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Association of severe stunting in indigenous Yanomami children with maternal short stature: clues about the intergerational transmission

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Abstract *This study evaluates the nutritional status of children and women of an indigenous Yanomamigroup, and seeks to clarify associated factors. It was a cross-sectional study, carried out in 17 villages, in 2014. For evaluation of nutritional status we used 2006 growth standards to assign height-for-age (stunting)Z-scores (Z), weight-for-age Z (underweight) and weight-for-height Z (wasting and overweight), using the software WHO-Anthro and WHO-AnthroPlus. Short stature (SS) was defined as values lower 145cm for mothers over the age of 18. The Poisson regression was made in R software. Among children under 60 months the prevalences were: stunting 83.8%; underweight 50%; wasting 5.4%; and overweight 2.7%. In 59.5% of the children there was severe stunting, and 68.1% of the mothers were SS. Prevalence ratio (PR) for severe stunting was higher in age group 36-59 months, in comparison with age group 0.1-23 (PR = 1.3; CI 95%: 1.1-2.3), as did also children of mothers with SS, when compared to the children of mothers without SS (PR = 2.1; CI 95%; 1.2-3.6). The alarming rates of stunting and severe stunting reveal the seriousness of the nutritional situation children. The association of severe stunting in infants and in mothers reflects the intergenerational nature of the problem.*

Key words *Nutritional assessment, Indigenous South American people, Intergenerational transmission, Health surveys, Brazil*

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Introduction

Assessment of linear growth in children is a sensitive indicator of health and well-being of a population, and considered to be a good marker for inequalities in human development[1]. According to the World Health Organization[2], in the period 2000-2015, global prevalence of stunting in children under the age of five fell from 32.7% to 23.2%. In spite of the worldwide tendency for this indicator to decline, the situation is still considered to be one of concern, especially in Asia and Africa. Also, significant differences are still found between and within countries, especially in vulnerable groups. In Latin America, for example, the prevalence of stunting in Chile in 2005 was estimated at 1.8%; while in Guatemala, where approximately 41% of the population is of indigenous origin, the prevalence was 48.0%. It should be remembered that prevalence of stunting is disproportionately higher among indigenous children than in non-indigenous children[3,4].

In Brazil, a recent nationwide survey indicated that 25.7% of indigenous children under the age of five had low height for their age. In the Northern Region of the country the situation was more severe, with 40.8% of children having stunting (short stature)[3]. In 2015 similar values (38.5%) were reported for children of sub-Saharan Africa, a region where Unicef[5] has identified the highest prevalence of stunting on the planet.

Early nutritional disturbances can have a range of different consequences over the course of a life. In earliest infancy, for example, low stature is commonly associated with higher rates of hospitalization and death from infectious diseases. In adult life, the adverse effects associated with stunting in infancy include lower final height of these individuals, a lower level of schooling, lower income, and lower performance in IQ tests[1,6,7]. Further, according to Martorell and Zongrone[8], the association between precarious living conditions and stunting in infancy results in an additional concern, in that this combination may not only result in adverse effects for the individual, but can also be transmitted to future generations.

However, evidence suggests that the negative consequences of delay in growth can be minimized or even reversed if timely interventions are offered to children at risk, especially in the first thousand days of life[1,7]. Thus it can be useful to understand the factors associated with stunting in indigenous people, for whom there is strong evidence that the problem is on a large scale, and has persisted for generations over a range of indigenous groups[3,9,10], not only for an understanding of the most prevalent nutritional disorders, but also for construction of appropriate and opportune interventions, enabling full development of the growth potential of these children.

This study is part of a wider research study named 'Evaluation of Environmental Exposure to Mercury from Gold Mining in the Indigenous Yanomami Territory of Roraima, Amazon Region, Brazil' (*Avaliação da exposição ambiental ao mercúrio proveniente do garimpo de ouro na Terra Indígena Yanomami, Roraima, Amazônia, Brasil*), which was carried out to meet a request by the Hutukara Yanomami Association (*Hutukara Associação Yanomami* – HAY). Davi Kopenawa Yanomami, Chairman of HAY, in a letter to the Oswaldo Cruz Foundation National School of Public Health, requested support to investigate exposure to mercury in two separate regions of the Yanomami Territory. Children below the age of five and women of fertile age are considered to be the groups most vulnerable to the consequences of contamination by mercury. Thus, the objective of the study was to assess the nutritional status of indigenous Yanomami children and women, and deduce associated factors.

Methods

Population and area of study

The Yanomami are indigenous groups considered to be hunter-gatherers, and farmers of traditional slash-fallow (coivara) systems, who live in the Amazon tropical forest. They occupy a territory that extends from the Massif of the Guianas, on both sides of the frontier between Brazil (Upper Rio Branco Basins, and left bank of the Rio Negro) and Venezuela (Basins of the Upper Orinoco and Cassiquiare Rivers), in an area that totals 192,000km^2. This study was carried out on the Brazilian side, in the Yanomami Indigenous Territory, located in the Northwest of the Amazon region (Figure 1).

In Brazil healthcare for the Yanomami is under the responsibility of the Special Yanomami Indigenous Peoples' Health District (DSEI-Y), which is linked to the Special Indigenous Health Department of the Health Ministry. The DSEI-Y is subdivided into 37 Base Stations (considered as Basic Health Units), which provide care to approximately 22,000 indigenous people of the Yanomami and Ye'kuana ethnic groups, living in 258 villages in the states of Amazonas and Rorai-

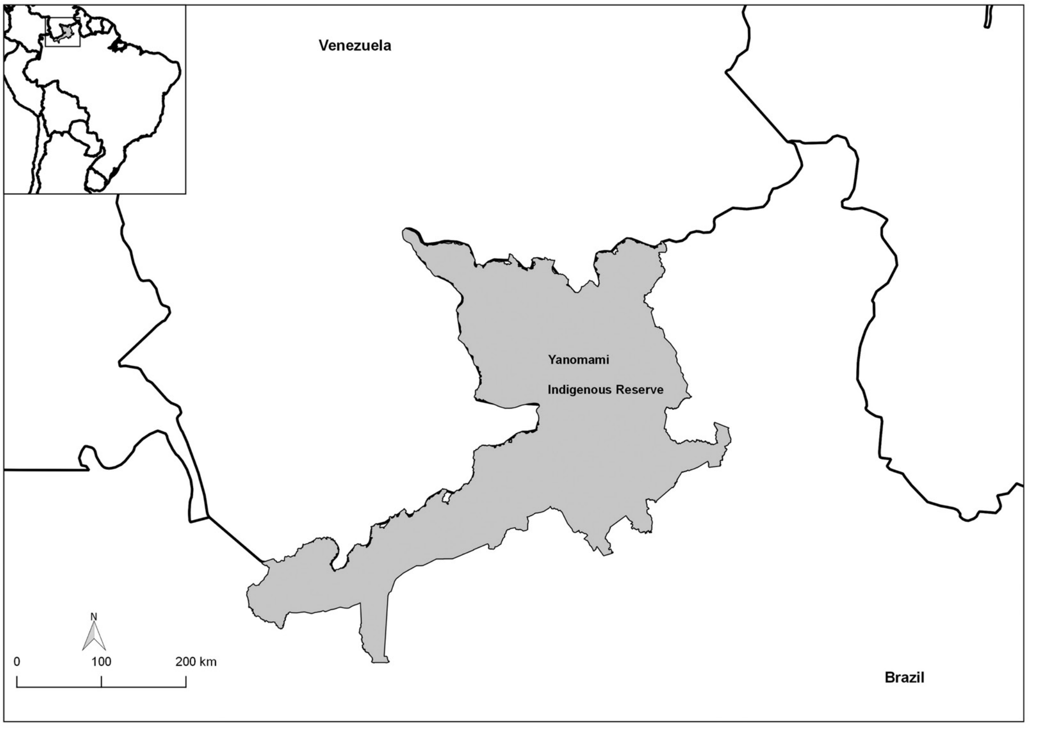

Figure 1. Location of the Yanomami Indigenous Territory, in the states of Roraima and Amazonas, Brazil, 2014.

ma[11]. In most of them the villages are in remote areas accessible only by air or river. The absence of roads or highways, the seasonal character of navigation and the high costs of air transport make the Yanomami dependent on intermittent visits by 'flying' health teams to their villages.

Study design

A cross-sectional study was carried out in November and December 2014, in 13 villages served by the Paapiu Base Station, and 4 other villages served by the Waikás Base Station, and a population census was taken at the same time. As reported in the introduction, these locations were indicated for assessment by the HAY.

Data collection and variables

The collection of data was accompanied by at least two native interpreters and/or bilingual community leaders, speakers of Portuguese and Yanomami/Ye'kuana. The interviews were with the mother and/or person responsible for the children. The following variables were recorded: Date of birth; gender; date of the interview; weight; height or body length; home village; and origin Base Station.

Eligibility: All children under the age of five and their mothers who were present in the villages at the moment of the investigators' visits were considered eligible. Measurement of height and weight: Children older than 23 months, and all the mothers in the study, had their height ascertained in orthostatic position by a portable anthropometer (Alturexata®), to accuracy of 0.1cm. Smaller children were measured in the dorsal position using an infant anthropometer (Alturexata®), to accuracy of 0.1cm. For weighing, an electronic balance (SECA®, model 770), with maximum capacity of 150 kg and accuracy of 0.1 kg, was used. Infants in mothers' arms were weighed using the mother-and-baby function of the electronic weighing device.

Data on dates of birth and age were obtained from the health records of the child, vaccination cards, and record books of indigenous health agents, and from consultation of the demographic module of the Indigenous Healthcare Information System (*Sistema de Informação da Atenção à Saúde Indígena* – SIASI).

Operational criteria

The z-scores for the indicators height/age, weight/age, weight/height and Body Mass Index vs. age were estimated using the WHO growth curves as reference[9]. Height/age, weight/age and weight/height indicators with ESZ <–2 were descriptors for stunting and underweight, respectively, and wasting. Indicators below –3 were descriptors for severe stunting for the individual's age. The following ranges were characterized as inplausible[12], and excluded from the analyses: Height/age <–6 or >6; weight/age <–6 or >5; and weight/height and BMI/age ß–5 or >5.

For women in the age range 15–18 the classification of height was based on the weight/age index, with values lower than –2 adopted as descriptors of low height for age[12]. For women over 18, height below 145cm was adopted as descriptor for short stature[13].

Four authors (JDYO, CMVR, CLMA and MWO) took part in the collection of data, following the WHO anthropometry recommendations[12]. The two software programs WHO-Anthro and WHO-AnthroPlus were used to generate the nutritional indices.

Analyses

To estimate prevalence ratios, and identify factors associated with low stature in children under five, and their mothers, a Poisson regression with robust adjustment of variance was used. Values of $p < 0.05$ were considered significant in the multiple regression analysis. The quality of the adjustment of the final model was evaluated using the Wald Test. The analyses were made on R Software Version 3.1.2.

Ethical aspects

This study is part of a wider investigation named 'Evaluation of Environmental Exposure to Mercury from Gold Mining in the Indigenous Yanomami Territory of Roraima, Amazon Region, Brazil' (*Avaliação da exposição ambiental ao mercúrio proveniente do garimpo de ouro na Terra Indígena Yanomami, Roraima, Amazônia, Brasil*), approved by the National Research Ethics Committee of the National Health Council (CONEP/CNS).

Results

A total of 74 (90.2%) of the 82 children living in the villages visited were included. Six were not present in the villages at the moment of the researchers' visit, and two were excluded for Z-scores considered to be outside the 'plausible' range. For the children under five, the prevalence of low height/age was 83.8%, the prevalence of low weight/age was 50.0%; and the prevalence of low weight/height was 5.4%. The prevalence of the overweight indicator was 2.7% (Table 1).

No significant associations were found between gender and age group when comparing the indicators of nutritional deviations studied ($p > 0.05$). Also no significant association was observed between the origin Base Station of the children and the indicators low and very low height/age ($p > 0.05$). Significant differences were found, however (p-value = 0.01) between the prevalence of low weight/age for children living in the Waikás region, with 18.7% (3/16), where people of the Ye'kuana ethnic group also live, compared to 58.6% (34/58) for the people living in the Paapiu region, where only Yanomami live.

Table 1. Distribution of nutritional deviations in indigenous Yanomami children less than 60 months old, by age group and anthropometric index. Yanomami Indigenous Territory, Roraima, Brazil, 2014.

Age group (months)	Height/Age Z Score < -2 % (n)	Weight/Age Z Score < -2 % (n)	Weight/Height Z Score < -2 % (n)	Weight/Height Z Score > 2 % (n)
0.1 – 11.9	66.7 (6/9)	44.4 (4/9)	11.1 (1/9)	0.0 (0/9)
12.0 – 23.9	83.3 (15/18)	61.1 (11/18)	11.1 (2/18)	0.0 (0/18)
24.0 – 35.9	80.0 (12/15)	46.7 (7/15)	6.7 (1/15)	6.7 (1/15)
36.0 – 59.9	90.6 (29/32)	46.9 (15/32)	0.0 (0/32)	3.1 (1/32)
Total	83.8 (62/74)	50.0 (37/74)	5.4 (4/74)	2.7 (2/74)

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The prevalence of the overweight indicator in Waikás children was 12.5% (2/16), whereas there were no overweight children in the Paapiu region. In total, 59.5% (44/72) of children aged less than 60 months had severe stunting. Of the mothers of the children evaluated, 68.1% (49/72) had height lower than 145cm, and of these, approximately 50% were less than 25 years old (Table 2).

The Poisson regression revealed that the risk of severe stunting was 30% higher in children from 36.0 to 59.0 months of age, compared to those aged from 0.1 to 23 months (Prevalence ratio - PR = 1.3; IC 95%: 1.1-2.3). The risk was also 2.1 times greater in children whose mothers were below 145cm in height, compared to the others (PR = 2.1; IC 95%; 1.2-3.6) (Table 3).

Discussion

The nutritional deficits of the Yanomami children reported here are the most severe ever reported among indigenous children on the American continent. The prevalences of stunting, underweight and wasting that we report have no precedents in the specialized literature. The association between severe stunting in the children and low maternal height that we report in this study suggests that there is intergenerational transmission of the condition.

Although some authors have reported high prevalences of stunting in indigenous children in South America[10,14] and in Guatemala[15], prevalences above 80% have only been recorded among the Yanomami. Pantoja et al.[16], in a study that evaluated the coverage of the Indigenous Yanomami Territory Food and Nutrition Vigilance System, including the Base Stations of Paapiu and Waikás, reported a prevalence close to 80%, of stunting in children below the age of five, similar to those revealed in this study. Hidalgo et al.[17] also reported 72.3% prevalence of stunting in children of this age group. However, it should be remembered that the study by Hidalgo et al.[17] included only children resident in villages located in Venezuela.

One highlight of our findings is the prevalence of underweight of 60%, and prevalence of wasting of 11%, among children less than 24 months old, both results being considered high. These findings suggest a recent factor negatively affecting growth[10] and underline the precariousness of the nutritional situation of Yanomami children, specifically at a time window of high vulnerability, the repercussions of which can continue over the whole of the individual's life[18].

Considering that deficits in infantile growth have very adverse consequences both in the short term (high rates of morbidity-mortality and disabilities in infancy), and also in the long term (risk of low height in adult life, adverse effects on cognitive development and reduction of human capital)[19,20], the situation that the Yanomami are undergoing is of great concern, meriting special attention from the health authorities.

Table 2. Age distribution and characteristics of height of Yanomami women studied. Yanomami Indigenous Territory, Roraima, Brazil, 2014.

Variables	% n
Age group (years)	
15.0 – 24.9	44.4 (32/72)
25.0 – 34.9	41.7 (30/72)
35.0 – 40.0	13.9 (10/72)
Low maternal height (<145cm)	
Yes	68.1 (49/72)
No	31.9 (23/72)

Table 3. Poisson model for severe stunting (Z score < –3.00) in Yanomami children under the age of 60 months; Yanomami Indigenous Territory, Roraima, Brazil, 2014.

Variables	Unadjusted PR (IC 80%)	Adjusted PR (IC 95%)	p*
Age group (months)			
0.1 – 23.9	1.0	1.0	
24.0 – 35.0	1.5 (0.8–2.6)	1.5 (0.8–2.6)	0.218
36.0 – 59.9	1.8 (1.2–3.0)	1.3 (1.1–2.9)	0.018
Mother's height < 145cm			
No	1.0	1.0	
Yes	2.2 (1.3–3.7)	2.1 (1.2–3.6)	0.012

*IC95%: 95% confidence interval; Number of children in final model = 67. PR: Prevalence ratio.

One characterization that could to some extent contribute to deterioration of nutritional status is the high level of expenditure of energy resulting from the Yanomami's high mobility. This is a marked characteristic of the group: they travel long distances in the interior of the forest, mainly in hunting and gathering activities, but also in ceremonial visits to distant villages, and in search of new areas to live[16,21]. Another consequence that could further exacerbate the situation is the limited access to basic health services and the permanent exposure to the illnesses that are typical endemic in the region, such as malaria, tuberculosis, acute respiratory conditions and onchocerciasis (river blindness)[16,22,23]. Knowledge on this complex local scenario could help explain the alarming rates of illness and death found among Yanomami children and support preparation of interventions that are adapted to the local conditions.

An interesting example comes from Grenfell et al.[24] who, when investigating epidemiological aspects associated with malaria, anemia and diarrhea among the Yanomami, concluded that the inequality in access to health services has a strong impact on health conditions in the villages. According to these authors, the prevalences of the adverse conditions they were investigating were higher in the communities that received only intermittent visits than those that were visited regularly.

Analysis, in this present study, of the differences in nutritional indices by Base Station showed a double proportion of deficits in different areas of the Yanomami Indigenous Territory. On the one hand, a high prevalence of underweight was found, with zero prevalence of overweight cases in the Paapiu Base Station. On the other hand, in the Waikás Base Station, the prevalence of underweight was approximately one-third of that in the Paapiu Base Station, and there were cases of overweight children. Both areas have a history of influence from illegal gold-mining activity. At the time of the study, in the Waikás Base Station, dozens of prospecting rafts were operating in the local area. Indeed, in some situations, indigenous people were observed taking part in these activities[25]. An assessment of the exposure to mercury was carried out in this same group – the report on those results is still being written and not yet available.

It is believed that studies to elucidate the relationship between physical activity patterns, food practices and changes in lifestyle arising from the involvement of indigenous people with informal mining could help in understanding of the differences found between the nutritional patterns of the children of the Waikás and Paapiu base region shown in this present report. It is known that the activity of informal mining indiscriminately releases large quantities of metallic mercury into the soil and the bodies of water, affecting the entire aquatic ecosystem, in particular fish. In general, fish are one of the main sources of animal protein for the indigenous people of this region. It is widely known that fish, especially carnivorous fish, accumulate methylmercury (the result of methylation of mercury) in their organism. When the traditional populations eat these creatures contaminated with methyl mercury, they expose themselves chronically and continuously to this dangerous metal, with the potential to cause neurotoxic, nephrotoxic and immunotoxic effects, adversely affecting the cognitive and motor development of children[26]. However, as shown in the analyses in this study, there were no significant differences for the nutritional deficits reported, between the two regions.

Children older than 35 months showed a 30% higher risk of severe stunting than those aged less than 24 months. This increased risk may be the result of the cumulative effect of food deprivations, or other experiences, that are adverse to health[20]. It is worth remembering that gastroenteritis and acute respiratory infections, especially pneumonia, are among the principal causes of hospitalization of Yanomami children[23], emphasizing the impact of infections and parasitic diseases on the health of these children.

It is important to mention that even among children aged less than 12 months the prevalence of underweight was very high, close to 70.0%, indicating not only failures in growth in the first year of life of the Yanomami children, but also possible problems during the formation of the embryo and in the gestation, which are known predictors of stunting and adverse conditions in adult life[18].

The high proportion of mothers with short height (< 145cm), approximately 2/3 of the sample studied in this investigation, is compatible with the historic precariousness of the Yanomamis' nutritional situation, which has already been pointed out by other authors at different times and in different scenarios[16,27], indicating that these adverse processes take place continuously and over a long period. The association between severe stunting in infancy and low height in Yanomami mothers suggests that these height deficits have been repeated for several genera-

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tions, possibly resulting in premature births and in newborns being less than the expected weight, and small for their gestational age[28].

Authors that concentrate on studying the relationship between delays in early growth/development of children and the adverse later effects on health argue that various factors, both environmental and non-environmental, not only in the first years of life but also in the womb, can have a negative effect on individuals' health over the whole of life[29,30]. Further, Barker et al.[31] indicated that these consequences are not limited to linear growth or weight gain in children, but are also factors for heart and metabolic risks, and can also have repercussions in the field of mental health.

Sacker and Kelly[32] argue that in certain ethnic minorities, height deficits cannot be explained only by genetic factors or factors of ethnic-racial origin. They say that, for a broader assessment, all the adverse conditions undergone in infancy should be taken into account. Some authors argue that the Yanomami are among the shortest of the indigenous peoples, in height, in South America, also suggesting that their usual low height can be explained by genetic factors[27]. However, environmental factors that include suffering from innumerable diseases, especially infectious and parasitic diseases, and also problems related to access to and availability of food, and also health services, are usually the principal factors inhibiting adequate growth of these children[33].

In this perspective, it is acceptable to think that if appropriate interventions, culturally adapted to the local conditions, were to take place, these deficits could be corrected in future generations, improving the health conditions of these children gradually, until the nutritional anomalies highlighted here finally disappear completely. However, at present, this possibility still appears to be remote for the Yanomami, since their severe deficits in height have been noted for decades, indicating that their living and health conditions continue to be precarious, and unchanged, over time.

A recent study of a cohort among the Xavante indigenous population, who live in the Center-West Region of Brazil, indicates that the pattern of growth of these children, especially in the first six months of life, is very similar to the reference world median. After six months and up to age 36 months, this pattern becomes floating, and constantly lower than the reference median, which may be the result of the influence of precarious health conditions, food insecurity and environmental factors on the growth of indigenous children[10]. Also, it is known that social inequalities affect the nutrition and health of children of countries with low and average income, and are responsible for the excessive number of deaths and malnutrition of this group, usually due to irregular supply and low quality of health services[34]. The arguments above appear to be in line with the reality lived by the Yanomami people and, more generally, with the reality of indigenous peoples in Brazil.

Even recognizing the limits of cross-sectional studies in estimation of risk, it can be assumed that the association observed between severe stunting in infancy and low maternal height, revealed here, is free of bias arising from reverse causality, since the exposure, in this case maternal height, was already in place before the pregnancy and the birth of the child. Expansion of the size of the sample and inclusion of other variables related to comorbidities, breast feeding and eating habits could not only increase the power of our statistical analyses, but also contribute to expanding understanding on the nutritional situation of all indigenous children in Brazil, in particular the Yanomami.

It was not possible to make a comparative assessment of the results between all the regions of the Yanomami Indigenous Territory. On the one hand, this is due to the fact that the study was oriented by a demand from the Hutukara Yanomami Association and, on the other, due to the impossibility in practice of making an analysis including 258 villages spread over an area of 192,000 km^2, in dense equatorial forest.

The severe nutritional situation of indigenous Yanomami children and mothers presented here takes place in a challenging scenario. Problems of an operational, logistical, and political nature, and related to financial support, are added to the need to expand knowledge on the mechanisms that cause low stature in children and mothers in the villages. Also, continuous monitoring of the growth and development, together with interventions that are culturally adapted to the local reality, are of great importance for ensuring better conditions of health and nutrition to indigenous children below the age of five.

Collaborations

JDY Orellana and L Marrero participated in the conception, interpretation and final writing of the manuscript. JDY Orellana, CLM Alves, and MW Oliveira, participated in data collection. CMV Ruiz, SS Hacon, MW Oliveira and PC Basta participated in the interpretation and critical review of the manuscript. All authors approved the final version forwarded.

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