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Food resources management and multilevel determinants of stunting: Insights from a national socio-ecological analysis in Indonesia

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ABSTRACT

Introduction: Factors influencing stunting are multifaceted, particularly at individual, household, and institutional levels. However, Indonesia's significant research gap regarding integrating these ecological levels in stunting prevention efforts remains. Therefore, the present study analysed individual (children and mothers), household, and healthcare service factors contributing to stunting. **Methods:** The study design was an ecological study using secondary data from 2023 Indonesian Health Survey in Numbers report (response rate: 98.74%). The dataset consisted of 38 units of analysis representing Indonesia's provinces. This study applied the socio-ecological model (SEM), which illustrates United Nations Children's Fund (UNICEF) Conceptual Framework on Maternal and Child Nutrition. The analysis employed Pearson's correlation tests, followed by linear regression, with a 95% significance level (α=0.050). **Results:** Results showed that stunting in Indonesia remained above the 14% national target for 2024, with a prevalence of 21.5% in 2023. Preventing stunting requires minimising risks within food resource management and public health services. The model explained 99.2% of stunting determinants, aligning with UNICEF's Conceptual Framework, using SEM to analyse direct, indirect, and fundamental causes. Furthermore, food consumption and infection status were direct causes shaped by regional food ecosystems, while environmental health and public health services were crucial indirect factors. Socio-economic disparities also contributed to better healthcare and economic conditions in Western Indonesia, while stunting prevalence remained higher in Eastern Indonesia. **Conclusion:** Strengthening cross-sectoral programme synergies targeting children, mothers, households, and institutions is essential for a comprehensive and sustainable approach to stunting reduction.

Keywords: determinant, food resources management, socio-ecological model, stunting

INTRODUCTION

Food consumption is pivotal in managing food resources, particularly within sustainable management practices aimed at improving nutritional status and promoting health. This is highlighted in the second goal of the Sustainable Development Goals (SDGs), which advocates for zero hunger and improved nutrition globally. The United Nations Children's Fund (UNICEF) Conceptual Framework on Maternal and Child Nutrition in 2021 also emphasises food consumption as a direct determinant

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influencing nutritional status, contributing to malnutrition, besides other essential factors, such as public health situation as an indirect factor and ecological situation as a fundamental determinant. Therefore, factors influencing stunting are multifaceted, particularly in developing countries; other than individual consumption, factors at the individual (Santosa *et al.,* 2022), household (Yani *et al.,* 2023), and institutional levels (Azriani *et al.,* 2024) must also be considered. The complexity calls for an ecological approach, with a socio-ecological model (SEM) used to explore the layered causes of stunting. However, in Indonesia, a major research gap remains in integrating these levels into stunting prevention efforts.

Infectious diseases are critical direct determinants of stunting among children in Indonesia (Audiena & Siagian, 2021). Furthermore, maternal health status also directly influences the growth and development of a child in lower- and middle-income countries (Santosa *et al.,* 2022). A systematic review identified the main phases requiring optimal maternal roles to prevent stunting in children during the first 1,000 days of life; these include complying with maternal, foetal, infant, and child nutrition; carrying out early breastfeeding initiation, exclusive breastfeeding, and appropriate complementary feeding; optimising the environment for child development; optimising family support; and avoiding various psychosocial factors that can be detrimental during growth and child development (Saleh *et al.,* 2021). In addition, household-level variables play crucial roles, as families in many rural or impoverished areas of South and Southeast Asia face challenges, such as lack of clean water, which heighten the risk of stunting (Rahut *et al.,* 2024).

The availability and quality of public health services are often overlooked in stunting research. Maternal and child health (MCH) programmes, immunisations, and nutrition interventions are vital in preventing stunting. Nevertheless, access to these services is uneven across Indonesia, particularly in remote regions (Mahendradhata *et al.,* 2017). For instance, a study in East Nusa Tenggara revealed that limited healthcare facilities and a shortage of trained healthcare professionals (Suhardin *et al.,* 2024) and healthcare insurance coverage were significant contributors to the high rates of stunting in the region (Picauly *et al.,* 2024).

Beal *et al.* (2018) reviewed stunting factors, including household factors and community factors. However, these factors were not specifically listed in the framework but were added under the most relevant sub-elements. Hurun *et al.* (2024) found that several risk factors significantly contributed to stunting in children aged 6–36 months in Indonesia, including low birth weight (p<0.050), lack of exclusive breastfeeding (p<0.010), inappropriate complementary feeding (p<0.010), history of infectious diseases (p<0.010), maternal knowledge (p<0.001), and family income (p<0.050). Among these, maternal knowledge was found to be the most dominant factor in the multivariate analysis (p<0.001). However, both studies did not explore household variables, particularly housing quality (adequate housing) and food consumption.

Empirical evidence suggests that inadequate consumption of nutritionally diverse foods significantly contributes to stunting. Sari *et al.* (2024) stated that excessive reliance on staple foods without adequate protein intake and a diverse food intake leads to nutrient insufficiency, a direct cause of children's stunting. Similarly, Mahfouz *et al.* (2021) consistently underscore that inadequate dietary practices and monotonous food consumption can lead to significant deficiencies in essential vitamins and minerals, adversely affecting children's growth and overall health.

A previous report (the 2023 Thematic Indonesia Health Survey) published by the Ministry of Health, particularly concerning the nutritional status of children under five, descriptively outlined several factors contributing to stunting, including maternal factors (during the prenatal period, birth, and postnatal care) and household factors (access to drinking water, hygiene, and suitable housing) (Ministry of Health, 2024a). However, key analytical gaps remain, especially in aligning the management of food and nutrition resources alongside health and healthcare services, such as immunisation delivery, growth monitoring, complementary feeding (local-based and animal-based), dietary diversity, waste management, household-level food consumption, appropriate stunting knowledge, and socio-economic determinants. The present study addressed these gaps using a SEM approach to infer multilevel interactions across individual, household, and institutional levels.

Most studies have examined isolated determinants without considering their interactions across ecological levels. In contrast, this study adopted a multilevel approach, grounded in the UNICEF Conceptual Framework on Maternal and Child Nutrition, to address the root causes of stunting within the local context. It highlighted links among immediate, underlying, and fundamental determinants, incorporating key variables absent from the 2023 Thematic Indonesia Health Survey. Using a socio-ecological lens, the study analysed individual (child and mother), household, and healthcare service factors contributing to stunting in Indonesia.

METHODOLOGY

This was an ecological study using secondary data from the 2023 Indonesian Health Survey in Numbers report (SKI) (Ministry of Health, 2024b). The dataset consisted of 38 analysis units. Each unit represents one of Indonesia's provinces. SKI is a comprehensive national survey assessing population health and nutrition. It sampled 315,646 regular households and 284,117 with children under five, totalling 1,191,692 respondents. Data were collected by local enumerators under technical and administrative supervision, achieving a high response rate of 98.74%. The process included household updating, interviews, measurements, and examinations to ensure representativeness and reliability. Ethical approval was granted by the Ethics Committee of Poltekkes Kemenkes Jakarta II (LB.02.01.I/KE/L/287/2023). All participants provided their agreement through informed consent and assent, and secondary data were used.

This study applied the SEM, which highlights the interconnected roles of individuals and systemic structures according to the UNICEF Conceptual Framework on Maternal and Child Nutrition. The study analysis of forty-one independent variables, including 20 individual-level variables (child and mother), 17 household-level variables, and four institutional-level variables, was highly relevant to the field of public health. At the individual level, particularly for children, the health services component consisted of 9 variables, the food consumption and nutrition component represented 17, and three variables related to infection status. The food consumption and nutrition component consisted of 3 variables at the maternal individual level. At the institutional level, there were

Institutional Factors		Household Factors		Individual Factors	
Health services	Assistance during childbirth (X38)	Socio-economic	Middle-high economic status (X21)	**Child**	
	Complete antenatal care (X39)		Access to primary health care (X22)	Health services	Completeness MCH handbook (X1)
	Complete postnatal care (X40)		Appropriate knowledge of stunting (X23)		Low birth weight (X2)
Health financing	Health insurance ownership (X41)	Food consumption	Consumption of cereals (X24)		Normal birth history (X3)
			Consumption of tubers (X25)		Complete basic immunization (X4)
			Consumption of legumes (X26)		Complete advanced immunization (X5)
			Consumption of meat and poultry (X27)		Complete new antigen immunization (X6)
			Consumption of fish (X28)		Weight monitoring (X7)
			Consumption of eggs (X29)		Length and height monitoring (X8)
			Consumption of milk (X30)		Growth monitoring (X9)
		Environmental health	Access to safe drinking water (X31)	Food consumption and nutrition	Complementary feeding (X10)
			Proper waste management (X32)		Local-based food complementary feeding (X11)
			Availability of handwashing facilities (X33)		Animal-based food complementary feeding (X12)
			Availability of running water (X34)		Minimum dietary diversity (X13)
			Access to basic hygiene (X35)		Vitamin A supplementation (X14)
			Adequate houshing (X36)	Infection status	Prevalence of diarrhoea (X15)
			Access to adequate sanitation (X37)		Prevalence of ARI (X16)
					Prevalence of pneumonia (X17)
				Mother	
				Food consumption and nutrition	Supplementary feeding for pregnant women (X18)
					Iron and folic acid supplementation (X19)
					Chronic energy deficiency prevalence (X20)

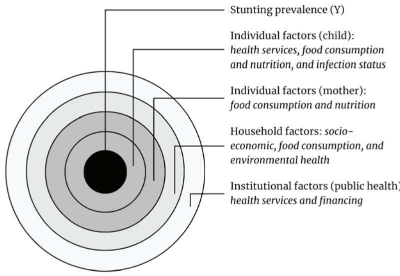

Figure 1. Determinants of stunting prevalence using the socio-ecological model (SEM)

components such as socio-economic status (3 variables), food consumption (7 variables), and environmental health (7 variables).

The variable "access to primary health care" was particularly noteworthy as it defined socio-economic status through factors such as the availability of transportation, associated costs, and distance to healthcare facilities. The "appropriate stunting knowledge" referred to family members who accurately understood the definition of stunting as having a low height for one's age, representing a social variable. Furthermore, at the institutional (public health) level, there were components related to health services (3 variables) and one variable on health financing, specifically health insurance ownership.

Figure 1 presents the variables analysed at each level, conceptualised through the socio-ecological framework. Multivariate analysis was performed to assess the influence of multiple factors simultaneously. Linear regression analysis was applied to identify the strength and direction of the associations between independent variables and the dependent variable, as well as stunting prevalence, with a significance level set at 95% (α=0.050). Statistical analysis was performed using SPSS Inc. 2007 (Statistics for Windows, Version 16.0 [Computer software], Chicago, IL: SPSS Inc).

RESULTS

The prevalence of stunting in Indonesia, as reported by SKI, stood at 21.5% (2023). Among the 38 provinces, 23 exhibited stunting prevalences above the national average. Provinces with the highest prevalences were Central Papua (39.3%), East Nusa Tenggara (37.9%), and Highland Papua (37.3%), while Bali recorded the lowest prevalence at 7.2%, followed by Jambi (13.5%) and Riau (13.6%) (Figure 2). Geographical disparities were evident, with the highest rates concentrated in Eastern Indonesia and the lowest predominantly in the western regions.

Table 1 outlines the general characteristics of the study variables, classified according to levels of the socio-ecological model. Significant variations existed in Indonesia's health indicators at the individual, household, and institutional levels, reflecting diverse regional and socio-economic conditions.

At the individual level (child), significant factors negatively correlated

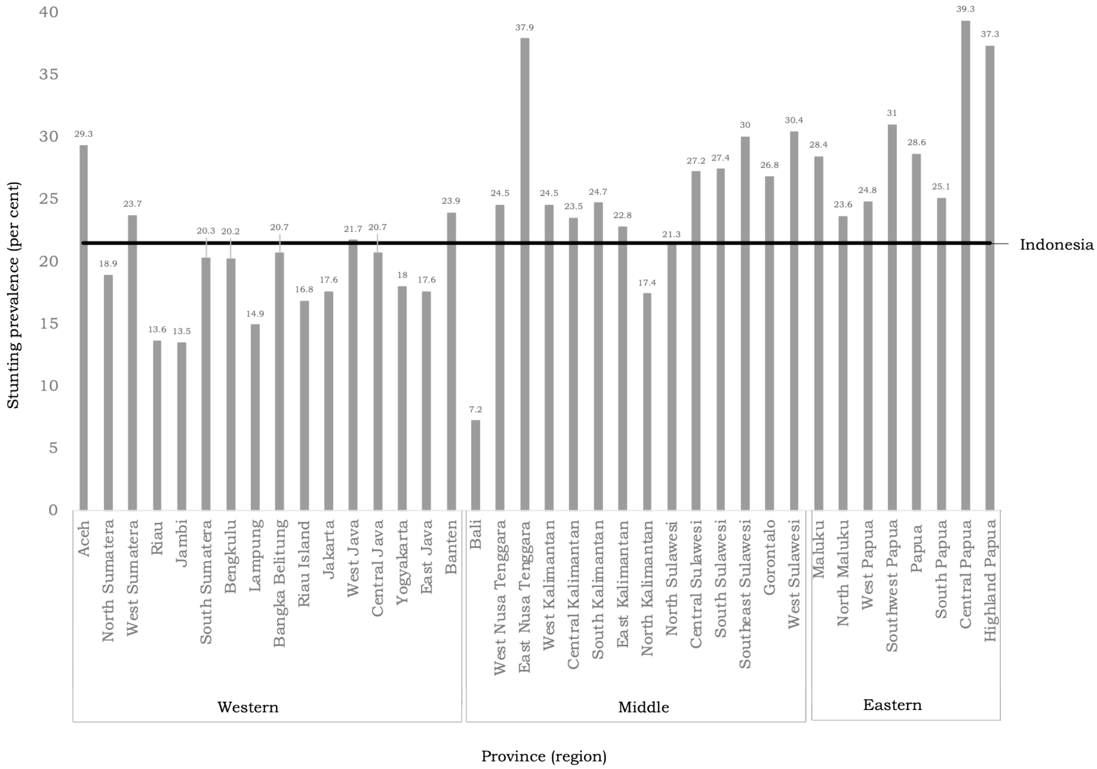

Figure 2. Stunting prevalence in Indonesia by province

with stunting prevalence included completeness of the MCH handbook (r=-0.353, p<0.050), full-term birth (37–42 weeks; r=-0.625, p<0.001), complete immunisation (basic, advanced, and PCV; r=-0.521, r= -0.521 to -0.599, p<0.010), regular weight and height measurements (r=-0.516, p<0.01; r=-0.458, p<0.010), growth monitoring (r=-0.321, p<0.50), animal-based complementary feeding (r=-0.676, p<0.001), minimum dietary diversity (r=-0.587, p<0.001), and vitamin A supplementation (r=-0.391, p<0.050). Conversely, low birth weight (r=0.493, p<0.010), diarrhoea (r=0.530, p<0.010), and pneumonia (r=0.408, p<0.050) were positively correlated with stunting prevalence. Moreover, pneumonia and diarrhoeal diseases were direct causes contributing to stunting, consistent with UNICEF's identification of infection as a primary determinant of stunting. At the maternal level, consuming iron and folic acid (IFA) supplementation (r=-0.491, p<0.010) was a significant negative correlation. In addition, chronic energy deficiency prevalence was a significant positive correlation (r=0.424, p<0.010).

At the household level, strong negative correlations were observed between stunting prevalence and middle–high economic status (-0.566, p<0.001), access to primary health care (-0.496, p<0.010), access to safe drinking water (r=-0.611, p<0.001), proper waste management (r=-0.453, p<0.010), availability of handwashing facilities (r=-0.697, p<0.001), running water (r=-0.613, p<0.001), and basic

Table 1. General characteristics of provinces in Indonesia (*N*=38)

Level	*Variables (Code)*	*Average*	*Minimum*	*Maximum*	*Indonesia*
Individual factors (child)					
Health services	Completeness of MCH handbook (X1)	72.60	49.20 (North Sumatera)	91.10 (Yogyakarta)	78.5
	Low birth weight (X2)	6.10	2.80 (Jambi)	9.00 (Central Papua)	6.2
	Normal birth history (X3)	74.94	24.00 (Highland Papua)	90.20 (North Kalimantan)	78.5
	Complete basic immunisation (X4)	30.62	3.90 (Aceh)	73.50 (Bali)	35.8
	Complete advanced immunisation (X5)	37.63	8.80 (Highland Papua)	78.50 (Bali)	42.5
	Complete new antigen (PCV) immunisation (X6)	36.56	3.80 (Highland Papua)	80.60 (Yogyakarta)	42.0
	Weight measurement (X7)	75.48	32.40 (Central Papua)	96.20 (Yogyakarta)	83.2
	Length and height measurements (X8)	70.29	28.20 (Central Papua)	92.00 (Yogyakarta)	78.2
	Growth monitoring (X9)	33.47	4.20 (Highland Papua)	66.00 (Yogyakarta)	43.3
Food consumption and nutrition	Complementary feeding (X10)	25.27	7.20 (North Kalimantan)	54.50 (Yogyakarta)	32.6
	Local-based food complementary feeding (X11)	43.37	10.50 (Highland Papua)	86.40 (West Nusa Tenggara)	53.0
	Animal-based food complementary feeding (X12)	75.98	40.00 (Highland Papua)	88.30 (Yogyakarta)	78.4
	Minimum dietary diversity (X13)	56.64	26.00 (Highland Papua)	77.60 (Yogyakarta)	60.9
	Complete vitamin A supplementation (X14)	29.85	16.30 (Central Papua)	44.70 (Jambi)	32.2
Infection status	Prevalence of diarrhoea (X15)	4.62	1.40 (Riau Island)	17.50 (Highland Papua)	4.9
	Prevalence of ARI (X16)	3.93	0.70 (West Sulawesi)	11.80 (Central Papua)	4.8
	Prevalence of pneumonia (X17)	1.11	0.20 (Riau)	5.30 (Highland Papua)	1.1
Individual factors (mother)					
Food consumption and nutrition	Supplementary feeding for pregnant women (X18)	29.36	16.8 (North Kalimantan)	45.4 (Central Sulawesi)	32.1
	IFA supplementation (X19)	40.69	14.50 (Maluku)	81.50 (Bali)	44.2
	Chronic energy deficiency prevalence (20)	17.15	5.20 (North Kalimantan)	44.70 (Highland Papua)	16.9

to be continued...

Table 1. General characteristics of provinces in Indonesia (N=38) (continued)

Level	*Variables (Code)*	*Average*	*Minimum*	*Maximum*	*Indonesia*
Household factors					
Socio-economic	Middle – high economic status (X21)	61.0	23.0 (East Nusa Tenggara)	92.7 (Jakarta)	80.0
	Access to primary health care (X22)	46.8	18.3 (Highland Papua)	69.0 (Yogyakarta)	49.9
	Appropriate knowledge of stunting (X23)	73.33	62.40 (East Nusa Tenggara)	84.30 (West Papua)	69.4
Food consumption	Consumption of cereals (X24)	80.97	46.90 (Central Papua)	97.70 (Yogyakarta)	87.7
	Consumption of tubers (X25)	9.87	2.60 (Gorontalo)	63.00 (Highland Papua)	6.5
	Consumption of legumes (X26)	16.27	4.90 (Gorontalo)	50.40 (Central Java)	27.9
	Consumption of meat and poultry (X27)	6.97	2.80 (Gorontalo)	20.10 (Bali)	7.2
	Consumption of fish (X28)	25.14	4.00 (Yogyakarta)	68.10 (Maluku)	15.1
	Consumption of eggs (X29)	17.00	7.20 (East Nusa Tenggara)	32.80 (West Java)	20.3
	Consumption of milk (X30)	8.84	5.20 (East Nusa Tenggara)	15.30 (Jakarta)	9.3
Environmental health	Access to safe drinking water (X31)	85.98	57.50 (Highland Papua)	96.20 (Jakarta)	89.6
	Proper waste management (X32)	36.57	12.10 (East Nusa Tenggara)	98.40 (Jakarta)	37.80
	Availability of handwashing facilities (X33)	80.24	42.50 (Highland Papua)	97.70 (Bali)	85.5
	Availability of running water (X34)	70.44	35.30 (East Nusa Tenggara)	95.50 (Bali)	82.8
	Access to basic hygiene (X35)	72.43	23.60 (Highland Papua)	92.10 (Bali)	78.9
	Adequate housing (X36)	63.92	21.50 (Highland Papua)	80.80 (Jambi)	65.1
	Access to adequate sanitation (X37)	69.32	22.80 (Highland Papua)	84.20 (Bangka Belitung)	69.4
Institutional factors (public health services)					

to be continued...

hygiene (r=-0.706, p<0.001). Adequate housing (r=-0.469, p<0.010) and cereal consumption (r=-0.557, p<0.001) also significantly reduced stunting prevalence. Furthermore, the results also showed that access to safe drinking water and handwashing facilities aligned with UNICEF's framework on poor

Table 1. General characteristics of provinces in Indonesia (*N*=38) (continued)

Level	*Variables (Code)*	*Average*	*Minimum*	*Maximum*	*Indonesia*
Health services	Assistance during childbirth (X38)	91.87	41.00 (Central Papua)	100.00 (Yogyakarta)	96.1
	Complete ANC (X39)	56.44	13.90 (Central Papua)	90.90 (Bali)	68.1
	Complete postnatal care (X40)	23.35	7.50 (Central Papua)	47.10 (Bali)	26.8
Health financing	Healthcare insurance ownership (X41)	75.03	44.60 (Highland Papua)	99.20 (Aceh)	72.2

MCH: Maternal and Child Health, PCV: Pneumococcal Conjugate Vaccine, ARI: Acute Respiratory Infection, IFA: Iron and Folic Acid, ANC: Antenatal Care

environmental conditions as indirect causes of stunting.

At the institutional level, significant factors included assistance during childbirth by healthcare workers (*r*=-0.638, *p*<0.001), complete postnatal care (*r*=-0.432, *p*<0.050), and complete antenatal care (ANC) (*r*=-0.601, *p*<0.001). These findings underscore the critical roles of healthcare services, WASH (water, sanitation and hygiene) conditions, and maternal nutrition in reducing stunting prevalence.

The cumulative influence of these variables on stunting prevalence accounted for 99.2% of the variance (R^2=0.985), as indicated by the regression model with *VIF*<7 (moderate collinearity and still accepted based on the theoretical justification), which significantly predicts stunting prevalence (*p*<0.010). The results found the following coefficients across components, with the highest values highlighted for each level. For individual factor (child), low birth weight was the highest coefficient under the health services component (*B*=0.935), minimum dietary diversity (*B*=0.132) for the food consumption and nutrition aspect, and prevalence of pneumonia at *B*=1.820 under infection status. Chronic energy deficiency prevalence was the strongest factor for stunting at the maternal level, with a coefficient value of -0.319. For household factors, access to primary health care (*B*=0.213) was the strongest factor in the socio-economic aspect, consumption of tubers for the consumption component (*B*=-0.226), and availability of handwashing (*B*=-1.150) for the environmental health aspects. Complete postnatal care (*B*=-0.168) was the strongest factor for institutional factors towards stunting prevalence (Table 3). The linear regression model delineating the determinants of stunting prevalence in Indonesia, organised according to the levels of the socio-ecological model (SEM) approach, is presented as follows:

$$\text{Stunting prevalence } (Y) = 97.281 + 1.820X17 + 0.935X2 - 0.309X7 + 0.301X1 + 0.206X8 - 0.170X3 - 0.165X5 + 0.132X13 + 0.117X4 + 0.110X15 - 0.091X12 - 0.079X6 + 0.043X14 - 0.025X9 - 0.319X20 - 0.065X19 - 1.150X33 + 1.007X35 - 0.251X31 - 0.226X25 + 0.216X24 + 0.213X22 - 0.182X21 - 0.149X36 - 0.142X32 - 0.123X34 - 0.096X37 - 0.004X28 - 0.168X40 - 0.111X34 - 0.029X38$$

DISCUSSION

Stunting in Indonesia remained above the 2024 national target of 14%, with a prevalence of 21.5% in 2023. Significant regional disparities existed, with eastern areas like Central Papua (39.3%) and East Nusa Tenggara (37.9%) far exceeding rates in western regions such as Bali (7.2%) and Jambi (13.5%).

Table 2. Correlations between stunting prevalence and independent variables

Level	*Independent variables (code)*	*Stunting prevalence*	
		Pearson's correlation	*Significance level*
Individual factors (child)			
Health services	Completeness of MCH handbook (X1)	-0.353	0.030*
	Low birth weight (X2)	0.493	0.002**
	Normal birth history (X3)	-0.625	<0.001**
	Complete basic immunisation (X4)	-0.521	0.001**
	Complete advanced immunisation (X5)	-0.554	<0.001**
	Complete new antigen (PCV) immunisation (X6)	-0.599	<0.001**
	Weight measurement (X7)	-0.516	0.001**
	Length and height measurements (X8)	-0.458	0.004**
	Growth monitoring (X9)	-0.321	0.050*
Food consumption and nutrition	Complementary feeding (X10)	-0.266	0.107
	Local-based food complementary feeding (X11)	-0.013	0.938
	Animal-based food complementary feeding (X12)	-0.676	<0.001**
	Minimum dietary diversity (X13)	-0.587	<0.001**
	Complete vitamin A supplementation (X14)	-0.391	0.015*
Infection status	Prevalence of diarrhoea (X15)	0.530	0.001**
	Prevalence of ARI (X16)	0.292	0.076
	Prevalence of pneumonia (X17)	0.408	0.011*
Individual factors (mother)			
Food consumption and nutrition	Supplementary feeding for pregnant women (X18)	0.123	0.460
	IFA supplementation (X19)	-0.491	0.002**
	Chronic energy deficiency prevalence (X20)	0.424	0.008**
Household factors			
Socio-economic	Middle – high economic status (X21)	-0.566	<0.001**
	Access to primary health care (X22)	-0.496	0.002**
	Appropriate knowledge of stunting (X23)	-0.064	0.702
Food consumption	Consumption of cereals (X24)	-0.557	<0.001**
	Consumption of tubers (X25)	0.574	<0.001**
	Consumption of legumes (X26)	-0.239	0.149
	Consumption of meat and poultry (X27)	-0.255	0.122
	Consumption of fish (X28)	0.413	0.010**
	Consumption of eggs (X29)	-0.133	0.427
	Consumption of milk (X30)	0.091	0.587
Environmental health	Access to safe drinking water (X31)	-0.611	<0.001**
	Proper waste management (X32)	-0.453	0.004**
	Availability of handwashing facilities (X33)	-0.697	<0.001**
	Availability of running water (X34)	-0.613	<0.001**
	Access to basic hygiene (X35)	-0.706	<0.001**
	Adequate housing (X36)	-0.469	0.003**
	Access to adequate sanitation (X37)	-0.518	0.001**
Institutional factors (public health services)			
Health services	Assistance during childbirth (X38)	-0.638	<0.001**
	Complete ANC (X34)	-0.601	<0.001**
	Complete postnatal care (X40)	-0.432	0.007**
Health financing	Healthcare insurance ownership (X41)	-0.259	0.117

MCH: Maternal and Child Health, PCV: Pneumococcal Conjugate Vaccine, ARI: Acute Respiratory Infection, IFA: Iron and Folic Acid, ANC: Antenatal Care

*Correlation is significant at 0.05 level (two-tailed); **Correlation is significant at 0.01 level (two-tailed)

Table 3. Coefficients of model

Level	*Variables (Code)*	*Constant*	*95% Confidence interval of B*	
			Lower bound	*Upper bound*
	Constant	97.281		
Individual factors (child)	Prevalence of pneumonia (X17)	1.820	-5.383	9.024
	Low birth weight (X2)	0.935	-1.279	3.149
	Weight measurement (X7)	-0.309	-2.506	1.887
	Completeness MCH handbook (X1)	0.301	-0.166	0.768
	Length and height measurements (X8)	0.206	-1.612	2.024
	Normal birth history (X3)	-0.170	-0.572	0.232
	Complete advanced immunisation (X5)	-0.165	-0.741	0.411
	Minimum dietary diversity (X13)	0.132	-0.192	0.455
	Complete basic immunisation (X4)	0.117	-0.379	0.613
	Prevalence of diarrhoea (X15)	0.110	-1.137	1.358
	Animal-based food complementary feeding (X12)	-0.091	-0.582	0.401
	Complete new antigen (PCV) immunisation (X6)	-0.079	-0.389	0.232
	Complete vitamin A supplementation (X14)	0.043	-0.465	0.550
	Growth monitoring (X9)	-0.025	-0.521	0.471
Individual factors (mother)	Chronic energy deficiency prevalence (X20)	-0.319	-0.892	0.254
	IFA supplementation (X19)	-0.065	-0.250	0.120
Household factors	Availability of handwashing facilities (X33)	-1.150	-2.715	0.416
	Access to basic hygiene (X35)	1.007	-0.737	2.752
	Access to safe drinking water (X31)	-0.251	-0.757	0.256
	Consumption of tubers (X25)	-0.226	-1.043	0.591
	Consumption of cereals (X24)	0.216	-0.508	0.940
	Access to primary health care (X22)	0.213	-0.304	0.370
	Middle – high economic status (X21)	-0.182	-0.373	0.009
	Adequate housing (X36)	-0.149	0.388	0.089
	Proper waste management (X32)	-0.142	-0.512	0.227
	Availability of running water (X34)	-0.123	-0.433	0.186
	Access to adequate sanitation (X37)	-0.096	-0.420	0.228
	Consumption of fish (X28)	-0.004	-0.289	0.281
Institutional factors (public health services)	Complete postnatal care (X40)	-0.168	-0.249	0.013
	Complete ANC (X34)	-0.111	-0.381	0.159
	Assistance during childbirth (X38)	-0.029	-0.539	0.482

MCH: Maternal and Child Health, PCV: Pneumococcal Conjugate Vaccine, ARI: Acute Respiratory Infection, IFA: Iron and Folic Acid, ANC: Antenatal Care
The results found the following coefficients across components, with the highest values highlighted for each level

Despite 73.3% having proper knowledge of stunting, prevalence remained high. This study investigated additional key determinants using 41 variables from the UNICEF Conceptual Framework on Maternal and Child Nutrition, with 31 showing correlations and included in a linear regression analysis.

The findings highlighted economic disparities, with middle-to-high economic status being more prevalent in western regions, such as Jakarta

(92.9%), while significantly lower in eastern regions, such as East Nusa Tenggara (23%). Descriptive analysis also showed disparities in access to primary healthcare, with Highland Papua having low access (18.3%) compared to Yogyakarta, which remained high (69%). This economic gap may limit access to nutritious foods and healthcare services, contributing to stunting. A previous study also indicated that children from lower socio-economic backgrounds are at a higher risk of stunting (Akbar *et al.,* 2021).

The UNICEF Conceptual Framework serves as a cornerstone for understanding the key determinants of food consumption and their direct influence on nutritional status. This is supported by SEM analysis, showing significant correlations between reduced stunting and animal-based complementary feeding, minimum dietary diversity, and vitamin A supplementation (r=-0.676, p<0.001; r=-0.587, p<0.001; r=-0.391, p<0.050). Children's dietary intake varied markedly by region, with animal-based complementary feeding and dietary diversity more common in Western Indonesia (e.g., Yogyakarta 88.3%, Jambi 44.7%) than in Eastern Indonesia (Highland Papua 40%, Central Papua 16.3%). Similarly, household food consumption was higher in the west, particularly cereals (Yogyakarta 97.7%), legumes (Central Java 63%), eggs (West Java 32.8%), and milk (32.8%). These findings align with Vidyarini, Martianto & Syarief (2021), who linked high stunting rates in West Papua, East Nusa Tenggara, and Papua to poor food quality and limited dietary variety.

This study highlighted how food availability shapes regional dietary patterns, exemplified by the dominance of fish as the main animal protein in Eastern Indonesia, reflecting the local food ecosystem and natural resources. A previous study showed that food consumption in Indonesia varies by agro-ecological zone, region, season, and socio-economic factors (Dewi *et al.*, 2024). This ecosystem influences the diversity of foods accessible to households and individuals, making the use of local foods crucial for maternal and child nutrition. Additionally, the results showed significant correlations between stunting and consumption of cereals, tubers, and fish. However, the positive correlation with fish may indicate a paradox, as fish intake was recorded at the household rather than individual level.

Gibson *et al.* (2020), in their study conducted in the Komodo District of Eastern Indonesia, found that despite the abundant availability of fish and it being served as the primary source of protein in households, stunting prevalence remained high. The analysis examined a positive correlation between household fish consumption and stunting; however, this should not be interpreted as a causal correlation since household data may not accurately reflect children's protein intake, especially where intra-household food distribution is unequal, a common pattern in low-income settings (Bogard *et al.*, 2017). Lestari *et al.* (2024) found that stunted children did not meet minimum dietary diversity. The present research consistently showed that low minimum dietary diversity was significantly associated with higher rates of stunting (r=-0.587, p<0.001). Monotonous diets (low minimum dietary diversity), which are prevalent in such regions, often lack the essential micronutrients required for healthy growth and development (Beal *et al.,* 2024).

Household food resource management influences maternal nutrition and thus affects child nutrition. Maternal malnutrition, particularly chronic energy deficiency, can lead to low birth weight (LBW), which has profound implications on child growth and development (Kusumawati *et al.*, 2019). A study indicated that LBW is a significant predictor of stunting, as children born with LBW are more vulnerable to a range of health challenges, including chronic malnutrition and poor nutritional outcomes during their early years (Kusumawati *et al.*, 2019).

A correlation exists between adequate water access and nutritional status, as children from households without safe drinking water face heightened risks of infection and stunting prevalence (Cumming & Cairncross, 2016). Proper waste management is associated with a lower prevalence of stunting, as poor waste disposal can lead to unsanitary environments conducive to spreading infections, such as diarrhoea and pneumonia among children (Vilcins *et al.,* 2018), which directly impacts nutrient absorption (Wolf *et al.,* 2022). In addition, proper waste disposal mechanisms likewise play a crucial role in maintaining a sanitary environment conducive to good health and effective feeding practices. By improving WASH conditions, communities can mitigate health risks associated with poor hygiene, supporting better health and nutritional strategies. Hygiene practices, such as handwashing facilities (r=-0.697, p<0.001) and running water (r=-0.613, p<0.001), further support better child health and lower stunting rates.

Current evidence indicated that IFA supplementation was negatively correlated with stunting (r=-0.491, p<0.010), highlighting the crucial role of maternal nutrition during pregnancy in preventing stunting. Additionally, vitamin A supplementation and growth monitoring through anthropometric measurements among children also showed a negative correlation with stunting. These findings underscore the importance of nutritional interventions and monitoring, particularly through MCH services, to ensure early detection and prevention of stunting. A systematic review highlighted MCH policies as key in tackling stunting, a public health issue driven by nutrition, disease, and socio-economic factors (Ramlan *et al.,* 2025). The review also showed that maternal health interventions during pregnancy and postnatal care directly impact children's nutrition (Ramlan *et al.,* 2025).

Ramlan *et al.* (2025) highlighted that programmes, including nutritional supplementation, immunisation, and prenatal care, have significantly reduced stunting prevalence in developing countries. The present study confirmed that MCH services are critical in addressing the prevalence of stunting, showing significant correlations between childbirth assistance, complete ANC, and postnatal care with stunting outcomes. However, postnatal care rates were low, with only 23.35% of mothers receiving comprehensive care. Inadequate postnatal care prevents mothers from receiving vital information on infant nutrition and development, further contributing to stunting (Sartika *et al.,* 2021).

This study confirmed that 99.2% of the UNICEF model employs a SEM within the food and nutrition resource management framework, addressing food consumption and infection status as direct causes, public health services and environmental health as indirect causes, and socioeconomic factors as fundamental causes. A similar SEM study in Kiribati highlighted the need for a multilevel approach to address policy, community, interpersonal, and individual determinants of infant nutrition (Kodish *et al.*, 2019). The variance inflation factor (VIF) values in this study were below 7, indicating acceptable levels of multicollinearity; while VIFs above 10 generally signal high multicollinearity, values between 5 and 10 are acceptable, depending on context.

Multicollinearity is usually considered present when VIF exceeds 5–10 or condition indices range from 10 to 30 (O'Brien, 2007), but these thresholds may not consistently apply in health research (Kim, 2019). Furthermore, Akinwande, Dikko & Samson (2015) suggest that VIF values below 10 rarely distort regression coefficients when variable inclusion is supported by sound theoretical and empirical evidence.

This study was limited by its cross-sectional design, offering only a snapshot in time and preventing analysis of changes or causal relationships over the long term; therefore, longitudinal studies are needed to better understand stunting dynamics. Additionally, as an ecological study using aggregate data, it cannot directly reflect individual or household circumstances. The absence of socio-demographic variables meant the study instead relied on proxies such as stunting knowledge and access to primary healthcare.

These findings have important policy implications, indicating that reducing stunting risk can be enhanced through cross-sectoral programme synergies targeting children, mothers, households, and public health institutions. Indonesia has made notable progress via the Presidential Regulation Number 72 of 2021 on Accelerating Stunting Reduction. To reinforce this policy, the study recommends promoting animal-based complementary feeding and adopting minimum dietary diversity standards as key strategies. Furthermore, the Indonesian government has aligned its stunting reduction efforts with global commitments like the SDGs, tailoring approaches to regional needs. Globally, this study supports the Scaling Up Nutrition (SUN) Movement's call for multi-sectoral food and nutrition planning to accelerate stunting reduction.

CONCLUSION

Stunting in Indonesia remained above the 2024 national target of 14%, with a prevalence of 21.5% in 2023. Based on the 2023 overview, preventing stunting requires minimising risks within food resource management and public health services. This study explained 99.2% of the factors contributing to stunting, aligning with UNICEF's Conceptual Framework, using the SEM approach to analyse direct, indirect, and fundamental causes.

As a direct cause, child and household food consumption and infection status significantly correlated with stunting. Food consumption patterns were shaped by regional food ecosystems, influencing dietary intake. At the indirect level, environmental health and public health services played a crucial role in stunting prevalence. Socioeconomic disparities were also evident, with middle-to-high economic status and healthcare access being more dominant in Western Indonesia. At the same time, stunting prevalence remained higher in Eastern Indonesia, where these resources are more limited. These findings have important policy implications, highlighting the need to strengthen stunting prevention through cross-sectoral programme synergies across national and global contexts. Targeted interventions should address multiple levels, including children, mothers, households, and institutions (public health services), to ensure a comprehensive and sustainable approach to reducing stunting in Indonesia.

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Conflict of interest

The authors declare no competing interests related to this study.

Authors' contributions

Yayuk FB, principal investigator, conceptualised and designed the study, reviewed the manuscript, advised on data analysis and interpretation, conducted the study; Akifa LR, led the data collection, prepared the draft of the manuscript, conducted the study, data analysis and interpretation, reviewed the manuscript.

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