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Research paper

A comparative study of nutritional status and helminth infections among school-attending Mangyan children in the Philippines

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ABSTRACT

Background: This study focuses on growth patterns and helminth infections to assess the health of the marginalized Mangyan people, the indigenous population on Mindoro in the Philippines.
Methods: In this comparative cross-sectional study, 90 school-attending children aged 5–15 years were recruited from two remote Mangyan villages, Ambang and Sipit Saburan, and the less remote village Baclayan. Participants were recruited through convenience sampling in August and September 2023. Inclusion criteria were permanent residence, school attendance, age 5–15 years, and understanding Tagalog. Exclusion criteria included lack of parental consent and missing key demographic data. Children completed a structured interview, clinical examination, and collection of a stool sample. Interviews covered food intake, disease symptoms, and access to healthcare. Growth patterns were measured using standardized anthropometry, and stool samples were analyzed by same-day conventional microscopy with direct fecal smear. Data were analyzed using Fisher's Exact Test. In addition, odds ratios (OR) with 95 % confidence intervals (CI) were calculated. Ethical approvals were obtained from the local Indigenous People's Structures (IPS), Barangay Council of Villaflor, and the Department of Education.
Results: School-attending children from remote Mangyan villages had a significantly higher prevalence of parasitic infections ($P = .02$). Additionally, living in the remote villages was highly associated with stunted growth ($P < .01$).
Conclusions: School-attending Mangyan children from remote villages have lower growth patterns and a higher prevalence of helminth infections, highlighting the need for targeted health interventions. Future research should focus on larger studies to gather comprehensive data on health needs of this marginalized population.

1. Introduction

Indigenous people (IP) across the globe are characterized by a unique cultural diversity, yet they face widespread marginalization and discrimination within their societies. This marginalization contributes to social inequities, food insecurity, and limited access to health resources, which leads to a range of health challenges [1]. IP are three times more likely to live in extreme poverty and have a lower life expectancy compared to non-indigenous groups, further exacerbating the burden of diseases and malnutrition [2].

Soil-transmitted helminth (STH) infections are a common global health issue, particularly in tropical and subtropical regions, where limited healthcare access and poor sanitation increase the risk among the most vulnerable populations such as IP [3,4]. Helminth infections and malnutrition form a negative feedback loop, where malnutrition weakens immunity, increasing susceptibility to parasitic infections, which in turn exacerbate nutrient deficiencies [5]. Deficiencies in vitamin A, iron, and zinc have been suggested to predispose to helminth infections, while helminth infections can intensify the level of malnutrition and suppress the immune system [6]. Given this connection,

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investigating helminth infections and malnutrition, particularly among marginalized populations, is important as both factors are likely to have an impact on the health status [7,8].

In the Philippines on Mindoro, the Mangyan people represent the IP inhabiting the island. They face challenges due to their geographical isolation and traditional way of life [9]. Historically, the Mangyans were forced into remote areas, and they have continuously struggled with poverty and limited access to modern healthcare [6]. Their traditional belief systems, such as the belief that hygiene practices make individuals more prone to diseases as it attracts harmful spirits, complicate efforts to improve health and sanitation. Additionally, the common practice of chewing betel nut is linked with poor oral hygiene, organ damage, and nutrient deficiencies [10,11], but these harmful effects are not widely known among the Mangyan communities. Combined with their isolation, this exacerbates their vulnerability to parasitic infections and malnutrition.

Despite the challenges faced by the Mangyans, there is a lack of studies focusing on the health and nutritional status of Mangyan children. Especially, research among children in remote villages is limited, and there is a significant absence of comparative analyses between more and less remote Mangyan communities. This study aimed to assess the impact of geographic isolation on child health by comparing the prevalence of helminth infections and malnutrition among remote and less remote Mangyan villages.

The objectives of this study were to assess growth rates among marginalized Mangyan children (1), to assess the prevalence of helminth infections among these children (2) and to examine whether the level of remoteness of the Mangyan villages has an impact on the children's health status by comparing results from the remote Mangyan villages, Ambang and Sipit Saburan with the less remote village of Baclayan (3). It was hypothesized that Mangyan school-attending children from the remote villages would have a higher prevalence of parasitic infections and lower growth rates compared to school-attending children from Baclayan.

2. Methods

2.1. Study design and study setting

This study is a comparative cross-sectional analysis of health outcomes among school-attending Mangyan children from the three Mangyan villages, Ambang, Sipit Saburan, and Baclayan, located around Puerto Galera on the island of Mindoro in the Philippines.

The remote villages of Ambang and Sipit Saburan are located deep in the jungle, approximately 30 km from Puerto Galera, and require several hours of walking to reach. From Puerto Galera, transportation involves a combination of jeepney and/or motorcycle in addition to walking, taking approximately 3–4 h in total. This complexity of transportation further contributes to the remoteness of the villages, as multiple modes of transportation are required to reach them. Ambang is difficult to reach, as the route through the jungle requires several river crossings. Traveling to Ambang during the rainy season, when water levels are high, is impossible. Sipit Saburan is isolated, and has a challenging terrain characterized by tall hills, which makes access even more difficult. Most of the children in these villages have never seen the ocean, despite the relatively short distance from the coast, which illustrates their sociocultural isolation. Life in these villages is characterized by communal living, early marriage and childbirth, and a recent transition from nomadic to settled way of life.

In contrast, Baclayan is more accessible and located on a steep hill 3.5 km from Puerto Galera. The village can be reached by motor bike or car without the need for walking. However, many of the schoolchildren walk long distances to attend the Baclayan Mangyan School. Unlike Ambang Mangyan School and Sipit Saburan Mangyan School, Baclayan Mangyan School appears on maps and is well known among inhabitants in Puerto Galera.

The access to the Mangyan communities was facilitated by Stairway Foundation, a non-governmental organization based in Puerto Galera. The organization has been working with the Mangyan communities since 1991 and has supported the village Baclayan with a daily feeding program for more than a decade [12]. Two research assistants from Stairway Foundation guided the access to the villages, facilitated communication with the locals in the Mangyan communities, and contributed with valuable insights into life on Mindoro.

2.2. Participants

The study population consisted of school-attending children aged 5 to 15 years, who were permanent residents in either Ambang, Sipit Saburan, or Baclayan. Participants were recruited through convenience sampling. Participants were recruited among school-attending children due to accessibility and an established collaboration with local schools. We acknowledge that the results of this study therefore may not reflect the health status of all Mangyan children. The inclusion criteria were permanent residency in the village, school attendance, age 5 to 15 years, and understanding Tagalog. Exclusion criteria were lack of parental consent to participate and missing key demographic data (e.g. age). Additionally, to reduce sex bias, participants were randomly excluded to ensure equal distribution of male and female participants.

A total of 90 school-attending children were included in the study, 30 children from each village. The participants were divided into two comparison groups consisting of children from the remote villages (Ambang and Sipit Saburan) and children from Baclayan.

2.3. Data collection tools

Data was collected from August to September 2023. Data were collected by the first author and the two research assistants from Stairway Foundation through face-to-face interviews and clinical examinations. All study participants answered a close-ended questionnaire. The questionnaire was developed in English, specifically for the purpose of this study, covering essential topics such as self-reported daily food intake, preventive healthcare, and symptoms of diseases. Although the questionnaire was not formally pilot-tested or validated, it was reviewed and refined based on feedback from health professionals, including an infectious disease doctor and a general practitioner from Stairway Foundation. The questionnaire was then translated to Tagalog. Additionally, the questionnaire was discussed with the local research assistants who conducted the interviews. This process helped to ensure that the questionnaire was relevant and understandable for the participants. To minimize interviewer bias, the same local research assistants conducted all interviews using the same questionnaire. The assistants were fluent in both English and Tagalog, with Tagalog as their mother tongue, which helped reduce miscommunication. To reduce recall bias, questions focused on food consumed or symptoms of diseases within the previous week, rather than longer time frames.

After each interview, a clinical examination was made to assess the health status of the participants. Anthropometric measurements were registered by a Standard Powertape Flexometro and a General Master Japan Technology scale from Stairway Foundation. The medical equipment used for the clinical examination was brought to the villages to ensure standardized and consistent measurements. Additional clinical assessments included identification of the Bacillus Calmette-Guérin (BCG) vaccine on the right deltoid region of the arm, measuring upper arm circumference, auscultation of the heart and lungs, abdominal findings, and lymphadenopathy. Finally, the children were asked to provide a stool sample in a specimen container, which were brought to the Puerto Galera Urgent Care Clinic and Diagnostic Center for same-day conventional microscopy-based analysis. The direct fecal smear technique was used by mixing a small amount of feces with a drop of saline. The direct smear technique was chosen because it is the standard diagnostic procedure at the local laboratory and it was not possible to train technicians in a more sensitive method, such as the Kato-Katz. Quality control was ensured by experienced laboratory technicians performing microscopy and re-checking samples, including examination under low (10×) and high (40×) power fields to identify helminth ova, larvae, and protozoan cysts. However, the limitation of direct smear technique is its lower sensitivity compared to other semi-quantitative methods.

2.4. Data analysis

The software program R was used for all statistical analyses. Due to the small sample size, Fisher's Exact Test was applied on 2 × 2 contingency tables to assess associations between categorical variables and statistical significance [13]. Odds ratios (OR) with 95 % confidence intervals (CI) were calculated to quantify the strength of associations. The Department of Education (DepEd) in the Philippines categorizes malnourished children as wasted and/or stunted based on recommendations from the World Health Organization (WHO) [14]. WHO defines stunting as a height-for-age more than 2 standard deviations (SD) below the WHO Child Growth Standards median. Severely stunted is defined as a height-for-age below −3 SD. Wasting refers to low Body Mass Index (BMI)-for-age. A child is classified as wasted if the BMI-for-age is below −2 SD, and severely wasted if it is below −3 SD [15]. Three models were developed to evaluate the effects of stunting, wasting, and living in remote villages on the prevalence of positive stool samples. Additionally, two models were constructed to assess the relationship between living in the remote villages and the outcomes of low growth scores and low BMI.

2.5. Ethics

The study was conducted in accordance with the Declaration of Helsinki, with careful attention to cultural sensitivity and privacy. Permissions were secured from the Indigenous People's Structure (IPS), the Barangay Council of Villaflor, and the Department of Education through local Mangyan schools. Community leaders and teachers supported the study, and meetings were held to ensure transparency and mutual understanding. Informed consent was obtained from parents or guardians, either verbally or in writing, with full respect for community norms and traditions. Health concerns identified during the study were referred to the Stairway Foundation's general practitioner for further evaluation, and children diagnosed with helminth infections were offered treatment with albendazole or mebendazole.

3. Results

3.1. Descriptive statistics

Table 1 summarizes the sociodemographic characteristics of the school-attending Mangyan children across the three villages, highlighting key data on general health status.

Table 1
General information on participants from each village, self-reported food intake, dental hygiene, and preventive health care.

Variable	Ambang (*n* = 30)	Sipit Saburan (n = 30)	Baclayan (n = 30)
General information			
Male	13	16	15
Female	17	14	15
Median age	11 years	9.5 years	10 years
Tribe	Iraya	Iraya	Iraya, Alangan, Hanunoo
Median number of siblings	3	2	3
Born at home	28 (93.33 %)	28 (93.33 %)	15 (50 %)
Self-report ("yes"/"no")			
Intake of sugary snacks/ sweet beverages everyday	17 (56.67 %)	20 (66.67 %)	17 (56.67 %)
Never feeling hungry	14 (46.67 %)	19 (63.33 %)	17 (56.67 %)
Symptoms the previous week			
Feeling unwell	13 (43.33 %)	12 (40 %)	13 (43.33 %)
Nausea/feeling like throwing up	18 (60 %)	17 (56.67 %)	13 (43.33 %)
Stomach pain	19 (63.33 %)	15 (50 %)	17 (56.67 %)
Diarrhea	4 (13.33 %)	7 (23.33 %)	3 (10 %)
Seeing blood in feces	3 (10 %)	8 (26.67 %)	0 (0 %)
Coughing	17 (56.67 %)	16 (53.33 %)	19 (63.33 %)
Dental hygiene			
Never brushing teeth	22 (73.33 %)	25 (83.33 %)	8 (26.67 %)
Never been to the dentist	29 (96.67 %)	29 (96.67 %)	26 (86.67 %)
Chewing betel-nut ("nga-nga")	15 (50 %)	14 (46.67 %)	0 (0 %)
Preventive healthcare			
No handwashing after going to the toilet	12 (40 %)	2 (6.67 %)	0 (0 %)
No handwashing before preparing food	1 (3.33 %)	0 (0 %)	1 (3.33 %)
Keeping no distance when someone is sick	29 (96.67 %)	27 (90 %)	14 (46.67 %)
Vaccinated as a baby/an infant	22 (73.33 %)	13 (43.33 %)	21 (70 %)
Vaccinated against COVID	5 (16.67 %)	1 (6.67 %)	8 (26.67 %)

The participants were comparable in sex distribution and median age, ranging from 9.5 to 11 years, across the three villages. In Ambang and Sipit Saburan, participants were exclusively from the Iraya tribe, which was the only residing tribe in these villages. In Baclayan, most participants were from Iraya, although there were two participants from the Alangan and Hanunoo tribes, as these tribes coexist on the island. Home births were prevalent, with 93.33 % of children born in Ambang and Sipit Saburan being delivered at home, compared to 50 % in Baclayan.

Sugary snacks and sweet beverages were consumed daily in all three villages among more than half of the children, with 56.67 % of the children in Ambang and Baclayan and 66.67 % in Sipit Saburan. Some children reported never feeling hunger, including 46.67 % in Ambang, 63.33 % in Sipit Saburan, and 56.67 % in Baclayan.

Illness symptoms during the previous week were reported in all villages, with 43.33 % of children feeling unwell in Ambang and Baclayan, and 40 % in Sipit Saburan. Common symptoms across the villages included nausea, vomiting, stomach pain, and coughing. While less often reported, the highest percentages of diarrhea and blood in feces were reported in Sipit Saburan (23.33 % and 26.67 %, respectively).

Ambang and Sipit Saburan had the lowest percentage of children brushing their teeth, with 73.33 % in Ambang and 83.33 % in Sipit Saburan never brushing their teeth. Across all three villages, most children had never been to the dentist, with 96.67 % in the remote villages and 86.67 % in Baclayan reporting no prior dental visits. Chewing betel nut was reported only in the remote villages, with 50 % in Ambang and 46.67 % in Sipit Saburan.

Handwashing after going to the toilet was more frequent in Baclayan than in the remote villages. Self-reported vaccination rates varied, with 73.33 % of children in Ambang, 70 % in Baclayan, and 43.33 % in Sipit Saburan vaccinated as infants.

3.2. Growth measurements/clinical examination

Table 2 presents the results from the clinical assessment, including the categorization of participants based on BMI and height measurements. The classification of children's growth using the categories normal, stunted, severely stunted, wasted, or severely wasted were based on recommendations by WHO used by the DepEd in the Philippines (see Supplementary Tables 1–4).

In all three villages, stunting was more prevalent than wasting. In Ambang, 50 % of the included children were classified as severely stunted, compared to 60 % in Sipit Saburan and 16.67 % in Baclayan. Sipit Saburan had the highest percentage of wasted children, with 20 % categorized as wasted and 13.33 % as severely wasted.

The highest prevalence of children with a BCG scar was observed in the most remote villages, with 56.67 % in Ambang and 50 % in Sipit Saburan. In Baclayan, a BCG scar was noted in only 16.67 % of the children. Clinical findings, including heart murmurs and wheezing lung sounds, were exclusively observed among the school-attending children in the most remote villages.

3.3. Parasitic infection prevalence

The majority of the stool samples were positive for at least one parasitic infection, as summarized in Table 3. The differences in the number of stool samples collected from the villages are because not all children were able to provide a sample during the study period. Consequently, fewer school-attending children from Baclayan provided stool samples ($n = 15$), resulting in a smaller sample size compared to school-attending children from Ambang ($n = 28$) and Sipit Saburan ($n = 25$). Sipit Saburan showed the highest prevalence of parasitic infections, where all collected samples were positive. In Ambang, 92.86 % of the samples were positive. In Baclayan, the less remote village, the prevalence of positive parasitic samples was 73.33 %. Reports of visible worms in feces and anal itching were documented in all three villages, with the highest prevalence in the more remote villages. The most common parasitic infection was *Ascaris lumbricoides* (*A. lumbricoides*), frequently in a combination with *Trichuris trichiura* (*T. trichiura*) in Sipit Saburan. Other parasites were only identified in the remote villages.

3.4. Associations between parasitic infections, village and BMI-for-age

Fig. 1 illustrates the variation in the proportion of positive stool samples across the three Mangyan villages. The remote villages had the highest proportions of positive samples, with 100 % in Sipit Saburan and 92.86 % in Ambang compared to 73.33 % in Baclayan.

All participants classified as wasted and severely wasted had positive stool samples across the villages. However, children with positive stool samples were also seen among the participants with normal BMI, as illustrated in Fig. 2.

Table 2
Results from the clinical examination.

Variable	Ambang (n = 30)	Sipit Saburan (n = 30)	Baclayan (n = 30)
Clinical examination			
Wasted children	3 (10 %)	6 (20 %)	5 (16.67 %)
Severely wasted children	0 (0 %)	4 (13.33 %)	1 (3.33 %)
Stunted children	9 (30 %)	5 (16.67 %)	9 (30 %)
Severely stunted children	15 (50 %)	18 (60 %)	5 (16.67 %)
BCG scar (right deltoid region of the arm)	17 (56.67 %)	15 (50 %)	5 (16.67 %)
Heart auscultation: Murmurs	7 (23.33 %)	6 (20 %)	0 (0 %)
Chest findings: Wheezing sounds	3 (10 %)	4 (13.33 %)	0 (0 %)
Abdominal findings: pain and discomfort	14 (46.67 %)	16 (53.33 %)	6 (20 %)
Lymphadenopathy (neck, axilla, inguinal)	20 (66.67 %)	23 (76.67 %)	19 (63.33 %)

Table 3
Self-reported symptoms of parasitic infections and stool sample analysis.

Variable	Ambang (n = 30)	Sipit Saburan (n = 30)	Baclayan (n = 30)
Self-reported symptoms			
Self-reported observation of worms in feces	6 (20 %)	5 (16.67 %)	2 (6.67 %)
Self-reported anal itching	7 (23.33 %)	4 (13.33 %)	3 (10 %)
Analyzed stool samples	***n* = 28**	**n = 25**	**n = 15**
Positive stool samples*	26 (92.86 %)	25 (100 %)	11 (73.33 %)
A. lumbricoides	19 (67.86 %)	24 (96 %)	10 (66.67 %)
T. trichiura	17 (60.71 %)	16 (64 %)	3 (20 %)
A. lumbricoides + *T. trichiura*	10 (35.71 %)	16 (64 %)	2 (13.33 %)
Other parasites#	3 (10.70 %)	2 (8 %)	0 (0 %)
No findings	2 (7.14 %)	0 (0 %)	4 (26.67 %)

* "Positive stool samples" indicate the prevalence of at least one parasite.
# *Strongyloides stercoralis* larvae, hookworm (*Necator americanus* and *Ancylostoma duodenale*), *Entamoeba histolytica* cysts/trophozoites, and *Trichomonas hominis* trophozoites.

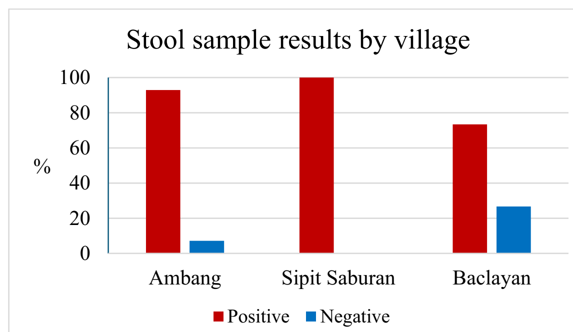

Fig. 1. Results of stool samples in percentage distributed between the villages.

3.5. Statistical significance of associations (key findings from fisher's exact test)

Table 4 and Table 5 present the results from the fisher's exact test, including the 2 × 2 contingency tables, odds ratios (OR), 95 % confidence intervals (CI), and P values.

Regarding positive stool samples, no significant association was found between positive stool samples and low height-for-age (stunted) or low BMI-for-age (wasted), with P values of 0.34 in Model 1 and 0.33 in Model 2. In Model 1, the odds of having a positive stool sample were

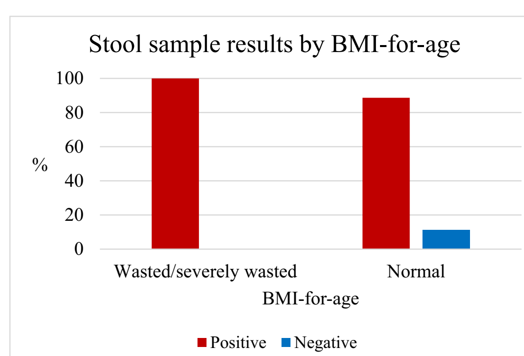

Fig. 2. Stool sample results in percentage among normal and wasted participants.

Table 4
Distribution of stunted and wasted children and village type by stool sample results, with odds ratios (OR), 95 % confidence intervals (CI), and *P* values for Model 1, 2, and 3.

Variable	Positive stool sample* (n = 62)	Negative stool sample (n = 6)	OR (95 % CI)	*P* value
Model 1: *Low height-for-age*				0.34
Stunted#	46	3	2.88 (0.53–15.71)	
Normal	16	3		
Model 2: *Low BMI-for-age*				0.33
Wasted&	15	0	Not estimable†	
Normal	47	6		
Model 3: *Remote villages*				0.02
Remote villages	51	2	9.27 (1.51–57.13)	
Baclayan	11	4		

* "Positive stool sample" indicates the prevalence of at least one parasite.
# The category "stunted" includes both stunted and severely stunted.
& The category "wasted" includes both wasted and severely wasted.
† OR not estimable because one cell has zero counts.

Table 5
Distribution of stunted and wasted children by village type, with odds ratios (OR), 95 % confidence intervals (CI), and *P* values for Model 4 and 5.

Variable	Remote villages (n = 60)	Baclayan (n = 30)	OR (95 % CI)	*P* value
Model 4: *Low height-for-age*				< *0.01*
Stunted#	47	14	4.13 (1.61–10.62)	
Normal	13	16		
Model 5: *Low BMI-for-age*				1.00
Wasted&	13	6	1.11 (0.37–3.27)	
Normal	47	24		

The category "stunted" includes both stunted and severely stunted.
& The category "wasted" includes both wasted and severely wasted.

2.88 times higher in stunted children compared to children with normal height-for-age (95 % CI 0.53–15.71). In Model 2, the odds ratio could not be estimated due to a cell with zero.

A significant association was found between living in the remote villages and having positive stool samples in Model 3 (OR 9.27, 95 % CI 1.51–57.13, $P = .02$). Similarly, in Model 4, children living in remote villages had 4.13 times higher odds of stunted growth (95 % CI 1.61–10.62). Additionally, this association was significant with a *P* value $< .01$. However, no significant association was found in Model 5 between low BMI-for-age (wasted) and living in the remote villages (OR 1.11, 95 % CI 0.37–3.27, $P = 1.00$).

School-attending children living in the remote villages had higher rates of parasitic infections and stunted growth compared to those in Baclayan, but no difference was observed in BMI-for-age.

4. Discussion

Findings from the present study indicate that living in the remote Mangyan villages is associated with a higher level of stunted growth and a higher prevalence of STHs. Although research on the Mangyan population is limited, one prior study investigating microfilariae found that the majority of parasitic infections among the Mangyans [16]. The findings of this study align with those results, indicating a high burden of parasitic infections among the Mangyans. In this study, parasitic infections were predominantly found among school-attending Mangyan children from remote villages, with 92.86 % of stool samples testing positive in Ambang and 100 % in Sipit Saburan. These results are consistent with the sanitary customs that were observed in the remote villages. However, due to the cross-sectional design of this study, it is only possible to identify associations, rather than determine causal relationships between remoteness, parasitic infections, and nutritional status.

Interestingly, *A. lumbricoides* was the most frequent parasite in the Mangyan villages reported in this study, even though *T. trichiura* has been the commonly reported STH infection in studies among indigenous populations in Malaysia, Southeast Asia and the Western Pacific region [17,18].

A. lumbricoides has previously been identified as a common STH in the Philippines. A study conducted in 2015 found that this STH was endemic in Luzon and Visayas [19]. Given its location, Mindoro may also be particularly affected by this helminth, which is therefore likely to be present in the area around the Mangyan villages involved in this study. Additionally, *A. lumbricoides* prevalence has been found to be higher among indigenous people on the island of Mindanao in the Philippines compared to non-indigenous people [3]. *A. lumbricoides* eggs are highly resistant and can survive in soil for several years, increasing the risk of transmission in the Mangyan communities. Furthermore, transmission occurs through ingestion of eggs from contaminated soil, water, or food, making Mangyan children particularly vulnerable to the infection due to inadequate sanitation and poor hygiene practices [19].

Study results also indicate a high prevalence of wasted and stunted children across the three Mangyan villages, with the highest prevalence in the remote villages, Ambang and Sipit Saburan, where a combined 78.33 % of Mangyan children were stunted and 55 % severely stunted. Similar tendencies have been observed in other indigenous communities, such as the Mbyá-Guaraní children in the Argentinian Atlantic Forest in South America, where malnutrition has been previously reported as prevalent – in a study from 2018, only 13.2 % of the included Mbyá-Guaraní children were not classified as malnourished [20].

In the remote villages, where a significant difference in the prevalence of stunting compared to the less remote Baclayan village was observed ($P < .01$), a high proportion of Mangyan children were born outside of hospital settings – 93.33 % in the remote villages compared to 50 % in Baclayan. Previous research on Wayuú children in indigenous communities of Colombia has linked malnutrition to being born outside of hospital settings, which could also be the case for the relation observed in this study [21].

The impact of remoteness has been investigated in other studies involving the indigenous Orang Asli communities in Malaysia [22]. The Orang Asli Negrito tribe has been divided into those living in Inland Jungle Villages and in less remote resettlements, initiated decades ago to improve the health status of the indigenous communities. However, research has shown increased malnutrition and higher burdens of STH infections among those living in the less remote resettlements, compared to the more isolated Inland Jungle Villages [22]. This discordance with the results of the present study illustrates the complex relations between remoteness, lifestyle, and health status. In both the Mangyan and the Orang Asli communities, it is likely that remoteness alone does not necessarily lead to poor health. Instead, changes in lifestyle and environment can have critical negative consequences, if not accompanied by improvement of healthcare access and preservation of traditional practices and lifestyles to ensure sustainable health interventions.

The health disparities faced by indigenous populations highlight the need for targeted public health interventions. Generally, the prevalence of STH infections remains high in the Philippines, despite years of a national mass drug administration (MDA) program [4]. However, the study sites in the Mangyan villages do not have regular access to these interventions, perhaps due to the isolation of the communities. Furthermore, inadequate sanitation, insufficient deworming across entire households, lack of education and awareness could contribute to the high level of parasitic infections.

In Panamá, a previous study on the indigenous Ngäbe children found that reinfection with STHs occurred rapidly after treatment with albendazole and returned to be three times higher than the baseline levels within 9 months [23]. Several factors may contribute to these results such as poor sanitation, the efficacy of the deworming treatment, the health status of the children, and a rainy climate. Wet soil plays a role in the transmission of *A. lumbricoides,* because it facilitates the survival of the larvae, which can lead to faster reinfection [23]. Similarly, a study conducted in Peru on the indigenous Matsigenka people found that 70.7 % of the included children were stunted and remained malnourished after receiving albendazole treatment [24]. The prevalence of *A. lumbricoides* remained at 18 % two weeks post-treatment, also indicating a rapid reinfection cycle.

While regular distribution of MDA programs remains essential to reduce the prevalence of parasitic infections, improving the health outcomes of indigenous communities in the long-term requires comprehensive health strategies that extend beyond MDA. These strategies should integrate environmental interventions, education, improved sanitation and hygiene in the communities. Additionally, combining multiple deworming treatments could increase the efficacy and lower reinfection rates. An integrated strategy has shown to control STHs in some regions globally and offers the best prospects for breaking the cycle of reinfection [24].

Ensuring the sustainability of health interventions requires that indigenous communities can feel ownership over these initiatives. This can be achieved by meaningful involvement of tribal leaders and community members in the development and implementation of these strategies.

Interventions that strengthen the community's ability to manage their health problems independently can lead to healthier futures for marginalized populations. Mobile health clinics could be offered regularly and health workers in the local community should be trained to take care of basic healthcare services. Nutritional programs that provide education on dietary intake, promote local food sources, and offer micronutrient supplements could also be relevant.

The uniqueness of the data gathered in this study is one of its main strengths. To the best of the authors' knowledge, research in the specific Mangyan villages included in this study has not been reported before, making the findings valuable for understanding the health status of this marginalized population. By focusing on indigenous and isolated communities, this study not only addresses specific gaps in scientific literature, in relation to malnutrition and parasitic infections, but also contributes for better research representation of a marginalized population.

In addition to the medical insights, the study also considered the strong traditional belief systems of the Mangyan communities, where medical practices often involve the use of herbs and spiritual rituals to heal illnesses. Recognizing these cultural aspects was important, as medical and cultural insights were combined in the study through health examinations, inputs from the local research assistants, and meetings with the residents in the Mangyan villages to understand their way of life and their own perceptions of health challenges. This knowledge was not considered as qualitative data collected systematically, but information gathered through field observations and community engagement in the village. However, it provided a better understanding of cultural practices related to hygiene and care-seeking. One of the research assistants had been working in the specific communities for two decades which helped the Mangyans feel comfortable and familiar with the visiting research group. Additionally, it was crucial that the anthelmintic treatment was presented as a voluntary option and acknowledging the general apprehension against surgical procedures. Therefore, the study was kept strictly observational, ensuring that the participants and their families were not pressured into any medical treatments. These approaches prioritized respect for local beliefs and autonomy to avoid further marginalization of the Mangyan population.

The small sample size is the main limitation of the study, and the results might not be applicable to Mangyan villages in a larger context. The sample size was constrained not only by the remote location of the villages but also by the small population within them. Additionally, it was logistically challenging to gain access to more villages within the timeframe and resources available. As data collection was conducted over a short period from August to September, seasonal variations in helminth infections prevalences and nutritional status may not be highlighted, which is a limitation of the findings. Another limitation is the different number of stool samples collected in the three villages, with only 15 samples from Baclayan, compared to 28 samples from Ambang, and 25 samples in Sipit Saburan. In Baclayan, fewer children returned stool samples, resulting in a smaller number ($n = 15$) compared to the other villages. However, the children from Baclayan were able to provide samples in a longer period because of the shorter distance to Puerto Galera, and because the first author and research assistants made additional visits to collect more samples. The children from Baclayan appeared more embarrassed to provide stool samples compared to those from the more remote villages of Ambang and Sipit Saburan, which might have contributed to the different number. While this may have influenced the statistical power, Fisher's Exact Test was used to account for small and unequal sample sizes, supporting valid comparisons between villages. Odds ratios (OR) and 95 % confidence intervals (CI) were calculated to quantify the strength of the associations. However, estimates were imprecise, as reflected by wide CI due to low cell counts. Adjustments for potential confounders, such as age and sex, were not performed due to the limited statistical power.

A key limitation of this study is that it only included school-attending children. This may have led to an underestimation of the prevalence of helminth infections and malnutrition, as children not attending school can be more socioeconomically disadvantaged and have poorer health outcomes. This introduces selection bias, and as a result, the findings may not reflect the health status of all Mangyan children in the villages.

Another limitation concerns the laboratory technique used in this study. The direct fecal smear can be considered as a method with a limited sensitivity. However, in highly endemic areas this method is adequate for detecting high concentrations of eggs of STH, such as *A. lumbricoides* and larvae of *Strongyloides stercoralis* [25]. As a qualitative method, it detects the presence of parasitic infections but does not quantify the burden of infection. Therefore, the level of worms could not be assessed.

Additionally, some children were shy and unable to answer all the questions in the interview, leading to responses from siblings, which may have affected data reliability. Children could also hear each other's interviews which could have influenced their responses. Language barriers, including translating interviews to Tagalog, might have affected the reliability of self-reported responses due to potential loss of meaning. A limitation is the reliance on self-reported data for hygiene, symptoms, and food intake, which may introduce reporting bias. Direct verification or cross-checking of participants individual answers was not possible due to the challenges by interviewing children and the context within the indigenous communities. The collective responses were compared to field notes from observations of daily life like available food in the communities, hand-washing practices and sanitation and conversations with schoolteachers to assess the plausibility of participants answers. Some of the data had to be excluded due to discrepancies in children's reported food intake compared to the availability of food in the village.

Therefore, the nutritional intake was not systematically assessed and conclusions regarding dietary adequacy cannot be drawn from this study. This study only determined the children's stunting, wasting, and helminth infections, thereby not offering other important health outcome markers such as determination of anemia or broader nutritional deficiency. Contextual information on existing health programs in the study villages was not available, as no official records exist, and previous health interventions have not been systematically documented. During fieldwork, it was observed that deworming had been attempted in the communities. However, these efforts were not systematic and reinfection among the children occurred rapidly. This suggests that deworming alone may be insufficient. However, such information would have provided valuable insight into the health situation in the study area.

Finally, the classifications of stunted and wasted children, as defined by the DepEd in the Philippines, might not be fully applicable to ethnical groups such as the Mangyan children. BMI has several limitations as a measurement tool, such as the fact that it does not consider body shape or the distribution of muscle versus fat mass [26]. Additionally, BMI standards vary by age, sex, and ethnicity [27], and were originally developed on white male populations [28], which might not reflect body shape variations in other populations. For example, studies have shown that Asian populations have a lower mean BMI compared to European populations [26]. Other measurements, such as waist and upper-arm circumference, waist-to-height ratio, and body fat percentage can contribute to a more nuanced view of the body composition [29]. Measurement errors must also be considered as anthropometry can be sensitive to miscalculations. Inaccuracy of anthropometric measurements can be caused by the equipment quality and variations in the technique, though efforts were made to standardize the procedure.

The results presented in this study are a baseline for future research among the Mangyans. In future research studies, it would be relevant to conduct a larger-scale study across more Mangyan villages on Mindoro. Investigating respiratory infections among the Mangyan children would be valuable, as coughing is a frequent symptom reported in this study. Future studies should include detailed dietary assessments and other health metrics such as a determination of anemia, broader nutritional deficiency, and socioeconomic status. Additionally, water, sanitation, and hygiene (WASH) conditions should be included to better understand their impact on helminth transmission in the Mangyan communities. Besides this, implementation of periodic MDA programs and hygiene education interventions to reduce the STH infections should be developed with consideration of the cultural context and evaluated for their effectiveness in these marginalized communities. A combined intervention approach that include regular MDA alongside education on hygiene and sanitation, developed in close collaboration with the Mangyan communities, might have an effect in reducing parasitic infections and improving health status.

5. Conclusion

School-attending Mangyan children living in the more remote villages of Mindoro have a significantly higher prevalence of stunted growth and parasitic infections compared to the less remote Baclayan village. There is need for targeted health interventions, particularly focused on indigenous and geographically isolated communities. Future research, with larger study populations and longitudinal designs, is essential to further investigate the prevalences and associations reported in this study. Further studies should also involve more Mangyan communities on Mindoro to obtain comprehensive data on the health needs of this marginalized indigenous population, considering both medical efforts and an understanding of their unique cultural context.

CRediT authorship contribution statement

Ida Marie Aaberg Mortil: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Francisca Gaifém:** Writing – review & editing. **Chalotte Willemann Stecher:** Resources, Methodology, Conceptualization. **Christian Morberg Wejse:** Resources. **Tara Ballav Adhikari:** Writing – review & editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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