Journal Interdisciplinary Health

Volume 2 Issue 4, 2026
DOI: https://doi.org/10.61099/jih.v2i4.557

Original Article

OPEN ACCESS

Stunting among under-five children in remote indonesia: associations with feeding practices, immunization adherence, and safe water use

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Received: 2026-08-16 ○ Revised: 2026-10-25 ○ Received: 2026-10-28

ABSTRACT

Introduction: Childhood stunting remains a major public health concern, particularly in remote areas where nutritional inadequacy, limited access to preventive health services, and unsafe household water may occur simultaneously. This study examined the associations of feeding practices, immunization adherence, and clean water use with stunting among under-five children in the Arimop Public Health Center area, Boven Digoel Regency, Indonesia.

Research Methodology: An observational analytic study with a cross-sectional design was conducted in July 2026. The study population comprised 296 registered under-five children, from whom 75 children were selected using purposive sampling. Data were obtained through questionnaires and anthropometric measurements. Descriptive and bivariate analyses were performed to examine associations between the independent variables and stunting.

Results: Of the participating children, 53.3% had suboptimal feeding practices, 44.0% had incomplete or non-adherent immunization, and 30.7% used household water that did not meet health requirements. Stunting was identified in 34.7% of children. Feeding practices, immunization adherence, and clean water use were each significantly associated with stunting (all $p<0.001$).

Conclusion: Stunting among under-five children was associated with nutritional practices, preventive healthcare adherence, and household water conditions. Integrated prevention should therefore strengthen appropriate child feeding, completion of routine immunization, and access to safe household water, particularly in remote communities.

Keywords: child nutrition; immunization; stunting; water supply

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INTRODUCTION

Stunting remains a persistent child health problem because it reflects not only inadequate linear growth but also prolonged exposure to nutritional deficits, recurrent infection, and adverse living conditions during critical periods of development. Its consequences extend beyond short stature, affecting cognitive development, learning capacity, susceptibility to illness, and later-life productivity. In the manuscript, stunting is defined according to the World Health Organization growth standard as a height-for-age z-score below −2 standard deviations[1,2]. The problem is particularly important in settings where nutritional vulnerability intersects with limited access to preventive services and unsafe environmental conditions. Globally, the burden remains substantial, with the manuscript citing approximately 150.2 million children under five affected by stunting in 2024. Indonesia has made progress in reducing the national prevalence, yet the problem remains a public health priority, especially in geographically disadvantaged regions.

The challenge is especially pronounced in Papua Selatan and Boven Digoel Regency, where geographical isolation, limited healthcare access, and household-level environmental constraints may intensify the risk of poor child growth. The manuscript reports that stunting in the Arimop Public Health Center area remained high across recent years, with 47 cases in 2023, 56 cases in 2024, and 54 cases in 2025. These figures indicate that stunting is not an isolated nutritional event but a sustained local health problem[3]. The local context is characterized by difficult geographical access, suboptimal use of health services, limited knowledge regarding child feeding, incomplete immunization coverage, and constraints in access to clean water. Such conditions suggest that effective stunting prevention requires attention to multiple interacting determinants rather than focusing solely on food intake[4].

Child feeding practices constitute one of the most proximal determinants of nutritional status. Appropriate feeding during infancy and early childhood requires adequate food quantity, quality, diversity, and frequency, alongside age-appropriate breastfeeding and complementary feeding. Inadequate feeding practices can lead to prolonged deficits in energy, protein, micronutrients, and other nutrients required for linear growth[5]. The literature summarized in the manuscript indicates that children exposed to poor feeding patterns are more likely to experience growth faltering than those receiving nutritionally appropriate diets. This association is biologically plausible because insufficient nutrient intake over time directly limits tissue growth and may also weaken immune function, thereby increasing vulnerability to infection[6].

However, feeding practices do not operate independently. Immunization adherence represents an important preventive health component that may indirectly influence growth by reducing the burden of vaccine-preventable infections. Children who do not complete routine immunization are more vulnerable to illnesses such as measles, tuberculosis, respiratory infection, and diarrheal disease. Recurrent infection may reduce appetite, interfere with nutrient absorption, increase metabolic demands, and ultimately impair physical growth. The manuscript also emphasizes that compliance with recommended immunization schedules is shaped by parental knowledge, access to services, family support, and community confidence in vaccination[7,8]. From a public health perspective, immunization therefore represents not only an infectious disease intervention but also a potentially important component of an integrated strategy to protect child growth.

Environmental exposure provides a third pathway that may contribute to stunting. Safe water is essential for drinking, food preparation, personal hygiene, and household sanitation.

Water that does not meet health requirements increases the risk of diarrheal disease and gastrointestinal infection, both of which can compromise nutrient absorption and contribute to repeated episodes of illness. In remote communities, where households may depend on unprotected or inadequately treated water sources, these risks can become chronic. The manuscript further notes that water source, physical water quality, treatment before consumption, and proximity to potential contamination are important components in assessing household water safety[9,10]. Evidence summarized in the manuscript also suggests that children living in households with unsafe water sources may experience a higher prevalence of stunting than those with access to safer water and sanitation conditions.

Despite the established importance of nutrition, immunization, and water-related factors, an important evidence gap remains in remote Indonesian settings. Previous studies reviewed in the manuscript generally examined these exposures separately, for example focusing on feeding patterns, complete basic immunization, hygiene behavior, or clean water availability as individual correlates of stunting. This fragmented approach may not adequately represent the reality of rural and geographically isolated communities, where multiple risks frequently coexist. In Boven Digoel, there is limited local evidence assessing feeding practices, immunization adherence, and household clean water use within the same analytical framework. This gap is relevant because intervention priorities in remote primary healthcare settings depend on identifying whether nutritional, preventive healthcare, and environmental factors are simultaneously associated with stunting.

The novelty of this study lies in its integrated assessment of three modifiable domains—child feeding, immunization adherence, and household clean water use—within a remote primary healthcare context in Boven Digoel Regency. Rather than treating stunting exclusively as a nutritional outcome, the study approaches it as a multidimensional public health problem shaped by household behavior, preventive service utilization, and environmental conditions. This perspective may provide more locally relevant evidence for designing coordinated interventions through primary healthcare services.

Accordingly, this study aimed to examine the associations of feeding practices, immunization adherence, and clean water use with stunting among children aged 12–59 months in the Arimop Public Health Center area, Boven Digoel Regency. By identifying the contribution of these modifiable factors, the study is expected to inform integrated stunting prevention strategies that combine nutrition education, routine immunization completion, and improvements in safe household water use in remote communities.

MATERIALS AND METHODS

Study Design

This study employed a quantitative observational analytic design with a cross-sectional approach. The design was selected to examine the associations between feeding practices, immunization adherence, household clean water use, and stunting status among under-five children at a single period of observation. Because exposure and outcome variables were assessed within the same study period, the analysis was intended to identify statistical associations rather than establish temporal or causal relationships.

Setting and Participants

The study was conducted in July 2026 in the working area of Arimop Public Health Center, Boven Digoel Regency, Papua Selatan Province, Indonesia. The target population

comprised 296 under-five children registered in the Arimop Public Health Center records up to May 2026.

Participants were selected using purposive sampling according to predefined eligibility criteria. The inclusion criteria were mothers with children aged 12–59 months, residence within the Arimop Public Health Center catchment area, and willingness to participate in the study. Mothers were excluded when they were unavailable during the data-collection period or withdrew from participation during the study. The minimum sample size was calculated using the Slovin formula based on a population of 296 children and a precision level of 10%. The calculation yielded 74.74 participants, which was rounded to a final sample of 75 mother–child pairs.

Variables and Measurement

The primary outcome was stunting status. Stunting was operationally defined using the height-for-age indicator, with children classified as stunted when the height-for-age z-score was below −2 standard deviations according to the World Health Organization growth standard. Children with values above the specified threshold were categorized as non-stunted. The exposure variables were feeding practices, immunization adherence, and household clean water use. Feeding practices reflected maternal or caregiver practices related to breastfeeding, complementary feeding, food type, amount, and feeding frequency appropriate to the child's age. Responses were assessed using a questionnaire and information from the Maternal and Child Health Book (Buku KIA). Feeding practices were categorized as good when the obtained score was ≥50% and poor when the score was <50%. Immunization adherence referred to parental compliance with the recommended basic childhood immunization schedule. Children were categorized as adherent when all required basic immunizations, including HB0, BCG, polio, DPT, measles, and PCV, had been completed. A child was categorized as less adherent when at least one required basic immunization had not been completed.

Household clean water use was assessed according to indicators related to the type of water source, physical characteristics of water, water treatment, and distance between the water source and potential sources of contamination. Water was classified as meeting health requirements when it complied with the specified physical water-quality standards. The assessment referred to Indonesian environmental health standards, including Ministry of Health Regulation No. 2 of 2023 and Ministry of Health Regulation No. 32 of 2017. Primary data were obtained directly from respondents through questionnaires and observation. Anthropometric measurements were conducted using a stadiometer or microtoise for height measurement and a weighing scale for body weight. Secondary data were obtained from the Arimop Public Health Center profile and other supporting documentary sources. The original study manuscript does not report a formal psychometric assessment of questionnaire validity or reliability. Therefore, no validity coefficient or reliability statistic is presented in this report.

Data Collection

Data collection involved direct interviews with mothers or caregivers using structured questionnaires, review of relevant child-health information, observation of household-related variables, and anthropometric assessment of participating children. A questionnaire and observation sheet were used to collect information on the study exposures, while anthropometric equipment was used to determine child growth status. Data quality was maintained during data processing through several procedural checks. Completed questionnaires were first reviewed through an editing process to assess completeness, clarity, consistency, and correctness. Responses were subsequently coded to facilitate computerized

processing, after which coded data were entered into the statistical database. These procedures were intended to reduce incomplete records and data-entry inconsistencies before statistical analysis.

Data Analysis

Data were processed and analyzed using IBM SPSS Statistics version 24.0. Descriptive analysis was performed to summarize maternal and child characteristics and the distribution of feeding practices, immunization adherence, household clean water use, and stunting status. Categorical variables were presented as frequencies and percentages. Bivariate associations between each exposure variable and stunting status were examined using the Pearson Chi-square test in 2 × 2 contingency tables. Statistical significance was established at a two-sided α level of 0.05, with $p<0.05$ interpreted as evidence of a statistically significant association.

Ethical Approval

Participation was voluntary, and eligibility required mothers or caregivers to agree to participate in the study. However, the submitted manuscript does not provide the name of an institutional research ethics committee, an ethical approval number, or a detailed description of the written informed-consent procedure. These details should be added from the original ethical approval documentation before submission to an international peer-reviewed journal.

RESULTS

A total of 75 mothers and their children aged 12–59 months participated in the study. Most mothers were aged 31–35 years (58.7%), while 32.0% were aged 26–30 years and 9.3% were aged 16–25 years. The majority of mothers were homemakers (89.3%). Regarding educational attainment, junior secondary school was the most common level (40.0%), followed by primary school (24.0%), senior secondary school (21.3%), higher education (10.7%), and no formal education (4.0%). Among the children, 45.3% were aged 25–36 months, 41.3% were aged 37–49 months, 9.3% were aged 50–59 months, and 4.0% were aged 12–24 months. Female children represented 54.7% of the sample and male children 45.3%.

Table 1. Characteristics of mothers and under-five children (n = 75)

Characteristics	Category	n	%
Maternal age (years)	16–25	7	9.3
	26–30	24	32.0
	31–35	44	58.7
Maternal occupation	Honorary worker	8	10.7
	Homemaker	67	89.3
Maternal education	No formal education	3	4.0
	Primary school	18	24.0
	Junior secondary school	30	40.0
	Senior secondary school	16	21.3
	Higher education	8	10.7
Child age (months)	12–24	3	4.0
	25–36	34	45.3
	37–49	31	41.3
	50–59	7	9.3
Child sex	Male	34	45.3
	Female	41	54.7

Regarding the study variables, 40 children (53.3%) received poor feeding practices, whereas 35 (46.7%) received good feeding practices. Forty-two children (56.0%) had

compliant immunization status and 33 (44.0%) were classified as less compliant. Household clean water use met the specified requirements for 52 children (69.3%), whereas 23 (30.7%) lived in households where clean water use did not meet the requirements. Overall, 26 children (34.7%) were stunted and 49 (65.3%) were not stunted. Bivariate analysis using the Chi-square test demonstrated significant associations between feeding practices, immunization adherence, clean water use, and stunting.

Table 2. Bivariate associations between feeding practices, immunization adherence, clean water use, and stunting (n = 75)

Variable	Category	Stunted n (%)	Non-stunted n (%)	Total n (%)	p-value
Feeding practices	Good	2 (5.7)	33 (94.3)	35 (100.0)	<0.001
	Poor	24 (60.0)	16 (40.0)	40 (100.0)	
Immunization adherence	Compliant	7 (16.7)	35 (83.3)	42 (100.0)	<0.001
	Less compliant	19 (57.6)	14 (42.4)	33 (100.0)	
Clean water use	Meets requirements	4 (7.7)	48 (92.3)	52 (100.0)	<0.001
	Does not meet requirements	22 (95.7)	1 (4.3)	23 (100.0)	

Among children who received good feeding practices, only 2 of 35 (5.7%) were stunted, whereas stunting was identified in 24 of 40 children (60.0%) with poor feeding practices. The Chi-square test showed a statistically significant association between feeding practices and stunting ($p<0.001$). A similar pattern was observed for immunization adherence. Stunting occurred in 7 of 42 children (16.7%) with compliant immunization status compared with 19 of 33 children (57.6%) with less compliant immunization status. This association was statistically significant ($p<0.001$). The most pronounced difference was observed for clean water use. Among children whose household clean water use met the specified requirements, 4 of 52 (7.7%) were stunted. In contrast, 22 of 23 children (95.7%) whose household clean water use did not meet the requirements were stunted. The association between clean water use and stunting was statistically significant ($p<0.001$).

To complement the significance tests reported in the manuscript, effect sizes can be derived from the reported 2 × 2 contingency tables using the phi coefficient. The association between feeding practices and stunting was large ($\varphi = 0.57$), while immunization adherence showed a moderate-to-large association ($\varphi = 0.43$). Clean water use demonstrated the largest association with stunting ($\varphi = 0.85$). These effect-size estimates are calculated from the frequencies reported in the manuscript and were not part of the original SPSS output.

The findings show that stunting in the Arimop Public Health Center area is associated with three modifiable domains: child feeding, immunization adherence, and household clean water use. More than half of children with poor feeding practices were stunted, suggesting that inadequate feeding remains an important nutritional concern in this population. The substantially higher proportion of stunting among children with incomplete immunization also indicates that preventive healthcare utilization may be closely linked to child growth. In addition, the striking concentration of stunting among children living in households whose clean water use did not meet health requirements points to the importance of environmental conditions.

Taken together, the findings indicate that stunting prevention in this setting should not

rely exclusively on nutritional counselling. Primary healthcare interventions need to combine improvement in age-appropriate feeding practices, active monitoring of routine immunization completion, and promotion of safe household water use. The findings also support closer integration between nutrition, maternal and child health, immunization, and environmental health programs at the primary care level. Nevertheless, because the study used a cross-sectional design and only bivariate analysis, these findings should be interpreted as associations rather than causal effects. Further analyses using multivariable models are needed to determine whether the observed relationships remain after adjustment for potential confounding factors.

DISCUSSION

The present study indicates that stunting among children aged 12–59 months in the Arimop Public Health Center area is closely associated with three modifiable domains: feeding practices, immunization adherence, and household clean water use. Rather than viewing stunting only as a consequence of insufficient food intake, the findings support a broader conceptual interpretation in which child growth is shaped by the interaction between nutrition, preventive healthcare, and environmental exposure. This perspective is particularly relevant in a remote setting such as Boven Digoel, where access to health services, food resources, and safe household infrastructure may be constrained simultaneously. In the study sample, 34.7% of children were stunted, while 53.3% had poor feeding practices, 44.0% had less-than-complete immunization adherence, and 30.7% lived in households where clean water use did not meet the specified requirements. These patterns suggest that stunting prevention in this context cannot be adequately addressed through a single-sector intervention.

The association with feeding practices provides the most direct nutritional pathway. Stunting was substantially more frequent among children exposed to poor feeding practices than among those receiving good feeding. In the original data, 24 of 40 children with poor feeding practices were stunted, compared with only 2 of 35 children with good feeding practices[11,12]. This difference is consistent with the biological understanding of linear growth. Children require sufficient energy, high-quality protein, micronutrients, and age-appropriate feeding frequency to sustain growth during early childhood[13]. When feeding is inadequate in quantity, quality, or diversity, nutrient deficits may accumulate over time and contribute to impaired linear growth. In the local discussion, the manuscript also describes practical challenges such as limited food availability, inappropriate introduction of foods, and household sharing of supplementary foods intended for children[14,15]. These observations are important because they show that feeding practices are influenced not only by maternal knowledge but also by household food access and resource constraints. Therefore, counselling alone may have limited impact if families are unable to translate nutritional advice into everyday practice.

This interpretation is broadly consistent with previous studies cited in the manuscript. A significant relationship between feeding patterns and stunting, with poorly fed children having a greater likelihood of impaired growth[16,17]. The literature summarized in the manuscript also emphasizes that breastfeeding, complementary feeding, food diversity, meal frequency, and the suitability of food for a child's age are important components of growth-promoting feeding practices. The contribution of the present study is therefore not simply confirmation that feeding matters[18]. Its relevance lies in demonstrating that feeding-related vulnerability exists alongside immunization and environmental problems within the same remote population. Conceptually, this supports a cumulative-risk interpretation of stunting, whereby nutritional disadvantage may

become more consequential when combined with recurrent infection and adverse environmental exposure.

The relationship between immunization adherence and stunting provides a second pathway linking preventive healthcare to child growth. Among children whose immunization was classified as compliant, 16.7% were stunted, compared with 57.6% among those with poor adherence. Immunization itself does not directly increase linear growth; instead, its relevance is likely to operate through protection against infectious diseases. Repeated infections can reduce appetite, increase metabolic requirements, interfere with nutrient utilization, and prolong periods of nutritional vulnerability. The manuscript specifically notes that recurrent infections may disrupt nutrient absorption and increase energy requirements, thereby interfering with growth. Seen from this perspective, immunization completion should be understood as part of a broader growth-protection strategy rather than as an isolated vaccination outcome.

Children without complete basic immunization had a greater likelihood of stunting than children who completed the recommended schedule. However, the present findings should not be interpreted as evidence that incomplete immunization directly causes stunting[19,20]. Immunization adherence may also reflect wider differences in healthcare access, caregiver knowledge, family resources, geographical distance, or engagement with primary care. A household that has difficulty completing immunization may also have reduced access to growth monitoring, nutrition counselling, early treatment of infection, or other preventive services. This possibility strengthens the need for a system-level interpretation[21]. Poor immunization adherence may function partly as a marker of inadequate continuity of child healthcare, especially in geographically dispersed communities.

Household clean water use showed the most pronounced difference in stunting prevalence. Of 23 children living in households where water use did not meet the specified requirements, 22 were stunted, whereas only 4 of 52 children whose household water met the requirements were stunted. This finding highlights the potential importance of environmental pathways in chronic growth impairment. Unsafe water may increase exposure to diarrhoeal and gastrointestinal infections, which can reduce nutrient absorption and contribute to repeated episodes of illness[22]. The manuscript also describes water safety in terms of source, physical quality, treatment, and distance from potential contamination. Thus, the exposure measured in this study represents more than simple availability of water; it reflects several aspects of household environmental safety.

This pattern is supported by previous evidence included in the manuscript. Research cited from Papua Tengah reported that children using unsafe drinking-water sources had a 4.07-fold greater risk of stunting, while a study in Kampar found higher stunting prevalence among families using unprotected water sources or failing to treat drinking water before consumption[23,24]. The literature also emphasizes that contaminated water can facilitate diarrhoeal and other infectious diseases, which may subsequently impair nutritional status and growth[25]. The strong association observed in Arimop therefore reinforces the argument that stunting prevention must incorporate environmental health. Nevertheless, the magnitude of the observed difference must be treated cautiously because the sample was small and one cell contained only a single child[26]. Such sparse data can produce unstable effect estimates and exaggerated apparent associations.

Taken together, the three findings suggest that stunting in this setting may be better understood as the result of intersecting vulnerabilities. Poor feeding compromises nutrient

availability; incomplete immunization may increase vulnerability to preventable infection; and unsafe water may increase exposure to enteric disease. These pathways are not mutually exclusive. They may operate sequentially or simultaneously, creating a cycle in which inadequate intake, infection, and environmental exposure reinforce each other. This systems interpretation has important implications for primary healthcare. The manuscript itself identifies Puskesmas Arimop as a frontline facility responsible for maternal and child health, growth monitoring, immunization, nutrition services, and promotive and preventive activities. This institutional structure provides an opportunity to integrate interventions that are often delivered separately.

In practical terms, children identified with poor growth should not only receive nutritional counselling. Their immunization records, household water conditions, recent infection history, and barriers to accessing services should also be assessed. Similarly, outreach immunization activities could be used as opportunities for anthropometric screening and nutrition education, while environmental health visits could prioritize households with young children or documented growth faltering. Such integration would shift service delivery from a program-specific model toward a child-centered risk-management approach. This is particularly important in remote areas, where repeated travel to health facilities may be difficult and fragmented services can increase the burden on families.

Several limitations, however, require careful interpretation. First, the cross-sectional design measures exposures and stunting status within the same study period. Temporal sequence therefore cannot be established, and causal statements should be avoided. Feeding practices or healthcare behaviors observed at the time of data collection may not fully represent exposures during the period when linear growth faltering developed. Second, the sample included only 75 children selected using purposive sampling from one primary healthcare catchment area. Consequently, the findings may not be generalizable to all children in Boven Digoel, Papua Selatan, or other remote Indonesian populations. The manuscript confirms that the sampling procedure was purposive and based on predefined criteria.

Third, the analysis reported in the manuscript was limited to univariate and bivariate Chi-square tests. Potential confounding by maternal education, child age, socioeconomic conditions, infection history, sanitation, household food security, or healthcare accessibility was therefore not controlled statistically. Associations observed in the bivariate analysis cannot be interpreted as independent effects. Fourth, feeding practices and household behaviors were partly assessed through questionnaires, creating potential recall and reporting bias. The manuscript also does not report formal psychometric validation or reliability testing of the questionnaire, which limits assessment of measurement quality. Finally, the clean-water variable was primarily based on defined household and physical criteria rather than laboratory microbiological testing; consequently, meeting physical standards does not necessarily establish microbiological safety.

Future research should address these methodological limitations while preserving the multidimensional perspective generated by the present findings. Larger studies involving several districts or health-center catchment areas would improve representativeness and provide sufficient statistical power for multivariable modeling. Binary logistic regression should be used to estimate adjusted associations between feeding practices, immunization adherence, water conditions, and stunting while accounting for relevant maternal, child, socioeconomic, and environmental confounders. Prospective cohort designs would be particularly valuable because they could establish temporal relationships between early

feeding, infection exposure, immunization completion, environmental conditions, and subsequent linear growth.

Measurement should also be expanded. Future studies could incorporate dietary diversity indicators, minimum meal frequency, household food security, documented immunization records, episodes of diarrhoea or respiratory infection, sanitation characteristics, and microbiological water-quality testing. Qualitative inquiry would further help explain why recommended feeding practices, immunization schedules, or safe-water behaviors are difficult to maintain in remote communities. Factors such as travel distance, food availability, household decision-making, local beliefs, health-worker outreach, and infrastructure could then be examined alongside quantitative associations.

Overall, the principal contribution of this study lies in showing that nutrition, preventive healthcare, and environmental health converge within the same stunting problem in Arimop. The findings therefore support a conceptual shift from treating stunting as an isolated nutritional deficit toward understanding it as a multidimensional primary-healthcare and household-environment challenge. For remote settings, the most meaningful response may be one that integrates growth monitoring, feeding support, immunization follow-up, infection prevention, and household water safety within coordinated community-based services. Future research should test whether such integrated approaches produce measurable improvements in child growth and whether they are feasible and sustainable within resource-constrained primary healthcare systems.

CONCLUSIONS

This study found that feeding practices, immunization adherence, and household clean water use were significantly associated with stunting among children aged 12–59 months in the Arimop Public Health Center area, Boven Digoel Regency. Stunting was more common among children with poor feeding practices, incomplete immunization adherence, and household water use that did not meet health requirements. These findings indicate that childhood stunting in this remote setting is linked to interconnected nutritional, preventive healthcare, and environmental conditions rather than to a single factor. Stunting prevention should therefore be implemented through an integrated primary healthcare approach. Arimop Public Health Center should strengthen age-appropriate feeding counselling, actively monitor completion of routine childhood immunization, and promote safe household water use through coordinated nutrition, maternal and child health, immunization, and environmental health programs. Children exposed to multiple vulnerabilities should receive priority for growth monitoring and follow-up. Because the study used a cross-sectional design and bivariate analysis, the findings should be interpreted as associations rather than causal relationships. Further studies using larger samples and multivariable analyses are needed to identify independent factors associated with stunting.

Funding Statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The study was conducted using the authors' own resources.

Conflict of Interest

The authors declare that there are no financial, professional, or personal conflicts of interest that could have influenced the conduct, analysis, interpretation, or reporting of this

study.

Authors' Contributions

Hendra Ruru: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft, and Writing – Review & Editing. The author approved the final version of the manuscript and takes responsibility for the integrity and accuracy of the work.

Acknowledgments

The authors gratefully acknowledge the management and staff of Arimop Public Health Center, Boven Digoel Regency, for their support during data collection. The authors also thank all mothers and caregivers who participated in the study and provided the information required for this research.

Declaration of Generative AI Use

Generative artificial intelligence tools were used only to assist with language refinement, academic phrasing, and improvement of manuscript readability. All scientific content, interpretation of findings, statistical results, and conclusions were reviewed and verified by the authors. The authors take full responsibility for the accuracy and integrity of the final manuscript.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable ethical and confidentiality considerations.

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