PLOS ONE

RESEARCH ARTICLE

Prevalence, correlates of undernutrition and intestinal parasitic infection among children below 5 years living in the forest community of Ndelele, East Region of Cameroon: A cross-sectional assessment

Bertha Fru Asa[1], Cabirou Mounchili Shintouo[1,2], Robert Adamu Shey[1], Mildred Tita Afoumbom[3], Nadia Siekeh[4], Adolf Yoah[4], Emmanuel Kah[1], Amy Ickowitz[5], Caleb Yengo Tata[6], Emmanuel Asongalem[4], Stephen Mbigha Ghogomu[1]*

1 Department of Biochemistry & Molecular Biology, Faculty of Science, University of Buea, Buea, Cameroon, **2** Department of Gerontology, Faculty of Medicine and Pharmacy, Vrije Universiteit Brussel, Brussel, Belgium, **3** Hasselt University, Martelarenlaan, Hasselt, Belgium, **4** Department of Public Health, Faculty of Health Science, University of Buea, Buea, Cameroon, **5** Center for International Forestry Research (CIFOR) Bogor, Jawa Barat, Indonesia, **6** Forests, Resources and People (FOREP), Botanic Gardens Limbe, Limbe, Cameroon

* stephen.ghogomu@ubuea.cm

OPEN ACCESS

Citation: Asa BF, Shintouo CM, Shey RA, Afoumbom MT, Siekeh N, Yoah A, et al. (2022) Prevalence, correlates of undernutrition and intestinal parasitic infection among children below 5 years living in the forest community of Ndelele, East Region of Cameroon: A cross-sectional assessment. PLoS ONE 17(12): e0278333. https://doi.org/10.1371/journal.pone.0278333

Editor: Fela Mendlovic, Universidad Nacional Autonoma de Mexico, MEXICO

Received: February 4, 2022

Accepted: November 14, 2022

Published: December 8, 2022

Peer Review History: PLOS recognizes the benefits of transparency in the peer review process; therefore, we enable the publication of all of the content of peer review and author responses alongside final, published articles. The editorial history of this article is available here: https://doi.org/10.1371/journal.pone.0278333

Abstract

In low- and middle-income countries, undernutrition often co-exists with intestinal parasites, especially Soil Transmitted Helminth (STH) infections in children. The collective impact of both conditions result in undernutrition and can exacerbate the general poor health status of children. A cross-sectional survey of 422 mother-child (12–59 months old) pairs from 14 villages in the District of Ndelele, East Region of Cameroon, was carried out to assess the magnitude and correlates of undernutrition and intestinal parasites. Socio-demographic data were collected from mothers and anthropometric data were collected from children. Parasitological assessment was performed using a combination of direct microscopy flotation, sedimentation and centrifugation techniques. Correlates of undernutrition and intestinal parasites were identified using multinomial logistic regression at individual and household levels. 83.77% of the children assessed for undernutrition were undernourished and 66.82% were positive for one or more intestinal parasites. It was not uncommon for the study participants to be concurrently infected with two or more intestinal parasites. The most common intestinal parasitic infections detected in the study were *A. lumbricoides*, *E. histolytica/dispar* and *Hookworm* infection. Multinomial logistic regression using Nutritional status as outcome showed that, children who were not exclusively breastfed were 106% (RR = 2.06; C.I = 1.12–3.80) more likely to be underweight compared to those who were exclusively breastfed. The household size of 4 to 6 persons also significantly impacted wasting (p-value = 0.007) at 7% (RR = 1.07, C.I = 0.49–2.32). Analysis by a logistic regression model with STH infection as outcome revealed that, Fingernail cleanness (p-value = 0.044; AOR = 1.75; CI = 1.09–2.78) and household size (p-value = 0.038; AOR = 0.55; CI = 0.32–0.92) were positively associated with intestinal parasite infection at the 5% significant level.

Data Availability Statement: All relevant data are within the manuscript and its Supporting Information files.

Funding: Initials: CIFOR Grant number: ENV/2017/389-491 Sponsor: European Union UTR: https://ec.europa.eu/eip/agriculture/en/find-connect/funding-opportunities The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

This study reveals that intestinal helminthic parasitic infections (STH) and undernutrition are serious health problems in children below five in the study area. To address this dire situation, concerted efforts are needed to improve sanitation, hygiene education access, community deworming programs, and improve diets.

Introduction

Child undernutrition is a major public health problem, especially in many low and middle-income countries [1] where children are at highest risk to die of starvation [2]. For children below 5 years of age, undernutrition can be compounded by severe or repeated infections, with intergenerational influences and consequences [3].

Intestinal parasitic infections (IPIs) are a major public health problem affecting vulnerable populations in low- and middle-income countries [4]. Soil-transmitted helminth infections, (STHs), are neglected tropical diseases (NTDs) and constitute one of the most important causal agents of intestinal parasitic infections. The STHs of major concern to humans are: roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*), and hookworm (*Necator americanus* and *Ancylostoma duodenale*). Studies on NTDs across the world have shown that their impacts have severe consequences, especially in children. Approximately 270 million pre-school children and more than 550 million school-age children live in areas where these parasites are extensively transmitted [5]. In Cameroon, more than 10 million people suffer from intestinal worms with approximately 7.6 million children at risk of STH infection [6, 7]. The prevalence of *A*. *lumbricoides*, hookworm, and *T*. *trichiura* in 2011was 28.1%, 9.8%, and 6.3%, respectively in Cameroon [4].

In low-and-middle income countries, undernutrition often co-exists with STH infections in children [8]. The cause-and-effect relationship between undernutrition and STH infections is reciprocal in that undernutrition may be a predisposing factor for STH infections and several communicable and non-communicable diseases as it affects the physical fitness of the host including their immune status. On the contrary, STH infections may result in undernutrition by consuming nutrients from the host and/or adversely affecting nutrient absorption [9].

Many studies have centered on the prevalence of either undernutrition or intestinal parasite infections alone, and the association of intestinal parasite infections with undernutrition or vice versa has received limited attention, especially in Cameroon. Undernutrition is widespread in Cameroon (35.8%) [10], with prevalence rates among children <5 years of age of 33.0%, 15.0%, and 6.0% for stunting, underweight, and wasting, respectively [11], rates for stunting are even higher in the East Region at 37.3%, although rates of underweight and wasting are similar to national averages [11]. Cameroon has made some progress towards achieving the target for stunting, but 28.9% of children under 5 years of age are still affected. Cameroon is 'on course' for the target for wasting, with 4.3% of children under 5 years of age affected. This study investigates the prevalence and determinants of both undernutrition as well as intestinal parasitic infection in children below five in 14 villages in the East Region of Cameroon.

Material and methods

Study area and population

The Municipality of Ndelele is located in the Kadey Division, East Region of Cameroon. It covers a surface area of 4000 Km^2 with 45,000 inhabitants divided into 2 health districts, and six health areas of 68 villages. The study was carried out in 14 villages in the Ndelele community: Ngotto, Sobolo, Wosso, Banga, Aito, Mendengueme, Sembe, Ndoumbe, Bekele, Dime, Mepouta, Belita, Gamago and Sone.

Study design

A cross-sectional household survey was conducted between April and May 2019. This study was part of a larger project that investigated diets and reliance on fishing around the Kadey River therefore the villages were chosen based on their proximity to the river and use of fishing. Children aged 12–59 months whose parents gave their consent and who had lived in the area for more than 6 months were selected for the study. Children who presented with a detectable handicap that could alter linear growth were excluded from the study. If parents of selected children withdrew informed consent forms or were absent during the household visit, those children were replaced. Children of parents who were not residents of the study area, had moved into the study area within the past 3 months or lacked complete demographic data, were also excluded from the study population. In addition, children who were outliers for nutritional status were also excluded from the study. Subjects in each household were registered and anthropometric, demographic, and parasitological data were collected from each child while sociodemographic data came from the mothers of the children as principal respondents. Interpreters (who were selected community relay agents, familiar to the people), were used to translate and interpret the questions on the questionnaires to the kakor dialect for mothers who had no formal education and could understand neither French nor pidgin English. The investigational methods included the use of structured questionnaires, clinical evaluation, and laboratory experiments.

The sample size was determined using the formula by Fisher [12]. In estimating the sample size (n), 50% prevalence of undernutrition was considered at 95% CI for Z statistics which is conventionally 1.96 and 5% precision giving a target sample size of 385 mother/child pairs. To avoid errors due to non-responses, **10%** of the initial sample size was added (13), hence making an overall sample size of **422**.

Ethical approval

This study was approved by the Cameroon Ethics Committee (No. 0977/A/MINSANTE/SES/SG/DROS) and administrative authorization was obtained from the Divisional Officer of Batouri. Participation in the study was strictly voluntary with written informed consent obtained from parents/guardians.

Socio-demographic data

A socio-demographic questionnaire that had been pre-tested in the Muea (a village in Buea) health area on 30 respondents was used. The rationale for this pre-test was to rephrase poorly-structured questions and to evaluate the time used per questionnaire. At the end of this pre-test, some questions were left out and others were rephrased to eliminate any form of information bias.

Visits to households to administer questionnaires were done in the afternoon to include children returning with their mothers from the farms.

Anthropometrics assessment

Height/length and weight measurements of each child were taken by a trained and certified nurse. A digital weight scale was used to measure the weight of children to the nearest 0.1 kg with the child barefoot and wearing light clothing. Children who were unable to stand on the scale (12–24 months) were weighed with the mother or legal guardian who was thereafter weighed alone, and the differences were used to obtain the net weight of the children.

The height of the children was measured using a calibrated height measuring board to the nearest 0.1cm. The height of a child who could not stand erect was measured in the supine position while that of a child who could stand erect and above 24 months was measured with the child standing against a calibrated height measuring board. Mid-Upper Arm Circumference (MUAC) was measured at the mid-point between the tip of the shoulder and the tip of the elbow of the left upper arm using non-stretchable tape to the nearest 1 mm. WHO Anthro version 3.2.2 software was used to convert the anthropometric measures; age, weight, height/length values into Z-scores of the indices: low Weight-for-Height (WHZ) signifying wasting, low Weight- for-Age (WAZ) signifying underweight, and low Height-for-Age (HAZ) signifying stunting) taking gender of the child into consideration using WHO 2006 standards [13]. In all analyses regarding the nutritional status, Z-scores $<$-6.00 or $>$6.00 were considered outliers and excluded from the study. Accordingly, HAZ (n = 0), WAZ (n = 2) and WHZ (n = 1) were excluded from the study. Undernutrition was diagnosed based on a low weight for height (below -3 z-scores of the median WHO growth standards) or mid-upper arm circumference below 11.5cm (MUAC$<$11.5 cm) or the presence of bilateral pitting oedema based on WHO definition of Severe Acute Malnutrition (SAM).

Parasitological examinations

Direct microscopy. A clean and dried specimen tube that had an integrated spatula was handed to the child's parent or caregiver accompanied by ample instructions and demonstrations on how to get a small portion of fresh stool into the bottles. The parents ensured compliance and the samples collected were immediately examined by a trained laboratory technician. Approximately 2 mg of faeces were mixed with normal saline (0.85% of Sodium Chloride) on a microscopy slide and examined for helminth eggs. Another 2 mg of faeces were mixed with a drop of Lugol's iodine and examined for protozoan cysts at 10X and 40X magnifications to identify any larvae or helminthic eggs. STHs like hookworms (*N*. *americanus*, *A*. *lumbricoides)*, *T*. *trichuria*, which had been associated with undernutrition in other studies and were easily detectable microscopically, were investigated.

Faecal concentration method. Approximately 1.5 g of faecal sample was placed into a clean paper cup containing 7 ml of 10% formal saline (27.0 ml of 37% formaldehyde in 73.0 mL of 0.85% sodium chloride) and stirred using a wooden stick to form a suspension. The suspension was strained through a wet gauze into a clean 15 ml test tube and, if necessary, was adjusted to a total volume of 7 ml by topping up with 10% formal saline. A final volume of 10 mL was obtained by adding 3 mL of ether to the suspension. The mixture was vigorously mixed for 2 min and then centrifuged for 5 min at 2,000 rpm. The centrifugation resulted in four layers comprising the top ether, a debris plug, formalin and sediment containing parasites at the bottom. The debris plug layer was freed from the sides of the tube with an applicator stick and the supernatant was decanted by inverting the centrifuge tube in one smooth motion.

The sediment was withdrawn with a Pasteur pipette and mixed with a drop of iodine solution on a clean, dry microscope slide. The smear was covered with a coverslip and viewed under a light microscope using 10X, 20X and 40X magnifications for detecting the presence of helminth eggs. The morphology of the helminth eggs was confirmed by 2 experienced parasitologists and recorded to their specific genus. Diagnosis was based on the identification of helminth ova in the sample during microscopic analysis.

Statistical analyses

Data were collected using standardized questionnaires, checked for completeness, and entered into Microsoft excel version 13 sheet files. The outcome variables were categorical for the nutritional status (normal, stunting, wasting, and underweight), whereas it was binary for soil-transmitted helminths infection status (positive or negative) for any species. In addition, the potential predictors used were socio-demographic (mothers and children's age, parity, education level, marital status, household size, monthly income, water source, and type of toilet), health status (vaccination and deworming status), as well as feeding and hygiene habits (feeding habits, meal frequency, fingernail cleanness). Before the data analysis, we re-coded some continuous variables. To this end, children's age was classified into 12 to 28, 29 to 45, and 46 to 59 months, whereas it was less than 21, from 21 to 30, 31 to 40, and at least 41 years for mothers age, respectively. Likewise, the household size was re-coded into three levels: from 1 to 3, from 4 to 6, and at least 7 individuals. The sample size considered to assess the risk factors for helminths infections was 422, whereas it was 419 for all analyses with nutritional status as outcome due to the exclusion of three outliers.

Similarly, the meal frequency was dichotomized into less than 3 meals per day and at least three meals. Descriptive statistics were performed using proportions for categorical variables. Also, chi-square and Fisher exact tests were used to compare child gender and soil-transmitted helminths infection status proportions. These comparisons were made for intestinal helminths, intestinal protozoa, and different levels of infections. These levels of infections were single (only one specie), multiple (at least two species), and overall (at least one species) intestinal parasitic infections.

Furthermore, univariate and multivariable logistic regression models were used to assess the association between soil-transmitted helminths infections status and potential predictors. To this end, we first performed the univariate logistic regression, and only variables with a p-value ≤ 0.25 were included in the multivariable regression. The variables included in the multivariable logistic regression were mother's education level, marital status, monthly income, household size, finger cleanness, type of toilet, deworming, water contact and water source. Furthermore, multinomial logistic regression was performed using the different forms of undernutrition as the outcome, and the predictors were socio-demographic characteristics. Also, the children with normal nutritional status were considered as reference for the multinomial logistic regression. Stata version 14 IC (Stata Corp, USA) was used for the data analysis, and a p-value less than 5% was considered statistically significant.

Results

Socio-demographic characteristics of participants

Descriptive statistics. As shown in Table 1, most of the sociodemographic characteristics (variables) were recorded from the 422 mother and child pairs who participated in the study, with the exception of maternal parity (N = 367) and possession of domestic animals (N = 419). Most mothers (33.18%; 140/422) were between 21 and 30 years. However, 64.69% (273/422) of these women were either married or cohabiting. Their predominant source of income was farming, with 93.13% (393/422) farmers. Although 25.36% (107/422) of them had a household size above 6 persons, the majority (54.27%; 229/422) had a household size of between 4 to 6. Only about 6.16% (26/422) of them always washed their hands before a meal compared to 93.83% (396/422) who sometimes or never washed their hands before meals. It was noted that, only about 29.38% (122/422) of the participants were found with clean fingernails with sub-optimal hand washing and shoe-wearing habits. The monthly income of most (71.86%; 303/

Table 1. Sociodemographic characteristics of participants.

Variables	Category	N	Proportion (%)
Maternal parity	1	165	44.96
	2	155	42.23
	3+	47	12.91
Maternal education	No Formal education	65	15.40
	Primary	354	83.89
	Secondary	2	0.47
	Tertiary	1	0.24
Maternal age in years	< 21	80	18.96
	21–30	140	33.18
	31–40	91	21.56
	41+	111	26.30
Marital status	Single	41	9.72
	Married/Cohabiting	273	64.69
	Divorced/Widow(er)	108	25.59
Religion	Christian	405	95.97
	Muslim	17	4.03
Occupation	Farmer	393	93.13
	Housewife	14	3.32
	Student	6	1.42
	Civil Servant	1	0.24
	Private Sector Worker	2	0.47
	Trader	6	1.42
Household size	1–3	86	20.38
	4–6	229	54.27
	6+	107	25.36
Water source	Public Tap (borehole)	246	58.29
	Spring or well	176	41.71
Type of toilet	Pit Latrine	129	30.57
	No toilet	293	69.43
Possession of domestic animals	Yes	265	63.25
	No	154	36.75
Average monthly income	≤68 USD	303	71.80
	>68 USD	119	28.20
Age of the child (months)	12–28	37	8.77
	29–45	146	34.60
	46–59	239	56.64
Gender of the child	Male	185	43.84
	Female	237	56.16
Vaccination status	Complete vaccination	351	83.18
	Partial vaccination	60	14.22
	No vaccination	11	2.61
Deworming (last 3 months)	Yes	122	28.91
	No	300	71.09
Feeding habit (when the child < 6 months)	Exclusive breastfeeding	223	52.84
	Mixed feeding	199	47.16
Meal frequency	< 3 times	317	75.12
	≥3 times	105	27.88

(*Continued*)

Table 1. (Continued)

Variables	Category	N	Proportion (%)
Hand washing habit (before meal)	Sometimes	371	87.91
	Always	26	6.16
	Never	25	5.92
Fingernail cleanliness	Not clean	298	70.62
	Clean	124	29.38
Shoe wearing habits	Sometimes	340	80.57
	Always	68	16.11
	Never	14	3.32
Water contact	Yes	324	76.78
	No	98	23.22

https://doi.org/10.1371/journal.pone.0278333.t001

422) households was less than 68 dollars. Most of the mothers had had some form of formal education (attended primary school). About 58.29% (246/422) of the participants used public taps (boreholes) for drinking and a majority (69.43%; 293/422) did not own a toilet and practiced open defecation.

The majority (56.63%; 239/422) of the children in the study were between 46 and 59 months old and slightly more (56.16%; 237/422) were females. Most (83.18%; 351/422) of the children had had complete vaccination as required on the Extended Program for Immunization (EPI) vaccination calendar in Cameroon, but many children (71.09%; 300/422) had not been dewormed in the past 3 months. Although, 52.84% (223/422) were exclusively breastfed, 75.12% (317/422) took less than three meals a day and about three-quarters (76.78%; 324/422) of the children were in contact with dirty water of rivers, swamps in their daily routine of swimming and fishing.

Nutritional status

Table 2 shows the health/nutritional status of the children. The most frequent nutritional status was undernourished (83.77%; 351/419), while being underweight the most frequent form of undernutrition (32.94%; 138/419).

Socio-demographic predictors of undernutrition among children 12–59 months

Table 3 presents results after performing multinomial logistic regression with nutritional status as the outcome and socio-demographic factors as predictors. It was noticed that the mother's age, monthly income, and gender had no significant effect on the nutritional status. Among underweight children, exclusive breastfeeding habits had a significant impact (p-value = 0.012) on their nutritional status. Children who were not exclusively breastfed were 2.06 (RRR = 2.06;

Table 2. Nutritional status.

Variables (N = 419)	Category	n	Proportion (%)
Undernutrition	Normal	68	16.23
	Undernourished	351	83.77
Forms undernutrition	Normal	68	16.23
	Underweight	138	32.94
	Stunting	93	22.20
	Wasting	120	28.64

https://doi.org/10.1371/journal.pone.0278333.t002

Table 3. Undernutrition risk factors among children 12–59 months old.

Variables	Category	N	n(%)	Chi-square p-value	RRR	95%CI
Underweight (n = 138)						
Mother's age	41+	110	38(34.55)	0.759	Ref	
	31–40	91	30(32.97)		0.60	0.25–1.43
	21–30	138	41(29.71)		0.53	0.24–1.18
	< 21	80	29(36.25)		1.26	0.47–3.36
Household size	1–3	86	27(31.40)	0.525	ref	
	4–6	226	71(31.42)		1.23	0.56–2.68
	7+	107	40(37.38)		1.35	0.57–3.26
Exclusive breastfeeding	Yes	222	61(27.48)	0.012	ref	
	No	197	77(39.09)		2.06**	1.12–3.80
Monthly income	≥68	117	97(32.12)	0.568	ref	
	<68	302	41(35.04)		1.29	0.66–2.66
Gender	Male	185	52(28.11)	0.062	ref	
	Female	234	86(36.75)		0.87	0.46–1.61
Stunting (n = 93)						
Mother's age	41+	110	29(26.36)	0.542	ref	
	31–40	91	20(21.98)		0.53	0.21–1.32
	21–30	138	30(21.74)		0.54	0.23–1.23
	< 21	80	14(17.50)		0.77	0.26–2.25
Household size	1–3	86	16(18.60)	0.140	ref	
	4–6	226	46(20.35)		1.15	0.49–2.72
	7+	107	31(28.97)		1.56	0.60–4.03
Exclusive breastfeeding	Yes	222	57(25.68)	0.069	ref	
	No	197	36(18.27)		1.04	0.53–2.01
Monthly income	≥68	117	65(21.52)	0.595	ref	
	<68	302	28(23.93)		1.30	0.63–2.66
Gender of child	Male	185	49(26.49)	0.060	ref	
	Female	234	44(18.80)		0.50**	0.26–0.96
Wasting (n = 120)						
Mother's age	41+	110	29(26.36)	0.498	ref	
	31–40	91	23(25.27)		0.69	0.28–1.71
	21–30	138	40(28.99)		0.72	0.32–1.63
	< 21	80	28(35.00)		1.41	0.52–3.84
Household size	1–3	86	29(33.70)	0.007	ref	
	4–6	226	73(32.30)		1.07	0.49–2.32
	7+	107	18(16.82)		0.54	0.21–1.38
Exclusive breastfeeding	Yes	222	63(28.38)	0.900	ref	
	No	197	57(28.93)		1.57	0.84–2.93
Monthly income	≥68	117	89(29.47)	0.546	ref	
	<68	302	31(26.50)		1.12	0.56–2.26
Gender of child	Male	185	60(32.43)	0.127	ref	
	Female	234	60(25.64)		0.53**	0.28–0.99

RRR = Relative risk Ratio, CI = Confidence Interval

**: statistically significant (p-value < 0.05)

https://doi.org/10.1371/journal.pone.0278333.t003

C.I = 1.12–3.80)) times more likely to be underweight compared to those who were exclusively breastfed, keeping other variables constant. However, breastfeeding a child had no significant impact on child stunting and wasting. Meanwhile, household size significantly impacted wasting (p-value = 0.007). A child from a household with 4 to 6 persons was 7% (RRR = 1.07, C.I = 0.49–2.32) more likely to be wasted compared to that from a household of size 1 to 3 persons keeping all variables constant. On the contrary, in a household of more than 7 persons the risk of wasting decreased by 54% compared to a house with 1 to 3 persons. There was no significant impact of household size on underweight or stunting.

Prevalence of intestinal parasites and multiple infections

Table 4 depicts a descriptive analysis and differences of proportions between groups. An univariate analysis of the different STH infections based on child gender was carried out. Among the 422 children who participated in the study, 282 (66.82%) were positive for one or more intestinal parasites. Double and triple infections were also common and more among females; 53 study participants (12.56%) were infected by two or more intestinal parasites concurrently. The most common intestinal parasitic infections detected in the study were *A. lumbricoides* (34.12%), *E. histolytica/dispar* (27.96%), and *Hookworm* infection (17.30%). Analysis of the table according to gender did not reveal gender-related differences with respect to infection.

Correlates of intestinal parasitic infections in children

Analysis by a logistic regression model with STH infection (yes or no) as outcome revealed the following as shown in Table 5. Fingernail cleanness (p-value = 0.044; AOR = 1.75; CI = 1.09–2.78) and household size (p-value = 0.038; AOR = 0.55; CI = 0.32–0.92) were positively and negatively associated with intestinal parasite infection at the 5% significant level, respectively. Those whose fingernails were not clean were 1. 75 times more likely to be infected with at least one species of STH compared to those with clean fingernails. On the other hand, the risk of

Table 4. Prevalence of intestinal parasitic infection in children 12–59 months old.

Infection	Category	Infection by gender			
		Total n (%)	Male (n = 185) n (%)	Female (n = 237) n (%)	p-value
Overall Intestinal Parasitic Infection	Yes	282(66.82)	121 (64.41)	161 (67.93)	0.584
	No	140 (33.18)	64 (34.59)	76 (32.07)	
Single Intestinal Parasitic Infection	Yes	229 (54.27)	93 (50.27)	136 (57.38)	0.146
	No	193 (45.73)	92 (49.73)	101 (42.62)	
Multiple Intestinal Parasitic infection	Yes	53 (12.56)	28 (15.14)	25 (10.55)	0.158
	No	369 (87.44)	157 (84.86)	212 (89.45)	
Intestinal Helminthes					
lumbricoides	Yes	144 (34.12)	63 (34.05)	81 (34.18)	0.979
	No	278 (65.88)	122 (65.95)	156 (65.82)	
Hookworm	Yes	73 (17.30)	30 (16.22)	43 (18.14)	0.604
	No	349 (82.70)	155 (83.78)	194 (81.86)	
T. trichiura	Yes	1 (0.24)	1 (0.54)	0 (0)	
	No	421 (99.76)	184 (99.46)	237 (100)	0.438
Intestinal Protozoa					
E. histolytica/dispar	Yes	118 (27.96)	53 (28.65)	65 (27.43)	0.781
	No	304 (72.04)	132 (71.35)	172 (72.57)	
G. lamblia	Yes	2 (0.47)	2 (1.08)	0 (0)	0.192
	No	420 (99.53)	183 (98.92)	237 (100)	

https://doi.org/10.1371/journal.pone.0278333.t004

Table 5. Determinants of intestinal parasitic infection among children 12–59 months old.

Variable	Category	n(%)	STH "no" n(%)	STH "yes" n(%)	Chi-square p-value	UOR	95%CI	AOR	95%CI
Age of children	12–28	37 (8.77)	13(35.14)	24(64.86)	0.301	ref1		ref	
	29–45	146(34.60)	55 (37.67)	91 (62.33)		0.89	0.42–1.90	0.73	0.31–1.69
	46–59	239(56.64)	72(30.13)	167(69.87)		1.25	0.60–2.60	0.91	0.40–2.08)
Gender of children	Male	185(43.84)	64(34.59)	121(65.41)	0.584	ref1		Ref	
	Female	237(56.16)	76(32.07)	161(67.93)		1.12	0.74–1.68	1.06	0.69–1.63
Education level	No Formal education	65 (15.40)	17(26.15)	48(73.85)	0.090	ref1		1	
	Primary	354 (83.89)	121(34.18)	233(65.82)		0.68	037–1.23	0.689	0.365–1.26
	Secondary	2 (0.47)	2(100)	0(0)		-	-		
	Tertiary	1 (0.24)	0(0)	1(100)		-	-		
Marital status	Married/Cohabiting	41 (9.72)	18(43.90)	23(56.10)	0.260	ref1		1	
	Single	273 (64.69)	85(31.14)	188(68.86)		0.57	0.29–1.12	0.4950	0.234–1.013
	Divorced/Widow	108 (25.59)	37(34.26)	71(65.74)		0.86	0.54–1.39	0.865	0.521–1.441
Monthly income	≥ 68 USD	119(28.20)	35(29.41)	84(70.59)	0.303	ref1		ref1	
	< 68 USD	303(71.80)	105(34.65)	198(65.35)		0.78	0.49–0.496	0.823	0.51–1.3334
Household size	1–3	86 (20.38)	25(29.07)	61(70.93)	0.038	0.82	0.43–1.55	1.014	0.4951–2.089
	4–6	229 (54.27)	88(38.43)	141(61.57)		**0.54**	**0.32–0.90**	**0.545**	**0.32–0.923**
	7+	107(25.36)	27 (25.23)	80(74.77)		ref1		ref1	
Finger-nail cleanlin-ess	**Clean**	124 (29.38)	50(40.32)	74(59.68)	0.044	**ref1**		**ref1**	
	Not clean	298 (70.62)	90(30.20)	208(69.80)		**1.56**	**1.01–2.41**	**1.745**	**1.0910–2.78**
Type of toilet	Pit Latrine	129 (30.57)	41(31.78)	88(68.22)	0.687	ref1		ref1	
	No toilet	293 (69.43)	99(33.79)	194(66.21)		1.09	0.70–1.70	1.259	0.80–2.09
Deworming (last 3 months)	Yes	122 (28.91)	45(36.89)	77(68.11)	0.302	ref		ref1	
	No	300(71.09)	95(31.67)	205(68.33)		1.26	0.81–1.95	1.19	0.774–2.04
Water contact	Yes	324 (76.78)	102(31.48)	222(68.52)	0.179	ref		ref1	
	No	98 (23.22)	38(38.78)	60(61.22)		0.72	0.45–1.15	0.71	0.42–1.17
Water source	Public Tap (borehole)	246 (58.29)	80(32.52)	166(67.48)	0.735	ref		ref	
	Spring or well	176 (41.71)	60(34.09)	116(65.91)		0.93	0.61–1.40	1.02	0.65–1.60
Meal frequency	< 3 times	317 (75.12)	103(32.49)	214(67.51)	0.604				
	≥3 times	105(27.88)	37(35.24)	68(64.76)		1.13	0.71–1.79		
Hand washing habit	Sometimes	371 (87.91)	124(33.42)	247(66.58)	0.845				
	Always	26 (6.16)	9(34.62)	17(65.38)		0.94	0.41–2.18		
	Never	25 (5.92)	7(28)	18(72)		1.29	0.52–3.17		

UOR = Unadjusted Odds Ratio, AOR = Adjusted Odds Ratio, CI = Confidence Interval

https://doi.org/10.1371/journal.pone.0278333.t005

being infected was 1.01 times higher for households of 1 to 3 persons than in houses with 4 to 6 persons. All other variables were not associated with the risk of infection at a 5% significant level.

Association of intestinal parasites and undernutrition, stunting, wasting and underweight

Table 6 is similar to Table 3, both tables are multinomial logistic regressions performed with nutritional status as the outcome. However, Table 6 has a different set of predictor variables with the addition of *A.lumbricoides* (which was the most prevalent parasite) infection as one of the predictors. The aim was to see if infection with this parasite, is a risk factor for one or more forms of undernutrition. As shown in the table, the presence of Ascaris infection did not significantly impact the nutritional status of the child at the 5% significance level. Nonetheless,

Table 6. Association of intestinal parasites and nutritional status.

Variables	Category	N	n(%)	Chi-square p-value	RRR	95%CI
			Underweight (n = 138)			
Household size	1–3	86	27(31.40)	0.525	Ref	
	4–6	226	71(31.42)		1.04	0.48–2.26
	7+	107	40(37.38)		1.17	0.49–2.80
Gender of the child	Male	185	52(28.11)	0.062		
	Female	234	86(36.75)		0.90	0.49–1.66
Frequency of meal	≥3 times	105	31(29.52)	0.390	0.82	0.41–1.63
	< 3 times	314	107(34.08)		ref	
Fingernail cleanliness	Clean	124	36(29.03)	0.270	0.69	0.36–1.31
	Not clean	295	102(34.58)		ref	
Type of toilet	Pit Latrine	129	40(31.01)	0.575	0.55	0.30–1.03
	No toilet	290	98(33.79)		ref	
A. lumbricoides Infection	Yes	144	45 (31.25)	0.595	0.83	0.44–1.56
	No	275	93 (33.82)		Ref	
			Stunting (n = 93)			
Household size	1–3	86	16(18.60)	0.140	Ref	
	4–6	226	46(20.35)		1.13	0.48–2.66
	7+	107	31(28.97)		1.49	0.58–3.84
Gender of the child	Male	185	49(26.49)	0.060	Ref	
	Female	234	44(18.80)		**0.49****	**0.25–0.94**
Frequency of meal	≥3 times	105	23(21.90)	0.934	0.96	0.46–2.01
	< 3 times	314	70(22.29)		ref	
Fingernail cleanliness	Clean	124	32(25.81)	0.249	1.02	0.51–2
	Not clean	295	61(20.68)		Ref	
Type of toilet	Pit Latrine	129	34(26.36)	0.172	0.74	0.38–1.44
	No toilet	290	59(20.34)		Ref	
A. lumbricoides Infection	Yes	144	36(25.00)	0.318	1.12	0.57–2.17
	No	275	57(20.73)		Ref	
			Wasting (n = 120)			
Household size	1–3	86	29(33.72)	0.007	Ref	
	4–6	226	73(32.30)		1.01	0.46–2.18
	7+	107	18(16.82)		0.51	0.20–1.32
Gender of the child	Male	185	60(32.43)	0.127	Ref	
	Female	234	60(25.64)		0.55	0.29–1.02
Frequency of meal	≥3 times	105	33(31.43)	0.465	0.99	0.49–1.99
	< 3 times	314	87(27.71)		ref	
Fingernail cleanliness	Clean	124	32(25.81)	0.406	0.70	0.36–1.38
	Not clean	295	88(29.83)		Ref	
Type of toilet	Pit Latrine	129	26(20.16)	0.010	**0.40** **	**0.20–0.77**
	No toilet	290	94(32.41)		Ref	
A. lumbricoides Infection	Yes	144	39(27.08)	0.610	0.89	0.46–1.70
	No	275	81(29.45)		Ref	

RRR: Relative risk ratio

** p-value < 0.05

https://doi.org/10.1371/journal.pone.0278333.t006

the household size (p-value = 0.007) and the type of toilet (p-value = 0.01) had significant impact on wasting but not on stunting and underweight. Those who had no toilet were likely (RRR = 0.40; CI = 0.20–0.77) to be wasted compared to those who had pit latrines. Fingernail cleanness, gender of the child and meal frequency had no significant impact on the nutritional status.

Discussion

This study was designed to determine the prevalence and correlates of undernutrition and intestinal parasitic infection in children below 5 years living in the District of Ndelele in the East Region of Cameroon. The data show that many children in the community experienced a double burden of intestinal parasitic (most especially STH) infection and undernutrition.

Out of the 419 children whose anthropometric data were collected to assess their nutritional status in this study, 351 (83.77%) were undernourished, with 32.94% underweight, 22.20% stunted, and 28.64% wasted, which far exceeded the national estimates for undernutrition (35.8%), wasting (6%) and underweight (15%) except for stunting (22.20%), which was lower than the national estimate at (33.0%) (Table 2) [14]. Statistics from Cameroon have demonstrated the prevalence of undernutrition among children <5 years of age in the East Region of the Republic of Cameroon to be 37.3%, 15.4%, and 5.9% for stunting, underweight, and wasting, respectively [15]. The prevalence of underweight (32.94%) and wasting (28.64%) were higher than the prevalence of underweight (30.2%) and wasting (11.3%) in Batouri, the administrative headquarters of the East region. According to WHO standards, these rates are considered as of "very high" public health significance [16], needing urgent intervention.

From this study, it was noticed that the mother's age, household size, and monthly income had no significant effect on the nutritional status (Table 3). Other studies showed that the low monthly income of a family plays a big role in child nutrition. Poor economic status may limit families' access to food and health services [17]. The reason why the low monthly income had no effect on the nutritional status might be the fact that, families do not depend on that little money they have for food. They depend on crops from their farms for nutrition. The little income they have is channeled toward 'more important' needs like medication, batteries for torchlights, kerosene to light lamps and other need considered to be equally as important as food. Among underweight children, breastfeeding habits had a significant impact. Children who were not exclusively breastfed were 2.06 (RRR = 2.06; 95% CI = 1.12–3.80) times more likely to be underweight compared to those who were exclusively breastfed, keeping other variables constant (Table 3). If complementary feeding is introduced too early, it is not possible for the child to absorb the necessary nutrients, and if it is introduced too late, the mother's milk will not be able to supply the nutrients required for optimal continued growth. It is therefore recommended by the World Health Organization [18], that complementary feeding be introduced at approximately 6 months of age. In contrast, authors of a research in Senegal reported that "no correlation was found between exclusive breastfeeding and the nutritional status of children [19]." Studies in Ethiopia and Botswana showed that exclusive breastfeeding reduced the odds of a child being underweight and wasted [20, 21]. The results of this study conflict with the results of the longitudinal study conducted by Fawzi and colleagues, which showed that prolonged breastfed children from poorer and illiterate mothers had a higher risk of being undernourished [22].

Household size significantly impacted wasting (p-value = 0.007), where a child from a household of 4 to 6 persons was 7% (RRR = 1.07, 95% CI = 0.49–2.32) more likely to be wasted compared to that from a household of 1 to 3 persons, keeping all variables constant. This result was contrary to a study carried out in Nepal where the household size was not associated with underweight, stunting, and wasting of children [23].

The high stunting, underweight and wasting rate observed in this study could partially be attributed to the low socio-economic status of the caregivers. Majority of the caregivers (71.8%) lived on a monthly income of less than $68. Caregivers' illiteracy rate was nearly 50%. Though the household size of between 4 to 6 (54.27%) had no significant effect on the nutritional status in this study, a study carried out in Meerut in India, reported that the size of family was a determinant of undernutrition [24]. The larger the family, the more people to feed making it more difficult for children to meet the required nutritional demands for their growth. The prevalence of undernutrition was found to be higher in those children who had $\geq$ 3 siblings compared to children with 1–2 siblings.

Among the 422 children whose samples were collected to assess the risk factors of soil helminths infections in the study, (66.8%) were positive for one or more intestinal parasites (Table 4). This prevalence was like the even higher prevalence rate of 70% found in Kwara State in Nigeria [25]. Such high prevalence may be attributed to poor environmental and personal hygiene, lack of clean potable water, lack of toilet facilities and open-air defecation.

Double and triple infections were also common and more among females; 53 study participants (12.6%) were infected by two or more intestinal parasites concurrently. This occurrence of polyparasitism in this study was in line with previous results reported in Anambra state in Nigeria [26].

The most common intestinal parasitic infections detected in the study were *A*. *lumbricoides* (34.12%), *E*. *histolytica/dispar* (27.96%), and *Hookworm* infection (17.30%). Poor eating habits, such as unhygienic handling food, not washing hands before eating (dirty hand and fingernails) and lack of potable drinking water could have exposed children to *Ascaris*. The poor faecal disposal system and lack of toilets/latrines, coupled with the fact that most of the children played barefooted could have exposed them to the infective stage of the hookworm larvae [27].

Majority (93.13%) of the participants are farmers who carry their children to the farms. Loose humus soil as suitable environmental conditions for the survival of hookworm eggs and larvae, it is possible that the longevity of hookworm eggs and larvae in soil and on vegetation might enhance it's transmission. Children are in the habit of eating whatever they come across while crawling and this exposes them to *E*. *histolytica/dispar*.

About three-quarters (76.78%) of the children were in contact with dirty water of rivers, swamps in their daily routine of swimming and fishing. This activity exposes them to the larvae of soil transmitted helminths thereby exposing them to infections. Children playing barefooted in the field and in the rain are more liable to infection by the filariform lavae of hookworm. The high prevalence of intestinal parasites in a community reflects the level of personal hygiene and fecal contamination of the environment.

Overall, in this study, females were more infected with at least one of these species of STH, compared to males (Table 4). This result was similar to results from a study carried in the Southwest of Ethiopia, where the prevalence rate in females was slightly higher than in males [28]. The cause of this is unknown in this study. This result was contrary to results from a study carried out in Loum in the Littoral region of Cameroon where, the prevalence of STH was significantly higher in male children than in females. The reason given was that boys play more outdoors bringing them in frequent contact with soil, feces, dirt and unclean water [29]. However, the possible explanation for sex as a predictor is that high intensity *Ascaris* infection is associated with other intestinal nematodes [28].

Analysis by a logistic regression model with STH infection as outcome revealed that: fingernail cleanness (AOR = 1.75; CI = 1.09–2.78) and household size (AOR = 0.55; CI = 0.32–0.92) were positively and negatively associated with intestinal parasite infection at the 5% significant level, respectively. Those whose fingernails were not clean were 1. 75 times more likely to be infected with at least one species of STH compared to those with clean fingernails (Table 5).

Fingernail carries large amounts of parasites as children crawl and play with their hands. Fingernail biting also increase the risk of soil transmitted helminth infection. These results were similar to those in a study carried out in Tachgayint Woreda in Northcentral Ethiopia, where fingernail status was found to be significant predictors of STH infection [30].

Household size (AOR = 0.55; CI = 0.32–0.93) was negatively associated with intestinal parasite infection at the 5% significant level (Table 5). This finding was a with previous studies conducted by other researchers, Ostan et al. [31] and Maia et al. [32] who reported that an increased number of household members and overcrowded conditions are associated with a higher frequency of parasitic infections. Our results agree with these findings. Large households increased the risk of infection which may be attributed to the close contact within the crowded houses and lead to a high risk of intra-family transmission. On the other hand, the risk of being infected was 1.04 times higher for households of 1 to 3 persons than more (4–6) persons in the house. All other variables were not associated with the risk of infection at a 5% significant level.

The household size (p-value = 0.007) and the type of toilet (p-value = 0.01) had a significant impact on wasting but not on stunting and being underweight. Those who had no toilet were more likely (RRR = 0.40; 95%CI = 0.20–0.77) to be wasted compared to those who had pit latrines.

Most children defecated indiscriminately in the backyards and bushes around dwelling places due to lack of latrine facilities. These results were in agreement with a study carried out by Fink et al. [33] where children with "low quality" toilet access had significantly and substantially higher odds of being stunted compared to children with "high quality" sanitation, even with adjustments for a range of covariates. It was also stated in this study that, a range of other factors might also influence stunting and thinness, not simply access to improved water and toilets.

Limitations of the study

A limitation of this study is that it was part of a larger study whose main objectives were not those of the sub-analysis which made it difficult to account for some unknown confounding variables. Secondly, due to the cross-sectional nature of the study, we could only discuss the association rather than causation. Thirdly, the present study was conducted only in one of the many health districts of Cameroon. Therefore, generalization of the results is difficult owing to the influence of regional characteristics on all aspects of the study. Fourthly, the faecal concentration technique employed for processing faecal samples do not yield data on parasite intensity but only on the prevalence rate. The methods were chosen for their efficiency and cost-effectiveness but are less sensitive than other commonly used procedures. Additional technique such as Kato-Katz would have been able to provide useful data on the relative intensity of infections. Lastly, another important limitation of our study is that the generalizability of our finding is limited to young children (12–59 months), which might result in different risk factors in other age groups.

Conclusion

There is a double burden of undernutrition and STH in the district of Ndelele among children below 5 year which are both public health problems of great importance. Children who were not exclusively breastfed, were more likely to be underweight. Children from large households were more likely to be wasted. The household size and the type of toilet had a significant impact on wasting but not on stunting and underweight. Fingernail cleanliness and household size were positively associated to STH infection. A mechanism could be proposed which points at poor breastfeeding habits, large household size and lack of toilets as risk factors for undernutrition and fingernail cleanliness and household size a risk factors of intestinal parasite infection. These risk factors are responsible for the different forms of undernutrition in children between 0 and 59 months. Public policies are therefore needed to guarantee clean water, sanitation, hygiene and nutrition education, and community deworming programs.

Recommendations

Parents and caregivers should be given practical lessons on the amount and the quality of food recommended for infants and children, the importance of potable water, proper hygiene, and sanitation. There is a need for nutrition programs to liaise with other sectors such as health, water and sanitation, mother and childcare, and education to curb the high prevalence of undernutrition and parasitosis in the study area.

Supporting information

S1 File.
(DOCX)

Acknowledgments

The authors thank the study participants, quarter heads, chiefs, data collectors and all staff of both the Ngotto and Banga health centers. We would also like to thank the University of Buea for support in materials and postgraduate funds. We are equally grateful to the Molecular and Cell Biology laboratory of the University of Buea for their support in the accomplishment of this study. We thank the field staff and data collectors for taking their precious time to collect the data and most especially our field coordinator Mr Caleb Yengo and our data analyst Ms Rahmah Mahdiyatur.

Author Contributions

Conceptualization: Bertha Fru Asa, Amy Ickowitz, Caleb Yengo Tata, Stephen Mbigha Ghogomu.

Data curation: Bertha Fru Asa, Adolf Yoah.

Formal analysis: Bertha Fru Asa, Cabirou Mounchili Shintouo, Robert Adamu Shey, Mildred Tita Afoumbom, Nadia Siekeh, Adolf Yoah, Emmanuel Kah.

Funding acquisition: Stephen Mbigha Ghogomu.

Investigation: Bertha Fru Asa, Cabirou Mounchili Shintouo, Robert Adamu Shey, Nadia Siekeh, Adolf Yoah, Emmanuel Kah, Amy Ickowitz, Caleb Yengo Tata, Emmanuel Asongalem, Stephen Mbigha Ghogomu.

Methodology: Bertha Fru Asa, Cabirou Mounchili Shintouo, Robert Adamu Shey, Mildred Tita Afoumbom, Nadia Siekeh, Adolf Yoah, Emmanuel Kah, Amy Ickowitz, Caleb Yengo Tata, Stephen Mbigha Ghogomu.

Project administration: Stephen Mbigha Ghogomu.

Resources: Caleb Yengo Tata, Stephen Mbigha Ghogomu.

Software: Bertha Fru Asa, Mildred Tita Afoumbom.

Supervision: Caleb Yengo Tata, Emmanuel Asongalem, Stephen Mbigha Ghogomu.

Validation: Bertha Fru Asa, Mildred Tita Afoumbom, Amy Ickowitz, Caleb Yengo Tata, Stephen Mbigha Ghogomu.

Visualization: Bertha Fru Asa, Amy Ickowitz, Stephen Mbigha Ghogomu.

Writing – original draft: Bertha Fru Asa, Stephen Mbigha Ghogomu.

Writing – review & editing: Bertha Fru Asa, Cabirou Mounchili Shintouo, Robert Adamu Shey, Mildred Tita Afoumbom, Nadia Siekeh, Adolf Yoah, Emmanuel Kah, Amy Ickowitz, Caleb Yengo Tata, Emmanuel Asongalem, Stephen Mbigha Ghogomu.

References

1. UNICEF. Improving child nutrition: the achievable imperative for global progress. 2013. Available from: https://data.unicef.org/resources/improving-child-nutrition-the-achievable-imperative-for-global-progress/ United Nations Publication sales No. E.13XX4.
2. Scoones I, & Bishop J. The hidden harvest: The role of wild foods in agricultural systems. In IIED Research Series. 1994; 3 (1).
3. Prendergast AJ, & Humphrey JH. The stunting syndrome in developing countries. Paediatr int child health. 2014; 34(4), 250–265. World health organization. https://doi.org/10.1179/2046905514Y.0000000158 PMID: 25310000
4. World Health Organization. Helminth control in school-age children: a guide for managers of control programmes. 2nd edition. World Health Organization. 2011. https://apps.who.int/iris/handle/10665/44671
5. World Health Organization. Guideline: preventive chemotherapy to control soil-transmitted helminth infections in at-risk population groups. World Health Organization. 2017. https://apps.who.int/iris/handle/10665/258983.
6. Tchuem TL-A, Dongmo NC, Ngassam P, Kenfack CM, Gipwe NF, Dankoni E. et al. Mapping of schistosomiasis and soil-transmitted helminthiasis in the regions of Littoral, Northwest, South and South-West Cameroon and recommendations for treatment. BMC Infect Dis. 2013; 13:602. https://doi.org/10.1186/1471-2334-13-602 PMID: 24365046
7. Feleke B.E. Nutritional status and intestinal parasite in school age children: a comparative cross-sectional study. Int J Pediatr. 2016. 1962128. https://doi.org/10.1155/2016/1962128 PMID: 27656219
8. Mekonnen Z., Hassen D., Debalke S., Tiruneh A., Asres Y., Chelkeba L., et al. (2020) "Soil-transmitted helminth infections and nutritional status of school children in government elementary schools in Jimma Town, Southwestern Ethiopia." SAGE open medicine, 2020; 8 2050312120954696. https://doi.org/10.1177/2050312120954696 PMID: 32953118
9. Cameroon U.N.O.C.H.A.: Food security and Malnutrition. www.ca.humanitarianresponse info Ministère de la Santé Publique au Cameroun. Enquête Démographique et de Santé et à Indicateurs Multiples (EDS-MICS). 2011; 1:160–5.
10. UNICEF. The state of the world's children 2015. New York, NY: UNICEF, 2015; 43–47.
11. Global nutrition Report. Country nutrition profile, 2020. https://globalnutritionreport.org/resources/nutrition-profiles/cameroun/middle-africa/cameroon/
12. Fisher AA, Laing JE, Stoeckel JE, Townsend J. Second edition. Handbook for Family Planning Operations Research Design. New York, Population Council, 1991.
13. World Health Organization. WHO child growth standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development, Geneva, Switzerland: WHO, 2006. https://www.who.int/publications/i/item/924154693X
14. Institut National de la Statistique. Enquête par grappes à indicateurs multiples (MICS5). Rapport de resultats clés: Yaoundé, Cameroun. Institut National de la Statistique, 2015.
15. Ministère de la Santé Publique au Cameroun. Enquête Démographique et de Santé et à Indicateurs Multiples (EDS-MICS). Yaoundé, 2011; 1:160–5.
16. World Health Organization. WHO/NLIS country profile indicators: interpretation guide. World Health Organization, 2010; Geneva, Switzerland.
17. Sharkey JR, Johnson CM, Dean WR. Relationship of household food insecurity to health-related quality of life in a large sample of rural and urban women. Women Health, 2011; 51(5):442–60. https://doi.org/10.1080/03630242.2011.584367 PMID: 21797678
18. World Health Organization. Complementary feeding. Geneva: World Health Organization, 2000; 1–2.

19. Gupta N, Gehri M, Stettler N. Early introduction of water and complementary feeding and nutritional status of children in northern Senegal. Pub Health Nutr, 2007; 10:1299–304. https://doi.org/10.1017/S1368980007696384 PMID: 17381901
20. Fekadu Y, Mesfin A, Haile D, Stoecker BJ. Factors associated with nutritional status of infants and young children in Somali Region, Ethiopia: A cross-sectional study. BMC Public Health, 2015; 15, 846. https://doi.org/10.1186/s12889-015-2190-7 PMID: 26330081
21. Mahgoub SE, Nnyepi M, Bandeke T. Factors affecting prevalence of malnutrition among children under three years of age in Botswana. Afr. J. Food Agric. Nutr. 2006; 6: (1), 1–11.
22. Fawzi WW, Herrera MG, Nestel P, El Amin A, Mohamed KA. A longitudinal study of prolonged breastfeeding in relation to child undernutrition. Int. J. Epidemiol. 1998; 27, 255–260. https://doi.org/10.1093/ije/27.2.255 PMID: 9602407
23. Shrestha A, Bhusal CK, Shrestha B, Bhattarai KD. Nutritional Status of Children and Its Associated Factors in Selected Earthquake-Affected VDCs of Gorkha District. Nepal. Int J Pediatr. 2020; https://doi.org/10.1155/2020/5849548 PMID: 32695188, PMCID: PMC7362290 (https://doi.org/10.1155/2020/5849548).
24. Murarkar S, Gothankar J, Doke P. Prevalence and determinants of undernutrition among under-five children residing in urban slums and rural area, Maharashtra, India: a community-based cross-sectional study. BMC Public Health. 2020; 20(1):1559. https://doi.org/10.1186/s12889-020-09642-0 PMID: 33066763
25. Awogun IA. The Prevalence of intestinal parasitic infections in children living in Illorin, Kwara state Nigeria. West African Journal of Medicine. 1984; 4(1):16–21.
26. Oluboy BO, Enweani IB, Ekejindu IM, Iuboyo AO. Prevalence of some intestinal parasitic infections in relation to body mass index of children resident in orphanages in anambra state, Nigeria. European scientific journal. 2014; 10 (36):1857–7881.
27. Asaolu SO, Holland CV, Jegede JO, Frasser NR, Stoddard RC, Crompton DW. The prevalence and intensity of soil-transmitted helminthiasis in rural communities in southern Nigeria. Ann Trop Med Parasito. 1992; 86: 279–287.
28. Tefera E, Belay T, Mekonnen SK, Zeynudin A, Belachew T. Prevalence, and intensity of soil transmitted helminths among school children of Mendera Elementary School, Jimma, Southwest Ethiopia. Pan Afr Med J. 2017; 27:88. https://doi.org/10.11604/pamj.2017.27.88.8817 PMID: 28819509
29. Nkengni SMM, Zoumabo ATC, Soppa NPS, Sizono ABN, Vignoles P, Tchuenté LT. Current decline in schistosome and soil-transmitted helminth infections among school children at Loum, Littoral region, Cameroon. Pan Afr Med J. 2019; 10: 33:94. https://doi.org/10.11604/pamj.2019.33.94.18265 PMID: 31489072
30. Eyayu T, Yimer G, Workineh L, Tiruneh T, Sema M, Legese B. Prevalence, intensity of infection and associated risk factors of soil-transmitted helminth infections among school children at Tachgayint woreda, Northcentral Ethiopia. Plos one. 2022; 17(4): e0266333. https://doi.org/10.1371/journal.pone.0266333 PMID: 35395035
31. Ostan I. Kilimcioğlu A A, Girginkardeşler N, Ozyurt BC, Limoncu ME, & Oku UZ. (2007). Health inequities: lower socio-economic conditions and higher incidences of intestinal parasites. *BMC Public Health*. 2007; 7: 342–349. https://doi.org/10.1186/1471-2458-7-342 PMID: 18042287
32. Maia MM, Fotso MA, Vieira EL, Benetoton ML, Carneiro M. Intestinal parasitic infections and associated risk factors among children presenting at outpatient clinics in Manaus, Amazonas state, Brazil. Ann Trop Med Parasitol. 2009; 103: 583–591.
33. Fink G, Günther I, Hill K. The effect of water and sanitation on child health: evidence from the Demographic and Health Surveys 1986–2007. Int J Epidemiol. 2011; 40: 1196–204. https://doi.org/10.1093/ije/dyr102 PMID: 21724576