

Prevalence of malnutrition, anemia, and soil-transmitted helminthiasis in preschool-age children living in peri-urban populations in the Peruvian Amazon

Prevalencia de desnutrición, anemia y helmintiasis transmitida por el contacto con el suelo en niños de edad preescolar que viven en poblaciones periurbanas de la Amazonía peruana

Prevalência de desnutrição, anemia e helmintíase transmitida pelo solo em crianças em idade pré-escolar que vivem em populações periurbanas na Amazônia peruana

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Abstract

Stunting, anemia, and soil-transmitted helminth (STH) infections are major health concerns for children in extremely poor regions of the world, especially rural and periurban ones. This study aimed to determine the prevalence of these three cooccurring conditions in preschool-age children in an extremely poor district on the outskirts of Iquitos, in the Peruvian Amazon, to inform public health actions. Malnutrition was assessed by standard World Health Organization-recommended metrics; anemia, by hemoglobin levels; and STH, by the Kato-Katz technique. Logistic regression analyses were performed to identify the risk factors for our three outcomes of interest. A total of 572 children aged 6-59 months were recruited in March 2019. We found a 31.3% stunting, 47.2% anemia, and 34.1% STH prevalence. Stunting and anemia figures exceeded both regional and national estimates for 2019. Having more children was a risk factor for stunting, whereas married mothers were associated with a lower risk. Risk factors for anemia included younger age and the male sex, whereas those for STH, older age, incomplete vaccination, and a lower socioeconomic status. Mothers' employment outside the home was also associated with a lower STH risk. This recent evidence highlights the need for prompt and integrated clinical attention and public health actions to address both short- and long-term health consequences in this vulnerable child age group. The integration of a monitoring and evaluation framework is important to effectively manage these conditions, optimize resources and accountability, and show their impact.

Malnutrition; Anemia; Helminthiasis; Child Preschool

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Introduction

Malnutrition, anemia, and soil-transmitted helminth (STH) infections are major health problems in early childhood. According to the World Health Organization (WHO), about 45% of deaths in children aged under five years relate to undernutrition in any of its forms: stunting, wasting, or underweight¹. Moreover, undernutrition predisposes children to infections, creating a vicious cycle which contributes to 35% of early childhood morbidity^{2,3}. These pathologies can have a lifelong impact on personal health and development⁴. Stunting and anemia are particularly significant in early childhood (between six months and two years of age) since the lack of essential nutrients can impair growth and irreversibly deteriorate cognitive capacity^{2,3,5}. STH infections constitute a neglected tropical disease with almost 2 billion people infected in the world⁶. The literature has associated STH infections with cognitive and verbal impairment in early childhood^{7,8}. These co-occurring diseases affect children living in poverty, especially in rural and peri-urban areas⁹. Immediate causes include inadequate food intake and disease burden and underlying ones, household food insecurity, disadvantaged social position, poor access to health care, and unhealthy environments – manifested by social, economic, and political factors such as poverty, inequality or low educational attainment¹⁰.

The other side of malnutrition is obesity. In 2019, an estimated 38.2 million children under five years of age were overweight or obese. Once considered a problem exclusive to high-income countries, overweight and obesity are increasingly prevalent in low- and middle-income nations, especially in urban settings. Childhood obesity is associated with breathing difficulties, hypertension, increased risk of fractures, insulin resistance, psychological effects, and adult premature death and disability¹¹.

The Convention on the Rights of the Child¹² recognizes the right of every child to a standard of living which would suit their physical, mental, spiritual, moral, and social development. According to the WHO, an adequate level of nutrition and health care results in similar growth patterns in children anywhere¹³. However, 2018 WHO data classified 155 million children worldwide as stunted and 52 million as wasted¹. In 2015, following the Millennium Development Goals campaign, it globally endorsed new Sustainable Development Goals. This initiative aims to end poverty in all its forms worldwide, end hunger, achieve food security, and improve nutrition by 2030¹⁴. It is an eminently worthwhile (but long) journey. However, undernutrition remains a major threat to the survival, health, growth, and development of millions of children and the progress of countries.

Data published by the 2019 *Peruvian Demographic and Family Health Survey* (known by its Spanish acronym, ENDES)^{15,16} showed that stunting affected 12.2% of children under five years of age, with the highest rates in rural, dispersed, indigenous, and low-income populations¹⁷. Loreto, the largest Peruvian department, has a 23.7% and 0.9% stunting and wasting prevalence, respectively. That of anemia reached 41.4%¹⁶, 11.9% above the national average. Loreto is highly endemic for STH infections¹⁸ but the literature has few publications on STH infections in preschool-age children. A study conducted in 2007 found a 32.1% *Ascaris lumbricoides*, 38.9% *Trichuris trichiura*, and 3.2% hookworm infection prevalence, respectively¹⁹.

Santo Tomás is a peripheral region in Iquitos, the capital of Loreto. It exemplifies spontaneous urban growth lacking any municipal planning for populations arriving from rural areas, as with many Peruvian cities. In the last eight years, the population of Santo Tomás has multiplied by 10 due to the many low-income families who have settled in the area, having migrated from communities situated along the Amazon River and its tributaries and from previously dismantled settlements in and around Iquitos. These peri-urban settlements lack basic services such as electricity, clean water, and sanitation and, to date, no studies have assessed their health needs.

This study aimed to determine the prevalence of malnutrition (i.e., stunting), anemia, and STH infections in preschool-age children (i.e., aged 6 to 59 months) in Santo Tomás, Loreto, Peru, to (i) evaluate the local magnitude of these conditions and (2) inform health policies and services to adapt national and regional protocols aligned with the Integrated Management of Childhood Illness (IMCI) approach.

Materials and methods

Study population

Our study population was composed of children aged from 6 to 59 months living in Santo Tomás and the surrounding settlements under its jurisdiction in the district of San Juan Bautista, Maynas province, located approximately 15km from the municipality of Iquitos. As of March 2019, the studied area consisted of Santo Tomás and 23 settlements with an approximate combined population of 12,808 people (data from the Santo Tomás health post; Evelyn Maritza Orbe Villasis, personal communication, July 9, 2018).

Sample size

A sample size of 572 children was required by a 23.8% estimated stunting prevalence²⁰, an estimated population of 2,321 individuals under five years of age, a $\pm 4\%$ precision, and a 1.5 design effect (i.e., the possible recruitment of two children per household).

Recruitment

This study was conducted in March 2019. Households with children in the targeted age group were randomly selected in each settlement to achieve a sample size proportional to its total population. Inclusion criteria for children to participate in this study involved age between 6 and 59 months, habitation in any of the 24 recruitment areas (Santo Tomás and settlements), and parents or legal guardians' consent. Our only exclusion criterion were serious congenital or chronic medical conditions (e.g., preterm birth – i.e., < 28 weeks gestation –, cerebral palsy, neural tube defects, etc.).

A questionnaire, adapted from previous studies^{19,21}, was administered to the primary caregiver in the household. This survey aimed to determine the child and family's sociodemographic characteristics and health information. Children's weight was measured while they were unclothed via a portable digital baby scale (Beurer BY-80, accuracy 5g; <https://www.beurer.com>) if they weighed less than 20kg or via an electronic standing scale if they exceeded 20kg (only if the child could stand without moving). Participants' length was measured by their recumbent crown-heel length on a flat surface via an infantometer (ADE BYT-MZ10040, 1mm gradation; <https://ade-germany.de>) if younger than two years of age or, if older, standing by a wall-mounted roll-up tape measure (ADE BYT-MZ10017; 1mm gradation). Both weight and length were measured twice and their mean, registered. Hemoglobin concentration was determined by finger-prick blood via a HemoCue analyzer (HemoCue Hb 301; <https://www.hemocue.com>). Stool specimens were analyzed daily by experienced laboratory technologists from the Selva Amazónica Civil Association by the Kato-Katz technique within 24 hours of initial collection, according to WHO recommendations²², to assess both the prevalence and intensity of STH infection. A single stool specimen was collected from each child. Families of children showing malnutrition, anemia or STH infections received detailed explanations on these conditions and were referred to the local public health system for treatment and follow-up.

Statistical analyses

To classify children's anthropometric measurements into stunting, underweight, and wasting, the WHO Anthro software, version 3.2.2 (<http://www.who.int/childgrowth/software/en/>), was used to calculate age- and sex-specific length-for-age, weight-for-age, and weight-for-length z-scores. Our moderate stunting, underweight, and wasting categories were based on < -2 SD (standard deviation) and ≥ -3 SD z-scores, whereas severe ones, as < -3 SD z-scores. Overweight and obesity were defined as a weight-for-height z-score between > 2 SD and ≤ 3 SD and > 3 SD, respectively.

Anemia was defined as a hemoglobin value below 11g/dL and classified as mild, moderate or severe if 10.9-10.0g/dL, 9.9-7.0g/dL or < 7.0g/dL, respectively, as per WHO recommendations²³. STH infection intensity was categorized as light, moderate or heavy based on *A. lumbricoides*, *T. trichiura*,

and hookworm egg counts per gram of feces. Data were entered into an SPSS, version 25 (<https://www.ibm.com/>).

Child, maternal, and household characteristics were summarized by frequencies for categorical variables and means with SD for continuous ones. Our baseline population for analyses of the prevalence of STH infection consisted of a subset which provided stool specimens.

Logistic regression analyses were performed to identify the risk factors for our three outcomes (i.e., stunting, anemia, and STH infection). Models were run by a generalized estimating equation to account for the clustering effect at households. All variables were examined for collinearity prior to inclusion in regression models. Marital status and maternal education were collapsed to create dichotomous variables. Multiple component analysis was used to create an asset-based index for household socioeconomic status by construction material, flooring material, cooking fuel, television ownership, radio ownership, electrification, running water, and source of drinking water. Socioeconomic status variables were subsequently divided into quartiles based on index-derived cut-points for inclusion in our regression models.

Univariate analyses were used to assess unadjusted associations between potential risk factors and each outcome of interest. Variables which obtained a $p < 0.20$ in our univariate analyses, as well as those we considered clinically and epidemiologically relevant, were included in our multivariate analyses. Sparse or collinear variables were removed from the model. Odds ratios (OR) and 95% confidence intervals (95%CI) for the association between independent risk factors and each binary dependent variables were computed for both univariate and multivariate analyses. Variables with a significance level of $p < 0.05$ in our multivariate models were considered important risk factors. All statistical analyses were performed in R, version 4.0.5 (<http://www.r-project.org>).

Ethics considerations

This study was approved by the Institutional Ethics Committee for Clinical Research at the Felipe S. Arriola Iglesias Regional Hospital and the local office of the Peruvian Ministry of Health (Regional Health Directorate in Loreto) in Quito (protocol ID-011-CIEI-19). Participants' parents or legal guardians signed written informed consent forms.

Results

Baseline characteristics of the studied population

We recruited 572 children. Table 1 lists their baseline characteristics. They showed a mean age of 32.1 months (SD: 15.8) and 51.7% of them were boys. Only 60.2% had all vaccinations according to the guidelines of the Peruvian Ministry of Health. We found that mothers' mean age was 29.0 years (SD: 7.1), 2.8% (16) of them became one under 18 years of age, only 32.9% had completed secondary education, and 18.9% worked outside their homes. The mean number of children per mother was 3.1 (SD: 1.8). 17.4% of children had four or more siblings. The average number of persons living in the household was 6.3 (SD: 2.5).

Studied population's profile of malnutrition, anemia, and STH infection

In total, 33.9% of the studied population (194 children) had one or more forms of malnutrition (i.e., stunting, wasting or underweight). We found a 31.3% prevalence of stunting; severe in 5.2% of the children (Table 2), a 3.2% prevalence of wasting; severe in 1.1%, comorbidities with two or three concurrent forms of malnutrition in 8.2% ($n = 47$) of participants, and a 1.6% and 0.7% prevalence of overweight and obesity, respectively.

We observed a 47.2% overall prevalence of anemia, moderate in 18.9% of our sample (Table 3). We found no cases of severe anemia for any age.

Table 1

Prevalence of stunting, anemia, and soil-transmitted helminth (STH) infection by child, maternal, and household characteristics. Santo Tomás and settlements, Peru, March 2019.

Characteristics	Overall	Prevalence of stunting	Prevalence of anemia	STH baseline population *	Prevalence of STH infection **
	N (%)	n (%)	n (%)	N (%)	n (%)
Total	572 (100.0)	179 (31.3)	270 (47.2)	481 (100.0)	164 (34.1)
Child					
Age (months) [mean ± SD] ***	32.1 ± 15.8	32.4 ± 15.0	26.9 ± 15.6	31.9 ± 15.6	37.5 ± 13.9
Age (months)					
0-11	77 (13.5)	13 (16.9)	55 (71.4)	61 (12.7)	4 (6.6)
12-23	120 (21.0)	49 (40.8)	82 (68.3)	107 (22.2)	31 (29.0)
24-35	121 (21.2)	39 (32.2)	51 (42.1)	105 (21.8)	35 (33.3)
36-47	136 (23.8)	45 (33.1)	44 (32.4)	109 (22.7)	46 (42.2)
48-59	118 (20.6)	33 (28.0)	38 (32.2)	99 (20.6)	48 (48.5)
Sex					
Female	276 (48.3)	81 (29.3)	114 (41.3)	232 (48.2)	85 (36.6)
Male	296 (51.7)	98 (33.1)	156 (52.7)	249 (51.8)	79 (31.7)
Birth weight #					
Normal (≥ 2,500g)	476 (83.2)	138 (29.0)	237 (49.8)	399 (16.4)	133 (33.3)
Low (< 2,500g)	92 (16.1)	40 (43.5)	32 (34.8)	79 (83.0)	28 (35.4)
Place of delivery					
Health facility	537 (93.9)	161 (30.0)	253 (47.1)	450 (93.6)	148 (32.9)
Home	35 (6.1)	18 (51.4)	17 (48.6)	31 (6.4)	16 (51.6)
Attended any antenatal care					
Yes	549 (96.0)	173 (31.5)	255 (46.4)	461 (95.8)	155 (33.6)
Up-to-date vaccinations					
Yes	346 (60.5)	103 (29.8)	148 (42.8)	292 (60.7)	90 (30.8)
Hospitalization since birth					
No	430 (75.2)	129 (30)	213 (49.5)	356 (74.0)	115 (32.3)
Breastfed					
Yes	550 (96.2)	174 (31.6)	259 (47.1)	463 (96.3)	159 (34.3)
Deworming in the previous 6 months					
No	286 (50.0)	92 (32.2)	150 (52.4)	240 (49.9)	77 (32.1)
Maternal #					
Children [mean ± SD] ***	3.1 ± 1.8	3.5 ± 2.0	3.1 ± 1.8	3.1 ± 1.8	3.4 ± 2.0
Marital status					
Single	78 (13.6)	32 (41.0)	39 (50.0)	68 (14.1)	24 (35.3)
Married/Common-law	482 (84.3)	143 (29.7)	226 (46.9)	404 (83.4)	138 (34.2)
Divorced/Widowed	8 (1.4)	2 (25.0)	4 (50.0)	5 (1.0)	1 (20.0)
Educational attainment					
Illiterate	12 (2.1)	3 (25.0)	5 (41.7)	9 (1.9)	4 (44.4)
Can read and write	12 (2.1)	2 (16.7)	9 (75.0)	11 (2.3)	6 (54.5)
Elementary school	317 (55.4)	112 (35.3)	158 (49.8)	261 (54.3)	91 (34.9)
Secondary school	188 (32.9)	53 (28.2)	81 (43.1)	163 (33.9)	58 (35.6)
Higher education	39 (6.8)	7 (17.9)	16 (41.0)	33 (6.9)	4 (12.1)
Employment outside of the home					
No	460 (80.4)	146 (31.7)	217 (47.2)	386 (80.2)	140 (36.3)

(continues)

Table 1 (continued)

Characteristics	Overall N (%)	Prevalence of stunting n (%)	Prevalence of anemia n (%)	STH baseline population * N (%)	Prevalence of STH infection ** n (%)
Household					
Inhabitants [mean ± SD] ***	6.3 ± 2.5	6.5 ± 2.5	6.5 ± 2.5	6.4 ± 2.5	6.7 ± 2.6
Construction material					
Rustic	521 (91.1)	169 (32.4)	248 (47.6)	439 (91.3)	152 (34.6)
Brick	51 (8.9)	10 (19.6)	22 (43.1)	42 (8.7)	12 (28.6)
Floor					
Soil	349 (61.0)	119 (34.1)	159 (45.6)	284 (59.0)	108 (38.0)
Wood	27 (4.7)	13 (48.1)	16 (59.3)	24 (5.0)	10 (41.7)
Cement/Tile	196 (34.3)	47 (24.0)	95 (48.5)	173 (36.0)	46 (26.6)
Stove					
Firewood/Coal	190 (33.2)	68 (35.8)	96 (50.5)	161 (33.5)	59 (36.6)
Gas	321 (56.1)	97 (30.2)	149 (46.4)	268 (55.7)	86 (32.1)
Both	61 (10.7)	14 (23.0)	25 (41.0)	52 (10.8)	19 (36.5)
Television					
Yes	445 (77.8)	134 (30.1)	210 (47.2)	379 (78.8)	121 (31.9)
Radio					
Yes	260 (45.5)	74 (28.5)	116 (44.6)	221 (45.9)	67 (30.3)
Electricity					
Yes	534 (93.4)	159 (29.8)	254 (47.6)	459 (95.4)	156 (34.0)
Running water					
Yes	121 (21.2)	30 (24.8)	53 (43.8)	111 (23.1)	34 (30.6)
Source of drinking water					
Artesian well	340 (59.4)	106 (31.2)	168 (49.4)	281 (58.4)	84 (29.9)
Bottled water	232 (40.6)	73 (31.5)	102 (44.0)	200 (41.6)	80 (40.0)

SD: standard deviation.

Note: for binary yes/no variables, the category shown corresponds to the referent category in our regression analyses.

* The baseline population for the analyses of the prevalence of STH infection is a subset of the overall population due to missing data from stool specimens (n = 91 missing);

** The prevalence of STH infections was assessed based on the presence of any infection;

*** SD from the mean. Values are rounded to one decimal point;

Totals fail to sum to 572 due to missing responses on birth weight (n = 4) and maternal characteristics (n = 4).

Of the 572 children, 481 (84.1%) provided a stool specimen which we Kato-Katz examined. We found a 34.1% overall prevalence of STH infections (Table 4), 25.2% of *A. lumbricoides*, 18.5% of *T. trichiura*, and 2.3% of hookworm ones (presumably *Necator americanus*). We observed that 48 children (10%) had *A. lumbricoides* and *T. trichiura* coinfection and four (0.8%) suffered with all three infections. Of children older than two years (n = 375) – the starting age of the national deworming program –, 62.7% (n = 235) were dewormed in the previous six months, of which 30.6% (n = 72) had an STH infection despite previous treatment.

Risk factors for stunting, anemia, and STH infections

In identifying risk factors, our adjusted models showed that stunting was significantly statistically associated with a higher number of children per mother and single mothers. Mothers' educational attainment was disassociated with stunting in either unadjusted or adjusted analyses (Table 5).

Statistically significant risk factors for anemia consisted of younger age and the male sex (Table 5). We found no statistically significant association between anemia and stunting or STH infections in either our unadjusted or adjusted analyses.

Table 2

Nutritional indicators in preschool-age children. Santo Tomás and settlements, Peru, March 2019 (N = 572).

Nutritional indicators	n	%
Stunting		
Stunting: length for age z-score \leq -2 SD	179	31.3
Moderate stunting: length for age z-score \leq -2 SD and $>$ -3 SD	149	26.1
Severe stunting: length for age z-score \leq -3 SD	30	5.2
Wasting		
Wasting: weight for length z-score \leq -2 SD	18	3.2
Moderate wasting: weight for length z-score \leq -2 SD and $>$ -3 SD	12	2.1
Severe wasting: weight for length z-score \leq -3 SD	6	1.1
Underweight		
Underweight: weight for age z-score \leq -2 SD	53	9.3
Moderate underweight: weight for age z-score \leq -2 SD and $>$ -3 SD	40	7.0
Severe underweight: weight for age z-score \leq -3 SD	13	2.3

SD: standard deviation.

Table 3

Prevalence of anemia in preschool-age children by age and hemoglobin (Hb) level. Santo Tomás and settlements, Loreto, Peru, March 2019.

Anemia	Total n (%)	6-36 months * n (%)	6-12 months n (%)
Mild **	162 (28.3)	102 (32.1)	25 (28.1)
Moderate ***	108 (18.9)	86 (27.0)	38 (42.7)
Severe #	0 (0.0)	0 (0.0)	0 (0.0)
No	302 (52.8)	130 (40.9)	26 (29.2)
Total	572 (100.0)	318 (100.0)	89 (100.0)

Note: "mild" is a misnomer as iron deficiency is already advanced when anemia is detected. Iron deficiency has consequences even in the absence of clinical manifestations of anemia.

* The figure includes all children aged up to 36 months, not inclusive of 36 months;

** Hb 10.9-10g/dL;

*** Hb 9.9-7g/dL;

Hb $<$ 7g/dL.

Statistically significant risk factors for STH infections included older age and incomplete vaccinations (Table 5). Maternal employment outside the home was associated with a lower risk of infections. We found a statistically significant association between STH infections and lower socioeconomic status when we compared the third highest quartile with the lowest quartile. Our multivariable analyses found a statistically significant association (adjusted OR = 0.57; 95%CI: 0.34; 0.98; $p = 0.044$) by combining the third and fourth quartiles and comparing them with our reference. We found no statistically significant association between STH infections and stunting or anemia in either our unadjusted or adjusted analyses.

Table 4

Prevalence and intensity of soil-transmitted helminth (STH) infections in preschool-age children who provided a stool specimen. Santo Tomás and settlements, Peru, March 2019 (N = 481).

STH	n	%
Any		
% positive	164	34.1
<i>Ascaris lumbricoides</i>		
% positive	121	25.2
Light intensity	40	33.1
Moderate intensity	58	47.9
Heavy intensity	23	19.0
<i>Trichuris trichiura</i>		
% positive	89	18.5
Light intensity	76	85.4
Moderate intensity	12	13.5
Heavy intensity	1	1.1
Hookworm		
% positive	12	2.5
Light intensity	11	91.7
Moderate intensity	1	8.3
Heavy intensity	0	0.0
Coinfection <i>A. lumbricoides</i> - <i>T. trichiura</i>		
% positive	48	10.0
Coinfection <i>A. lumbricoides</i> - <i>T. trichiura</i> -hookworm		
% positive	4	0.8

Note: intensity (eggs per gram), according the World Health Organization guidelines ²²: *A. lumbricoides* – light 1-4,999, moderate 5,000-49,999, and heavy \geq 50,000; *T. trichiura* – light 1-999, moderate 1,000-9,999, and heavy \geq 10,000; and hookworm – light 1-1,999, moderate 2,000-3,999, and heavy \geq 4,000.

Discussion

We found a high prevalence of different forms of malnutrition in preschoolers from Santo Tomás and its surrounding settlements. We observed a stunting prevalence (31.3%) 18.6% higher than the South American average (12.7%) ²⁴, 19.1% above the national one (12.2%), and 7.6% greater than the 2019 official figures for the Loreto department (23.7%) ¹⁵. Although this study focused on stunting as an indicator of malnutrition, it observed a high wasting prevalence, 3.5 times above the official average for Loreto and 7.9 times above the national average in 2019 ¹⁶. Severe wasting was 10.5 times above the national and Loreto department averages. We found few cases of overweight and obesity, far below national statistics (6.4% for overweight and 1.6% for obesity) and closer to those of Loreto (3.6% for overweight and 0.9% for obesity) in 2019 ²⁵.

Note the association between a higher number of children per household and stunting. Loreto is the Peruvian department with the most precarious access to family planning services, the highest rate of adolescent pregnancy, and with significant gaps in women's access to identity documents and secondary and higher education ²⁶. Peru has implemented several public health ²⁷ and family support policies ²⁸ but their translation into effective interventions shows gaps which important inequalities in health coverage, infrastructure, and staff and access to support according to geographical area exacerbate. The public budget of healthcare is lower than the Latin American average and inefficiencies in the management of resources are common ²⁹.

We found a concerning association between mothers caring for their children by themselves and stunting. Some mothers can often avoid face-to-face or financial support from fathers in raising their children. Moreover, single mothers have fewer job opportunities than nulliparous individuals,

Table 5

Association between relevant child, maternal, household, and clinical characteristics and stunting, anemia, and soil-transmitted helminth (STH) infections in the Santo Tomás and settlements study population, Peru, March 2019.

Character- istics	Stunting				Anemia				STH infection *			
	Univariate associations		Multivariate associations		Univariate associations		Multivariate associations		Univariate associations		Multivariate associations	
	OR (95%CI)	p-value	aOR ** (95%CI)	p-value	OR (95%CI)	p-value	aOR ** (95%CI)	p-value	OR (95%CI)	p-value	aOR ** (95%CI)	p-value
Child												
Age (months)	1.00 (0.99; 1.01)	0.735	1.00 (0.98; 1.01)	0.707	0.96 (0.95; 0.97)	< 0.001	0.96 (0.95; 0.98)	< 0.001	1.04 (1.02; 1.05)	< 0.001	1.05 (1.03; 1.06)	< 0.001
Gender												
Female	Reference	-	Reference	-	Reference	-	Reference	-	Reference	-	Reference	-
Male	1.16 (0.82; 1.65)	0.394	1.48 (0.98; 2.22)	0.060	1.59 (1.13; 2.23)	0.008	1.96 (1.30; 2.95)	0.001	1.80 (0.55; 1.16)	0.239	1.03 (0.68; 1.57)	0.884
Birth weight												
Normal (≥ 2,500g)	Reference	-	Reference	-	Reference	-	Reference	-	NS	-	NS	-
Low (< 2,500g)	1.58 (0.96; 2.58)	0.069	1.31 (0.75; 2.27)	0.339	0.54 (0.34; 0.86)	0.010	0.57 (0.32; 1.00)	0.050	NS	-	NS	-
Place of delivery												
Health facilit	Reference	-	Reference	-	NS	-	NS	-	Reference	-	Reference	-
Home	2.30 (1.11; 4.78)	0.025	1.61 (0.71; 3.61)	0.252	NS	-	NS	-	2.13 (1.06; 4.27)	0.033	1.93 (0.90; 4.11)	0.090
Attended any antenatal care												
Yes	NS	-	NS	-	Reference	-	Reference	-	NS	-	NS	-
No	NS	-	NS	-	2.16 (0.90; 5.20)	0.085	1.51 (0.60; 3.79)	0.378	NS	-	NS	-
Up-to-date vaccinations												
Yes	NS	-	NS	-	Reference	-	Reference	-	Reference	-	Reference	-
No	NS	-	NS	-	1.57 (1.12; 2.20)	0.009	1.36 (0.91; 2.04)	0.136	1.42 (0.98; 2.07)	0.065	2.07 (1.34; 3.20)	0.001
Hospitali- zation since birth												
No	NS	-	NS	-	Reference	-	Reference	-	Reference	-	Reference	-
Yes	NS	-	NS	-	0.68 (0.46; 1.01)	0.054	0.66 (0.42; 1.03)	0.069	1.35 (0.89; 2.03)	0.155	1.27 (0.81; 1.99)	0.289

(continues)

Table 5 (continued)

Character- istics	Stunting				Anemia				STH infection *			
	Univariate associations		Multivariate associations		Univariate associations		Multivariate associations		Univariate associations		Multivariate associations	
	OR (95%CI)	p-value	aOR ** (95%CI)	p-value	OR (95%CI)	p-value	aOR ** (95%CI)	p-value	OR (95%CI)	p-value	aOR ** (95%CI)	p-value
Deworming in the previous 6 months												
No	NS	-	NS	-	Reference	-	Reference	-	Reference	-	Reference	-
Yes	NS	-	NS	-	0.66 (0.47; 0.91)	0.010	1.07 (0.72; 1.61)	0.726	1.21 (0.83; 1.77)	0.325	0.97 (0.63; 1.50)	0.881
Maternal												
Children in the household	1.17 (1.06; 1.30)	0.002	1.15 (1.02; 1.30)	0.020	NS	-	NS	-	1.15 (1.04; 1.27)	0.005	1.11 (1.00; 1.23)	0.050
Marital status												
Single/ Divorced/ Widowed	Reference	-	Reference	-	NS	-	NS	-	NS	-	NS	-
Married/ Common- law	0.67 (0.41; 1.11)	0.121	0.47 (0.27; 0.81)	0.007	NS	-	NS	-	NS	-	NS	-
Educational attainment												
Secondary not completed	Reference	-	Reference	-	Reference	-	Reference	-	NS	-	NS	-
Secondary completed	0.68 (0.45; 1.02)	0.059	0.94 (0.59; 1.51)	0.805	0.73 (0.52; 1.03)	0.072	0.75 (0.49; 1.15)	0.184	NS	-	NS	-
Employment outside of home												
No	NS	-	NS	-	NS	-	NS	-	Reference	-	Reference	-
Yes	NS	-	NS	-	NS	-	NS	-	0.59 (0.36; 0.98)	0.042	0.52 (0.30; 0.91)	0.023
Household												
Persons living in the household	1.07 (0.99; 1.15)	0.075	1.02 (0.94; 1.11)	0.555	1.06 (0.99; 1.13)	0.101	1.06 (0.98; 1.14)	0.172	1.08 (1.00; 1.16)	0.047	1.08 (1.00; 1.17)	0.052
Socio- economics status index												
Lowest quartile	Reference	-	Reference	-	Reference	-	Reference	-	Reference	-	Reference	-
Third quartile	NS	-	NS	-	NS	-	NS	-	0.41 (0.23; 0.74)	0.003	0.47 (0.24; 0.90)	0.022
Highest quartile	0.44 (0.26; 0.75)	0.003	0.59 (0.33; 1.08)	0.086	0.77 (0.49; 1.21)	0.263	0.69 (0.41; 1.18)	0.174	0.60 (0.35; 1.01)	0.053	0.67 (0.38; 1.21)	0.183

(continues)

Table 5 (continued)

Character- istics	Stunting				Anemia				STH infection *			
	Univariate associations		Multivariate associations		Univariate associations		Multivariate associations		Univariate associations		Multivariate associations	
	OR (95%CI)	p-value	aOR ** (95%CI)	p-value	OR (95%CI)	p-value	aOR ** (95%CI)	p-value	OR (95%CI)	p-value	aOR ** (95%CI)	p-value
Proximal risk factors												
STH infection (any)												
No	Reference	-	Reference	-	NS	-	NS	-	NA	-	NA	-
Yes	1.32 (0.89; 1.96)	0.173	1.17 (0.74; 1.83)	0.504	NS	-	NS	-	NA	-	NA	-
<i>Trichuris trichiura</i> and/ or hookworm												
Neither	NS	-	NS	-	Reference	-	Reference	-	NA	-	NA	-
<i>T. trichiura</i> and/or hookworm	NS	-	NS	-	0.74 (0.47; 1.16)	0.187	1.09 (0.64; 1.84)	0.761	NA	-	NA	-

95%CI: 95% confidence interval; aOR: adjusted odds ratio; NA: not applicable; NS: non significant; OR: odds ratio.

* The outcome of STH infection was assessed based on the presence of any infection;

** Adjusted for all variables shown in table.

preventing them from acquiring their own income³⁰, which can cause nutritional problems in their children^{31,32}. This situation affects many families in Loreto, can go unnoticed, and is difficult to identify and redress^{26,33}.

Another cause which might explain the high prevalence of malnutrition in this study include the rapid increase in urban and peri-urban populations over a relatively short period of time. In 2019, the World Bank reported that more than 50% of the world population lives in cities (one third in the 1960s). In total, 90% of urban expansion is taking place in low-income countries and much of it (about 1 billion people) occurs via informal settlements and slums³⁴. Cities have failed to address this rapid and unplanned urban growth, resulting in inequalities, widespread social stratification, and the breakdown of social support systems and networks³⁵. Moreover, basic sanitation services, health services, social services, etc. have failed to accompany these settlements and, together with the population's economic difficulties to access basic foodstuffs, cause serious health problems, such as malnutrition. Such is the case for the peri-urban population in Santo Tomás.

Breastfeeding is of critical importance to early childhood anemia. It occurs during the rapid growth of children, which increase their iron demands. Although we found that a high proportion of infants had been breastfed (over 95%), cultural practices include supplementing breastmilk with other foods within weeks of birth. Anemia in infants and young children may stem from an inadequate amount of iron in breastmilk, deficient intake, and low bioavailability of iron-rich foods^{36,37}. Although we found a statistically significant association between anemia and boys, we are unable to offer any explanation regarding their culture, religion or diet. According to Domellöf et al.³⁸, people may show hormone-mediated differences in their iron metabolism, related to the synthesis of lean versus fat body mass. We found no association between stunting and anemia, a finding previously observed and thought to be the result of similar causal factors³⁶.

Few studies have reported the prevalence of STH infections in preschoolers from Loreto. Casapía et al.¹⁹, found a 48% prevalence of STH infections in this age group in the survey they conducted in 2005-2006. Although the government launched two major deworming initiatives since that time (i.e., seven cycles of school-based deworming between 2012 and 2014 in Loreto and an annual national

deworming program beginning in 2017)²⁷, the 34.1% prevalence we found and its higher incidence among older children indicate that the area still suffers with active transmission. Further assessments of deworming program coverage would help inform public health services. Its association with incomplete vaccination could reflect caregivers' poor knowledge of basic health issues, economic difficulties in accessing health centers or high population mobility, which would hinder access to both vaccination and deworming programs but the literature needs more studies to assess this association^{39,40}. The lower risk among children whose mothers worked outside the home and those with higher socioeconomic status suggests that improved socioeconomic capacity may reduce opportunities for contracting infections. We found no association between STH infections and malnutrition or anemia, despite a combined 20% *T. trichiura* and hookworm prevalence, known causes of anemia^{41,42}. This may in part be due to the low predictive values associated with the Kato-Katz technique⁴³, the extremely low prevalence of hookworms, and the light intensity of these infections, which are thus less likely to result in overt morbidity or pathology⁴⁴.

Among the strengths of our study is its household-based recruitment strategy. This enabled us to include all children in the targeted age group, rather than only those who attended school (as with most other studies). Moreover, experienced technical personnel based at an organization which has participated in several seminal research studies on STH in the area performed our laboratory analyses.

This study includes limitations, such as the absence of data on iron dietary intake and variability. Some measurement error is attributable to the Kato-Katz estimates of STH infections, which the technical personnel's substantial expertise mitigated to some extent. Some recall and report biases may be present but well-trained interviewers and objective measurements and outcomes rather attenuated them.

According to 2020 United Nations Development Program (UNDP) data⁴⁵, Peru has the 79th highest Human Development Index (HDI: 0.777) – a positive condition. HDI measures factors such as life expectancy, education, and per capita income. It is paradoxical that a country with these characteristics (fairly high HDI ranking, classified as a middle-income country in 2008 and no longer as a developing one) should have such large health inequalities among its population. Our study highlights the serious problems malnutrition, anemia, and STH infections still comprise today in extremely poor populations such as ours^{3,5,8}. The lack of public policies which promote adequate living conditions for rural populations in their places of origin is leaving many rural communities without feasible options for survival, generating a growing exodus of riverine families to cities, and aggravating public health problems such as malnutrition, in stark contrast to the national prevalence, which has decreased year after year.

Our study population is highly vulnerable and needs strong health and public policies. Over the last few years, Peru has significantly progressed toward improving access to health care and taken numerous actions to reduce stunting. Its 2017-2021 National Plan to reduce and control maternal and child anemia and chronic child malnutrition outlines specific strategies such as iron and micronutrient supplementation for children under 36 months, iron and folic acid supplementation, and prenatal care for pregnant adolescents, child growth and development control, vitamin A supplementation for children under five years of age, deworming for schoolchildren and families, practices to improve infant and pregnant women's nutrition, salt iodization, promotion of safe water consumption and hand washing, and capacity-building programs in educational communities, neighborhoods, and municipalities²⁷. Most of these actions have been in effect since 2014 but our study highlights the persisting inequality. Urgent interventions by relevant institutions are needed to correct these inequalities and monitor their impact.

Overall, our study found a high prevalence of malnutrition, anemia, and intestinal parasite infections in young children in small rural settlements in the Loreto department of the Peruvian Amazon. With the additional disease burden and emergency demands of the ongoing coronavirus pandemic, we expect a further economic crisis, which may worsen the already local precarious health and food security situation. We attest the urgent need to reprioritize children's health and development within all relevant government sectors and their partners so appropriate policies and services can ensure a healthy and productive future for children.

Contributors

M. C. Segoviano-Lorenzo contributed to the study design and conception, writing, and review. E. Trigo-Esteban contributed to the writing and review. T. W. Gyorkos, K. St-Denis, and F. Martínez-De Guzmán contributed to the data analysis and interpretation. M. Casapía-Morales contributed to the study design and conception. All the authors approved the final version of the manuscript.

Additional informations

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Resumen

El retraso en el crecimiento, la anemia y la infección por helmintos transmitidos por el contacto con el suelo (STH) son los principales problemas de salud de la infancia en las regiones del mundo caracterizadas por la extrema pobreza, especialmente en las zonas rurales y periurbanas. Este estudio se llevó a cabo para determinar la prevalencia de estas tres condiciones concurrentes en niños de edad preescolar en un distrito de extrema pobreza en las afueras de Iquitos, en la Amazonía peruana, con el fin último de informar la acción de salud pública. La malnutrición se evaluó mediante las mediciones estándar recomendadas por la Organización Mundial de la Salud (OMS), la anemia mediante los niveles de hemoglobina y la STH mediante la técnica de Kato-Katz. Se realizaron análisis de regresión logística para identificar los factores de riesgo de los tres resultados de interés. Un total de 572 niños de entre 6 y 59 meses fueron reclutados en marzo de 2019. Se determinó que la prevalencia de retraso en el crecimiento era del 31,3%, la anemia del 47,2% y el STH del 34,1%. Las cifras de retraso en el crecimiento y anemia superaron las estimaciones regionales y nacionales para 2019. Tener más hijos fue un factor de riesgo para el retraso del crecimiento, mientras que el hecho de que la madre estuviera casada se asoció con un riesgo menor. Los factores de riesgo para la anemia fueron la edad más joven y el sexo masculino, mientras que los factores de riesgo para el STH fueron la edad más avanzada, las vacunas incompletas y el nivel socioeconómico más bajo. El empleo de las madres fuera del hogar también se asoció a un menor riesgo de STH. Estos datos recientes ponen de manifiesto la necesidad de una atención clínica y una acción de salud pública rápidas e integradas para abordar las consecuencias sanitarias a corto y largo plazo en este grupo de edad infantil vulnerable. La integración de un marco de seguimiento y evaluación sería importante para una gestión eficaz, la optimización de los recursos y la rendición de cuentas, y para demostrar el impacto.

Desnutrición; Anemia; Helmintiasis; Preescolar

Resumo

Desnutrição, anemia e infecção por helmintos transmitidos pelo solo (HTS) são as principais preocupações da saúde infantil em regiões do mundo caracterizadas pela extrema pobreza, especialmente em áreas rurais e periurbanas. Realizou-se este estudo para determinar a prevalência dessas três condições coocorrentes em crianças em idade pré-escolar num distrito de extrema pobreza nos arredores de Iquitos, na Amazônia peruana, com a visão final de informar a ação da saúde pública. A desnutrição foi avaliada utilizando métricas padrão recomendadas pela Organização Mundial da Saúde (OMS); a anemia, utilizando níveis de hemoglobina e a HTS, utilizando a técnica Kato-Katz. Realizaram-se análises de regressão logística para identificar fatores de risco para os três desfechos de interesse. Em março de 2019, foram recrutadas 572 crianças de 6 a 59 meses. A prevalência de desnutrição foi determinada em 31,3%, anemia em 47,2% e HTS em 34,1%. Os números de desnutrição e anemia superaram as estimativas regionais e nacionais para 2019. Ter mais filhos foi um fator de risco para a desnutrição, enquanto a mãe ser casada foi associado a um menor risco. Os fatores de risco para anemia foram idade mais jovem e sexo masculino, enquanto os fatores de risco para HTS foram idade mais avançada, vacinação incompleta e menor nível socioeconômico. O emprego das mães fora de casa também foi associado a um menor risco de HTS. Esta evidência recente destaca a necessidade de atenção clínica rápida e integrada e ações da saúde pública para enfrentar as consequências a curto e longo prazo para a saúde nessa faixa etária infantil vulnerável. A integração de um quadro de monitoramento e avaliação seria importante para uma gestão eficaz, otimização de recursos e prestação de contas, e para demonstrar impacto.

Desnutrição; Anemia; Helmintíase; Pré-Escolar

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