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Escherichia coli Contamination in Drinking Water with Stunting Among Children Under Five: A Case-Control Study

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ABSTRACT

Stunting remains a major public health problem influenced by nutritional, infectious, and environmental factors. The presence of *Escherichia coli* in drinking water indicates fecal contamination and potential exposure to enteric pathogens that may contribute to impaired child growth. This study aimed to examine the association between *E. coli* contamination in household drinking water and stunting among children aged 24-59 months in Kejajar District, Wonosobo Regency, while also assessing selected child-related and household WASH factors. An analytical observational case-control study included 70 children, comprising 35 stunted cases and 35 non-stunted controls. Case and control status was determined using height-for-age data of e-PPGBM/SIGIZI Terpadu system. Data were collected through caregiver interviews, household observations, review of health records, and laboratory examination of household drinking water. *E. coli* was examined using the Most Probable Number method. Bivariate associations were assessed using the Chi-square or Fisher's exact test. *E. coli* contamination was detected in 58.6% of household drinking-water samples and was significantly associated with stunting (OR = 3.852; 95% CI: 1.401-10.590; $p = 0.008$). Significant associations were also observed for low birth weight (OR = 3.273), diarrhea history (OR = 3.692), poor handwashing with soap practices (OR = 3.333), and inadequate household latrine sanitation (OR = 3.750). Exclusive breastfeeding was not significantly associated with stunting ($p = 0.145$). These findings indicate associations rather than causal effects and support the relevance of safe household drinking water, sanitation, hand hygiene, diarrhea prevention, and child health monitoring within integrated stunting-prevention strategies in this highland agricultural community.

Keywords: *Escherichia coli*; Drinking water; Stunting; Sanitation.

INTRODUCTION

Stunting is a form of chronic malnutrition that continues to affect nearly 150 million children under five years of age worldwide (Girma et al., 2024). This condition impairs cognitive development and reduces children's ability to concentrate, retain information, and solve problems. Although the global prevalence of stunting has shown a declining trend, the burden remains high and relatively stagnant in low- and middle-income countries, particularly in Sub-Saharan Africa and South Asia (Utami et al., 2024). In several countries in East and Central Africa, including Ethiopia and the Democratic Republic of the Congo, the prevalence of stunting has been reported to exceed 50% (Rah et al., 2020).

Global efforts to prevent stunting are also reflected in the Sustainable Development Goals (SDGs), particularly Goal 6, which aims to ensure the availability and sustainable management of water and sanitation for all (4). Target 6.1 emphasizes universal access to safe and affordable drinking water, while Target 6.2 focuses on achieving adequate sanitation and eliminating open defecation by 2030 (Pradana et al., 2023). These targets are closely associated with environmental and behavioral determinants of stunting. Children who grew up in the households with improved sanitation access have been reported to have a 29% lower risk of stunting than those without adequate sanitation (Rahman et al., 2024).

In addition to sanitation, household hygiene practices play a crucial role in interrupting the transmission of microorganisms that cause gastrointestinal infections (Anwar et al., 2025). Open defecation, handwashing with soap, and household drinking water management are key determinants that may influence the occurrence of stunting (Andrestian et al., 2025). However, public awareness of critical handwashing moments and their implications for health remains limited. This indicates that stunting prevention cannot rely solely on improvements in infrastructure but also requires sustained behavioral changes to promote proper hygiene practices (Handoyo et al., 2024).

In Indonesia, the prevalence of stunting remained at 19.8% in 2024 according to the Indonesian Nutritional Status Survey (Survei Status Gizi Indonesia), exceeding the National Medium-Term Development Plan (RPJMN) 2020-2024 target of 14%. In the same year, Central Java Province reported a stunting prevalence of 17.1% (Ratnawati et al., 2025). Wonosobo Regency has shown a persistent upward trend, with prevalence increasing from 11% in 2021 to 15.4% in 2022, 16.76% in 2023, and 18.2% in 2024. Kejajar District recorded the highest prevalence, reaching 18%, equivalent to 658 cases among 3,621 measured children under five years of age (Profil Kesehatan Jawa Tengah, 2024). These findings highlight the need to further evaluate environmental conditions, sanitation, and household hygiene practices as potential contributors to the persistently high prevalence of stunting.

Contamination of household drinking water by *Escherichia coli* is a well-established indicator of fecal pollution, reflecting that the water fails to meet microbiological quality standards and may serve as a source of infectious disease exposure among children . *E. coli* is widely recognized as the primary indicator of fecal contamination in drinking water because its presence suggests the possible occurrence of other enteric pathogens that can cause diarrheal diseases, particularly among children in low- and middle-income countries (Alonzo et al., 2022). Exposure to *E. coli*-contaminated drinking water has been identified as an important environmental risk factor for stunting, as repeated enteric infections may impair nutrient absorption and hinder child growth. Previous studies have also demonstrated that contamination of household drinking water with *E. coli* is closely associated with inadequate sanitation and poor hygiene practices, including the use of unclean water storage containers and insufficient household water treatment (Hernández-Vásquez et al., 2022).

Kejajar District, located in Wonosobo Regency, faces a dual burden of a relatively high prevalence of stunting and challenges related to household drinking-water quality. Inadequate sanitation and unsafe drinking water may contribute to environmental exposure to enteric pathogens and have been associated with impaired child growth in previous studies. Previous evidence has shown that children from households that have more adequate sanitary facilities have a 5% lower likelihood of being stunted, while residing in communities free from open defecation can reduce the risk of stunting by up to 10% (Cameron et al., 2021).

The environmental challenges in Kejajar District warrant particular attention, as a 2025 assessment detected *Escherichia coli* contamination in all 30 household drinking water samples examined, while more than 4,000 households still lacked access to improved sanitation facilities (Dinkes Kab.Wonosobo, 2024). These conditions may increase the risk of infectious diseases, particularly diarrhea, which has been consistently associated with impaired child growth. Conversely, access to clean drinking water and improved drinking water services in Wonosobo Regency reached 82.9% and 95.24%, respectively, in 2024 (Dinkes Kab Wonosobo, 2026). The discrepancy between the high coverage of drinking water access and the poor microbiological quality of household drinking water suggests that access indicators alone do not adequately reflect water safety.

Although previous studies have established the importance of water, sanitation, and hygiene conditions in childhood stunting, evidence specifically examining the association between laboratory-confirmed Escherichia coli contamination in household drinking water and stunting remains limited, particularly in highland agricultural communities. Moreover, commonly reported drinking water access indicators may not adequately capture microbiological exposure at the household level. This study provides context-specific evidence by directly assessing *E. coli* contamination in household drinking water and its association with stunting among children aged 24-59 months in a highland agricultural setting. Accordingly, this study aimed to examine the association between *Escherichia coli* contamination in household drinking water and stunting, while also assessing selected child-related and household WASH factors.

METHODS

Study Design and Setting

This analytical observational study employed a case-control design and was conducted in Kejajar District, Wonosobo Regency, Central Java, Indonesia, from February to August 2026. The study area was selected based on its relatively high prevalence of stunting and concerns regarding the microbiological quality of household drinking water. Household drinking-water sampling was conducted during April-May 2026.

Study Population and Sampling

The study population consisted of children aged 24-59 months residing in the working areas of Kejajar I and Kejajar II Public Health Centers. A total of 70 children were included, comprising 35 stunted children as cases and 35 non-stunted children as controls, with a case-to-control ratio of 1:1. Case and control status was determined using the most recent height-for-age data recorded in the e-PPGBM/SIGIZI Terpadu system. The minimum sample size was calculated using the Lemeshow formula for a case-control study based on an expected odds ratio of 8.61, a 95% confidence level, and 95% statistical power. The calculation yielded a minimum of 32 participants per group. To account for the possibility of incomplete data, the sample size was increased by approximately 10%, resulting in 35 participants per group. Participants were selected using purposive sampling. Cases were identified from children registered as stunted in the e-PPGBM/SIGIZI Terpadu system, while controls were selected from non-stunted children living in the same villages or residential areas to improve environmental comparability between groups. Eligible children had resided in Kejajar District for at least two years, and their household basic sanitation facilities had not undergone renovation during the

preceding two years. Children with congenital abnormalities, disabilities, or other special conditions that could substantially affect growth, as well as children whose mothers or caregivers could not be contacted during data collection, were excluded.

Variables and Measurements

Stunting status was defined as a height-for-age z-score (HAZ) <-2 standard deviations, whereas HAZ ≥-2 standard deviations was classified as non-stunted. The primary exposure was *Escherichia coli* contamination in household drinking water. Water was classified as contaminated when *E. coli* was detected (>0 CFU/100 mL) and as meeting the microbiological requirement when no *E. coli* was detected (0 CFU/100 mL). Low birth weight (LBW) was defined as birth weight <2,500 g, while birth weight ≥2,500 g was classified as normal. Exclusive breastfeeding was defined as receiving breast milk only, except for medicines or vitamins, during the first six months of life. A history of diarrhea was defined as caregiver-reported diarrhea during the preceding two months.

Handwashing with soap was categorized as good when practiced at all five critical times and poor when fewer than five were fulfilled. The five critical times included before and after eating, after urination or defecation, before preparing food, before breastfeeding, and after activities. Household latrine sanitation was assessed using six criteria: adequate ventilation, water availability, adequate structural condition of the walls, roof, and door, absence of unpleasant odor, use of an individual septic tank, and a septic tank located at least 10 m from the household water source. Latrine sanitation was categorized as adequate when all six criteria were fulfilled and inadequate when at least one criterion was not met.

Data Collection and Laboratory Examination

Data were collected through structured interviews with mothers or caregivers, household observations, review of health records, and laboratory examination of household drinking water. Data collection was conducted by the researcher with assistance from enumerators and local health cadres. Exclusive breastfeeding history was obtained through interviews and verified with village health cadres, while LBW history was obtained from Maternal and Child Health (KIA) books and medical records from the local public health centers. Diarrhea history was obtained from interviews with mothers or caregivers. Household sanitation and handwashing practices were assessed using the study questionnaire and observation checklist. Household drinking-water samples were collected at the point of use using sterile 250-mL sampling bottles. Before sampling, the water outlet was allowed to run for approximately 2-3 minutes, disinfected, and allowed to flow again before approximately 100 mL of water was collected. Samples were immediately closed, labeled, transported in an ice box, and examined at the Wonosobo Regency Regional Health Laboratory (Laboratorium Kesehatan Daerah Kabupaten Wonosobo). *Escherichia coli* was examined using the Most Probable Number (MPN) method. The Wonosobo Regency Regional Health Laboratory reported the examination results in CFU/100 mL, and these reported values were used for exposure classification.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 25. Descriptive analysis was used to summarize the distribution of study variables using frequencies and percentages, while crosstabulation was performed to compare exposure characteristics between cases and controls. Bivariate associations between each independent variable and stunting status were assessed using the Chi-square test. Continuity correction was applied when appropriate, and Fisher's exact test was used when the assumptions of the Chi-square test were not fulfilled. Associations were expressed as odds ratios (ORs) with 95% confidence intervals (CIs), and a p-value <0.05 was considered statistically significant.

Ethical Considerations

The study protocol was approved by the Health Research Ethics Committee, Faculty of Public Health, Diponegoro University (Ethical Approval No. 132/EA/KEPK-FKM/2026). Written informed consent was obtained from the parent or legal guardian of each participating child before data collection.

RESULTS AND DISCUSSION

Bivariate analysis was performed to examine the associations between selected environmental, hygiene, and child-related factors and stunting among children aged 24-59 months in Kejajar District, Wonosobo Regency. The variables included *Escherichia coli* Contamination in Household Drinking Water, History of Low Birth Weight (LBW), History of Diarrhea, Exclusive Breastfeeding, Handwashing with Soap, and Household Latrine Sanitation. The results are presented as frequencies and percentages for the case and control groups, together with odds ratios (ORs), 95% confidence intervals (CIs), and *p*-values.

Table 1
Bivariate Associations Between Study Variables and Stunting Status

Variables	Cases	Controls	*p-value*	OR	95% CI	
	n= 35	n= 35			Lower	Upper
Escherichia coli Contamination in Household Drinking Water			0.008*	3.852	1.401	10.590
Contaminated	26 (74.3%)	15 (42.9%)				
Not Contaminated	9 (25.7%)	20 (57.1%)				
History of Low Birth Weight (LBW)			0.016*	3.273	1.224	8.748
LBW	24 (68.6%)	14 (40.0%)				
Non-LBW	11 (31.4%)	21 (60.0%)				
History of Diarrhea			0.008*	3.692	1.372	9.933
Yes	22 (62.9%)	11 (31.4%)				
No	13 (37.1%)	24 (68.6%)				
Exclusive Breastfeeding			0.145	2.400	0.725	7.949
Non-Exclusive Breastfeeding	10 (28.6%)	5 (14.3%)				
Exclusive Breastfeeding	25 (71.4%)	30 (85.7%)				
Handwashing with Soap			0.016*	3.333	1.235	8.997
Poor	20 (57.1%)	10 (28.6%)				
Good	15 (42.9%)	25 (71.4%)				
Household Latrine Sanitation			0.008*	3.750	1.383	10.169
Inadequate	25 (71.4%)	14 (40.0%)				
Adequate	10 (28.6%)	21 (60.0%)				

*$p < 0.05$ was considered statistically significant

Escherichia coli contamination in household drinking water was significantly associated with stunting (OR = 3.852; 95% CI: 1.401-10.590; $p = 0.008$). Children exposed to contaminated drinking water had approximately 3.9 times the odds of being stunted compared with those whose drinking water contained no detectable *E. coli*. Although the confidence interval supports statistical significance, its width indicates some uncertainty regarding the precise magnitude of the association. The finding therefore suggests that microbiological drinking-water quality is an important environmental factor associated with stunting in this population, but it does not establish causality.

This association is biologically plausible because the presence of *E. coli* in drinking water indicates fecal contamination and therefore signals the potential exposure of children to enteric microorganisms. Repeated exposure through contaminated drinking water may increase the occurrence of gastrointestinal infections, particularly diarrhea, which can reduce dietary intake, increase nutrient losses, and interfere with intestinal nutrient absorption (Torlesse et al., 2016). When such exposure occurs repeatedly during periods of rapid growth, the cumulative nutritional and inflammatory burden may contribute to impaired linear growth. This interpretation is consistent with (Parvin et al., 2021), who reported that fecal contamination of household environments and water sources was associated with subsequent diarrhea among young children. Children who living in households exposed to poorer drinking-water quality, including *E. coli* contamination, had a greater probability of undernutrition and stunting across low- and middle-income countries. Together, these findings support a plausible pathway in which microbiological contamination of drinking water contributes to repeated enteric exposure and infection, which may subsequently interfere with adequate child growth (Gabain et al., 2023).

The findings are particularly relevant in Kejajar District because the study assessed microbiological quality directly in household drinking water at the point of use

rather than relying solely on indicators of access to improved water sources. This distinction is important because access to an improved source does not necessarily guarantee microbiological safety at the time the water is consumed. Contamination may be introduced or amplified during water collection, transportation, household storage, preparation, or handling, and recent evidence has demonstrated that fecal contamination can occur between the water source and the point of use (Gebeyehu et al., 2026). The present findings therefore extend previous WASH-related evidence by demonstrating a significant association using laboratory-confirmed *E. coli* contamination in household drinking water within a highland agricultural community. From a practical perspective, stunting-prevention strategies in Kejajar should not focus solely on expanding access to drinking-water infrastructure but should also strengthen routine microbiological monitoring, safe household water treatment and storage, hygienic handling, and protection of water quality up to the point of consumption. These interventions should ultimately be integrated with improvements in sanitation, handwashing practices, and prevention of diarrheal disease, because microbiological drinking-water contamination represents one component of the broader fecal-oral exposure pathway associated with child growth.

Beyond microbiological drinking-water exposure, early-life biological vulnerability also appeared to be relevant to stunting in this population. A history of low birth weight was significantly associated with stunting (OR = 3.273; 95% CI: 1.224-8.748; $p = 0.016$). Children with a history of LBW therefore had approximately 3.3 times the odds of being stunted compared with children born with a normal birth weight. The confidence interval excluded the null value but remained relatively wide, indicating some uncertainty in the magnitude of the estimate. LBW should therefore be interpreted as an early-life factor associated with stunting rather than as an independent predictor or direct cause.

The association is biologically plausible because LBW reflects growth restriction or other adverse conditions occurring during fetal development and may place children at a disadvantage at the beginning of postnatal growth. Infants born with a birth weight below 2,500 g may have more limited physiological and nutritional reserves and may experience greater difficulty achieving adequate catch-up growth when subsequent nutritional intake, infection control, or caregiving conditions are suboptimal. This interpretation is consistent with Mertens et al. (2023), who emphasized that child growth faltering in low-resource settings results from the interaction of prenatal conditions, birth size, infection, environmental exposures, and postnatal nutrition (Mertens et al., 2023). Similar findings have been reported in Indonesia. Wahyuningrum et al. (2023) identified LBW as an important factor associated with stunting among children in Magelang Regency, Central Java, while Mariyami and Sanjaya (2022) also reported an association between LBW and stunting among young children. Together, these findings suggest that vulnerability to impaired growth may begin before or around birth and remain relevant during subsequent periods of rapid child growth (Mariyami & Sanjaya, 2022).

In the context of the present study, the significant association between LBW and stunting should also be considered alongside the postnatal environmental and health conditions identified in the same population. Children who begin life with a lower birth weight may have less capacity to compensate for later nutritional deficits or repeated infectious exposures; however, the present study did not test statistical interactions between LBW and environmental variables, and therefore no synergistic or modifying effect can be inferred. Rather, the findings support the broader interpretation that stunting is associated with both early-life biological vulnerability and postnatal environmental conditions. From a practical perspective, children with a history of LBW represent an important group for closer growth monitoring, nutritional support, prevention and early management of infection, and continued follow-up through maternal and child health services. At the preventive level, strengthening maternal nutrition and antenatal care to reduce the occurrence of LBW, together with appropriate postnatal growth surveillance, may complement household-level interventions addressing drinking-water safety, sanitation, and hygiene.

In addition to early-life vulnerability, recent infectious morbidity was also associated with stunting, particularly a history of diarrhea during the preceding two months. A recent history of diarrhea was significantly associated with stunting (OR = 3.692; 95% CI: 1.372-9.933; $p = 0.008$). Children with caregiver-reported diarrhea during the preceding two months had approximately 3.7 times the odds of being stunted. Although the confidence interval excluded 1, its relatively wide range indicates uncertainty regarding the precise magnitude of the association. Because diarrhea was assessed retrospectively within a case-control design, the finding should be interpreted as an association rather than evidence of a direct causal relationship.

The observed association is biologically plausible because diarrheal illness can interfere with child growth through several interconnected mechanisms. Acute and recurrent enteric infections may reduce food intake, increase losses of fluids and nutrients, impair intestinal absorption, increase metabolic requirements during the immune response, and promote intestinal inflammation. When episodes occur repeatedly during periods of rapid growth, these processes may contribute to a negative nutritional balance and impaired linear growth. Longitudinal evidence reported by Sarfraz et al. (2023) showed that diarrhea and other infections were associated with environmental enteric dysfunction and impaired growth among malnourished children, supporting a pathway in which repeated intestinal infection affects both intestinal function and subsequent growth (Sarfraz et al., 2023). Evidence from Gazi et al. (2022) further

demonstrated that infection with enteropathogenic *Escherichia coli* was associated with biomarkers of intestinal enteropathy and nutritional status among malnourished children (Gazi et al., 2022). These studies strengthen the biological interpretation of the present finding by indicating that enteric infection may influence growth not only through overt episodes of diarrhea but also through persistent intestinal dysfunction and inflammation.

The association between diarrhea and stunting should also be interpreted within the broader fecal-oral and WASH pathway identified in this study. Fecal contamination of household environments and drinking-water sources has previously been associated with subsequent diarrhea among young children, supporting the role of environmental exposure in enteric disease transmission. In the present population, *E. coli* contamination in household drinking water, poor handwashing with soap practices, and inadequate household latrine sanitation were also significantly associated with stunting, suggesting that diarrhea may occur within a broader pattern of environmental and hygiene-related exposures; however, no mediation or interaction analysis was performed, so diarrhea should not be interpreted as a statistically demonstrated mediator. In addition, diarrhea history was based on caregiver-reported episodes during the preceding two months, which may not capture the cumulative frequency, duration, severity, or timing of diarrheal illness throughout early childhood. From a public health perspective, these findings support integrating diarrhea prevention and management into stunting-control strategies through microbiologically safe drinking water, adequate sanitation, consistent handwashing with soap, hygienic food and water handling, prompt diarrhea treatment, and continued growth monitoring among affected children.

While recent diarrheal illness showed a significant association with stunting, not all child-related factors examined in this study demonstrated the same pattern. Exclusive breastfeeding history was not significantly associated with stunting in this study (OR = 2.400; 95% CI: 0.725-7.949; p = 0.145). Although the point estimate for non-exclusive breastfeeding was above 1, the confidence interval included the null value and was wide, indicating insufficient statistical evidence and substantial uncertainty regarding the magnitude of the association. This non-significant result should not be interpreted as evidence that exclusive breastfeeding has no biological or public-health benefit.

Biologically, exclusive breastfeeding during the first six months may support healthy growth through several interconnected nutritional, immunological, and gastrointestinal pathways. Breast milk provides the energy and nutrients required during early infancy while avoiding premature exposure to potentially contaminated complementary foods or drinking water, thereby reducing opportunities for fecal-oral exposure during a period of substantial physiological vulnerability. In addition, human milk contains bioactive components, particularly human milk oligosaccharides (HMOs), that influence early intestinal microbial development (Jalaluddin et al., 2025). Asqy Dendy et al. (2024) reported an association between exclusive breastfeeding and stunting among children aged 12-60 months, whereas Elisia et al. (2023) found a significant association among children aged 6-24 months. Differences in age distribution, sample characteristics, and post-infancy nutritional and environmental exposures may partly explain why the association was not statistically significant in the present study. Thus, a plausible biological sequence is that exclusive breastfeeding supports adequate early nutrition while limiting pathogen exposure and promoting a favorable intestinal environment, which may reduce enteric infection and inflammation, limit nutrient losses and malabsorption, and thereby support linear growth (Ngure et al., 2014). However, these intermediate mechanisms were not directly measured in the present study and should therefore be regarded as biological explanations rather than demonstrated causal pathways.

The non-significant finding should also be considered in relation to the relatively high prevalence of exclusive breastfeeding in both groups, with 55 of 70 children (78.6%) having been exclusively breastfed, leaving only 15 children in the non-exclusive category. This limited exposure contrast may have reduced statistical precision, as reflected in the wide confidence interval. In addition, the children were aged 24-59 months, so their current growth status reflected cumulative influences occurring well beyond the exclusive breastfeeding period, including complementary feeding, diarrheal illness, drinking water quality, sanitation, and hygiene. Breastfeeding history was also obtained retrospectively, although verified with village health cadres, so some exposure misclassification cannot be excluded. The lack of a significant association in this study should not alter recommendations for exclusive breastfeeding during the first six months. Stunting prevention should combine appropriate breastfeeding with adequate complementary feeding, infection prevention, safe drinking water, sanitation, handwashing with soap, and continued growth monitoring.

In contrast to the non-significant finding for exclusive breastfeeding, household hygiene practices showed a significant association with stunting, particularly handwashing with soap. Poor handwashing with soap practices were significantly associated with stunting (OR = 3.333; 95% CI: 1.235-8.997; p = 0.016). Children from households with poor practices had approximately 3.3 times the odds of being stunted compared with those from households with good practices. Although statistically significant, the relatively wide confidence interval suggests uncertainty in the magnitude of the association. The finding is more appropriately interpreted through the role of hand hygiene in limiting fecal–oral exposure than as a direct effect of handwashing on linear growth.

The association is biologically plausible through the fecal-oral transmission pathway. When handwashing with soap is not consistently performed at critical times, fecal microorganisms may remain on the hands and subsequently contaminate food, eating utensils, household drinking water, surfaces, or be transferred directly to the child's mouth. Rifqi et al. (2023) demonstrated that handwashing reduced *Escherichia coli* contamination on children's hands in an Indonesian urban setting (Rifqi et al., 2023). Simanjuntak et al. (2023) identified children's hands as an important vehicle for Gram-negative bacterial contamination associated with diarrhea risk (Simanjuntak et al., 2023). Repeated exposure to enteric pathogens may lead to overt diarrheal illness or subclinical intestinal dysfunction, resulting in intestinal inflammation, impaired mucosal integrity and nutrient absorption, reduced dietary intake, nutrient losses, and increased metabolic requirements during infection (Shofifah et al., 2022). If these processes recur during periods of rapid childhood growth, less energy and fewer nutrients may be available for tissue formation and linear growth (Putri et al., 2025). The present study did not directly measure pathogen transmission, intestinal inflammation, or environmental enteric dysfunction. Therefore, these mechanisms provide biological explanations for the observed association rather than demonstrated causal pathways.

This finding should also be interpreted within the broader WASH pattern observed in the study, in which *E. coli* contamination in household drinking water, a history of diarrhea, and inadequate household latrine sanitation were also significantly associated with stunting. The concurrence of these findings is consistent with an interconnected fecal-oral exposure pathway, although no mediation or interaction analysis was performed and the specific contribution of handwashing cannot be isolated from the present bivariate analysis. Previous studies have similarly reported higher odds or occurrence of stunting among children living in households with suboptimal handwashing practices, supporting the relevance of hand hygiene within the broader fecal-oral transmission pathway. In this study, good handwashing required adherence to all five predefined critical times, indicating that the practical implication concerns consistent handwashing behavior rather than occasional handwashing alone. Accordingly, stunting-prevention strategies should promote handwashing with soap at critical times, ensure reliable availability of water and soap, and integrate these measures with microbiologically safe drinking water, adequate household latrine sanitation, and diarrhea prevention. Such an integrated approach is more consistent with the multifactorial nature of stunting than treating hand hygiene as an isolated intervention.

Household latrine sanitation represents another component of the same fecal-oral exposure pathway, as inadequate fecal containment may increase opportunities for environmental contamination. Inadequate household latrine sanitation was significantly associated with stunting (OR = 3.750; 95% CI: 1.383-10.169; p = 0.008). Children living in households with inadequate latrine sanitation had approximately 3.8 times the odds of being stunted compared with those living in households with adequate sanitation. The confidence interval excluded 1 but remained relatively wide, indicating uncertainty regarding the precise magnitude of the estimate. Given the case-control design and bivariate analysis, the finding should be interpreted as an association rather than a direct causal effect.

The association is biologically plausible because inadequate sanitation can increase opportunities for human feces to contaminate soil, household surroundings, water sources, hands, and food, thereby facilitating fecal-oral transmission of enteric pathogens. In this study, household latrine sanitation was assessed using several sanitary criteria, including water availability, structural condition, use of an individual septic tank, and adequate separation between the septic tank and the household water source, rather than latrine ownership alone (Wibasusanti et al., 2024). When fecal containment is inadequate, repeated exposure to enteric microorganisms may contribute to diarrhea or subclinical intestinal infection. Over time, intestinal inflammation and impaired mucosal function may reduce nutrient absorption, while infection can also increase nutrient losses and metabolic demands, leaving fewer nutritional resources available for linear growth (Rahma et al., 2025).

This pathway is biologically plausible, although intestinal inflammation and environmental enteric dysfunction were not directly measured in the present study and therefore should be considered explanatory mechanisms rather than demonstrated causal pathways. These findings are consistent with the study by Purnamasari (2024), which identified environmental sanitation as an important factor to consider in the context of stunting, although the magnitude of its association may vary according to local environmental conditions and other contextual factors (Nor Aisyah Purnamasari, Mursid Raharjo, 2021). Putri et al. (2025) demonstrated that characteristics of on-site sanitation systems were related to fecal contamination of shallow groundwater, highlighting the importance of effective fecal containment and appropriate separation from water sources (Putri et al., 2025). Similar findings were reported in previous Indonesian studies, which identified associations between household sanitation conditions and childhood stunting (Herawati et al., 2020).

However, Hurint et al. (2023) reported that overall family environmental health status was associated with stunting, whereas latrine ownership considered individually was not statistically significant, suggesting that differences in facility quality, use, water availability, fecal containment, and local environmental conditions may influence findings across settings (Hurint et al. 2023). In Kejajar, the association should also be viewed together with the significant findings for *E. coli* contamination in household drinking water, diarrhea history, and poor

handwashing practices. This pattern is consistent with an interconnected fecal-oral exposure pathway, although no mediation or interaction analysis was performed. Therefore, stunting-prevention efforts should focus not only on latrine availability, but also on maintaining adequate latrine conditions, safe fecal containment, appropriate septic tank-water source separation, safe drinking water, and consistent handwashing with soap as part of an integrated WASH approach.

This study has several strengths and limitations that should be considered when interpreting the findings. A key strength was the direct laboratory assessment of household drinking water at the point of use, together with the use of health-record information to support birth-weight data. However, the case-control design limits temporal and causal inference, and a single household water sample may not represent long-term or seasonal microbiological exposure. The relatively small sample size contributed to wide confidence intervals, while purposive sampling and restriction to one district may limit generalizability. In addition, diarrhea and breastfeeding histories relied partly on caregiver recall and may therefore be subject to recall or exposure misclassification. Because the reported odds ratios were derived from bivariate analyses, residual confounding by nutritional, maternal, socioeconomic, or other environmental factors cannot be excluded. Despite these limitations, the findings provide context-specific evidence that microbiological drinking-water quality and broader household WASH conditions are relevant environmental health considerations in stunting prevention

CONCLUSIONS

This study found that *Escherichia coli* contamination in household drinking water was significantly associated with stunting among children aged 24-59 months in Kejajar District, Wonosobo Regency. Children exposed to drinking water contaminated with *E. coli* had higher odds of being stunted than those whose household drinking water contained no detectable *E. coli*. Significant bivariate associations were also observed for a history of low birth weight, a history of diarrhea, poor handwashing with soap practices, and inadequate household latrine sanitation, whereas exclusive breastfeeding was not significantly associated with stunting. These findings indicate that microbiological drinking-water quality, biological vulnerability, and household WASHis relevant to the occurrence of stunting in this population. However, because the study used a case-control design and bivariate analysis, the findings should be interpreted as associations rather than causal or independent effects. Overall, the study supports the importance of integrating household drinking-water safety, sanitation, hygiene, diarrhea prevention, and child health monitoring within stunting-prevention strategies.

SUGGESTION

Stunting-prevention programs in Kejajar District should strengthen household drinking-water safety through routine microbiological monitoring, safe household water treatment, storage, and handling, together with improvements in household latrine sanitation and consistent handwashing with soap at critical times. Prevention and prompt management of diarrheal illness should also be integrated with these environmental health interventions, while children with a history of low birth weight should receive closer growth monitoring and appropriate nutritional follow-up. Future studies should use longitudinal or prospective designs to better clarify the temporal relationship between environmental exposures and child growth, include repeated microbiological assessment of household drinking water to account for temporal or seasonal variation, and consider additional nutritional, socioeconomic, maternal, and household environmental factors that may influence stunting.

REFERENCES

Andrestian, M. D., Hariati, N. W., & Mau, E. A. J. C. (2025). Analysis of Nutrition Intervention Policies in the Prevalence of Stunting in Indonesia. *Universal Journal of Public Health*, *13*(1), 210–222. [Crossref], [Publisher]

Anwar, W., Nurjazuli, & Joko, T. (2025). Study of Household Environmental Sanitation Risk Factors on Stunting Incidence in Toddlers in Dongos Village, Kedung I Health Center Working Area. *Jurnal Penelitian Pendidikan IPA*, *11*(2), 542–547. [Crossref], [Publisher]

Asqy Dendy, E. R., Putri, R. G. P., Yuniasih, D., & Kurniawan, N. U. (2024). The Association Between Exclusive Breastfeeding and the Occurrence of Stunting Among Children Aged 12-60 Months in Community Health Centers in Yogyakarta City. *Jurnal Kedokteran Diponegoro (Diponegoro Medical Journal)*, *13*(1), 37–43. [Crossref], [Publisher]

Dinkes Kab.Wonosobo. (2024). Profil Kesehatan Kabupaten Wonosobo Tahun 2023. *Dinas Kesehatan Kabupaten Wonosobo*. [Publisher]

Elisia, L., Etika, R., Aprilawati, D., & Mahiroh, H. (2023). The Relationship Between Exclusive Breastfeeding History to Stunting Incidence in Children Aged 6-24 Months in The Working Area of The Gunung Anyar Community Health Center, Surabaya, Indonesia. *Journal of Community Medicine and Public Health Research*, *4*(2), 123–129. [Crossref], [Publisher]

Gabain, I. L., Ramsteijn, A. S., & Webster, J. P. (2023). Parasites and Childhood Stunting: A Mechanistic Interplay with Nutrition, Anaemia, Gut Health, Microbiota, and Epigenetics. *Trends in Parasitology*, *39*(3), 167–180. [Crossref], [Publisher]

Gazi, M. A., Alam, M. A., Fahim, S. M., Wahid, B. Z., Khan, S. S., Islam, M. O., Hasan, M. M., Hasan, S. M. T., Das, S., Mahfuz, M., Haque, R., & Ahmed, T. (2022). Infection With Escherichia Coli Pathotypes Is

Associated With Biomarkers of Gut Enteropathy and Nutritional Status Among Malnourished Children in Bangladesh. *Frontiers in Cellular and Infection Microbiology*, *12*(July), 1–9. [Crossref], [Publisher]

Gebeyehu, F. G., Bitew, B. D., Dessie, A., Necho, Y. E., Teym, A., Adane, B., & Gelaw, Y. B. (2026). Fecal Contamination of Drinking Water from Source to Point of Use and Associated Factors Among Households in Debre-Tabor Town, Northwest Ethiopia. *Tropical Diseases, Travel Medicine and Vaccines*, *12*(1), 1. [Crossref], [Publisher]

Girma, M., Hussein, A., Norris, T., Genye, T., Tessema, M., Bossuyt, A., Hadis, M., van Zyl, C., Goyol, K., & Samuel, A. (2024). Progress in Water, Sanitation and Hygiene (WASH) coverage and potential contribution to the decline in diarrhea and stunting in Ethiopia. *Maternal and Child Nutrition*, *20*(S5). [Crossref], [Publisher]

Handoyo, E., Joko, T., Nurjazuli, N., & Fitri, Y. P. (2024). Faktor Risiko Lingkungan yang Berhubungan dengan Stunting pada Balita di Kelurahan Periuk Jaya Kota Tangerang. *Muhammadiyah Journal of Nutrition and Food Science (MJNF)*, *5*(1), 29. [Crossref], [Publisher]

Herawati, A., Anwar, A., & Setyowati, D. L. (2020). Hubungan Sarana Sanitasi, Perilaku Penghuni, dan Kebiasaan Cuci Tangan Pakai Sabun (CTPS) oleh Ibu dengan Kejadian Pendek (Stunting) pada Batita Usia 6--24 Bulan di Wilayah Kerja Puskesmas Harapan Baru, Samarinda. *Jurnal Kesehatan Lingkungan Indonesia*, *19*(1), 7–15. [Crossref], [Publisher]

Jalaluddin, M. S., Yusriani, A., Dwinata, D. S., Bujawati, S., & Akbar, M. (2025). Evaluasi Peran Kepemilikan Jamban dalam Kejadian Stunting: Temuan dari Kabupaten Jeneponto, Sulawesi Selatan. *Jurnal Kesehatan Lingkungan Indonesia*, *24*(1), 101–108. [Crossref], [Publisher]

Jawa Tengah, D. K. (2024). Jawa Tengah. *Profil Kesehatan Provinsi Jawa Tengah Tahun 2024*, 1–260. [Publisher]

Maria Theodora Natalia Hurint, Hendras Bintari, Yuliani, Yulinda Kurniasari,Herwinda Kusuma Rahayu, A. S. A. (2023). *Sanitation and Family Environmental Health Status and its Association with Stunting in Kulon Progo, Indonesia*. *3*(2), 267–278. [Crossref], [Publisher]

Mariyami, T., & Sanjaya, R. (2022). Hubungan BBLR dan Status Pemberian ASI Dengan Kejadian Stunting pada Baduta. *Journal of Current Health Sciences*, *2*(1), 13–18. [Crossref], [Publisher]

Mertens, A., Benjamin-Chung, J., Colford, J. M. J., Coyle, J., van der Laan, M. J., Hubbard, A. E., Rosete, S., Malenica, I., Hejazi, N., Sofrygin, O., Cai, W., Li, H., Nguyen, A., Pokpongkiat, N. N., Djajadi, S., Seth, A., Jung, E., Chung, E. O., Jilek, W., … Ki Child Growth Consortium. (2023). Causes and consequences of child growth faltering in low-resource settings. *Nature*, *621*, 568–576. [Crossref], [Publisher]

Ngure, F. M., Reid, B. M., Humphrey, J. H., Mbuya, M. N. N., Pelto, G., & Stoltzfus, R. J. (2014). Water, Sanitation, and Hygiene ({WASH}), Environmental Enteropathy, Nutrition, and Early Child Development: Making The Links. *Annals of the New York Academy of Sciences*, *1308*(1), 118–128. [Crossref], [Publisher]

Nor Aisyah Purnamasari, Mursid Raharjo, Y. H. (2021). Environmental Sanitation and PHBS Analysis of Stunting Incidents in Toddler in Paser District. *Media Publikasi Promosi Kesehatan Indonesia*, *1*(1), 1–12. [Crossref], [Publisher]

Parvin, T., Thomas, E. D., Bhuyian, M. S. I., Uddin, I. M., Hasan, M. T., & Rahman, M. (2021). Fecal Contamination on The Household Compound and in Water Sources are Associated with Subsequent Diarrhea in Young Children in Urban Bangladesh (CHoBI7 Program). *The American Journal of Tropical Medicine and Hygiene*. https://www.ajtmh.org/ [Crossref], [Publisher]

Pradana, V. N., Suparmi, S., & Ratnawati, R. (2023). Personal Hygiene, Water Availability, and Environmental Sanitation with the Incidence of Stunting in Toddlers Aged 6–59 Months in the Working Area of the Singorojo I Public Health Center, Kendal Regency. *Amerta Nutrition*, *7*(3), 421–426. [Crossref], [Publisher]

Putri, G. L., Ilmi, A. M., Handayani, R., Iskandar, D., Priadi, C. R., Willetts, J., & Foster, T. (2025). On-Site Sanitation System and Fecal Contamination in Shallow Groundwater in Urban Indonesia: Assessing Influence of Distance and Rainfall Variables. *Water Research*, 124431. [Crossref], [Publisher]

Rah, J. H., Sukotjo, S., Badgaiyan, N., Cronin, A. A., & Torlesse, H. (2020). Improved Sanitation is Associated with Reduced Child Stunting Amongst Indonesian Children Under 3 Years of Age. *Maternal and Child Nutrition*, *16*(S2). [Crossref], [Publisher]

Rahma, A., Khadafi, M. Z., Nayla, N. A., Azmiyannoor, M., Rahman, F., Arifa, S., Setiawan, M. I., & Sai'dah, H. (2025). Association Between Access to Clean Water and Health Services and The Incidence of Stunting in Sungai Landas Village, Banjar District, South Kalimantan. *Ruwa Jurai: Jurnal Kesehatan Lingkungan*, *19*(1), 15. [Crossref], [Publisher]

Rahman, F., Setiawan, M. I., Arifin, S., Jannah, R., Ahdani, N., Ardiansyah, M., Wati, R. M., & Thalib, A. (2024). Multisector Policy to Accelerate Stunting Reduction in South Kalimantan. *Pakistan Journal of Life and Social Sciences*, *22*(2), 4529–4536. [Crossref], [Publisher]

Ratnawati, R., Irene Kartasurya, F. M., Kartini, A., & Noe, E. R. (2025). Prenatal Risk Factors for Stunting in Children aged 12-24 Months in Central Java, Indonesia. *Bangladesh Journal of Medical Science*, *24*(2), 579–588. [Crossref], [Publisher]

Rifqi, M. A., Hamidah, U., Sintawardani, N., Harada, H., Nyambe, S., Sai, A., & Yamauchi, T. (2023). Effect of handwashing on the reduction of Escherichia coli on

children's hands in an urban slum Indonesia. *Journal of Water and Health*, *21*(11), 1651–1662. [Crossref], [Publisher]

Sarfraz, A., Jamil, Z., Ahmed, S., Umrani, F., Qureshi, A. K., Jakhro, S., Sajid, M., Rahman, N., Rizvi, A., Ma, J. Z., Mallawaarachchi, I., Iqbal, N. T., Syed, S., Iqbal, J., Sadiq, K., Moore, S. R., & Ali, S. A. (2023). Impact of Diarrhoea and Acute Respiratory Infection on Environmental Enteric Dysfunction and Growth of Malnourished Children in Pakistan: A Longitudinal Cohort Study. *The Lancet Regional Health - Southeast Asia*, *15*, 100212. [Crossref], [Publisher]

Shofifah, A., Sulistyorini, L., & Praveena, S. M. (2022). Environmental Sanitation At Home and History of Infection Diseases As Risk Factors for Stunting in Toddlers in Drokilo Village, Kedungadem District, Bojonegoro Regency. *Jurnal Kesehatan Lingkungan*, *14*(4), 289–295. [Crossref], [Publisher]

Simanjuntak, D. F., Kusumawati, R. L., Bader, O., Lüder, C. G. K., Zimmermann, O., & Groß, U. (2023). A Comparative Pilot Study on Gram-Negative Bacteria Contaminating The Hands of Children Living in Urban and Rural Areas of Indonesia Versus Germany – A Suitable Monitoring Strategy for Diarrhea Risk Assessment? *Frontiers in Microbiology*, *14*(April), 1–13. [Crossref], [Publisher]

Torlesse, H., Cronin, A. A., Sebayang, S. K., & Nandy, R. (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*, 669. [Crossref], [Publisher]

Utami, W., Rashid, N. A., & Sansuwito, T. (2024). The Effectiveness of Educational Puzzle on the Cognitive Ability of Stunting Children at the Age of Preschool: Literature Review. *Malaysian Journal of Medicine and Health Sciences*, *20*, 195–199. [Publisher]

Wahyuningrum, S. N., Asturiningtyas, I. P., Martiyana, C., & Mirzautika, A. (2023). Low Birth Weight and Low Mother Education as Dominant Risk Factors of Stunting Children in Magelang Regency, Central Java. *AcTion: Aceh Nutrition Journal*, *8*(1), 111. [Crossref], [Publisher]

Wibasusanti, G. P., Thohari, I., Winarko, Wardoyo, I. R. E., Sulistijowati, & Laksono, C. W. (2024). Basic Sanitation Factors and Clean and Healthy Living Behavior as Determinants of Stunting: A Case Study in Bondowoso. *Public Health Research Development*, *1*(2), 58–68. [Crossref], [Publisher]

Wonosobo, D. K. K. (2026). *Profil Kesehatan Kabupaten Wonosobo Tahun 2025*. 2–3. [Publisher]