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Access to Water, Sanitation, and Household Hygiene, and the Nutritional Status of Children Under Five in Rural Areas

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Abstract
Limited access to water, sanitation, and hygiene (WASH) is recognized as a contributing factor to child malnutrition, yet local empirical evidence from the rural mountainous areas of Timor-Leste remains scarce. This study examined the relationship between household WASH access and the nutritional status of children under five years of age in rural Lautém City. A community-based analytical cross-sectional study was conducted among 628 mother–child pairs in twelve sucos, using stratified cluster sampling between February and May 2024. Anthropometric indices were calculated using the 2006 World Health Organization (WHO) Child Growth Standards, and household WASH access was classified using the WHO/United Nations Children's Fund (UNICEF) Joint Monitoring Program service ladder. Associations were assessed using the chi-square test and multivariate binary logistic regression, reporting adjusted odds ratios (AOR) with 95% confidence intervals (CI) at a significance level of $p < 0.05$. Stunting, underweight, and wasting affected 51.0%, 33.4%, and 9.2% of children, respectively. After adjusting for maternal education, household wealth, and child age, unsafe drinking water (AOR = 1.84; 95% CI: 1.21–2.79), inadequate sanitation (AOR = 1.67; 95% CI: 1.14–2.45), and limited or no hygiene facilities (AOR = 1.59; 95% CI: 1.06–2.38) were independently associated with stunting; sanitation showed the most consistent association, while no indicator was associated with wasting. Inadequate household WASH conditions are strongly associated with stunting among rural children in Timor-Leste. Integrated, area-based sanitation and clean water programs, combined with maternal education and poverty alleviation, are needed to accelerate stunting reduction in Lautém.

Keywords: Child undernutrition, hygiene, sanitation, stunting, water supply

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INTRODUCTION

Child undernutrition continues to undermine human development across low- and middle-income countries, where impaired linear growth during the first thousand days carries consequences that reach well beyond early childhood. Stunting, the clearest marker of chronic deprivation, is

closely tied to delayed cognitive development, lower educational attainment, and reduced adult economic productivity, and its prevalence remains stubbornly high in much of sub-Saharan Africa and South-East Asia (Karlsson et al., 2023; Quamme & Iversen, 2022). Because growth faltering accumulates with age and is difficult to reverse after the second birthday, the window from conception to twenty-four months has become the central focus of global nutrition policy. Understanding the conditions that shape early growth, particularly those that are modifiable through public investment, is therefore essential for any serious attempt to reduce the burden of childhood malnutrition.

Timor-Leste illustrates the persistence of this problem in an especially acute form. National surveys place stunting among children under five at roughly one in two, one of the highest proportions recorded globally, with rural communities and the mountainous east bearing a disproportionate share of the burden (Ministry of Health & UNICEF, 2022; Nomura et al., 2023). Wasting and underweight also remain common, and recent country-level analyses confirm that rural children under five carry substantially higher odds of undernutrition than their urban counterparts. Lautém, a predominantly rural municipality at the country's far eastern tip, combines subsistence agriculture, dispersed settlement, seasonal food insecurity, and limited basic services, a configuration repeatedly associated with elevated nutritional risk across comparable settings.

Among the modifiable determinants of growth faltering, household water, sanitation, and hygiene (WASH) conditions have attracted sustained scientific attention. Inadequate WASH exposes young children to repeated enteric infection, and the resulting cycle of diarrhoea and subclinical intestinal damage diverts energy and nutrients away from growth toward immune defence and repair (Masset & Sharma Waddington, 2025; Wolf et al., 2022). The biological plausibility of this pathway is reinforced by research on environmental enteric dysfunction, which demonstrates that persistent gut inflammation suppresses growth signalling and constrains linear growth even when dietary intake appears adequate (Lowe et al., 2026).

WASH is therefore best understood as a nutrition-sensitive concern rather than a purely environmental one, with direct relevance to stunting prevention. This framing matters for policy, because it positions water and sanitation improvements alongside dietary and health interventions rather than treating them as separate infrastructure goals. Community-level evidence is consistent with this mechanism, showing that poorer household water quality and sanitation accompany a higher incidence of diarrhoea in toddlers, the proximal clinical expression of the pathway (Samuel

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et al., 2026). Taken together, these findings suggest that sustained reductions in childhood stunting are unlikely to be achieved without concurrent gains in household WASH conditions.

Observational evidence consistently links poor WASH to child undernutrition. Pooled and meta-analytic studies report that children in households lacking improved sanitation or safe drinking water face markedly higher odds of stunting, and that sanitation frequently emerges as the single most influential WASH component. National analyses from Benin, Brazil, and Ethiopia reach similar conclusions, linking the absence of basic water, sanitation, and hygiene services to stunting and underweight even after adjustment for socioeconomic confounders (Gaffan et al., 2023; Mudadu Silva et al., 2023; Sahiledengle et al., 2022). Taken together, these findings establish WASH deprivation as a credible and recurrent correlate of impaired child growth.

The evidence is not, however, entirely uniform, and this nuance matters for programme design. Several studies report that water and sanitation operate through distinct pathways and that their effects on chronic and acute undernutrition differ in magnitude and direction. Recent survey-based analyses suggest that improved water is more protective against stunting than sanitation in some contexts, while sanitation matters more in others, and that broader socioeconomic factors strongly modify these relationships (Castillo et al., 2025). Findings from Ghana and Somaliland likewise indicate that household poverty and unimproved toilets can outweigh infant-feeding indicators as predictors of undernutrition (Addae et al., 2024; Dahir et al., 2026). This heterogeneity underscores the value of localised, context-specific evidence rather than uncritical extrapolation from other regions.

Within the Asia-Pacific region, studies repeatedly demonstrate that combined WASH and feeding practices produce the largest reductions in malnutrition risk. Analyses from Lao PDR and China show that improved sanitation together with adequate infant and young child feeding jointly lower the odds of stunting, and that urban–rural disparities in child malnutrition are partly explained by unequal WASH access (Lin & Feng, 2023; Som et al., 2023). Evidence from Bangladesh similarly links household access to water, sanitation, and handwashing facilities with a lower prevalence of undernutrition among children below five years of age (Hasan et al., 2023). These regional patterns are particularly instructive for Timor-Leste, which shares ecological and developmental features with its South-East Asian neighbours.

Neighbouring Indonesia offers especially comparable insights, given its shared geography, climate, and persistent stunting challenge. Recent national and review studies report that unimproved water sources and weak sanitation systems remain significant correlates of stunting, and that

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integrated WASH–nutrition programming is essential for accelerating progress toward national targets. Spatial analyses from South Asia reinforce the message, identifying sanitation deprivation as a persistent driver of child growth failure that clusters geographically and demands area-based targeting (Jain et al., 2024). Such work highlights both the policy salience of WASH and the importance of mapping risk at sub-national scales. Multi-state analyses from India converge on the same conclusion, reporting that socio-economic disadvantage and household environmental conditions remain dominant determinants of stunting even where large-scale nutrition missions are already operating (Kumari & Kamal, 2026), and that these determinants are established as early as 6–23 months of age (Lavanya et al., 2026).

Despite this rich international literature, municipality-level evidence from Timor-Leste is sparse, and few studies have quantified associations between WASH and nutrition in its rural eastern districts. Global monitoring confirms that the country lags on safely managed water and sanitation and that rural coverage gaps remain wide and slow to close, while food security and child malnutrition assessments identify Timor-Leste as a priority setting for nutrition-sensitive investment (FAO IFAD & WHO, 2023; UNICEF WHO & Bank, 2023). Generating local estimates is thus both Layout scientific and a programmatic necessity.

Accordingly, the present study addresses three specific objectives: (i) to estimate the prevalence of stunting, underweight, and wasting among children aged 0–59 months in rural Lautém Municipality; (ii) to describe household drinking-water, sanitation, and hygiene service levels using the JMP service ladders; and (iii) to determine whether household WASH access is independently associated with each form of undernutrition after adjustment for sociodemographic confounders. We hypothesised that children living in households with unimproved WASH conditions would have significantly higher odds of stunting than children in households with improved or basic services. The novelty of this study lies in providing the first municipality-level, JMP-based quantification of the WASH–undernutrition association in Timor-Leste's far eastern highlands, thereby supplying evidence that can be used directly for targeted, area-based intervention planning.

METHODOLOGY

Type of Research

This study employed a community-based analytical cross-sectional design to examine associations between household WASH access and nutritional status among children under five in rural Lautém Municipality, Timor-Leste. A quantitative approach was adopted, using structured field

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measurements and a pre-tested questionnaire to generate anthropometric data and to classify household WASH service levels. The design was selected for its efficiency in characterising prevalence and associations within a defined population at a single point in time. Reporting follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies.

Time and Place of Research

Data were collected between February and May 2024 in rural Lautém Municipality, the easternmost district of Timor-Leste. Lautém is characterised by mountainous terrain, subsistence farming, dispersed rural settlements, and constrained access to piped water and improved sanitation, making it a representative high-burden setting for studying WASH and child growth. The municipality comprises five administrative posts, from which predominantly rural sucos (villages) were selected as the study area.

Sample Size and Sampling

The source population comprised all children aged 0–59 months living in rural sucos of Lautém Municipality together with their mothers or primary caregivers. Children were eligible if they were permanent residents of the selected cluster for at least six months; children with physical deformities preventing valid anthropometry and those whose caregivers declined consent were excluded. The required sample size was estimated using the single-population proportion formula, assuming a stunting prevalence of 50% from national survey data, a 95% confidence level, a 5% margin of error, a design effect of 1.5 for cluster sampling, and a 10% non-response allowance, yielding a target of approximately 620 children. A multistage cluster sampling approach was applied: twelve sucos were selected with probability proportional to size; households with at least one child aged 0–59 months were listed within each cluster; and eligible children were then chosen by systematic random sampling. Where a household contained more than one eligible child, the youngest was selected. In total, 628 mother–child pairs were enrolled, corresponding to a response rate of 96.2%.

Variables and Operational Definitions

The outcome variables were stunting, underweight, and wasting, defined respectively as height-for-age (HAZ), weight-for-age (WAZ), and weight-for-height (WHZ) z-scores below minus two standard deviations of the WHO 2006 Child Growth Standards. The independent variables were household drinking water, sanitation, and hygiene service levels, classified according to the WHO/UNICEF Joint Monitoring Programme (JMP) service ladders and subsequently dichotomised

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into improved or basic versus unimproved or limited categories for inferential analysis. Covariates comprised child age and sex, maternal age and education, household size, a wealth tertile derived from a principal-components asset index, and distance to the nearest health facility (≤ 5 km versus > 5 km).

Data Collection Techniques and Instrument Development

Trained enumerators fluent in Tetum administered a structured, pre-tested questionnaire to mothers or primary caregivers, capturing sociodemographic characteristics, maternal education, household assets, and WASH conditions. The instrument was adapted from the JMP core questions on household WASH and from the Timor-Leste Food and Nutrition Survey, translated into Tetum, back-translated into English, and pre-tested on 30 households outside the study clusters; internal consistency of the composite WASH module was acceptable. Child weight was measured to the nearest 0.1 kg using calibrated electronic scales, and recumbent length or standing height was measured to the nearest 0.1 cm using standard length/height boards following WHO procedures. Age was verified from immunisation cards or birth records. Anthropometric z-scores were generated using WHO Anthro software. All measurements were taken in duplicate by paired enumerators, and a five-percent random sample of households was revisited for quality control to minimise measurement error; biologically implausible z-scores were flagged and excluded according to WHO cut-offs.

Data Analysis Techniques

Data were double-entered, cleaned, and analysed using [statistical software and version]. Categorical variables were summarised as frequencies and percentages. Bivariate associations between each WASH indicator and each nutritional outcome were tested using the Pearson chi-square test. Variables significant at $p < 0.20$ in bivariate analysis, together with established confounders (maternal education, household wealth, and child age), were entered into multivariable binary logistic regression models. Adjusted odds ratios (AOR) with 95% confidence intervals (CI) were reported, and statistical significance was set at $p < 0.05$. Multicollinearity was assessed using variance inflation factors, and model fit was evaluated with the Hosmer–Lemeshow goodness-of-fit test. Clustering at suco level was accounted for in the variance estimation. Missing data were minimal (< 2%) and handled by complete-case analysis.

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RESULTS AND DISCUSSION

RESULTS

A total of 628 children aged 0–59 months and their mothers participated, corresponding to a response rate of 96.2%. Just over half of the children were male (51.0%), and the sample was distributed across all age bands. Maternal education was low overall: 28.0% of mothers had no formal schooling and only 30.7% had reached secondary level or above. More than a third of households (36.0%) were in the lowest wealth tertile, and 44.6% lived more than five kilometres from the nearest health facility. The full sociodemographic profile is presented in Table 1.

Table 1. Sociodemographic characteristics of the study participants

Characteristic	Category	n	%
Child sex	Male	320	51.0
	Female	308	49.0
Child age (months)	0–11	124	19.7
	12–23	144	22.9
	24–35	130	20.7
	36–47	120	19.1
	48–59	110	17.5
Maternal education	None	176	28.0
	Primary	259	41.2
	Secondary or higher	193	30.7
Household wealth tertile	Lowest	226	36.0
	Middle	208	33.1
	Highest	194	30.9
Distance to health facility	> 5 km	280	44.6
	≤ 5 km	348	55.4

Percentages are column percentages and may not total 100.0 because of rounding.

Household WASH access was limited across the sample (Table 2). Slightly more than half of households (54.9%) relied on improved drinking water, while 39.5% used unimproved sources and 5.6% depended on limited services or surface water. Only 42.5% had access to basic sanitation; 25.0% used unimproved facilities and 15.1% reported open defecation. Basic hygiene facilities with water and soap were available in just 39.0% of homes. Each of the three service ladders accounts for all 628 households.

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Table 2. Household WASH service levels based on the JMP ladders

WASH indicator	Service level	n	%
Drinking water	Improved / basic	345	54.9
	Unimproved	248	39.5
	Limited / surface water	35	5.6
Sanitation	Basic / improved	267	42.5
	Limited (shared)	109	17.4
	Unimproved	157	25.0
	Open defecation	95	15.1
Hygiene	Basic (water + soap)	245	39.0
	Limited	202	32.2
	No facility	181	28.8

The overall burden of undernutrition was high. Stunting affected 51.0% of children (n = 320), underweight 33.4% (n = 210), and wasting 9.2% (n = 58) (Figure 1). Stunting therefore represented the dominant form of malnutrition, consistent with a pattern of chronic rather than acute deprivation.

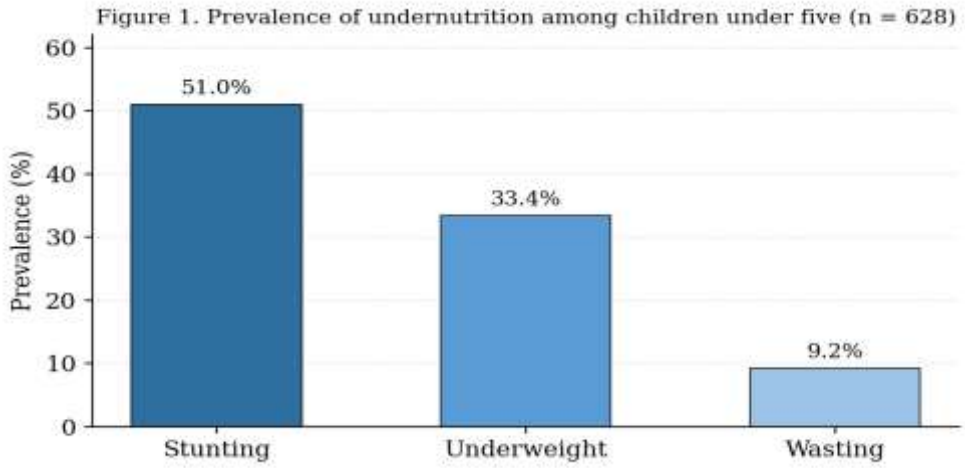

Figure 1. Prevalence of stunting, underweight, and wasting among children aged 0–59 months

Bivariate analysis revealed clear gradients in undernutrition by WASH status (Table 3). Stunting prevalence was significantly higher among children from households using unimproved drinking water (60.4% of exposed children were stunted, versus 43.2% of those with improved water; $\chi^2 = 18.49$, $p < 0.001$), sanitation that was not basic (57.6% versus 41.9%; $\chi^2 = 15.08$, $p < 0.001$), and limited or no hygiene facilities (55.1% versus 44.5%; $\chi^2 = 6.72$, $p = 0.010$). Comparable bivariate associations for wasting and underweight are summarised in Tables 4 and 5, respectively. Wasting showed weaker, statistically non-significant associations with all three WASH indicators, whereas underweight followed an intermediate pattern, being significantly associated with drinking water (p .003) and sanitation (p = 0.003) but not with hygiene (p = 0.085). These contrasts are visualised in Figure 2.

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Table 3. Association between household WASH exposures and childhood stunting

WASH Exposure	Stunting Status				X^2	p value
	Stunted		Not stunted			
	f	%	f	%		
Improved water	149	46.6	196	63.6	18.49	<0.001
Unimproved water	171	53.4	112	36.4		
Basic sanitation	112	35.0	155	50.3	15.08	<0.001
Not basic sanitation	208	65.0	153	49.7		
Basic hygiene	109	34.1	136	44.2	6.72	0.010
Limited / no hygiene	211	65.9	172	55.8		
TOTAL	**320**	**100.0**	**308**	**100.0**		

f = frequency. Percentages are column percentages within each nutritional status category; percentages cited in the text are row percentages, that is, the proportion of children affected within each exposure group. χ^2 = Pearson chi-square statistic with 1 degree of freedom. Statistical significance was set at $p < 0.05$.

Figure 2. Stunting prevalence by household WASH service level

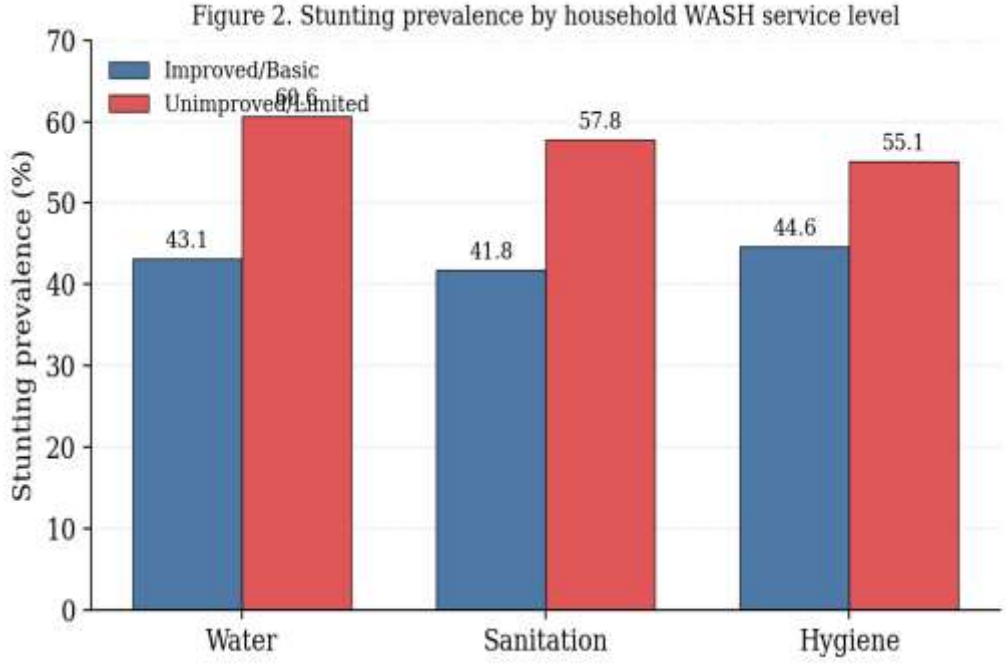

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Figure 2. Stunting prevalence by household WASH service level

Table 4. Association between household WASH exposures and childhood wasting

WASH Exposure	Wasting Status				X^2	p value
	Wasting		Not wasting			
	f	%	f	%		
Improved water	28	48.3	317	55.6	1.15	0.285
Unimproved water	30	51.7	253	44.4		
Basic sanitation	18	31.0	249	43.7	3.45	0.063
Not basic sanitation	40	69.0	321	56.3		
Basic hygiene	18	31.0	227	39.8	1.71	0.191
Limited / no hygiene	40	69.0	343	60.2		
TOTAL	**58**	**100.0**	**570**	**100.0**		

f = frequency. Percentages are column percentages. χ^2 = Pearson chi-square statistic with 1 degree of freedom. Statistical significance was set at $p < 0.05$.

Table 5. Association between household WASH exposures and childhood underweight

WASH Exposure	Underweight Status				X^2	p value
	Underweight		Not underweight			
	f	%	f	%		
Improved water	98	46.7	247	59.1	8.72	0.003
Unimproved water	112	53.3	171	40.9		
Basic sanitation	72	34.3	195	46.7	8.74	0.003
Not basic sanitation	138	65.7	223	53.3		
Basic hygiene	72	34.3	173	41.4	2.96	0.085
Limited / no hygiene	138	65.7	245	58.6		
TOTAL	**210**	**100.0**	**418**	**100.0**		

f = frequency. Percentages are column percentages. χ^2 = Pearson chi-square statistic with 1 degree of freedom. Statistical significance was set at $p < 0.05$.

In the multivariable logistic regression model for stunting, all three WASH indicators retained independent significance after adjustment for maternal education, household wealth, and child age (Table 6; Figure 3). Children from households with unimproved drinking water had 1.84 times higher adjusted odds of stunting (95% CI: 1.21–2.79; p = 0.004), those with unimproved sanitation 1.67

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times higher odds (95% CI: 1.14–2.45; p = 0.008), and those with limited or no hygiene facilities 1.59 times higher odds (95% CI: 1.06–2.38; p = 0.025). Sanitation showed the most consistent effect across model specifications. Older child age (24–59 months), absence of maternal education, and membership of the lowest wealth tertile were also independently associated with stunting. The Hosmer–Lemeshow test indicated good model fit (χ^2 = 8.32, df = 8, p = 0.41), and all variance inflation factors were below 2.0, indicating no problematic multicollinearity.

Table 6. Adjusted odds ratios for child stunting from multivariable logistic regression

Predictor	AOR	95% CI	p-value
Unimproved drinking water (ref: improved/basic)	1.84	1.21–2.79	0.004
Unimproved sanitation (ref: basic/improved)	1.67	1.14–2.45	0.008
Limited / no hygiene facility (ref: basic hygiene)	1.59	1.06–2.38	0.025
No maternal education (ref: secondary or higher)	1.72	1.13–2.62	0.011
Lowest wealth tertile (ref: highest tertile)	1.55	1.02–2.36	0.040
Child age 24–59 months (ref: 0–23 months)	2.10	1.45–3.04	< 0.001

AOR = adjusted odds ratio; CI = confidence interval; ref = reference category. The model was mutually adjusted for all variables listed and accounted for clustering at suco level. Model fit: Hosmer–Lemeshow χ^2 = 8.32, df = 8, p = 0.41.

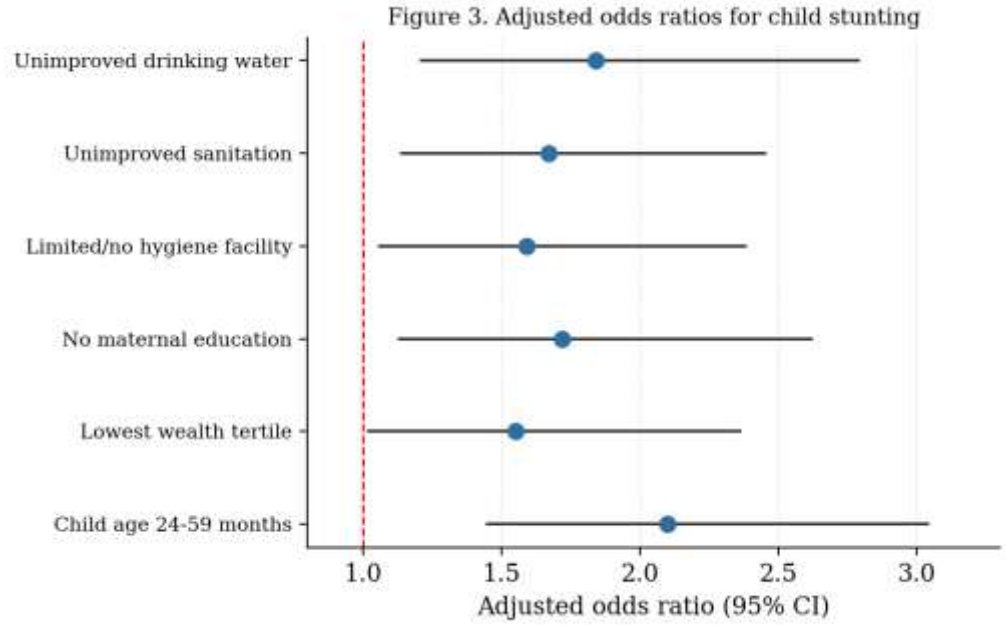

Figure 3. Adjusted odds ratios and 95% confidence intervals for predictors of child stunting

DISCUSSION

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This study quantified the association between household WASH access and the nutritional status of children under five in rural Lautém, one of Timor-Leste's most disadvantaged municipalities. The central finding is that unimproved drinking water, unimproved sanitation, and inadequate hygiene were each independently associated with substantially higher odds of stunting, even after accounting for maternal education, household wealth, and child age. With stunting affecting just over half of the children studied, the results confirm that chronic undernutrition remains the dominant nutritional problem in this setting and that deficient WASH conditions form a meaningful part of its aetiology. These findings echo the national picture and reinforce concern that rural Timorese children continue to face an exceptionally high burden of impaired linear growth (Ministry of Health & UNICEF, 2022).

The observed magnitude of the WASH–stunting association is consistent with the broader international evidence base. Meta-analytic and pooled studies have repeatedly shown that children without improved water or sanitation experience elevated odds of stunting, and that the WASH–enteric infection pathway is biologically credible (Masset & Sharma Waddington, 2025; Wolf et al., 2022). The adjusted odds ratios observed here, ranging from 1.59 to 1.84, sit comfortably within the range reported by national analyses elsewhere, including work demonstrating that unimproved sanitation and open defecation raise stunting risk in African settings (Gaffan et al., 2023). The convergence of these municipality-level estimates with larger studies strengthens confidence that the associations reflect a genuine phenomenon rather than a local artefact.

Sanitation emerged as the most consistent WASH correlate of stunting in the present models, a pattern that aligns closely with evidence identifying sanitation as the single most influential WASH component for chronic undernutrition (Mudadu Silva et al., 2023; Sahiledengle et al., 2022). The plausible mechanism is the repeated faecal oral exposure that accompanies poor sanitation, which sustains environmental enteric dysfunction, blunts nutrient absorption, and suppresses growth signalling even when dietary intake is adequate (Htet et al., 2026; Lowe et al., 2026). This mechanistic framing helps explain why sanitation deprivation translates into linear growth deficits over time and why sanitation-focused interventions may yield disproportionate nutritional returns in high-burden rural communities.

At the same time, these results contribute to an ongoing debate about the relative importance of individual WASH components. Some studies report that improved water is more protective than sanitation, while others find the reverse, and the balance appears to depend heavily on local infrastructure and socioeconomic context (Castillo et al., 2025). The finding that water, sanitation,

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and hygiene were all independently associated with stunting in Lautém suggests that no single component dominates in this setting; instead, multiple deficiencies coexist and compound one another. Caregiver practice remains relevant alongside these structural factors, since parenting and feeding practices are themselves associated with stunting in toddlers (Mustika, 2025). This interpretation is consistent with evidence that household poverty and unimproved facilities jointly shape undernutrition risk, sometimes outweighing feeding indicators (Addae et al., 2024).

The regional literature offers useful comparators. Studies from Lao PDR and China demonstrate that combined WASH and appropriate infant feeding practices produce the greatest reductions in stunting and that urban–rural disparities are partly mediated by unequal WASH access (Lin & Feng, 2023; Som et al., 2023). Evidence from Bangladesh and Lao PDR points in the same direction, linking household WASH conditions to a lower prevalence of undernutrition (Hasan et al., 2023; Som et al., 2023). Lautém's profile of high stunting, low sanitation coverage, and widespread rural poverty mirrors these settings, suggesting that the integrated WASH–nutrition approaches validated in neighbouring countries are likely to be transferable here.

Insights from Indonesia and South Asia are especially pertinent given shared ecological and developmental conditions. National and review studies report that unimproved water and weak sanitation systems remain significant stunting determinants and that integrated programming is essential to accelerate progress (Arief et al., 2025; Soegijanto et al., 2025). Spatial analyses that identify geographic clustering of sanitation deprivation and child growth failure further support area-based targeting (Jain et al., 2024). For Lautém, this implies that blanket national strategies may be less effective than locally tailored interventions that prioritise the sucos with the deepest WASH deficits, an approach supported by the marked bivariate gradients observed in the present data.

The weaker association between WASH and wasting also merits comment. Wasting reflects acute, short-term nutritional stress driven largely by recent illness and food shortage, whereas stunting captures cumulative deprivation; WASH conditions, which act gradually through chronic infection and inflammation, would therefore be expected to associate more strongly with stunting than with wasting. The observed pattern of strong stunting associations and weak wasting associations is internally coherent with this physiological distinction and consistent with country evidence that rural children under five carry elevated chronic, more than acute, undernutrition risk (Bahwere et al., 2024; Karlsson et al., 2023; Quamme & Iversen, 2022).

Taken together, the findings point to several intersecting determinants of stunting. Stunting reduction in Lautém appears contingent on nutrition-sensitive WASH investment, including the

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expansion of safely managed water, the elimination of open defecation, and the promotion of hygiene, delivered in combination with maternal education and poverty-reduction measures. The maternal dimension of this combination is supported by evidence that parenting patterns and maternal education are associated with child nutritional status in low-income households (Sidik et al., 2025). This pattern is consistent with global monitoring data confirming that Timor-Leste's rural WASH coverage gaps remain wide and with international assessments identifying the country as a priority for nutrition-sensitive financing (UNICEF et al., 2023; WHO & UNICEF, 2023). Practically, the results support three actions: prioritising sucos with the lowest JMP service levels for water-system rehabilitation and sanitation subsidies; integrating hygiene promotion into existing maternal and child health contacts; and embedding WASH indicators in routine nutrition surveillance so that progress can be monitored at municipality level.

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inference, and the temporal ordering between WASH exposure and growth outcomes cannot be firmly established. Second, self-reported WASH practices may be subject to social desirability bias, and observation-based verification was not feasible for all households. Third, unmeasured confounders such as dietary diversity, breastfeeding history, birth weight, and infection history could influence the observed associations, raising the possibility of residual confounding. Fourth, the single-municipality focus, while a strength for local relevance, may limit generalisability to other parts of Timor-Leste. Nonetheless, the probability-based sampling strategy, standardised anthropometry against WHO standards, duplicate measurement with quality-control revisits, and adjustment for key confounders lend credibility to the findings and provide a sound basis for future longitudinal and intervention research.

CONCLUSION

This study provides municipality-level evidence that inadequate household WASH conditions are strongly and independently associated with child stunting in rural Lautém, Timor-Leste. More than half of the children surveyed were stunted, and children from households relying on unimproved water, unimproved sanitation, or limited hygiene facilities carried significantly higher adjusted odds of chronic undernutrition, with sanitation emerging as the most consistent WASH correlate. By contrast, WASH indicators were only weakly related to wasting, reinforcing the interpretation that deficient WASH acts primarily through cumulative, chronic pathways rather than acute nutritional stress.

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These results situate Lautém within a wider body of regional and global evidence linking environmental deprivation to impaired linear growth, while supplying the locally grounded estimates that have until now been lacking. The findings argue for nutrition-sensitive, area-based interventions that simultaneously expand safe water and improved sanitation, promote hygiene, and address the underlying maternal and economic disadvantages that shape child nutrition.

The scale of stunting documented here represents a serious public-health challenge that warrants urgent, coordinated action across the health, water, and education sectors, supported by sustained domestic and international financing. Prioritising the most deprived sucos and integrating WASH with infant and young child feeding support offer a credible route to accelerating stunting reduction. Future longitudinal and intervention studies are needed to confirm causality and to evaluate the effectiveness of combined WASH–nutrition programming in this high-burden rural context.

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