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RESEARCH ARTICLE

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Stunting in indigenous Waorani children living near the oil-extraction sites: What can the determinants of health tell us about this?

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ABSTRACT

The Waorani are a recently contacted indigenous group inhabiting oil extraction territories in the Amazon. This study aimed to analyse the prevalence of stunting and explore its association with health determinants in Waorani children under 5 years of age. A cross-sectional study was conducted with 102 children. Mothers were surveyed about biological, socioeconomic, environmental and health service determinants. Bivariate, multivariate and weight-adjusted logistic regression models were performed. A total of 39.2% of the children exhibited stunting. Health determinants such as male sex (OR = 2.73, 95% CI: 1.63–4.64), short maternal stature (OR = 4.96, 95% CI: 2.38–10.84), child age (OR = 1.04, 95% CI: 1.02–1.05), reduced dietary diversity (OR = 2.37, 95% CI: 1.27–4.53) were associated with a higher prevalence of stunting. Prenatal care was also associated with stunting (OR = 1.59, 95% CI: 1.16–2.21, for two or more checkups), with a potential reverse causality effect. Tall birth height (OR 0.28, 95% CI: 0.13–0.57) was associated with a lower prevalence of stunting. No socioeconomic differences were found related to stunting. The health determinants model may have limitations in socioeconomically homogeneous populations. Stunting prevention policies should take this model into account, contextualised to the specific territory.

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KEYWORDS
Stunting; ethnic minorities; health inequalities; indigenous peoples; cross-sectional

Introduction

Stunting in children is a highly prevalent health problem around the world. It is estimated that stunting affected 23.2% or 150.2 million children under five globally in 2024 (United Nations Children's Fund [UNICEF], World Health Organization [WHO], & World Bank Group [WBG], 2025). In the last 10 years, there has been a significant reduction in stunting in most countries, but this reduction has not been equitable (Dessie et al., 2025; World Health Organization [WHO], 2025). In Ecuador, a South American country, the prevalence of stunting reaches 17.5% of children under 5 years of age (Instituto Nacional de Estadística y Censos, 2024), one of the highest in the Region. This percentage is notably higher in indigenous populations and ethnic minorities, characterised by a history of marginalisation and a context of exclusion and social inequality (Ramirez-Zea et al., 2014; Rivadeneira et al., 2022). In Ecuador, one in four indigenous children is stunted (Instituto Nacional de Estadística y Censos, 2024).

The Waorani population is of particular interest among Ecuador's indigenous minority groups, as they were relatively isolated until six decades ago. After the contact process due to the exploitation of natural resources, most Waorani people settled in small villages. Despite some Waorani resistance, the extractive frontier expanded into their territory as a result of government policy (Lu et al., 2017; Rival, 2016). This research focuses on villages located near oil camps in three provinces: Orellana, Pastaza and Napo. The Waorani population is

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estimated at around 3500 people, living in around 40 communities (High, 2025). Their moods of subsistence had changed in the last decades, from a forest-based economy focused on hunting, gathering and small horticulture, to the development of agroecological systems to sustain bigger communities (Rival, 2016; Zurita, 2014). They also maintain several strategies to access the market economy, from the selling of crafts and local resources to engaging in wage labour. Their diets have also integrated market products, in particular rice and soft drinks (Bravo Díaz, 2023).

Few studies address the nutritional status of the Waorani population. However, previous studies have suggested that the changes to the Waorani's way of life, from a nomadic, hunter-gatherer existence to an 'urbanised' lifestyle involving less production and consumption of native foods, have impacted their nutritional health. This has resulted in a double burden, maintaining a high prevalence of stunting in children while also leading to an increase in overweight and obesity in adults (Donders & Barriocanal, 2020; Houck et al., 2013).

One of the approaches commonly used to analyse persistent health problems in the population has been the social determinants of health model (Braveman et al., 2011; Marmot & Wilkinson, 2005). This model emphasises the role of social inequality as a structural element that determines the presence of disease and death (Braveman et al., 2011). Several studies have shown that social inequalities are associated with lower social and cognitive development in children (Maggi et al., 2010; Moore et al., 2015), as well as higher rates of illness and death (Spencer, 2018). Children in vulnerable situations have an increased probability of experiencing stunting (Huda et al., 2018; Kundu et al., 2025). Meanwhile, biological, environmental and health service-related determinants of health have been shown to play an important role in understanding health and disease (Wamani et al., 2007). Specifically, it is known that children exposed to unhealthy environments (Gyimah et al., 2023) with less access to sanitation services (Silva et al., 2023), less stimulating family environments (Sonuga-Barke et al., 2022) and less access to health services (Ayelign & Zerfu, 2021), tend to have a higher prevalence of stunting. However, there has been little exploration of the role of health determinants in native indigenous populations (Oré et al., 2024). Specially in Latin America, the literature about health inequalities in indigenous people is limited (Serván-Mori & Meneses-Navarro, 2025). A case in point is the Waorani indigenous people, who inhabit a particularly vulnerable social, geographical and environmental setting.

This study aims to analyse the prevalence of stunting and to explore the associated health determinants in the Waorani child population under 5 years of age. The malnutrition model proposed by the United Nations Children's Fund was the conceptual framework for this research (United Nations Children's Fund [United Nations Children's Fund, 1990). This model comprises immediate, underlying and basic determinants, which are illustrated in Figure 1. Basic causes refer to structural determinants, such as insufficient education, low income and limited access to resources (Rivadeneira et al., 2022; United Nations Children's Fund [UNICEF], 1990). These factors led to poverty and malnutrition. Underlying determinants include food insecurity in households, inadequate childcare, poor sanitation and limited health services. On the other hand, immediate

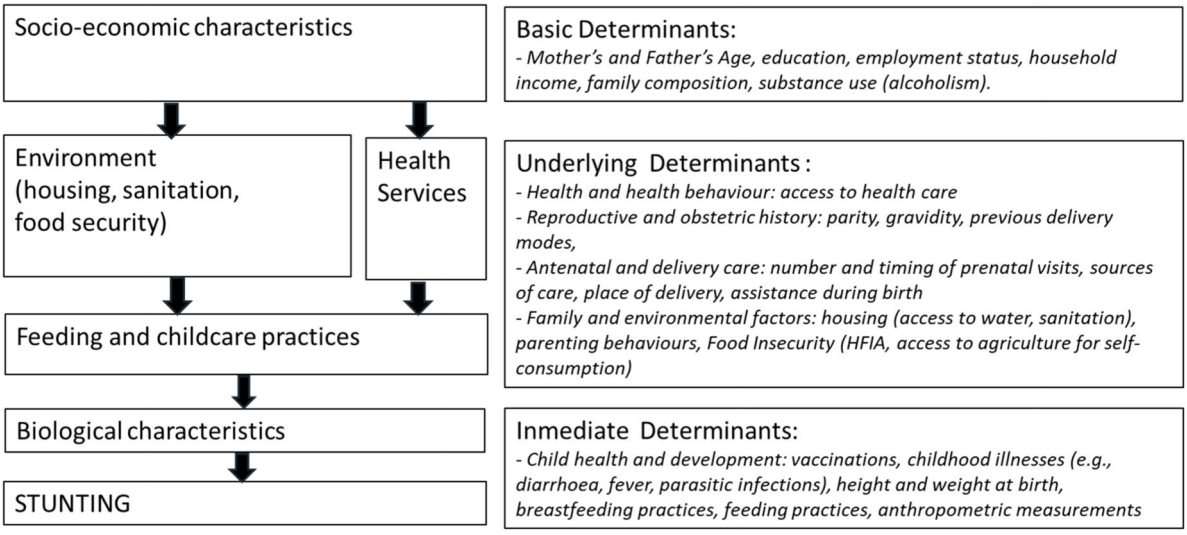


Figure 1. Conceptual model of health determinants for stunting in Waorani children and survey components.

determinants are directly related to an individual's biological condition, such as insufficient dietary intake, the presence of diseases and other factors like sex and age (Rivadeneira et al., 2022; United Nations Children's Fund [UNICEF], 1990).

The hypothesis guiding this study is that structural determinants, such as extreme poverty and lower maternal education, are associated with a higher prevalence of stunting. Underlying determinants, such as poorer access to food and less access to health services, would be associated with a higher prevalence of stunting in Waorani children. Similarly, immediate determinants, such as low birth weight, would also be associated with a higher prevalence of stunting.

Methods

Setting and study population

The Waorani territory lies in the northeastern part of Ecuador's lowland rainforest, between the Tiputini River in the north and the Curaray River in the south, which forms part of the western Amazon basin. The Waorani people hold land rights within the Waorani Ethnic Reserve, an area of 6125.6 km^2 that overlaps with Yasuní National Park, where they retain rights of use (Lu et al., 2017). The eastern part of this territory is also known as the Tagaeri-Taromenani Intangible Zone, which is a protected area where Waorani families in voluntary isolation live. The Waorani communities are also distributed across the Ecuadorian provinces of Orellana, Napo and Pastaza, with around 40 communities spread out over a large area and far apart from each other. This territorial dispersion has consequences regarding equitable access to drinking water, sanitation, health services, etc. (Sierra et al., 2023). The native language of the Waorani people is Wao-tededo, but most adults are bilingual, speaking and understanding both Spanish and Wao-tededo.

Waorani communities vary in size; some have reached up to 300 people, in contrast with the traditional matrilocal arrangements of longhouses of up to 35 people (Bravo Díaz, 2023). Small communities are dedicated to hunting and gathering, with a minimal production of agricultural products, many of which they sell or exchange for other, more elaborate foods (Donders & Barriocanal, 2020). Yet, most communities have currently intensified agriculture with more than two gardens per family, some of which can reach up to a hectare (Bravo Díaz, 2023). Agricultural products include a variety of crops, from which manioc and plantain stand out. This intensification in agricultural practices has been analysed as an agroecological system (Rival, 2016; Zurita, 2014). To access the market economy, women make crafts that they sell for their subsistence. Many of the Waorani, in particular men, engage in wage labour for short periods of time, particularly for the oil companies.

To support the activities of the oil industry, two main roads were built in the Waorani territory, named Auca and Maxus. These roads not only facilitated greater oil exploitation, but also accelerated the colonisation of nearby lands. The Auca road, called like this because of the access to the oilfield of the same name, was built in the late 1970s. The Maxus Road was built in the 1990s. The Maxus Road, called like this because of the name of the foreign oil company that built it, extends over 140 km inside the Yasuní National Park and Waorani Ethnic Reserve (Donders & Barriocanal, 2020; Espinosa et al., 2014).

This study was carried out in ten Waorani communities: part of the Maxus Road circuit in the Orellana province are Ganketapare, Guiyero, Nenkeguiro, Timpoka, Dikaro, Yarentaro and Gabaro; part of the Auca Road circuit is Miwaguno, also in Orellana and Tiwino-Waorani on the border of Orellana and Pastaza province. Finally, the community of Gareno, located in the Napo province, is also part of the oil circuit (Figure 2). Although both main roads are part of an oil circuit, colonisation along the Auca Road has led to uncontrolled deforestation driven by the expansion of land for livestock. In contrast, the Maxus Road, which crosses the protected Yasuní area, has been subject to stricter controls and restrictions to curb deforestation and settlement—at least until recent years. These communities were selected by convenience sampling. Several points were considered when selecting these communities: 1) being in the area of influence of the Maxus and Auca roads, 2) information from community leaders about the presence of children under 5 years old and 3) interest and consent of the community for the research team to enter the territory during data collection. The feasibility of access was also considered when selecting the study sites. While this may be a limitation of the study, it is important to take some considerations into account. Before conducting the research project presented here, it was necessary to establish connections with the community and gain an understanding of their worldview. This study was part of a larger project, which included several components of both research and community training. While the

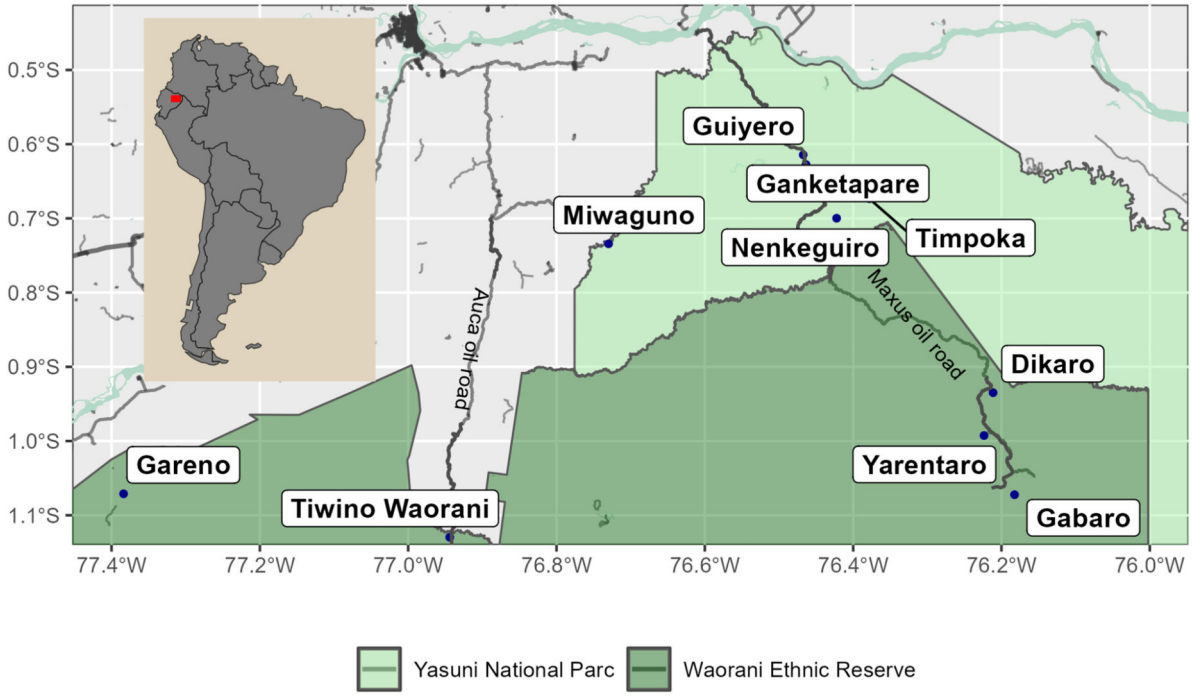


Figure 2. Map of the Waorani territory included in the study. (dark green: Waorani Ethnic Reserve, light green: Yasuní National Parc).

community training process itself is not the subject of this article, it enabled us to build trust with the community and identify its key issues, including childhood malnutrition. In that sense, the selected communities could not be too isolated, due to logistical limitations that prevented a closer dialogue with the research team.

For this study, all children residing in the communities who met the criteria of being under 5 years of age and identified by their mothers as Waorani were included. The children did not present any acute illness at the time of the study or any chronic health problem that could affect their growth (congenital diseases, hypothyroidism, etc.).

Sampling representativeness and census coverage

By targeting major settlements within three provinces, the study reached the main area of residence of the Waorani population. This excludes the small percentage of Waorani people living in urban areas outside of their ancestral Amazonian territory. Demographic data from Amazon indigenous populations are notoriously difficult to estimate, and common information sources are prone to under-registration, while local public services do not reach isolated rural populations. Information from the national census provides better estimates but still remains incomplete. Nevertheless, an updated census conducted during the same period as the survey for this research (2022) was used to evaluate the representativeness of this research in greater detail (Instituto Nacional de Estadística y Censos, 2022). Using the latest national census of Ecuador, variables about ethnic auto-identification and nationality were employed to identify the Waorani children. Table 1 shows the comparison between the census data and the sample. It is worth noting that the survey covered more than 16% of the total child population in each age group across all geographic areas. This study investigated 102 children, representing 25.6% of the Waorani children from 0 to 5 years residing in Ecuador.

Table 1. Children under 5 years old census population (2022) in survey regions (along the Auca and Maxus roads) compared to survey coverage, Ecuador.

		Survey region	
Group	Age groups	Auca road and gareno *n* (%)[a]	Maxus road *n* (%)[a]
Children	<2 years	174 (25.3%)	59 (44.1%)
	2–5 years	130 (16.2%)	36 (30.6%)

[a] *n* = Waorani individuals in National Census, % = coverage reached in this study.

A Waorani community census, conducted during 2023 but not available, reported population totals similar to the National Census. Post-stratification was conducted to evaluate representativity and population weights for this population (Supplementary Material 1).

Study design and data collection

This study employed a cross-sectional design. The data were collected from a survey of 102 Waorani children under 5 years old and their mothers. Data collection was carried out with the prior consent of the Waorani communities regarding the entry of the research team and for the collection of information. Children and their mothers were recruited through a call made by the community leaders. The location for data collection was a space designated by the community for conducting surveys and anthropometric measurements.

Trained nutritionists administered a face-to-face survey to the children's mothers, based on the Spanish version of the Multiple Indicator Cluster Survey (MICS), a questionnaire for children under five designed by United Nations Children's Fund [UNICEF] (2018) and the National Health and Nutrition Survey of Ecuador (ENSANUT-2012) (Freire et al., 2013). It is important to note that the questionnaire underwent a cultural adaptation process before its application to make it more sensitive to the cultural context of the Waorani population. The survey covered socioeconomic, biological, environmental, feeding and childcare practices and health-care services-related determinants. A Waorani translator supported the data collection team, constantly translating information from Spanish to Wao-Tededo if necessary.

Portable electronic microscales (ADE model M320600, Hamburg, Germany) were used to measure the weight of mothers and children. The height of mothers and children over two years old was measured using a portable stadiometer (SECA model SECA 213, Hamburg, Germany). For children under two years of age, the length of the reclining baby was measured on a length table (ADE model MZ10027-1, Hamburg, Germany). The average of the two measurements was considered as the final data. If there were variations or more than 100 g in weight or 0.1 cm in height and length between the two measurements, a third measurement was taken. The instruments were periodically calibrated. The recommended criteria for anthropometric evaluation were followed (de Onis et al., 2007; United Nations Children's Fund [UNICEF], 2018). Height-for-age Z-scores (HAZ) were calculated using the 2006 WHO growth standard (de Onis et al., 2007).

Analysis model and variables

The outcome variable for this study was child stunting. *Stunting* was reported as a height-for-age z-score under -2, according to the WHO reference tables and cutoffs. We used the R Anthro WHO package to identify children with stunting.

In this study, the health determinants associated with stunting were analysed, following the multicausal model proposed by UNICEF (1990). Based on the conceptual model explained in Figure 1, the following proxy indicators were applied to measure the health determinants:

Basic determinants

- *Socioeconomic determinants:*

  The following proxy indicators were considered:

  -Unsatisfied Basic Needs (UBN): Four components were evaluated to assess households' socio-economic status: (i) School Attendance: Households with children aged 6–12 not attending school; (ii) Housing Materials: Evaluated for deficiencies based on floor and wall materials. Floors of 'Pambil' or 'Tierra' and walls made of 'Choza' material were considered deficient. (iii) Basic Services: assessed access to adequate water sources and sanitation facilities, and Sanitation: Connection to a septic system considered adequate and (v) overcrowding: calculated as the number of persons per room, with more than three persons per room indicating overcrowding.

  UBN commonly includes economic dependency, but wasn't evaluated in this survey; thus, the index leans heavily on physical living conditions and human capital investment (schooling) to proxy for structural poverty. The sum of the above indicators was used to construct the Unsatisfied Basic Needs (UBN) index,

categorising households further as: Not poor (sum equal 0), Poor (sum equal to 1), or Extreme poverty (sum > 1) (Alkire et al., 2015).

-Mother's education: categorised as a) high school, b) none/basic.

-Receives any financial aid: The family or one of its members receives some financial support from the government or a non-governmental organisation.

Underlying determinants

- *Environmental determinants:* Deficient materials housing (roofs, floors, or walls of the house in poor condition), adequate sanitation services (access to drinking water, sewage system, toilet) were considered.

  The variable 'reduction in dietary diversity' corresponds to one of the food security measures, which answers the question: 'Have you found it necessary to reduce the diversity of foods consumed by family members due to a lack of money or other resources in the last year?' This component is part of the Household Food Insecurity Access Scale (HFIAS), which includes nine standardised questions regarding food access (Coates et al., 2007). For this study, only the issue of access to food diversity was shown, as the other questions did not show significant differences between the groups.
- *Determinants related to health services:* a) complete vaccination: the child has received all the necessary vaccinations for their age according to the Ecuadorian national vaccination schedule (Ministerio de Salud Pública del Ecuador, 2025), b) number of prenatal check-ups and c) the mother received care from a health professional (doctor, qualified nurse, midwife) during childbirth.

Immediate determinants

- *Biological characteristics:* included *biological Children's characteristics (*sex, tall height at birth (according to the mother's information, the child was larger than average at birth), received antiparasitic (the child has received antiparasitic medication in the last year), children was ill last month (the child had any infectious or non-infectious illness last month) and *biological Mother's characteristics:* included age, number of children (number of live births), short height (height less than 150 cm, the cut-off point was based on previous studies in Ecuadorian indigenous communities (Rivadeneira et al., 2022). A sensitivity analysis for the maternal stature cutoff point can be found in Supplementary Material 1.

Further information on the variables and indicators used for their calculation can be found in Supplementary Material 1.

Statistical analysis

This study investigates the determinants of malnutrition, specifically stunting using standardised height-for-age z-scores, within the Waorani communities. A preliminary exploratory analysis guided the prior selection of determinants, and while the sample size is modest, we carefully monitored the degrees of freedom and events per variable (EPV) by limiting the number of predictors to ensure the models remained stable and to mitigate the risks of overfitting and inflated confidence intervals. This exploratory analysis guided the selection of determinants, and a subset of determinants was then selected using exhaustive stepwise logistic regression model selection, first exploring how best multivariable associations were used to model stunting. The Morgan-Tatar exhaustive enumeration algorithm was used to search for best subset selection with a weighted model (Morgan & Tatar, 1972). Variance inflation factor (VIF) analysis was performed on implemented models, ensuring no multicollinearity between determinants was detected (with values below 1.6).

Bivariate models were constructed for each variable and compared with a complete weighted model, and a model with post-stratified sampling weights was reported (Supplementary Material 1). The decision to choose the weighted parsimonious model over the unweighted adjusted model was evaluated. The impact of weighting on variance inflation was measured using the Kish Design Effect. While an unweighted adjusted model maximises statistical power under the assumption of random missing data, it produces biased estimates if sample selection is correlated with risk factors for stunting. To correct for this selection bias and mitigate the

variance inflation introduced by unequal weighting, a weighted parsimonious model was chosen. The unweighted sample (n = 102) overrepresented communities along the Maxus oil road and underrepresented remote settlements along the Auca road and in the Gareno region (see Supplementary material 1). This variance inflation reduced the effective sample size to 67. Post-stratification weighting corrected these discrepancies, resulting in a weighting design effect of 1.58.

Given the logistical and resource difficulties that resulted in the sample being collected in two different data collection periods (March 2022 vs. June 2024), a sensitivity analysis was performed. This analysis excluded one of the two time periods and compared the results. The model coefficients remained comparable, and tests for heterogeneity (Chi^2 tests for malnutrition) between time periods showed no significance. Finally, the survey period as a covariate in the models showed no significant effect (Supplementary Material 1).

The regression results are reported including odds ratios, confidence intervals and p-values. The R scripts used for this analysis have been made publicly accessible via the https://github.com/PBG-Ec/Waorani_StuntingModel repository, and data upon request to the authors.

Ethics approval

This study was approved by the Committee on Ethics for Research with Human Beings of the Pontifical Catholic University of Ecuador, code OSV-003-2024, V3. Written informed consent was obtained from all mothers/fathers or guardians of the participating children. The consent of the community leaders was obtained for the entry of the research team into the Waorani communities. After collecting the data, the research team returned to the communities to share the results of the research with the mothers/caregivers and community leaders.

Results

Sample characteristics

Figure 2 shows the distribution of the communities studied in the oil circuit. In total, 102 children were studied, 65 from the Auca Road and Gareno and 37 from the Maxus roadway. Stunting was present in 39.2% of the Waorani children studied. More than half of the children studied were female (Table 2). About 20% of the children had a tall height at birth, according to their mothers' verbal reports; 46.1% of the children had been ill in the past month. Regarding the mother's characteristics, the average age was 26.5 years old and the average number of children per mother was 3. 15.7% of the mothers were shorter than 1.50 m (Table 2).

Regarding environmental determinants, only 52.9% of households had access to sanitation services, such as drinking water, sewage systems and toilets. On the other hand, 74.5% of the families had to reduce the diversity of their food due to economic hardship or lack of other resources. About socioeconomic determinants, 26.5% of families lived in overcrowded conditions, 37.3% of households lived in extreme poverty, 60.8% in poverty and 47.1% of the mothers had a high school education. Regarding access to health services and care, it was found that 48% of the mothers had received their first prenatal care in the third trimester of pregnancy. More than half of the children studied (56.8%) had not received all the vaccinations recommended for their age group (Table 2).

Stunting and determinants of health

Regarding the health determinants analysed, a higher percentage of stunting was observed in male children (51.1%) versus female children (29.8%) (Figure 3). Stunting was present in 43% of children who received deworming medication in the past year and 48.9% of those who were sick in the past month. 68.8% of children of mothers shorter than 1.5 m experienced stunting. On the other hand, those born taller than average, as reported by their mothers, had a lower percentage of stunting compared to those born average or short (20% vs. 43.9%).

50% of children from homes with inadequate housing materials and 41.7% of children without adequate sanitation services exhibited stunting. Furthermore, 42.1% of children whose households experienced a reduction in food diversity exhibited stunting. Among those who did not experience a reduction in food diversity, 30.8% exhibited stunting. On the other hand, 34.2% of households in extreme poverty and 40.7% of

Table 2. Characteristics of the sample, Waorani children under 5 years of age, residing in communities along the Auca and Maxus roads, Ecuador (n = 102).

Dimension	Variable	Value	Total
Dependent variable	Stunting	Yes	40 (39.2%)
		No	62 (60.8%)
Immediate determinants			
Biologic determinants			
Children's characteristics	Sex	Male	45 (44.1%)
		Female	57 (55.9%)
	Tall height at birth	No	82 (80.4%)
		Yes	20 (19.6%)
	Received Antiparasitics	No	50 (49%)
		Yes	52 (51%)
	Child sick in last month	No	55 (53.9%)
		Yes	47 (46.1%)
Mother's characteristics	Average mothers age		26.5
	Average number of children		3
	Short height mother (<1.5 m)	No	86 (84.3%)
		Yes	16 (15.7%)
Underlying determinants			
Environmental determinants			
	Deficient housing materials	No	96 (94.1%)
		Yes	6 (5.9%)
	Adequate sanitary services	No	48 (47.1%)
		Yes	54 (52.9%)
	Reduction in food diversity	No	26 (25.5%)
		Yes	76 (74.5%)
Health services related determinants			
	Prenatal care (number of check-ups)	None	29 (28.4%)
		One	22 (21.6%)
		2 or more	49 (48%)
	Complete vaccination	No	58 (56.9%)
		Yes	44 (43.1%)
	Care at delivery by a health professional	No	46 (45.1%)
		Yes	56 (54.9%)
	Receives financial aid	No	73 (71.6%)
		Yes	29 (28.4%)
Basic determinants			
Socioeconomic determinants			
	Overcrowding	No	74 (72.5%)
		Yes	27 (26.5%)
	Poverty by UBN	Not poor	2 (2%)
		Poor	62 (60.8%)
		Extreme poverty	38 (37.3%)
	Mother's education	High school	48 (47.1%)
		Basic or none	54 (52.9%)
	Receives financial aid	No	73 (71.6%)
		Yes	29 (28.4%)
Total			102 (100%)

overcrowded households had stunted children. The educational level of 40.7% of the mothers of children with stunting was basic or none, while in 37.5% of children with stunting, their mothers had attained a high school level (Figure 3).

Stunting was found in 51% of children whose mothers had 3 or more prenatal checkups during pregnancy and in 43.5% who did not receive care from a health professional during childbirth. 46.6% of those who did not receive complete vaccinations exhibited stunting, while among those who did receive complete vaccinations, 29% were stunted (Figure 3).

Figure 4 shows the trend in length/height z-scores by age, according to the children's age in months. It is noteworthy that as children get older, their average z-scores are lower than those of younger children, with a notable decline in children between 0 and 20 months and show no sign of recovery as children get older.

Multivariate regression model

Table 3 displays the estimates from the bivariate and weight-adjusted multivariate regressions, as well as the parsimonious weight-adjusted model. Older children were associated with a higher probability of stunting (OR = 1.03, 95% CI: 1.00–1.05); this association remained significant in the model with population weights (OR = 1.04, 95% CI: 1.02–1.05). Male sex was also associated with a 2.73 times greater probability of stunting than

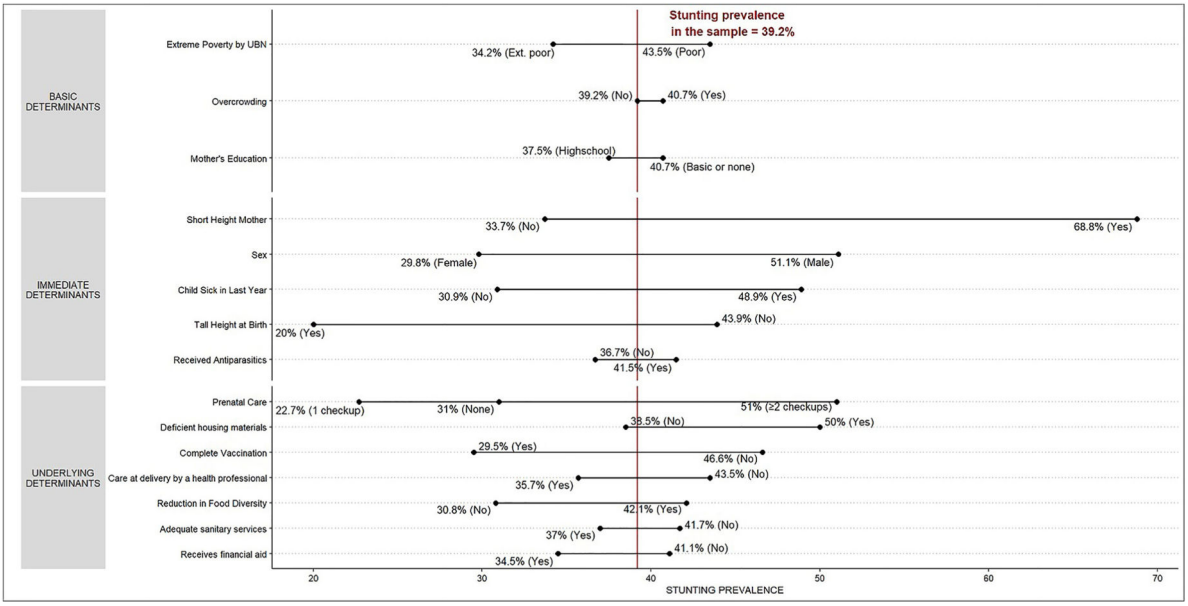


Figure 3. Stunting prevalence per health determinants, Waorani children under 5 years (n = 102), the red line indicates population prevalence.

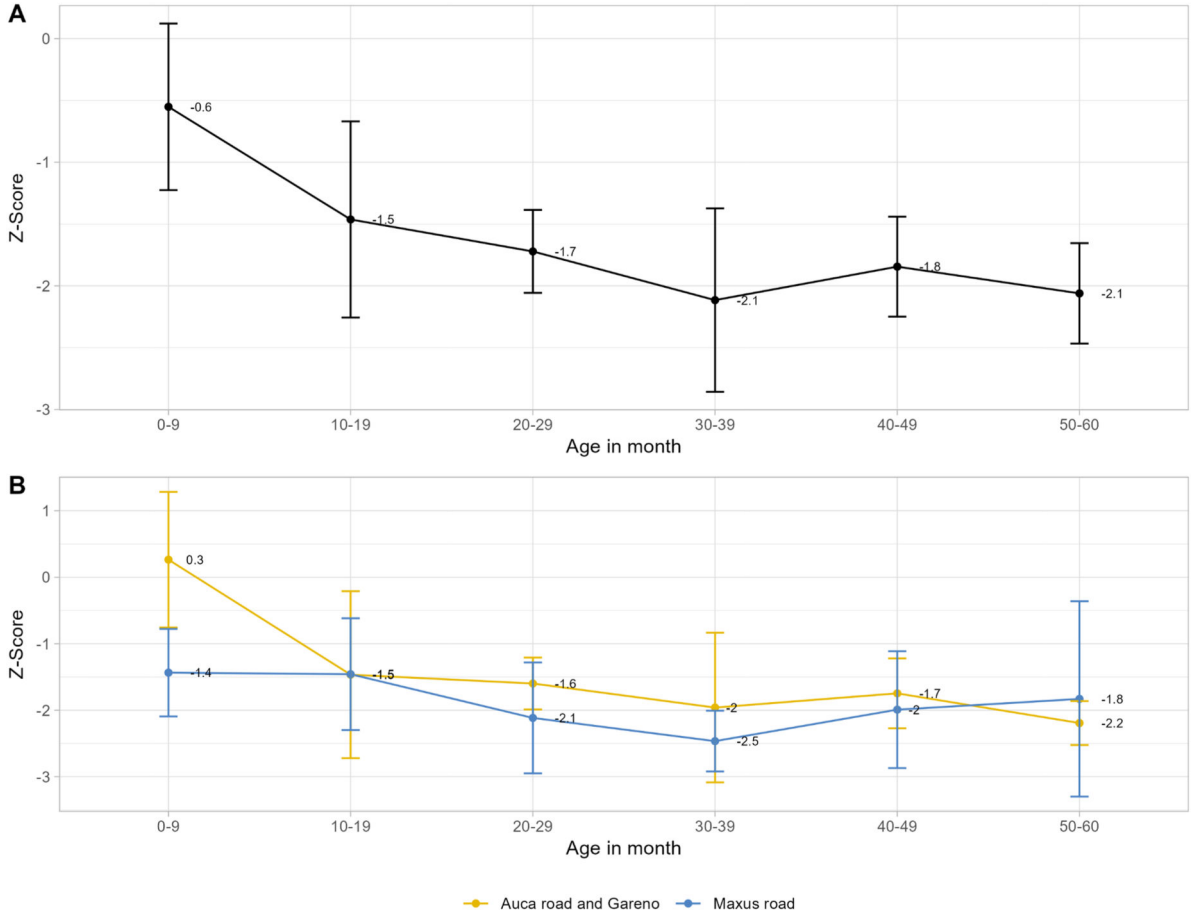


Figure 4. Box-plot showing mean length/height Z-scores for age, according to age in months of the children, in A: total sample, B: Auca road and Gareno (yellow line) and Maxus road (blue line).

Table 3. Bivariate and multivariate logistic regression of health determinants and stunting. Waorani children under 5 years, Ecuador (n = 102).

	OR non-adjusted		Weighted model OR adjusted			W. Parsimonious OR adjusted		
Determinants	(95% CI)	*p*-value	(95% CI)	*p*-value	VIF	(95% CI)	*p*-value	VIF
Immediate determinants: Biologic								
Children's age	1.03 [1.00, 1.05]	0.030*	1.04 [1.02, 1.06]	0.000***	1.59	1.04 [1.02, 1.05]	0.000***	1.09
Sex of children (male)	2.46 [1.10, 5.64]	0.030*	2.60 [1.50, 4.59]	0.001***	1.16	2.73 [1.63, 4.64]	0.000***	1.05
Tall height at birth	0.32 [0.09, 0.96]	0.058+	0.26 [0.11, 0.54]	0.001***	1.07	0.28 [0.13, 0.57]	0.001***	1.04
Short height mother (<1.5 m)	4.32 [1.43, 14.83]	0.012*	5.40 [2.48, 12.30]	0.000***	1.17	4.96 [2.38, 10.84]	0.000***	1.07
Child sick in last month	2.14 [0.96, 4.87]	0.065+	1.53 [0.89, 2.62]	0.125	1.09			
Received Antiparasitics	1.30 [0.59, 2.92]	0.515	0.62 [0.32, 1.20]	0.166	1.62			
Underlying determinants: Health services-related determinants								
Prenatal care (≥2 checkups)	1.64 [1.02, 2.71]	0.046*	1.62 [1.15, 2.31]	0.007**	1.22	1.59 [1.16, 2.21]	0.004**	1.05
Complete vaccination	0.48 [0.21, 1.09]	0.084+	0.74 [0.41, 1.34]	0.318	1.22			
Underlying determinants: Environmental determinants								
Reduction in food diversity	1.64 [0.65, 4.42]	0.309	2.67 [1.39, 5.33]	0.004**	1.14	2.37 [1.27, 4.53]	0.008**	1.05
Basic determinants: Socioeconomic determinants								
Mother's education (basic or none vs high school)	1.21 [0.54, 2.71]	0.641	1.25 [0.70, 2.24]	0.459	1.24			
Extreme poverty (UBN)	0.71 [0.30, 1.63]	0.426	0.61 [0.33, 1.13]	0.122	1.23			

+ Marginally significant *p*-value: less than 0.1. *Statistically significant *p*-value, less than 0.05. **Very significant *p*-value, less than 0.01. ***Highly significant *p*-value, less than 0.001.

female sex (95% CI: 1.63–4.64). This association was independent of other variables in both the adjusted and weight-adjusted models. A mother's stature less than 1.5 m was associated with a 4.96 times greater probability of stunting in children (95% CI: 2.38–10.84) compared to children of taller mothers when adjusted by other variables. A tall birth height, as reported by the mother, was associated with a lower probability of stunting (OR = 0.28, CI: 0.13–0.57).

Among the environmental determinants, the only factor significantly associated with stunting was reduced food diversity. In the weight-based model, it was found that children in households where food diversity was reduced had a 2.37-fold increased prevalence of stunting compared to those in households with food diversity (95% CI: 1.27–4.53). Among the socioeconomic determinants, the mother's educational level did not show a significant association with stunting in the unadjusted and adjusted model for no education/primary education versus high school, and the poverty index was not significantly associated with stunting.

When analysing determinants related to health services, prenatal care (≥2 check-ups) was significantly associated with stunting (OR = 1.59; CI: 1.16–2.21). Complete vaccination for age was not found to be significant in the stunting models.

Discussion

Stunting in Waorani children living near the oil-extraction sites: about the resource curse paradox

In this study, 39% of Waorani children under 5 years of age were stunted. This prevalence is twice as high as that of other Ecuadorian children (Instituto Nacional de Estadística y Censos, 2024) and higher than the global estimate of 23.2% (United Nations Children's Fund [UNICEF], World Health Organisation [WHO], & World Bank Group [WBG], 2025). The Waorani people are an indigenous group from the Ecuadorian Amazon that remained in relative isolation until a few decades ago. The children included in this study lived along the Auca Road and Gareno and Maxus Road, on the land of the Yasuní ecological reserve. These roads were planned and built following the oil industry's involvement in the territory (Donders & Barriocanal, 2020; Espinosa et al., 2014). The Waorani territory is considered to hold the largest Ecuadorian oil reserve. It is estimated that oil represented, on average, 51% of national income in the last two decades (Bunce & Carrillo-Maldonado, 2023). Despite living in one of the territories with the greatest oil wealth, the high prevalence of stunting reveals deficiencies in their living conditions. This speaks to the inequalities present in the distribution of the benefits of the extractive industry.

According to the findings of this study, only 53% of Waorani children have access to adequate sanitation services, piped water, toilets and sewage systems. 37% of the families with Waorani children live in conditions of extreme poverty. These results suggest a lack of livelihoods amidst an abundance of natural resources. The extractive model, which is supposed to have a positive effect on the population's living standards, appears to

have a contradictory effect on people living in this territory. It has been observed that extractive activities greatly affect isolated indigenous territories whose livelihoods depend directly on the natural environment and who live in community systems (Acuña, 2015; O'Faircheallaigh, 2013). This territory, their source of livelihood, is affected on various levels: environmental, economic, social and cultural (Bozigar et al., 2016; Scheidel et al., 2023). The presence of roads and oil infrastructure, and the new forms of employment associated with the extractive industry, leads to new forms of trade and money dependence. This, along with the presence of people from outside their community, alters their culture and way of life. At the same time, pollutants derived from oil activity affect the water and soil, disrupting the natural environment and impacting food security (Bozigar et al., 2016).

Studies conducted in other populations exposed to extractive activities also reveal negative effects on their livelihoods and health (Adu Sarfo & Tweneboah, 2024). This is known as the resource curse. In Africa, a study documented that life expectancy and mortality were negatively affected in areas with abundant natural resources that have been exploited by industry (Oduyemi et al., 2021). The impact on territories with extractive activities was even greater when, in addition to low economic growth, healthcare spending for these populations was limited (Oduyemi et al., 2021). This situation also highlights the limited role of the State in protecting these populations, especially in hard-to-reach areas.

Another study analysed data from 167 countries, from 1960 to 2011, to examine the relationship between oil wealth and infant mortality (Wigley, 2017). The evidence shows that countries with limited oil resources perform better than oil-rich countries in reducing under-five mortality. This could suggest a limited effectiveness of oil-rich countries' governments in using these resources to improve children's health. Regarding child nutrition, a negative effect has also been observed in countries or territories with abundant extractive resources (Njangang et al., 2024). Countries with fewer natural resources have achieved better results in reducing child malnutrition compared to their counterparts with greater natural resources. Dependence on natural resources would explain the prevalence of malnutrition (Njangang et al., 2024). This dependence on natural resources as a source of state revenue limits social participation in state decision-making. This, in turn, leads to policies that do not prioritise the improvement of human capital (Njangang et al., 2024). The structures of inequality affecting indigenous groups remain in place.

In parallel to this, the Waorani social organisation has faced changes. First ethnographic works describe the Waorani people as an egalitarian society, meaning that those who lived together had a similar access to forest resources (Rival, 2002). Yet, recent studies have recorded that in contemporary communities, tensions related to unequal distribution of resources are rising (Houck et al., 2013). These tensions are also related to the economic dependence resulting from new forms of work and relationships with the extractive industry. Access to jobs in the oil sector generates income that benefits the Waorani population inequitably. This income is often used to purchase non-traditional, usually processed foods, leading to a poorer diet and negatively impacting their nutritional health. In other words, there is a social shift that also affects their traditional habits and customs, and their social relationships.

Biological determinants and stunting

This study aimed to explore the presence of stunting according with the determinants of the health model. After performing bivariate and multivariate analyses, biological determinants such as male sex (OR = 2.73, 95% CI: 1.63–4.64) when compared with female sex, short maternal stature (OR = 4.96, 95% CI: 2.38–10.84) when compared with taller mothers and child age (OR = 1.04, 95% CI: 1.02–1.05) were significantly associated with stunting. Similarly, a tall height at birth was associated with a lower prevalence of stunting (OR = 0.28, 95% CI: 0.13–0.57) compared with normal or short height at birth.

A significant association between male sex and stunting was observed in this study. Other studies have reported greater vulnerability to stunting in males (Thompson et al., 2024; Wamani et al., 2007). Although sex differences in stunting vary between countries and regions, some authors consider that greater vulnerability of males to infections at early ages could lead to undernutrition (Wamani et al., 2007; Thompson et al., 2024). Cultural and caregiving factors that may favour one sex over the other must also be considered (Wamani et al., 2007). In the case of the Waorani population, more research should be done to understand the differences between boys and girls in terms of care.

On the other hand, it should be noted that the older the children are, the greater the prevalence of stunting. This phenomenon has been observed in other studies (Ayelign & Zerfu, 2021; Rivadeneira et al., 2022). Some explanations may stem from the delayed introduction of solid foods or insufficient nutrient and calorie intake as children get older (Rivadeneira et al., 2022). Short maternal stature has also been associated with stunting in their children in other studies (Azriani et al., 2025; Niragire et al., 2025; Rivadeneira et al., 2022). This association demonstrates an intergenerational relationship between maternal height and growth retardation in offspring (Azriani et al., 2025; Niragire et al., 2025). Short maternal stature may imply lower nutrient reserves, which can result in insufficient nutrient availability for the foetus during pregnancy (Javid & Pu, 2020). In addition, short women may have a narrower pelvis which would affect optimal foetal growth (Wells, 2017) and is associated with low birth weight. In turn, short maternal stature and low birth weight are associated with a high risk of stunting (Sinha et al., 2018).

Environmental determinants and stunting

In this study, 74.5% of the households where the Waorani children live have reduced the diversity of their diet in the last year. When applying the model with weights, a significant association was found between stunting and reduced dietary diversity. Other studies have observed an association between food insecurity and dietary diversity in households with stunting (Harper et al., 2023; M'Kaibi et al., 2017). This indicator, used as a proxy for food security, highlights the potential impact of the extractive model on the social and cultural environment of the Waorani population. Food security is a determinant interrelated with environmental, cultural and socioeconomic factors, as it depends on both food availability and access, but also with cultural practices that influence what they eat, when and how. In the case of the Waorani population, modifications to their environment and their traditional ways of accessing and consuming food can limit their food diversity and lead to reduced food security. Indeed, the presence of roads or highways has had a negative impact on traditional communities due to increased mobility to urban environments and access to industrialised and ultra-processed foods (Abdullah & Wang, 2024; Makbul et al., 2019).

A study conducted in Indigenous communities in Colombia, residing in extractive territories, mentions how changes in culture and the environment led to limitations in the availability, access and diversity of food (Agudelo-Hernández & Guapacha-Montoya, 2025). Changes in cultural practices determine modifications in how food is obtained, shifting from hunting and gathering to the buying and selling of products. Furthermore, climate change results in reduced food availability (Agudelo-Hernández & Guapacha-Montoya, 2025). This is also observed in the Waorani communities, who have rapidly modified their subsistence and food systems due to their recent contact with Western culture. For example, hunting and fishing, their traditional means of survival and food sources, have been displaced by other activities, such as employment in the oil fields. These jobs, in turn, generate a limited income, which nevertheless allows them access to different types of food in more urbanised local markets (Byron & Reyes-García, 2021). Some of these non-traditional foods, such as rice or canned tuna, require different cooking and consumption methods.

At the same time, modifications to the natural environment, resulting from the presence of roads, oil infrastructure and environmental pollutants, reduce access to local foods. According to the Waorani people's account, game animals, for example, are harder to find, having moved deeper into the jungle. Some rivers no longer have the same abundance of fish as before. Another shift can also be observed in the consumption of traditional beverages. Drinks like 'chicha', a fermented beverage made from cassava and other tubers, have been replaced by sodas, fruit juices, beer and flavoured beverages. Increased exposure to local markets has also led to changes in the traditional diet (Byron & Reyes-García, 2021). Researchers have also observed a change in food consumption, including the food that is shared at parties and community gatherings, with the introduction of ultra-processed beverages and other non-traditional foods.

Another important shift is in family dynamics. It has been observed that family or community care networks play a protective role against stunting, especially in more economically disadvantaged populations (Astuti et al., 2025; Prayitno et al., 2025). Waorani people used to live in matrilocal arrangements where sisters lived together with their families, and the care of the longhouse children was shared. Recent studies suggest that young couples currently choose to move to the husband's village if it is located near a source of external resources such as the oil company (Bravo-Díaz, 2021); this means that the matrilocal extended caring support

is also changing. This, in turn, implies less support for the nuclear family, which could also affect the quality and time spent preparing food and feeding infants.

Health service-related determinants and stunting

In Waorani children, 4 out of 10 had not received all the vaccinations for their age. Similarly, 29% of mothers did not receive any prenatal care. This gap in preventive care activities provided by health services is concerning. Health inequalities among indigenous populations in Latin America have been well documented (Garza & Abascal Miguel, 2025; Ruano et al., 2021). The health system in the region is characterised by its fragmentation and segmentation, which presents a major challenge in terms of providing quality services for all (Garza & Abascal Miguel, 2025). This challenge is particularly acute for rural indigenous populations, as is the case with the Waorani people. Among the persistent health problems in Latin America that exhibit the greatest inequalities in indigenous child populations is stunting (Garza & Abascal Miguel, 2025).

In this research, complete vaccination was considered a proxy indicator of access to health services. No significant association was found between complete vaccination and stunting. Vaccination is a preventative measure taken by health services that protects against the main infectious diseases in childhood (Dadras et al., 2024; Loli & Carcamo, 2020; Pramono et al., 2024). Complete vaccination requires greater attention to care and continuous access to more comprehensive health services (Dadras et al., 2024). The effect of vaccination on stunting depends on when the vaccination is administered. Timely access to vaccination appears to be important in early childhood (Berendsen et al., 2016; Pramono et al., 2024). However, the complete vaccination indicator, as a proxy for health services, could have a marginal effect if the other basic and structural determinants of health are not addressed.

In this study, a higher number of prenatal checkups was associated with a higher prevalence of stunting. This result was not what was expected. Prenatal care is related to improving the identification and treatment of mothers with anaemia and low birth weight, which in turn could influence foetal growth and newborn weight. However, greater prenatal coverage is not always associated with better outcomes for mothers and children (Abanga et al., 2025; Siregar et al., 2023), especially in regions with specific cultural practices, such as Waorani communities. The counterintuitive finding of this study could be related to other unaddressed aspects of prenatal care. For example, beyond the number of checkups, the timing and quality of prenatal care have been shown to have a positive effect on greater height for age (Abanga et al., 2025; Siregar et al., 2023). In this study, 48% of mothers received their first prenatal care only in the third trimester, which would be interpreted as delayed access to prenatal care. This delay would hinder the timely identification and management of risk factors and health problems in both the mother and foetus, which could result in lower birth weight or length (Siregar et al., 2023). This could partially explain the counterintuitive finding of prenatal care being associated with stunting in this research. In Ghana, high-quality prenatal care was significantly associated with a lower likelihood of resulting in low birth weight or premature babies (Abanga et al., 2025). A recent study observed that the protective effect attributed to prenatal care also depends on the synergy with other factors (Liu et al., 2017). The benefits of prenatal care are greater in environments that promote equity and health, where other well-being conditions exist (Tessema et al., 2025), such as access to clean water and medicines, and better incomes, which is far from the reality for the Waorani population.

The finding observed in this study could also be due to reverse causality. The mother may have received several checkups during pregnancy due to her health problems or the foetus. These, in turn, could be related to a higher risk of stunting in the child. A subsequent study that considered elements of the quality and cultural adaptation of prenatal care and its effects on maternal and child health in the Waorani population would better explain that finding.

Socioeconomic determinants and stunting

Despite scientific evidence suggesting the effect of socioeconomic factors on stunting (Sonuga-Barke et al., 2022; Taderegew et al., 2025), this effect could not be found in this study. We found no significant differences in the mother's education or household poverty in children with stunting. One possible explanation may be the relative homogeneity of the living conditions of the Waorani. In this study, 88% of the households where Waorani children live are poor, and 37% are extremely poor. Livelihoods, income, access to basic services and

education are relatively homogeneous across the Waorani community. This leads us to discuss a possible limitation of the structural determinants of health in explaining disease in this particular context. Therefore, more research is needed to understand socioeconomic differences in societies that have recently come into contact with the outside world, have a highly dispersed population and have intermittent access to a steady income. The classic approach to the determinants of health could be limited in homogeneous populations, which also have different practices and cultural views, as is the case with the Waorani. Krumeich and Meershoek (2014) emphasise the limitations of the health determinants model in understanding ill health in specific contexts. The authors evidence the intricate processes and pathways that explain disease that are not considered in the classic model. Elements such as the history and the population's own cultural elements are pathways outside the health determinants model and are not visible in the classical model (Krumeich 201438; Meershoek,). The health determinants model may have limitations in highlighting factors related to health inequalities in a constantly changing world, with dynamics that intertwine various elements, including commercial, digital and climatic ones (Gupta & Lugani Sethi, 2025). Understanding and addressing these 'different pathways' that explain disease and health inequities in local contexts when formulating public policies is fundamental. Governments need to contextualise the determinants and pathways that reproduce health inequity to ensure the effectiveness and sustainability of their policies (Shokouh et al., 2017). Furthermore, it raises the need to identify additional, more sensitive and context-specific indicators to evidence social inequities within this minority group.

In particular, economically homogeneous populations such as the Waorani, who also live in a territory with multiple complexities, require a rethinking of the determinants of health. According to the findings of this study and previous studies, it is important to consider at least the following elements to identify intra-group inequality: health rights over territory (Diaz et al., 2020), food sovereignty and continuity of the traditional food system (Jernigan et al., 2023), sociocultural transition and degree of market integration (Bjerregaard et al., 2018), social position, access to healthy environments/health assets, social and economic support networks (Bjerregaard et al., 2018) and marginalisation within the group (Jackson et al., 2016). These elements could more sensitively reveal the most vulnerable among the vulnerable. However, it is necessary to explore other elements that could explain intra-group inequalities, such as those related to culture, which are more complex to objectify.

Study limitations

This study has several limitations. Its cross-sectional design does not allow for the establishment of cause-and-effect relationships. The Waorani population is a relatively small group, approximately 3000 inhabitants, in a dispersed and difficult-to-access territory. This study included 102 children under 5 years of age, which may limit the statistical significance. The research was conducted using convenience sampling, given the need to obtain approval from the communities and their leaders to participate in the data collection process. This could mean that the most remote or least-served communities are not represented. The use of the post-stratification method, based on the national census, provides better estimates, but may still lack coverage for more isolated and nomadic Waorani communities.

Some variables come from the mother's verbal report, such as the child's birth length and illnesses. This could introduce information bias. Given the limited geographic accessibility of the Waorani populations, not all children have birth data or documented information about their health problems. In this sense, the mother's verbal report is the only possible source of information. The use of the single dietary diversity item from the HFIAS scale, instead of the full scale, was a later decision, made after observing its association with stunting. This decision may limit a complete understanding of the food insecurity scale. However, it also suggests the need to review the sensitivity of scales that measure food insecurity in rural, predominantly agricultural populations.

An important observation of this study is that, despite the scientific evidence, no significant differences were found in the prevalence of stunting based on socioeconomic levels. A possible explanation could be the relative homogeneity of the living conditions of the Waorani. This could perhaps represent a limitation of the classic model of the determinants of health for small populations in similar living conditions. The authors believe it is necessary to understand the determinants of health and other factors associated with children's nutritional health, in light of research that includes cultural and environmental elements, which could not be addressed

in this article. An intercultural and multidisciplinary approach is needed in the systemic analysis of factors associated with childhood malnutrition.

Conclusions

This study found a high prevalence of stunting in Waorani children under 5 years of age living in communities near oil wells in Ecuador. Four out of ten Waorani children studied suffered from stunting. When exploring the determinants of health, proximal determinants such as male sex, older children age and short maternal height (less than 150 cm) were significantly associated with stunting. Conversely, a larger birth height in children was associated with a lower prevalence of stunting. These findings highlight the need for health policies that integrate protective and care elements with an intercultural approach. Monitoring and support are essential during the critical stages of a child's development: pregnancy, early childhood and late childhood. The strategies used must be adapted to the cultural, social and geographical context of the region. Among the intermediate determinants, children showed a higher prevalence of stunting in households with less access to food diversity. Therefore, preventive policies against stunting must address food security, agricultural issues and climate change. Regarding the distal determinants, the study did not find socioeconomic differences that remained significant in the final model. This suggests a possible limitation of the classic model of health determinants. It appears that this model would not allow for the identification of differences in small and relatively homogeneous populations in socioeconomic terms, such as the Waorani population. More sensitive instruments are needed to analyse the structures and means of subsistence of the Waorani population, as well as a territorial contextualisation of their health determinants. In any case, the more descriptive findings, which reveal limited access to health services and economic resources, highlight the need for strategies that prioritise access to safe drinking water, sanitation and context-appropriate livelihoods. A comprehensive policy that considers the structural, intermediate and distal determinants related to stunting, culturally adapted to the context, is essential. The Waorani population inhabits a territory that contributes significantly to the state budget; however, they live in conditions of extreme poverty. The high prevalence of stunting reflects this social inequity. Policies that strengthen redistributive justice and accountability, with the return of budgets for the Waorani population, are fundamental. Territory becomes a social determinant of health in indigenous populations (Diaz et al., 2020). This underscores the need to guarantee indigenous territorial rights in health matters through coherent state policies (Barreto et al., 2025).

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author, [MR]. The data are not publicly available due to their containing information that could compromise the privacy of research participants.

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