



WASH Determinants of Stunting among Toddlers in Jayapura, Papua: Evidence from a Multivariate Analysis

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Abstract

Stunting has severe consequences, including impaired growth, cognitive deficits, reduced productivity, and increased susceptibility to disease. This study aimed to examine the determinants of stunting, emphasizing water, sanitation, and hygiene (WASH) practices. A case-control design involving toddlers aged 25–59 months in Jayapura City from May to August 2023 was applied. Three hundred twenty-six children were recruited using consecutive sampling, with a 1:1 ratio of cases and controls. Inclusion criteria were residence within the public health center catchment area and parental consent to participate. Controls were selected after matching for age, sex, and ethnicity within the same neighborhood as cases. Data were collected through structured questionnaires and analyzed using multivariate logistic regression. The prevalence of stunting was 50%. Significant associations were observed between stunting and household factors, including drinking water and food management, access to clean water, latrine conditions, liquid waste disposal, and solid waste management. Among these, drinking water and food management practices emerged as the most dominant determinant, indicated by the highest adjusted odds ratio (AOR). These findings underscore the critical role of WASH practices in reducing the burden of stunting in Papua.

INTRODUCTION

Stunting remains one of the most critical public health challenges globally, with serious long-term effects on children's growth, cognitive capacity, productivity, and health. The Global Nutrition Report (2018) estimated that about 150.8 million children under five, representing 22.2% of this age group worldwide, are stunted, underscoring its role as a significant barrier to human development (The 2018 Global Nutrition Report, 2018). In response, the World Health Assembly (WHA) set an ambitious target of a 40% reduction in global stunting prevalence by

2025. However, progress has been slower than required, as highlighted in the Global Nutrition Report (2020), which noted that the current global Annual Average Reduction Rate (AARR) is only 2.2%, falling short of the 3.9% annual rate needed to reach the WHA goal (UNICEF, 2022; WHO, 2023; Woldesenbet et al., 2020).

In Southeast Asia, Indonesia ranks third-highest in stunting prevalence (Azriani et al., 2024). The determinants of stunting are multifactorial and can be broadly categorized into direct and indirect causes (Azriani et al., 2024). Direct factors include maternal nutritional status, infec-

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tious diseases, and infant feeding practices. In contrast, indirect factors are shaped by socioeconomic conditions and environmental influences such as water, sanitation, and hygiene (WASH) practices (Laksono et al., 2024). Previous studies in Indonesia have linked inadequate sanitation and poor hygiene practices to diarrheal disease and stunting (Rah et al., 2020). For instance, poor household water quality, limited access to latrines, and inadequate hygiene practices such as handwashing have all been associated with impaired growth outcomes in children (Meiyetrian & Utomo, 2025).

Despite national progress, sanitation disparities remain striking across Indonesia. According to the Ministry of Health's 2021 Health Profile, 80.29% of households nationwide have access to improved sanitation. However, Papua recorded the lowest coverage, with only 40.81% of households having adequate sanitation facilities (Statistics Indonesia (BPS), 2022). Evidence also shows that combining unimproved latrines with untreated drinking water increases the likelihood of stunting among Indonesian children (Torlesse et al., 2016a). Local health surveillance data from the Jayapura City Health Office further demonstrate the magnitude of the stunting burden in the region. In 2020, the North Jayapura Health Center reported 175 stunting cases, equivalent to 26% of its total toddler population, followed by 129 cases (16.6%) in Kotaraja and 63 cases (15.6%) in Abepura (Irjayanti et al., 2024). The prevalence of stunting in these health centers showed an upward trend between 2021 and 2022, with North Jayapura rising from 18.4% to 19.8% and Abepura from 12.3% to 15.9%. As of March 2023, North Jayapura remained the highest at 16.5%, followed by Abepura at 16% (Jayapura City Health Office, 2023).

Water, Sanitation, and Hygiene (WASH) represents an integrated public health framework that promotes equitable access to safe drinking water, adequate sanitation facilities, and appropriate hygiene practices as fundamental determinants of human health. The framework is closely aligned with the global development agenda, particularly Sustainable Development Goal (SDG) 6, which aims to ensure the availability and sustainable management of water and sanitation for all. Conceptually, WASH is grounded in the environmental determinants of disease model, especially the fecal–oral transmission pathway. Recurrent exposure to fecal contamination through unsafe water sources, inadequate sanitation infrastructure, and poor hygiene practices increases susceptibility to enteric infections,

including diarrheal diseases. Chronic exposure to enteric pathogens has also been associated with environmental enteric dysfunction (EED), a subclinical inflammatory condition of the small intestine that compromises nutrient absorption and contributes to linear growth faltering in children (Hall et al., 2017; Lowe et al., 2025).

Much of the existing research in Indonesia has emphasized maternal nutrition and infant feeding as the primary determinants of stunting, often treating WASH-related factors as secondary (Handayani et al., 2023; Wulandari et al., 2025). However, in areas such as Papua, where access to safe drinking water and sanitation is limited WASH may play a more dominant role. To date, limited evidence has highlighted WASH as the principal determinant of stunting, particularly using rigorous designs such as matched case-control studies. This study addresses this gap by investigating WASH practices, especially drinking water and food management, as the dominant predictor of stunting in Jayapura, Papua. This study analyzes the association between child and maternal characteristics, diarrheal disease history, hygiene behaviors, and household sanitation with stunting among toddlers aged 25–59 months in Jayapura City. Emphasis is placed on examining the dominant role of WASH practices in influencing stunting outcomes.

METHOD

Study Design

This research employed an observational case-control design to investigate the determinants of stunting among toddlers. The case-control approach was chosen because stunting, while prevalent, has multifactorial causes that are best examined by comparing affected (cases) and unaffected (controls) groups within the same community. Compared with prospective cohort studies, this design was considered efficient for assessing multiple risk factors concurrently within a limited timeframe and with limited resources. A case-control study is a commonly used observational analytical design in epidemiology in which participants are selected based on outcome status (cases with the outcome and controls without the outcome) and exposures of interest are then compared between groups. This design is particularly useful when multiple risk factors need to be examined concurrently, and when the outcome of interest has a relatively low incidence in the population, as it allows efficient estimation of associations through odds ratios. Previous studies examining WASH-related determinants of stunting have similarly employed case-control or

comparable analytical designs to efficiently identify independent predictors within defined populations (Pérez-Guerrero et al., 2024; Torlesse et al., 2016b).

The dependent variable was stunting status, defined as a height-for-age (HAZ) Z-score <-2 SD based on the WHO Child Growth Standards. Anthropometric data were obtained from the Child Health Card (Kartu Menuju Sehat/KMS), which contains routine growth monitoring records measure by trained health personel at community health centers and Posyandu service following national standardized anthropometric procedures, while the independent variables encompassed: (1) child characteristics (sex: boy/girl and ethnicity: native Papua/non Papua); (2) maternal characteristics (age: ≤ 22 , 23–35, and > 35 years, education: primary/secondary/higher, and occupation: not work/work); (3) environmental health determinants, including both direct factors (history of diarrheal disease: yes/no) and indirect factors (hygiene practices such as handwashing, defecation, waste management, and drinking water and food handling, categorized as bad or good based on predefined criteria); and (4) household sanitation indicators (access to drinking water, latrine condition, liquid and solid waste disposal, categorized as non eligible or eligible according to national sanitation standards).

The study was carried out between May and August 2023 in two health center catchment areas in Jayapura City, North Jayapura Community Health Center and Abepura Community Health Center. Based on the 2021 Indonesian Nutritional Status Study (SSGI), the prevalence of stunting in Papua Province was 29.5%, while Jayapura City reported a prevalence of 22.9%. Local health surveillance data indicated that North Jayapura and Abepura Community Health Centers consistently recorded the highest stunting rates in the city. In 2020, North Jayapura reported 26.3% (175/665) and Abepura 15.6% (63/403). Subsequent monitoring data from 2022–March 2023 showed persistently elevated prevalence in these areas. Therefore, these two health center catchment areas were selected as the study sites (SSGI, 2021; Jayapura City Health Office, 2023).

Data Collection and Sources

The study population comprised children aged 25–59 months living in the catchment areas of the selected health centers. The accessible population was children in the same age group registered between January and March 2023. Using consecutive sampling, 326 participants were recruited, including 163 cases and 163 controls,

maintaining a 1:1 case-to-control ratio. Inclusion criteria were age 25–59 months, residence in the designated health center catchment area, and caregiver informed consent. The control group was matched to the case group by age, sex, ethnicity, and residential proximity within the same health center catchment area. Data were collected via structured questionnaires administered during face-to-face interviews with mothers or primary caregivers. The structured questionnaire was developed based on WASH indicators and previous validated studies on environmental determinants of stunting in Indonesia. The instruments used to measure the variables in this study were adopted from the 2021 Indonesian Nutritional Status Survey (SSGI) questionnaire and the Community-Based Total Sanitation (STBM) Guidelines in Indonesia, as stipulated in Minister of Health Regulation No. 3 of 2014. Lists of eligible children were identified from community health center growth monitoring records. Mothers were contacted through local health cadres and invited to participate. Face-to-face interviews were conducted at participants' homes after informed consent was obtained.

Data Analysis

Data from the questionnaires were coded numerically and entered into STATA version 14. Data cleaning procedures included range checks, consistency verification, and screening for missing values. Records with incomplete key variables were excluded from the analysis ($<5\%$ of total observations). Analysis was conducted in three stages: univariate analysis to describe variable distributions, bivariate analysis using the chi-square test (or fisher's exact test when expected cell counts were <5) to assess associations between independent variables and stunting, and multivariate analysis using logistic regression to construct a predictive model of stunting determinants. Variables with a p-value <0.25 in the bivariate analysis were entered into the initial logistic regression model. Backward stepwise elimination was applied to obtain the final model. Multicollinearity was assessed using the variance inflation factor (VIF). Adjusted odds ratios (AOR) with 95% confidence intervals were reported.

Ethical Considerations

Ethical clearance for the study was obtained from the Health Research Ethics Committee, Faculty of Public Health, Cenderawasih University, under approval number 071/KEPK-FKM UC/2023.

RESULT AND DISCUSSION

A total of 326 children were included in the analysis, comprising 163 stunted children (cases) and 163 non-stunted children (controls), as presented in Figure 1.



Figure 1. Case and control stunting rates

Regarding child characteristics, neither gender nor ethnicity was significantly associated with stunting. Boys and girls had similar odds of stunting (COR=1.13; 95% CI: 0.73–1.74; $p=0.580$), and no difference was observed between Papuan and non-Papuan children (COR=1.00; 95% CI: 0.60–1.65; $p=1.000$). For maternal characteristics, age and education emerged as significant determinants. Mothers aged 23–35 years were significantly less likely to have stunted children than those aged ≤ 22 (COR=0.27; 95% CI: 0.11–0.70; $p=0.016$). Similarly, higher maternal education was protective against stunting, with mothers completing a diploma or university education having a 61% lower risk than those with only primary education (COR=0.39; 95% CI: 0.17–0.90; $p=0.047$). In contrast, maternal occupation was not associated with stunting ($p=0.825$). In terms of child health history, previous diarrheal episodes were strongly associated with stunting. Children who had experienced diarrhea were more than three times as likely to be stunted as those without such a history (COR=3.26; 95% CI: 1.87–5.68; $p=0.001$), as shown in Table 1.

Analysis of WASH-related factors demonstrated several significant associations. Inadequate drinking water and food management were associated with a more than threefold increase in the likelihood of stunting (COR=3.14; 95% CI: 1.99–4.95; $p=0.001$). Children from households without access to safe drinking water (COR=1.72; 95% CI: 1.11–2.66; $p=0.015$) and with non-eligible latrine sanitation (COR=2.84; 95% CI: 1.80–4.47; $p=0.001$) had significantly higher odds of stunting. Likewise, inadequate liquid waste disposal (COR=1.73; 95% CI: 1.10–2.73; $p=0.017$) and poor household waste sani-

tation (COR=0.56; 95% CI: 0.36–0.87; $p=0.011$) were significantly related to stunting. By contrast, handwashing practices, defecation practices, and general household waste management did not exhibit significant associations with stunting (all $p>0.05$), as shown in Table 1.

Multivariate Analysis

In the final multivariate model, environmental and sanitation-related factors emerged as the strongest determinants of stunting among children. Household waste management practices showed the most pronounced effect, with children from households that practiced proper waste management exhibiting more than an eightfold increase in the odds of not being stunted compared with those from households with poor waste management (AOR = 8.23, 95% CI: 4.19–16.1, $p < 0.001$). Similarly, appropriate management of drinking water and food significantly reduced the likelihood of stunting (AOR = 1.94, 95% CI: 1.18–3.19, $p = 0.001$), underscoring the role of safe handling and storage of food and drinking water in child health outcomes. Access to eligible drinking water was also independently associated with nutritional status. Children in households with access to safe drinking water were nearly three times less likely to be stunted than those without access (AOR = 2.75, 95% CI: 1.65–4.56, $p = 0.001$). In contrast, households with proper liquid waste disposal demonstrated a substantially protective effect, reducing the odds of stunting by approximately 80% (AOR = 0.20, 95% CI: 0.10–0.40, $p = 0.001$), as shown in Table 2.

This study examined the determinants of stunting among toddlers in Jayapura, focusing on maternal characteristics, child health history, and household environmental factors. The final multivariate model identified four independent predictors significantly associated with stunting: household waste management practices, food and drinking water management practices, access to safe drinking water, and liquid waste disposal and sanitation. Other variables, including maternal age, maternal education, history of diarrhea, defecation practices, and handwashing, did not retain statistical significance after adjustment. These findings highlight the dominant role of household-level water, sanitation, and hygiene (WASH) environments in shaping child nutritional outcomes. An important finding of this study was the attenuation of several associations after adjustment in the multivariate model. Maternal age, maternal education, and diarrheal history were significant in the bivariate analysis but lost statistical significance after controlling for

Table 1. Distribution of Child, Maternal, and Environmental Factors in Relation to Stunting (Univariate and Bivariate Analysis)

Variables	Case (n=163)		Control (n=163)		p-value	COR Low	95% CI	
	n	%	n	%			Upper	
Characteristics of Toddlers								
Gender								
Boy	84	51.5	79	48.5	0.580	ref		
Girl	79	48.5	84	51.5		1.13	0.73	1.74
Child Ethnicity								
Native Papua	40	24.5	40	24.5	1.000	ref		
Non-Papua	123	75.5	123	75.5		1.00	0.60	1.65
Characteristics of Mothers								
Age (in years)								
≤ 22	20	12.2	6	3.6	0	ref		
23-35	131	80.4	145	89.0	0.004*	0.27	0.11	0.70
>35	12	7.4	12	7.4	0.048*	0.30	0.09	1.01
Education								
Primary (Elementary & Junior High School Graduate)	21	12.9	13	8.0	0.047*	ref		
Medium (High School Graduate)	113	69.3	104	63.8		0.67	0.32	1.41
High (Diploma & S1 Completion)	29	17.8	46	28.2		0.39	0.17	0.90
Occupation								
Not Work	79	48.5	77	47.2	0.825	ref		
Work	84	51.5	86	52.8		1.05	0.68	1.62
History of Diarrheal Disease								
Yes	55	33.7	22	13.5	0.001*	ref		
No	108	66.3	141	86.5		3.26	1.87	5.68
Hand Washing Practices								
Bad	78	47.9	72	44.2	0.505			
Good	85	52.1	91	55.8		1.15	0.75	1.79
Defecation Practices								
Bad	50	30.6	65	39.9	0.083	ref		
Good	113	69.4	98	60.1		0.66	0.42	1.05
Household Waste Management Practices								
Bad	81	49.7	66	40.5	0.095	ref		
Good	82	50.3	97	59.5		1.45	0.93	2.25
Drinking Water and Food Management Practices								
Bad	96	58.9	51	31.3	0.001*	ref		
Good	67	41.1	112	68.7		3.14	1.99	4.95
Drinking Water Access								
Non eligible	92	56.4	70	42.9	0.015*	ref		
Eligible	71	43.6	93	57.1		1.72	1.11	2.66
Latrine Sanitation								
Non eligible	92	56.4	51	31.3	0.001*	ref		
Eligible	71	43.6	112	68.7		2.84	1.80	4.47
Sanitation of Household Liquid Waste Disposal								
Non eligible	112	68.7	91	55.8	0.017*	ref		
Eligible	51	31.3	72	44.2		1.73	1.10	2.73
Household Waste Sanitation								
Non eligible	77	47.2	100	61.4	0.011*	ref		
Eligible	86	52.8	63	38.6		0.56	0.36	0.87

Table 2. Results of Multivariate Analysis

	Initial Modeling			Final Modeling		
	P-value	AOR	95%CI	P-value	AOR	95%CI
History of Diarrheal Disease						
Yes		ref		-		
Not	0.001*	3.99	2.05-7.76			
Mother's Age						
≤ 24		ref		-		
>24	0.246	1.49	0.75-2.93			
Mother's Education						
Primary (Primary & Junior High School)		ref		-		
Medium (senior high School)	0.265	1.65	0.68-4.01			
High (University/college)	0.027	3.08	1.13-8.39			
Hand Washing Practices						
Bad		ref		-		
Good	0.241	0.71	0.41-1.24			
Defecation Practices						
Bad		ref		-		
Good	0.099	1.57	0.91-2.71			
Household Waste Management Practices						
Bad		ref			ref	
Good	0.001*	8.95	4.37-18.3	0.001*	8.23	4.19-16.1
Drinking Water and Food Management Practices						
Bad		ref			ref	
Good	0.005*	2.14	1.25-3.66	0.001*	1.94	1.18-3.19
Drinking Water Access						
Non eligible		ref			ref	
Eligible	0.001*	2.59	1.50-4.49	0.001*	2.75	1.65-4.56
Latrine Sanitation						
Non eligible		ref		-		
Eligible	0.017*	1.93	1.12-3.33			
Sanitation of Household Liquid Waste Disposal						
Non eligible		ref			ref	
Eligible	0.001*	0.22	0.11-0.46	0.001*	0.20	0.10-0.40

WASH-related factors, suggesting confounding and potential mediation. Maternal education and age likely influence child nutrition indirectly through caregiving capacity, hygiene practices, and household environmental conditions. After accounting for household water, sanitation, and hygiene, these maternal characteristics no longer independently predicted stunting, indicating that their effects operate largely through environmen-

tal pathways rather than biological mechanisms alone. The loss of significance of diarrheal history after adjustment is also noteworthy. Although diarrhea is a recognized proximal cause of growth faltering, it is itself a consequence of environmental exposure. When food hygiene, drinking water safety, and sanitation were simultaneously considered, diarrheal history no longer showed an independent association with stunting.

ng. This indicates that WASH conditions serve as upstream determinants, with diarrhea acting as an intermediate step connecting environmental contamination to undernutrition. These results reinforce the conceptual model where repeated enteric infections and environmental enteric dysfunction mediate the link between poor sanitation and compromised child growth.

Household waste management

Household waste management showed the strongest association in the final model. Children from households with poor waste management were more than eight times more likely to experience stunting than those with appropriate waste handling (AOR = 8.23; 95% CI: 4.19–16.1). Although the crude association was also high, the persistence of a large adjusted effect indicates that this factor is not explained by maternal or socioeconomic characteristics alone. Unmanaged solid waste creates vector breeding sites, increases environmental contamination, and exposes children to pathogens through soil and play surfaces (Rahut et al., 2024; Zhang et al., 2024). Such exposure is particularly relevant for toddlers who frequently engage in hand-to-mouth behavior. Therefore, waste management functions as a direct environmental exposure rather than merely a proxy for poverty. This helps explain why the association remained strong even after adjusting for maternal characteristics and child health history.

Food and drinking water management

Inadequate food and drinking water management practices were also significantly associated with stunting (AOR = 1.94; 95% CI: 1.18–3.19). Although the magnitude of association was reduced compared with the crude analysis. This attenuation suggests partial confounding by other sanitation variables, particularly drinking water access and wastewater disposal. Poor food hygiene exposes children to enteric pathogens that contribute to environmental enteric dysfunction and impaired nutrient absorption (Bekele et al., 2020; Muhoozi et al., 2018). The reduction in effect size after adjustment indicates that food hygiene does not act in isolation but interacts with the broader household sanitation environment.

Drinking water access

Access to safe drinking water emerged as another significant predictor, where children from households with adequate access were almost three times more likely to avoid stunting (AOR = 2.75; 95% CI: 1.65–4.56). This finding reinforces global evidence linking access to safe

water with reduced stunting prevalence (Wolf et al., 2023). In Jayapura, where many rural and peri-urban communities rely on unimproved sources, ensuring sustainable access to clean drinking water remains a critical challenge. The result is consistent with Indonesia's National Strategy to Accelerate Stunting Reduction (RAN-PASTI), which prioritizes universal access to safe water by 2030, aligned with the Sustainable Development Goals (SDGs).

Sanitation of household liquid waste disposal

Interestingly, proper disposal of liquid waste was associated with a protective effect against stunting (AOR = 0.20; 95% CI: 0.10–0.40). Households with adequate drainage and wastewater systems reduced the risk of stunting by 80%. This aligns with the concept of a “safe play environment” for toddlers, minimizing exposure to fecal contamination in domestic surroundings. Previous studies in South Asia and East Africa have similarly highlighted the role of wastewater management in reducing child morbidity and malnutrition (Rahmadiyah et al., 2023; Sara et al., 2022). However, liquid waste disposal remains the least addressed sanitation component in public health programs, suggesting a crucial policy gap.

Implications of the attenuation between COR and AOR

Overall, the comparison between COR and AOR indicates that child stunting in this population is driven less by individual maternal characteristics and more by environmental exposure. Maternal education, age, and diarrheal history initially appeared important because they are correlated with household hygiene conditions. After adjustment, WASH variables retained their effects, demonstrating that they represent more proximal determinants in the causal pathway. This reinforces the view that improving environmental health conditions may yield larger nutritional benefits than interventions focused solely on individual behavior or demographic characteristics.

Policy and program implications

These findings emphasize the need to strengthen integrated WASH interventions within stunting reduction programs. Beyond infrastructure provision, behavioral components, particularly safe food handling and household waste management, should be prioritized. The strong associations observed for solid and liquid waste management suggest that sanitation policies

should extend beyond latrine coverage to include comprehensive environmental hygiene. Community-based solutions, including localized waste treatment systems and culturally adapted hygiene promotion, may be especially relevant for geographically dispersed settings such as Papua.

Strengths and limitations

This study provides robust evidence of the link between WASH and child stunting in an under-researched setting, using a case-control design to identify independent predictors. Nevertheless, several limitations should be acknowledged. The cross-sectional exposure assessment limits causal inference, and self-reported hygiene practices may be subject to recall or social-desirability bias. Furthermore, the absence of dietary intake data prevents assessment of interactions between nutrition and WASH factors. Despite these limitations, the consistency and strength of associations observed reinforce the conclusion that WASH play a pivotal role in shaping child growth outcomes.

CONCLUSION

This study shows that household environmental conditions are crucial factors influencing stunting among toddlers in Jayapura. The multivariate analysis identified four independent factors: poor solid waste management, unsafe handling of food and drinking water, limited access to safe drinking water, and inadequate liquid waste disposal. These results imply that ongoing stunting in this area is closely connected to daily environmental exposures at home, rather than solely to maternal or child demographics. The results imply concrete actions for different stakeholders. Local health offices and primary health-care centers should incorporate household environmental assessments into routine maternal and child health services, including home visits and growth monitoring programs. Health promotion activities should prioritize practical counseling for caregivers on safe food preparation, hygienic water storage, and maintaining clean household surroundings. Community health workers and sanitation cadres can support households in improving waste separation, drainage maintenance, and safe disposal practices. At the policy level, local governments should strengthen community-based waste collection systems and expand access to safe water sources, particularly in peri-urban and rural areas. By linking stunting prevention with household-level WASH improvements, interventions may address upstream causes of growth faltering. Future studies using

longitudinal designs are needed to better clarify causal pathways, and incorporating dietary intake and household food security measures would further explain how environmental and nutritional factors interact in influencing child growth outcomes in Papua.

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REFERENCES

- Azriani, D. *et al.* (2024) "Risk factors associated with stunting incidence in under five children in Southeast Asia: a scoping review," *Journal of Health, Population, and Nutrition*, 43(1). Available at: <https://doi.org/10.1186/S41043-024-00656-7>.
- Barredo, L. (2018) *2018 Global Nutrition Report Released, Sustainable Development Solutions Network*. Available at: https://www.unsdsn.org/news/2018-global-nutrition-report-released/?utm_source=chatgpt.com (Accessed: September 5, 2025).
- Bekele, T., Rawstorne, P. and Rahman, B. (2020) "Effect of water, sanitation and hygiene interventions alone and combined with nutrition on child growth in low and middle income countries: a systematic review and meta-analysis," *BMJ Open*, 10(7). Available at: <https://doi.org/10.1136/BMJOPEN-2019-034812>.
- Handayani, N.S., Huriyati, E. and Hasanbasri, M. (2023) "Association of Maternal Education With Nutritional Outcomes of Poor Children With Stunting in Indonesia," *Asia-Pacific journal of public health*, 35(5). Available at: <https://doi.org/10.1177/10105395231185980>.
- Irjayanti, A., Irmanto, M. and Furianto Wibowo, T. (2024) "Risk Factors for Diarrhea Among Under-Five Children in the Jayapura Utara Health Center Catchment Area," *Indonesian Journal of Environmental Health*, 23(1). Available at: <https://doi.org/10.14710/JKLI.23.1.1-9>.
- Laksono, A.D. *et al.* (2024) "Risk Factors for Stunting Among Children Under 2 Years with Single Mothers: A Cross-Sectional Study in Indonesia," *Global Social Welfare* [Preprint]. Available at: <https://doi.org/10.1007/S40609-024-00368-0/METRICS>.
- Meiyetrian, E. and Utomo, B. (2025) "Improved sanitation and co-occurrence of anemia and stunting in Indonesian children: A retrospective cohort study," *Narra J*, 5(1). Available at: <https://doi.org/10.1016/j.narra.2025.100001>.

- doi.org/10.52225/NARRA.V5I1.2070.
- Muhoozi, G.K.M. *et al.* (2018) "Effects of nutrition and hygiene education on oral health and growth among toddlers in rural Uganda: follow-up of a cluster-randomised controlled trial," *Tropical Medicine & International Health*, 23(4). Available at: <https://doi.org/10.1111/TMI.13036>.
- Rah, J.H. *et al.* (2020) "Improved sanitation is associated with reduced child stunting amongst Indonesian children under 3 years of age," *Maternal & child nutrition*, 16 Suppl 2(Suppl 2). Available at: <https://doi.org/10.1111/MCN.12741>.
- Rahmadiyah, D.; C.; *et al.* (2023) "Analysis of the Determinants of Stunting among Children Aged below Five Years in Stunting Locus Villages in Indonesia," *Healthcare*, 11(6). Available at: <https://doi.org/10.3390/HEALTHCARE11060810>.
- Rahut, D.B., Mishra, R. and Bera, S. (2024) "Geospatial and environmental determinants of stunting, wasting, and underweight: Empirical evidence from rural South and Southeast Asia," *Nutrition (Burbank, Los Angeles County, Calif.)*, 120. Available at: <https://doi.org/10.1016/J.NUT.2023.112346>.
- Sara, H.H., Bayazid, A.R. and Quayyum, Z. (2022) "Occupational Health Sufferings of Child Waste Workers in South Asia: A Scoping Review," *International journal of environmental research and public health*, 19(14). Available at: <https://doi.org/10.3390/IJERPH19148628>.
- Statistics Indonesia (BPS) (2022) *In 2021, 80.29% of Indonesian Households Had Access to Improved Sanitation*, BPS. Available at: https://sanitariankit.id/sebanyak-8029-rumah-tangga-ri-miliki-sanitasi-layak-pada-2021/?utm_source=chatgpt.com (Accessed: September 5, 2025).
- Torlesse, H. *et al.* (2016) "Determinants of stunting in Indonesian children: evidence from a cross-sectional survey indicate a prominent role for the water, sanitation and hygiene sector in stunting reduction," *BMC public health*, 16(1). Available at: <https://doi.org/10.1186/S12889-016-3339-8>.
- UNICEF (2022) *Nutrition, for every Child | Global Annual Results Report 2022*. UNICEF. Available at: <https://www.unicef.org/media/145641/file/Nutrition%20Global%20Annual%20Results%20Report%202022.pdf> (Accessed: July 27, 2024).
- WHO (2023) *Maternal, infant and young child nutrition Comprehensive implementation plan on maternal, infant and young child nutrition: biennial report Report by the Director-General*. Geneva. Available at: <https://data.unicef.org/resources/who-unicef-discussion-paper-nutrition-targets/>, (Accessed: July 27, 2024).
- Woldesenbet, B., Tolcha, A. and Negash, B.T. (2020) "Water, hygiene and sanitation practices are associated with stunting among children of aged 24-59 months in Lemo district, South Ethiopia, in 2021," *BMC Nutrition* [Preprint]. Available at: http://eprints.poltekkesjogja.ac.id/11902/1/BMC_1_WASH.pdf (Accessed: May 2, 2024).
- Wolf, J. *et al.* (2023) "Burden of disease attributable to unsafe drinking water, sanitation, and hygiene in domestic settings: a global analysis for selected adverse health outcomes," *The Lancet*, 401(10393). Available at: [https://doi.org/10.1016/S0140-6736\(23\)00458-0/ATTACHMENT/BED09094-E35B-4282-8952-3DFEE56EDC90/MMC2.XLSX](https://doi.org/10.1016/S0140-6736(23)00458-0/ATTACHMENT/BED09094-E35B-4282-8952-3DFEE56EDC90/MMC2.XLSX).
- Wulandari, R.D. *et al.* (2025) "Determining Policy Targets for Reducing the Number of Stunted Papuan Children Under Five Years Old in Indonesia: A Secondary Data Analysis of the 2022 Indonesian National Nutritional Status Survey," *Malaysian Journal of Medical Sciences*, 32(3). Available at: <https://doi.org/10.21315/MJMS-10-2024-798>.
- Zhang, Z. *et al.* (2024) "Municipal solid waste management challenges in developing regions: A comprehensive review and future perspectives for Asia and Africa," *Science of The Total Environment*, 930. Available at: <https://doi.org/10.1016/J.SCITOTENV.2024.172794>.