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Child, maternal, and environmental factors in stunting among children aged 12–59 months

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Abstract

Background: Stunting is an irreversible condition resulting from inadequate nutritional intake, recurrent infections, or chronic illness during the first 1,000 days of life. It can adversely affect children's cognitive and social development, physical health, and long-term economic productivity.
Purpose: To identify factors associated with stunting among children aged 12–59 months in Indonesian border regions.
Method: This cross-sectional study analyzed secondary data from the 2023 Indonesian Health Survey (SKI) among children aged 12–59 months living in Indonesian border regions. The analysis was conducted from March to May 2026. A total of 3,914 eligible children were included. The dependent variable was stunting, while the independent variables were diarrhea, tuberculosis (TB), acute respiratory infection (ARI), low birth weight (LBW), handwashing practices, sanitation facilities, maternal educational level, and parity. Data were analyzed using univariate and bivariate analyses.
Results: The prevalence of stunting was 27.5%. Bivariate analysis showed significant associations between ARI, LBW, sanitation facilities, maternal educational level, parity, and stunting ($p < 0.001$). No significant associations were found between diarrhea ($p = 0.999$), TB ($p = 0.669$), handwashing practices ($p = 0.130$), and stunting.
Conclusion: ARI, LBW, sanitation facilities, maternal educational level, and parity were significantly associated with stunting among children aged 12–59 months in Indonesian border regions. In contrast, diarrhea, TB, and handwashing practices were not significantly associated with stunting. These findings suggest that stunting in border regions is associated with a combination of child health, birth-related, environmental, and socio-demographic factors.

Keywords: Border Regions; Child Nutrition; Infectious Diseases; Public Health; Stunting.

INTRODUCTION

Stunting during a child's growth and development period, particularly from birth to two years of age, is one of the most significant barriers to physical and cognitive development. Stunting is an irreversible condition caused by inadequate nutritional intake, recurrent infections, or chronic illness during the first 1,000 days of life. Stunting affects children's cognitive and social development, national economic performance, and physical health. Recent longitudinal studies involving children from Brazil, Guatemala, India, the Philippines, and South Africa have shown that stunting is associated with reduced educational attainment. Adults who were stunted at the age of two completed nearly one year less of schooling compared to individuals who were not stunted (World Health Organization, 2014).

Globally, an estimated 150.2 million children under the age of five are affected by stunting. These children begin their lives at a significant disadvantage, including not achieving their full height potential and

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experiencing impaired brain development that prevents them from reaching their cognitive potential. In 2024, approximately 51% of stunted children under five lived in Asia, while 43% lived in Africa (United Nations Children's Fund, World Health Organization, & World Bank Group, 2025). The national prevalence of stunting in Indonesia has declined over the past three years. Data from the 2022 Indonesian nutritional status survey showed a stunting prevalence of 21.6% (Health Development Policy Agency, 2022), which decreased slightly to 21.5% in 2023 (Health Development Policy Agency, 2024) and further declined to 19.8% in 2024 (Health Development Policy Agency, 2025). Despite this progress, the prevalence remains above the national target set in the National Medium-Term Development Plan (*RPJMN*), which aims to reduce stunting to 14%, and the long-term target of achieving a prevalence of ≤5% by 2045. Because stunting reflects the quality of a country's human resources, the Indonesian government has designated the acceleration of stunting reduction as one of its national development priorities (Ministry of National Development Planning/National Development Planning Agency, 2025).

Stunting causes chronic growth impairment in children under five and has serious consequences for health and development, both in the short and long term. The short-term effects of stunting include reduced immune function, an increased risk of infections, illness, and mortality among children (Khotimah, 2022; Martony, 2023). Children's cognitive, motor, and verbal development is also adversely affected, accompanied by increased healthcare costs for families (Akbar et al., 2023). These impairments often result from chronic malnutrition and recurrent infections during the first 1,000 days of life. In the long term, stunting leads to short adult stature, an increased risk of obesity, degenerative diseases such as diabetes and cardiovascular disease, and reproductive health problems (Alwi et al., 2022). Children who experience stunting are more likely to have lower intelligence levels, poorer academic performance, reduced work productivity, and contribute to national economic losses due to persistent poverty (Rozalina et al., 2024). These effects are permanent, including irreversible brain damage and hindered human resource potential, as demonstrated by cohort studies conducted in Guatemala (Dewey & Begum, 2011).

Border communities are predominantly composed of indigenous ethnic groups with cross-border kinship ties, shared languages, and similar social norms with neighboring countries, as well as high mobility driven by traditional migration and socio-economic activities. Their economies largely depend on subsistence agriculture, plantations, livestock farming, and informal cross-border trade, with high levels of poverty and reliance on local commodities. Although these regions possess substantial natural resources, limited resource management has contributed to persistent development disparities compared to central regions (Wesnawa & Sudhirta, 2017). In Indonesia, border areas such as North Central Timor Regency, East Nusa Tenggara, which borders Timor-Leste, have experienced a high prevalence of stunting, reaching 46.7% in rural border communities in 2022. This high prevalence has been attributed to disparities in healthcare access, inadequate sanitation infrastructure, low socioeconomic status, limited maternal education, and complex sociodemographic factors, including economic inequality and poor environmental conditions (Lestari et al., 2024).

Stunting is a multifactoral condition influenced by interconnected biological, behavioral, and social factors. Direct causes include infectious diseases such as acute respiratory infections (ARI), tuberculosis (TB), and diarrhea, which can impair nutrient absorption and increase nutrient losses; recurrent ARI has been reported to increase the risk of stunting by up to 5.3 times (Sari, 2016). Indirect factors include inadequate handwashing practices and inadequate sanitation, which increase the risk of infection and contribute to the cycle of malnutrition, as highlighted by the association between poor sanitation and stunting (Aprilyaningsih et al., 2025). Other significant risk factors include low birth weight (LBW) (Nainggolan & Sitompul, 2019), high maternal parity (Aryawati et al., 2025), and inadequate parental knowledge regarding nutrition and child feeding practices during the first 1,000 days of life. Despite ongoing interventions, stunting remains a major public health concern in Indonesia, with a prevalence of 19.8% in 2024 (Health Development Policy Agency,

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2025). Low maternal education is associated with suboptimal childcare practices and may contribute to chronic undernutrition during the first 1,000 days of life. A cross-sectional study in the Kandanghaur Community Health Center area, Indramayu, found a significant association between maternal education and stunting (p = 0.005) (Husnaniyah et al., 2020).

Border regions in Indonesia continue to experience developmental disparities compared with other areas and often have a high prevalence of stunting. For instance, North Central Timor Regency reported a stunting prevalence of 47.3% based on the 2024 Indonesian Nutritional Status Survey (Health Development Policy Agency, 2025). However, evidence regarding factors associated with stunting in border communities remains limited. Further research is therefore needed to address this knowledge gap and provide empirical evidence to inform context-specific policies and targeted interventions for stunting reduction.

RESEARCH METHOD

This study employed a quantitative analytical observational design with a cross-sectional approach. The study was conducted from March to May 2026 using secondary data from the 2023 Indonesian Health Survey (Survei Kesehatan Indonesia/SKI 2023). The study focused on Indonesian provinces sharing international land or maritime borders with neighboring countries, namely the Riau Islands, East Nusa Tenggara, West Kalimantan, North Kalimantan, Papua, and South Papua.

The data were obtained from the 2023 Indonesian Health Survey, provided by the Health Development Policy Agency under the Ministry of Health of the Republic of Indonesia. The dataset contained information on nutritional status, health conditions, environmental sanitation, and socio-demographic characteristics of children under five years of age.

The study population consisted of children aged 12–59 months living in the selected Indonesian border regions. A total of 3,914 eligible observations were included in the analysis. All eligible observations available in the dataset were included; therefore, no sampling procedure was applied at the individual level.

The dependent variable was stunting status, defined based on height-for-age (for children aged 24–59 months) or length-for-age (for children aged 12–23 months) with a height-for-age or length-for-age z-score below −2 standard deviations (SD) according to the applicable WHO Child Growth Standards.

The independent variables included diarrhea, acute respiratory infection (ARI), tuberculosis (TB), low birth weight (LBW), handwashing practices, sanitation facilities, maternal educational level, and parity.

Diarrhea was defined as whether the child had experienced diarrhea within the previous month. ARI was defined as whether the child had experienced an acute respiratory infection within the previous month. TB was defined as whether the child had been diagnosed with or experienced tuberculosis within the previous year. LBW was defined as a birth weight of less than 2,500 g.

Handwashing practices were assessed based on whether respondents reported washing their hands with clean water at relevant times, including before eating, when their hands were dirty, after defecation, after handling pesticides, after cleaning a child following defecation, and before breastfeeding.

Sanitation facility was defined according to access to an improved sanitation facility or healthy latrine, characterized by a pour-flush/gooseneck toilet, a toilet located within or adjacent to the household premises, and a septic tank or other appropriate fecal sludge containment system.

Maternal educational level was categorized as high when the mother had completed tertiary education. Parity was categorized based on the number of children born to the mother, with higher parity defined as having more than two children.

The inclusion criterion was children aged 12–59 months living in the selected Indonesian border regions and recorded in the SKI 2023 dataset. Observations with missing data for the variables required for the analysis were excluded.

Data analysis consisted of univariate and bivariate analyses. Univariate analysis was performed to describe the distribution of each study variable using frequencies and percentages. Bivariate analysis was conducted to examine the association between each

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independent variable and stunting status using the chi-square test. Statistical significance was determined using a two-sided p-value <0.05 with a 95% confidence interval (CI).

This study received ethical approval from the Research Ethics Commission of the Faculty of Health Sciences and Psychology, Universitas Muhammadiyah Pontianak, under approval number 013/KEPK-FikPsi/UM PONTIANAK/2026. The study used secondary, anonymized data, and no personally identifiable information was accessed. Data confidentiality and applicable ethical principles for research involving human subjects were maintained throughout the study.

RESEARCH RESULTS

Table 1. Characteristics of Respondents (N=3,914)

Variable	Results
Province (n/%)	
Riau Islands	641/16.4
East Nusa Tenggara	1406/35.9
West Kalimantan	990/25.3
North Kalimantan	433/11.1
Papua	294/7.5
South Papua	150/3.8
Age (Mean±SD)(Range)(Year)	(2.43 ± 1.09) (1–4)
Age (n/%)	
1	1002/25.6
2	1092/27.9
3	963/24.6
4	857/21.9
Gender (n/%)	
Male	2055/52.5
Female	1859/47.5
Stunting Status (n/%)	
Stunted	1075/27.5
Not Stunted	2839/72.5
Diarrhea (n/%)	
Yes	253/6.5
No	3661/93.5
Tuberculosis (TB) (n/%)	
Yes	6/0.2
No	3908/99.8
Acute Respiratory Infection (ARI) (n/%)	
Yes	814/20.8
No	3100/79.2
Birth Weight (n/%)	
Low (< 2500 g)	225/5.7
Normal (≥ 2500 g)	3689/94.3

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Variable	Results
Handwashing Practices (n/%)	
Inadequate	3066/78.3
Adequate	848/21.7
Sanitation Facility (n/%)	
Unimproved	1168/29.8
Improved	2746/70.2
Educational Level (n/5%)	
Low	3158/80.7
High	756/19.3
Parity (n/%)	
>2 children	1788/45.7
≤2 children	2126/54.3

Table 1 presents the characteristics of the 3,914 children aged 12–59 months included in the study. The largest proportion of children were from East Nusa Tenggara (35.9%), followed by West Kalimantan (25.3%) and the Riau Islands (16.4%). The mean age of the children was 2.43 ± 1.09 years, with an age range of 1–4 years. More than half of the children were male (52.5%). The prevalence of stunting was 27.5%, while 72.5% of children were not stunted.

Regarding health conditions, 6.5% of children had experienced diarrhea and 20.8% had experienced acute respiratory infection (ARI), whereas only 0.2% had tuberculosis. Low birth weight (<2,500 g) was reported in 5.7% of children. Most respondents reported inadequate handwashing practices (78.3%), while 70.2% had access to improved sanitation facilities. In terms of maternal educational level, 80.7% of mothers had low educational attainment, whereas 19.3% had high educational attainment. Regarding parity, 45.7% of mothers had more than two children, while 54.3% had two or fewer children.

Table 2. Bivariate Analysis by Chi-Square (N=3,914)

Variables	Stunting Status		PR	95% CI	p-value
	Stunted	Not Stunted			
Diarrhea (n/%)					
Yes	69/27.7	184/72.3	1.008	0.820 − 1.239	0.999
No	1006/27.5	2655/72.5			
Tuberculosis (TB) (n/%)					
Yes	2/33.3	4/66.7	1.214	0.391 − 3.769	0.669
No	1073/27.5	2835/72.5			
Acute Respiratory Infection (ARI) (n/%)					
Yes	224/31.2	590/68.8	1.178	1.047 − 1.325	0.008*
No	851/26.5	2249/73.5			
Birth Weight (n/%)					
Low (< 2500 g)	62/42.2	163/57.8	1.589	1.352 − 1.869	0.000*
Normal (≥ 2500 g)	1013/26.6	2676/73.4			

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Variables	Stunting Status		PR	95% CI	p-value
	Stunted	Not Stunted			
Handwashing Practices (n/%)					
Inadequate	842/28.0	2224/72.0	1.106	0.973 − 1.258	0.130
Adequate	233/25.4	615/74.6			
Sanitation Facility (n/%)					
Unimproved	321/33.2	847/66.8	1.328	1.197 − 1.473	0.000*
Improved	754/25.0	1992/75.0			
Educational Level (n/5%)					
Low	867/28.7	2291/71.3	1.283	1.111 − 1.482	0.001*
High	208/22.4	548/77.6			
Parity (n/%)					
>2 children	491/30.4	1297/69.6	1.218	1.100 – 1.349	0.000*
≤2 children	584/25.0	1542/75.0			

*: significantly associated

Bivariate analysis was conducted to examine the association between the dependent variable and the independent variables using the Chi-Square Test and calculation of the Prevalence Ratio (PR) with 95% confidence interval (CI). The results of the bivariate analysis are shown in Table 2.

The prevalence of stunting was 27.7% in children with diarrhea and 27.5% in those without. Diarrhea and stunting did not significantly correlate (p = 0.999; PR = 1.008; 95% CI: 0.820 − 1.239). Stunting was also more common in children with TB (33.3%) than in children without TB (27.5%). However, this difference was not statistically significant (p = 0.669; PR = 1.214; 95% CI: 0.391 − 3.769).

Stunting was more common in children with ARI (31.2%) than in children without ARI (26.5%), and the difference was statistically significant (p = 0.008; PR = 1.178; 95% CI: 1.047 − 1.325). Similarly, stunting was much more common in children with LBW (42.2%) than in children with normal birth weight (26.6%), with a strong correlation (p < 0.001; PR = 1.589; 95% CI: 1.352 − 1.869).

Respondents with inadequate handwashing practices had a slightly higher prevalence of stunting (28.0%) than those with adequate handwashing practices (25.4%). However, no significant association was observed (p = 0.130; PR = 1.106; 95% CI: 0.973 − 1.258). In contrast, children living in households with unimproved sanitation facilities had a significantly higher prevalence of stunting (33.2%) than those living in households with improved sanitation facilities (25.0%) (p < 0.001; PR = 1.328; 95% CI: 1.197 − 1.473).

Children of respondents with low educational attainment had a higher prevalence of stunting (28.7%) than those of respondents with high educational attainment (22.4%), with a significant association observed (p = 0.001; PR = 1.283; 95% CI: 1.111 − 1.482). Similarly, children from families with a higher-than-ideal number of births had a greater prevalence of stunting (30.4%) compared with those from families with an ideal number of births (25.0%), indicating a significant association (p < 0.001; PR = 1.218; 95% CI: 1.100 – 1.349).

DISCUSSION

Association Between Diarrhea and Stunting

The results of this study showed no significant association between diarrhea and stunting among children under five. This finding is consistent with previous studies reporting no significant association between a history of diarrhea and stunting among children under five in Bilalang Health Center, North Kotamobagu District, Kotamobagu City (Purba et al., 2019), among children aged 13–48 months in Manyar Sabrangan Village, Surabaya (Safitri & Nindya, 2017), and between a history of infectious diseases and stunting in West Kalimantan (Ashari, 2022). In Indonesian border districts, where access to safe water and sanitation infrastructure may vary across

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frontier areas, diarrhea could theoretically contribute to nutritional deficits and impaired child growth. However, the absence of a significant association in this study may be partly explained by the measurement of diarrhea in the 2023 Indonesian Health Survey (SKI), which recorded diarrhea occurring only within the previous month. This relatively short recall period may not adequately capture recurrent, prolonged, or cumulative episodes of diarrhea that could have a greater impact on nutrient absorption and contribute to chronic growth impairment. Therefore, the lack of a significant association should not necessarily be interpreted as evidence that diarrhea has no role in stunting, but rather may reflect limitations in the temporal measurement of diarrheal exposure within the dataset.

In young children, diarrhea and stunting are intimately associated, with repeated or prolonged diarrheal episodes serving as both a cause and an effect of chronic malnutrition. Recurrent episodes of diarrhea decrease the body's capacity to absorb vital nutrients like protein, vitamins, and minerals required for healthy bone and tissue growth, while also increasing nutrient losses and energy expenditure during illness recovery. A meta-analysis of nine studies involving 69,549 children under five from Ethiopia, Uganda, Indonesia, and Pakistan revealed that toddlers with a history of diarrhea had a significantly higher risk of stunting compared to those without such a history (Firmansyah et al., 2023). In light of this evidence, interventions targeted at enhancing water, sanitation, and hygiene (WASH) practices, in addition to encouraging exclusive breastfeeding and promptly managing diarrheal episodes, are crucial tactics to lower the incidence of diarrhea and its long-term effects on child growth, especially in resource-constrained settings like Indonesian border regions, where access to clean water and sanitation infrastructure may be uneven.

Association Between Tuberculosis (TB) and Stunting

In this study, tuberculosis (TB) was not significantly associated with stunting among children under five in Indonesian border regions. Although TB may contribute to impaired growth through chronic inflammation, increased metabolic demands, and reduced nutritional status, the absence of a significant association in this study may be related to the very low prevalence of TB in the study population. Only six children were identified as having TB, including children who were both stunted and not stunted. The small number of TB cases may have limited the statistical power to detect an association between TB and stunting. This finding is consistent with previous research in East Nusa Tenggara, which reported no significant association between TB infection and stunting among children under five ($p = 0.801$) (Friska et al., 2025). Similarly, a study conducted in Bengkulu City and North Bengkulu Regency found that a history of TB treatment was not significantly associated with stunting ($p = 0.393$) (Hariadi et al., 2022). These findings suggest that the low occurrence of TB among children in the present study may have contributed to the absence of a statistically significant association, although the potential role of TB in child growth should not be excluded.

The lack of a significant association may be attributed to the small number of children with TB in the study population. The current study's finding that TB was not associated with stunting is different from several recent Indonesian studies, which generally report a positive association between TB and poor growth or stunting risk. For example, a study in Bandung reported that pulmonary TB was present in more than half of stunted under-five children, suggesting overlapping vulnerability between TB and stunting (Nataprawira et al., 2024). Chronic TB infection and repeated TB exposure impair nutritional status through prolonged inflammation, increased metabolic demands, reduced appetite, and frequent illness, which can retard linear growth and increase the odds of stunting in young children (World Health Organization, 2024).

Association Between Acute Respiratory Infection (ARI) and Stunting

In this study, acute respiratory infection (ARI) was significantly associated with stunting among children under five in Indonesian border regions. This finding is consistent with previous studies reporting a significant association between a history of ARI and stunting among children under five (Pulungan et al.,

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2024) and among children aged 1–5 years (Maro et al., 2023). However, this finding contrasts with a study conducted among children attending Posyandu X in Padang City, which reported no significant association between ARI and stunting (p = 0.734) (Rikandi & Nurhaida, 2023). The significant association observed in the present study may be explained by the potential effects of recurrent respiratory infections on nutritional status and child growth. Repeated episodes of ARI may increase metabolic demands and reduce appetite and nutrient intake, while inflammatory responses may increase energy requirements and divert available nutrients away from linear growth. These effects may be more pronounced among children living in settings with limited access to healthcare services and preventive measures. Thus, the significant association between ARI and stunting in Indonesian border regions may reflect the cumulative nutritional and physiological consequences of recurrent respiratory infections during early childhood.

Stunting and acute respiratory infections are closely connected illnesses in children under five, especially in low- and middle-income nations like Indonesia. Stunting, which is a sign of chronic undernutrition, weakens a child's immune system and makes them more susceptible to respiratory infections. On the other hand, frequent or recurrent ARI episodes can impede nutrient absorption, reduce appetite, and focus energy on fighting infection rather than growth, all of which can exacerbate or cause linear growth faltering (Desye et al., 2025). This bidirectional link is supported by quantitative evidence; a Bayesian multilevel study in Ethiopia found that under-five children who were stunted were 59.5% more likely to experience ARI than children who were not stunted (Merera et al., 2022), reinforcing the view that nutritional status and respiratory illness reinforce one another in a cyclical manner rather than acting as isolated risk factors. To break the cycle of infection and growth faltering in vulnerable populations, such as those in Indonesian border regions where both conditions tend to be more prevalent due to limited healthcare access and socioeconomic constraints, integrated public health interventions that concurrently target nutritional status (through adequate complementary feeding, micronutrient supplementation, and growth monitoring) and respiratory health (through immunization, reduction of indoor air pollution, and improved access to healthcare).

Association Between Low Birth Weight (LBW) and Stunting

The results of this study indicate a significant association between low birth weight (LBW) and stunting among children under five. This finding is consistent with previous studies reporting a significant association between a history of LBW and stunting. A study conducted among children aged 24–59 months found that LBW was significantly associated with stunting (p = 0.004) (Febyani et al., 2026). Similarly, a study conducted in Gunung Lurah reported a significant association between LBW and stunting among children under five (p = 0.012) (Karmadani & Yektiningtyastuti, 2025). The association observed in this study may reflect the influence of impaired fetal growth and suboptimal intrauterine conditions on subsequent linear growth. Children born with low birth weight may have reduced physiological reserves and remain vulnerable to growth faltering during early childhood, particularly when exposed to inadequate nutrition or recurrent illness. In border populations, geographical barriers and variations in access to maternal and child health services may further contribute to these vulnerabilities. However, the observed association may also be influenced by unmeasured maternal factors, such as pre-pregnancy nutritional status, maternal health, and genetic growth potential, which may affect both birth weight and subsequent child growth trajectories.

Low birth weight (LBW), defined as a birth weight below 2,500 grams, has been consistently identified as a significant determinant of stunting in children, as low birth weight reflects impaired fetal growth that often originates from inadequate maternal nutrition during pregnancy, leaving affected infants with a growth disadvantage that can persist into childhood if not corrected through adequate postnatal nutrition. This association is supported by multilevel logistic regression evidence from Bontang, East Kalimantan, where children under five with a history of LBW had a significantly higher risk of stunting compared to those with normal birth weight (p = 0.043); growth hampered

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since the womb increases the possibility of stunted growth after birth (Sugiyanto et al., 2019). Similarly, a study using Indonesia's national Nutrition Status Survey (SSGI) data confirmed that children with a history of LBW had significantly higher odds of stunting compared to those with normal birth weight (Rahmadiani et al., 2025). This finding underscores the importance of prenatal care, maternal nutrition during pregnancy, and early postnatal growth monitoring as key intervention points to reduce both LBW and its downstream effect on stunting prevalence.

Association Between Handwashing Practices and Stunting

The results of this study showed a negative association between handwashing practices and stunting among children under five in Indonesian border regions. This finding is consistent with a study conducted in Gorontalo Regency, which found no significant association between handwashing with soap and stunting ($p = 0.053$) (Ahmad & Nurdin, 2019). Similarly, no significant association was reported between mothers' handwashing practices and stunting among children under five ($p = 0.672$) (Pertiwi et al., 2019). Another study also found no significant association between handwashing practices and stunting ($p = 0.821$) (Ramadhania et al., 2025). These findings suggest that handwashing practices alone may not be sufficient to prevent stunting, as child growth is influenced by multiple interconnected factors, including household sanitation, drinking-water quality, dietary intake, infection, socioeconomic conditions, and access to health services. Therefore, the relationship between hygiene practices and stunting may depend on the broader WASH environment and its interaction with other determinants of child growth, particularly in geographically vulnerable border regions.

Handwashing practices in border communities may show limited variability because households may face similar constraints in accessing water and sanitation facilities, potentially reducing the variability needed to detect a statistical association with stunting. In addition, handwashing practices were self-reported, which may have introduced social desirability bias and resulted in overreporting of desirable hygiene behaviors. Although several studies have reported no statistically significant direct association between handwashing practices and stunting, this does not necessarily exclude an indirect or context-dependent role of hygiene in child growth. Evidence suggests that WASH interventions may have greater effects on child health and growth when implemented as part of integrated interventions rather than as isolated measures. For example, integrated WASH interventions combined with nutritional support have been associated with reductions in diarrhea and improvements in child growth outcomes (Luby et al., 2018). Similarly, evidence from a randomized trial indicated that isolated WASH interventions had limited effects on linear growth, suggesting that improvements in water, sanitation, and hygiene may need to be accompanied by broader environmental, nutritional, and behavioral interventions to produce meaningful effects on child growth (Null et al., 2018).

Association Between Sanitation Facility and Stunting

This study found a significant association between access to sanitation facilities and stunting among children under five in Indonesian border regions. These findings are consistent with a study conducted in Sigi Regency, which reported a significant association between access to sanitation facilities and stunting (Suarayasa et al., 2022). Similarly, another study found a significant association between household latrine ownership and stunting among children under five (Pratama et al., 2024). Inadequate sanitation facilities may remain an important challenge in border regions where infrastructure and access to basic services can vary considerably. Poor sanitation may increase children's exposure to fecal pathogens and contaminated environments, potentially contributing to repeated infections and impaired nutrient absorption. This mechanism may involve environmental enteric dysfunction, which can adversely affect nutrient utilization and linear growth over time. Therefore, the significant association observed in this study may reflect the broader influence of household sanitation conditions on children's exposure to environmental health risks.

The significant association between improved sanitation facility ownership and stunting in this study supports the broader evidence that sanitation is an

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important indirect determinant of child linear growth. Access to an improved sanitation facility breaks the fecal–oral transmission chain, reducing recurrent infections such as diarrhea that impair nutrient absorption and contribute to chronic growth failure. A study in Dairi District, North Sumatra, Indonesia, reported that ownership of sanitation facilities that do not meet standards triggers infectious diseases due to poor hygiene and sanitation, which inhibits nutrient absorption in the digestive tract and affects toddler growth (Tanjung et al., 2024). Improved sanitation facilities are not only a sanitation infrastructure issue but a critical public health intervention that reduces infection-related constraints and supports optimal child nutrition.

Association Between Educational Level and Stunting

This study found a positive association between educational level and stunting among children under five in Indonesian border regions. This finding appears to differ from previous evidence suggesting a protective effect of higher parental education against stunting. Previous research reported that the odds of stunting generally increased as parental education levels decreased, with the odds being approximately twice as high among children of parents with low education compared with those whose parents had high education (Beal et al., 2018). Similarly, maternal education was significantly associated with stunting among children (Kuswanti et al., 2024), while parental educational level, particularly maternal education, was also significantly associated with stunting (Prapatti et al., 2025). Maternal education's protective effect is consistent with its role in border communities, where lower attainment may limit access to health information and appropriate feeding practices amid constrained service availability. Yet this association may be confounded by household wealth, which tends to correlate strongly with both maternal education and access to healthcare in frontier settings, making it difficult to isolate education as an independent causal factor.

Maternal education plays a critical protective role against stunting, as it shapes a mother's capacity to acquire and apply nutrition knowledge throughout pregnancy and early childhood. A case-control study conducted in Sidenreng Rappang, South Sulawesi, found that toddlers born to mothers with low education were significantly more at risk of stunting than those with higher education ($p = 0.022$). Maternal education reflects a mother's capacity in terms of nutritional knowledge, since avoiding stunting in children requires adequate awareness to sustain practices such as exclusive breastfeeding through the recommended first six months of life (Sulaiman et al., 2021). This protective mechanism operates because mothers who understand the importance of proper nutrition are motivated to seek and sustain optimal feeding practices, whereas those lacking such knowledge may have no clear motivation to do so, ultimately affecting the quality and adequacy of nutritional intake provided to their children, given that fulfilling nutritional needs from pregnancy to toddlerhood requires support from family knowledge and awareness. Mothers with at least secondary education had significantly lower odds of having stunted children (Setiawati et al., 2025), emphasizing that education empowers mothers to make informed nutritional choices and access early childhood health programs more effectively. Higher levels of education contribute to better nutritional knowledge, improved decision-making regarding child care, and greater access to healthcare services. Families with higher educational attainment may have greater access to resources needed to provide adequate nutrition and healthcare for their children, thereby reducing the risk of stunting.

Association Between Number of Births (Parity) and Stunting

The results of this study showed a significant association between parity and stunting among children in Indonesian border regions. This finding is consistent with previous research showing that having a large number of children was significantly associated with stunting and was the most dominant factor related to its occurrence (Aprisupiati et al., 2025). Similarly, parity has been reported to be associated with stunting at birth (Sari & Sartika, 2021). In contrast, another study reported a correlation coefficient of 0.38 between the number of births and the number of stunted infants, indicating a relatively weak association (Binuko, 2023). The significant

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association observed in the present study may reflect the challenges faced by larger families in allocating adequate nutritional, caregiving, and healthcare resources among children. These challenges may be particularly relevant in border regions, where limited household resources and access to healthcare services may further constrain families' capacity to meet the nutritional and caregiving needs of all children.

A study on repeated pregnancy among young mothers found that higher parity was associated with an increased risk of stunting, with repeated pregnancies increasing the odds of both stunting and persistent stunting through pathways such as low birth weight and suboptimal feeding practices (Maravilla et al., 2020). This suggests that the relationship between parity and child growth may involve not only biological mechanisms but also behavioral and economic factors, as repeated pregnancies may deplete maternal nutritional reserves and reduce the attention and resources available to each child. As family size increases, household demand for food and other essential resources also rises, potentially resulting in inadequate nutritional intake among children. Such conditions may compromise nutritional status and increase the risk of impaired growth and development. Therefore, high parity may compound existing nutritional and socioeconomic risks and contribute to chronic growth failure.

CONCLUSION

This study identified acute respiratory infections (ARI), low birth weight (LBW), sanitation facilities, educational level, and parity as significant factors associated with stunting among children aged 12–59 months in Indonesian border regions. In contrast, diarrhea, tuberculosis (TB), and handwashing practices were not significantly associated with stunting. These findings highlight that stunting in border regions is influenced by a combination of child health, birth, environmental, and socio-demographic factors. Therefore, multisectoral interventions that strengthen maternal and child health services, improve sanitation, promote education, and support family planning are essential to accelerate the reduction of stunting in Indonesian border communities. This study has several limitations. The cross-sectional design of the SKI 2023 data does not allow causal associations to be established, and the use of self-reported and secondary data may have introduced recall bias and limited the inclusion of other relevant determinants.

SUGGESTION

Based on the findings of this study, several recommendations are proposed for stakeholders and policymakers. Early detection and management of acute respiratory infections (ARI) should be strengthened through integrated child health services at the community level, while antenatal care quality must be improved to reduce the incidence of low birth weight (LBW). Expansion of healthy sanitation facilities and latrine access requires cross-sectoral collaboration between health and local government agencies. Maternal education and family planning programs should be reinforced to improve caregiver health literacy and support optimal birth spacing, both of which were identified as significant factors associated with stunting. Future research is encouraged to evaluate the effectiveness of integrated interventions targeting these determinants in the Indonesian border region context.

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