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RESEARCH ARTICLE

The seasonality of nutrition status in Shawi Indigenous children in the Peruvian Amazon

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Abstract

Research on the impact of seasonal and climatic variability on childhood nutritional status in the Amazon is limited. We examined how the nutritional status of Shawi children under five years changed seasonally and explored parental participation in food system activities (fishing, livestock, agriculture, hunting) as a potential influence. Using a community-based research approach with Indigenous Shawi Peoples, we conducted cross-sectional surveys in pre-harvest (July-August 2014) and post-harvest (November-December 2015) seasons. Sociodemographic data, parental participation, weight, height, and hemoglobin concentration were collected for childhood nutritional assessment. We employed bivariable linear regression to analyze associations between seasonal variations in children's nutrition and parental food system engagement. The study took place across eleven Indigenous Shawi communities in Loreto, Peruvian Amazon. In total, 74 Shawi children and their parents were analyzed. Results indicated a decrease in childhood wasting (4.9% to 0.0%) and persistent anemia (66.2% to 66.2%), while stunting increased (39.2% to 41.9%) from pre-harvest to post-harvest. Parental participation in food activities varied seasonally, but its impact on childhood nutritional status was not statistically significant. Our findings highlight significant levels of undernutrition in Indigenous Shawi children, with slight seasonal variation. Future interventions must consider seasonal dynamics, and further exploration of parental roles in children's diets is warranted.

Introduction

A sustainable planet and equitable society require the elimination of hunger and malnutrition; thus, working with populations who are currently experiencing undernutrition is a research

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priority [1]. The second Sustainable Development Goal (zero hunger, SDG 2) pursues the elimination of all forms of malnutrition by 2030 to guarantee that all people will be food secure and to foster the implementation of sustainable food systems [2]. To achieve those targets, it is fundamental to understand the factors impacting the nutrition of populations living in rural and remote locations, such as socioeconomic, political, cultural, or biophysical factors including climate change [3]. In addition, a better characterization of local food systems, seasonal effects, and their impacts on children's nutrition status will help when designing and implementing climate-resilient nutrition interventions [4].

Undernutrition remains a pressing global issue, affecting millions of individuals across the world, particularly in low- and middle-income countries [1]. The incidence of undernutrition remains despite considerable advancements in the fight against hunger and malnutrition, posing serious obstacles to the growth and welfare of people. Stunting, wasting, and anaemia are just a few examples of undernutrition, all of which have serious effects on a person's ability to grow physically and intellectually, their immune system, and their general health [4]. Beyond affecting a person's health, undernutrition has negative effects on communities and civilizations, reduces economic output, and prolongs cycles of poverty [5]. Undernutrition persists as a health concern in the Amazon region, especially affecting Indigenous communities [5–7].

Furthermore, in regions like the Amazon, climate change acts as an environmental stressor challenging the nutrition of populations, projected to bring about ecological transformations and alterations in precipitation patterns [8]. Recognizing the interconnectedness between undernutrition and the impacts of climate change is vital for implementing comprehensive approaches that address the intertwined challenges of nutrition and environmental sustainability. While models project decreasing precipitation by the end of the century across South America, there is substantial heterogeneity in the Amazon ecological region, with more intense and frequent precipitation projected in the western area [9] and more frequent extreme hydrological events projected throughout the Amazon [10]. These changes have important implications for local food systems that depend directly on the forest and natural resources [11–14], presenting new risks to nutritional security. We distinguish forest from natural resources, because it symbolises a deeper link between the spiritual world of ancestors and Indigenous peoples, unlike other natural resources [15]. For countries like Peru, where 90% of the agriculture in the Amazon depends on rain-fed systems [16], food production has a deep seasonal cycle that is affected by seasonal interannual local climate. For example, the increased frequency of extreme hydrological events in the last twenty years in the Amazon has included extreme megadroughts in 2005, 2010, 2016, as well as extreme floods in 2009, 2012, and 2014 [17], which has had significant negative consequences on the food production and security of local populations [14,18].

Climate change presents additional challenges to the nutritional security and overall health of the Amazon Indigenous Peoples [14]. While infectious diseases, limited access to safe water and health services, and poverty [19] are among the most studied drivers of childhood undernutrition in Latin American countries, there is limited information on how environmental determinants, like climatic drivers, shape nutrition and food security of these populations [20]. Some relevant climate drivers affecting food and nutrition security include seasonal variability and more frequent and intense extreme weather events, like droughts and heavy precipitation [21]. Previous studies investigating the impacts of seasonality on food security of Indigenous Peoples have taken place in Africa [22] or the Andes [23], with a virtual absence of information on climatic drivers of nutrition in the Amazon. However, recent information indicates that interannual weather variation directly impacts food consumption and diversity of children's diet in a peri-urban city in the Peruvian Amazon, with authors highlighting the importance of considering climatic factors to design public nutritional programs [24].

Research about seasonal changes in children's nutritional status in the Peruvian Amazon are rare. A study performed in 2015 found levels of stunting were doubled for Indigenous children compared to non-Indigenous (56,2% versus 21,9%); however, climate variables nor seasonality were taken into account [5]. Another study in 1991 evaluated seasonal fluctuations and energy intake from children in remote areas in the Peruvian Andes, which concluded they are the more vulnerable to nutritional stress than adults [23]. For the Shipibo indigenous communities from Peru, seasonal flooding was characterized as important to food insecurity; however, nutrition status was not investigated [14]. Globally, evidence demonstrates the important role of seasonality and climate variables for children's nutritional status, especially among Indigenous households and those dedicated to subsistence agriculture [22]. More research is needed to understand the locally specific pathways through which climate variability and change, impacts children's nutritional status in Peru, to develop effective climate-resilient public health strategies. For example, Amazonian Indigenous food systems in Peru are rooted in family networks, with 90% of the agriculture being familial. In this system, parents' activities are key to producing food for selling, as well as for self-consumption. However, the mechanism by which parents' food system activities can influence children's food and nutrition security has not yet been clarified [25].

The anticipated and observed effects of climate change on precipitation patterns and temperature suggest that current seasonality will differ in the future [17]. Thus baseline information on food systems and current seasonal patterns is key to monitoring and detecting changes in seasonal food availability and nutrition [24]. The majority (98%) of Amazonian Indigenous communities source their food from traditional food system activities (e.g. agriculture, hunting, and fishing) [26], which are influenced by local meteorological conditions, including seasonality. While we know a lot about demographic, socioeconomic, and disease drivers of children nutrition in Latin America, researchers have recognized that more work is needed to tackle undernutrition among Indigenous Peoples [20]; however, given the present threat of climate change on food systems, this research cannot be separated from climatic drivers to properly inform climate-resilient nutrition and food security interventions [4]. Our study addresses this research gap in partnership with Indigenous Shawi Peoples of the Peruvian Amazon by assessing how the nutritional status of Shawi children under five years old changes seasonally and exploring how parental participation in various food system activities (i.e., fishing, livestock, agriculture, hunting) may play a role.

Methods and materials

Ethics statement

This research was approved by the Cayetano Heredia University Institutional Review Board (SIDISI 104118 and 59472) at Lima Perú and by the McGill University Research Ethics Board in Montreal, Canada (REB 497–0514). The work was built upon previous work in the region on the ethics of community engagement in research. Written Informed consent was acquired from authorities in each community, individuals, and from both parents in the case of children. Nutritional consultation was provided by a nutritionist (in partnerships with a Shawi translator) to the entire household and in cases where anemia was detected; iron was supplied to anemic individuals in coordination with the closest health post. Local health personnel were notified to facilitate follow-up medical consultations with individuals diagnosed with any malnutrition condition.

Indigenous Shawi Peoples and food systems

Shawi Peoples, one of 55 ethnic groups in Peru [27], live in the sparsely populated regions of Loreto and San Martín of the Peruvian Amazon (Fig 1). These regions are warm year-round

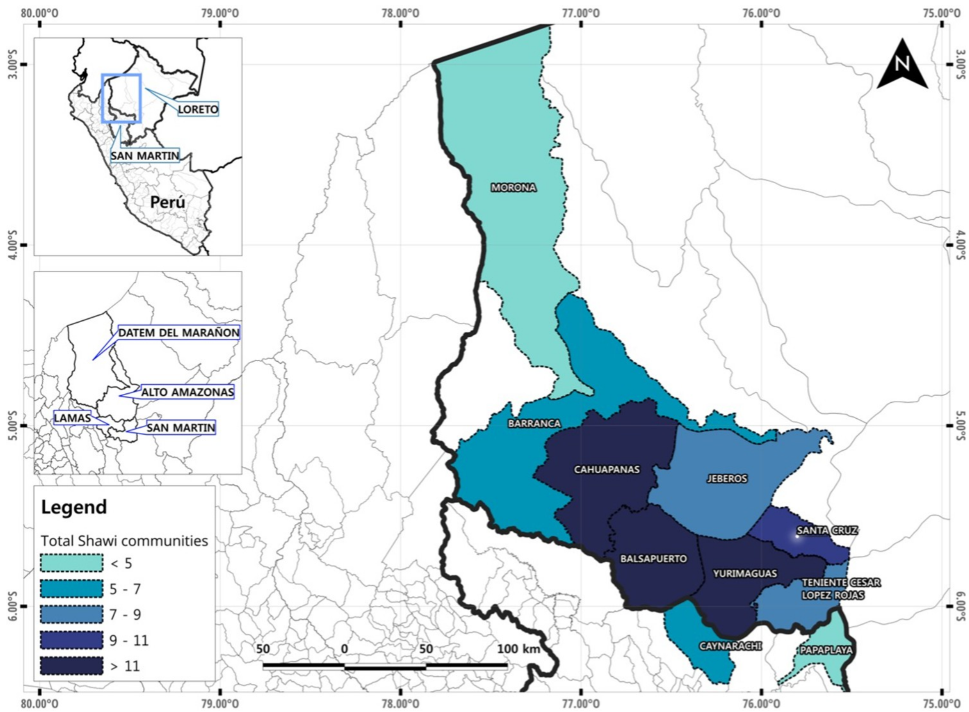

Fig 1. Peruvian regions where Indigenous Shawi Peoples reside. Base layer: https://github.com/healthinnovation/QShawi, created with QGIS 3.20 Bonn [Terms of Use: https://docs.github.com/en/site-policy/acceptable-use-policies/github-acceptable-use-policies].

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(average annual temperature: 25.5˚C) and have distinct wet (November-April) and dry (May-October) seasons [28–30]. According to the Peruvian Ministry of Culture, 26,841 Shawi live throughout these regions [31]. Shawi Peoples have been in contact with Peruvian non-Indigenous people since early in the Spanish colonization when Jesuit religious representatives approached them [32], and later on, during the post-independence era, when religious people, landlords, legal and illegal loggers had emigrated to the jungle to develop their activities.

Shawi live in small communities, ranging from 50 to 300 people, and typically reside with family members from up to three generations Shawi culture is rich, deeply connected with mother nature, and favours building social relationships with community members through cultural activities. One of key cultural characteristics of Shawi is that they still communicate using their traditional language *Camponan*. Family and community members typically engage in a food systems activities call *minga* which is a collective reciprocal work, dedicated to perform heavy tasks for example cleaning the land before planting cassava [33].

Over the past ten years, multiple social and environmental changes such as the rise of poverty, irregular precipitation, and droughts have altered Shawi livelihoods, territory, and food system practices [29]. In response, Shawi leaders are working to unify communities through an *Autonomous Territorial Government of the Shawi Nation*, which works to recover Indigenous knowledge, protect Shawi land and natural resources, and reinforce Shawi political autonomy [34].

Shawi maintain subsistence food systems to support their food and nutrition security. A food system includes activities such as food obtention, production, processing, distribution, preparation, and consumption, and is an interconnected system that is impacted by social, economic, and environmental factors [3]. The Shawi food systems relies primarily on small scale agriculture (primarily maize, cassava, and plantain), livestock, fishing, and hunting as food sources [31]. Infrequently, Shawi also obtain food from external sources (e.g. government social programs or purchased in the closest city) [13]. Shawi occupy distinct gender roles in their subsistence food activities: for example, while males are the primary hunters, both females and males are responsible for fishing and agriculture [13,28]. Additionally, most of these subsistence food activities are seasonal in nature [29–31]. During the dry season (May-October), Shawi typically clean, burn, and plant their agricultural land [28–30]. Harvesting peaks between September and October [28–30]. During the wet season (November-April), rain and flooding limit agricultural, fishing, and hunting opportunities leading to low food productivity, particularly between March and April [28–30]. Accordingly, prior studies show that Shawi experience more food insecurity in the rainy season compared to the dry season [28–30]. Fig 2 summarizes the seasonal variation in precipitation and perceived food security for Shawi Peoples [28].

The Armanayacu River, on which most Shawi communities are located, is only navigable by boat during certain seasons. Other transportation options, such as car, motorbike, and foot travel, are highly dependent on local weather which influences road and path conditions.

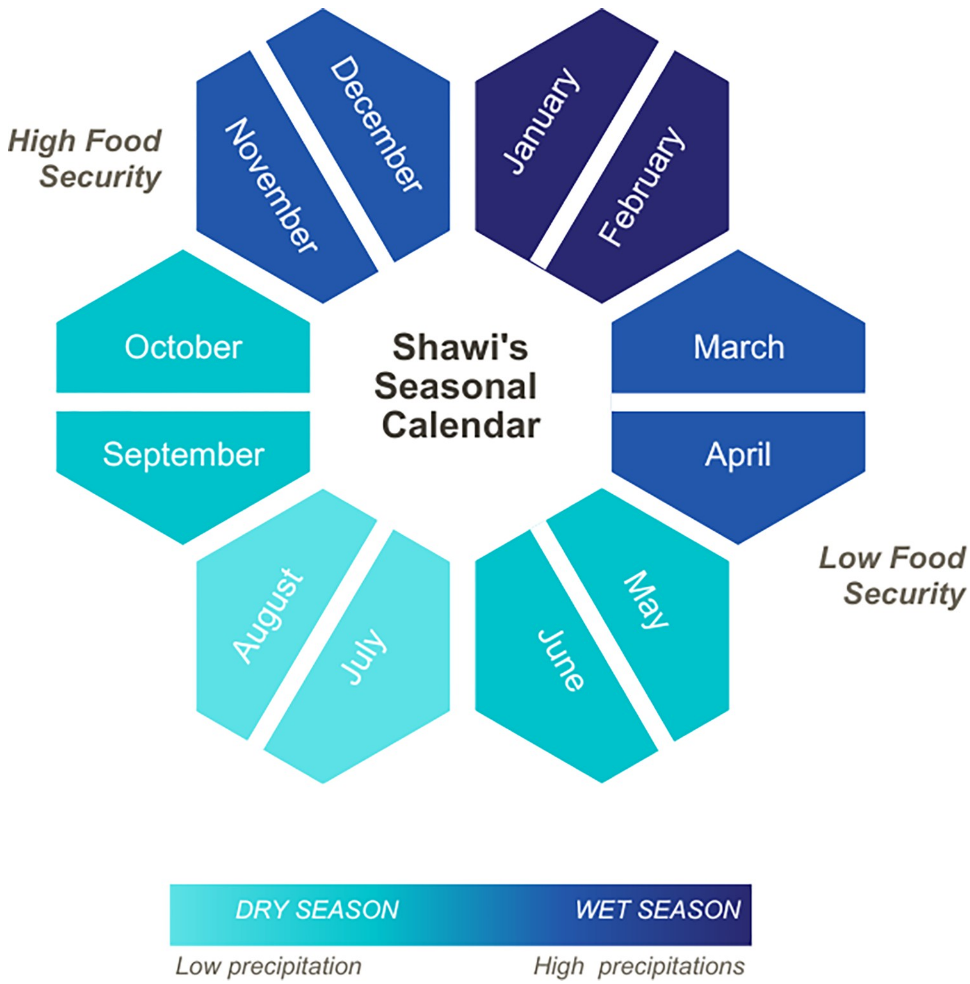

Fig 2. Seasonal calendar illustrating the variation in precipitation and perceived food security for Indigenous Shawi Peoples in the Peruvian Amazon. Note: This image was created by AVG from the data of Zavaleta, C. et al. [13,28].

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Consequently, access to all external goods and services is limited for Shawi communities. Biomedical healthcare services are also scarce in the Peruvian Amazon: only 70% of Indigenous communities in the Peruvian Amazon have a local health post [35]. While there is an average physician-patient ratio of 9.4 per 10,000 across Peru, Loreto region has one of the lowest ratios at 4.4 per 10,000 [36]. Furthermore, biomedical healthcare services in Peru generally do not incorporate Indigenous knowledge or practices [37]. These barriers to care could explain the persistence of poor health indicators among Shawi children [30].

Research approach

This study builds on a long-standing research partnership with Indigenous Shawi communities and leaders located in the Balsapuerto district of Loreto region in the Peruvian Amazon, via the Indigenous Health Adaptation to Climate Change (IHACC) research program. A community-based participatory research approach was employed, aiming to equitably involve communities as meaningful partners in order to develop rich research questions and data that are beneficial to communities in order to help achieve constructive change [38]. EcoHealth principles also guided the research approach, emphasizing the principles of transdisciplinary, equity, systems thinking, sustainability and knowledge to action [39].

This study was conceptualized after Shawi communities identified food and nutrition security as important climate-sensitive community health outcomes during pilot research phases [29]. Initial food and nutrition research conducted in these communities demonstrated that Shawi perceived their food security to vary seasonally [13,28]. Furthermore, parental participation in food system activities was perceived to be an important determinant of childhood nutritional status. Participants reported that food system was performed mainly by family members specifically "the parents", with a key result was to provide a healthy and cultural appropriated food to benefit the health of their children [13,28,29]. These findings, seasonality, and parent's participation in food systems, informed the current study's objectives and supported the use of a seasonal approach.

Study design and data collection

A longitudinal observational study design was used to assess how the nutritional status of Shawi children under 5 years old changed seasonally, and how parental participation in various food system activities may play a role. The first survey was conducted in June and July 2014 (i.e., end of the wet season with limited food availability), which is referred to as the pre-harvest season. The second survey was conducted in November and December 2015 (i.e., the end of the dry season with more food abundance), which is referred to as the post-harvest season.

To identify participants, a sampling frame was created by conducting a census of 18 Shawi communities located in Balsapuerto district, which were selective purposively for the study. A complete list of households, including household members and ages, was prepared for each community. Eleven of these communities (n = 204 households) were subsequently invited to participate in the study based on the following inclusion criteria: community leader interest, accessibility from Yurimaguas (closest city) via a maximum of 2 hours driving and 5 hours on foot; and having households with children under five years old in the community (see Table A in S1 Text for community details). Due to difficulties accessing some of the remote households in these communities, 188 of the 204 eligible households were invited to participate in the study. For households with more than one child under five years old, the participating child was randomly selected.

A survey questionnaire was used to collect data, and it was validated before fieldwork. Eleven Indigenous community members were trained to administer the survey orally in their local language, and a Shawi research coordinator (GL) was designated and trained. The questionnaire was usually completed by the selected child's mother or the grandmother, as females are typically responsible for childcare in Shawi culture. The questionnaire captured data on the following exposure (independent) variables: child's sex, birth order, child and parental age, parental education level, parental involvement in various food system activities (i.e., fishing, agriculture, hunting) during the prior two weeks using a yes/no question, and it also captured the use of food.

Household participation in social programs (as a proxy for external food or aid) was also included. Anthropometric information was also collected for the child and their parents using the Peruvian National Center for Food and Nutrition's (CENAN) protocol [40]. A digital scale (SECA 803; precision of 100 grams) was used to measure weight and a wooden stadiometer (precision of 2mm) was used to measure length in children from 0 to 2 years of age and standing height in children > 2 years of age. A HemoCue Hb 201+ was used to measure hemoglobin in three drops of finger prick blood from all children and parents to determine anemia status. All anthropometric measurements were taken by a Peruvian expert previously trained by the CENAM.

Data analysis

The raw data from survey questionnaires were input into Microsoft Excel, cleaned, and then analyzed in Stata version 16. Outcomes (dependent variables) of interest included stunting, wasting, and anemia in children under 5 years old. WHO Growth standards [41] were used to assign the height-for-age Z-Score (stunting) and Z-score BMI-for-age (wasting). For the 13 children who were more than 5 years old on the second visit, the WHO-AnthroPlus software was used to calculate these values [42]. Children were considered to be stunted or wasted if their respective Z-Score values were more than 2 standard deviations below the median. The WHO hemoglobin concentration guidelines [43] were used to assess for anemia wherein a hemoglobin value of ≤11 mg/dL was considered to be anemia.

The prevalence of each malnutrition condition was calculated for both seasons and seasonal changes were compared descriptively. The change in the mean Z-scores and hemoglobin concentration were compared using a paired t-test. Linear regression was used to examine the association between the variation of the mean anthropometric indicators (outcome/dependant variables) with sociodemographic characteristics (exposure/independent variables).

Results

Participants

All 188 invited households with children up to 5-year-old consented to participate in the first survey (2014); however, 83 (44%) households were lost to follow-up in the second survey (2015). Additionally, 31 households did not have complete information. Consequently, 74 (39.4%) households were included in the final analysis (Fig 3).

Nutrition status across seasons

Anemia was equally and highly prevalent in both seasons at 66.2% (x^2 = 1.7615, p = 0.184). Stunting increased from 39.2% in the pre-harvest season to 41.9% in the post-harvest season (x^2 = 44.6929, p = 0.000) while wasting decreased from 4.9% in the pre-harvest season to 0% in the post-harvest season (x^2 = N/A, p = N/A). Changes in each nutritional condition is shown

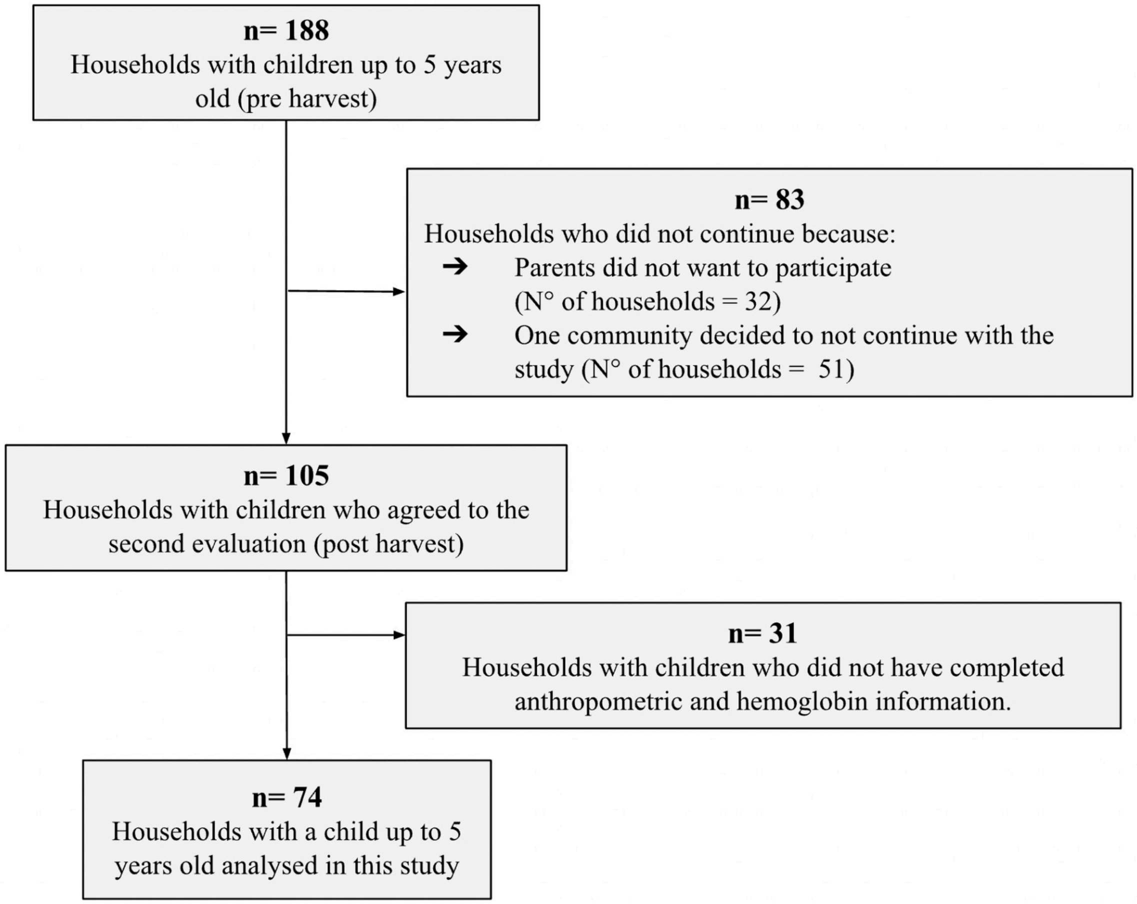

Fig 3. Household participants flow diagram for the nutrition research in partnership with Shawi communities, Peru.

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in Fig 4. As depicted in Fig 4, anemia exhibited the highest prevalence rate during both pre- and post-harvest periods, standing at 47.3%. This was followed by stunting, which affected 35.1% of the children during both periods. Notably, approximately 18.9% of the children experienced the onset of anemia from the pre-harvest to the post-harvest phase, while an equal proportion (18.9%) ceased to be anemic during the post-harvest period. Furthermore, it is noteworthy that all children diagnosed with wasting returned to the standard growth parameters during the post-harvest season.

With respect to anthropometric measurements, the average height-for-age Z score was the only value that significantly differed between seasons, with children having a higher height-for-age mean in the post-harvest season (Table 1).

Parental participation in food system activities

Maternal participation in all food system activities was higher in the post-harvest season compared to the pre-harvest season (Fig 5). Fathers rarely participated in agricultural activities in either season. There was no statistically significant difference in parental participation in food systems between seasons. The Fig 5 also indicates variations in the involvement of parents in different food system activities across seasons. Fathers exhibit a higher frequency of engagement in fishing and hunting, while mothers are primarily involved in agriculture and livestock management. This distinction in participation potentially influences the composition of diets,

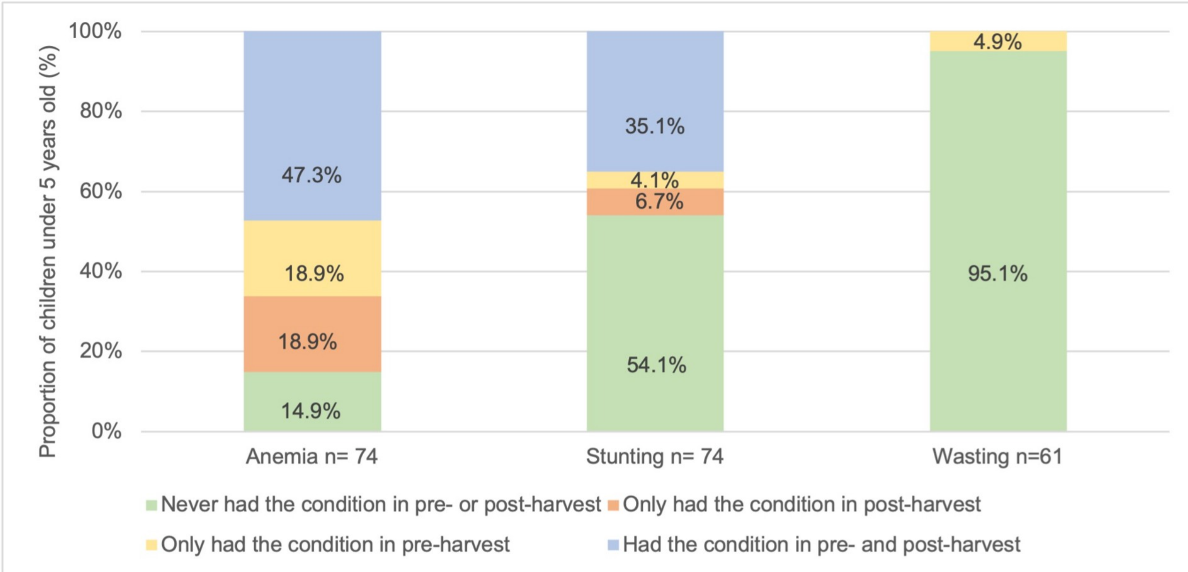

Fig 4. Changes in nutritional conditions (types of malnutriton) for Shawi Indigenous children under 5 years old between pre-harvest and post-harvest seasons, Peruvian Amazon.

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with fathers contributing to "traditional" animal-based food sources and mothers being responsible for plant-based food sources and a "modern" activity, raising livestock. These findings align with previous research conducted within these populations, which highlights the existence of a gender-based division of labour in food production activities [44].

In the pre-harvest season, most food produced was destined for household consumption (Table 2). During the post-harvest season, most participants continued to dedicate food for household consumption, except for livestock, which was used for both self-consumption and for sale.

Characteristics associated with seasonal variation in children nutritional status

Tables 3–5 show the variables that were statistically significant ($p<0.1$) for seasonal variation in children's nutritional status; more detailed data displays are provided in Tables B, C and D in S1 Text. Age of the child was the only variable that was significantly associated with Z-score variation in height-for-age (Table 3). Age of the child, birth order, mother's education level, and mother's BMI were significantly associated with the variation of the BMI Z-Score (Table 4). Father's education level and having a father with anemia was significantly associated with the variation of hemoglobin (Table 5). Parents' food system activities were not significantly associated with the seasonal variation in nutritional indicators.

Table 1. Variation in the anthropometrical measures of Indigenous Shawi children under 5 years old between pre-harvest and post-harvest seasons, Peruvian Amazon.

Outcome	Number	S1: Pre-Harvest Mean (CI)	S2: Post-Harvest Mean (CI)	p-value
Height-for-age Z score	74	-1.83 (-4.1, 0.41)	-1.59 (-3.69, 5.05)	**0.0413**
BMI-for-age Z Score	74	0.03 (-6.16, 2.41)	-0.01 (-2.16, 2.85)	0.7928
Hemoglobin (g/Dl)	74	10.52 (8, 14.2)	10.7 (8.7, 13.6)	0.1984

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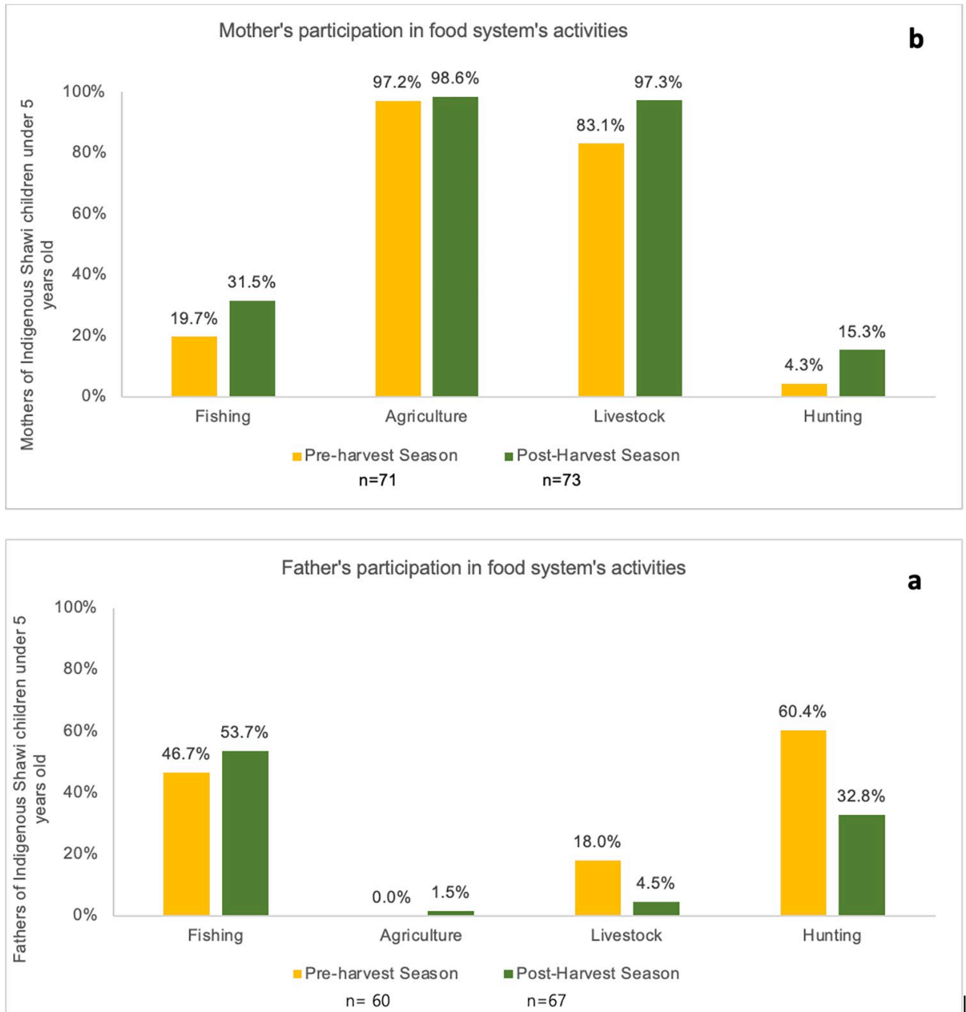

Fig 5. Frequency of food system activities performed by the father (a) and mother (b) of Indigenous Shawi children under 5 years old during the pre-harvest and post-harvest seasons, Peruvian Amazon.

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Discussion

Anemia prevalence did not change across seasons but stunting increased and wasting decreased at the post-harvest season; however, the mean value of height for age- Z score did increase significantly. These findings point to a modest improvement in the nutritional status of Shawi children during the post-harvest season. The levels of undernutrition among Shawi children in this study (stunting: 39%; wasting: 5%; anemia: 66%), were much higher than those for children across Peru (stunting: 15%; wasting: 0.6%; anemia: 36%) and in the Loreto region (stunting: 25%; wasting: 1%; anemia: 55%) [45].

Our findings highlights that despite improvements in the nutritional status of Latin American children [46], undernutrition remains a public health concern among Shawi Indigenous Peoples, and requires urgent attention. Studies from other Amazon countries have found that the rates of stunting, wasting and anemia in children are particularly high among Amazonian Indigenous Peoples, compared to the general urban population [5,47]. Specifically in Peru, despite extensive public health programs, the prevalence of anemia in children from 6 to 35 months in the coastal region (36.1%), is considerably lower than in the Amazon region

Table 2. Destiny of foods reported by parents of Indigenous Shawi children under 5 years old during the pre-harvest and post-harvest seasons, Peruvian Amazon.

	Mother food system activities			Father food system activities		
	Pre-harvest season 2014	Post-harvest season 2015	P-value Chi-square test	Pre-harvest season 2014	Post-harvest season 2015	P-value Chi-square test
	N ((%)	N (%)		N (%)	N (%)	
Fishing						
Eat only	14 (100.0)	23 (100.0)	NA	34 (100.0)	31 (100.0)	NA
Eat and sell	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
Sell only	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
Agriculture						
Eat only	51 (78.5)	70 (95.9)	0.348	41 (65)	13 (19.7)	0.905
Eat and sell	14 (21.5)	3 (4.1)		21 (33)	52 (78.8)	
Sell only	0 (0.0)	0 (0.0)		1 (1.6)	1 (1.5)	
Livestock						
Eat only	38 (66)	10 (14.1)	0.696	32 (61.5)	3 (4.7)	0.523
Eat and sell	16 (28)	61 (85.9)		18 (34.6)	61 (95.3)	
Sell only	3 (5.2)	0 (0.0)		2 (3.8)	0 (0.0)	
Hunting						
Eat only	3 (100.0)	10 (100.0)	NA	16 (88.8)	39 (86.7)	NA
Eat and sell	0 (0.0)	0 (0.0)		2 (11.1)	6 (13.3)	
Sell only	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	

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(53.6%) where most Indigenous Peoples reside [48]. Both iron deficiency anemia and chronic malnutrition in children can lead to extremely negative consequences, including negative impacts on growth and cognitive development, especially when affecting children under the age of 5 years old [49]. Therefore, the negative impact of under-nutrition and anemia threatens to maintain or enlarge the health and socioeconomic inequities that ethnic minorities currently face in the Amazon region and Peru.

Parental participation in food system activities was not associated with the variation in childhood nutritional status; however, it was observed, that at the post-harvest season most of the food system activities increased in frequency, which could explain the modest improvement on the nutritional indicators during the post-harvest season. Investigation and strategies to tackle undernutrition among Amazon Indigenous children will require a better understanding of the food system activities performed at a household level and their impact on children's diet. For example, a previous study found that children are likely to help their father with fishing preparation tools, accompanying them in hunting trips, or harvesting with their mothers–

Table 3. Bivariate analysis of the Height for Age Z-score of Indigenous Shawi children under 5 years old, Peruvian Amazon (*).

Predictors	Number	Pre-harvest season (2014) Z-score (mean + S.D.)	Post-harvest season (2015) Z-score (mean + S.D.)	Z Score Variation (2015–2014)	P-value
CHILD Age in months					
6–11.9	8	-1.50 ± 1.04	-1.67 ± 0.66	-0.17 ± 0.59	Ref.
12–23.9	18	-2.16 ± 0.89	-2.27 ± 0.82	-0.11 ± 0.39	0.877
24–35.5	20	-2.07 ± 1.02	-1.42 ± 1.92	0.65 ± 1.32	**0.041**
36–47.7	20	-1.50 ± 1.01	-1.47 ± 1.09	0.03 ± 0.45	0.614
48–60	8	-1.63 ± 0.56	-0.70 ± 1.77	0.93 ± 1.65	**0.023**

*Exposure/independents variables of children, parents and household recollected in 2014 were used to perform the analysis with the outcomes Z-score.

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Table 4. Bivariate analysis of the BMI for Age Z-score of Indigenous Shawi children under 5 years old, Peruvian Amazon (*).

Predictors	Number	Pre-harvest season (2014) Z-score (mean ± S.D.)	Post-harvest season (2015) Z-score (mean ± S.D.)	Z Score Variation (2015–2014)	p-value
CHILD					
Age in months					
6–11.9	8	-1.18 ± 1.06	0.11 ± 1.53	1.29 ± 1.65	Ref.
12–23.9	18	-0.27 ± 1.75	0.17 ± 0.55	0.44 ± 1.62	0.125
24–35.5	20	0.50 ± 0.72	-0.06 ± 0.71	-0.56 ± 0.63	**0.001**
36–47.7	20	0.50 ± 0.86	0.12 ± 0.81	-0.39 ± 1.01	**0.003**
48–60	8	-0.42 ± 1.78	-0.74 ± 0.62	-0.32 ± 1.82	**0.015**
Sex					
Male	35	0.17 ± 1.23	-0.18 ± 0.76	-0.35 ± 1.09	Ref.
Female	39	-0.09 ± 1.43	0.14 ± 0.89	0.23 ± 1.57	**0.070**
Birth order					
1–2	12	0.58 ± 0.97	0.10 ± 0.42	-0.47 ± 0.99	Ref.
3 a 6	39	-0.03 ± 1.43	-0.15 ± 0.88	-0.11 ± 1.38	0.437
7 or higher	14	-0.20 ± 1.47	0.44 ± 1.03	0.64 ± 1.68	**0.047**
MOTHER					
Education level					
None	20	-0.21 ± 1.97	0.37 ± 1.00	0.59 ± 2.07	Ref.
Primary school	45	0.34 ± 0.85	-0.12 ± 0.77	-0.45 ± 0.85	**0.005**
Secondary or more	7	-1.01 ± 1.27	-0.33 ± 0.54	0.68 ± 1.18	0.870
Mother's BMI					
Underweight	2	-3.85 ± 3.27	0.04 ± 0.33	3.89 ± 2.93	Ref.
Normal	50	0.16 ± 1.02	0.05 ± 0.80	-0.12 ± 1.19	**0.000**
Overweight	9	-0.35 ± 1.83	-0.31 ± 1.10	0.05 ± 1.62	**0.000**

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all activities which can provide them access to food products for consumption [28]. Participation of children accompanying their parents to perform food systems activities has been also reported for Amazon Indigenous communities of the Corrientes River Basin in Peru [47]. Given that Amazon Indigenous food systems are deeply connected with local food resources, any alteration of the natural environmental or external intervention without consultation with the Indigenous Peoples, can create a double-burden of over- and under-nutrition, where the prevalence of overweight and obesity increase while undernutrition does not disappear, as it has been observed in the other

Table 5. Bivariate analysis of the hemoglobin levels of children under 5 years old, Peruvian Amazon (*).

Predictors	Number	Pre-harvest season (2014) (g/Dl) (mean ± S.D.)	Post-harvest season (2015) (g/Dl) (mean ± S.D.)	Hemoglobin Variation (2015–2014)	p-value
FATHER					
Education level					
None	9	10.42 ± 1.39	11.37 ± 1.08	0.94 ± 1.44	Ref.
Primary school	44	10.58 ± 1.11	10.58 ± 0.82	-0.01 ± 1.18	**0.030**
Secondary school or more	8	10.61 ± 0.93	10.84 ± 0.81	0.23 ± 0.67	0.211
Anemia					
No	40	10.37 ± 1.20	10.70 ± 0.83	0.33 ± 1.31	Ref.
Yes	12	11.16 ± 0.73	10.67 ± 0.75	-0.49 ± 0.81	**0.045**

* Exposure/independents variables of children, parents and household recollected in 2014 were used to perform the analysis with the outcomes Z-score.

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parts of the world [50] and recently reported in the Peruvian Amazon [51]. Peru and other Latin American countries need to work with Indigenous Peoples to achieve the goal of ending hunger and malnutrition by 2030, as set by the Sustainable Development Goals.

Our results found that currently, the Shawi food systems are based on the participation of mothers and fathers, and the main purpose of produced food during both seasons is for self-consumption. Given that projected warming associated with climate change will decrease the capacity of outdoor labor [52] and moreover, increase precipitations during wet season, projected for the Peruvian Amazon in the next decades related with global warming [53], can make it almost impossible to gather food, food instability can be high, and decreased food security can become a key reason for Indigenous Peoples to consider moving to urban centres [54]. But even more worrisome is that the climatic drivers of ecosystem change could potentially bring repercussions for the nutrition of multiple Indigenous Peoples in the Amazon region [55] if adaptation is not taken promptly.

Amazon Indigenous Peoples are vulnerable to impacts of climate change [18], in part due to the reliance on subsistence farming and also because meteorological changes may disturb food transportation and local access to parental incomes. When it is a good food period, they will have enough to stock and save ahead, and climate exposure would not be a problem to perform hunting or fishing [14]. In South America, a sporadic event La Niña was characterized by intense precipitation in the Amazon including extreme flooding events during 2011–12, and results in reduced staple crop (maize, rice, sugar) consumption [24]. In addition, this extreme event highlighted the important role that the river played in food transportation: trade activity is higher when river levels decline, and the transportation of market products is compromised when river levels are too high [24]. Thus, during the dry season, reported from June to November in that particular study, there was an increase of economic flow generating more income for the families in the community to buy food products such as fruits [24]. This finding implies that seasonality and precipitation could affect children's nutrition not only through parental food production but also by altering the accessibility and transportation of food sources. Climate change, seasonality, meteorological changes, and their effects on parental food systems activities thus, required to be accounted for food and nutritional interventions.

Limitations and strengths

Working with remote Indigenous communities, represented a challenge for conducting typical epidemiological studies, on one side they are minorities, implying that big sample size is sometimes difficult to achieve. Indigenous communities usually inhabited disperse locations, with additional cost and time to reach participants, compared with populations that are in locations with good roads or public transportation. We acknowledge that because we are using accessibility to the closest city, as a selection criterion for including communities, representativity of our population may be reduced. With the support of the communities, we have trained a culturally sensitive team to visiting each household, and we wanted to respect the community decisions. For example, when one community decide to do not participate during the second round of data collection. We recognized the importance to partner with Indigenous communities, working under their preferences and times, to carry on more studies and the monitoring of their nutritional status in the future years. Consequently, it is important to highlight our research approach, the Community based participatory research, which allows meaningful engagement with the community, will provide deeper understanding, and empower them.

While the study may have investigated various factors related to children's health and well-being, the specific assessment of their diet intake was not included, which represent another limitation.

Conclusion

Research anticipates that climate change will increasingly compromise food security for Indigenous Peoples. Therefore, understanding how local food systems activities vary by seasons, and the effects on childhood nutrition status can inform the development of interventions that target specific food difficulty periods and to plan climate resilient policy adaptations. Further nutritional research will need to address not only more unstable meteorological conditions, but also persistent inequities to health services access, socioeconomic disparities, endemic infectious diseases, and challenges related to remoteness. Since food systems activities in Amazon Indigenous communities, including Shawi communities, are highly influenced by gender roles, further investigation is warranted to understand the mechanism of how climate change would influence children's nutrition through both of their parents, mother, and father.

Supporting information

S1 Text. Tables A–D. Table A. Characteristics of the eleven Shawi communities included and questionnaires. This table provides an overview of the characteristics of the eleven Shawi communities included in the study (community name, geographical access from the closest city, services in the community), along with information about the questionnaires used for data collection. Table B. Bivariate analysis of the Height for Age Z-score of Indigenous Shawi children under 5 years old in the Peruvian Amazon. Table presents the statistical analysis of the relationship between age and height, providing the Z-scores for assessing the growth status. It includes the exposure/independent variables of children, parents, and household, which were collected in 2014, and their association with Z-score outcomes. Table C. Bivariate analysis of the BMI for Age Z-score of Indigenous Shawi children under 5 years old in the Peruvian Amazon. The table presents the statistical analysis of the relationship between age and BMI, providing the Z-scores for assessing the growth status. It includes the exposure/independent variables of children, parents, and household, which were collected in 2014, and their association with Z-score outcomes. Table D. Bivariate analysis of the Hemoglobin levels of Indigenous Shawi children under 5 years old in the Peruvian Amazon. The table presents the statistical analysis examining the relationship between age and hemoglobin levels, providing insights into the nutritional status and potential anaemia prevalence in this population. It includes the exposure/independent variables of children, parents, and household, which were collected in 2014, and their association with hemoglobin levels outcomes.
(DOCX)

S2 Text. PLOS' questionnaire. PLOS' questionnaire on inclusivity in global research. Details ethical, cultural, and scientific factors unique to fostering inclusivity in global research.
(PDF)

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