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Multidomain Determinants of Stunting in Six High-Prevalence Districts in Sulawesi, Indonesia: A Cross-Sectional Analysis of the 2024 Indonesian Nutritional Status Survey

Yessy Kurniati[1]*, Nazihah Mukhtar[2]

[1] Program Study of Public Health, Faculty of Medicine and Health Sciences, Universitas Islam Negeri Alauddin, Makassar
[2] Program Study of Nutrition, Faculty of Nursing and Midwifery, Megarezky University
*Corresponding author: yessy.kurniati@uin-alauddin.ac.id

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ABSTRACT

Stunting remains a major public health challenge, particularly in areas characterized by socioeconomic and environmental disparities. Although the prevalence of stunting in Indonesia declined to 19.8% in 2024, several districts in Sulawesi continue to report substantially higher rates. This study aimed to identify family, nutrition-sensitive, and nutrition-specific determinants of stunting across six high-prevalence districts in Sulawesi, Indonesia. A cross-sectional study was conducted using secondary data from the 2024 Indonesian Nutritional Status Survey (SSGI). The study included 3,263 households with children under five years of age from Mamuju (n=552), Gorontalo City (n=561), Buton Selatan (n=580), Minahasa Selatan (n=480), Jeneponto (n=580), and Buol (n=510). Data were analyzed using descriptive statistics, bivariate analysis, and multivariate logistic regression. Multivariate analysis revealed substantial district-level variation in the determinants of stunting. In Mamuju, proper kitchen wastewater disposal systems were associated with lower odds of stunting (AOR=0.36; 95% CI: 0.181–0.706; p=0.003). In Buton Selatan, incomplete hepatitis immunization increased the odds of stunting (AOR=1.88; 95% CI: 1.036–3.401; p=0.038). In Buol, higher maternal education was associated with lower odds of stunting (AOR=0.71; 95% CI: 0.524–0.969; p=0.031). In Minahasa Selatan, higher paternal education (AOR=0.56; 95% CI: 0.338–0.932; p=0.026) and health insurance ownership (AOR=0.43; 95% CI: 0.208–0.891; p=0.023) were protective factors. An association between paternal employment and stunting was also observed, although this finding should be interpreted cautiously because of the small subgroup size. No significant determinants were identified in Gorontalo City or Jeneponto. Determinants of stunting varied across districts, indicating that stunting is highly context-dependent. District-specific interventions focusing on sanitation, immunization coverage, parental education, and socioeconomic support are needed to accelerate stunting reduction in high-prevalence areas.

Keywords: stunting; under-five children; sanitation; immunization; health insurance; multivariate logistic regression; cross-sectional study

INTRODUCTION

Stunting remains one of the most persistent global public health challenges, reflecting chronic undernutrition during the critical first 1,000 days of life and resulting in irreversible consequences for physical growth, cognitive development, and long-term human capital [1]. Globally, stunting continues to pose a significant public health challenge, affecting an estimated 148 million children under five years of age worldwide [2]. Despite gradual reductions over the past decade, the burden remains concentrated in low- and middle-income countries, where socioeconomic inequality, inadequate healthcare access, and poor environmental conditions continue to hinder child growth and development [3,4]. Beyond its immediate nutritional implications, stunting is associated with impaired educational achievement, reduced productivity in adulthood, and increased susceptibility to chronic diseases, thereby contributing to intergenerational cycles of poverty and poor health outcomes [5].

In Indonesia, the prevalence of stunting declined from 30.8% in 2018 to 19.8% in 2024, reflecting substantial national progress in child nutrition improvement programs [6]. However, these national achievements conceal considerable regional disparities, particularly in eastern Indonesia, including Sulawesi, where several districts continue to report prevalence rates exceeding 30% [6]. Districts such as Mamuju and Jeneponto remain categorized as high-burden areas despite ongoing national stunting reduction initiatives [7,8]. These disparities suggest that the determinants of stunting may differ across regions due to variations in socioeconomic conditions, environmental sanitation, healthcare access, and local sociocultural contexts, highlighting the need for more localized evidence to support targeted interventions.

Previous studies have identified stunting as a multifactorial condition influenced by biological, socioeconomic, environmental, and healthcare-related factors [9,10]. Evidence from recent studies indicates that low parental education, inadequate maternal health, poor sanitation, incomplete immunization, low birth weight, and suboptimal feeding practices are consistently associated with an increased risk of stunting among children under five [11]. Environmental factors such as inadequate sanitation facilities and unsafe wastewater disposal systems have also been strongly linked to recurrent infectious diseases, particularly diarrhea, which impairs nutrient

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absorption and contributes to chronic malnutrition [12,13]. In addition, limited healthcare utilization and inadequate maternal supplementation further exacerbate the risk of impaired child growth [14,15]. Collectively, these findings emphasize that stunting is not solely a nutritional problem but a multidimensional issue shaped by the interaction of family, environmental, and health-related determinants.

Despite the growing body of evidence, several important gaps remain in the literature. Most previous studies have examined determinants of stunting in isolation, focusing separately on socioeconomic, environmental, or biological factors without simultaneously assessing their multidomain interactions [16,17]. Furthermore, comparative analyses across multiple high-prevalence districts remain limited, particularly in Indonesia and the Sulawesi region, where substantial geographic and sociocultural diversity may influence the pattern of determinants. Consequently, current evidence remains insufficient to explain why stunting prevalence and associated risk factors vary considerably across districts with similarly high burdens.

To address this complexity, the present study adopts the UNICEF conceptual framework of child malnutrition, which classifies determinants into immediate, underlying, and basic causes. Within this framework, nutrition-specific factors, such as immunization and maternal supplementation, interact with nutrition-sensitive factors, including sanitation, environmental conditions, and socioeconomic characteristics, to influence child nutritional outcomes. Family characteristics, parental education, household resources, and healthcare access further shape the vulnerability of children to chronic undernutrition. This framework provides a comprehensive basis for examining the multidomain determinants of stunting and understanding their contextual variation across districts.

Accordingly, this study aimed to analyze the associations between family characteristics, environmental conditions, and health-related factors and the occurrence of stunting in six high-prevalence districts in Sulawesi, Indonesia. The study hypothesized that inadequate sanitation, low parental education, limited healthcare access, and incomplete immunization would be significantly associated with stunting, with the magnitude and pattern of associations varying across districts. By applying a comparative multidistrict approach using secondary data from the 2024 Indonesian Nutritional Status Survey (SSGI), this study seeks to provide evidence for more targeted and context-specific stunting reduction strategies in high-burden settings.

MATERIALS AND METHODS

This study employed an observational analytical design using a cross-sectional approach based on secondary data derived from the 2024 Indonesian Nutritional Status Survey (SSGI). The cross-sectional design allows for the simultaneous assessment of exposure and outcome variables within a defined population at a single point in time. This approach is widely used in nutritional epidemiology due to its efficiency in identifying associations between determinants and health outcomes, although it does not permit causal inference. The use of large-scale survey data enhances the representativeness and generalizability of findings, particularly in the context of population-based nutritional assessments.

The primary data source for this study was the SSGI 2024 dataset, developed and administered by the Ministry of Health of the Republic of Indonesia. The SSGI is a nationally representative survey designed to assess nutritional status and its determinants among children under five years of age. The survey employs standardized data collection procedures, including anthropometric measurements and structured household interviews, ensuring data reliability and comparability across regions. The methodological framework of SSGI aligns with international standards for nutritional surveillance and incorporates validated tools such as WHO Anthro for calculating child growth indicators.

The study focused on six district-level administrative areas in Sulawesi identified as having the highest prevalence of stunting, comprising five regencies (Mamuju, Buton Selatan, Minahasa Selatan, Jeneponto, and Buol) and one city (Gorontalo City). These areas were selected to represent high-burden settings with diverse socio-economic and environmental characteristics. The study population comprised households with children under five years of age residing in these districts. The selection of high-prevalence regions enables a more targeted analysis of determinants in areas where intervention is most urgently needed.

The sampling design followed the methodology of the Indonesian Nutritional Status Survey (SSGI), which applies a two-stage, one-phase stratified sampling technique. In the first stage, census blocks were selected using Probability Proportional to Size (PPS) with replacement. In the second stage, households with eligible children under five years of age were selected systematically from updated household listings within each selected census block. This probabilistic sampling approach was intended to enhance representativeness and minimize selection bias.

The initial dataset consisted of 3,566 children under five years of age from six districts, including Mamuju (n = 597), Gorontalo (n = 596), Buton Selatan (n = 620), Minahasa Selatan (n = 510), Jeneponto (n = 687), and Buol (n = 556). Prior to analysis, the dataset underwent a data cleaning process to address missing values and outliers. Cases with incomplete anthropometric measurements or missing key independent variables were excluded through listwise deletion. After data cleaning, the final analytical sample comprised 3,263

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households with children under five years of age, consisting of Mamuju (n = 552), Gorontalo (n = 561), Buton Selatan (n = 580), Minahasa Selatan (n = 480), Jeneponto (n = 580), and Buol (n = 510). The relatively large sample size increased the statistical power of the analysis and supported subgroup comparisons across districts.

The dependent variable in this study was stunting status, defined based on the height-for-age z-score (HAZ). The selection of variables is based on the theoretical framework of UNICEF.[18] Anthropometric data were analyzed using WHO Anthro software, and children were classified as stunted if their HAZ was below –2 standard deviations (< –2 SD) from the WHO Child Growth Standards median, and non-stunted if ≥ –2 SD. This definition is consistent with global standards for assessing chronic malnutrition. The independent variables were categorized into three groups:

a) Family Factors: These included paternal education, maternal education, paternal occupation, and maternal occupation. Education levels were categorized into low, medium, and high based on formal schooling attainment.

b) Nutrition-Sensitive Indicators: These variables reflected environmental and structural determinants, including household health insurance ownership, access to safe drinking water, availability of sanitary latrines, and household wastewater management systems (kitchen and bathroom wastewater disposal). Operational definitions and classifications were based on the 2024 Indonesian Nutritional Status Survey (SSGI) guidelines. Household wastewater disposal systems were categorized as "meets standards" when wastewater was discharged into a properly constructed closed infiltration pit, soak pit, or equivalent facility equipped with adequate containment and filtration structures. Systems that did not meet these criteria were categorized as "does not meet standards." The same coding scheme was consistently applied throughout the descriptive, bivariate, and multivariate analyses

c) Nutrition-Specific Indicators: These included child health and maternal nutrition-related variables, such as history of diarrhea, immunization status (hepatitis, BCG, and polio), and maternal intake of iron supplementation (Tablet Tambah Darah/TTD) and multiple micronutrient supplements (MMS) during pregnancy.

Data analysis was conducted using Statistical Package for the Social Sciences (SPSS) version 23. The analysis proceeded in three stages:

a) Descriptive Analysis: Frequency distributions and proportions were calculated to describe the characteristics of the study population and the distribution of variables across regions.

b) Bivariate Analysis: The Chi-square (χ^2) test was used to assess the association between independent variables and stunting status. A significance level of $p < 0.05$ was applied to determine statistical significance.

c) Multivariate Analysis: Logistic regression analysis was conducted to identify dominant determinants of stunting while controlling for potential confounding variables. Variables with $p < 0.25$ in bivariate analysis and variables considered theoretically relevant were included in the multivariate logistic regression model. Adjusted Odds Ratios (AOR) and 95% Confidence Intervals (CI) were reported to quantify the strength of associations. This analytical approach allows for both the identification of individual associations and the examination of the combined effects of multiple determinants.

The analyses did not incorporate complex survey weights or survey design adjustments. Therefore, the reported estimates should be interpreted as analytical associations within the study sample rather than population-representative estimates. While this approach is useful for exploring relationships between determinants and stunting, the absence of weighting may affect representativeness and the precision of standard error estimation. Accordingly, the findings should be interpreted with caution when generalizing to the broader population.

RESULTS

The analysis of 3,263 households with children under five years of age across six districts in Sulawesi revealed substantial variation in the prevalence of stunting. The highest prevalence was observed in Buton Selatan (35.2%), followed by Mamuju (34.6%) and Jeneponto (33.8%). Buol also demonstrated a relatively high prevalence at 31.4%. In contrast, the lowest prevalence rates were found in Minahasa Selatan (26.3%) and Gorontalo (26.4%). Despite these variations, all six districts exhibited stunting prevalence rates exceeding the national average of 19.8%, indicating a persistent burden of chronic undernutrition in these regions. The distribution of parental education varied across districts. A high proportion of fathers with low educational attainment was observed in Jeneponto (40.5%) and Mamuju (39.5%), while Minahasa Selatan had the highest proportion of fathers with higher education (10.4%). Similarly, maternal education levels were lowest in Mamuju (35.9%) and Jeneponto (34.0%), whereas Gorontalo and Buton Selatan showed relatively higher proportions of mothers with secondary and higher education. In terms of employment status, the majority of fathers across all districts were employed, with proportions exceeding 96%. Conversely, maternal employment varied significantly between regions. The highest proportion of working mothers was found in Buton Selatan (44.1%), followed by Mamuju (40.4%) and Buol (37.8%), while Jeneponto had the lowest proportion (17.6%) (table 1)

The ownership of health insurance differed considerably across districts. Minahasa Selatan (85.4%) and Gorontalo (82.9%) had the highest proportions of households with health insurance coverage, while Buol (31.8%) and Jeneponto (49.5%) showed markedly lower coverage. Access to safe drinking water was generally high across most regions, with Gorontalo reporting full coverage (100%) and other districts exceeding 88%, except for Buton Selatan, where 24.5% of households relied on unsafe water sources. The availability of adequate sanitation

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facilities also varied, with nearly universal access in Buton Selatan (99.5%) and Minahasa Selatan (99.6%), while Buol had the highest proportion of households with inadequate sanitation facilities (14.9%). Waste management practices were predominantly inadequate across all districts. The majority of households did not meet the criteria for proper kitchen waste disposal, particularly in Buol (98.0%), Jeneponto (93.4%), and Mamuju (92.9%). Similar patterns were observed for bathroom waste disposal, with more than 80% of households in most districts lacking proper systems (table 1).

Most children did not have a history of diarrhea, with proportions exceeding 80% in all districts. The highest proportion of diarrhea cases was found in Buton Selatan (18.4%) and Mamuju (17.2%). Immunization coverage varied across regions. Gorontalo demonstrated the highest coverage rates for hepatitis (96.8%), BCG (97.3%), and polio (95.4%). In contrast, Minahasa Selatan showed lower immunization coverage, particularly for hepatitis (46.3%), BCG (45.2%), and polio (39.0%). Buol also exhibited relatively low immunization coverage compared to other districts. The coverage of maternal iron supplementation (TTD) during pregnancy was generally high in most regions, particularly in Mamuju (95.7%) and Jeneponto (91.7%), but significantly lower in Minahasa Selatan (16.5%). The use of multiple micronutrient supplementation (MMS) was low across all districts, with the highest coverage in Mamuju (43.7%) and minimal uptake in Jeneponto (0.3%) and Buton Selatan (1.7%) (table 1)

Table 1. Distribution of Stunting, Family Factors, Sensitive Nutrition Indicators, and Specific Nutrition Indicators in Six Districts/Cities with the Highest Stunting Prevalence in Sulawesi Island

Variables	Mamuju (n=552)	Gorontalo (n=561)	South Buton (n=580)	South Minahasa (n=480)	Jeneponto (n=580)	Buol (n=510)
Stunting Status						
Stunted	191 (34,6%)	148 (26,4%)	204 (35,2%)	126 (26,3%)	196 (33,8%)	160 (31,4%)
Non-stunted	361 (65,4%)	413 (73,6%)	376 (64,8%)	354 (73,8%)	384 (66,2%)	350 (68,6%)
Family Factors						
Father's education level						
High	73 (13,2%)	81 (14,4%)	106 (18,3%)	50 (10,4%)	56 (9,7%)	51 (10%)
Middle	261 (47,3%)	362 (64,5%)	277 (47,8%)	391 (81,5%)	289 (49,8%)	253 (49,6%)
Low	218 (39,5%)	118 (21%)	197 (34,0%)	39 (8,1%)	235 (40,5%)	206 (40,4%)
Mother's education level						
High	104 (18,8%)	130 (23,2%)	132 (22,8%)	62 (12,9%)	87 (15,0%)	64 (12,5%)
Middle	250 (45,3%)	360(64,2%)	302 (52,1%)	392 (82,5%)	296 (51,0%)	276 (54,1%)
Low	198 (35,9%)	71 (12,7%)	146 (25,2%)	22 (4,6%)	197 (34,0%)	170 (33,3%)
Father's employment status						
Employed	545 (98,7%)	559 (99,6%)	562 (96,9)	477 (99,4%)	568 (97,9%)	508 (99,6%)
Unemployed	7 (1,3%)	2 (0,4%)	18 (3,1%)	3 (0,6%)	12 (2,1%)	2 (0,4%)
Mother's employment status						
Employed	223 (40,4%)	145 (25,8%)	256 (44,1%)	111 (23,1%)	102 (17,6%)	193 (37,8%)
Unemployed	329 (59,6%)	416 (74,2%)	324 (55,9%)	369 (76,9%)	479 (82,4%)	317 (62,2%)
Sensitive Nutrition Indicators						
Health Insurance						
Insured	397 (71,9%)	456 (82,9%)	403 (69,5%)	410 (85,4%)	289 (49,5%)	162 (31,8%)
Uninsured	155 (28,1%)	96 (17,1%)	177 (30,5%)	70 (14,6%)	291 (50,2%)	348 (68,2%)
Water Source						
Improved	487 (88,2%)	561 (100%)	438 (75,5%)	472(98,3%)	576 (99,3%)	496 (97,3%)
Unimproved	65 (11,8%)	0 (0%)	142 (24,5%)	8(1,7%)	4 (0,7%)	14 (2,7%)
Sanitation (Toilet Facilities)						
Adequate	477 (86,4%)	549 (97,9%)	577 (99,5%)	478 (99,6%)	549 (94,7%)	434 (85,1%)
Inadequate	75 (13,6%)	12 (2,1%)	3 (0,5%)	2(0,4%)	31 (5,3%)	76 (14,9%)
Kitchen Waste Disposal						
Meets standards	39 (7,1%)	78 (13,9%)	187(32,2%)	103 (21,5%)	38 (6,6%)	10 (2,0%)
Does not meet standards	513 (92,9%)	483 (86,1%)	393 (67,8%)	377 (78,5%)	542 (93,4%)	500 (98,0%)
Bathroom Waste Disposal						
Meets standards	23 (4,2%)	74 (13,2%)	223 (38,4%)	90 (18,8%)	22 (3,8%)	11 (2,2%)
Does not meet standards	529 (95,8%)	487 (86,8%)	357 (61,6%)	390 (81,3%)	558 (96,2%)	499 (97,8%)

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Variables	Mamuju (n=552)	Gorontalo (n=561)	South Buton (n=580)	South Minahasa (n=480)	Jeneponto (n=580)	Buol (n=510)
Specific Nutrition Indicators						
History of Diarrhea						
No	457 (82,8%)	551 (98,2%)	473 (81,6%)	471 (98,1%)	557 (96,0%)	504 (98,8%)
Yes	96 (17,2%)	10 (1,8%)	107 (18,4%)	9(1,9%)	23 (4,0%)	6 (1,2%)
Hepatitis Immunization History						
Yes	476 (86,2%)	543 (96,8%)	385 (66,4%)	222(46,3%)	506 (87,2%)	371 (72,7%)
No	76 (13,8%)	18 (3,2%)	195 (33,6%)	258(53,8%)	74 (12,8%)	139 (27,3%)
BCG Immunization History						
Yes	460 (83,3%)	546 (97,3%)	409 (70,5%)	217(45,2%)	502 (86,8%)	346 (67,8%)
No	92 (16,7%)	15 (2,7%)	171 (29,5%)	263 (54,8%)	78 (13,4%)	164 (32,2%)
Polio Immunization History						
Yes	453 (82,1%)	535 (95,4%)	401 (69,1%)	187(39,0%)	446 (76,7%)	319 (62,5%)
No	99 (17,9%)	26 (4,6%)	179 (30,9%)	293 (61,0%)	135 (23,3%)	191 (37,5%)
Iron Supplementation During Pregnancy (TTD)						
Yes	528 (95,7%)	465 (82,9%)	497 (85,7%)	79 (16,5%)	532 (91,7%)	421 (82,5%)
No	24 (4,3%)	96 (17,1%)	83 (14,3%)	401 (83,5%)	48 (8,3%)	89 (17,5%)
Multiple Micronutrient Supplementation (MMS) During Pregnancy						
Yes	241 (43,7%)	30 (5,3%)	10 (1,7%)	51 (10,6%)	2 (0,3%)	106 (20,8%)
No	311 (56,3%)	531 (94,7%)	570 (98,3%)	429 (89,4%)	578 (99,7%)	404 (79,2%)

Bivariate Analysis of Determinants of Stunting

In Mamuju, significant associations with stunting were identified for paternal education (p=0.032), maternal education (p=0.003), maternal employment (p=0.016), kitchen waste disposal (p=0.009), and child history of diarrhea (p=0.030). Other variables did not show statistically significant associations (Table 2). In Gorontalo, significant relationships were observed for paternal education (p=0.027) and maternal education (p=0.016). No significant associations were found for environmental or health-related variables (Table 3). . In Buton Selatan, the only variable significantly associated with stunting was hepatitis immunization status (p=0.003), indicating that incomplete immunization was linked to a higher prevalence of stunting. Other variables were not statistically significant (Table 4)

Table 2. The Role of Family Factors, Sensitive Nutrition Indicators, and Specific Nutrition Indicators on Stunting in Mamuju District

Variables	Mamuju (n=552)		
	Stunted	Non-stunted	p-value
Family factors			
Father's education level			
High	88 (40,4%)	130 (59,6%)	
Middle	85 (32,6%)	176 (67,4%)	0,032
Low	18 (24,7%)	55 (75,3%)	
Mother's education level			
High	80 (40,4%)	118 (59,6%)	
Middle	89 (35,6%)	161 (64,4%)	0,003
Low	22 (21,2%)	82 (78,8%)	
Father's employment status			
Unemployed	2 (28,6%)	5 (71,4%)	0,736
Employed	189 (34,7%)	356 (65,3%)	
Mother's employment status			
Employed	127 (38,6%)	202 (61,4%)	0,016
Unemployed	64 (28,7%)	159 (71,3%)	
Sensitive Nutrition Indicators			
Health Insurance			
Insured	46 (29,7%)	109 (70,3%)	0,129
Uninsured	145 (36,5%)	252 (63,5%)	
Water Source			
Improved	25 (38,5%)	40 (61,5)	

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Variables	Mamuju (n=552)		
	Stunted	Non-stunted	p-value
Unimproved	166 (34,1%)	321 (65,9%)	0,486
Sanitation (Toilet Facilities)			
Adequate	24 (32,0%)	51 (68,0%)	0,610
Inadequate	167 (35,0)	310 (65,0%)	
Kitchen Waste Disposal			
Meets standards	170 (33,1%)	343 (66,9%)	0,009
Does not meet standards	21 (53,8%)	18 (46,2%)	
Bathroom Waste Disposal			
Meets standards	181 (34,2%)	348 (65,8%)	0,361
Does not meet standards	10 (43,5%)	13 (56,5%)	
Specific Nutrition Indicators			
History of Diarrhea			
Yes	42 (44,2%)	53 (55,8%)	0,030
No	149 (32,6%)	308 (67,4%)	
Hepatitis Immunization History			
No	25 (32,9)	51 (67,1%)	0,736
Yes	166 (34,0%)	310 (65,1%)	
BCG Immunization History			
No	31 (33,7%)	61 (66,3%)	0,841
Yes	160 (34,8%)	300 (65,2%)	
Polio Immunization History			
No	35 (35,4%)	64 (64,6%)	0,862
Yes	156 (34,4%)	297 (65,6%)	
Iron Supplementation During Pregnancy (TTD)			
No	10 (41,7%)	14 (58,3%)	0,457
Yes	181 (34,3%)	347 (65,7%)	
Multiple Micronutrient Supplementation (MMS) During Pregnancy			
No	110 (35,4%)	201 (64,6%)	0,666
Yes	81 (33,6%)	160 (66,4%)	

Table 3. The Role of Family Factors, Sensitive Nutrition Indicators, and Specific Nutrition Indicators on Stunting in Gorontalo City

Variables	Gorontalo City (n=561)		
	Stunted	Non-stunted	p-value
Family factors			
Father's education level			
High	37 (31,4%)	81 (68,6%)	
Middle	99 (27,3%)	263 (72,7%)	0,027
Low	12 (14,8%)	69 (85,2%)	
Mother's education level			
High	23 (32,4%)	48 (67,6%)	
Middle	103 (28,6%)	257 (71,4%)	0,016
Low	22 (16,9%)	108 (83,1%)	
Father's employment status			
Unemployed	0 (0,0%)	2 (10,00%)	0,396
Employed	148 (26,5%)	411 (73,5%)	
Mother's employment status			
Employed	112 (26,9%)	304 (73,1%)	0,622
Unemployed	36 (24,8)	109 (75,2%)	
Sensitive Nutrition Indicators			
Health Insurance			
Insured	23 (24,0%)	73 (76,0%)	0,554
Uninsured	125 (26.9%)	340 (73,1%)	
Water Source			
Improved	0 (0%)	0 (0%)	NA
Unimproved	148 (26,4%)	413 (73,6%)	

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Variables	Gorontalo City (n=561)		
	Stunted	Non-stunted	p-value
Sanitation (Toilet Facilities)			
Adequate	5 (41,7%)	7 (58,3%)	0,225
Inadequate	143 (26,0%)	406 (74,0%)	
Kitchen Waste Disposal			
Meets standards	132 (27,3%)	351 (72,7%)	0,205
Does not meet standards	16 (20,5%)	52 (79,5%)	
Bathroom Waste Disposal			
Meets standards	134 (27,5%)	353 (72,5%)	0,118
Does not meet standards	14 (18,9%)	60 (81,1%)	
Specific Nutrition Indicators			
History of Diarrhea			
Yes	1 (10%)	9 (90,0%)	0,236
No	147 (26,7%)	404 (73,3%)	
Hepatitis Immunization History			
No	6 (33,3%)	12 (66,7%)	0,469
Yes	142 (26,2%)	401 (73,8%)	
BCG Immunization History			
No	2 (13,3%)	13 (86,7%)	0,245
Yes	146 (26,7%)	400 (73,3%)	
Polio Immunization History			
No	5 (19,2%)	21 (80,8%)	0,397
Yes	143 (26,7%)	392 (73,3%)	
Iron Supplementation During Pregnancy (TTD)			
No	22 (22,9%)	74 (77,1%)	0,397
Yes	127 (27,1%)	339 (72,9%)	
Multiple Micronutrient Supplementation (MMS) During Pregnancy			
No	144 (27,1%)	387 (72,9%)	0,096
Yes	4 (13,3%)	26 (86,7%)	

Table 4. The Role of Family Factors, Sensitive Nutrition Indicators, and Specific Nutrition Indicators on Stunting in South Buton Distric

Variables	South Buton (n=580)		
	Stunted	Non-stunted	p-value
Family factors			
Father's education level			
High	72 (36,5%)	125 (63,5%)	
Middle	105 (37,9%)	172 (62,1%)	0,066
Low	27 (25,5%)	79 (74,5%)	
Mother's education level			
High	56 (38,4%)	90 (61,6%)	
Middle	110 (36,4%)	192 (63,6%)	0,200
Low	38 (28,8%)	94 (71,2%)	
Father's employment status			
Unemployed	6 (33,3%)	12 (66,7%)	0,868
Employed	198 (35,2%)	364 (64,8%)	
Mother's employment status			
Employed	119 (36,7%)	205 (63,3%)	0,377
Unemployed	85 (33,2%)	171 (66,8%)	
Sensitive Nutrition Indicators			
Health Insurance			
Insured	61 (34,5%)	116 (65,5%)	0,813
Uninsured	143 (35,5%)	260 (64,5%)	
Water Source			
Improved	56 (39,4%)	86 (60,6%)	0,221
Unimproved	148 (33,8%)	290 (66,2%)	

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Variables	South Buton (n=580)		
	Stunted	Non-stunted	p-value
Sanitation (Toilet Facilities)			
Adequate	2 (66,7%)	1 (33,3)	0,252
Inadequate	202 (35,0%)	375 (65,0%)	
Kitchen Waste Disposal			
Meets standards	70 (37,4%)	117 (62,6%)	0,432
Does not meet standards	134 (34,1%)	259 (65,9%)	
Bathroom Waste Disposal			
Meets standards	117 (32,8%)	240 (67,2%)	0,126
Does not meet standards	87 (39,0%)	136 (61,0%)	
Specific Nutrition Indicators			
History of Diarrhea			
Yes	40 (37,4%)	67 (62,6%)	0,569
No	164 (34,7%)	309 (65,3%)	
Hepatitis Immunization History			
No	85 (43,6%)	110 (56,4%)	0,003
Yes	119 (30,9%)	266 (69,1%)	
BCG Immunization History			
No	65 (38,0%)	106 (62,0%)	0,354
Yes	139 (34,0%)	270 (66,0%)	
Polio Immunization History			
No	72 (40,2%)	107 (59,8%)	0,089
Yes	132 (32,9%)	269 (67,1%)	
Iron Supplementation During Pregnancy (TTD)			
No	37 (44,6%)	46 (55,4%)	0,053
Yes	167 (33,6%)	330 (66,4%)	
Multiple Micronutrient Supplementation (MMS) During Pregnancy			
No	200 (35,1%)	370 (64,9%)	0,747
Yes	4 (40,0%)	6 (60,0%)	

In Minahasa Selatan, paternal education (p=0.037) and BCG immunization status (p=0.022) were significantly associated with stunting. In Jeneponto, both paternal education (p=0.014) and maternal education (p=0.018) were significantly associated with stunting. No significant associations were found for environmental or health-related variables. In Buol, significant associations were identified for sanitation facilities (p=0.014), BCG immunization (p=0.018), and polio immunization (p=0.006), indicating that inadequate sanitation and incomplete immunization were associated with higher stunting prevalence (Table 3)

Table 5. The Role of Family Factors, Sensitive Nutrition Indicators, and Specific Nutrition Indicators on Stunting in South Minahasa District

Variables	Minahasa Selatan (n=480)		
	Stunted	Non-stunted	p-value
Family factors			
Father's education level			
High	17 (43,2%)	22 (56,4%)	
Middle	97 (24,8%)	294 (75,2%)	0,037
Low	12 (24,0%)	38 (76,0%)	
Mother's education level			
High	9 (40,9%)	13 (59,1%)	
Middle	102 (25,8%)	294 (74,2%)	0,269
Low	15 (24,2%)	47 (75,8%)	
Father's employment status			
Unemployed	2 (66,7%)	1 (33,3%)	0,110

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Variables	Minahasa Selatan (n=480)		
	Stunted	Non-stunted	p-value
Employed	124 (26,0%)	353(74,0%)	
Mother's employment status			
Employed	97 (26,3%)	272 (73,7%)	0,973
Unemployed	29 (26,1%)	82 (73,9%)	
Sensitive Nutrition Indicators			
Health Insurance			
Insured	12 (17,1%)	58 (82,9%)	0,061
Uninsured	114 (27,8%)	296 (72,2%)	
Water Source			
Improved	4 (50,0%)	4 (50,0%)	0,124
Unimproved	122 (25,8%)	350 (74,2%)	
Sanitation (Toilet Facilities)			
Adequate	1 (50,0%)	1 (50,0%)	0,456
Inadequate	125 (26,2%)	353 (73,8%)	
Kitchen Waste Disposal			
Meets standards	98 (26,0%)	279 (74,0%)	0,808
Does not meet standards	28 (27,2%)	75 (72,8%)	
Bathroom Waste Disposal			
Meets standards	100 (25,6%)	290 (74,4%)	0,528
Does not meet standards	26 (28,9%)	64 (71,1%)	
Specific Nutrition Indicators			
History of Diarrhea			
Yes	125 (26,5%)	346 (73,5%)	0,297
No	1 (11,1%)	8 (88,9%)	
Hepatitis Immunization History			
No	77(29,8%)	181 (70,2%)	0,054
Yes	49(22,1%)	173 (77,9%)	
BCG Immunization History			
No	46 (21,2%)	171 (78,8%)	0,022
Yes	80 (30,4%)	183 (69,6%)	
Polio Immunization History			
No	85 (29,0%)	208 (71,0%)	0,085
Yes	41 (21,9%)	146 (78,1%)	
Iron Supplementation During Pregnancy (TTD)			
No	110 (27,4%)	291 (72,6%)	0,185
Yes	16(20,3%)	63 (79,7%)	
Multiple Micronutrient Supplementation (MMS) During Pregnancy			
No	112 (26,1%)	317 (73,9%)	0,837
Yes	14 (27,5%)	37 (72,5%)	

Table 6. The Role of Family Factors, Sensitive Nutrition Indicators, and Specific Nutrition Indicators on Stunting in Jeneponto District

Variables	Jeneponto (n=580)		
	Stunted	Non-stunted	p-value
Family factors			

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Variables	Jeneponto (n=580)		
	Stunted	Non-stunted	p-value
Father's education level			
High	90 (38,2%)	145 (61,7%)	
Middle	96 (33,2%)	193 (66,8%)	0,014
Low	10 (17,9%)	46 (82,1%)	
Mother's education level			
High	73 (37,1%)	124 (62,9%)	
Middle	105 (35,5%)	191 (64,5%)	0,018
Low	18(20,7%)	69 (79,3%)	
Father's employment status			
Unemployed	5 (41,7%)	7 (58,3%)	0,560
Employed	191 (33,6%)	377 (66,4%)	
Mother's employment status			
Employed	170 (35,6%)	308 (64,4%)	0,051
Unemployed	26 (25,5%)	76 (74,5%)	
Sensitive Nutrition Indicators			
Health Insurance			
Insured	101 (34,7%)	190 (65,3%)	0,640
Uninsured	95 (32,9%)	194 (67,1%)	
Dringking Water Source			
Improved	3 (75,0%)	1 (25,0%)	0,080
Unimproved	193 (33,5%)	383 (66,5%)	
Sanitation (Toilet Facilities)			
Adequate	13 (41,9%)	18 (58,1%)	0,325
Inadequate	183 (33,3%)	366 (66,7%)	
Kitchen Waste Disposal			
Meets standards	186 (34,3%)	356 (65,7%)	0,313
Does not meet standards	10 (26,3%)	28(73,7%)	
Bathroom Waste Disposal			
Meets standards	187 (33,5%)	371 (66,5%)	0,472
Does not meet standards	9 (40,9%)	3 (59,1%)	
Specific Nutrition Indicators			
History of Diarrhea			
Yes	7 (30,4%)	16 (69,6%)	0,728
No	189 (33,9%)	368 (66,1%)	
Hepatitis Immunization History			
No	31 (41,9%)	43 (58,1%)	0,115
Yes	165 (32,6%)	341 (67,4%)	
BCG Immunization History			
No	174 (34,7%)	328 (65,3%)	0,262
Yes	22 (28,2%)	56 (71,8%)	
Polio Immunization History			
No	43 (31,9%)	92 (68,1%)	0,586
Yes	153 (34,4%)	292 (65,6%)	
Iron Supplementation During Pregnancy (TTD)			
No	15 (31,3%)	33 (68,8%)	0,697
Yes	181 (34,0%)	351 (66,0%)	
Multiple Micronutrient Supplementation (MMS) During Pregnancy			
No	196 (33,8%)	384(66,2%)	0,552
Yes	0 (0,0%)	2 (100,0%)	

Table 7. The Role of Family Factors, Sensitive Nutrition Indicators, and Specific Nutrition Indicators on Stunting in Buol District

Variables	Buol (n=510)		
	Stunte	Non-stunted	p-value
Family factors			
Father's education level			

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Variables	Buol (n=510)		
	Stunte	Non-stunted	p-value
High	69 (33,5%)	137 (66,5%)	
Middle	80 (31,6%)	173 (68,4%)	0,257
Low	11 (21,6%)	40 (78,4%)	
Mother's education level			
High	62 (36,5%)	108 (63,5%)	
Middle	86 (31,2%)	190 (68,8%)	0,033
Low	12 (18,8%)	52 (81,3%)	
Father's employment status			
Unemployed	0 (0,0%)	2 (100,0%)	0,338
Employed	160 (31,5%)	348 (68,5%)	
Mother's employment status			
Employed	94 (29,7%)	223 (70,3%)	0,283
Unemployed	66 (34,2%)	127 (65,8%)	
Sensitive Nutrition Indicators			
Health Insurance			
Insured	108 (31,0%)	240 (69,0%)	0,809
Uninsured	52 (32,1%)	110 (67,9%)	
Dringking Water Source			
Improved	3 (21,4%)	11 (78,6%)	0,416
Unimproved	157 (31,7%)	339 (68,3%)	
Sanitation (Toilet Facilities)			
Adequate	33 (43,4%)	43 (56,5%)	0,014
Inadequate	127 (29,3%)	307 (70,7%)	
Kitchen Waste Disposal			
Meets standards	157 (31,4%)	343 (68,6%)	0,925
Does not meet standards	3 (20,0%)	7 (70,0%)	
Bathroom Waste Disposal			
Meets standards	157 (31,5%)	342 (68,5%)	0,767
Does not meet standards	3 (27,3%)	8 (72,7%)	
Specific Nutrition Indicators			
History of Diarrhea			
Yes	158 (31,3%)	346 (68,7%)	0,917
No	2 (33,3%)	4 (66,7%)	
Hepatitis Immunization History			
No	50 (35,0%)	89 (64,0%)	0,171
Yes	110 (29,6%)	261 (70,4%)	
BCG Immunization History			
No	97 (28,0%)	249 (72,0%)	0,018
Yes	63 (38,4%)	101 (61,6%	
Polio Immunization History			
No	74 (38,7%)	117 (61,3%)	0,006
Yes	86 (27,0%)	233 (73,0%)	
Iron Supplementation During Pregnancy (TTD)			
No	32 (36,0%)	57 (64,0%)	0,305
Yes	128 (30,4%)	293 (69,6%)	
Multiple Micronutrient Supplementation (MMS) During Pregnancy			
No	126 (31,2%)	278 (68,8%)	0,861
Yes	34 (32,1%)	72 (67,9%)	

Multivariate Analysis of Determinants of Stunting

Multivariate logistic regression analysis identified key determinants of stunting in several districts. In Mamuju, the ownership of proper kitchen wastewater disposal systems (SPAL dapur) was a significant determinant (p=0.003; AOR=0.36; 95% CI=0.181–0.706), indicating a protective effect. In Buton Selatan, hepatitis immunization status emerged as a significant determinant (p=0.038; AOR=1.88; 95% CI=1.036–3.401), suggesting that incomplete immunization increased the likelihood of stunting. In Buol, the availability of adequate sanitation facilities was significantly associated with stunting (p=0.005; AOR=1.670; 95% CI=1.000–2.799), with inadequate facilities increasing risk. In Minahasa Selatan, multiple determinants were identified, including

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paternal education (p=0.026; AOR=0.560; 95% CI=0.338–0.932), paternal employment (p=0.040; AOR=13.99; 95% CI=1.128–17.336), and health insurance ownership (p=0.023; AOR=0.430; 95% CI=0.208–0.891). No statistically significant determinants were identified in Gorontalo and Jeneponto in the multivariate analysis (table 4)

Table 4. Multivariate Analysis of Determinants of Stunting in High-Prevalence Areas in Sulawesi Island

District/City	p-value	Adjusted Odds Ratio (AOR)	CI 95%
Mamuju			
Father's Education	0.114	0.763	0.546-1.067
Mother's Education	0.131	0.784	0.572-1.075
Mother's Occupation	0.102	1.38	0.938-2.031
Kitchen Wastewater Disposal System	0.003	0.36	0.181-0.706
History of Diarrhea	0.247	0.76	0.473-1.213
Health Insurance Ownership	0.059	0.66	0.435-1.015
Gorontalo			
Father's Education	0.087	0.73	0.507-1.047
Mother's Education	0.079	0.72	0.502-1.038
History of Diarrhea	0.218	3.73	1.450–9.580
Bathroom Wastewater Disposal System	0.136	1.61	0.861-3.005
Multiple Micronutrient Supplementation	0.062	2.80	0.949-8.263
Buton Selatan			
Father's Education	0.615	0.93	0.686-1.249
Mother's Education	0.417	0.88	0.650-1.195
Bathroom Wastewater Disposal System	0.659	0.91	0.612-1.364
Water Source	0.364	1.20	0.807-1.796
Hepatitis Immunization	0.038	1.88	1.036-3.401
Polio Immunization	0.287	0.72	0.400-1.312
Iron Supplementation During Pregnancy	0.36	1.28	0.754-2.177
Jeneponto			
Father's Education	0.088	0.75	0.536-1.044
Mother's Education	0.608	0.92	0.658-1.277
Mother's Occupation	0.320	1.32	0.943-2.607
Hepatitis Immunization	0.083	1.57	0.762-2.296
Water Source	0.145	5.46	0.556-5.535
Buol			
Mother's Education	0.031	0.71	0.524-0.969
Sanitation (Toilet Facilities)	0.05	1.67	1.000-2.799
Hepatitis Immunization	0.122	0.55	0.261-1.171
BCG Immunization	0.262	1.58	0.709-3.538
Polio Immunization	0.084	1.79	0.924-3.458
Minahasa Selatan			
Father's Education	0.026	0.56	0.338-0.932
Father's Occupation	0.04	13.99	1.128-17.336
Health Insurance Ownership	0.023	0.43	0.208-0.891
Water Source	0.149	2.88	0.685-12.104
Hepatitis Immunization	0.558	0.71	0.224-2.239
BCG Immunization	0.174	2.44	0.676-9.801

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Polio Immunization	0.705	0.83	0.319-2.165
Iron Supplementation During Pregnancy	0.473	1.25	0.677-2.319

DISCUSSION

The present study demonstrated substantial district-level heterogeneity in the determinants of stunting across six high-prevalence districts in Sulawesi. Environmental sanitation emerged as the dominant determinant in Mamuju, incomplete hepatitis immunization was more strongly associated with stunting in Buton Selatan, whereas parental education and health insurance ownership played a greater role in Minahasa Selatan and Buol. These findings indicate that the determinants of stunting are highly context-dependent and may differ according to local socioeconomic, environmental, and healthcare conditions. The observed variation suggests that generalized intervention strategies may be insufficient to address the complex and localized drivers of stunting in high-burden regions [19,20].

Parental education emerged as an important determinant of stunting in Buol and Minahasa Selatan. This finding suggests that educational attainment may influence child nutritional status through multiple pathways, including healthcare utilization, feeding practices, health literacy, and household decision-making. Previous studies have consistently shown that children from families with lower parental education are more likely to experience inadequate dietary diversity, poor childcare practices, and reduced access to maternal and child health services [21]. However, the present study extends previous evidence by demonstrating that the influence of parental education varied across districts, indicating that educational disadvantage may interact with local socioeconomic and environmental conditions. In areas with limited healthcare access and lower socioeconomic resources, the protective role of parental education may become more pronounced because educated parents are generally better equipped to utilize available services and adopt preventive health behaviors [22].

Environmental and sanitation-related factors also played a significant role, particularly in Mamuju. Unlike previous studies that primarily focused on toilet ownership or drinking water access, this study identified household kitchen wastewater disposal systems as a significant determinant of stunting. This finding may reflect the local environmental context in Mamuju, where inadequate household wastewater management potentially increases exposure to environmental pathogens and recurrent enteric infections that impair nutrient absorption and linear growth. This result supports existing evidence demonstrating that poor water, sanitation, and hygiene (WASH) conditions contribute to chronic malnutrition through repeated diarrheal diseases and environmental enteric dysfunction [23,24]. The findings therefore reinforce the importance of strengthening environmental health infrastructure as part of integrated stunting reduction strategies, particularly in rural and underserved communities [25].

Health-related factors, particularly immunization status, were also significantly associated with stunting in several districts, especially Buton Selatan. Children with incomplete hepatitis immunization had higher odds of stunting, supporting previous evidence that inadequate immunization coverage increases children's vulnerability to infectious diseases that may impair nutritional status and growth [26]. In high-prevalence settings, incomplete immunization is often linked to limited healthcare access, low caregiver awareness, and inconsistent utilization of child health services [27]. The present findings are consistent with studies showing that children exposed to recurrent infections, including diarrhea and respiratory infections, are more likely to experience chronic growth failure [28]. However, the district-specific significance of immunization observed in this study suggests that the contribution of healthcare-related factors to stunting may vary depending on local service availability and community health practices.

Another important finding was the variability of determinants across districts, underscoring the context-specific nature of stunting. While parental education showed stronger associations in Buol and Minahasa Selatan, environmental sanitation and immunization factors were more dominant in Mamuju and Buton Selatan. This heterogeneity reflects the complex interaction between socioeconomic, geographic, environmental, and healthcare-related conditions across districts [29]. Rural and economically disadvantaged communities are often characterized by limited healthcare access, inadequate sanitation infrastructure, and lower dietary diversity, all of which contribute to persistent stunting [30]. Conversely, districts with relatively better infrastructure may experience different patterns of risk, where socioeconomic or behavioral factors become more influential [31]. These findings suggest that uniform intervention models may not adequately address the diverse determinants operating across high-prevalence regions [32].

The extremely high odds ratio observed for paternal employment status in Minahasa Selatan should be interpreted cautiously. The subgroup of unemployed fathers was very small (n = 3), which may have produced

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unstable estimates and wide confidence intervals. Therefore, this finding may not represent a robust population-level association and should be interpreted as exploratory rather than conclusive. Further studies with larger and more balanced subgroup distributions are needed to clarify the relationship between paternal employment and child nutritional outcomes.

No significant determinants were identified in Gorontalo and Jeneponto after multivariate adjustment. In Jeneponto, several variables demonstrated significant associations during bivariate analysis but lost significance in the multivariate model, suggesting potential confounding or overlapping effects among predictors. The absence of statistically significant determinants may also reflect relatively homogeneous exposure patterns, limited statistical power after adjustment, or the influence of unmeasured contextual factors such as cultural feeding practices, intra-household food allocation, maternal mental health, and community-level environmental conditions [33,34]. These findings indicate that the determinants of stunting in certain districts may extend beyond the variables captured in the SSGI dataset and highlight the complexity of nutritional problems in high-burden settings.

From a broader perspective, the findings of this study support the growing consensus that stunting is a multidimensional problem requiring integrated and multisectoral solutions [35]. Socioeconomic inequalities reflected in disparities in education, income, and access to resources fundamentally shape children's nutritional vulnerability [36]. Households with limited economic resources are more likely to experience food insecurity, rely on lower-quality diets, and have inadequate access to healthcare and sanitation services, thereby increasing the risk of chronic malnutrition [37]. In addition, the concept of resource dilution, in which limited household resources are distributed among multiple family members, may further exacerbate nutritional vulnerability in larger households [10]. These structural determinants should therefore be addressed alongside direct nutrition interventions to achieve sustainable reductions in stunting prevalence [38].

The findings also emphasize the importance of strengthening healthcare systems and improving utilization of maternal and child health services. Access to antenatal care, postnatal care, immunization, and child growth monitoring services plays an essential role in preventing chronic undernutrition [39]. However, in many high-prevalence districts, inadequate healthcare coverage and low participation in community-based nutrition programs may reduce the effectiveness of existing interventions [40]. Previous evidence indicates that insufficient maternal healthcare utilization is associated with increased risk of adverse child growth outcomes, including stunting [41]. These findings reinforce the importance of improving healthcare accessibility and continuity of care in high-burden communities.

The observed heterogeneity across districts suggests that stunting reduction strategies should move beyond uniform national interventions toward more localized and context-specific approaches. In Mamuju, interventions focusing on wastewater management and environmental sanitation may be prioritized, whereas strengthening immunization coverage and healthcare utilization may be more relevant in Buton Selatan. In Buol and Minahasa Selatan, strategies aimed at improving parental education, health literacy, and socioeconomic protection may contribute more substantially to reducing stunting risk. The use of localized evidence is therefore essential for designing targeted interventions that integrate both nutrition-specific and nutrition-sensitive approaches according to district needs.

This study has several limitations. First, the cross-sectional design precludes causal inference and limits the ability to establish temporal relationships between exposure variables and stunting outcomes. Second, the use of secondary SSGI data restricted the analysis to variables available in the dataset, preventing assessment of potentially important factors such as dietary intake, maternal mental health, cultural feeding practices, and household food security. Third, several variables, including immunization history and sanitation conditions, relied partly on self-reported information, which may be subject to recall bias and reporting inaccuracies. Finally, although the SSGI applies a complex survey sampling design, the present analysis did not fully incorporate survey weighting and design effects due to limited availability of detailed survey design variables, which may have influenced standard error estimation and confidence intervals. Despite these limitations, the study provides important district-level evidence regarding the multidimensional and context-specific determinants of stunting in high-prevalence regions of Sulawesi.

CONCLUSION AND RECOMMENDATIONS

The determinants of stunting varied considerably across high-prevalence districts in Sulawesi, indicating that stunting is strongly influenced by local contextual factors. In Mamuju, household kitchen wastewater disposal systems emerged as the primary environmental determinant associated with stunting. In Buton Selatan, incomplete hepatitis immunization was significantly associated with higher odds of stunting, highlighting the importance of healthcare access and immunization coverage. In Buol, low maternal education was identified as an important determinant, suggesting that parental educational attainment plays a critical role in child nutritional outcomes. In Minahasa Selatan, paternal education and health insurance ownership were associated with lower odds of stunting, indicating the importance of socioeconomic and healthcare-related protection factors.

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No significant multivariate determinants were identified in Gorontalo and Jeneponto using the variables available in the SSGI dataset. This finding suggests that the determinants of stunting in these districts may involve additional contextual factors not captured in the present analysis, including cultural feeding practices, behavioral factors, household food allocation, maternal caregiving patterns, and community-level environmental conditions. Future studies should therefore incorporate broader social, cultural, and behavioral variables to better understand district-specific drivers of stunting.

Overall, the findings demonstrate that the determinants of stunting are multidimensional and context-dependent, with substantial variation across districts. These results fill an important evidence gap by providing comparative district-level analysis of family, environmental, and health-related determinants across multiple high-prevalence areas in Sulawesi using an integrated analytical approach. The findings support the need for localized and multisectoral intervention strategies that integrate nutrition-specific and nutrition-sensitive approaches according to the dominant risk factors within each district.

AUTHOR'S CONTRIBUTION STATEMENT:

Conceptualization, data analysis, and discussion writing were conducted by Yessy Kurniati. Nazihah Mukhtar was responsible for data cleaning, results preparation, and assisting in manuscript writing. Both authors reviewed, revised, and approved the final version of the manuscript.

CONFLICTS OF INTEREST:

The authors declare that there are no conflicts of interest related to this study.

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