Tropical Biomedicine 42(3): 344-355 (2025)
https://doi.org/10.47665/tb.42.3.014

RESEARCH ARTICLE

High burden of soil-transmitted helminth infections among preschool and school aged-children in North Kodi, Southwest Sumba, Indonesia: A cross-sectional study

Ali, S.[1¶], Anggraini, F.[1¶], Kurniawan, F.[2], Kristin, H.[3], Hengestu, A.[1], Lede, Y.K.[4], Kerans, G.[5], Jerawu, A.A.L.[5], Joprang, F.S.[3], Kaisar, M.M.M.[1,3*]

[1]Master in Biomedicine Study Program, School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia, Jakarta, 14440, Indonesia
[2]Department of Public Health and Nutrition, School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia, Jakarta, 14440, Indonesia
[3]Department of Parasitology, School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia, Jakarta, 14440, Indonesia
[4]Mathematics Education Study Program, Weetebula Catholic University, Southwest Sumba, 87254, Indonesia
[5]Natural Science Education Study Program, Weetebula Catholic University, Southwest Sumba, 87254, Indonesia
[¶]These authors contributed equally to this work
*Correspondence author: maria.kaisar@atmajaya.ac.id

ARTICLE HISTORY

Received: 16 February 2025
Revised: 15 June 2025
Accepted: 3 July 2025
Published: 30 September 2025

ABSTRACT

Soil-transmitted helminth (STH) infections remain a significant global health concern due to their high prevalence in many areas and ease of transmission via the fecal-oral route. To control and enhance the declining helminth infection rate in children, Indonesia initiated a nationwide mass drug administration (MDA) in 2017, encompassing rural areas such as Southwest Sumba (SWS). Nevertheless, the prevalence of STH in SWS remained at 54% by 2021. Children are particularly susceptible owing to frequent exposure to helminth-egg-contaminated environments, which may lead to nutrient deficiencies. Therefore, we sought to assess STH prevalence in this post-MDA period and to investigate the impact of STH infection on anemia, nutritional status, and hygiene practices among preschool-aged children (PAC) and school-aged children (SAC) in Hameli Ate and Homba Karipit Villages, North Kodi District. A total of 223 stool samples were examined using the Kato-Katz technique, revealing an overall STH prevalence of 58.3%, with the majority of children exhibiting light infections (*Ascaris lumbricoides*: 37.7%; *Trichuris trichiura*: 26.5%). Infection rates were notably higher in younger SAC (26.6%; 34/128) and older SAC (40%; 10/25) compared to PAC (21.1%; 8/38) groups. Despite this, 67.9% of the children had normal nutritional status, and 61.5% were found to be non-anemic. There was a significant correlation between maternal education and STH infections (OR = 0.4; 95%CI = 0.2-0.79; p = 0.016). A highly educated mother would improve children's hygiene, subsequently contribute to the reduction of infection severity and enhance the child's health. Altogether, our findings indicate the high burden of STH infection on children in this rural area. Thus, this study emphasize the importance of the re-evaluation of the MDA program and improvement of hygiene facilities, such as clean water and sanitation, to mitigate disease risk and promote children's health.

Keywords: Soil-transmitted helminth (STH); anemia; nutritional status; hygiene practices; children's health.

INTRODUCTION

Soil-transmitted helminth (STH) infections, classified as a Neglected Tropical Disease (NTD), remain a global health concern with detrimental effects on health, social, and economic aspects. It is caused by a group of intestinal parasitic helminths transmitted through the fecal-oral route (i.e., *Ascaris lumbricoides* and *Trichuris trichiura*) or skin penetration (i.e., *Strongyloides stercoralis*, hookworms: *Ancylostoma duodenale* and *Necator americanus*) (O'Connell & Nutman, 2016). Children are especially more susceptible to STH infection due to their limited understanding of hygiene practices such as handwashing before eating and after defecating. Additionally, their frequent physical activities, which often involve playing in contaminated soil, allow the helminth transmission to occur (O'Connell & Nutman, 2016; Wendt *et al*., 2025; Jourdan *et al*., 2018). The World Health Organization (WHO) has classified STH infections as the most frequent infectious disease worldwide, affecting around 24% (1.5 billion) of the world's population. Moreover, around one billion children are at risk of at least one STH species infection. These infections primarily impact impoverished and destitute populations living in tropical and subtropical climates, with the highest frequency recorded in Sub-Saharan Africa, China, South America, and Southeast Asia (World Health Organization, 2023).

As of 2014, there were a total of 59 082 148 reported cases of STH infection in Indonesia. These numbers continued to rise annually, posing a health concern, particularly in children (World Health Organization, 2022). In 2015, the prevalence of helminth infection in Indonesia was 28.12%, which is categorized as moderate (Ministry of Health of The Republic of Indonesia, 2015). This highlights the urgent need for immediate actions, including treatment programs as recommended by the WHO and further actions to maintain the elimination of STH. In 2017, The Ministry of Health of Indonesia has issued Regulation No. 15 nationwide, which mandates the biannual mass drug administration (MDA) to be implemented on children under five, preschool-aged children, and school-aged children in areas with higher or moderate prevalence levels. This program aligns with the global WHO roadmap for ending NTDs by 2030, with a focus on eradicating soil-transmitted helminthiases in preschool and school-age children. Furthermore, this program requires an evaluation every five years (Ministry of Health of The Republic of Indonesia, 2017; World Health Organization, 2023). The first evaluation of the post-deworming program in 2021 revealed that 26 out of 92 districts/cities surveyed in Indonesia continue to have a prevalence rate above 10%, while the remaining districts/cities had already achieved a rate below 5%, which is the indicator targeted in the decree (Ministry of Health of The Republic of Indonesia, 2023).

The higher prevalence of STH infection is usually observed in regions with socioeconomic disparities (O'Connell & Nutman, 2016), particularly in the frontier, outermost, and least developed areas (termed "3T" in Indonesian–*terdepan, terluar, tertinggal*). Southwest Sumba (SWS) is listed as a 3T region (Ministry of Villages and Development of Disadvantaged Regions of Indonesia, 2015), which has a high prevalence of STH infection. A previous STH examination in 2021 with the direct smear method revealed a prevalence of 54% of infections among North Kodi children aged 36–45 months (Athiyyah *et al*., 2023). North Kodi is classified as the least developed district (Ministry of Villages and Development of Disadvantaged Regions of Indonesia, 2015), suggesting that the area is susceptible to poverty due to its inability to effectively manage potential socioeconomic and ecological resources, as well as its vulnerability to natural disasters and social unrest (Ministry of Villages and Development of Disadvantaged Regions of Indonesia, 2017). As a result there is a likelihood of insufficient awareness regarding the importance of maintaining proper hygiene, particularly among children, thus increasing the risk of infection.

Children possess an underdeveloped immune system compared to adults, rendering them susceptible to STH infection. The mechanism of STH infection in absorbing nutrients from the human gut causes insufficient intake of nutrients and can result in stunted growth and development (Lepper *et al*., 2018). This untreated condition could lead to malnutrition and gradually cause stunting (Fauziah *et al*., 2022). Additionally, particular STH, such as hookworm, can damage blood vessels in the intestinal wall and lead to bleeding, which may result in anemia (Loukas *et al*., 2016). Therefore, by eliminating STH infection in children, the risk of malnutrition and anemia will also be reduced.

A systematic evaluation of STH infection among children in SWS is crucial, especially during the post-MDA period. Supporting the biannual MDA initiatives, previous studies have evaluated the prevalence of STH infection in several areas of SWS with varied target populations (Sungkar *et al*., 2015; Athiyyah *et al*., 2023). However, other remote areas in SWS have yet to be assessed. Therefore, we conducted a cross-sectional study focused on STH to assess its prevalence using stool specimens obtained from preschool and school-aged children in Hameli Ate and Homba Karipit Villages, North Kodi District, Southwest Sumba Regency. The Kato-Katz method was employed to assess the STH in our study (World Health Organization, 2019), which was yet to be utilized in the previous studies (Sungkar *et al*., 2015; Athiyyah *et al*., 2023). The method was proven to have higher sensitivity in diagnosing STH prevalence compared to direct smears (Gunasari *et al*., 2021). Thus, implementing Kato-Katz method would provide a better understanding of STH prevalence. Furthermore, due to the absence of previous documentation regarding the occurrence of STH in these villages, the current investigation serves as a valuable indicator of the current state of helminthiases in these areas. This study aims to examine the prevalence of STH infection post-MDA period and its impact on nutritional status, anemia, as well as hygiene practices in preschool and school-aged children.

MATERIALS AND METHODS

Ethical Statement

This study was approved by the ethics committee of the School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia (SMHS-AJCUI), with document No. 25/08/KEP-FKIKUAJ/2023. Prior to specimen collection, parents or guardians of the preschool-aged children (PAC) and school-aged children (SAC) received information about the study either directly or through an information sheet. Furthermore, an informed consent form was provided for parents or guardians to obtain written consent, ensuring the authorization of the children's participation. This study involved collaboration among the SMHS-AJCUI, Karitas Clinic in Homba Karipit, and Weetebula Catholic University of Indonesia in Sumba.

Study Design and Areas

A cross-sectional study was conducted in Homba Karipit and Hameli Ate Villages, North Kodi District, Southwest Sumba Regency, in September 2023. The study in Karitas Clinic focused on PAC. This study was undertaken as a part of the children's health assessment clinic program. Meanwhile, the sampling for SAC was conducted in a public elementary school in Hameli Ate Village. This study used total sampling method to analyze the overall prevalence of STH infection and its related factors among children, with a total of 199 participants were required to join this study based on the calculation using the G*Power 3.1.9.7 software (Kang, 2021), applying an effect size of 0.3, 95% confidence interval (CI), and 80% power. Figure 1 shows the two study locations.

Parasitic Examination

Participants were provided with labelled stool containers and instructed to collect and submit their fresh stool specimens (≤24 hours) once within a period of three days. The stool was examined on the same day as specimen collection using a single standardized Kato-Katz method according to WHO. This method was chosen for its cost-effectiveness, time efficiency, and practicality, particularly in under-resourced areas. This method detects the eggs of *A. lumbricoides*, *T. trichiura*, and hookworms. The number of eggs observed under a light microscope was further calculated for eggs per gram (EPG) by multiplying the number of eggs found per slide by 24 (World Health Organization, 2019). The EPG was categorized into three groups based on the intensity of infection: light (1–4 999 EPG for *A. lumbricoides*; 1–999 EPG for *T. trichiura*; 1–1 999 EPG for hookworms), moderate (5 000–49 999 EPG for *A. lumbricoides*; 1 000–9 999 EPG for *T. trichiura*; 2 000–3 999 EPG for hookworms), and heavy (≥50 000 EPG for *A. lumbricoides*; ≥10 000 EPG for *T. trichiura*; ≥4 000 for hookworms) infection (World Health Organization, 1987, 1998).

Demographic and Hygiene Data Collection

During the preparation phase, a team of local enumerators, composed of teachers and undergraduate students of Weetabula Catholic University who are familiar with Kodi dialect, underwent training to standardize their approach and ensure consistent data collection using the prepared set of questions. This was necessary because the majority of elementary school children in the area speak the local dialect and have limited proficiency in the national language (Indonesian). A supervisor from the core study team was available for the enumerators during the whole interview session

Figure 1. Study location. The black pint point Showed Sumba Island in East Nusa Tenggara of Indonesia, blue represented Southwest Sumba Regency, and red represented two study locations in North Kodi District. (Map image was obtained from Google search engine and compiled using Canva.com).

should there be a doubt. The participant's age demographic was categorized into PAC (0–5 years old) and SAC based on the Ministry of Health categorization (Ministry of Health of The Republic of Indonesia, 2014). The interviews were performed directly with SAC students and the parents of the PAC. The questionnaire consisted of 15 questions: demographic information (age, gender, birthdate), both parents' education level and current occupation, family size, animal ownership (any animals or none), hygiene practices including handwashing habits before consumption and after, nail clipping habits, footwear usage habits, defecation site, and household water sources.

Nutritional and Anemia Assessment

The nutritional assessment involved measuring anthropometric variables, including body height (BH) and body weight (BW), using the stature meter (GEA, Indonesia) and digital weighing scale (Tanita, Japan). The Body Mass Index (BMI) was calculated using both BH and BW data, coverted to Z-score value, and categorized according to the WHO classification for nutritional status. This categorization is divided into malnourished (Z-score < -3), undernutrition (-3 ≤ Z-score < -2), normal (-2 ≤ Z-score < 1), and overweight (1 ≤ Z-score ≤ 2) (World Health Organization, 2007). Anemia levels were assessed using a single-prick blood test to measure the children's hemoglobin (Hb) level with the Quik-Check Hb method. We categorized the anemia level based on the participants' age and gender. Amenia in children aged 6–59 months was categorized into normal (≥11.0 g/dL), mild (10.0–10.9 g/dL), moderate (7.0–9.9 g/dL), and severe (<7.0 g/dL), while anemia in children aged 5–11 was classified as normal (≥11.5 g/dL), mild (10.0–11.4 g/dL), moderate (8.0–10.9 g/dL), and severe (<8.0 g/dL). For children aged 12-14 years old and non-pregnant woman of more than 15 years old, anemia's category is divided into normal (≥12 g/dL), mild (10.0–11.9 g/dL), moderate (8.0–10.9 g/dL), and severe (<8.0 g/dL); meanwhile, men older than 15 years old is classified as normal (≥13 g/dL), mild (11.0-12.9 g/dL), moderate (8.0-10.9 g/dL) and severe (< 8.0 g/dL) (World Health Organization, 2011).

Data Management

We recategorized several of the previously mentioned factors for analysis purposes. The SAC group was reclassified into two groups according to median value of age: younger (6–11 years old) and older (12–16 years old) SAC. It is based on the likelihood that older years students may still be enrolled at the Elementary School (Ministry of Health of The Republic of Indonesia, 2014). The education level of parents was recategorized into low (no formal education up to junior high school) and high (senior high school or higher) educations based on the then compulsory 9-year education curriculum implemented by the Indonesian Ministry of Education, Culture, Research, and Technology (Government of Republic of Indonesia, 2008). The parent's occupation was reclassified as either farmer or non-farmer. (labourers, teachers, employees, entrepreneurs, and housewives). Family size was recategorized into small (≤5 people) and large (>5 people) families. We recategorized animal ownership according to whether it was present or absent. The location for defecation of fields, gardens, bushes, rivers, or beaches were regrouped as open areas. The water sources for cooking and drinking in the household obtained from rainfall, rivers, or wells were recategorized as natural sources and water supplies purchased in the form of bottles or gallons was reclassified as packaged water.

Data Analysis

The STH examination results, anemia status, nutritional status, and questionnaires data were entered into Microsoft Excel in Jakarta, Indonesia, and verified to ensure the accuracy of the data. Data analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, N.Y., USA). The normality of the Hb, Z-score of BMI, and EPG's data were analyzed using Kolmogorov-Smirnov (K-S) test; further analysis will be executed to observe the correlation between EPG of *A. lumbricoides* or *T. trichiura* to the BMO and Hb values. As the data were also presented in nominal scale, descriptive analysis was used to obtain an overview of the distribution of prevalence and intensity of STH infection infrequency and percentages. The Venn diagrams of prevalence of STH infection intensity among participants were created using an online tool (https://goodcalculators.com/venn-diagram-maker/). Pearson's Chi-square test was conducted on the nominal data to evaluate the association between STH infection profile of the children and their nutritional status, anemia level, and other hygiene-related factors. Multivariate analysis will also be conducted if the data is eligible to analyze the influence of certain factors ($p \leq 0.25$ in the Chi-square analysis) on the infection status of participants. The results for all statistical analysis would be deemed as significat when the p-value < 0.05.

RESULTS

Demographic Characteristics

A total of 238 children participated in this study, comprising of 48 and 190 SAC. Among those participants, 206 participants' age data were recorded. We observed the majority of children were aged 6 to 11 years old (64.4%), followed by children under 6 years (23.4%) and those over 11 years (12.2%) (Table 1). Fifteen out of 238 stool specimens were omitted from the examination due to inadequate sample volume. Data from 32 participants were excluded from the prevalence analysis for age group due to incomplete age information. Additionally, 36 out of 223 examined participants were excluded from Chi-square analysis due to insufficient questionnaire data. The overall specimens' selection in this study is shown in Figure 2. Among 187 participants, 47.6% (89/187) are male and 52.4% (98/187) are female. Most of the participants' parents had a low level of education, with a slightly higher proportion of fathers (154/184) having a low education level in comparison to the mothers (142/186). In contrast, only 16.3% (30/184) of fathers and 23.7% (44/186) of mothers had attained a higher level of education. The data indicated that the majority of fathers (90.2%; 166/184) and mothers (48.4%; 90/186) of the participants work as farmers. A summary of the demographic characteristics of the participants is shown in Table 1.

The Prevalence of Soil-transmitted Helminth (STH)

A total of 238 children participated in stool specimen collection in this study. There were 93.67% (223/238) of participants who provided a sufficient volume of stool specimens to be measured for STH infection using the Kato-Katz method. Our observation indicates that the overall prevalence of STH infection was 58.3% (130/223) (Figure 3), with *A. lumbricoides* and *T. trichiura* as the detected STH species. Among the samples, 53 specimens (23.8%) were a mixed infection between *A. lumbricoides* and *T. trichiura*. The infection for both species was found in light (*A. lumbricoides*: 37.7%; n=84; *T. trichiura*: 26.5%; n=59) and moderate (*A. lumbricoides*: 15.2%; n=34; *T. trichiura*: 2.7%; n=6) intensity (Figure 4). The findings revealed that mixed infections involving light and moderate infections across species were detected, with the prevalence dominated by light mixed infections (14.35%; n=32). Furthermore, moderate infections in either *A. lumbricoides* or *T. trichiura* were generally accompanied only by light infections of the other species. No cases of heavy infection were detected. The analysis of STH infections acrossmon different age groups also revealed that a single

Table 1. Demographic Characteristics of Participants

Category	Frequency (n)	Percentage (%)
Age[1]		
1–5	48	23,4
6–11	133	55.4
12–15	16	12,2
Gender[2]		
Male	103	49.1
Female	107	50.9
Education level of father[3]		
No school	55	26.6
Middle school	93	44.9
Junior high school	25	12.1
Senior high school	28	13.5
Bachelor	6	2.9
Education level of mother[4]		
No school	47	22.5
Middle school	79	37.8
Junior high school	33	15.8
Senior high school	40	19.1
Bachelor	10	4.8
Occupation of father[3]		
Famers	186	89.9
Laborers	6	2.9
Teachers	1	0.5
Employees	5	2.4
Entrepreneurs	9	4.4
Occupation of mother[4]		
Famers	103	49.3
Laborers	1	0.5
Teachers	1	0.5
Employees	4	1.9
Entrepreneurs	5	2.4
Housewives	95	45.5

[1]Total n=206; Age or birthdate data were not available in 32 participants.
[2]Total n=210; Twenty-eight participants were not present during the questionnaire session.
[3]Father's education and occupation data: n=207 due to father's absent (n=3) and participants were not present during the questionnaire session (n=28).
[4]Mother's education and occupation data : n=209 due to mother's absent (n=1) and participants were not present during the questionnaire session (n=28).

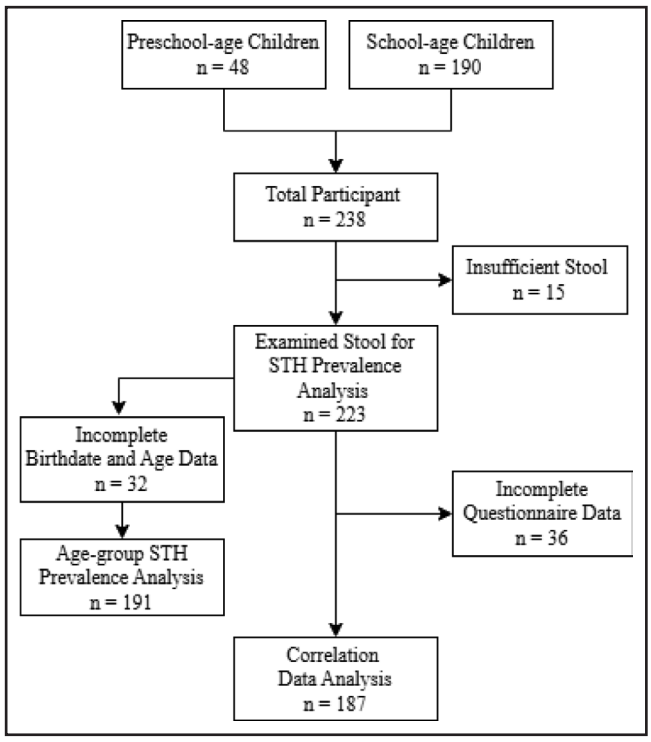

Figure 2. The flowchart of the specimen selection in this study.

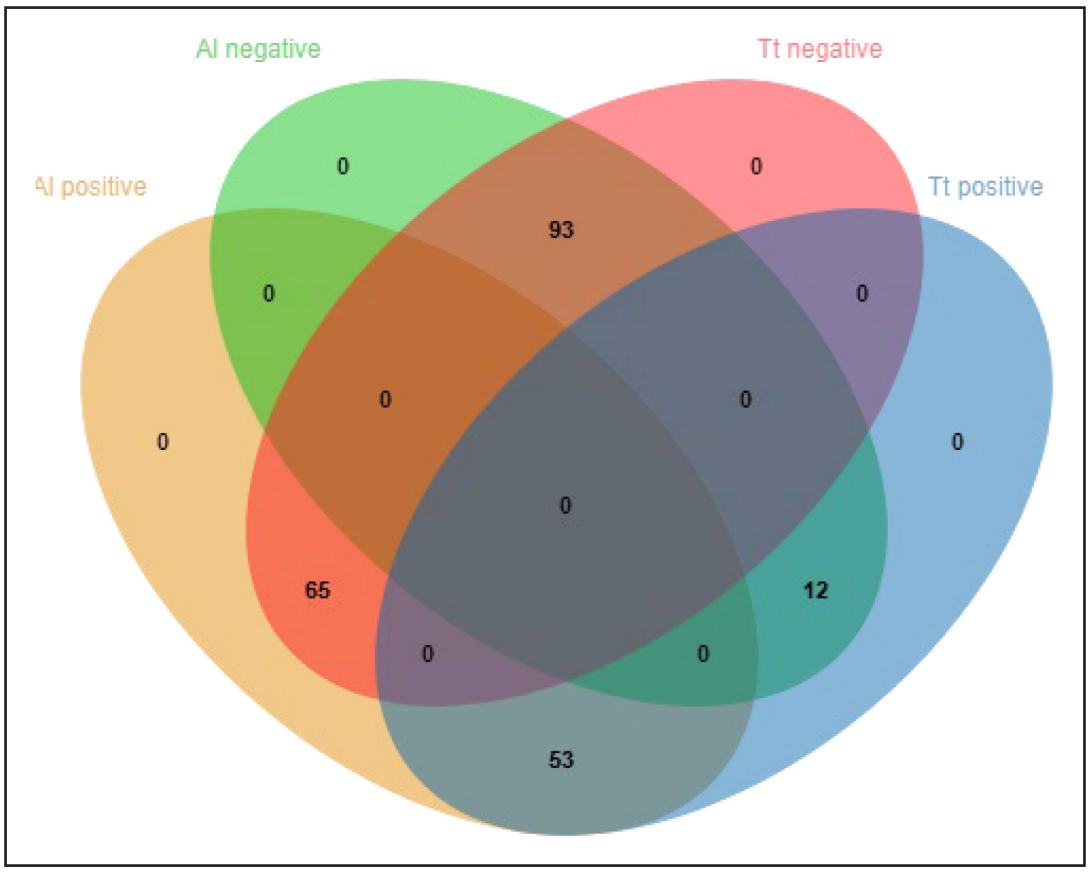

Figure 3. Venn Diagram for Prevalence of STH Infection among Participants. The number of infections can be seen as the total of Al and Tt positive (n=130). The mixed infection between Al and Tt can be seen in the overlapping areas (n=53). Al: *A. lumbricoides*; Tt: *T. trichiura*.

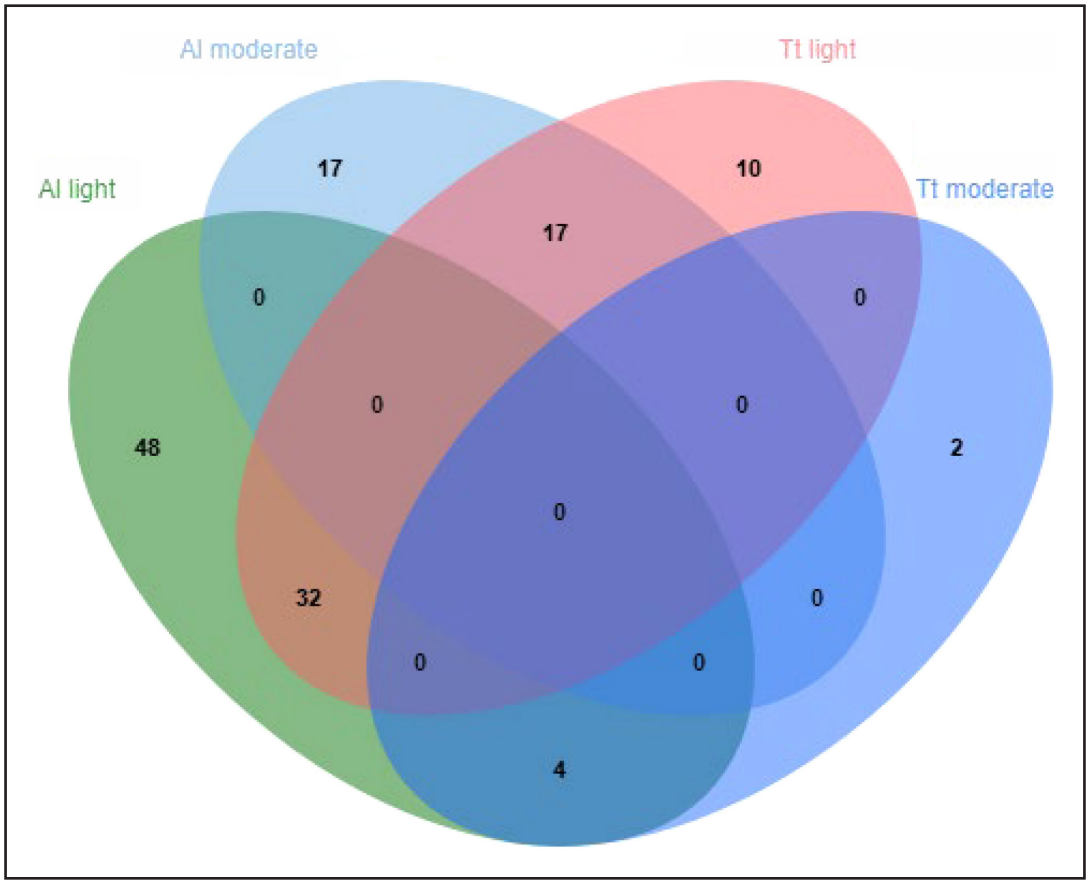

Figure 4. Venn Diagram showing the Distribution of STH Infection Intensity among Participants. Al: *A. lumbricoides*; Tt: *T. trichiura.*

infection by *A. lumbricoides* was the predominant STH infection in all groups, including PAC (21.1%; 8/38), younger SAC (26.6%; 34/128), and older SAC (40%; 10/25) groups, in contrast to *T. trichiura* (PAC: 7.9%, 3/38; younger SAC: 5.5%, 7/128; older SAC: 4%, 1/25). Table 2 provides a detailed overview of the STH infection across different age groups and the intensity of infection in each group. Nonetheless, this study did not identify any hookworm's infection. Upon study completion, each participant was administered with a single-dose treatment of Albendazole (400 mg), given that the prevalence of STH infection exceeded 20%.

Nutritional and Anemia Status

Among the 223 examined specimens, 187 participants were eligible for nutritional and anemia status assessments. Most children exhibited normal nutritional status (67.9%; n=127), whereas 23% (n=43) were classified as undernutrition and 8% (n=15) as malnourished. However, two children (1%) were classified as overweight. Based on the analysis of nutritional status and STH infection, a higher prevalence was found in children with normal nutritional status (40.1%; 75/187) compared to those who were classified as undernutrition (11.2%; 21/187) or malnourished (5.9%; 11/187). Most of the children (115/187) had normal hemoglobin levels, whereas 33 and 39 children were classified as having mild and moderate anemia, respectively. Based on the proportion of each anemia status, children with normal hemoglobin levels exhibited a lower prevalence of STH infection (55.7%; 64/115) compared to those with mild (66.7%; 22/33) or moderate anemia (56.4%; 22/39). Chi-square analysis revealed a non significant association between infection status and nutritional or anemia status of the children ($p > 0.05$). Table 3 provides a comprehensive overview of the data.

Correlation analysis was also performed for both BMI and Hb values. As the interval data from both parameters are not normally distributed ($p < 0.05$), Spearman's rank corellation analysis was performed to analyze the correlation between both data and the EPG of *A. lumbricoides* or *T. trichiura*. The findings found no significant correlation between the EPG *of A. lumbricoides* with Hb ($p = 0.227$) and BMI ($p = 0.987$), nor between the EPG *of T. trichiura* with Hb ($p = 0.452$) and BMI ($p = 0.061$) of the participants.

Socioeconomic and Hygiene-related Factors Contributing to STH Infection

Further analysis regarding STH infection and hygiene-related factors was conducted among 187 children with a complete questionnaire (Table 4). Our assessment revealed a higher STH infection in SAC (47.1%; 88/187) compared to PAC (10.7%; 20/187). Females had a slightly higher infection rate (59.2%; 58/98) than males (56.2%; 50/89), with no significant association between either gender or age and the infection. Nevertheless, a significant association was

Table 2. Prevalence and intensity of STH infection in different age groups

Infection Status	Age Group (n=191)[1]					
	PAC[2] (n=38)		Younger SAC[3] (n=128)		Older SAC[4] (n=25)	
	STH [n (% of age group)]					
	Al	Tt	Al	Tt	Al	Tt
Any infection	21 (55.3)		74 (57.8)		16 (64)	
Mixed infection[5]	10 (26.3)		33 (25.8)		5 (20)	
Single infection	8 (21.1)	3 (7.9)	34 (26.6)	7 (5.5)	10 (40)	1 (4)
Moderate	6 (15.8)	2 (5.3)	21 (16.4)	4 (3.1)	1 (4)	0 (0)
Light	12 (31.6)	11 (28.9)	46 (35.9)	36 (28.1)	14 (56)	6 (24)
Negative	20 (52.6)[6]	25 (65.8)[7]	61 (47.7)[6]	88 (68.8)[7]	10 (40)[6]	19 (76)[7]
No infection	17 (44.7)		54 (42.2)		9 (36)	

STH: Soil-Transmitted Helminth; Al: *A. lumbricoides*; Tt: *T. trichiura.*
[1]Thirty-two participants were excluded from the age group analysis due to incomplete birthdate data.
[2]PAC: Preschool-age children (0–5 years old).
[3]Younger SAC: Younger school-age children (6–11 years old).
[4]Older SAC: Older school-age children (12–16 years old).
[5]Mixed infections of *A. lumbricoides* and *T. trichiura* (n = 130 for all participants and n = 111 for participants with known ages).
[6]Kato-Katz negative for *A. lumbricoides.*
[7]Kato-Katz negative for *T. trichiura*.

Table 3. Association between nutritional and anemia status with STH infection based on chi-square analysis[1]

Variables	Infection Status (n, %)					
	Negative	Positive	*p*-value	Single Infection	Mixed Infection[2]	*p*-value
Nutritional Status						
Overweight	1 (0.5)	1 (0.5)		1 (0.5)	0 (0)	
Normal	52 (27.8)	75 (40.1)	0.387	39 (20.9)	36 (19.3)	0.251
Undernutrition	22 (11.8)	21 (11.2)		16 (8.6)	5 (2.7)	
Malnourished	4 (2.1)	11 (5.9)		5 (2.7)	6 (3.2)	
Anemia Status						
Normal	51 (27.3)	64 (34.2)	0.519	38 (20.3)	26 (13.9)	0.383
Mild	11 (5.9)	22 (11.8)		14 (7.5)	8 (4.3)	
Moderate	17 (9)	22 (11.8)		9 (4.8)	13 (7)	

[1]Total sample included in analysis was 187.
[2]Mixed infection of *A. lumbricoides* and *T. trichiura.*

Table 4. Socioeconomic and hygiene-related factors contributing to STH infection

Variables	Infection Status [n (%)]				Total Respondents
	Negative	Positive			
		Single Infection	Mixed Infection	Total Infection	
Gender					
Male	39 (20.9)	31 (16.6)	19 (10.2)	50 (26.7)	89 (47.6)
Female	40 (21.4)	30 (16)	28 (15)	58 (31)	98 (52.4)
Age					
PAC[2]	17 (9.1)	11 (5.9)	9 (4.8)	20 (10.7)	37 (19.8)
Younger SAC[3]	53 (28.3)	39 (20.9)	33 (17.6)	72 (38.5)	125 (66.8)
Older SAC[4]	9 (4.8)	11 (5.9)	5 (2.7)	16 (8.6)	25 (13.4)
Education level of father[5**]					
Low	61 (33.2)	53 (28.8)	40 (21.7)	93 (50.5)	154 (83.7)
High	17 (9.2)	8 (4.3)	5 (2.7)	13 (7.1)	30 (16.3)
Education level of mother[6*]					
Low	52 (28)	51 (27.4)	39 (20.9)	90 (48.4)	142 (76.4)
High	26 (13.9)	10 (5.4)	8 (4.3)	18 (9.7)	44 (23.6)
Occupation of father[5]					
Non-farmers	9 (4.9)	5 (2.7)	4 (2.2)	9 (4.9)	18 (9.8)
Farmers	69 (37.5)	56 (30.4)	41 (22.3)	97 (52.7)	166 (90.2)
Occupation of mother[6]					
Non-farmers	38 (20.4)	33 (17.7)	25 (13.4)	58 (31.2)	96 (51.6)
Farmers	40 (21.5)	28 (15.1)	22 (11.8)	50 (26.9)	90 (48.4)
Family size					
Small (≤5 people)	48 (25.7)	42 (22.5)	28 (15)	70 (37.4)	118 (63.1)
Large (>5 people)	31 (16.6)	19 (10.2)	19 (10.2)	38 (20.3)	69 (36.9)
Animal ownership					
No	16 (8.6)	14 (7.5)	10 (5.3)	24 (12.8)	40 (21.4)
Yes	63 (33.7)	47 (25.1)	37 (19.8)	84 (44.9)	147 (78.6)
Handwashing before consumption					
No	12 (6.4)	11 (5.9)	5 (2.7)	16 (8.6)	28 (15)
Yes, without soap	24 (12.8)	17 (9)	16 (8.6)	33 (17.6)	57 (30.4)
Yes, with soap	43 (23)	33 (17.6)	5 (2.7)	59 (31.6)	102 (54.6)
Handwashing after defecation					
No	19 (10.2)	15 (8)	11 (5.9)	26 (13.9)	45 (24.1)
Yes, without soap	21 (11.2)	19 (10.2)	16 (8.6)	35 (18.8)	56 (30)
Yes, with soap	39 (20.9)	27 (14.4)	20 (10.7)	47 (25.1)	86 (46)
Nail clipping habit					
No	23 (12.4)	21 (11.2)	11 (5.9)	32 (17.1)	55 (29.5)
Yes, once a week	56 (29.9)	40 (21.4)	36 (19.2)	76 (40.6)	132 (70.5)
Footwear usage habit					
No	36 (19.2)	33 (17.6)	21 (11.2)	54 (28.9)	90 (48.1)
Yes	43 (23)	28 (15)	26 (13.9)	54 (28.9)	97 (51.9)
Defecation site[**]					
Open field	32 (17.1)	29 (15.5)	29 (15.5)	58 (31)	90 (48.1)
Outdoor toilet	43 (23)	28 (15)	18 (9.6)	46 (24.6)	89 (47.6)
Indoor toilet	4 (2.1)	4 (2.1)	0 (0)	4 (2.1)	8 (4.2)
Household water source					
Nature (rain/river/well)	40 (21.4)	25 (13.4)	20 (10.7)	45 (24.1)	85 (45.5)
Individual tap water	10 (5.3)	7 (3.7)	8 (4.3)	15 (8)	25 (13.3)
Packaged water	29 (15.5)	29 (15.5)	19 (10.2)	48 (25.7)	77 (41.2)

[1]Mixed infection of *A. lumbricoides* and *T. trichiura.*
[2]PAC: Preschool-age children (0–5 years old).
[3]Younger SAC: Younger school-age children (6–11 years old).
[4]Older SAC: Older school-age children (12–16 year).
[5]Father's education and occupation: n=184 due to father's absent.
[6]Mother's education and occupation: n=186 due to mother's absent (OR = 0.4; 95%CI = 0.2-0.79).
[*]Significant association between the infection status of the participants (positive/negative) and the mother's education level; $p = 0.016$.
[**]Non-significant association between the infection status of the participants (positive/negative) with father's education level ($p = 0.213$) and defecation site ($p = 0.203$); however, as the p-value for both parameters are ≤ 0.250, the multivariate analysis was further conducted between STH infection status and these parameters.

found between maternal education and infection risk (OR = 0.4; 95%CI = 0.2-0.79; p = 0.016). Children whose mothers had a lower level of education had a higher risk of any infection (63.4%; 93/154) compared to those whose mothers had a higher level of education (40.9%; 13/30). However, we did not observe a significant association (p = 0.08) between maternal educational level and the occurrence of mixed infection. Single infections were more prevalent among mothers with low levels of education (35.9%; 51/142) than mixed infections (27.5%; 39/142). Conversely, there was no significant relationship between the level of paternal education and the risk of infection. However, the occurrence of infection was higher among children with low educated fathers (60.4%; 93/154) than those with highly educated fathers (43.3%; 13/30). The other potential risk factors include parents' occupation, family size, and animal ownership. However, the analysis in the current study indicates that none of these factors had a substantial impact on the risk of infection in children (Table 3). Our findings reveal those children with farmer fathers (58.4%; 97/166) had a higher infection rate compared to those with non-farmer fathers (50%; 9/18). Whereas children with non-farmer mothers (60.4%; 58/96) exhibited a slightly higher infection rate compared to children with farmer mothers (55.6%; 50/90). Additionally, children from smaller families exhibited a greater infection rate (59.3%; 70/118) than those from larger families (55.0%; 38/69). Furthermore, among 147 children who own animals, 84 were identified to be infected with STH.

Hygiene practices might also serve as a potential risk factor for infections. Our data revealed children had good hygiene practices by washing their hands with soap before consumption (102/187) and after defecation (86/187). However, children who did not implement good handwashing habits before consumption exhibited a slightly lower infection rate (57.2%; 16/28) compared to those who washed their hands, either with or without soap (57.9%; 92/159). On the contrary, handwashing habits after defecation revealed that the infection rate of individuals who utilize soap for handwashing (54.7%; 47/86) was slightly lower than those without soap (62.5%; 35/56) or no handwashing at all (57.8%; 26/45). Additionally, children demonstrated good hygiene practice by regularly clipping their nails on a weekly basis (132/187) and using footwear (97/187), reflected by the slightly lower infection rate among them (57.6% for nail clipping and 55.7% for footwear usage) compared to children who do not have a nail clipping habit (58.2%; 32/55) or footwear usage habit (60.0%; 54/90). However, both analyses showed a nonsignificant association with STH infection. The defecation site is another factor that could influence STH infection. The majority of the children did not have toilet facilities inside their house (179/187), with 47.6% (89/187) of children using outdoor toilets for defecation, while the remaining 48.1% (90/187) defecated in open fields. The infection was found to be higher in children who defecated in the open fields (58/90) as opposed to those who used outdoor (46/89) or indoor (4/8) toilets. In terms of household water sources, water obtained from nature (85/187) and packaged water (77/187) are preferable than individual tap water (25/187). Higher infection rates were observed in those who use packaged water (62.3%; 48/77) and individual tap water (60.0%; 15/25) than those who use water from nature (52.9%; 45/85). Multivariate analysis was also briefly conducted to further evaluate the combined effect of parents' educational level and defecation location on the STH infection status (positive/negative), as the p-value of each parameter was below 0.25 from bivariate analysis (Table 4). Nonetheless, there was no significant association between all the combined factors to the infection status in children (p = 0.108).

DISCUSSION

This study revealed an overall STH prevalence of 58.3%, deemed high according to WHO criteria (World Health Organization, 2017). *A. lumbricoides* was found as the predominant cause of the infection, followed by *T. trichiura*. Despite utilizing a standard method for STH diagnosis, our study did not identify any hookworm infection. Based on our observation, the study areas were approximately more than 10 km from the coastal region (Google Maps), which is less favourable for the survival of hookworms as they are more common in coastal regions (Tangpong *et al*., 2021). Meanwhile, *A. lumbricoides* and *T. trichiura* eggs are more resilient and capable of surviving in various soil types (Nisha *et al*., 2019), contributing to their higher prevalence in this study. However, *T. trichiura* was found to be more sensitive to heat (Manz *et al*., 2017); the extreme weather conditions in SWS likely explain its lower prevalence compared to *A. lumbricoides*.

The Kato-Katz method, commonly employed for detecting STH infection, has been reported to exhibit reduced sensitivity in the detection of hookworm. The Kato-Katz method exhibits low sensitivity in detecting hookworm infections primarily due to the fragility of hookworm eggs to environment conditions. Hookworm eggs can hatch into larvae within 24–48 hours after being exposed to environment under favorable temperature and humidity (Brooker *et al*., 2004). Delays between stool collection and slide preparation may result in the eggs hatching before examination, rendering them undetectable by microscopy. The possibility of participants collected stool samples in the afternoon and submitted them the following morning may have increased the likelihood of hookworm eggs hatching before processing, thereby reducing the chances of egg detection under microscopy. Therefore, it is recommended to prepare and read Kato-Katz thick smear within 60 minutes of sample collection, as the preparation beyond that duration will result in unreliable outcome such as false negative (Cools *et al*., 2019; World Health Organization, 2019; Bosch *et al*., 2021). Meanwhile, both *A. lumbricoides* and *T. trichiura* eggs remain viable for up to 24 hours as their eggs are less susceptible, therefore their eggs are detected easier than hookworms' (Bosch *et al*., 2021).

A. lumbricoides and *T. trichiura* exhibit a high prevalence globally (Silver *et al*., 2018; Pasaribu *et al*., 2019). The high prevalence of STH infection found in this study may be linked to the underdevelopment condition of SWS. The development of various infrastructures, including the construction of facilities, are constrained. Those conditions resulted in SWS possessing extensive open fields, which favoured the habitat of *A. lumbricoides* and *T. trichiura* (Sungkar *et al*., 2015; Silver *et al*., 2018; Pasaribu *et al*., 2019) . Moreover, the lack of proper sanitation facilities, such as toilets, could act as the source of the infection in this situation. *A. lumbricoides* and *T. trichiura* exhibit significant fertility rates, with *A. lumbricoides* producing as many as 200,000 eggs daily, while *T. trichiura* produces up to 10,000 eggs per day (de Lima Corvino & Horrall, 2023; Viswanath *et al*., 2023). This affirms the higher infection of *A. lumbricoides* compared to *T. trichiura* in this study. The thick shell of these eggs contributes to their durability in soil, enabling them to persist in the environment for an extended duration (Centers for Disease Control and Prevention, 2017). In SWS, the prevalence of open fields relative to buildings facilitates restricted access to clean water and sanitation facilities, thereby elevating their risk of exposure to STH species. The risk is exacerbated by insufficient hygiene practices stemming from restricted access to education. Children are more likely to comprehend and learn about the importance of hygiene when educational resources are readily available to them.

The participants who were infected with either *A. lumbricoides* or *T. trichiura* were mostly suffering from a light infection (Table 2). Out of 223 participants, 23.8% had mixed infection of *A. lumbricoides* and *T. trichiura*. A study demonstrated a positive correlation between *A. lumbricoides* and *T. trichiura* infections. However, mixed infection between these species may not significantly impact the egg production of each species (Lepper *et al*., 2018). This is consistent with the EPG range found in the current study, which demonstrated 72–56 472 EPG and 24–2 016 EPG for *A. lumbricoides* and *T. trichiura*, respectively. Mixed infection is likely to occur since both species are

transmitted by the fecal-oral route. Additionally, investigations have suggested that both species typically occupy the same condition, which is defined by moist, warm, and shaded soil found in SWS that resembles a tropical environment. This condition offers an ideal habitat for these organisms (Booth & Bundy, 1995).

A sub-analysis was conducted to determine the prevalence of STH infection in three age groups: PAC, younger SAC, and older SAC. The incidence of infection was greater in both younger SAC (57.8%; 74/128) and older SAC (64%; 16/25) than in PAC (55.3%; 21/38). This finding is consistent with a study conducted in Ethiopia, which identified a higher prevalence of *A. lumbricoides* and *T. trichiura* in SAC compared to PAC (Davis *et al*., 2014). Although no significant association was found between age and the risk of infection (Table 4), this study indicates that STH remains highly prevalent among SAC due to their inadequate understanding and awareness of proper sanitation practices, coupled with the higher outside activity of SAC than PAC. Furthermore, the underdeveloped immune systems of children and insufficient adherence to sanitation protocols heighten their susceptibility to infections (Dagne & Alelign, 2021). The reduced incidence of infection in PAC may be attributed to the role of parents/caregivers. The sanitation practices of these caregivers influence the hygiene and infection levels of young children, who are frequently fed by these caregivers. Caregivers who practice hand hygiene in crucial moments (food preparation, before feeding a child, after using the restroom, and after changing a child who has defecated) exhibit a reduced risk of their children experiencing acute diarrhea (Getahun & Adane, 2021; Soe *et al*., 2024). Children possessing a higher risk of STH infection may potentially have poor health conditions. Our study revealed that most STH-infected children had normal hemoglobin levels and nutritional status. There were 34.2% out of 61.5% non-anemic children who were infected with STH. This study did not find any association between hemoglobin levels and the STH infection status or correlation between EPG numbers of each species in children and their hemoglobin values despite existing literature indicating that STH infection may induce anemia through nutrient depletion and blood loss (Djuardi *et al*., 2021; Alnaz *et al*., 2022). Several studies in Indonesia have also indicated that there is no significant correlation between STH infection and anemia (Darlan *et al*., 2018; Sari *et al*., 2020). It is known that hookworm infection correlates with anemia. However, whether or not a person with a hookworm infection develops anemia is contingent upon multiple factors, including the species of the hookworm, infection intensity, infection duration, the individual's iron stores, dietary iron intake and absorption, and physiological iron requirements. Insufficient iron intake and depleted iron stores can result in anemia, even with a low hookworm load (Pawlowski *et al*., 1991; Ghodeif & Jain, 2023). Furthermore, the majority of participants in our study had light *A. lumbricoides* and *T. trichura* infections without any hookworm infection, thus potentially explains their lower risk of anemia. Many children who participated in our study have a normal nutritional status within the range classified by the WHO (Table 3). Among these children, 40.1% tested positive for STH infection. This study also concluded that there was no significant association between STH infections and nutritional status. Various factors, such as socioeconomic status and dietary habits, may influence the nutritional status of children. A prosperous family economy allows parents to provide a nutritious and substantial food supply, thereby enhancing children's immune systems and improving their ability to combat infections. Their nutrition may adequately support growth, even amidst a light infection. However, long-term exposure to STH infection without preventive measures or medical intervention can adversely affect a child's health. Understanding the transmission and management of the diseases is essential. Two straightforward practices, personal and environmental hygiene, can effectively prevent STH infection (Aniwada *et al*., 2016).

North Kodi, located in East Nusa Tenggara, is marked by underdevelopment, insufficient educational resources, and linguistic diversity. The data indicated that 83.7% of fathers and 76.4% of mothers completed their primary and secondary education spanning 6 to 9 years, with the majority employed as farmers. Parents significantly influence children's growth and development, especially in imparting hygienic practices (Annisa *et al*., 2018). Children of parents with low educational attainment showed a high infection rate (Table 4), especially among those with low-educated mothers (63.4%), which has a significant association with STH infection. The risk analysis indicated the odds of infection in the higher education group are 60% lower compared to the lower education group. Insufficient education among parents, especially mothers, elevates the risk of helminth infections in children. Mothers possessing higher educational qualifications demonstrate greater awareness of sustaining a clean and healthy lifestyle than those with lower educational attainment (Annisa *et al*., 2018). Parents possessing higher education levels are likely to exhibit greater understanding and awareness of hygiene practices. Consequently, they are better equipped to inherit their knowledge and teach their children the importance of maintaining proper hygiene. Another approach to prevent STH infections in children is to promote hygiene behavior since early age in school. A study demonstrated that educational interventions in hygiene and health significantly reduced helminthiasis in children (p = 0.046) (Puspita *et al*., 2020).

Children who possess knowledge and awareness of hygienic habits will engage in appropriate personal hygiene practices. Despite the fact that many children demonstrate good personal hygiene practices, infection rates persist at 57.9% for handwashing with soap before consumption. Our study findings indicated a high prevalence of infection, leading us to conclude that children continue to employ inadequate handwashing techniques, even with the use of soap. Mahmud *et al.* previously identified that regular nail clipping and proper handwashing with soap are effective approaches to prevent STH reinfections (Mahmud *et al*., 2015). Furthermore, the use of footwear plays a significant role in preventing STH infection. This study indicates that the prevalence of footwear use among children is similar to that of non-footwear users, with both groups exhibiting equivalent infection rates. Thus, no significant association was observed between footwear usage and the incidence of infection. Other factors may contribute to the absence of nail clipping habits and footwear usage with STH infection. Physical contact among children during play and interactions with animals may present alternative fecal-oral transmission routes. Additionally, the lack of direct observation regarding the children's consistent use of footwear outdoors could account for the observed findings.

Personal hygiene practices are also affected by the defecation site, especially for STH infection. Inadequate hygiene at the defecation sites can promote the transmission of infection among individuals. Most villages in SWS are deprived of indoor toilet facilities as a result of economic and infrastructural limitations. Among the children, 47.6% utilize outdoor toilets and 48.1% resort to open fields, whereas merely 4.2% have access to indoor toilets. According to a study, children who engage in open defecation are 2.15 times more susceptible to STH compared to those utilizing indoor toilets (Muluneh *et al*., 2020). Since *A. lumbricoides* and *T. trichiura* eggs can persist in the soil for several months (Brooker *et al*., 2006), the inclining of children to spend more time in open fields would heighten the possibility of contact with the eggs. Additionally, improper hygiene practices may contribute to an increased risk of ingesting helminth eggs.

Management of water sources is essential for maintaining personal hygiene habits, particularly for consumption purposes. To our knowledge, SWS had limited access to reliable clean water sources and primarily relied on collecting rainwater for their needs (Afifah *et al*., 2018; BPS-Statistics Indonesia Nusa Tenggara Timur

Figure 5. Containers utilized by villagers to collect rainwater.

Province, 2024). We observed the presence of water containers utilized by locals for the purpose of collecting rainwater (Figure 5). It might explain our findings, which indicate that the majority of people (45.5%; 85/187) use water sources from nature for their domestic water supply. Moreover, 52.9% (45/85) tested positive for either STH species (Table 4). Naturally sourced water poses a higher risk of parasite exposure and subsequent transmission. Consumption of these waters may elevate the risk of infection owing to potential contamination by animals or humans (Titcomb *et al*., 2021). Other than naturally sourced water, children were also drink from packaged water. We observed children who consume packaged water exhibit marginally higher infection rates (62.3%; 48/77) compared to those who utilize naturally sourced water (52.9%; 45/85). This may represent an alternative source of infection. This condition may be attributed to certain practices among the villagers, such as transferring packaged water into alternative storage containers, potentially heightening their exposure to undesirable contaminants. It is also worth noting that the packaging of the packaged water is mostly not done in the controlled factory but in the refill water depots. This practice may increase the risk of introducing harmful agents into the water.

Considering the high infection rates, at the end of our study, we administered albendazole, an anti-helminthic drug that is also used in the government's MDA program, to prevent the growth and reproducibility of STH in both study sites. Our study concluded that STH infection in North Kodi, SWS, remains concerning. The hygiene profile of participants was assessed using a questionnaire without direct observation. As a result, children may not provide accurate responses on several aspects. Furthermore, the sample size may not be sufficient enough for the statistical analysis. However, our present data can provide valuable information to the Public Health Office, serving as the foundation for intervention programs aimed at reducing helminth infection prevalence in North Kodi children. The existing data indicates that the North Kodi area needs further development to enhance the well-being of its children. Potential government initiatives encompass enhancing educational facilities to foster public comprehension of appropriate hygiene practices and upgrading infrastructure to ensure sufficient sanitation in environmental settings. Consequently, this will improve their overall quality of life, contributing to the achievement of the 2045 Golden Generation objective.

In general, this study found that the prevalence of STH infection among children in Homba Karipit and Hameli Ate Villages was high, exceeding 50%. Our findings indicate that the high infection rate did not have a direct impact on nutritional or anemia status, as most of the children exhibited normal nutritional and anemia status. The high infection rate may be attributed to exposure to the risk factor. The lower education level of parents, particularly that of the mother, is a significant risk factor for infection. Additionally, good personal hygiene practices and environmental sanitation are crucial for reducing infection rates. Despite the good personal hygiene habits of the children in this study, it remains important to educate both parents and children about proper hygiene practices and the importance of maintaining these habits, given the high infection rate, as this understanding may potentially reduce the infection. This study provided new insight to the latest health condition regarding STH infection in SWS post-MDA and managed to identify the factors that might influence STH infections thoroughly. It demonstrates the necessity of implementing an evaluation prior to the MDA program to assess treatment efficacy and as a reference to develop optimal strategies for managing STHs.

Conflict of interest

The authors declare that they have no conflict of interest.

ACKNOWLEDGMENT

The study was funded internally by the Research and Community Service Institutions of Atma Jaya Catholic University of Indonesia. We would like to thank Mardy Pangarungan, MD, a paediatrician who supported the team during the fieldwork and Yunisa Astiarani, MD, MPH for her assistance during the data analysis. We also would like to appreciate the assistance from volunteer students from Weetebula University, and staff of the Karitas clinic in Homba Karipit.

REFERENCES

Afifah, T., Nuryetty, M.T., Cahyorini, Musadad, D.A., Schlotheuber, A., Bergen, N. & Johnston, R. (2018). Subnational regional inequality in access to improved drinking water and sanitation in Indonesia: results from the 2015 Indonesian National Socioeconomic Survey (SUSENAS). *Global Health Action* **11**: 1496972. https://doi.org/10.1080/16549716.2018.1496972

Alnaz, A.R.M., Darlan, D.M., Andriyani, Y. & Lubis, R.R. (2022). Hemoglobin Level and Risk of Anemia in Soil-Transmitted Helminths Infections among Children: A Systematic Review and Meta-analysis. *Open Access Macedonian Journal of Medical Sciences* **10**: 355-363. https://doi.org/10.3889/oamjms.2022.8974

Aniwada, E., Uleanya, N., Igbokwe, L. & Onwasigwe, C. (2016). Soil transmitted helminths; prevalence, perception and determinants among primary school children in rural Enugu State, Nigeria. *International Journal of Tropical Disease & Health* **15**: 1-12. https://doi.org/10.9734/ijtdh/2016/24501

Annisa, S., Dalilah, Anwar, C. & Novrikasari. (2018). The relationship between soil transmitted helminthes (sth) infection and nutritional status in students of State Elementary School Number (SDN) 200 Palembang Indonesia. *Bioscientia Medicina: Journal of Biomedicine and Translational Research* **2**: 42-53. https://doi.org/10.32539/bsm.v2i2.39

Athiyyah, A.F., Surono, I.S., Ranuh, R.G., Darma, A., Basuki, S., Rossyanti, L., Sudarmo, S.M. & Venema, K. (2023). Mono-parasitic and poly-parasitic intestinal infections among children aged 36–45 months in East Nusa Tenggara, Indonesia. *Tropical Medicine and Infectious Disease* **8**: 45. https://doi.org/10.3390/tropicalmed8010045

Booth, M. & Bundy, D. (1995). Estimating the number of multiple-species geohelminth infections in human communities. *Parasitology* **111**: 645-653. https://doi.org/10.1017/s0031182000077131

Bosch, F., Palmeirim, M.S., Ali, S.M., Ame, S.M., Hattendorf, J., Keiser, J. & Cantacessi, C. (2021). Diagnosis of soil-transmitted helminths using the kato-katz technique: What is the influence of stirring, storage time and storage temperature on stool sample egg counts? *PLoS Neglected Tropical Diseases* **15**: e0009032. https://doi.org/10.1371/journal.pntd.0009032

BPS-Statistics Indonesia Nusa Tenggara Timur Province. (2024). Source of Water Supplay (Percent), 2023. BPS-Statistics Indonesia Nusa Tenggara Timur Province. https://ntt.bps.go.id/en/statistics-table/2/MjM3IzI%3D/source-of-water-supplay.html. Accessed 01 November 2024.

Brooker, S., Bethony, J. & Hotez, P.J. (2004). Human hookworm infection in the 21st century. *Advances in Parasitology* **58**: 197-288. https://doi.org/10.1016/S0065-308X(04)58004-1

Brooker, S., Clements, A.C.A. & Bundy, D.A.P. (2006). Global epidemiology, ecology and control of soil-transmitted helminth infections. *Advances in Parasitology* **62**: 221-261. https://doi.org/10.1016/S0065-308X(05)62007-6

Centers for Disease Control and Prevention. (2017). Trichuriasis – Laboratory Identification of Parasites of Public Health Concern. CDC. https://www.cdc.gov/dpdx/trichuriasis/index.html. Accessed 28 April 2024.

Cools, P., Vlaminck, J., Albonico, M., Ame, S., Ayana, M., Antonio, B.P.J., Cringoli, G., Dana, D., Keiser, J., Maurelli, M.P. *et al*. (2019). Diagnostic performance of a single and duplicate Kato-Katz, Mini-FLOTAC, FECPAKG2 and qPCR for the detection and quantification of soil-transmitted helminths in three endemic countries. *PLoS Neglected Tropical Diseases* **13**: e0007446. https://doi.org/10.1371/journal.pntd.0007446

Dagne, N. & Alelign, A. (2021). Prevalence of intestinal protozoan parasites and associated risk factors among school children in Merhabete District, Central Ethiopia. *Journal of Parasitology Research* **2021**: 9916456. https://doi.org/10.1155/2021/9916456

Darlan, D.M., Ananda, F.R., Sari, M.I., Arrasyid, N.K. & Sari, D.I. (2018). Correlation between iron deficiency anemia and intestinal parasitic infection in school-age children in Medan. *IOP Conference Series: Earth and Environmental Science* **125**: 012059. https://doi.org/10.1088/1755-1315/125/1/012059

Davis, S.M., Worrell, C.M., Wiegand, R.E., Odero, K.O., Suchdev, P.S., Ruth, L.J., Lopez, G., Cosmas, L., Neatherlin, J., Njenga, S.M. *et al*. (2014). Soil-transmitted helminths in pre-school-aged and school-aged children in an urban slum: A cross-sectional study of prevalence, distribution, and associated exposures. *American Journal of Tropical Medicine and Hygiene* **91**: 1002-1010. https://doi.org/10.4269/ajtmh.14-0060

de Lima Corvino, D.F. & Horrall, S. (2023). Ascariasis. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK430796/. Accessed 23 May 2025.

Djuardi, Y., Lazarus, G., Stefanie, D., Fahmida, U., Ariawan, I. & Supali, T. (2021). Soil-transmitted helminth infection, anemia, and malnutrition among preschool-age children in Nangapanda Subdistrict, Indonesia. *PLoS Neglected Tropical Diseases* **15**: e0009506. https://doi.org/10.1371/journal.pntd.0009506

Fauziah, N., Aviani, J.K., Agrianfanny, Y.N. & Fatimah, S.N. (2022). Intestinal parasitic infection and nutritional status in children under five years old: A systematic review. *Tropical Medicine and Infectious Disease* **7**: 371. https://doi.org/10.3390/tropicalmed7110371

Getahun, W. & Adane, M. (2021). Prevalence of acute diarrhea and water, sanitation, and hygiene (WASH) associated factors among children under five in Woldia Town, Amhara Region, northeastern Ethiopia. *BMC Pediatrics* **21**: 227. https://doi.org/10.1186/s12887-021-02668-2

Ghodeif, A.O. & Jain, H. (2023). Hookworm. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK546648/. Accessed 23 May 2025.

Government of Republic of Indonesia. (2008). Government Regulation No. 47/2008 concerning Compulsory Education. Government of Republic of Indonesia. https://peraturan.bpk.go.id/Details/4861/pp-no-47-tahun-2008. Accessed 15 May 2024.

Gunasari, L.F., Triana, D. & Reyuda Suringgar, S. (2021). Accuracy of the Kato-Katz and direct examination in the diagnosis of worms in preserved feces. The 8th UGM Public Health Symposium. Yogyakarta, Indonesia.

Jourdan, P.M., Lamberton, P.H.L., Fenwick, A. & Addiss, D.G. (2018). Soil-transmitted helminth Infections. *The Lancet* **391**: 252-265. https://doi.org/10.1016/S0140-6736(17)31930-X

Kang, H. (2021). Sample size determination and power analysis using the G*Power software. *Journal of Educational Evaluation for Health Professions* **18**: 17. https://doi.org/10.3352/JEEHP.2021.18.17

Lepper, H.C., Prada, J.M., Davis, E.L., Gunawardena, S.A. & Hollingsworth, T.D. (2018). Complex interactions in soil-transmitted helminth co-infections from a cross-sectional study in Sri Lanka. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **112**: 397-404. https://doi.org/10.1093/trstmh/try068

Loukas, A., Hotez, P., Diemert D, Yazdanbakhsh, M., McCarthy, J.S., Correa-Oliveira, R., Croese, J. & Bethony, J.M. (2016). Hookworm infection. *Nature Reviews Disease Primers* **2**: 16088. https://doi.org/10.1038/nrdp.2016.88

Mahmud, M.A., Spigt, M., Bezabih, A.M., Pavon, I.L., Dinant, G.J. & Velasco, R.B. (2015). Efficacy of handwashing with soap and nail clipping on intestinal parasitic infections in school-aged children: A factorial cluster randomized controlled trial. *PLoS Medicine* **12**: e1001837. https://doi.org/10.1371/journal.pmed.1001837

Manz, K.M., Clowes, P., Kroidl, I., Kowuor, D.O., Geldmacher, C., Ntinginya, N.E., Maboko, L., Hoelscher, M. & Saathoff, E. (2017). *Trichuris trichiura* infection and its relation to environmental factors in Mbeya region, Tanzania: A cross-sectional, population-based study. *PLoS One* **12**: e0175137. https://doi.org/10.1371/journal.pone.0175137

Ministry of Health of The Republic of Indonesia. (2014). Regulation of the Minister of Health No. 25/2014 concerning Children's Health Efforts. Ministry of Health of the Republic of Indonesia. https://peraturan.bpk.go.id/Details/117562/permenkes-no-25-tahun-2014. Accessed 02 October 2024.

Ministry of Health of The Republic of Indonesia. (2015). Performance Evaluation Report of the Directorate General of PP and PL in 2015. In: Ministry of Health of the Republic of Indonesia. Jakarta: Ministry of Health of the Republic of Indonesia, pp. 1-79.

Ministry of Health of The Republic of Indonesia. (2017). Regulation of the Minister of Health No. 15/2017 concerning Control of Worms. Ministry of Health of the Republic of Indonesia. https://peraturan.bpk.go.id/Details/111981/permenkes-no-15-tahun-2017. Accessed 02 October 2024.

Ministry of Health of The Republic of Indonesia. (2023). The Ministry of Health issues a public awareness campaign regarding several tropical diseases. Ministry of Health of the Republic of Indonesia. https://p2p.kemkes.go.id/kemenkes-minta-masyarakat-untuk-waspadi-sejumlah-penyakit-tropis-ini/. Accessed 12 April 2024.

Ministry of Villages and Development of Disadvantaged Regions of Indonesia. (2015). Data on The Least Developed Villages in Indonesia. Ministry of Villages and Development of Disadvantaged Regions of Indonesia. https://kemendesa.go.id/berita/assets/images/gallery/einfo/sangat tertinggal.pdf. Accessed 03 January 2025.

Ministry of Villages and Development of Disadvantaged Regions of Indonesia. (2017). Regulation of the Minister of Villages and Development of Disadvantaged Regions of Indonesia No. 23/2017 concerning the Development and Application of Appropriate Technology in Village Natural Resource Management. Ministry of Villages and Development of Disadvantaged Regions of Indonesia. https://peraturan.bpk.go.id/Download/142819/Permendesa Nomor 22 Tahun 2016.pdf. Accessed 02 October 2024.

Muluneh, C., Hailu, T. & Alemu, G. (2020). Prevalence and associated factors of soil-transmitted helminth infections among children living with and without open defecation practices in Northwest Ethiopia: A comparative cross-sectional study. *American Journal of Tropical Medicine and Hygiene* **103**: 266-272. https://doi.org/10.4269/ajtmh.19-0704

Nisha, M., Amira, N.A., Nadiah, N. & Davamani, F. (2019). Detection of *Ascaris lumbricoides* and *Trichuris trichiura* in various soil types from from an indigenous village in Malaysia. *Tropical Biomedicine* **36**: 201-208.

O'Connell, E.M. & Nutman, T.B. (2016). Molecular diagnostics for soil-transmitted helminths. *American Journal of Tropical Medicine and Hygiene* **95**: 508-514. https://doi.org/10.4269/ajtmh.16-0266

Pasaribu, A.P., Alam, A., Sembiring, K., Pasaribu, S. & Setiabudi, D. (2019). Prevalence and risk factors of soil-transmitted helminthiasis among school children living in an agricultural area of North Sumatera, Indonesia. *BMC Public Health* **19**: 1066. https://doi.org/10.1186/s12889-019-7397-6

Pawlowski, Z.S., Schad, G.A., Stott, G.J. & World Health Organization. (1991). Hookworm infection and anaemia: approaches to prevention and control. In: WHO. Geneva: WHO, pp. 1-96.

Puspita, W.L., Khayan, K., Hariyadi, D., Anwar, T., Wardoyo, S. & Ihsan, B.M. (2020). Health education to reduce helminthiasis: Deficits in diets in children and achievement of students of elementary schools at Pontianak, West Kalimantan. *Journal of Parasitology Research* **2020**: 4846102. https://doi.org/10.1155/2020/4846102

Sari, M.P., Nathasaria, T., Majawati, E.S. & Pangaribuan, H.U. (2020). Soil-transmitted helminth infections, anemia, and undernutrition among school-children in an elementary school in North Jakarta, Indonesia. *Majalah Kedokteran Bandung* **52**: 205-212. https://doi.org/10.15395/mkb.v52n4.2137

Silver, Z.A., Kaliappan, S.P., Samuel, P., Venugopal, S., Kang, G., Sarkar, R. & Ajjampur, S. S.R. (2018). Geographical distribution of soil transmitted helminths and the effects of community type in South Asia and South East Asia – A systematic review. *PLoS Neglected Tropical Diseases* **12**: e0006153. https://doi.org/10.1371/journal.pntd.0006153

Soe, T.K., Sornlorm, K. & Kumar Mahato, R. (2024). Hygiene practice and diarrhea prevalence among underve children in Myanmar: A cross-sectional study. *BMC Pediatrics* **24**: 675. https://doi.org/10.1186/s12887-024-05158-3

Sungkar, S., Pohan, A.P.N., Ramadani, A., Albar, N., Azizah, F., Nugraha, A.R.A. & Wiria, A.E. (2015). Heavy burden of intestinal parasite infections in Kalena Rongo village, a rural area in South West Sumba, eastern part of Indonesia: A cross sectional study. *BMC Public Health* **15**: 1296. https://doi.org/10.1186/s12889-015-2619-z

Tangpong, J., Sedionoto, B., Wasessombat, S., Punsawad, C., Anamnart, W. & Kotepui, M. (2021). High prevalence and risk factors for hookworm and *Strongyloides stercoralis* infections in rural. *Research Square* [**Preprint**]. https://doi.org/10.21203/rs.3.rs-154049/v1

Titcomb, G., Mantas, J.N., Hulke, J., Rodriguez, I., Branch, D. & Young, H. (2021). Water sources aggregate parasites with increasing effects in more arid conditions. *Nature Communications* **12**: 7066. https://doi.org/10.1038/s41467-021-27352-y

Viswanath, A., Yarrarapu, S.N.S. & Williams, M. (2023). *Trichuris trichiura* Infection. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK507843/. Accessed 23 May 2025.

Wendt, E.M., Kamb, M.L. & Montgomery, S.P. (2025). Post-Travel Parasitic Disease Including Evaluation of Eosinophilia. CDC. https://www.cdc.gov/yellow-book/hcp/post-travel-evaluation/post-travel-parasitic-disease.html. Accessed 17 January 2025.

World Health Organization. (1987). Prevention and control of intestinal parasitic infections. In: WHO. Geneva: WHO, pp. 1-88.

World Health Organization. (1998). Guidelines for the evaluation of soil-transmitted helminthiasis and schistosomiasis at community level. In: WHO. Geneva: WHO, pp. 1-48.

World Health Organization. (2007). BMI-for-age (5-19 years). WHO. https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/bmi-for-age. Accessed 06 January 2024.

World Health Organization. (2011). Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. World Health Organization. https://www.who.int/publications/i/item/WHO-NMH-NHD-MNM-11.1. Accessed 06 January 2024.

World Health Organization. (2017). Guideline: preventive chemotherapy to control soil-transmitted helminth infections in at-risk population groups. In: WHO. Geneva: WHO, pp. vii-75.

World Health Organization. (2019). Bench aids for the diagnosis of intestinal parasites (2nd ed.). In: WHO. Geneva: WHO, pp. 1-32.

World Health Organization. (2022). Soil-transmitted helminthiases: number of children (pre-SAC and SAC) requiring preventive chemotherapy for soil-transmitted helminthiases: 2022. WHO. https://apps.who.int/neglected_diseases/ntddata/sth/sth.html?geog=0&indicator=i0&date=2022&bbox=117.88579016393442,-13.128630030959748,133.33660983606558,-3.128630030959748&select=IDN&printmode=true. Accessed 17 January 2024.

World Health Organization. (2023). Soil-transmitted helminth infections. WHO. https://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections. Accessed 17 January 2024.