Collinearity was assessed using the Variance Inflation Factor (VIF), while discriminant validity was evaluated using the Fornell–Larcker criterion and cross-loadings. Collinearity assessment based on inner VIF values < 5 indicated that parameter estimates were not biased. Hypothesis testing was performed using a bootstrapping procedure with 5,000 iterations, and missing data were handled using the mean replacement method. Model adequacy was evaluated using R-squared, Q-squared, SRMR, PLS Prediction, and the Goodness-of-Fit (GoF) Index. R-squared values represented the explained variance of endogenous constructs; Q-squared values assessed predictive accuracy; the Standardized Root Mean Square Residual (SRMR) measured model fit by comparing observed and predicted correlation matrices; and the GoF Index provided an overall evaluation of both the measurement and structural models.

Results

Characteristics respondent

Respondents in this study were parents of children under five in the selected households as sample households from the 2022 Indonesia Nutritional Status Survey (INSS). The characteristics of the respondents are described by category of age, gender, father's education, father's occupation, and mother's occupation (Table 2).

Model fit evaluation

Outer model evaluation indicated acceptable indicator performance, with Outer Loadings ranging from 0.642 to 0.985, AVE from 0.500 to 0.968, and CR from 0.667 to 0.984. Inner VIF values were <5, indicating no multicollinearity. Model fit evaluation and inner model measurements were performed using bootstrapping with 5,000 iterations, and missing data were handled through mean replacement. R-squared

Table 1. Variable measurement and definition operational.

Dependent Variable		
Stunting	Growth disorders, chronic malnutrition in children	Anthropocentric measurements using the Height for Age index with a Z-score cut-off <-2SD of WHO Growth Charts
Independent Variable		
Latent Variable	**Observed Variable**	**Definition Operational**
Breast feeding	Early initiation of breastfeeding	History of initiation of breastfeeding: whether initiated or not
	Exclusive Breastfeeding	Exclusive Breastfeeding: < 6 or ≥ 6 month
Feeding	Age of complementary feeding	Age at introduction of complementary feeding: < 6 months or ≥ 6 months
	Milk formula	Age at first receiving formula milk: < 6 months or ≥ 6 months
	Diverse feeding	Dietary diversity: < 5 or > 5 food groups
Pregnancy	Antenatal Care (ANC)	Antenatal care during pregnancy: whether or not
	First Time ANC	First time doing it ANC, first-trimester, second-trimester, third-trimester
	Nutritional status pregnancy	Nutritional Status pregnancy (IMT): <18,5, 18,5-25,0, and ≥ 25,0 kg/m²
	Getting iron supplements	Getting iron supplement tablets: whether or not
	Consumption of iron supplements	Consumption of iron supplement Tablets: < 90 tablets or > 90 tablets
Birth	Low Birth Weight	Births Weight Status: < 2.5 or ≥ 2,5 kg
	Birth length	Baby's body length: < 48 cm or ≥ 48cm
	Aterm	Gestational age at birth: < 37 or ≥ 37 weeks
	Gender	Sex: male or female
Sick	Acute Respiratory Infection (ARI)	Diagnosed with diarrhea in the last month: whether or not
	Diarrhea	Diagnosed with ARI in the last month: whether or not
Infection	Measles	Diagnosed with Measles in the last year: whether or not
	Worm infection	Diagnosed with worm infection in the last year: whether or not
	Pneumonia	Diagnosed with pneumonia in the last year: whether or not
	Tuberculosis	Diagnosed with tuberculosis in the last year: whether or not
Sanitation	Drink water	Water sources of drinking: bottled water, Refillable Water, Regional Drinking Water Companies, Public Hydrants, Water Terminals, Rainwater, Springs, Dug Wells, Drilled Wells, and Surface Water.
	Daily water	Primary water used daily for: bathing, washing, Regional Drinking Water Companies, Public Hydrants, Water Terminals, Rainwater, Springs, Dug Wells, Drilled Wells, and Surface Water
	Fecal disposal	Household fecal disposal facilities: no facility, not used, or available
	Wasted dump	Distance to rubbish or waste disposal site < 10 m or ≥10 m
	House sanitation	Household sanitation conditions: eligible or ineligible

Independent Variable		
Latent Variable	**Observed Variable**	**Definition Operational**
Health Service	Health treatments	Receiving treatment from health services : always, sometimes, or never
	Worm medicine	Receive deworming twice a year: whether or not
	Immunization	Receiving age-appropriate basic immunizations: whether or not
	Health counseling	Receiving health counseling: whether or not
	Weight monitoring	Receiving weight monitoring 8 times a year: whether or not
	Height monitoring	Receiving height monitoring twice a year: whether or not
	Vitamin A	Receiving Vitamin A supplements at least twice a year: whether or not
Family	Father's education	Father's formal education level: did not complete elementary school, completed elementary school, completed junior high school, completed senior high school, completed university
	Father's work	Father's primary type of work with the intent to obtain income: Laborer, Farmer/Fisherman, Entrepreneur, Private Employee, Civil or Servant/State-Owned Enterprise Employee/Military/ Police
	Mother's education	Mother's formal education level: did not complete elementary school, completed elementary school, completed junior high school, completed senior high school or completed university
	Mother's work	Mother's primary type of income-generating work: working or not working
Insurance	Social Insurance	Social insurance status: does not have or have
	Use of Social Insurance	Use of social insurance status: does not use or uses
	Health Insurance	Health insurance status: does not have or has
	Use of Health Insurance	Use of health insurance: does not use or uses

Table 2. Characteristics of respondents.

	Nutritional status		
Faktor	**Stunting n (%)**	**Not Stunting n (%)**	**Total n (%)**
Age			
0-5 months	217 (17.7)	1,006 (82.3)	1,223 (100)
6-11 months	292 (20.6)	1,123 (79.4)	1,415 (100)
12-23 months	1,068 (32.9)	2,178 (67.1)	3,246 (100)
24-35 months	1,179 (35.0)	2,189 (65.0)	3,368 (100)
36-47 months	1,142 (33.8)	2,232 (66.2)	3,239 (100)
48-59 months	1,025 (31.6)	2,214 (68.4)	3,239 (100)
Gender			
Man	2,625 (32.6)	5,418 (67.4)	8,043 (100)
Woman	2,298 (29.4)	5,525 (70.6)	7,822 (100)

Table 2 (*Continued*)

Faktor	Nutritional status		
	Stunting n (%)	Not Stunting n (%)	Total n (%)
Father's Education			
Not complete elementary school	229 (35.6)	415 (64.4)	644 (100)
Complete elementary school	751 (37.9)	1,231 (62.1)	1,982 (100)
Complete high school	1,102 (36.5)	1,921 (63.5)	3,023 (100)
Complete high school	1,978 (30.1)	4,585 (69.9)	6,563 (100)
Complete University	913 (25.0)	2,740 (75.0)	3,653 (100)
Father's Occupation			
Does not work	18 (29.5)	43 (70.5)	61 (100)
Laborer	547 (28.7)	1,358 (71.3)	1,905 (100)
Farmer	2,224 (36.2)	3,926 (63.8)	6,150 (100)
Self-employed	1,589 (29.0)	3,883 (71.0)	5,472 (100)
Private Employer	227 (26.2)	638 (73.8)	865 (100)
Civil Servants/Soldiers/Police	272 (19.3)	1,140 (80.7)	1,412 (100)
Mother's Occupation			
Work	3,495 (70.3)	1,457 (29.7)	4,973 (100)
Does not work	7,471 (68.6)	3,421 (31.4)	10,892 (100)

values ranged from 0.000 to 0.056, and Q-squared values from 0.00 to 0.032, reflecting limited predictive strength. The SRMR value (0.084) indicated acceptable model fit, whereas the GoF Index (0.123) suggested a low overall structural fit (Figure 1).

Hypothesis testing

Hypothesis analysis shows a significant association between birth condition, sick condition, exclusive breastfeeding, maternal pregnancy status, infection, and feeding practices with stunting. (Table 3)

Intervention recommendations

Stunting-determinant intervention programs recommended for acceleration to expedite stunting prevention efforts in Aceh include Exclusive Breastfeeding, Complementary Food Feeding, worm infection in the past year, first-time Antenatal Care, and Birth Length (Table 4).

Priority interventions for hold included are Early Initiation of Breastfeeding, Diverse Feeding, Acute Respiratory Infection, measles, Antenatal Care, Low Birth Weight Status, Availability of fecal disposal facilities, Sanitary conditions of children under five' households, worm prevention programs, vitamin A supplementation services, father's formal education, mother's formal education, Health Insurance cards, and type of health insurance (Table 5).

Discussion

Birth condition was the primary factor associated with stunting (T-stat = 10.541, $p < 0.000$). Conditions at birth, such as low birth weight (LBW), are essential variables that affect stunting. Children born with a low birth weight of less than 2,500 grams have a greater risk of being wasted and stunted. Birth condition was the strongest factor associated with stunting. Low birth weight significantly increases the risk of growth faltering. Determinants of LBW include prematurity, maternal anemia, low maternal BMI, maternal infections, and inadequate antenatal care (10,11). Sick conditions in the month preceding the survey were significantly associated with stunting ($t = 5.887$, $p < 0.001$). Frequent Acute Respiratory Infection (ARI) and prolonged diarrhea are closely related to stunting among children under five. The incidence of diarrhea in this age group

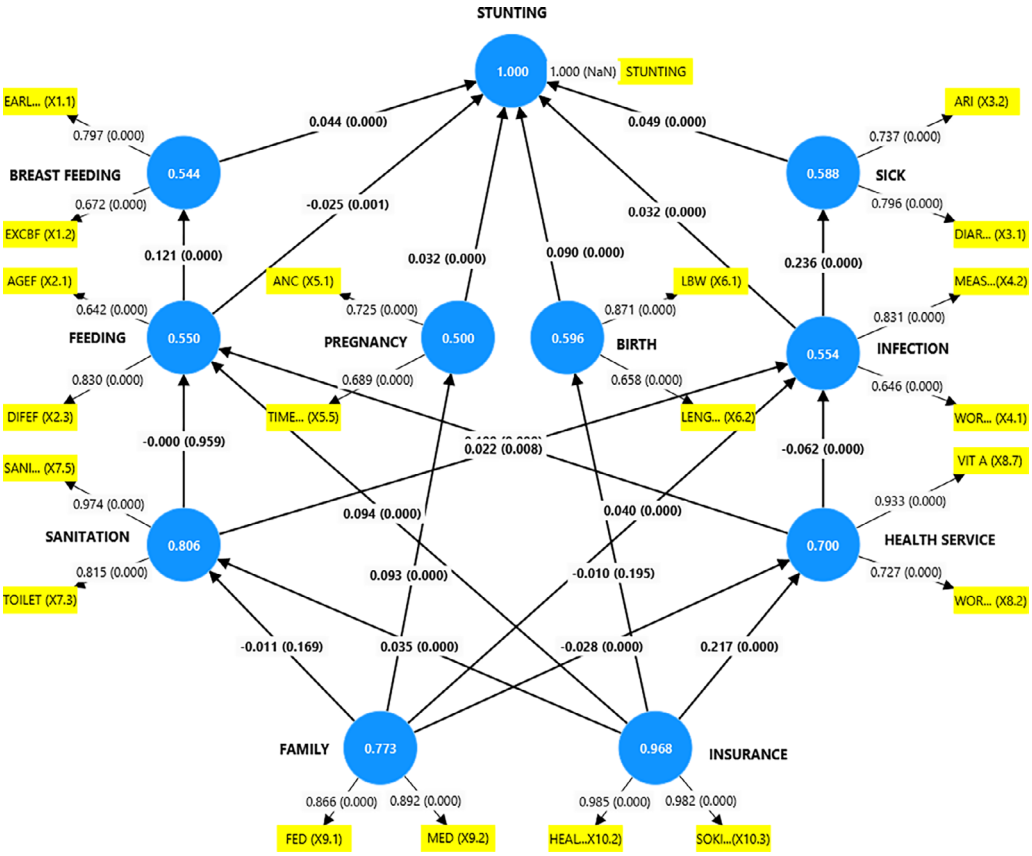

Figure 1. Exploration and evaluation of bootstrapping variable.

Table 3. Hypothesis analysis (Confidence intervals, T-statistic, P-Value, and F^2).

Variable	Confidence intervals	T-Statistic	P-Value	F^2
Birth factor	0.074 – 0.108	10.541	0.000	0.008
Sick condition	0.033 – 0.066	5.887	0.000	0.001
Breastfeeding	0.027 – 0.060	5.074	0.000	0.002
Pregnancy factor	0.017 – 0.047	4.061	0.000	0.001
Infection	0.016 – 0.047	3.873	0.000	0.001
Feeding Practices	-0.039 – -0.009	3.274	0.001	0.001

*) p-value < 0.01. All variables demonstrate a significant association with stunting.

Table 4. Stunting management intervention program to be accelerated.

Diterminant Intervention	Outer Loading*	Recommendation**
Exclusive Breastfeeding	0.672	Acceleration
Age of Complementary Food Feeding	0.642	Acceleration
Diagnosed with worms in the past year	0.646	Acceleration
First-time Antenatal Care (ANC)	0.689	Acceleration
Birth Length Status	0.658	Acceleration

*) Outer Loading < 0.700 Indicators have a weaker contribution to the construct being measured. **) Intervention recommendations for acceleration to reduce the prevalence of stunting.

Table 5. Stunting management intervention program maintained.

Diterminan Intervention	Outer Loading*	Recommendation
Early Initiation of Breastfeeding	0.797	Hold on
Diverse Feeding	0.830	Hold on
Diarrhea in the last month	0.796	Hold on
Acute Respiratory Infection past year	0.737	Hold on
Measles in the past year	0.831	Hold on
Antenatal Care (ANC)	0.725	Hold on
Low Birth Weight (LBW)	0.871	Hold on
Fecal disposal facilities in the household	0.815	Hold on
Sanitary conditions in the households	0.974	Hold on
Getting the Worm program	0.727	Hold on
Getting the Vitamin A program	0.933	Hold on
Father's formal education	0.866	Hold on
Mother's formal education	0.892	Hold on
Health Insurance card	0.985	Hold on
Type of health insurance	0.982	Hold on

*) Outer Loading > 0.700 Indicators strongly contribute to the measured construct. **) Intervention holds recommendations for acceleration to reduce the prevalence of stunting.

is closely related to hygiene and sanitation. *Shigella* is one of the pathogens most associated with diarrhea in young children and has a stronger relationship with linear growth disorders than other enteropathogens (12). Worm infections reduce appetite, increase the risk of gastrointestinal diseases in children, and contribute to delays in verbal and cognitive development (13–15). Infection conditions in the year preceding the survey are significantly associated with stunting ($t = 3.873$, $p < 0.001$). Infectious diseases combined with malnutrition increase morbidity and mortality rates. Measles, pneumonia, and tuberculosis are also associated with stunting in children under five. Severe stunting further increases the severity of pneumonia. Stunting in young children is also a determinant that can help identify tuberculosis cases. Completing basic immunization reduces the incidence of these infections and helps prevent stunting, particularly in low- and middle-income countries (16,17). Exclusive breastfeeding is significantly associated with stunting ($t = 5.074$, $p < 0.000$). Exclusive breastfeeding provides a strong protective effect against stunting. Stunting is closely associated with the absence of exclusive breastfeeding in babies aged six months (18,19). In developing and low-income settings, exclusive breastfeeding is the most effective effort to prevent stunting in children under five. Strengthening regulations and policy advocacy can improve exclusive breastfeeding coverage. However, cultural, social, and informational barriers continue to hinder breastfeeding uptake and require targeted interventions (20–22). Feeding practices are significantly associated with stunting ($t = 3.247$, $p < 0.001$). Inappropriate timing or inadequate dietary diversity also contributes to growth failure. Children who do not receive complementary breastmilk according to standard types or frequency are at greater risk of stunting. Introducing complementary foods before 4 to 6 months increases the risk of malnutrition, while delays beyond 6 months also increase stunting prevalence (23–26). Dietary diversity serves as an indicator of the quality of children's food intake, and inadequate diversity increases the risk of stunting (27). Integrated nutrition services, including nutrition education and growth monitoring through home visits, improve consumption patterns and reduce stunting (28,29). Pregnancy factors are significantly associated with stunting ($t = 4.061$, $p < 0.001$). Maternal

nutrition, anemia, young maternal age, infectious diseases, and inadequate ANC significantly affect fetal growth. High-quality ANC enables early detection and management of maternal and fetal conditions. During conception and pregnancy, the mother's nutritional status, including nutritional anemia, is closely related to fetal growth and development. Other factors influencing fetal growth include teenage pregnancy, infectious diseases, hypertension, and closely spaced pregnancies, all of which increase the risk of stunting (30). Antenatal care (ANC) is provided by healthcare professionals, including doctors, midwives, and nurses, during pregnancy. The World Health Organization (WHO) recommends the first ANC contact within the first trimester (12 weeks), with at least six visits and a minimum of two contacts with a doctor. High-quality ANC is associated with reduced infant morbidity and mortality rates. The first ANC visit provides more accurate detection of gestational age, fetal growth condition, possible congenital abnormalities, and infectious diseases (31–33).

Conclusion

This study identifies several key determinants associated with stunting among children under five in Aceh. As a cross-sectional analysis, the study describes model associations rather than causal determinants of stunting. Six key factors for accelerating the reduction of stunting in Aceh are:

1. Preventing ARI and diarrhea through improved sanitation.
2. Preventing LBW by ensuring adequate maternal nutrition and iron supplementation.
3. Reducing infectious diseases by strengthening complete immunization.
4. Improving early initiation and exclusive breastfeeding.
5. Enhancing ANC quality and timeliness.
6. Promoting diverse, age-appropriate complementary feeding.

The Government must strengthen convergence, coordination, and integration of specific and sensitive interventions to reduce stunting in Aceh.

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