Ethnoracial disparities in childhood growth trajectories in Brazil: a longitudinal nationwide study of four million children

Running title: Disparities in childhood growth trajectories

Helena Benes Matos da Silva[1,2*], Rita de Cássia Ribeiro-Silva[1,2], Juliana Freitas de Mello e Silva[2], Irina Chis Ster[3], Poliana Rebouças[2], Emanuelle F. Goes[2], Maria Yury Ichihara[2,] Andrêa Ferreira[2,4], Júlia M. Pescarini[5], Rosemeire Fiaccone[6], Enny S. Paixão[5], Maurício L. Barreto[2]

[1] School of Nutrition, Federal University of Bahia, Salvador, BA, Brazil.

[2] Center for Data and Knowledge Integration for Health (CIDACS), Gonçalo Moniz Institute, Oswaldo Cruz Foundation, Salvador, BA, Brazil.

[3] Infection and Immunity Research Institute, St George's University of London.UK.

[4] The Ubuntu Center on Racism, Global Movements, and Population Health Equity, Dornsife School of Public Health, Drexel University, US.

[5] Epidemiology and Population Health, London School of Hygiene and Tropical Medicine, London, UK.

[6] Department of Statistics, Federal University of Bahia, Salvador, BA, Brazil.

* **Corresponding author:** Helena Benes Matos da Silva[1]. Centro de Integração de Dados e Conhecimentos para Saúde, Instituto Gonçalo Moniz, Fundação Oswaldo Cruz. Edf. Tecnocentro, Sl. 315. Rua Mundo, 121. Trobogy, Salvador, BA, 41745-715, Brasil. Email: helena.benes@ufba.br

Abstract

Background: The literature contains scarce data on inequalities in growth trajectories among children born to mothers of diverse ethnoracial background in the first five years of life. **Objective:** we aimed to investigate child growth according to maternal ethnoracial group using a nationwide Brazilian database. **Methods:** A population-based retrospective cohort study employed linked data from the CIDACS Birth Cohort and the Brazilian Food and Nutrition Surveillance System (SISVAN). Children born at term, aged five years or younger who presented two or more measurements of length/height (cm) and weight (kg) were followed up between 2008 and 2017. Prevalence of stunting, underweight, wasting, and thinness were estimated. Nonlinear mixed effect models were used to estimate childhood growth trajectories, among different maternal ethnoracial groups (White, Asian descent, Black, Pardo, and Indigenous), using the raw measures of weight (kg) and height (cm) and the length/height-for-age (L/HAZ) and weight-for-age z-scores (WAZ). The analyses were also adjusted for mother's age, educational level, and marital status. **Results:** A total of 4090271 children were included in the study. Children of Indigenous mothers exhibited higher rates of stunting (26.74%) and underweight (5.90%). Wasting and thinness were more prevalent among children of Pardo, Asian, Black, and Indigenous mothers than those of White mothers. Regarding children's weight (kg) and length/height (cm), those of Indigenous, Pardo, Black, and Asian descent mothers were on average shorter and weighted less than White ones. Regarding WAZ and L/HAZ growth trajectories, a sharp decline in average z-scores was evidenced in the first weeks of life, followed by a period of recovery. Over time, z-scores for most of the subgroups analyzed trended below zero. Children of mother in greater social vulnerability showed less favorable growth. **Conclusion:** We observed racial disparities in nutritional status and childhood growth trajectories, with children of Indigenous mothers presenting less favorable outcomes compared to their White counterparts. The strengthening of policies aimed at protecting Indigenous children should be urgently undertaken to address systematic ethnoracial health inequalities.

Keywords: Ethnic-racial groups; child growth trajectories; food and nutrition surveillance system; racism; race

Background

Birth weight and infant growth are important markers of child health and future well-being [1], [2], [3], [4]. Some conditions, such as premature birth, low birth weight and maternal malnutrition, have been well-documented factors associated with growth trajectory [5] while others, including socioeconomic status (SES), have been a consistent object of study [6], [7], [8], [9].

In recent years a growing body of evidence has reported ethnoracial inequalities regarding infant growth and development [10], [7]. Race is a social construct that functions as an essential tool of racism, to separate and create social hierarchy, which has produced and reinforced segregation, differential quality and access to health care and unequal distributions of social determinants of health [11]. The ethnoracial inequities affecting mothers can also impact childhood outcomes [12]. Differences in rates of child survival among racial groups have been reported in Brazil [13], [14]. A study investigating mortality risk of children under five years of age by maternal self-declared race/ethnicity of over 19 million newborn babies in Brazil found that children born to Indigenous mothers had a 16-time higher risk of death due to malnutrition than their White counterparts [10]. Similarly, those born to Black or Pardo had over 2-times the risk of death due to malnutrition than their White counterparts [10].

Even though previous studies have evidenced the effects of racism and its manifestation on perinatal outcomes and child mortality, the literature on child growth outcomes by ethnoracial groups over time is scarce. Understanding the effects of ethnoracial inequities on growth trajectories requires thorough investigation to inform policy decision-making aimed at reducing inequalities and adequately achieving the 2025 global nutrition targets outlined by the World Health Organization (WHO) [11] and the United Nation's 2030 Sustainable Development Goals (SDG) (eradication of hunger and all forms of malnutrition) [12]. The present study aims to investigate child growth according to maternal ethnoracial group using a nationwide Brazilian database.

Methods

A population-based retrospective cohort study was conducted using data linked from two different Brazilian databases: (i) the CIDACS Birth Cohort [13] , and (ii) the Food and Nutrition Surveillance System (SISVAN). The data consisted of children aged 0 to 60 months of age, born between January, 2003 to November, 2015, and followed up from January, 2008 until December, 2017. Details regarding the linkage process performed are available in previous publication [14].

The CIDACS Birth Cohort resulted from the linkage of the Live Birth Information System (SINASC) and the 100 Million Brazilian Cohort baseline. SINASC coverage extends to over 97% of live births in Brazil, with records collected through the Declaration of a Live Birth by a health professional present during the child's delivery. This legally standardized form includes information about the parents, such as the mother's name, age, local of residence, marital status, educational level. Also, pregnancy details, such as length of gestation, number of prenatal visits, type of delivery, and characteristics of the newborn, including sex, birth weight, congenital anomalies, and other factors [13].

The 100 Million Brazilian Cohort baseline was developed using administrative records from low-income individuals, whose families applied for the National Unified Register for Social Programs (*Cadastro Único*). This baseline variables encompasses a range of socioeconomic and demographic characteristics [15].

Since 2008, SISVAN has been monitoring the nutritional status of the Brazilian population by routinely recording individual-level sociodemographic, anthropometric (length/height and weight measurements), and food consumption data from users of public health services in all stages of life. This database includes data collected by primary health care professionals from individuals under care of the Brazilian Unified Health System (SUS), anthropometric data recorded of people benefiting from cash transfer program (Bolsa Família Program), and data from the e-SUS Primary Care strategy [16]. They use the equipment available at the unit, which can be a digital scale, a pediatric scale, an anthropometer, or a child anthropometer. The procedures for anthropometric measurement follows the protocols established by the Brazilian Ministry of Health [17]. The SISVAN data quality showed improvement over the period of 2008 to 2017 with completeness to almost 100% for height and weight along the years, and coverage ranging from 17.7 to 45.4% among SUS users [18].

The present study protocol was approved by the institutional review boards of the Collective Health Institute of the Federal University of Bahia (reference number 41695415.0.0000.5030) and the School of Nutrition, Federal University of Bahia (reference number 67205423.6.0000.5023).

Study population

We followed up singleton children born at term from birth up to the age of 60 months for whom two or more measurements of length/height (cm) and weight (kg) were recorded. Children with congenital anomalies or missing information on this characteristic, no recorded gestational age, and no birth weight were excluded. Implausible birth weights (<500g or ≥6500g) were also excluded [19]. In an attempt to avoid bias in the analysis of low-birth-weight cases, multiple pregnancies were removed. We also excluded children with implausible z-scores for the following anthropometric variables: length/height-for-age z-scores (L/HAZ) <-6 or >6, weight-for-age z-scores (WAZ) <-6 or >5, weight-for-length/height z-scores (WHZ) <-5 or >5 and body-mass-index-for-age z-scores (BAZ) <-5 or >5, as these values are considered implausible under WHO recommendations [20]. Then, longitudinal outliers for height (<-5/>+5) and weight (<-5/>+5) were excluded [21] (**Figure 1**).

Exposure: Race/Ethnicity

Information on maternal race or skin color was obtained from the Brazilian Unified Registry for Social Programs at the CIDACS Birth Cohort. The adopted categories for race or skin color were those defined by the Brazilian Institute of Geography and Statistics (IBGE), which classifies racial groups as White, Black, Pardo, Yellow (which will be referred as Asian descent), and Indigenous [22]. For the purposes of the present analysis, "White" was adopted as a reference category, similarly to a previous study that indicated better overall health outcomes for children born to mothers who self-identified as White [23].

Outcome: Nutritional Status and Growth Outcome

Information on the included children's length/height (cm) and weight (kg) were retrieved from records in the SISVAN database.

Age (months) was calculated considering the time elapsed between date of birth and the date of the visit recorded in the SISVAN. Child sex (male or female) was obtained from SINASC registry.

The growth trajectories were estimated continuously as length/height (cm) and weight (kg), and with the standardized measures length/height-for-age z-scores (L/HAZ) and weight-for-age z-scores (WAZ), calculated according to the WHO Child Growth Standards [24]. Additionally, the nutritional status of the children was classified as stunting (low height-for-age), underweight (low weight-for-age), wasting (low weight-for-height), and thinness (low body-mass-index-for-age) using the WHO reference < -2 SD z-score cutoff point [24].

Maternal characterization

Maternal characteristics were available at the CIDACS Birth Cohort and the following covariates pertaining to mothers were described: maternal area of residence (rural or urban), household overcrowding (≤2 or >2 people per room, calculated dividing the total number of people who live in the same house by the number of rooms), maternal education level (≤3 years, 4-7 years, ≥8 years of formal schooling), marital status (single, married/stable union, divorced/widowed), number of prenatal visits (none, 1-3, 4-6, ≥7 visits), type of delivery (cesarean or vaginal birth), and maternal age categorized for descriptive analyzes (10-13, 14-19, 20-34, 35-50 years) and continuous for modeling approaches.

Statistical analysis

Initially, a descriptive analysis was performed considering maternal and child characteristics categorized according to ethnoracial groups [absolute value (n) and frequency (%) for categorical variables]. The prevalence of stunting, underweight, wasting, and thinness were calculated within each ethnoracial group. After removing missing observations non-linear mixed-effect (NLME) models were used to estimate length/height and weight trajectories in children by age since birth, with sex as a covariate [25]. Additional analyses were performed to investigate the trajectories of both L/HAZ and WAZ variables involving a mixed-effect model with cubic splines and eight knots (placed at age 2, 3, 6, 12, 18, 24, 36 and 58 months). The structure of NLME models includes both fixed and random effects; the former informs characteristics related to the population under study, while the latter accounts for the subject-specific associated variability of trajectories [25]. All models were adjusted for relevant confounding variables [maternal age (continuous variable), maternal education level and maternal marital status] [26], [27]. We also explored the possibility of interactions between child age *vs* race to examine to what extent growth trajectories differed by race/skin color [28].

The goodness of fit of the models was evaluated via training – with 70% of subjects - and testing – accounting for the remaining 30% - method. Sample procedure was performed in accordance with sex and maternal race/skin color. Measurement distributions for each sex were similar between both training and testing databases. All models were adjusted for maternal age, education level, and marital status.

Predictions from the most complex models representing the average fixed effects stratified by various explanatory variables and their uncertainties have been plotted.

Analyzes were performed in R (for server version 4.1).

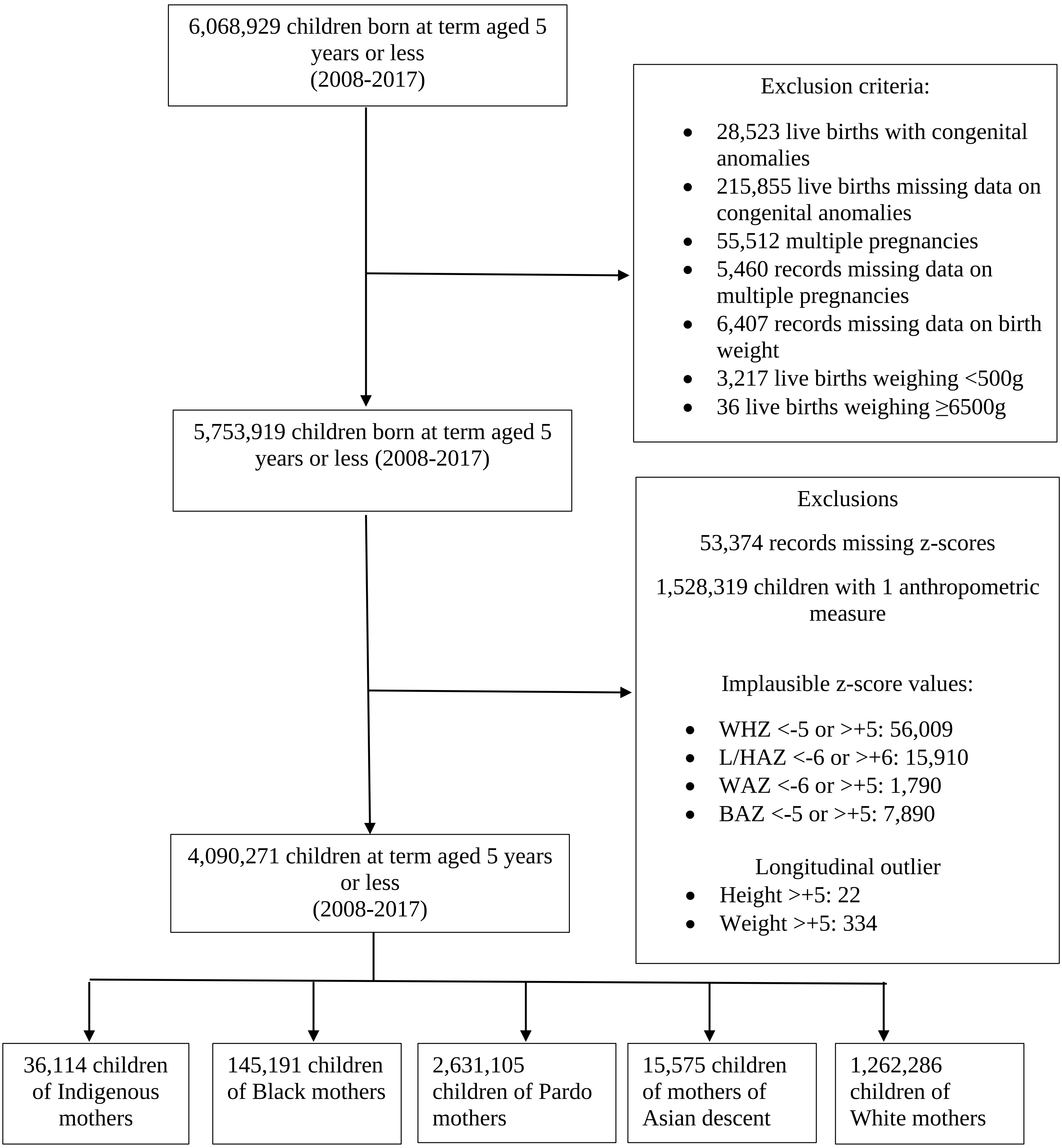

Figure 1. Flowchart detailing database construction and relevant exclusion criteria.

Results

We included 4090271 children in this study; 64.33% were born to Pardo mothers, 30.86% to White mothers, 3.55% to Black mothers, 0.88% to Indigenous mothers, and 0.38% to Asian descent mothers. The characteristics of the study population by maternal ethnoracial group are reported in Table 1. Almost all of them resided in urban areas (with the notable exception of Indigenous women, of whom 72.83% lived in rural areas) and in less favorable housing conditions (30.04%). Indigenous (27.52%) and Black mothers (13.76%) had lower levels of formal schooling. Almost half of the Indigenous mothers were single or divorced/widowed (53.42%). An inadequate number of prenatal visits (<7) were predominantly reported among Indigenous mothers (67.44%), followed by Pardo (48.55%), and Black (47.02%) mothers. While approximately 46.60% of live births to White mothers were delivered by cesarean section, this proportion was 17.48% for Indigenous women (**Table 1**).

Overall, the prevalence rates of stunting and underweight was higher among children of Indigenous mothers (26.74% and 5.90%), followed by those born to Pardo (11.82% and 3.77%), Asian descent (10.99% and 3.64%), Black (10.41% and 3.48%), and White mothers (8.61% and 2.48%). The prevalence distribution for wasting and thinness was higher among children of Pardo mothers (5.36% and 5.52%), Asian descent (5.28% and 5.46%), Black (5.08% and 3.91%), Indigenous (4.19% and 4.20%), when compared to those of White mothers (3.70% and 3.91%) (**Table Supl.1**). The descriptive statistics for age, anthropometric information, and the number of measurements is available in **Supplementary Table 2**.

Table 1: Distribution of maternal and child characteristics according to maternal race / skin color, 2008–2017.

Figures 2 and 3 display the estimated growth trajectories of both height/length (cm) and weight (kg) for age by sex. Fitted models do not include interactions of the available baseline factors with age as there were no indications of a significant result as such. The growth curve indicates that the mean weight and length/height of children born to mothers of each ethnoracial group studied exhibited comparatively less growth than their White counterparts, with more pronounced reductions evidenced in children born to Indigenous women (**Figures 2, 3).**

The results obtained from our adjusted growth curve models indicate that children born to Indigenous mothers were on average 3.3 cm (95% CI: -3.36, -3.27) shorter than their White counterparts. Similarly, children born to Pardo (-0.60; 95% CI: -0.61, -0.59), Black (-0.21; 95% CI: -0.24, -0.19) and Asian descent (-0.39; 95% CI: -0.46, -0.32) mothers were shorter on average than those in the White group. In addition, compared to children of White women, those of Indigenous (-0.74; 95% CI: -0.76, -0.72), Pardo (-0.25; 95% CI: -0.26, -0.25), Black (-0.15; 95% CI: -0.16, -0.14) and Asian descent (-0.22; 95%CI: - 0.24, -0.19) weighed less grams on average (**Table Supl. 3**)

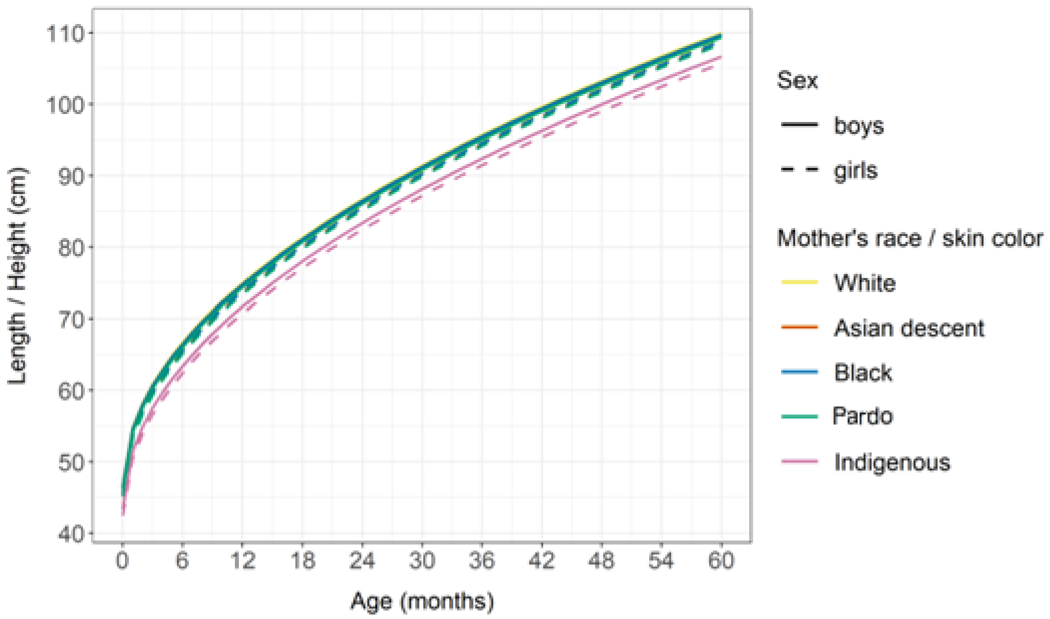

Figure 2: Estimated mean height according to sex and mother's race / skin color. Brazil, 2008-2017.

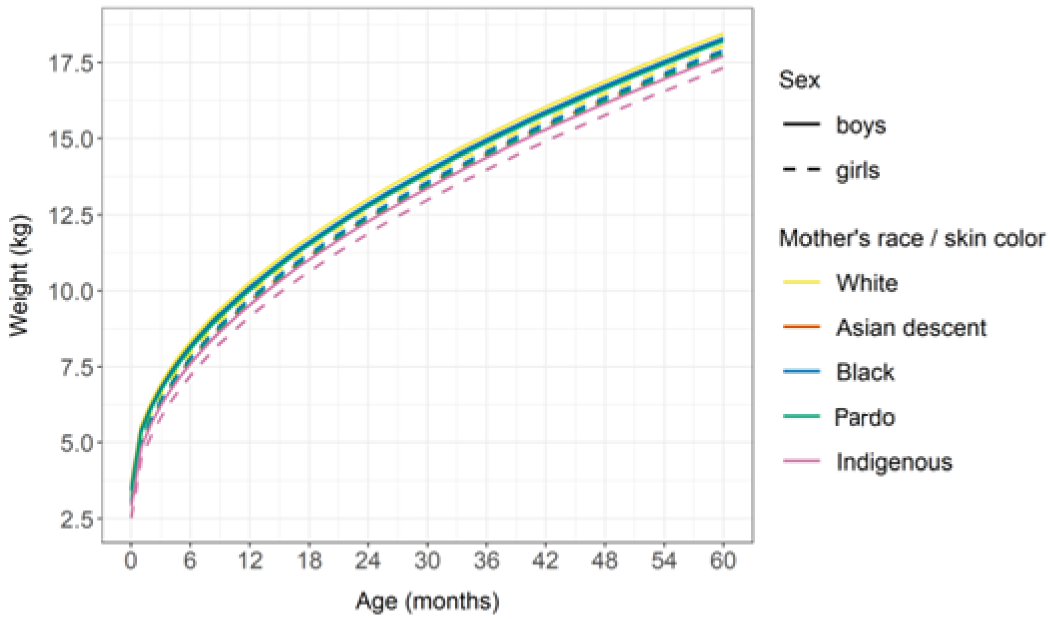

Figure 3: Estimated mean weight according to sex and mother's race / skin color. Brazil, 2008-2017.

Regarding WAZ and L/HAZ growth trajectories, a sharp decline in average z-scores was evidenced in the first weeks of life, followed by a period of recovery. The z-scores for most of the subgroups analyzed trended below zero across all ages. Growth patterns were similar in the groups, with children born to White women presenting the highest z-scores for WAZ and L/HAZ compared to children of Indigenous (WAZ -0.49; 95%CI: -0.51, -0.49; L/HAZ -0.87; 95%CI: -0.88, -0.85), Pardo (WAZ -0.17; 95%CI: -0.17, -0.17; L/HAZ -0.16; 95%CI: -0.16, -0.16) and Black (WAZ -0.11; 95%CI: -0.11, -0.10; L/HAZ -0.06; 95%CI: -0.07, -0.06) mothers, as well as those of Asian descent (WAZ -0.15; 95%CI: -0.16, -0.13; L/HAZ -0.11; 95%CI: -0.12, -0.09) (**Tables 2, 3**).

Table 2: Point and interval estimates for the parameters of the weight-for-age (WAZ) model. Brazil, 2008-2017.

Parameter	Estimate	Standard Error	CI 95%
Intercept	-0.1588	0.0091	[-0.1767, -0.1409]
Splines 1	-0.3273	0.0161	[-0.3590, -0.2957]
Splines 2	-0.2180	0.0086	[-0.2348, -0.2011]
Splines 3	0.0457	0.0097	[0.0267, 0.0647]
Splines 4	0.4605	0.0089	[0.4431, 0.4778]
Splines 5	0.4989	0.0090	[0.4813, 0.5165]
Splines 6	0.4744	0.0088	[0.4572, 0.4917]
Splines 7	0.3676	0.0088	[0.3503, 0.3848]
Splines 8	0.3038	0.0088	[0.2865, 0.3211]
Splines 9	0.2696	0.0089	[0.2522, 0.2869]
Splines 10	0.2464	0.0088	[0.2291, 0.2637]
Splines 11	0.2939	0.0121	[0.2701, 0.3177]
Sex (girls)	-0.0329	0.0010	[-0.0349, -0.0308]
Race / skin color (Asian descent)	-0.1474	0.0084	[-0.1638, -0.1309]
Race / skin color (Black)	-0.1085	0.0029	[-0.1142, -0.1028]
Race / skin color (Pardo)	-0.1727	0.0011	[-0.1749, -0.1705]
Race / skin color (Indigenous)	-0.4986	0.0056	[-0.5096, -0.4876]
Educational level (3 years or less)	-0.3217	0.0017	[-0.3250, -0.3184]
Educational level (4 to 7 years)	-0.1603	0.0011	[-0.1625, -0.1581]
Civil status (single)	-0.0253	0.0011	[-0.0274, -0.0233]
Civil status (divorced / widow)	0.0838	0.0054	[0.0732, 0.0945]
Mother's age at birth	0.0060	0.0001	[0.0058, 0.0062]
$\sigma_{\text{Intercept}}$	0.9576		
σ_{ε}	0.6675		

Reference category: Sex: Boys; Race/skin color: White; Educational level: 8 years or more; Marital status: Married or in a stable union.

Notes: The dimension of the splines accounts for the number of knots (K=8) and the polynomial degree (p = 3).

Table 3: Point and interval estimates for the parameters of the length/height-for-age (L/HAZ) model. Brazil, 2008-2017.

Parameter	Estimate	Standard Error	CI 95%
Intercept	-0.6357	0.0144	[-0.6639, -0.6075]
Splines 1	-0.5133	0.0260	[-0.5643, -0.4624]
Splines 2	-0.1505	0.0138	[-0.1776, -0.1234]
Splines 3	0.1967	0.0156	[0.1662, 0.2273]
Splines 4	0.3102	0.0143	[0.2822, 0.3382]
Splines 5	0.2356	0.0144	[0.2073, 0.2639]
Splines 6	0.0192	0.0141	[-0.0085, 0.0469]
Splines 7	0.3875	0.0142	[0.3598, 0.4153]
Splines 8	0.3635	0.0142	[0.3356, 0.3913]
Splines 9	0.4845	0.0142	[0.4566, 0.5125]
Splines 10	0.3844	0.0142	[0.3566, 0.4122]
Splines 11	0.4803	0.0194	[0.4422, 0.5184]
Sex (girls)	0.0399	0.0012	[0.0376, 0.0422]
Race / skin color (Asian descent)	-0.1063	0.0095	[-0.1250, -0.0876]
Race / skin color (Black)	-0.0651	0.0033	[-0.0716, -0.0587]
Race / skin color (Pardo)	-0.1589	0.0013	[-0.1614, -0.1564]
Race / skin color (Indigenous)	-0.8671	0.0064	[-0.8796, -0.8546]
Educational level (3 years or less)	-0.3590	0.0019	[-0.3628, -0.3553]
Educational level (4 to 7 years)	-0.1832	0.0013	[-0.1857, -0.1807]
Civil status (single)	-0.0423	0.0012	[-0.0447, -0.0400]
Civil status (divorced / widow)	0.0690	0.0062	[0.0569, 0.0810]
Mother's age	0.0066	0.0001	[0.0064, 0.0068]
$\sigma_{\text{Intercept}}$	0.9578		
σ_{ε}	0.6675		

Reference category: Sex: Boys; Race/skin color: White; Educational level: 8 years or more; Marital status: Married or in a stable union.

Notes: The dimension of the splines accounts for the number of knots (K=8) and the polynomial degree (p = 3).

Our analysis indicated that, in general, growth trajectory outcomes were within the limits of normality per the WHO reference standard (± 2SD). However, when evaluating child growth trajectories in accordance with the sociodemographic characteristics of their mothers, children born to mothers facing greater social vulnerability (i.e., single mothers, with lower levels of education) presented less favorable results (**Figures 4 and 5**).

Regarding the goodness of fit of the models, we verified based on the train and test analysis the models are well adjusted (**Table Supl.4,5,6,7; Figure Supl. 1,2,3,4**).

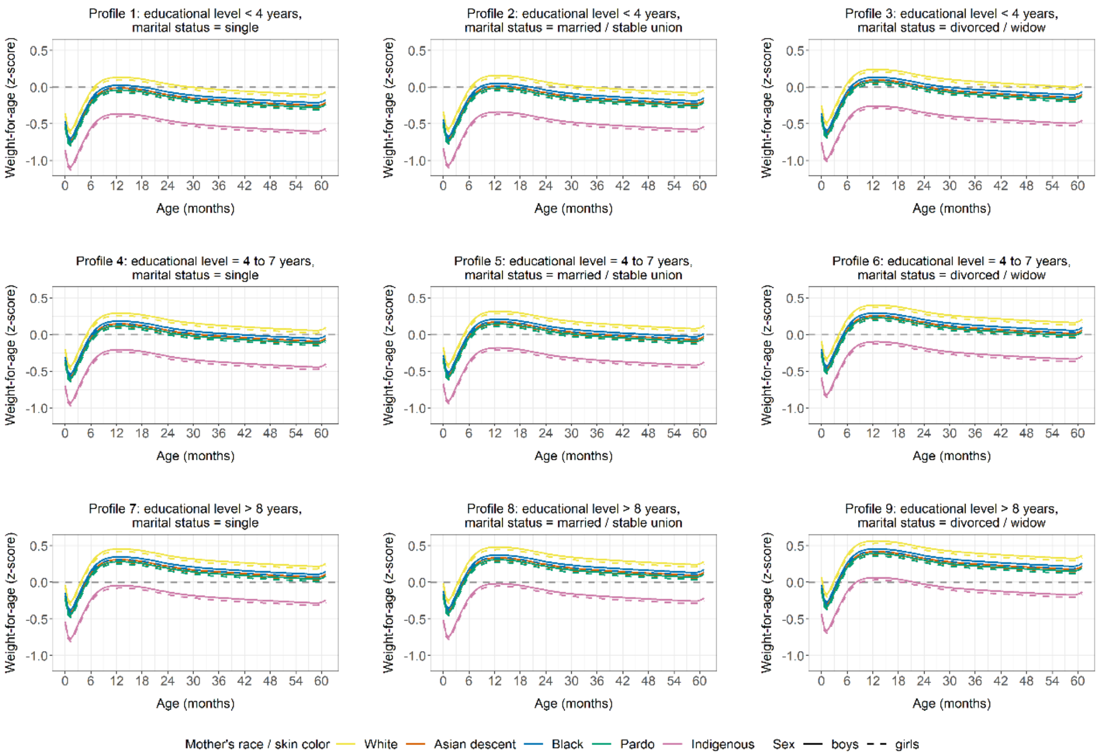

Figure 4: Estimated mean curves for weight-for-age z-scores model, according to mother's age, educational level, and marital status. Brazil, 2008-2017.

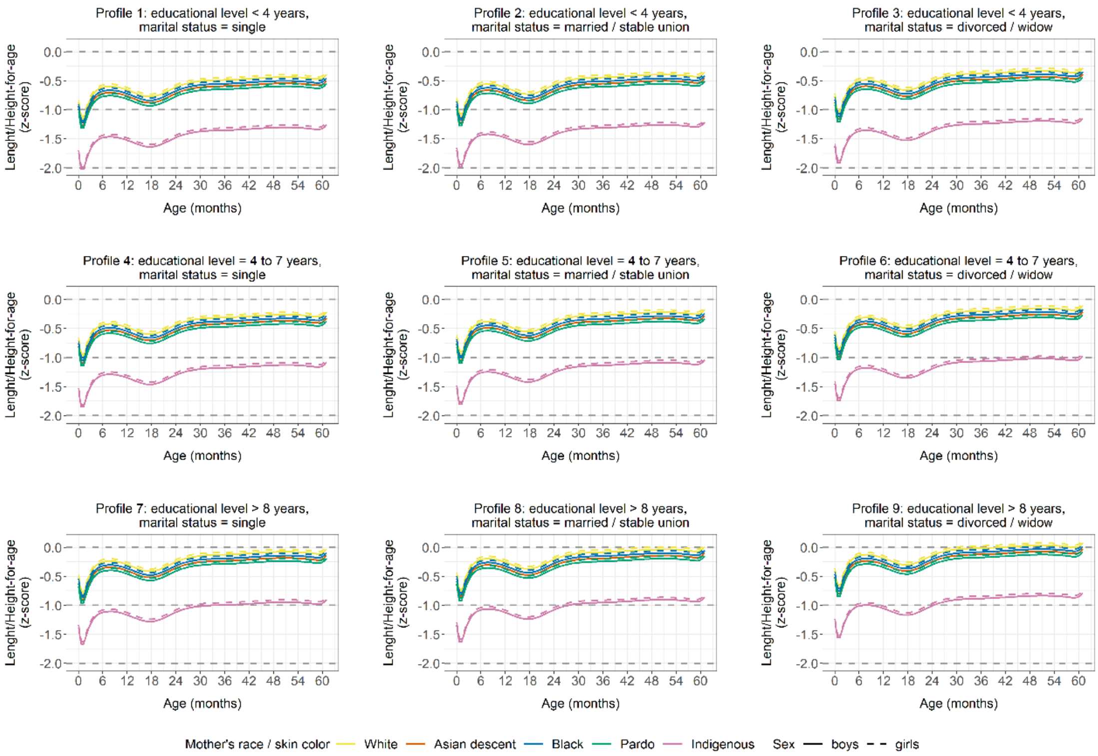

Figure 5: Estimated mean curves for length/height-for-age z-scores, according to mother's age, educational level, and marital status. Brazil, 2008-2017.

Discussion

In this study involving 4090271 individuals, we observed that those born to Indigenous mothers, as well as those born to Pardo, Black, and Asian descent women (to a lesser extent), exhibited less favorable growth outcomes compared to their White counterparts. High prevalence of stunting, underweight, thinness, and wasting were found across all ethnoracial groups, with the lower rates in children of White mothers. Disparities in mean weight and length/height for age persist between children of Indigenous women compared to White, although the z-score standardized growth trajectory remained within the limits of normality of the WHO reference standard for a general case (± 2SD). Our analysis indicated that social vulnerability further exacerbated the unfavorable growth trends observed in children born to mothers of ethnoracial background other than White.

The present study was conducted among the poorest population of a middle-income country with a history of major social and health inequalities, which may limit the generalizability of these findings. In this way, the ethnoracial distribution of our cohort may not be comparable to the Brazilian 2022 Census population [22], we found an underrepresentation of individuals who self-identified as White (30.86% vs 43.46%), Black (3.50% vs 10.17%), and Asian descent (0.38% vs 0.42%). Additionally, there was an overrepresentation of Pardo (64.33% vs 45.35%) and Indigenous (0.88% vs 0.60%) people [22].

In Brazil it has been observed a general decline in the prevalence of wasting and stunting among children under 5 years of age [7], [29], [30]. However, in our studied population, there is still a high burden of underweight, stunting, wasting, and thinness in children of Indigenous women, which aligns with the results of the First National Survey of Indigenous People's Health and Nutrition in Brazil [31]. When stratified by ethnoracial groups a similar pattern was also observed in other Latin America countries, where Indigenous, Black, and Pardo children under five years old showed higher risk of stunting and wasting compared to White children [32]. Although nutritional studies on the population of Asian descent in Brazil are scarce, it is noteworthy the high prevalence of stunting, underweight, wasting, and thinness in this group in our study.

While previous studies conducted in Brazil have demonstrated persistent disparities in physical growth indicators by ethnoracial group, childhood growth assessments were limited by the lack of longitudinal anthropometric data [33], [34], [35]. When repeated measurements over time are available, we can provide more consistent estimates regarding specific periods of child growth, enabling the detection of variations and a better understanding of the growth trajectory [27]. Longitudinal growth in children is considered to be a reliable indicator of the quality of the environment in which they live and has been employed as a global indicator of quality of life [36].

Our growth models reinforce that even among the most socially disadvantaged population, racial disparities persist. And, similar to other low- and middle-income countries, Brazil has insufficiencies in providing appropriate nutrition and living conditions for the growth of children, with markedly racial inequalities, with unfavorable results concentrated among children born from Indigenous, followed by Black and Pardo mothers [37], [31].

Racism and its manifestations can explain the disadvantageous effects of ethnoracial inequalities on the physical growth of children through different pathways [38], [23]. Racism is a structural social determinant of health that modulates the living context and the health-disease process, establishing a continuum that, since colonial times in Brazil, has disproportionately impacted Black, Pardo and Indigenous populations [39].

Undoubtedly, a population's health and nutrition conditions are inextricably linked to its respective social, economic, and environmental context [40], notably affected by racism [41], [7]. In line with this fact, our study revealed that maternal social vulnerability restrains child growth, as showed by the WAZ and L/HAZ open ward and downward shift in the growth trajectory curves when adjusted for mother’s age, educational level, and marital status. This draws even more attention to the children of Indigenous mothers, as, in general, this group remained below -1 SD z-score for L/HAZ in vulnerability profiles.

In this regard, Indigenous populations confront significant disadvantages in maintaining sustainable food sources as the introduction and propagation of predatory natural resource management practices (e.g., lumber harvesting, deforestation, mining, etc.) strike at the very heart of their food systems. Exacerbating this situation, rampant malaria, mercury contamination [42], and infectious and parasitic diseases further limit the biological uptake of nutrients, placing Indigenous people at risk of developing a range of malnutrition manifestations, in particular, nutrient and micronutrient deficiencies, with a mortality hazard ratio for malnutrition reaching 16.39 (95%CI 12.88-20.85) when compared to children of White mothers [43], [44], [45], [39], [23].

It is known that the conditions one lives in determine the way of birth, growing up, illness, and dying. In this sense, children born to Indigenous, Black, and Pardo mothers will accumulate inequalities and vulnerabilities prior to birth, as well as the negative experiences caused by racism suffered during pregnancy [46], [47].

This scenario places Brazil on a difficult path to achieve the Sustainable Development Goals laid out by the United Nations before the 2030 target date.

Study strengths and limitations

Our results provide valuable insight into early childhood growth trajectories among traditionally understudied racial/ethnic groups in Brazil; nonetheless, the present study has some limitations. Our study included records detailing complete length/height and weight information with biologically plausible values to improve accuracy. Notably, most of the individuals registered in the SISVAN database (≈68%) are beneficiaries of government assistance programs, which indicates an over-representation of poorer populations from smaller or rural municipalities and an under-representation of middle- and upper-class individuals residing in urban areas. Accordingly, the interpretation or generalization of the results presented herein warrants caution. Furthermore, the measurement of racism using the variable self-reported race/skin color constitutes a complex task, and data may vary according to whether an individual can self-classify or be effectively classified [48].

Nonetheless, our results present substantial evidence of the effects of ethnoracial disparities on children's growth. To the best of our knowledge, this study represents the first use of a population-based database consisting of administrative data to study growth outcomes, incorporating an extensive range of anthropometric data collected over a five-year postnatal period.

Conclusion

Our results reinforce that children born to vulnerable mothers, particularly Indigenous ones, experience systematically unfavorable physical growth compared to White children. Although prevalences for stunting, underweight, wasting, and thinness were high across all groups, a notable disparity exists in their distribution. These nutritional states reflect the unfavorable living conditions faced by these children. Recognizing racism as a central determinant of inadequate growth among some ethnoracial groups is an urgent priority to provide enhanced opportunities to thrive for minorities and historically neglected populations in Brazil. It is, therefore, of utmost importance to strengthen policies to protect Indigenous children to reduce the unacceptable large ethnoracial health inequalities observed. Future studies could investigate the inclusion of other social factors and geographical characteristics, which allow a better understanding of patterns of ethnoracial inequalities in child growth.

Abbreviations: BAZ (BMI-for-age z score), Brazilian Unified Health System (SUS), L/HAZ (length/height for age z-score), SISVAN (Brazilian Food and Nutrition Surveillance System), WAZ (weight-for-age z-score), WHZ (weight-for-length/height z-score)

Declarations

Ethics approval and consent to participate: The present study was approved by the Research Ethics Committee of the Collective Health Institute of the Federal University of Bahia (reference number 41695415.0.0000.5030) and the School of Nutrition, Federal University of Bahia (reference number 67205423.6.0000.5023). The need for informed consent was waived by the ethics committee/Institutional Review Board of the Collective Health Institute of the Federal University of Bahia (reference number 41695415.0.0000.5030) and the School of Nutrition, Federal University of Bahia (reference number 67205423.6.0000.5023), due to the exclusive use of secondary data from official information systems in accordance with the National Research Ethics Commission of the National Health Council standards, resolution 466 of December 2012.

Consent for publication: Not applicable.

Availability of data and materials: All data supporting this study were obtained from the Center for Data and Knowledge Integration for Health (CIDACS). These were licensed for exclusive use in the present study and, due to the privacy rules of the Brazilian Ethics Committee, are not openly available. Upon request with adequate justification and approval of an ethics committee, controlled access to data is evaluated; if possible, allowed access. Information on how to apply to access the data can be found at <https://cidacs.bahia.fiocruz.br/en/>. Requests to access the data should be directed to Helena B. M. da Silva at cidacs.curadoria@fiocruz.br.

Competing interests: The authors declare that they have no financial or non-financial competing interests.

Research funding: This study received funding from the Brazilian Science Ministry, Department of Science & Technology (MS-SCTIE-Decit/CNPq: grant number 25000.148278/2022-10) and the National Council of Scientific and Technological Development (CNPq: grant number 442948/2019-0). This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001. EPS is funded by the Wellcome Trust [grant number 225925/Z/22/Z]. HBMS is funded by the FAPESB. The study also used resources from the Centre for Data and Knowledge Integration for Health (CIDACS), which receives funding from the Bill & Melinda Gates Foundation, the Wellcome Trust [Grant Number: [202912/Z/16/Z], the Health Surveillance Secretariat of the Ministry of Health and the Secretariat of Science and Technology of the State of Bahia (SECTI-BA). Supporting source had no involvement regarding the publication of this paper.

Author's contributions to manuscript: HBMS and RCRS designed research and wrote the paper. JFMS performed statistical analysis and critically revised the paper. ICS analyzed data and critically revised the manuscript. PR, EFG, MYC, AF, JMP, RF, ESP, MLB revised the manuscript critically for important intellectual content. HBMS and JFMS contributed equally to this work. HBMS had primary responsibility for final content. All authors read and approved the final manuscript.

Acknowledgements: Not applicable.

References

1. Gluckman PD, Hanson MA, Cooper C, Thornburg KL: **Effect of in utero and early-life conditions on adult health and disease**. *N Engl J Med* 2008, **359**(1):61-73.
2. Jones-Smith JC, Neufeld LM, Laraia B, Ramakrishnan U, Garcia-Guerra A, Fernald LC: **Early life growth trajectories and future risk for overweight**. *Nutr Diabetes* 2013, **3**(2):e60.
3. Stein AD, Wang M, Martorell R, Norris SA, Adair LS, Bas I, Sachdev HS, Bhargava SK, Fall CH, Gigante DP *et al*: **Growth patterns in early childhood and final attained stature: data from five birth cohorts from low- and middle-income countries**. *Am J Hum Biol* 2010, **22**(3):353-359.
4. Monteiro PO, Victora CG, Barros FC, Monteiro LM: **Birth size, early childhood growth, and adolescent obesity in a Brazilian birth cohort**. *Int J Obes Relat Metab Disord* 2003, **27**(10):1274-1282.
5. Kesavan K, Devaskar SU: **Intrauterine Growth Restriction: Postnatal Monitoring and Outcomes**. *Pediatr Clin North Am* 2019, **66**(2):403-423.
6. Luo D, Song Y: **Socio-economic inequalities in child growth: Identifying orientation and forward-looking layout**. *Lancet Reg Health West Pac* 2022, **21**:100412.
7. Ribeiro-Silva RC, Silva NJ, Felisbino-Mendes MS, Falcao IR, de Andrade R, Silva SA, Nilson EAF, Spaniol AM, Fiaccone RL, Paixao E *et al*: **Time trends and social inequalities in child malnutrition: nationwide estimates from Brazil's food and nutrition surveillance system, 2009-2017**. *Public Health Nutr* 2021, **25**(12):1-11.
8. Robinson HA, Dam R, Hassan L, Jenkins D, Buchan I, Sperrin M: **Post-2000 growth trajectories in children aged 4-11 years: A review and quantitative analysis**. *Prev Med Rep* 2019, **14**:100834.
9. Von Holle A, North KE, Gahagan S, Burrows RA, Blanco E, Lozoff B, Howard AG, Justice A, Graff M, Voruganti VS: **Sociodemographic predictors of early postnatal growth: evidence from a Chilean infancy cohort**. *BMJ Open* 2020, **10**(6):e033695.
10. Rebouças P, Goes E, Pescarini J, Ramos D, Ichihara MY, Sena S, Veiga R, Rodrigues LC, Barreto ML, Paixão ES: **Ethnoracial inequalities and child mortality in Brazil: a nationwide longitudinal study of 19 million newborn babies**. *The Lancet Global Health* 2022, **10**(10).
11. WHO: **Global nutrition targets 2025: policy brief series.** . In. Geneva: World Health Organization; 2014.
12. UN: **Transforming Our World: The 2030 Agenda for Sustainable Development.** In. Resolution adopted by the General Assembly on 25 September 2015; 2015.
13. Paixao ES, Cardim LL, Falcao IR, Ortelan N, Silva NJ, Rocha ADS, Sena S, Almeida D, Ramos DO, Alves FJO *et al*: **Cohort Profile: Centro de Integracao de Dados e Conhecimentos para Saude (CIDACS) Birth Cohort**. *Int J Epidemiol* 2021, **50**(1):37-38.
14. Barbosa GCG, Ali MS, Araujo B, Reis S, Sena S, Ichihara MYT, Pescarini J, Fiaccone RL, Amorim LD, Pita R *et al*: **CIDACS-RL: a novel indexing search and scoring-based record linkage system for huge datasets with high accuracy and scalability**. *BMC Med Inform Decis Mak* 2020, **20**(1):289.
15. Barreto ML, Ichihara MY, Pescarini JM, Ali MS, Borges GL, Fiaccone RL, Ribeiro-Silva RC, Teles CA, Almeida D, Sena S *et al*: **Cohort Profile: The 100 Million Brazilian Cohort**. *Int J Epidemiol* 2022, **51**(2):e27-e38.
16. Brasil: **Marco de Referência da Vigilância Alimentar e Nutricional na Atenção Básica**. In. Brasília: Ministério da Saúde; 2015.
17. Brasil: **Orientações Para a Coleta e Análise de Dados Antropométricos em Serviços de Saúde: Norma Técnica do Sistema de Vigilância Alimentar e Nutricional – SISVAN**. In.

Brasília: Ministério da Saúde. Secretaria de Atenção à Saúde. Departamento de Atenção Básica.; 2011: 76.

18. Silva NJ, Silva J, Carrilho TRB, Pinto EJ, Andrade R, Silva SA, Pedroso J, Spaniol AM, Bortolini GA, Fagundes A *et al*: **Quality of child anthropometric data from SISVAN, Brazil, 2008-2017**. *Rev Saude Publica* 2023, **57**:62.
19. Villar J, Cheikh Ismail L, Victora CG, Ohuma EO, Bertino E, Altman DG, Lambert A, Papageorghiou AT, Carvalho M, Jaffer YA *et al*: **International standards for newborn weight, length, and head circumference by gestational age and sex: the Newborn Cross-Sectional Study of the INTERGROWTH-21st Project**. *Lancet* 2014, **384**(9946):857-868.
20. (UNICEF) WHOatUNCsF: **Recommendations for data collection, analysis and reporting on anthropometric indicators in children under 5 years old**. In. Geneva; 2019.
21. (WHO) WHO: **WHO Reference 2007: STATA macro package**. In.; 2007.
22. Estatística I-IBdGe: **Censo demográfico 2022: identificação étnico-racial da população, por sexo e idade : resultados do universo**. 2023:84.
23. Reboucas P, Goes E, Pescarini J, Ramos D, Ichihara MY, Sena S, Veiga R, Rodrigues LC, Barreto ML, Paixao ES: **Ethnoracial inequalities and child mortality in Brazil: a nationwide longitudinal study of 19 million newborn babies**. *Lancet Glob Health* 2022, **10**(10):e1453-e1462.
24. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J: **Development of a WHO growth reference for school-aged children and adolescents**. *Bull World Health Organ* 2007, **85**(9):660-667.
25. Fausto MA, Carneiro M, Antunes CM, Pinto JA, Colosimo EA: **[Mixed linear regression model for longitudinal data: application to an unbalanced anthropometric data set]**. *Cad Saude Publica* 2008, **24**(3):513-524.
26. Dugas C, Kearney M, Perron J, Weisnagel SJ, Marc I, Robitaille J: **Breastfeeding and growth trajectory from birth to 5 years among children exposed and unexposed to gestational diabetes mellitus in utero**. *Journal of perinatology : official journal of the California Perinatal Association* 2021, **41**(5):1033-1042.
27. Hosseini SM, Maracy MR, Sarrafzade S, Kelishadi R: **Child Weight Growth Trajectory and its Determinants in a Sample of Iranian Children from Birth until 2 Years of Age**. *International journal of preventive medicine* 2014, **5**(3):348-355.
28. Isong IA, Richmond T, Avendano M, Kawachi I: **Racial/Ethnic Disparities: a Longitudinal Study of Growth Trajectories Among US Kindergarten Children**. *Journal of racial and ethnic health disparities* 2018, **5**(4):875-884.
29. Monteiro CA, Benicio MH, Conde WL, Konno S, Lovadino AL, Barros AJ, Victora CG: **Narrowing socioeconomic inequality in child stunting: the Brazilian experience, 1974-2007**. *Bull World Health Organ* 2010, **88**(4):305-311.
30. Ferreira HDS, Albuquerque GT, Santos TRD, Barbosa RL, Cavalcante AL, Duarte LEC, Assuncao ML: **Stunting and overweight among children in Northeast Brazil: prevalence, trends (1992-2005-2015) and associated risk factors from repeated cross-sectional surveys**. *BMC Public Health* 2020, **20**(1):736.
31. Horta BL, Santos RV, Welch JR, Cardoso AM, dos Santos JV, Assis AM, Lira PC, Coimbra CE, Jr.: **Nutritional status of indigenous children: findings from the First National Survey of Indigenous People's Health and Nutrition in Brazil**. *Int J Equity Health* 2013, **12**:23.
32. Mena-Melendez L: **Ethnoracial child health inequalities in Latin America: Multilevel evidence from Bolivia, Colombia, Guatemala, and Peru**. *SSM Popul Health* 2020, **12**:100673.
33. Sacker A, Kelly YJ: **Ethnic differences in growth in early childhood: an investigation of two potential mechanisms**. *Eur J Public Health* 2012, **22**(2):197-203.

34. Ferreira AA, Welch JR, Cunha GM, Coimbra CE, Jr.: **Physical growth curves of indigenous Xavante children in Central Brazil: results from a longitudinal study (2009-2012)**. *Ann Hum Biol* 2016, **43**(4):293-303.

35. Silveira VNdC, Nascimento JBMd, Cantanhede NAC, Frota MTBA, Chagas DCd, Carvalho CAd, Viola PCdAF: **Desigualdade racial e regional na tendência temporal do déficit de estatura e excesso de peso de crianças brasileiras menores de cinco anos**. *Revista Brasileira de Epidemiologia* 2023, **26**.

36. Amigo H, Bustos P: **[Risk factors of short stature in Chilean school children from rural areas of high social vulnerability]**. *Arch Latinoam Nutr* 1995, **45**(2):97-102.

37. Santos LP, Gigante DP: **Relationship between food insecurity and nutritional status of Brazilian children under the age of five**. *Rev Bras Epidemiol* 2013, **16**(4):984-994.

38. Pilecco FB, Cabral CS: **Racism and health: the need for urgent action**. *Lancet Glob Health* 2022, **10**(10):e1369-e1370.

39. Yearby R: **Structural Racism and Health Disparities: Reconfiguring the Social Determinants of Health Framework to Include the Root Cause**. *J Law Med Ethics* 2020, **48**(3):518-526.

40. Thompson C: **Dietary health in the context of poverty and uncertainty around the social determinants of health**. *Proc Nutr Soc* 2022, **81**(2):134-140.

41. Araujo TS, Oliveira CS, Muniz PT, Silva-Nunes MD, Cardoso MA: **Child undernutrition in one of the cities with greater nutritional risk in Brazil: population-based study in the Western Brazilian Amazon**. *Rev Bras Epidemiol* 2016, **19**(3):554-566.

42. Silbergeld EK, Nash D, Trevant C, Strickland GT, de Souza JM, da Silva RS: **Mercury exposure and malaria prevalence among gold miners in Para, Brazil**. *Rev Soc Bras Med Trop* 2002, **35**(5):421-429.

43. Gebreegziabher E, Dah C, Coulibaly B, Sie A, Bountogo M, Ouattara M, Compaore A, Nikiema M, Tiansi J, Dembele N *et al*: **The Association between Malnutrition and Malaria Infection in Children under 5 Years in Burkina Faso: A Longitudinal Study**. *Am J Trop Med Hyg* 2023, **108**(3):561-568.

44. Mao L, Ren W, Liu X, He M, Zhang BT, Lin C, Ouyang W: **Mercury contamination in the water and sediments of a typical inland river - Lake basin in China: Occurrence, sources, migration and risk assessment**. *J Hazard Mater* 2023, **446**:130724.

45. Xu J, Zhang Q, Wang S, Nan Z, Long S, Wu Y, Dong S: **Bioavailability, transfer, toxicological effects, and contamination assessment of arsenic and mercury in soil-corn systems**. *Environ Sci Pollut Res Int* 2023, **30**(4):10063-10078.

46. Beck AF, Edwards EM, Horbar JD, Howell EA, McCormick MC, Pursley DM: **The color of health: how racism, segregation, and inequality affect the health and well-being of preterm infants and their families**. *Pediatric Research* 2020(1530-0447 (Electronic)).

47. Tempesta GA, Eneile M: **Racismo obstétrico: a política racial da gravidez, do parto e do nascimento**. *Amazônica - Revista de Antropologia; v 12, n 2 (2020)DO - 1018542/amazonicav12i29194* 2021.

48. Travassos C, Williams DR: **The concept and measurement of race and their relationship to public health: a review focused on Brazil and the United States**. *Cad Saude Publica* 2004, **20**(3):660-678.