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Distribution Pattern, Environmental Sanitation Analysis and Diarrhea with Stunting Incidence in Toddlers in Karo Regency, North Sumatra Province

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Abstract

Stunting is a national problem because its increasing prevalence and impact can increase less competitive human resources, affect work productivity, increase the risk of overweight and obesity, and trigger metabolic syndrome. Environmental factors such as sanitation and hygiene, drinking water sources, drinking water quality, and toilet ownership are indirect factors causing stunting. This study aims to analyze the distribution of stunting incidence and environmental sanitation factors causing stunting in Karo Regency, North Sumatra, Indonesia. A case-control design was conducted on 246 toddlers with a 1:1 ratio. The distribution pattern of stunting incidence and the relationship between patient characteristics and environmental risk factors were conducted using a Geographic Information System. Data on clean and healthy living behavior were collected using a questionnaire, and microbiological laboratory tests measured water quality. Spatial analysis used an average nearest-neighbor overlay. The relationship between characteristics and risk factors with stunting incidence was analyzed using chi-square and logistic regression. The average nearest neighbor analysis showed a nearest neighbor index of 0.19 (<1) (Z score -16.72, p-value 0.01). Regression analysis was carried out using GeoDa software (p-value 0.76). There was a relationship between clean water quality, clean and healthy lifestyles (PHBS), and diarrhea (p-value <0.05) and stunting. Family latrines, waste disposal facilities, and wastewater drainage (p-value >0.05) were not associated with stunting. Case distribution tended to be clustered, and no association was found between population density and stunting. This study's findings provide new insights that health promotion to prevent stunting should not only focus on nutritional fulfillment but also on clean and healthy living behaviors and water quality.

Keywords: Stunting, Sanitation, Diarrhea, Karo Regency, clean water, waste

INTRODUCTION

Stunting is a condition in children characterized by growth failure, resulting in a height lower than the standard for their age. Stunting remains a serious public health problem, particularly in poor and developing countries. According to the World Health Organization (WHO), approximately 149.2 million children under 5 years of age worldwide suffered from stunting in 2020 (Gabain et al., 2023). Indonesia ranks third in Southeast Asia in this regard, with an average prevalence of 36.4% (Kementerian Kesehatan, 2022). Stunting has a significant impact on physical and mental health, brain development, and overall achievement. Despite sustained efforts over the past 20 years, addressing stunting remains a persistent challenge (Aswi et al., 2024). National trends in Indonesia show significant improvement: stunting prevalence in 2024 fell to 19.8% based on the 2024 SSGI published in May 2025, exceeding Bappenas' projection of 20.1% for the same year (Kementerian Kesehatan, 2025).

Research exploring cases of stunting and the factors that cause it shows that malnutrition in children (Agri et al., 2024), parental education and socioeconomics (Wulandari, Y., & Arianti, 2023) are contributing factors. In addition, malnutrition and anemia in pregnant women can inhibit fetal growth, while poor sanitation increases the risk of infection and impaired nutrient absorption (Fardiani et al., 2025). However, these studies often ignore spatial effects, although stunting rates in one area may be influenced by values in spatially adjacent areas. Adjacent areas often share similarities in socioeconomic characteristics, environmental conditions, and access to health resources, all of which can influence stunting incidence.

North Sumatra recorded 22% (SSGI 2024), above the national average of 19.8% Dinas Kesehatan Provinsi Sumatera Utara, 2025). Meanwhile, in Karo Regency, local government data shows the prevalence ranged from 24.9% (2022) to 24.7% (2023) and will only decline further in 2024–2025, according to regional reports. Therefore, Karo remains a priority location for stunting reduction in the province. This situation underscores the urgency of mapping and refining evidence-based interventions at the district/city down to the sub-district/village level.

The incidence of stunting in toddlers is multifactorial, one of which is thought to be caused by environmental factors such as difficulty in obtaining drinking water suitable for consumption, a clean environment, and hygiene practices (WASH) (Syahrudin et al., 2023). The Ministry of Health, through its 2020 SKAMRT (Regional Health Survey), revealed that the majority (70%) of households in Indonesia still rely on drinking water sources contaminated with *E. coli* bacteria. Furthermore, the report noted that only around 11.9% of the population has access to truly safe drinking water (Munthe et al., 2024). Water factors, including limited public access to clean water, unimproved drinking water sources, and improperly treated water, are suspected to contribute to the increasing incidence of stunting among toddlers in Indonesia. Consuming water containing harmful bacteria can cause various illnesses, especially infectious diseases such as diarrhea, pneumonia, and others. These illnesses can affect a child's nutritional status, making them more susceptible to stunting (Putri et al., 2024).

Causally, evidence in Indonesia and middle-income countries places WASH (water, sanitation, hygiene) and digestive infectious diseases as important determinants of stunting alongside socio-economic factors, nutritional intake, and maternal-child health services. (Harahap et al., 2024). National studies show that the combination of inadequate toilets and untreated drinking water increases the chances of stunting compared to good WASH conditions (Girma et al., 2024). Recent literature also emphasizes the role of environmental enteric dysfunction (EED) dysbiosis and subclinical gut inflammation due to exposure to fecal

pathogens which impair micronutrient absorption and linear growth, with mixed findings on the magnitude of impact of WASH interventions on growth (Rizaldi et al., 2025).

This article aims to comprehensively analyze the relationship between environmental factors, sanitation, and infectious diseases with the incidence of stunting in toddlers in Karo Regency. The main focus is directed at mapping the distribution patterns of stunting cases to identify areas with high vulnerability. This analysis is expected to provide a more in-depth picture of the contribution of environmental conditions to children's nutritional status. More specifically, this article aims to 1) describe the distribution patterns of stunting cases in toddlers in Karo Regency. 2) Assess the risk of stunting related to access to clean water. 3) Analyze the relationship between ownership and use of toilet facilities and the incidence of stunting. 4) Analyze the effect of household waste disposal systems on the incidence of stunting. 5) Analyze the role of handwashing with soap in preventing stunting. 6) Analyze the relationship between wastewater drainage conditions and the incidence of stunting. 7) Analyze the relationship between recurrent diarrhea and child nutritional status characterized by stunting.

This study is expected to provide a stronger empirical basis for understanding how sanitation and environmental health dimensions contribute to stunting at the local level. The results are expected to not only enrich academic understanding of the determinants of stunting in mountainous and agrarian areas like Karo Regency, but also provide practical input for local governments and public health stakeholders in designing more targeted and effective stunting prevention and management strategies.

METHODS

This study used a quantitative approach with a case-control design to compare stunted and non-stunted toddlers (cases) and non-stunted toddlers (controls) and to analyze sanitation/WASH risk factors for stunting. The study population was all toddlers in the working areas of 19 Community Health Centers (Puskesmas) in Karo Regency (N=38,284), with a sample size of 246 toddlers (123 cases and 123 controls) determined using the Lemeshow formula and simple random sampling techniques. Primary data were collected through observations of sanitation facilities (drinking water, latrines, waste disposal facilities, and wastewater treatment facilities) and interviews using a questionnaire based on WHO (2014) WASH indicators. The instrument was tested for content validity through expert judgment, construct validity through item-total correlation, and reliability using Cronbach's Alpha ≥ 0.70 . Data analysis was performed using SPSS v.26 for descriptive tests, bivariate tests (Chi-square, $\alpha=0.05$), and multiple logistic regression to identify the dominant factors causing stunting.

Furthermore, spatial analysis was performed using SaTScan for cluster identification and GeoDa/QGIS for mapping case distribution using the Average Nearest Neighbor method. The results of the analysis are reported in the form of frequencies, OR, RR, 95% CI, p-values, and distribution map visualization. This study has received ethical approval from the Ethics Commission of the Medan Ministry of Health Polytechnic (No. 01.26504/KEPK/POLTEKKES KEMENKES MEDAN/2024), with informed consent from the toddler's parents and guaranteed confidentiality of respondent data.

RESULTS

The characteristics of the respondents in this case are mothers of toddlers, including age, education and occupation, which can be seen in Table 1.

Table 1. Distribution of Mothers of Toddlers Based on Characteristics

Characteristics	n	%
Age :		
- <20 years	33	13,4
- 21-25 years	16	6,5
- 26-30 years	69	28,0
- 31-35 years	43	17,5
- 36-40 years	65	26,4
- 41-45 years	20	8,1
Education :		
- Elementary School	3	1,2
- Elementary School (Elementary/Junior High School)	80	32,5
- Completed High School/Vocational High School	146	59,3
- Diploma/Bachelor's Degree	17	6,9
Occupation :		
- Housewife	46	18,7
- Farmer	138	56,1
- Civil Servant	2	0,8
- Self-Employed	44	17,9
- Other	16	6,5
Income :		

- < Rp. 2.500.000,-	131	53,3
- >= Rp. 2.500.000,-	115	46,7
Jumlah	246	100

Based on Table 1, it can be seen that the distribution of maternal ages is mostly at the age of 26-30 years at 28%, followed by the age of 36-40 years at 26.4% and the age of 31-35 years at 17.5%. When viewed in terms of maternal education level, it is known that the majority of mothers with secondary education (SMA/SMK) as much as 59.3% and followed by elementary education (SD/SMP) as much as 32.5%. This shows that the level of maternal education is still in the secondary education category, this will affect the type of work and the mother's ability to receive the education provided (Nisa et al., 2023) The most common occupation for mothers was farming, at 56.1%, followed by housewives at 18.7%. The high number of mothers in both categories likely stems from their limited educational attainment, resulting in limited job opportunities. Meanwhile, the dominant family income, at 53.3%, was Rp. 2,500,000.

Table 2. Distribution of Children Based on Characteristics

Characteristics	n	%
Age :		
- 6-12 Months	97	39,4
- 13-24 Months	127	51,6
- 25-36 Months	22	8,9
Jumlah	246	100

From Table 2, it can be seen that the ages of the children who were the research samples were 13-24 months at 51.6%, followed by 6-12 months at 39.4% and 25-36 months at 8.9%.

Distribution Pattern of Stunting in Karo Regency

Stunting is a characteristic that indicates recurring and long-term nutritional problems. Karo Regency is one of the regencies with a relatively high stunting rate. The distribution of stunting cases in Karo Regency can be seen in Figure 1.

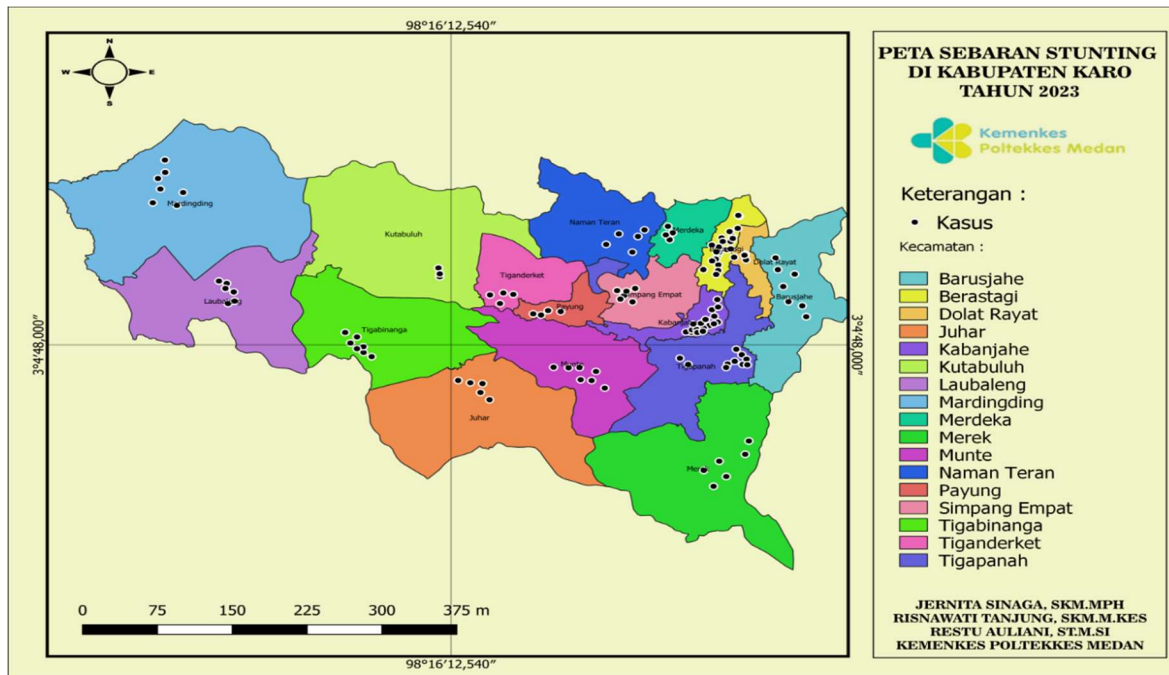


Figure 1. Distribution of Stunting Cases in Karo Regency

Stunting cases in Karo Regency are distributed across all villages. Based on the research, the highest number of cases occurred in Berastagi District, with 23 cases. Meanwhile, the villages with the lowest number of cases were Dolat Rayat and Kutabuluh Districts, with 3 cases.

1. The distribution of cases was then analyzed using the average nearest neighbor analysis method to determine the distribution pattern. The indicator used was the nearest neighbor index, taking into account the average distance from each case coordinate point. Based on the Satscan analysis, five largest clusters were identified:

2. 33 cases, $p\text{-value} < 0.0001$; RR: 4.51; radius: 31.68 km. This indicates a cluster of cases at highest risk, with a 4.51-fold increase in the risk of stunting for those within the cluster compared to those outside the cluster, with a radius of 31.68 km.

3. 20 cases, $p\text{-value} < 0.0001$; RR: 8.13; radius: 18.7 km, indicating a cluster of cases at highest risk, with an 8.13-fold risk of stunting for those within the cluster compared to those outside the cluster, with a radius of 18.7 km.

4. There were 17 cases, $p\text{-value} < 0.0001$; RR: 3.35; radius: 10.02 km, indicating a cluster of cases at highest risk, with a 3.35-fold risk of stunting for those within the cluster compared to those outside the cluster, with a radius of 10.02 km.

5. There were 15 cases, $p\text{-value} < 0.0001$; RR: 3.45; radius: 8.19 km, which means there is a cluster of cases at the highest risk, with a risk level of 3.45 times that of stunting for sufferers within the cluster compared to sufferers outside the cluster with a cluster radius of 8.19 km.

6. There are 10 cases, p -value < 0.0001 ; RR: 6.73; radius: 5.54 km, which means there is a cluster of cases at the highest risk, with a risk level of 6.73 times that of stunting for sufferers within the cluster compared to sufferers outside the cluster with a cluster radius of 5.54 km.

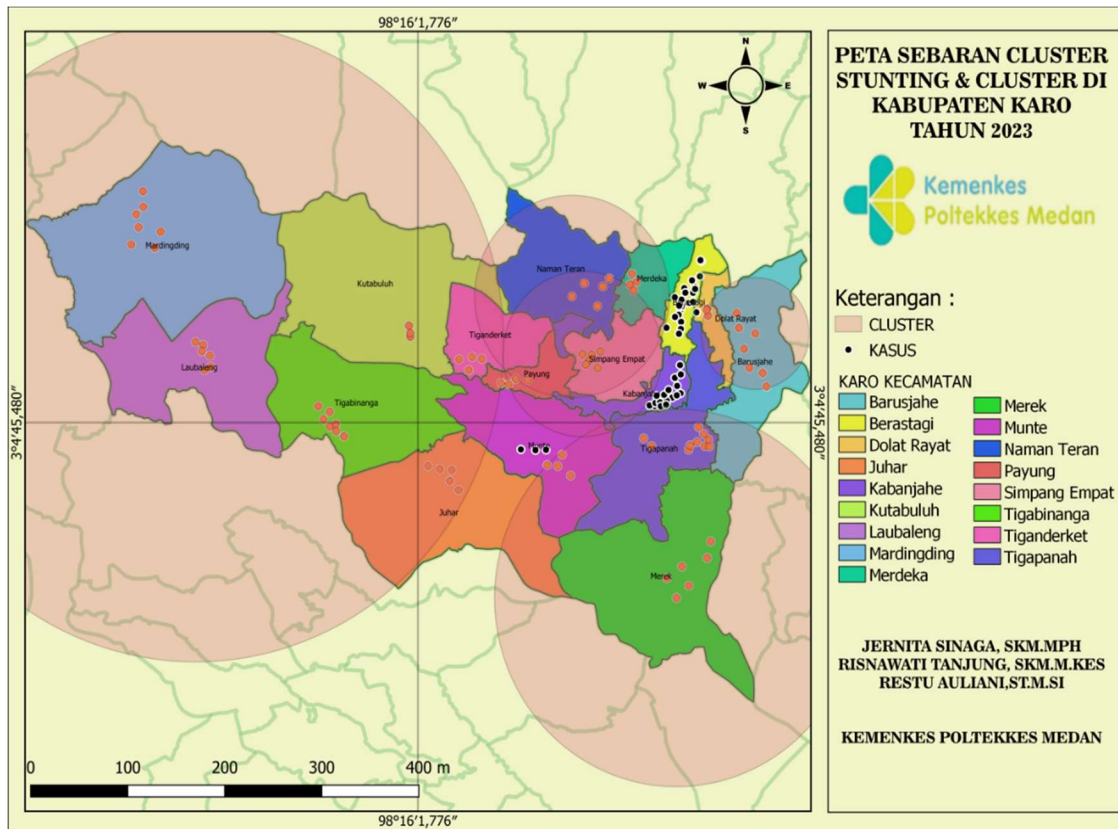


Figure 2. Nearest Neighbor Analysis and Distribution of Stunting Cases in Karo Regency

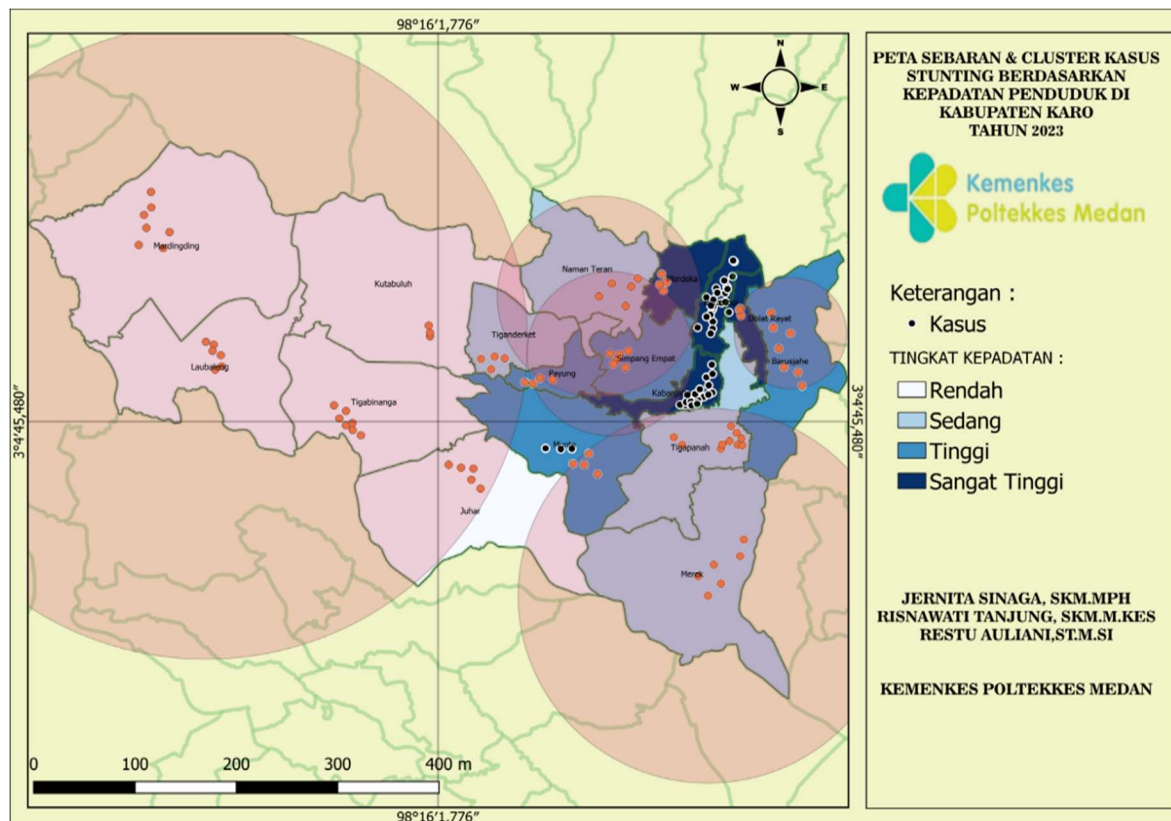


Figure 3. Map of Distribution of Stunting Cases Based on Population Density in Karo Regency

Based on the results of a regression analysis using GeoDa software, no relationship was found between population density and stunting in Karo Regency (p-value: 0.82). Stunting can occur due to both direct and indirect factors. The risk factors for stunting (clean water quality, toilet facilities, waste disposal facilities, handwashing habits with soap, wastewater drainage, and diarrhea) are shown in the table below :

Table 3. Relationship between Clean Water Quality, Clean and Healthy Living Behavior (PHBS), Toilet Facilities, Diarrhea Incidence, Waste Disposal Facilities, SPAL with Stunting Incidence

Variable		Stunting		Not Stunting		Total		OR	p value
		N	%	n	%	n	%		
Clean Water Quality:									
a.	Yes	93	75,6	47	38,2	140	56,9	5,01	0,000
b.	No	30	24,4	76	61,8	106	43,1		
Clean and Healthy Living Behavior									
a.	Good	58	47,2	82	66,7	140	56,9	2,24	0,003
b.	Poor	65	52,8	41	33,3	106	43,1		
Family Toilet Facilities									

a.	Qualify	63	51,2	77	62,6	140	56,9		
b.	Not eligible	60	48,8	46	37,4	106	43,1	1,59	0,094
1.	Diarrhea Incident								
a.	No Diarrhea	43	35,0	61	54,6	104	42,3		
b.	Diarrhea	80	65,0	62	50,4	142	57,7	1,83	0,028
Waste Disposal Facilities									
a.	Qualify	54	43,9	67	54,5	121	49,2	1,52	0,126
b.	Not eligible	69	56,1	56	45,5	125	50,8		
Wastewater Disposal Facilities (SPAL)									
a.	Qualify	56	45,5	69	56,1	125	50,8	1,52	0,126
b.	Not eligible	67	54,5	54	43,9	121	49,2		
Jumlah		123	100	123	100	246	100		

This study found that clean water quality, PHBS, and diarrhea incidence were significantly associated with stunting. Toddlers who used clean water containing *E. coli* had a 5.01 times greater risk of stunting ($p = 0.00$), toddlers from families with poor PHBS had a 2.24 times greater risk ($p = 0.01$), and toddlers who had experienced diarrhea had a 1.83 times greater risk ($p = 0.04$). Meanwhile, family toilet facilities ($OR = 1.59$; $p = 0.09$), waste disposal facilities ($OR = 1.52$; $p = 0.126$), and wastewater drainage channels ($OR = 1.52$; $p > 0.05$) did not show a significant association with stunting, although they still have potential risks.

DISCUSSION

Geographic Information Systems (GIS) are map-based epidemiological visualizations that depict the distribution of health conditions according to regional analysis (Santoso et al., 2025). GIS is useful for observing the distribution pattern of stunting and its relationship to risk factors through a spatial perspective. The results of the average nearest neighbor analysis show a clustered distribution pattern of stunting cases. Analysis using SaTScan identified 5 significant clusters ($p < 0.0001$), namely: (1) 33 cases, $RR = 4.51$, radius 31.68 km; (2) 20 cases, $RR = 8.13$, radius 18.7 km; (3) 17 cases, $RR = 3.35$, radius 10.02 km; (4) 15 cases, $RR = 3.45$, radius 8.19 km; and (5) 10 cases, $RR = 6.73$, radius 5.54 km. These findings indicate that there are areas with a higher risk of stunting compared to areas outside the cluster.

This research is in line with research (García Cruz et al., 2017) which states that there is a relationship between the rural-urban status of an area and the incidence of stunting in that

area. Children living in urban areas have a lower risk of experiencing stunting than children living in rural areas. Research (Rachmi et al., 2016) said the prevalence of stunting is increasing in densely populated and rural areas with a positive Moran I index value of 0.71 ($p=0.0001$) for stunting incidents in densely populated areas, 0.6 ($p=0.0002$) in rural areas and 0.45 ($p=0.0001$) in highland areas.

Clean water quality containing *E. coli* has been shown to be significantly associated with stunting ($p = 0.000$; OR = 5.01), with children exposed to contaminated water having a five-fold increased risk of stunting. Clean water is crucial because without adequate access, children are vulnerable to recurrent diarrhea and worm infections, which inhibit nutrient absorption, deplete essential micronutrients such as zinc, and ultimately impair growth (Kwami et al., 2019). The study results showed that 75.6% of stunted toddlers were exposed to water containing *E. coli* compared to 38.2% in the non-stunted group. Multivariate analysis confirmed that water quality was the primary risk factor with Exp B = 22.5 ($p = 0.000$). This condition confirms that limited access to clean water which is still experienced by one in three households has an impact on increasing infectious diseases and stunted child growth. (Torlesse et al., 2016).

Based on the research results, the Clean and Healthy Living Behavior (PHBS) variable also had a significant correlation with a p-value of 0.003 and an OR of 2.24. This means that families with poor PHBS were 2.24 times more likely to experience stunting than those with good PHBS. The persistently high prevalence of stunting, caused by multiple factors, requires prevention and management efforts through a multidisciplinary approach. Improving nutritional interventions is not sufficient; other factors include lifestyle, sanitation, and environmental hygiene. Poor sanitation and environmental hygiene are indicators of Clean and Healthy Living Behavior (Aprizah, 2021).

Perilaku Hidup Bersih dan Sehat (PHBS) merupakan upaya pencegahan penyakit yang berkontribusi sekitar 30–35% terhadap derajat kesehatan. Pada penelitian ini, kelompok stunting dominan memiliki PHBS kurang baik (67,4%), sedangkan kelompok tidak stunting didominasi PHBS baik (66,7%). This result is in line (Uliyanti et al., 2017), which shows a significant relationship between Clean and Healthy Living Behavior (PHBS) is a disease prevention effort that contributes approximately 30–35% to health. In this study, the stunted group predominantly had poor PHBS (67.4%), while the non-stunted group predominantly had good PHBS (66.7%). Behaviors that contribute to stunting include the habit of washing hands with soap, consuming boiled water, maintaining the cleanliness of eating utensils, covering food, cleaning children's nails, and using healthy latrines (RI, n.d.). Efforts to reduce stunting

rates are carried out through integrated household-based PHBS development, with the empowerment of individuals, families, and communities through village/sub-district forums, health cadres, Integrated Health Posts (Posyandu), home visits, and family assistance to improve PHBS practices (RI, n.d.).

Based on the research results, the incidence of diarrhea was significantly associated with stunting ($p=0.02$), with a 1.83 times higher risk in toddlers with diarrhea compared to those without. The relationship between infection and nutrition forms a vicious cycle, where chronic infection worsens nutrition, while malnutrition reduces immunity, making children more susceptible to infection. Each episode of diarrhea interferes with nutrient absorption and, if repeated or prolonged, can affect a child's growth. Diarrhea remains a major cause of childhood morbidity and mortality, contributing to 15–34% of all toddler deaths, or approximately 300 cases per year. The risk increases in toddlers with poor hand and nail hygiene and the habit of not washing their hands before eating. This condition facilitates the entry of bacteria into the body, compounded by a child's still weak immune system. Diarrhea damages intestinal villi, interferes with nutrient absorption, and if prolonged contributes to stunting (GeinBeist, 2023). Latrines are facilities for waste disposal, so the use of unsanitary latrines can contaminate the environment, such as clean water, and become a source of infection (Zahrawani et al., 2022).

Based on the research results, the variable of family toilet facilities was not significantly related to stunting ($p=0.09$), although there was a 1.59 times higher risk in toilets that did not meet the requirements compared to healthy toilets. The distribution of ownership of healthy toilets was relatively the same in the Stunting (51.2%) and Non-Stunting (62.6%) groups, with the majority of people in Karo Regency already using sanitary toilets with gooseneck toilets and septic tanks. Unhealthy toilets have the potential to trigger infectious diseases due to poor hygiene and sanitation, thus disrupting the absorption of nutrition by toddlers. This is in accordance with the Decree of the Minister of Health of the Republic of Indonesia No. 852/MENKES/SK/IX/2008 concerning healthy toilets as effective fecal disposal facilities to break the chain of disease transmission. These results align with research by Abidin et al. (2021) in Parepare and Hendraswari et al. (2019) which also found no significant relationship between toilet ownership and stunting, as well as research by Ihsan et al. (2020) which showed that toilet quality had no direct effect on stunting ($\beta = 0.172$) but had an indirect effect ($\beta = 0.556$). These results align with research by Al Ihsan (2012) which found that unsanitary toilet quality did not have a simultaneous and significant effect on stunting in toddlers with a

path/beta coefficient of 0.172 ($\beta = 0.172$). However, it did have an indirect effect with a path/beta coefficient of 0.556 ($\beta = 0.556$) (Ihsan et al., 2020).

Regarding waste disposal facilities, the study results showed that waste disposal facilities were not significantly associated with stunting ($p=0.126$), although the risk was 1.26 times higher in conditions that did not meet the requirements. In the stunting group, 43.9% of waste disposal facilities met the requirements, while in the non-stunting group, 54.5%. This finding aligns with research conducted by other groups (Linda, 2019) and Mukaramah & Wahyuni (2020) also found no significant association, in contrast to Fibrianti et al. (2021) who reported a relationship ($p=0.028$). Household waste management is important to prevent it from becoming a breeding ground for disease vectors. However, in this study, the majority of respondents managed their waste properly, thus not having a direct impact on stunting.

The study results showed that 54.5% of homes had inadequate wastewater drainage systems (SPAL) and 45.5% had adequate wastewater drainage systems (SPAL). Statistical tests showed no significant relationship between SPAL and stunting ($p=0.126$), but there was a 1.52-fold greater risk for toddlers living in homes with inadequate SPAL compared to those with adequate ones. This condition occurs because many households do not have SPAL and dispose of waste behind the house, causing puddles, unpleasant odors, and becoming a breeding ground for diseases that can reduce children's nutritional status, such as diarrhea, acute respiratory infections (ARI), or worms (Mayasari et al., 2022). However, the finding that toddlers did not experience stunting in homes with inadequate SPAL indicates that stunting is also influenced by other factors, one of which is clean and healthy living behaviors (PHBS). This is in line with Aprizah (2021), who stated that PHBS is related to toddler nutritional status, including stunting prevention.

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