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Childhood Malnutrition and Parasitic Helminth Interactions

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Background. There is evidence to support that nutritional deficiency can reduce the body's immune function, thereby decreasing resistance to disease and increasing susceptibility to intestinal parasites.

Methods. A cross-sectional survey was carried out on 693 school-aged children from 5 schistosomiasis-endemic villages in Northern Samar, the Philippines. Data on dietary intake, nutritional status, and intestinal parasitic infection were collected.

Results. The prevalence of stunting, thinness, and wasting was 49.2%, 27.8%, and 59.7% of all children. The proportion of children infected with *Schistosoma japonicum* (15.6%, $P = .03$) and hookworm (22.0%, $P = .05$) were significantly lower among children who met the recommended energy and nutrient intake (RENI) for total calories. The percentage of children infected with *Trichuris trichiura* was highest among children who did not meet the RENI for energy (74.1%, $P = .04$), iron (73.4%, $P = .01$), thiamine (74.0%, $P = .00$), and riboflavin (73.3%, $P = .01$). Susceptibility to having 1 or more parasitic infections was significantly associated with poor intake of energy ($P = .04$), thiamine ($P = .02$), and riboflavin ($P = .01$).The proportion of stunted children was significantly higher among children who did not meet the RENI for energy (68.9%, $P = .002$), protein (54.0%, $P = .004$), or niacin (30.8%, $P = .02$) and for those infected with hookworm (31.8%, $P = .0002$). After adjusting for potential confounders, protein intake less than the RENI (odds ratio [OR], 1.48; 95% confidence interval [CI], 1.03–2.14), and hookworm infection (OR, 1.77; 95% CI, 1.22–2.55) were the major predictors of stunting.

Conclusions. The results support the hypothesis that poor nutrient intake may increase susceptibility to parasitic diseases and together they negatively affect childhood nutritional status.

Keywords. childhood; adolescents; malnutrition; intestinal parasites; schistosomiasis.

Nutritional deficiencies and infectious diseases can negatively impact the nutritional status of children and adolescents [1, 2]. Intestinal helminth infections can damage a child's internal mucosa, leading to impaired digestion and poor absorption of nutrients [3]. Deficiencies in macro- and micronutrient intakes during childhood can impair both physical and cognitive growth as well as increase the risk of mortality [4]. Moreover, inadequate intake of selected micronutrients can cause immune deficiency and increase susceptibility to infection [5].

The micronutrients vitamin A, vitamin B12, vitamin C, β-carotene, riboflavin, zinc, selenium, and iron all have immunomodulating functions, enabling them to influence the course of an infection [5]. Laboratory studies have shown that vitamin A deficiency can reduce schistosome (human bloodfluke)–specific antibody responses, suggesting a possible link between vitamin A deficiency and susceptibility to schistosomiasis [1]. Deficiency of some nutrients may reduce the host's immune function, impairing the body's resistance to infectious diseases and increasing susceptibility

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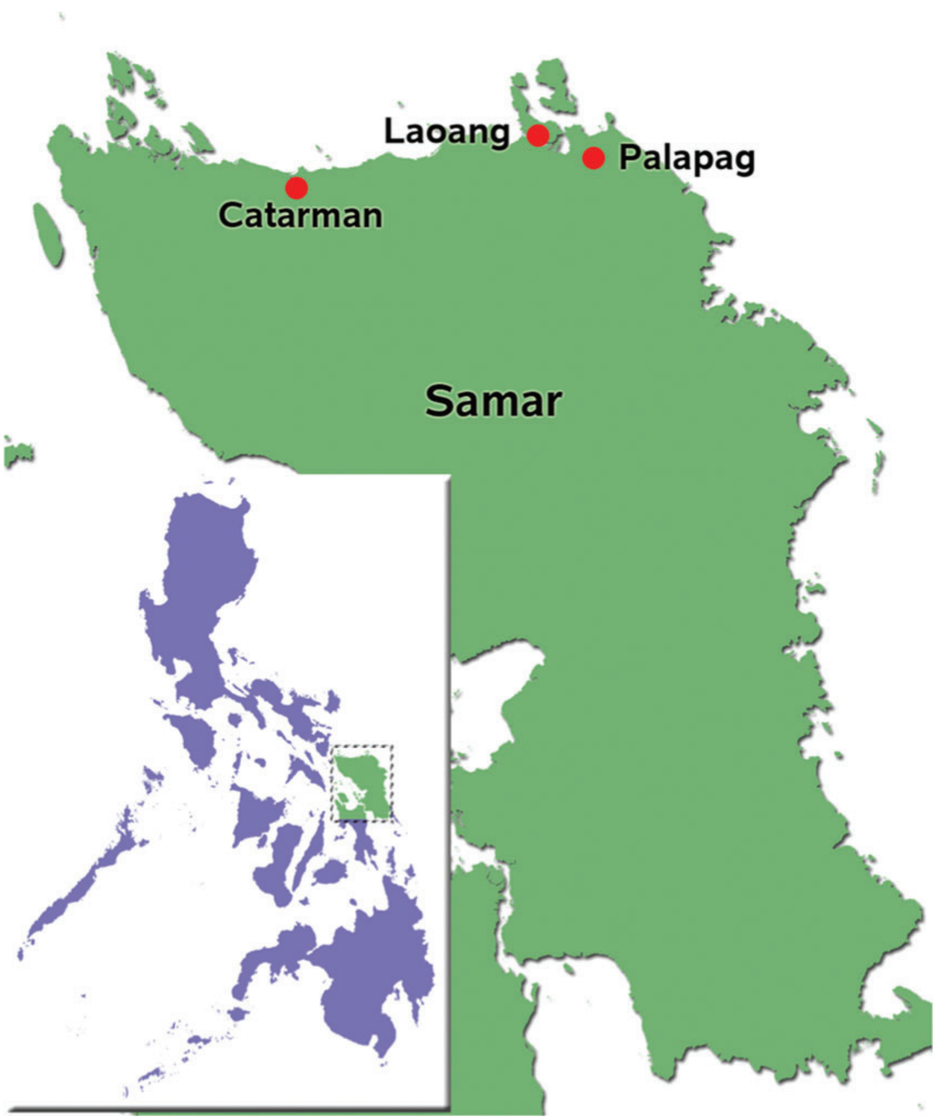

Figure 1. Map illustrating the location of the study villages in Palapag, Northern Samar, the Philippines.

to intestinal parasites [6]. Once present, parasitic infections can promote the further loss of nutrients, leading to reduced growth and poor nutritional status as part of a vicious cycle [7]. Children aged 5–14 years suffer from the highest burden of infectious disease [8], partly due to their increased behavioral risk, frequent outdoor exposure, and poor personal hygiene [9].

Malnutrition and parasitic diseases are found in similar geographical areas [7]. Parasitic infections are prevalent in tropical and subtropical regions where sanitation is poor and poverty is high [3]. This is true for the Philippines, where >12 million people are exposed to schistosomiasis. The disease is endemic in 28 of the 81 provinces and affects almost all of the Eastern Visayas, the Mindanao region, and several provinces in Luzon [10]. Recent research from China found that macronutrient intake was lower across rural areas, which meant that populations in schistosome-endemic areas were threatened by both infection and undernutrition [2]. Likewise, the latest Filipino nutrition survey reported that the proportion of households meeting the national recommendations for energy, protein, and iron are lowest in the provinces where schistosomiasis is most prevalent [11]. Similarly, stunting among children aged ≥5 is also most prevalent in these areas [12].

There is a significant body of evidence regarding the association between parasitic infection and poor nutritional status [2, 13]. However, less is known about the effect that macro- and micronutrient deficiencies have on increasing a host's susceptibility to contracting infectious diseases [4, 14]. Therefore, this study aimed to test the hypothesis that poor macro- and micronutrient intake is associated with increased susceptibility to parasitic disease, and that together they negatively affect the nutritional status of children and adolescents living in Northern Samar, the Philippines.

METHODS

Study Area

The cross-sectional survey was conducted in 5 *Schistosoma japonicum*–endemic rice-farming villages in Palapag, Northern Samar, the Philippines (Figure 1). The area is highly endemic for intestinal helminth infections. Indeed, the Visayas have the highest recorded prevalence of soil-transmitted helminths, including hookworm, *Ascaris*, and *Trichuris* in the Philippines [10]. Northern Samar is considered to be a very rural area, with more than half of its inhabitants living in rural dwellings [15]. Northern Samar's poverty incidence is 21.4%, higher than that of the national rate [16].

Study Design and Population

Data were collected during June 2013 at the respective Municipal Health Centers of each study village. Study participants were selected using the village census lists for all 5 villages. All of the study participants were aged between 6 and 14 years of age. The survey included data on dietary intake, household condition, stool examination, and nutritional status. The Griffith University Ethics Committee in Australia and the Department of Health in the Philippines approved the study.

Nutritional Assessment

Anthropometric measurements of height and weight were collected using standard procedures [17]. Weight was measured using a portable digital scale to the nearest 0.1 kg. Height was assessed to the nearest 0.1 cm using a tape measure. The z values for weight-for-height (WAZ) (children aged <10 years only), body mass index (BMI)–for-age (BAZ), and height-for-age (HAZ) were calculated according to World Health Organization (WHO) guidelines [18] using the new WHO growth standards [19]. Weight-for-height is considered an inappropriate indicator for monitoring child growth beyond the age of 10 due to its inability to distinguish between relative height and body mass. Therefore, BMI-for-age was used to assess thinness/wasting for children aged ≥10 and for adolescents [20]. Based on the z values, the children were categorized as "thin/wasted" (BAZ < −2 and/or WAZ < −2) and "stunted" (HAZ < −2) [15]. Children with z values > −2 for BAZ, WAZ, and HAZ were categorized as "normal."

Dietary Intake Data

Dietary intake information was elicited using a 24-hour recall method. Three qualified nutritionists together with 10 field nurses collected all of the data. Household food utensils were used to assist study participants quantify food portions and liquids consumed. All weights and household food measures recorded in the 24-hour recall were transformed into grams and then into intake values for macro- and micronutrients for each child together with the aid of the food composition tables developed by the Food and Nutrition Research Institute [21]. These tables contain data on 17 food components of 1541 foods commonly consumed in the Philippines [21]. All dietary intake data were categorized as either intake equal/above or

Table 1. Personal, Biological, and Demographic Characteristics of the Study Population

Variable	No. (%)
Sex (n = 693)	
Male	365 (52.7)
Female	328 (47.3)
Age, y (n = 693)	
6–9	289 (41.7)
10–14	404 (58.3)
Household roof material (n = 678)	
Palm leaves/nipa	380 (56.0)
Galvanized iron/cement	298 (44.0)
Height-for-age (n = 693)	
Normal	352 (50.8)
Stunted	341 (49.2)
BMI-for-age (n = 693)	
Normal	500 (72.2)
Thin	193 (27.8)
Weight-for-height (n = 288)	
Normal	116 (40.3)
Wasted	172 (59.7)
Schistosoma japonicum infection (n = 667)	
Egg negative	533 (79.9)
Infected	134 (20.1)
Infected with only *S. japonicum*	13 (2.0)
Ascaris lumbricoides infection (n = 667)	
Egg negative	304 (45.6)
Infected	363 (54.4)
Infected with only *A. lumbricoides*	41 (6.2)
Trichuris trichiura infection (n = 667)	
Egg negative	191 (28.6)
Infected	476 (71.4)
Infected with only *T. trichiura*	124 (18.6)
Hookworm infection (n = 667)	
Egg negative	498 (74.7)
Infected	169 (25.3)
Infected with only hookworm	6 (0.9)
Polyparasitism (n = 667)	
Not infected with any species	102 (15.3)
Infected with 1 species	184 (27.6)
Infected with 2 species	216 (32.4)
Infected with 3 species	134 (20.1)
Infected with 4 species	31 (4.6)

Abbreviation: BMI, body mass index.

Table 2. Helminth Status Among Children Meeting and Not Meeting the Recommended Energy and Nutrient Intake (n = 667)

	Schistosoma japonicum			*Trichuris trichiura*			Hookworm		
Status	EPG−	EPG+	*P* Value	EPG−	EPG+	*P* Value	EPG−	EPG+	*P* Value
Energy kcal			.03*			.04*			.05
≥RENI	205 (84.4)	38 (15.6)		81 (33.3)	162 (66.7)		192 (79.0)	51 (21.0)	
<RENI	328 (77.4)	96 (22.6)		110 (25.9)	314 (74.1)		306 (72.2)	118 (27.8)	
Protein			.44			.03*			.29
≥RENI	278 (81.0)	65 (19.0)		111 (32.4)	232 (67.6)		262 (76.4)	81 (23.6)	
<RENI	255 (78.7)	69 (21.3)		80 (24.7)	244 (75.3)		236 (72.8)	88 (27.2)	
Vitamin A			.31			.41			.79
≥RENI	138 (82.6)	29 (17.4)		52 (31.1)	115 (68.9)		126 (75.4)	41 (24.6)	
<RENI	395 (79.0)	105 (21.0)		139 (27.8)	361 (72.2)		372 (74.4)	128 (25.6)	
Vitamin C			.06			.62			.30
≥RENI	141 (84.9)	25 (15.1)		50 (30.1)	116 (69.9)		129 (77.7)	37 (22.3)	
<RENI	392 (78.2)	109 (21.8)		141 (28.1)	360 (71.9)		369 (73.6)	132 (26.4)	
Calcium			.70			.05			.88
≥RENI	24 (82.8)	5 (17.2)		13 (44.8)	16 (55.2)		22 (75.9)	7 (24.1)	
<RENI	509 (79.8)	129 (20.2)		178 (27.9)	460 (72.1)		476 (74.6)	162 (25.4)	
Iron			.65			.01*			.34
≥RENI	84 (81.6)	19 (18.4)		41 (39.8)	62 (60.2)		73 (70.9)	30 (29.1)	
<RENI	449 (79.6)	115 (20.4)		150 (26.6)	414 (73.4)		425 (75.4)	139 (24.6)	
Thiamine			.06			.00**			.08
≥RENI	100 (86.2)	16 (13.8)		48 (41.4)	68 (58.6)		94 (81.0)	22 (19.0)	
<RENI	433 (78.6)	118 (21.4)		143 (26.0)	408 (74.0)		404 (73.3)	147 (26.7)	
Riboflavin			.20			.01*			.58
≥RENI	83 (84.7)	15 (15.3)		39 (39.8)	59 (60.2)		71 (72.4)	27 (27.6)	
<RENI	450 (79.1)	119 (20.9)		152 (26.7)	417 (73.3)		427 (75.0)	142 (25.0)	
Niacin			.48			.70			.41
≥RENI	394 (80.6)	95 (19.4)		142 (29.0)	347 (71.0)		361 (73.8)	128 (26.2)	
<RENI	139 (78.1)	39 (21.9)		49 (27.5)	129 (72.5)		137 (77.0)	41 (23.0)	

Data are presented as No. (%).

Abbreviations: EPG, eggs per gram; RENI, recommended energy and nutrient intake.

* Statistically significant at $P < .05$, χ^2 test.

** Statistically significant at $P < .01$, χ^2 test.

intake below the national Filipino recommended energy and nutrient intake (RENI) values by age and sex [22]. The RENIs are a source of information on the recommended energy and nutrient intakes for the maintenance of good health [22].

Parasitological Examination

Individuals were asked, over the course of a week, to provide 2 stool specimens from which 6 Kato-Katz thick smears were prepared on microscope slides and examined under a light microscope by experienced laboratory technicians who counted the number of *S. japonicum* and soil-transmitted helminth eggs per slide. For quality control, 10% of slides were randomly selected and reexamined by a senior microscopist at the Research Institute for Tropical Medicine, Manila. Infection status was categorized as 0 or 1 for absence or presence of infection.

Statistical Analysis

Data were analyzed using SAS software, version 9.4. Proportions were used as the statistical parameter in the descriptive analysis. The χ^2 test was used to test for differences in proportions of infection with 1 or more parasites among children meeting and not meeting the RENI and to test for differences in proportions of stunting, wasting, and thinness among infected and uninfected children and among children meeting and not meeting the RENI. All variables found to be significantly associated ($P \leq .05$) with poor nutritional status in the bivariate analysis were included in the multivariate regression analysis. The stepwise logistic regression analysis was performed to assess the association between infection status, the number of parasitic infections, and macro- and micronutrient intake with nutritional status. The risks were expressed as odds ratios (ORs) with 2-sided 95% confidence intervals (CIs).

RESULTS

Population Descriptors

A cross-sectional survey was carried out on 693 children, of whom 52% were male by sex. A total of 41.7% of the study population was aged between 6 and 9 years and the remainder (58.03%) between 10 and 14 years. The majority of children (56.05%) lived in a house with a roof made from either palm leaves or nipa, an indirect indicator of lower socioeconomic status. Stunting and thinness were observed in 49.2%, and 27.8% of all children. Wasting was recorded in 59.7% of all children aged ≤10 years. Infection with *S. japonicum*, *Ascaris lumbricoides*, *Trichuris trichiura*, and hookworm was evident in 20.1%, 54.4%, 71.4%, and 25.3% of the 667 children sampled for parasites, respectively. The majority of the study sample (84.7%) was infected with 1 or more helminth species, with about one-quarter of the study sample (24.7%) infected with ≥3 different worm species (Table 1).

Dietary Intake and Infection

Table 2 examines the association between dietary intake and infection status. The proportion of children infected with *S. japonicum* was significantly lower among children who met the RENI for energy (15.6%, $P = .03$). The percentage of children infected with hookworm was lower among children who met the RENI for energy (21.0%, $P = .05$). The proportion of children infected with *T. trichiura* was highest among children who did not meet the RENI for energy (74.1%, $P = .04$), iron (73.4, $P = .01$), thiamine (74.0%, $P = .00$), riboflavin (73.3%, $P = .01$), and calcium (72.1%, $P = .05$). Susceptibility to having 1 or more infections was significantly associated with poor energy ($P = .04$), thiamine ($P = .02$), and riboflavin intake ($P = .01$) with the proportion of children not meeting the RENI for these nutrients rising as the number of parasite infections increased (not shown).

Dietary Intake and Nutritional Status

The association between dietary intake and nutritional status is depicted in Table 3. It revealed that the proportion of stunted children was significantly higher among children who did not meet the RENI for energy (68.9%, $P = .002$), protein (54.0%, $P = .004$), and niacin (30.8%, $P = .02$).

Parasitic Infection and Nutritional Status

The association between infection status and nutritional status is shown in Table 4. The proportion of stunted children was significantly higher among children infected with hookworm (31.8%, $P = .0002$), and the proportion of nourished children was significantly higher among children not infected with hookworm (80.9%, $P = .0002$). The proportion of stunted children increased significantly as the number of parasite species increased to 4 ($P = .003$). However, the same association was not found to be statistically significant for 3 species—*S. japonicum*, *A. lumbricoides*, and *T. trichiura*. The association between having any parasite and nutritional status was also not found to be statistically significant.

Table 3. Dietary Intake and Nutritional Status (n = 693)

	Height-for-Age		
Status	Normal	Stunted	*P* Value
Energy kcal			.002*
≥RENI	150 (42.6)	106 (31.1)	
<RENI	202 (57.4)	235 (68.9)	
Protein			.004*
≥RENI	200 (56.8)	157 (46.0)	
<RENI	152 (43.2)	184 (54.0)	
Vitamin A			.68
≥RENI	86 (24.4)	88 (25.8)	
<RENI	266 (75.6)	253 (74.2)	
Vitamin C			.23
≥RENI	81 (23.0)	92 (27.0)	
<RENI	271 (77.0)	249 (73.0)	
Calcium			.30
≥RENI	18 (5.1)	12 (3.5)	
<RENI	334 (94.9)	329 (96.5)	
Iron			.28
≥RENI	60 (17.0)	48 (14.1)	
<RENI	292 (83.0)	293 (85.9)	
Thiamin			.27
≥RENI	67 (19.0)	54 (15.8)	
<RENI	285 (81.0)	287 (84.2)	
Riboflavin			.18
≥RENI	58 (16.5)	44 (12.9)	
<RENI	294 (83.5)	297 (87.1)	
Niacin			.02**
≥RENI	272 (77.3)	236 (69.2)	
<RENI	80 (22.7)	105 (30.8)	

Data are presented as No. (%).

Abbreviation: RENI, recommended energy and nutrient intake.

* Statistically significant at $P < .01$, χ^2 test.

** Statistically significant at $P < .05$, χ^2 test.

Determinants of Stunting

Logistic regression analysis was used to find the independent predictors for nutritional status. Energy intake, protein intake, niacin intake, hookworm infection, and infection with all 4 parasites were all found to be significantly associated with stunting in the bivariate analysis. When hookworm was taken out of the "polyparasitic" variable, the remaining 3 parasites lost significance with stunting. Therefore, the "infection with all 4 parasites variable" was not included in the model. Because rice and rice products contribute to the majority of niacin intake

Table 4. **Status of Malnutrition Among Noninfected Children and Children Infected With 1 or More Parasites**

		Height-for-Age (n = 667)			BMI-for-Age (n = 667)			Weight-for-Height (n = 276)			
Parasite	No.	Normal	Stunted	*P* Value	Normal	Thin	*P* Value	No.	Normal	Wasted	*P* Value
Schistosoma japonicum				.10			.11				.70
Egg negative		280 (82.4)	253 (77.4)		391 (81.5)	142 (75.9)			96 (86.5)	140 (84.8)	
Infected		60 (17.6)	74 (22.6)		89 (18.5)	45 (24.1)			15 (13.5)	25 (15.2)	
Ascaris lumbricoides				.43			.24				.72
Egg negative		160 (47.1)	144 (44.0)		212 (44.2)	92 (49.2)			50 (45.0)	78 (47.3)	
Infected		180 (52.9)	183 (56.0)		268 (55.8)	95 (50.8)			61 (55.0)	87 (52.7)	
Trichuris trichiura				.14			.78				.88
Egg negative		106 (31.2)	85 (26.0)		136 (28.3)	55 (29.4)			36 (32.4)	55 (33.3)	
Infected		234 (68.8)	242 (74.0)		344 (71.7)	132 (70.6)			75 (67.6)	110 (66.7)	
Hookworm				.0002*			.36				.36
Egg negative		275 (80.9)	223 (68.2)		363 (75.6)	135 (72.2)			88 (79.3)	123 (74.6)	
Infected		65 (19.1)	104 (31.8)		117 (24.4)	52 (27.8)			23 (20.7)	42 (25.4)	
S. japonicum + *A. lumbricoides* + *T. trichiura* + hookworm				.003*			.24				.79
Negative	102	58 (17.1)	44 (13.5)		71 (14.8)	31 (16.6)		55	20 (18.0)	35 (21.2)	
1 species	184	98 (28.8)	86 (26.3)		133 (27.7)	51 (27.3)		76	35 (31.5)	41 (24.8)	
2 species	216	122 (35.9)	94 (28.8)		160 (33.3)	56 (30.0)		83	33 (29.7)	50 (30.3)	
3 species	134	51 (15.0)	83 (25.4)		99 (20.6)	35 (18.7)		52	19 (17.1)	33 (20.0)	
4 species	31	11 (3.2)	20 (6.1)		17 (3.5)	14 (7.5)		10	4 (3.6)	6 (3.6)	
S. japonicum + *A. lumbricoides* + *T. trichiura*				.054			.18				.93
Negative	108	59 (17.4)	49 (15.0)		73 (15.2)	35 (18.7)		56	21 (18.9)	35 (21.1)	
1 species	213	112 (32.9)	101 (30.9)		156 (32.5)	57 (30.5)		89	38 (34.2)	51 (30.9)	
2 species	278	145 (42.6)	133 (40.7)		208 (43.3)	70 (37.4)		109	43 (38.7)	66 (40.0)	
3 species	68	24 (7.1)	44 (13.5)		43 (9.0)	25 (13.4)		22	9 (8.1)	13 (7.9)	
				.20			.6				.51
Any species	565	282 (82.9)	283 (86.5)		409 (85.2)	156 (83.4)		221	91 (82.0)	130 (78.8)	

Data are presented as No. (%) unless otherwise indicated.

Abbreviation: BMI, body mass index.

* Statistically significant at $P < .01$, χ^2 test.

in the Filipino diet [22] and rice contributes to the majority of energy intake in the Philippines [11], in this study group, niacin was also not included in the model. Sociodemographic characteristics (age, sex, roof material) were found to be associated with both nutritional status and infection status (Table 5). Therefore, these variables were adjusted for in the multivariate analysis. The final model retained protein intake below the RENI (OR, 1.48; 95% CI, 1.03–2.14) and having hookworm infection (OR, 1.77; 95% CI, 1.22–2.55) as the major factors associated with stunting.

DISCUSSION

Intestinal parasites continue to inflict the heaviest burden of disease for school-aged children in developing countries [9], and the majority of this study sample (84.7%) suffered from infection with 1 or more intestinal parasites. The prevalence of infection by soil-transmitted helminths (82.8%) surpasses the national cumulative prevalence of 54% for the Philippines [23]. Of children between 6 and 10 years of age, almost half (42.2%) were stunted and the majority (59.7%) were wasted. These numbers top the national prevalence of stunting (33.6%) and wasting (8.5%) for this age group in the Philippines [12]. Among children aged 10–14 years, more than half (54.2%) were stunted, also exceeding the national prevalence of 36.7% for this age group [12]. The prevalence of stunting found in this study was considerably higher than the prevalence of stunting found in other studies in known helminth-endemic areas worldwide [24–29] (Figure 2).

Stunting, thinness, and wasting were most prevalent among males. Studies from Rwanda and Malaysia also found that male children having helminth infection were significantly more

Table 5. Association Between Major Sociodemographic Characteristics of the Study Population, Nutritional Status, and Infection Status

	Height-for-Age (n = 693)			BMI-for-Age (n = 693)			Weight-for-Height (n = 288)			Infection Status (n = 667)		
Characteristic	Normal	Stunted	*P* Value	Normal	Thin	*P* Value	Normal	Wasted	*P* Value	No Infection	Infection	*P* Value
Age group, y			.002*			.20						.006*
6–9	167 (57.8%)	122 (42.2%)		201 (69.6%)	88 (30.4%)		. . .	. . .		55 (19.9%)	222 (80.1%)	
10–14	185 (45.8%)	219 (54.2%)		299 (74.0%)	105 (26.0%)		. . .	. . .		47 (12.1%)	343 (87.9%)	
Sex			.04**			.04**			.002*			.31
Male	172 (47.1%)	193 (52.9%)		251 (68.8%)	114 (31.2%)		47 (31.5%)	102 (68.5)		49 (14.0%)	302 (86%)	
Female	180 (54.9%)	148 (45.1%)		249 (75.9%)	79 (24.1%)		69 (49.6%)	70 (50.4%)		53 (16.8%)	263 (83.2%)	
Roof material			.001*			.21			.39			.02**
Inexpensive	173 (45.5%)	207 (54.5%)		283 (74.5%)	97 (25.5%)		64 (38.8%)	101 (61.2%)		44 (12.1%)	320 (87.9%)	
Expensive	173 (58.1%)	125 (41.9%)		209 (70.1%)	89 (29.9%)		51 (44.0%)	65 (56.0%)		54 (18.6%)	236 (81.4%)	

Data are presented as No. (%).

Abbreviation: BMI, body mass index.

* Statistically significant at $P < .01$, χ^2 test.

** Statistically significant at $P < .05$, χ^2 test.

likely to be stunted than female children [30, 31]. This could be due to male household responsibilities that demand higher energy expenditure (ie, fishing) [31]. Infection status and stunting were most prevalent among children aged >10 years. A review on schistosomiasis in the Philippines also found that infection susceptibility increased with adolescence and attributed this association to the increased time (exposure) this age group spends working in the field [32]. A similar study from Brazil attributed this association to the increased energy intake demands required by the accelerated growth rate occurring during this age period [33].

We found that children who met the RENI for energy had a significantly lower prevalence of *S. japonicum* infection and a lower prevalence of the hookworm infection than the children who did not meet the RENI. A study conducted in China found a similar association between low intakes of energy and *S. japonicum* infection [2]. A recent study from Ghana found that average to high intake of animal source foods reduced the odds of hookworm infection, whereas low consumption of these foods was significantly associated with hookworm infection status [34]. Whether reduced susceptibility to hookworm infection was due to the specific dietary nutrients found in animal source foods [34] or due to the high-energy content of these foods [35] was not explored further.

A significant association was found between *T. trichiura* infection status and low intakes (below the RENI) of both macro- and micronutrients including protein, energy, iron, thiamine, and riboflavin. A study looking at the interaction between protein energy malnutrition and intestinal infection susceptibility in pigs found that low protein intake was associated with the pigs' reduced resistance to *Trichuris suis* and *Ascaris suum* infections. This study concluded that this could have similar implications for protein-deficient human individuals exposed to *T. trichiura* [36], possibly explaining the significant results we found. A Brazilian study that explored the association between multiple helminth infections, dietary intake, and anemia also found similar results in that low dietary intake of iron was associated with coinfection of *Schistosoma mansoni*, *Ascaris*, hookworm, and *T. trichiura* [37]. However, as these workers did not investigate the relationships between iron intake and each helminth species individually, it is difficult to determine if *T. trichiura* was independently associated with low iron intake [37]. Iron is present in many foods, and as such, its intake is correlated with energy intake [38]. This could partially explain the significant association of *T. trichiura* and low energy intake in our study.

A significant association was also found between the coinfection of all 4 parasites and the low intakes (below the RENI) of energy, thiamine, and riboflavin. Thiamine and riboflavin deficiencies are common in areas like Palapag, where dairy and meat intake are low and mostly rice-based diets are consumed [39]. Riboflavin deficiency can contribute to reduced iron

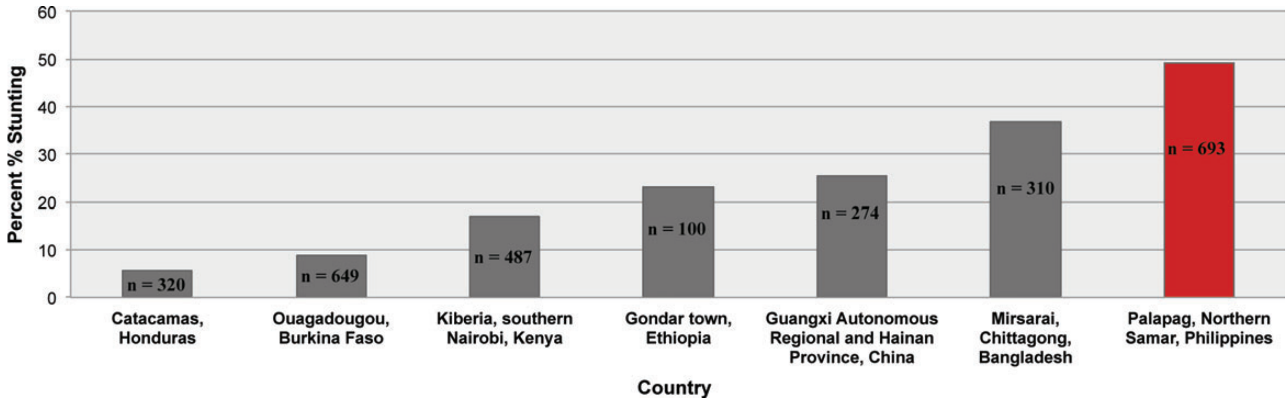

Figure 2. Prevalence of chronic malnutrition (stunting) in various countries worldwide. N represents study sample size.

absorption [40] and increased iron losses [39]. Iron deficiency has been associated with impairments in both the adaptive and innate immunity and with lowering the body's resistance to diseases [4]. The significant relationships found between riboflavin and *T. trichiura*, and riboflavin and coinfection of all 4 parasites, may suggest an underlying association between concurrent micronutrient deficiency interaction and increased parasite susceptibility.

The current study found that hookworm infection and protein intake below the RENI were significant predictors of stunting. However, energy lost its statistical association with stunting in the multivariate model. This could be due to the high correlation between energy and protein. The major source of protein in the diet of children in developing countries comes from plants such as rice [41]. Low protein intake was also associated with stunting in a study from Africa, which found that children whose diets consisted mostly of cassava were at higher risk of inadequate protein intake and stunting [42]. A study from China found that across all groups studied, low protein intake was associated significantly with growth faltering (stunting), whereas lower intakes of energy were not [29].

This study had some limitations. Firstly, limited data were collected on sociodemographic characteristics, which have been found to be associated with malnutrition [43]. Second, information on zinc and iodine intake was not calculated. There is a great deal of evidence supporting a role for zinc in the correct functioning of the immune system [44] and of iodine's role in growth attainment [4]. However, zinc and iodine are not part of the 17 food components included in the Philippines food composition tables [21], so we were unable to consider their effects.

The results reported here support our hypothesis that poor nutrient intake may increase susceptibility to parasitic diseases and together they negatively affect the nutritional status of children and adolescents living in Northern Samar, the Philippines. Conversely, the cross-sectional nature of this research makes it difficult to determine the original cause of poor nutrient intakes in this population. There are a few mechanisms by which intestinal parasites may have affected these children's nutrient intakes and availability. For instance, to combat parasitic infections, the immune system produces cytokines such as interleukin 1 [45, 46]. This cytokine has been found to decrease metabolic activity and suppress appetite by increasing blood leptin, the hormone responsible for suppressing food intake [46]. In regard to nutrient availability, studies have shown that *Ascaris* can cause intestinal damage and thus decrease the surface area available for digestion and absorption [47]. Similarly, hookworm [48], *T. trichiura*, and schistosomiasis can reduce nutrient availability by contributing to blood loss, subsequently causing iron deficiency anemia [49].

Nevertheless, iron deficiency anemia occurs when iron intake and reserves are lower than blood loss [50]. Therefore, well-nourished children with higher nutrient reserves would be less susceptible to the detrimental effects of parasite infections [51]. Thus, it is recommended that future studies test our hypothesis further using a longitudinal study design in this population or in similar endemic areas. Based on our findings, we recommend that future research regarding treatment of children suffering from parasitic infections should take care to evaluate dietary intake prior to commencing any treatment program.

Notes

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