Barreto et al. BMC Pregnancy and Childbirth (2020) 20:748
https://doi.org/10.1186/s12884-020-03396-8

BMC Pregnancy and Childbirth

RESEARCH ARTICLE Open Access

Low birthweight, prematurity, and intrauterine growth restriction: results from the baseline data of the first indigenous birth cohort in Brazil (Guarani Birth Cohort)

Carla Tatiana Garcia Barreto[1,2*], Felipe Guimarães Tavares[3], Mariza Theme-Filha[2], Yasmin Nascimento Farias[2], Lídia de Nazaré Pantoja[2] and Andrey Moreira Cardoso[2]

Abstract

Background: Low birthweight (LBW) remains an important global health problem, associated with a range of adverse life-course health outcomes. Evidence suggests that LBW is a relevant determinant of morbidity and mortality in indigenous groups, who generally have limited access to public policies on health and nutrition. Knowledge of the prevalence of LBW and its underlying causes can contribute essential steps to the prevention of its health effects. The study aimed to estimate the prevalence rates of LBW, prematurity, and intrauterine growth restriction (IUGR) and to investigate their determinants in the first indigenous birth cohort in Brazil.

Methods: This cross-sectional study used baseline data collected from the first indigenous birth cohort in Brazil, the Guarani Birth Cohort. Brazil is one of the most ethnically diverse countries in the world, with 305 indigenous peoples and 274 native languages. The Guarani are one of the five largest ethnic groups, with villages located mostly in the southern region. All singleton births from June 1, 2014, to May 31, 2016, were selected in 63 Guarani indigenous villages in the South and Southeast regions. Hierarchical multiple logistic regression was performed.

Results: Prevalence rates for LBW, prematurity, and IUGR were 15.5, 15.6, and 5.7%, respectively. The odds of LBW were lower in newborns of mothers living in brick and mortar housing (OR: 0.25; 95%CI: 0.07–0.84) and were higher in children of mothers ≤20 years of age (OR: 2.4; 95%CI: 1.29–4.44) and with chronic anemia before pregnancy (OR: 6.41; 95% CI: 1.70–24.16). Prematurity was statistically associated with the type of energy source for cooking (wood-burning stove – OR: 3.87; 95%CI: 1.71–8.78 and bonfires – OR: 2.57; 95%CI: 1.31–5.01). IUGR was associated with primiparity (OR: 4.66; 95%CI: 1.68–12.95) and chronic maternal anemia before pregnancy (OR: 7.21; 95%CI: 1.29–40.38).

(Continued on next page)

* Correspondence: carlatgbarreto@gmail.com
[1]Universidade do Estado do Rio de Janeiro (UERJ), Av. Marechal Rondon, 381. São Francisco Xavier, Rio de Janeiro, RJ CEP: 20950-000, Brazil
[2]Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz, Rio de Janeiro, RJ, Brazil
Full list of author information is available at the end of the article

(Continued from previous page)
Conclusions: Maternal age, nutritional status, and parity, housing conditions, and exposure to indoor pollution were associated with perinatal outcomes in the Guarani indigenous population. These results indicate the need to invest in access to, and improvement of, prenatal care; also in strengthening the Indigenous Healthcare Subsystem, and in inter-sector actions for the development of housing policies and sanitation and environmental improvements adjusted to needs and knowledge of the indigenous people.

Keywords: Indigenous population, children's health, Low birthweight, Premature birth, Intrauterine growth restriction, Prevalence

Background

Low birthweight (LBW) remains a highly relevant global health problem, associated with a range of adverse life-course health outcomes [1]. Birth weight can be determined by both fetal growth and pregnancy duration [2]. Children with LBW show increased risk of infections [3, 4], delays in growth and physical and cognitive development [5], and mortality [6]. The repercussions of LBW last into adulthood, conferring greater risk of chronic noncommunicable disease and all-cause and cardiovascular mortality [7]. In addition, studies report direct socioeconomic effects, evidenced by the association with lower schooling levels, lower employment rates, and higher dependence on social benefits [8].

The estimated global prevalence of LBW exceeds 15%, corresponding to some 20 million births. Although this rate is high, it appears to have been underestimated, since more than 95% of LBW cases occur in developing countries and in the most vulnerable populations, where there is a higher proportion of homebirths and less reliable data recorded on birthweight [1]. The identification of populations at increased risk of LBW and that face barriers to accessing health and nutrition policies and are thus a global health priority [1]. In addition, identifying the contribution of prematurity and intrauterine growth restriction (IUGR) to LBW and its underlying causes can provide essential steps for the prevention of these condition and their health effects.

Indigenous peoples are considered marginalized populations and largely experience low health standards [9–11]. Anderson et al. [9] compared the socioeconomic and health indicators of 28 indigenous peoples in 23 countries with the respective indicators of non-indigenous reference populations and showed a systematic disadvantage for indigenous peoples, including the prevalence of LBW. Despite the vast international literature on LBW, there are few studies relating to indigenous peoples, particularly in Latin America as a whole and in Brazil [12], a country with one of the world's most socially diverse indigenous populations [13].

A recent systematic review [12] found the risk factors for LBW in indigenous peoples to be similar to those identified in non-indigenous populations with low socioeconomic status. These included obstetric causes such as primiparity [14–16] and history of prematurity [15, 17–19], stillbirth [16, 18], or abortion [16], pregnancy-induced hypertension [15, 17, 19], and urinary infection during pregnancy [15, 17, 19]. The authors also found risk factors related to maternal nutritional status, including low gestational weight gain [17], pregestational malnutrition [18], and anemia [15], as well as limited access to health services [20, 21]. Multiple determinants of LBW, as described in the literature, coexist among indigenous peoples in Brazil, in addition to a high burden of adverse health outcomes usually associated with LBW, such as infant hospitalization and death caused by acute respiratory infection, diarrhea, and malnutrition [22–28]. This evidence suggests that LBW can be a relevant determinant of infant morbidity and mortality in indigenous groups in Brazil.

According to the most recent national census, carried out in 2010, there were 896,900 indigenous people in Brazil, corresponding to 0,4% of the national population [13]. Of these approximately 85,000 are Guarani, that is, 9,5% of the indigenous population. The Guarani are divided into three ethnic subgroups based on religious, linguistic, and cultural specificities - the Kaiowa, the Nhandéva, and the Mbya. The Mbya have the smallest population, about 25,000 people, one-third (8,000) of whom live on the southern coast [13, 29]. The coastal strip is part of the traditional territory of the Mbya population and although our studies were carried out among all the Guarani people living in this location, the vast majority of them are Mbya.

In recent years, epidemiological studies on the health of Guarani children in this area have reported high rates and proportions of hospitalization [30] and death [31] for acute lower respiratory tract infections in under-five children, especially in infants. The rates have exceeded the corresponding estimates among other indigenous ethnicities and in the non-indigenous. LBW was an independent risk factor for hospitalization of Guarani children for acute lower respiratory tract infections in a prospective population-based case-control study [23]. Additionally, results from the First National Survey of Indigenous People's Health and Nutrition in Brazil reported higher prevalence of pneumonia in children of the southern region, which was independently associated with LBW [22]. In order to generate robust scientific evidence on the determinants of Guarani infant health, with a view to reducing morbimortality from avoidable causes, and with a focus on acute respiratory infections, we recently carried out the first study of an indigenous birth cohort in Brazil - the Guarani Birth Cohort.

The objective of this study was to estimate the prevalence rates of LBW, prematurity, and IUGR, to investigate their determinants, and characterize the relative contribution of prematurity and IUGR to LBW in the baseline data from the Guarani Birth Cohort.

Methods

This cross-sectional study used baseline data collected from the Guarani Birth Cohort; participants were recruited from June 1, 2014, to May 31, 2016.

Since 1999, Brazil has implemented the Indigenous Healthcare Subsystem (SASI-SUS) as part of the Unified National Health System (SUS). SASI-SUS is organized into 34 Indigenous Health Sanitary Districts, which each have Multidisciplinary Indigenous Health Teams (EMSI). These teams are responsible for providing primary healthcare in the villages, coordinating care, and linking the Subsystem to the other complexity levels of assistance in the SUS, thereby guaranteeing comprehensive indigenous healthcare. Regarding pregnancy and childbirth, nurses and primary care physicians are responsible for prenatal care in the villages, based on protocols from the Ministry of Health and high-risk pregnancies are referred to obstetric specialists in the SUS in nearby municipalities. One of the pillars of SASI-SUS is that the biomedical care system must act concurrently with traditional practices of healing and care and should respect the indigenous cosmovision.

The Guarani Birth Cohort study was implemented in collaboration with the two existing Indigenous Health Sanitary Districts in South and Southeast Brazil in order to investigate determinants of infant health in the Guarani [32]. The population under investigation live in villages and camps, mainly on the coastal strip of southern region, surrounded by the largest cities in Brazil, exposing them to disadvantageous living conditions, such as small, degraded, polluted, and highly-populated territories. The majority of Guarani villages have some degree of access to the municipal health system in the surrounding cities, and the SASI-SUS offers support when the people use outside services, for example, providing transport or food. Most villages have indigenous midwives who attend home deliveries which account for 28.5% of births in the Guarani cohort.

Participants in the study were recruited from 63 villages (75.9%) of the 83 existing Guarani villages on the coastline extending from the state of Rio de Janeiro to the state of Santa Catarina and the entire state of Rio Grande do Sul (Fig. 1). Eligible villages for the birth cohort were defined as those with a structure that would allow us to implement a surveillance system for the study itself, aimed at providing weekly home follow-up of the children recruited during their first year of life. This would enable us to capture several health outcomes of interest, including vital events, incident episodes of acute short duration diseases, like acute respiratory infections and diarrhea, and the perinatal outcomes specifically analyzed in this study – LBW, prematurity and IUGR. The study aimed to include all liveborn singleton children of Guarani mothers in the eligible villages during the Guarani Cohort recruitment period. The mother was defined as Guarani if she lived in an eligible village and had reported her own indigenous ethnicity at the time of the recruitment interview.

Operationalization of the study

The data for analysis were gathered from the perinatal questionnaire of the Guarani Birth Cohort, which was applied to the mother during postpartum (ideally within 15 days of giving birth) by previously-trained nurses from the Multidisciplinary Indigenous Health Team (EMSI).

The perinatal questionnaire was designed by the research team and was based on questionnaires from the National Census, the First National Survey of Indigenous People's Health and Nutrition in Brazil, a population-based case-control study in the Guarani population, and other Brazilian reference studies on infant-maternal health, such as the four Pelotas Birth Cohorts (1982, 1993, 2004 and 2015) and the Birth in Brazil Study. We also added questions based on the forms routinely used in health services for prenatal care, the hospital discharge summary after birth, the health card of the child, and the birth certificate. If necessary, items were adapted to the local context, for example adding questions to measure specific variables related to the outcomes of interest in the cohort as a whole, such as household characteristics, sanitation, type and location of cooking and heating fire and additional sources of income.

The questionnaire (Supplementary file 1) comprised 102 questions and some dependent subquestions, that were organized in blocks to be completed during the interview with the mother (33 items). Some information was extracted from secondary registries (69 items), to avoid unnecessarily long interviews for the participant. The total time for completing the questionnaire was about an hour, including a 30-min interview.

Answers to the interview questions were collected through face-a-face interview with the mothers, or alternatively, with another relative of the child. The

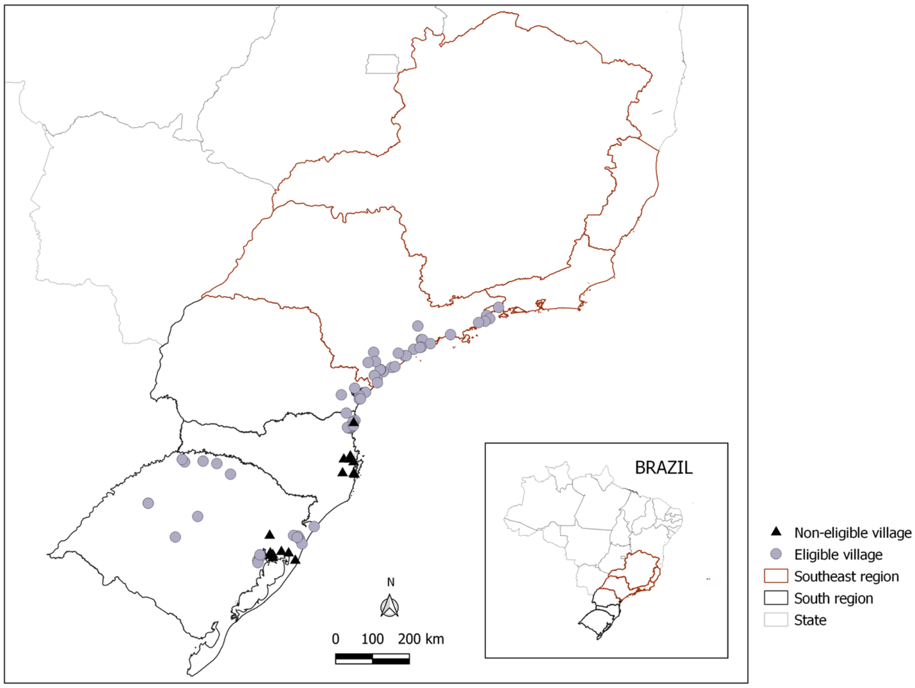


Fig. 1 Geographic Location of Villages and Indigenous Lands in the South and Southeast of Brazil

questionnaire was designed in digital format, operated on a handheld personal digital assistant (PDA), with subsequent online data transmission to the study coordinators. Several quality control strategies were adopted to ensure the best completion of the questionnaires; nevertheless, some registries were incomplete due to missing information on the secondary sources available or because interviewers did not receive an answer from the respondent. To minimize data loss and ensure information quality, periodic visits to the village health posts were scheduled by the study coordinators to extract secondary data recorded on the medical files of the mothers and infants, prenatal cards, registration books of pregnant women, ultrasound reports, maternal immunization records, birth certificates, and children's health booklets.

Study outcomes

Three target outcomes were considered: (1) low birthweight - LBW; (2) prematurity; and (3) intrauterine growth restriction– IUGR. The data used to estimate the three outcomes were extracted by the interviewers from the following secondary sources: birth certificate, child's health booklet, and hospital or outpatient medical file.

LBW was defined as birthweight < 2,500 g. Gestational age at birth was calculated by the following algorithm: estimate directly from an ultrasound report issued any time during the pregnancy; in the absence of such a report, use the record of the gestational age on the mother's medical file or the prenatal card, based on the ultrasound reported by the physician or nurse, or alternatively, based on the date of last menstruation (DLM) recorded on the maternal medical file or prenatal card [33]. Gestational age at birth was categorized as premature or term. Prematurity was defined as gestational age at birth < 37 weeks.

We calculated IUGR using the INTERGROWTH-21st program. IUGR was defined as birthweight Z-score for gestational age ≤ – 2 standard deviations (SD), according to the International Fetal and Newborn Growth Consortium for the twenty-first Century (INTERGROWTH-21st) [34].

Exposure variables

Socioeconomic

"Regular per capita household income in the last month" was calculated as the sum of wages from formal work, conditional cash transfers (*Bolsa Família*), retirement benefits, and pensions of all household residents aged 10 years or more in the previous month, divided by the number of residents in the household. This variable was categorized into levels of poverty as defined by the World Bank based on per capita daily income in dollars: above the poverty line ≥ US$ 5.50/day; poverty, < US$ 5.50/day to US$ 1.90/day; and extreme poverty ≤US$ 1.90/day [35].

Household characteristics

"Brick and mortar housing" was defined by the combination of construction materials used for the floor, walls, and roof, as "yes" (brick walls, floor tiles or cement floor, and zinc, asbestos, or ceramic roof tiles) or "no" (logs, wood, straw, mud, and other); and "use of additional covering on walls or ceiling", categorized as "no" or "yes" (use of tarpaulins, plastic sheets, blankets, or cloth to increase the durability of the house and protect the residents from the elements).

Reproductive variables, access to prenatal care, and maternal morbidity

Adequacy of prenatal care was assessed by two indicators, as proposed by Domingues et al. [36]. Indicator (1) was access to adequate prenatal care, when the prenatal visit occurred before the fourth month of pregnancy (16 weeks) and the number of visits corresponded to the recommendation for the gestational age at the pregnancy's conclusion. Indicator (2) was access to prenatal care when the conditions specified in indicator 1 were met, and routine laboratory tests were carried out at least once during the pregnancy (blood type, hemoglobin/hematocrit, blood glucose, VDRL, HIV test, and simple urine test or urine culture) and maternal tetanus vaccination, according to the recommended schedule. Since the perinatal interview was ideally held within 15 days of delivery and the postpartum follow-up visit can be scheduled up to 42 days after delivery, the postpartum visit was not considered in the definition of adequate prenatal care [36]. Indicator 2 is thus a more rigorous test of adequacy than indicator 1.

Pregestational and gestational hypertension were aggregated in the variable "maternal hypertension". Data on "maternal hypertension", "urinary infection during the pregnancy" and "chronic maternal anemia" before pregnancy were obtained from prenatal cards or patient medical charts.

Pregestational nutritional status was classified according to BMI (weight/height^2) based on weight only before the 13th gestational week. Pregestational BMI was classified as underweight (< 18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obesity (≥ 30 kg/m^2). For the purposes of analysis, overweight and obesity were grouped in one category, excess weight (BMI ≥ 25.0 kg/m^2).

Gestational weight gain was calculated based on the Institute of Medicine recommendations according to prepregnancy BMI: underweight - a gain of 12.5–18 kg; normal weight - a gain of 11.5–16 kg; overweight - a gain of 7–11.5 kg; and obese - a gain of 5–9 kg. We divided gestational weight gain into three categories: low, if the weight gain was below the recommendation; adequate if it was within the recommendation; and excessive, if it was above the recommendation. Total gestational weight gain was adjusted for length of gestation at the time the final weight was collected [37].

Maternal habits during the pregnancy

"Smoking during pregnancy" was defined as smoking at least one factory-made cigarette daily throughout pregnancy, categorized as yes or no. "Alcohol consumption during pregnancy" was defined as alcohol consumption for at least one trimester, independently of the period of the pregnancy, number of doses or type of beverage, categorized as yes or no.

Additional variables on household characteristics, maternal characteristics, reproductive variables, and type of delivery were considered self-explanatory and are presented only in the tables. Only in-hospital deliveries were considered in the calculation of the cesarean rate.

Data analysis

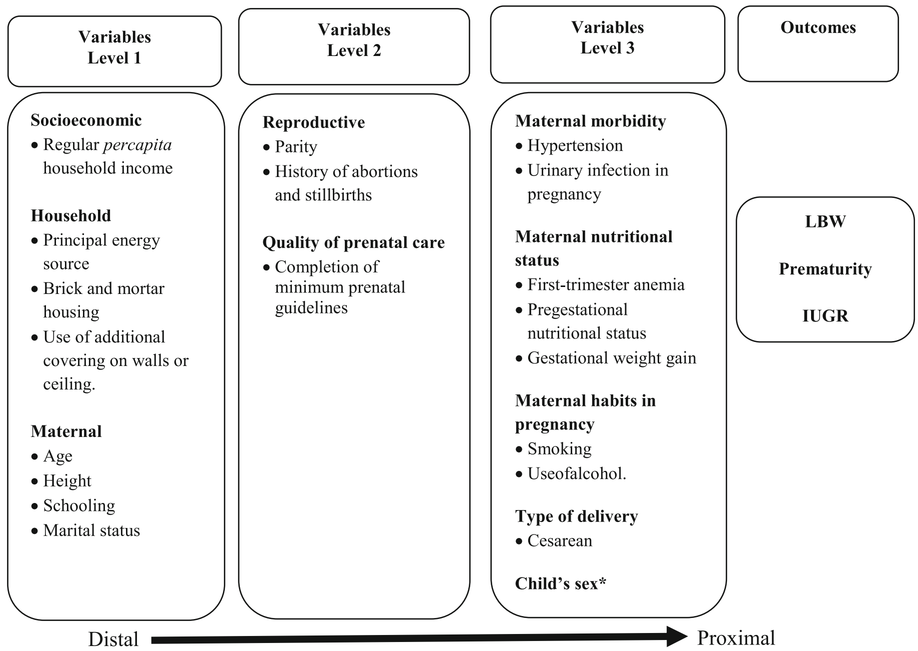
As the first step of the analysis, we ruled out extreme values of the variables which comprised the outcomes of interest which were considered implausible. This was the case for gestational age < 20 weeks and > 44 weeks and birthweight Z-score for gestational age < − 4 SD or > 4 SD, both used for IUGR estimates.

A comparative descriptive analysis was made between recruited and unrecruited births according to some variables, including rates of the study target outcomes, followed by a descriptive analysis of the rates of recruited births and the prevalence rates for the outcomes LBW, prematurity, and IUGR according to the categories of independent variables.

The crude associations between the independent variables and the outcomes were analyzed, estimating the crude odds ratios (OR) with respective 95% confidence intervals (95% CI) via logistic regression. For the multivariate analysis, we opted for hierarchical logistic regression using a theoretical model of the outcome determination based on the model originally proposed by Victora et al. [38] and adapted to the study population characteristics (Fig. 2).

Separate analyses were performed for each of the study's three target outcomes. The order for the entry of blocks of variables into the multivariate regression model was defined by the hierarchical levels of the theoretical model, from the most distal level (level 1) to the most proximal (level 3). Level 1 consisted of socioeconomic variables, household and maternal characteristics. Level 2 consisted of the reproductive variables and quality of prenatal care, and level 3 consisted of maternal morbidity and nutrition, maternal habits during pregnancy, type of delivery, and child's sex.

Variables in level 1 that reached significance at $p <$ 0.20 in the simple logistic regression were included jointly in the multivariate regression model pertaining to this level, adopting the backward procedure for stepwise exclusion of the variables with the lowest statistical



Notes: IUGR– intrauterine growth restriction;
*Child's sex was not included in the model for IUGR, since the latter is calculated according to the child's sex.

Fig. 2 Theoretical hierarchical model of determination of LBW, prematurity, and intrauterine growth restriction in the Guarani population in South and Southeast Brazil

significance, until the final model at this level only included variables with significance at $p < 0.05$.

For each level 2 variable, we estimated the OR adjusted by the significant variables kept at level 1. Variables at level 2 that reached significance at $p < 0.20$ were thus included jointly in the multiple regression model for this level, together with the variables kept in the final model from the previous level (level 1). The backward procedure was then used with stepwise exclusion of the variables with the lowest statistical significance until the final model at this level only kept the variables with significance at $p < 0.05$, adjusted by the variables kept at level 1 and mutually adjusted by the variables kept at level 2.

For level 3, the analytical procedures were performed as described for the previous level until the final model of determination for each of the target outcomes was reached.

Child's sex was not used as a variable in the model for IUGR, since this indicator is calculated separately for boys and girls.

The R program version 3.4.2 was used for the analyses [39].

Ethical aspects

The cohort study was approved by the National Research Ethics Commission (Comissão Nacional de Ética em Pesquisa – CONEP n. 719/2010) and the Research Committee of the National School of Public Health of the Oswaldo Cruz Foundation (CEP/ENSP n. 160/10). The Guarani Cohort was authorized by the indigenous leaders who signed the free and informed consent form, in addition to individual verbal consent from the mothers or guardians and authorization by the Brazilian National Health Foundation to enter indigenous territories for purposes of scientific research. This subproject of the Cohort was approved by the Institutional Review Board of the National School of Public Health of the Oswaldo Cruz Foundation (CEP/ENSP), protocol number 1.821.137.

Authorization of the Guarani Birth Cohort by the indigenous communities started in 2013. The proposal previously approved by other ethical and health services forums was presented at the District Council meeting, the regional forum for social control of SASI-SUS, evenly composed of health managers, health professionals, and indigenous users. Following this approval, the research coordinator visited all the villages in the territory over a six-month period and presented results from previous studies to local leaders, interested community members, and local health professionals, including indigenous community health agents, in order to request authorization for the new research. The Collective Informed Consent Form was written in Portuguese, which is reasonably well understood and spoken by most Guarani, although the indigenous health agents and other younger members of the communities always act as communication mediators in the villages. This presentation was guided by dialogue and attendees were given the opportunity to ask questions and make suggestions. Of the 83 villages, only one had no interest in participating, and 63 had suitable conditions to carry out the research.

The research team then provided seven regional workshops and a centralized workshop for technical training of indigenous health teams in the WHO strategy of Integrated Management of Childhood Illnesses-IMCI and in the procedures of surveillance and data collection. The study of this cohort was then started in June 2014. The recruitment of each newborn in the 2-year period was done by the local health team with the participation of indigenous health agents, who were trained to explain the research and obtain individual verbal informed consent, as planned in the research protocol and approved by the CEP/ENSP and the CONEP, based on situations foreseen in the national legislation on research with indigenous peoples. Refusal to consent or subsequent withdrawal of that consent was possible at any time without penalty. We believe that the research project helped parents learn to identify signs of disease severity in their children for themselves. Although the initiative constituted scientific research, it nevertheless played a role in the work of the indigenous health teams, contributing to technical training, active surveillance and timely identification and management of highly prevalent diseases and conditions in the child population.

Results

There were 435 eligible births in the study area, and 74 (17.0%) of these were not recruited. Subjects who were not recruited comprised: two refusals, one neonatal death, three migrations out of the study area soon after birth, and 68 failures to recruit due to gaps in surveillance on the part of the Multidisciplinary Indigenous Health Team (EMSI). Figure 3 shows a comparison of characteristics between recruited and unrecruited children.

There were higher proportions of non-recruitment among boys and among births in the states of Rio de Janeiro and Rio Grande do Sul (Fig. 3). No statistically significant differences were seen in mean birthweight, gestational age at birth, and birthweight Z-score for gestational age between recruited and unrecruited children. In view of the reduced level of missing data, we performed a complete case analysis.

Overall prevalence rates of LBW, prematurity, and IUGR were 15.5, 15.3, and 5.7%, respectively. There was no statistically significant difference in the prevalence

Proportions	Total	Recruited	Not recruited	p-value
	N (%)	N (%)	N (%)	
Births	435 (100.0)	361 (83.0)	74 (17.0)	
State of birth				
Rio de Janeiro	44 (10.1)	29 (8.0)	15 (20.3)	0.002*
São Paulo	269 (61.8)	245 (67.9)	24 (32.4)	
Paraná	12 (2.8)	12 (3.3)	0 (-)	
Santa Catarina	27 (6.2)	23 (6.4)	4 (5.4)	
Rio Grande do Sul	83 (19.1)	52 (14.4)	31 (41.9)	
Child's sex				
Male	232 (53.3)	186 (51.5)	46 (62.1)	0.045*
Female	197 (45.3)	173 (47.9)	24 (32.4)	

Means. Standard deviations (SD), and medians	Total		Recruited		Not recruited		p-value
	Mean (SD)	Median	Mean (SD)	Median	Mean (SD)	Median	
Birthweight (g)	2,912 (469.3)	2,910	2,917.6 (450.9)	2,915	2,877.7 (570.4)	2,860	0.607
GA (weeks)	38.1 (3.0)	39.0	38.1 (2.7)	39.0	38.3 (3.0)	39.0	0.695
Birthweight z-score for GA	-0.15 (1.1)	-0.14	-0.13 (1.1)	-0.14	-0.30 (1.3)	-0.13	0.354

Prevalence	Total	Recruited	Not recruited	p-value
	N (%)	N (%)	N (%)	
LBW	65 (15.5)	54 (15.0)	11 (18.3)	0.646
Prematurity	63 (15.3)	57 (16.1)	6 (10.5)	0.379
IUGR	23 (5.7)	16 (4.6)	7 (13.5)	0.019*

Notes: GA= Gestational age; LBW= low birthweight; IUGR= intrauterine growth restriction.

Fig. 3 Comparative analysis of selected characteristics in children recruited and not recruited. Baseline of the Guarani Birth Cohort, South and Southeast Brazil, 20,142,016 rates of LBW and prematurity between recruited and unrecruited children. However, prevalence of IUGR was significantly lower in recruited children. In more than two-thirds of the cases (69.8%), prematurity was late (34 to 36 weeks). Nearly half (48.2%) of the LBW infants were born prematurely and one-fourth had IUGR.

The descriptive analysis of the cohort baseline and investigation of the outcome determinants from this point on, as well as the results presented in Tables 1, 2, 3 and 4, refer only to the 361 recruited births.

All of the Guarani children recruited for the study lived below the poverty line, and two-thirds (66.3%) were below the cutoff for extreme poverty. More than 30% of the children lived in households that used bonfires as their principal energy source for cooking, 83.7% lived in houses built of logs, wood, straw, mud, or other similar materials, and more than half of these households (58.7%) used some additional material such as tarpaulins, plastic sheeting or blankets to cover the ceiling or walls (Table 1).

The proportion of mothers under 20 years of age was 36.8%, with mean maternal age of 23.9 years (SD: 7.6) and median of 22 years; 64.8% of the mothers were ≤ 150 cm tall, with mean and median maternal height of 148.5 cm (SD: 5.6) and 148.0 cm, respectively. Almost two thirds (63.2%) of the mothers had some formal education, 77.3% had a husband or partner, the majority were multiparous (76.5%) and had an obstetric history of stillbirths or abortions (80.3%) (Table 1).

Slightly more than 50% of the mothers of recruited children were classified as having adequate prenatal care, according to either of the indicators used. In 2.5% of the pregnancies there was pregestational and/or gestational hypertension. Urinary infection was diagnosed at some moment in 26.0% of the pregnancies; 2.8% of the mothers presented chronic anemia before pregnancy and 58.4% had adequate nutritional status when they became pregnant. However, 56.8% showed insufficient weight gain during the pregnancy, and 13.0% showed excessive weight gain. Prevalence rates for smoking and alcohol use during the pregnancy were 5.5 and 6.1%, respectively. Hospital deliveries represent 70.9% of all Guarani deliveries and the cesarean section prevalence rate was 11.9% in the hospital deliveries (Table 1).

Five variables from hierarchical level 1 showed crude significant association with LBW at $p < 0.20$ (Table 2). Use of bonfires (OR: 1.64, CI95%: 0.84–3.20) or wood-burning stove (OR: 2.08, 0.87–4.96) as the main energy source for cooking, use of additional covering on walls or ceiling (OR: 1.64, CI95%: 0.88–3.04), and low maternal height (OR: 1.6, CI95%: 0.82–3.13) lost statistical significance in the multivariate analysis. The only variables that remained in the final model were brick and mortar housing (OR: 0.27, CI95%: 0.08–0.89) and maternal age (< 20 - OR: 2.3, CI95%: 1.25–4.24; ≥ 35 – OR: 1.18, CI95%: 0.38–3.68), with significance at $p < 0.05$.

After adjusting for the variables kept in level 1, quality of prenatal care (limited indicator) (OR: 1.69, CI95%: 0.92–3.09) was the only variable in level 2 that was associated with LBW. As its significance was above $p < 0.05$, we left it out of the final model (Table 3). The variables hypertension (OR: 3.84, CI95%: 0.88–16.74), chronic anemia before pregnancy (OR: 6.41, CI95%: 1.7–24.16), pregestational nutritional excess weight (OR: 0.54; CI95%: 0.24–1.118), alcohol use in pregnancy (OR: 2.13, CI95%: 0.77–5.87), and child's female sex (OR: 1.52, CI95%: 0.83–2.78) showed significance at $p < 0.20$ and were included in the multivariate analysis in level 3, together with the variables kept in level 1 (Table 3).

At the end of the multivariate analysis in level 3, only chronic anemia before pregnancy remained associated with LBW, with significance at $p < 0.05$. In the final model, LBW was significantly associated with maternal age (< 20 - OR: 2.39, CI95%: 1.29–4.44), brick and mortar housing (OR: 0.25, CI95%: 0.07–0.84) and chronic maternal anemia before pregnancy (OR: 6.41, CI95%: 1.70–24.16) (Table 4).

Four variables from hierarchical level 1 showed crude association with prematurity at $p < 0.20$ (Table 2). Use of additional materials to cover the walls or ceiling (OR: 0.62, CI95%: 0.35–1.1) and maternal schooling (secondary or university – OR: 0.41, CI95%: 0.13–1.26; primary – OR: 0.57, CI95%: 0.31–1.07) lost statistical significance in the multivariate analysis, and the variable kept in the final model for level 1 was the principal energy source for cooking (wood-burning stove – OR: 3.87, CI95%: 1.71–8.78; bonfire - OR: 2.57, CI95%: 1.31–5.01), with significance at $p < 0.05$. Parity and quality of prenatal care were included in the level 2 multivariate analysis, together with the variable kept at level 1, but none of them remained statistically significant in the adjusted analysis. In the final model, prematurity was significantly associated with the type of principal energy source for cooking (wood-burning stove - OR: 3.87, CI95%: 1.71–8.78; bonfire - OR: 2.57, CI95%: 1.31–5.01) (Table 4).

With IUGR as the outcome, maternal age (< 20 - OR: 2.26, CI95%: 0.78–6.5), schooling (primary - OR: 3.27, CI95%: 0.71–15.04), and marital status (without husband/partner - OR: 2.18, CI95%: 0.77–6.21) showed crude associations with IUGR, with significance at $p < 0.20$ (Table 2). No level 1 variables remained in the final model with significance at $p < 0.05$. In the level 2 crude analysis, primiparous (OR: 4.66, CI95%: 1.68–12.95) was the only variable significantly associated with IUGR, with significance at $p < 0.05$ (Table 3). The variables hypertension, chronic maternal anemia before pregnancy, and gestational weight gain were added to the multivariate analysis in level 3, but chronic maternal anemia before

Table 1 Number and proportion of births and prevalence rates of LBW, prematurity, and IUGR according to categories of exploratory variables. Baseline of Guarani Birth Cohort, South and Southeast Brazil, 2014–2016

Hierarchical level, dimension, and variable	Births N (%)		Prevalence LBW N (%)		Prevalence prematurity N (%)		Prevalence IUGR N (%)	
Level 1								
Socioeconomic characteristics								
Regular per capita income (U$)								
Extreme Poverty	241	66.8	38	15.8	40	16.9	12	5.2
Poverty	120	33.2	16	13.4	17	14.3	4	3.4
Above poverty line	0	–	0	–	0	–	0	–
Household characteristics								
Principal energy source for cooking								
Gas stove	178	49.3	20	11.3	17	9.8	9	5.2
Wood burning stove	44	12.2	9	20.9	13	29.5	2	4.9
Bonfire	116	32.1	20	17.2	25	21.7	5	4.3
Brick and mortar housing								
No	302	83.7	51	16.9	47	15.8	16	5.4
Yes	59	16.3	3	5.2	10	17.5	0	
Additional covering on walls and ceiling								
No	149	41.3	17	11.5	29	19.9	6	4.3
Yes	212	58.7	37	17.5	28	13.4	10	4.8
Maternal characteristics								
Maternal age (years)								
< 20	133	36.8	29	21.8	25	19.1	9	6.9
20–34	196	54.3	21	10.8	25	13.0	6	3.2
≥ 35	32	8.9	4	12.5	7	21.9	1	3.1
Maternal height (cm)								
> 150	116	32.1	13	11.2	16	14.0	5	4.4
≤ 150	234	64.8	39	16.8	39	16.8	10	4.4
Maternal schooling								
Secondary or university	40	11.1	6	15.0	4	10.0	2	5.0
Primary	188	52.1	28	15.0	25	13.6	11	6.1
No formal schooling	107	29.6	14	13.2	23	21.5	2	1.9
Marital status								
With husband/partner	279	77.3	40	14.4	43	15.6	10	3.7
Without husband/partner	82	22.7	14	17.3	14	17.7	6	7.7
Level 2								
Reproductive variables								
Parity								
Multiparous	276	76.5	34	12.4	39	14.3	7	2.6
Primiparous	84	23.3	20	23.8	18	22.0	9	11.1
Stillbirths or abortions								
No	65	18.0	8	12.3	8	12.3	1	1.6
Yes	290	80.3	45	15.6	48	16.8	14	5.0
Quality of prenatal care								
Limited indicator								
Adequate	207	57.3	26	12.7	25	12.2	10	5.0

Table 1 Number and proportion of births and prevalence rates of LBW, prematurity, and IUGR according to categories of exploratory variables. Baseline of Guarani Birth Cohort, South and Southeast Brazil, 2014–2016 *(Continued)*

Hierarchical level, dimension, and variable	Births N (%)		Prevalence LBW N (%)		Prevalence prematurity N (%)		Prevalence IUGR N (%)	
Inadequate	153	42.4	28	18.3	32	21.5	6	4.1
Expanded indicator								
Adequate	184	51.0	24	13.2	22	12.0	9	5.0
Inadequate	176	48.8	30	17.0	34	19.9	7	4.1
Level 3								
Maternal morbidity								
Hypertension								
No	345	95.6	50	14.6	55	16.1	14	4.2
Yes	9	2.5	3	33.3	1	11.1	1	11.1
Urinary infection								
No	260	72.0	37	14.3	43	16.7	9	3.6
Yes	94	26.0	16	17.0	13	14.0	6	6.5
Maternal nutrition								
Chronic anemia before pregnancy								
No	344	95.3	48	14.0	54	15.9	13	3.9
Yes	10	2.8	5	50.0	2	20.0	2	20.0
Pre gestational nutritional status								
Underweight	9	2.5	2	22.2	2	22.2	1	11.1
Adequate weight	211	58.4	37	17.6	35	16.7	8	3.9
Excess weight	112	31.0	10	9.0	14	12.6	4	3.7
Gestational weight gain								
Insufficient	205	56.8	35	17.2	32	15.6	6	3.0
Adequate	69	19.1	7	10.3	10	14.5	5	7.4
Excessive	47	13.0	6	12.8	7	14.9	2	4.3
Maternal habits								
Smoking in pregnancy								
No	340	94.2	52	15.4	56	16.8	15	4.6
Yes	20	5.5	2	10.0	1	5.0	1	5.0
Alcohol use in pregnancy								
No	336	93.1	48	14.4	52	15.7	15	4.6
Yes	22	6.1	6	27.3	5	23.8	1	4.8
Type of deliveries (hospital only)								
Vaginal	207	57.3	35	17.0	33	16.2	10	5.0
Cesarean	43	11.9	5	11.6	3	7.1	1	2.3
Child's sex								
Female	173	47.9	31	17.9	26	15.3	–	–
Male	186	51.5	22	12.0	31	16.8		

pregnancy (OR: 7.21, CI95%: 1.29–40.38) was the only variable that remained in the final model ($p < 0.05$). In the final model, IUGR showed a statistically significant association with primiparity (OR: 4.66, CI95%: 1.68–12.95) and chronic anemia before pregnancy (OR: 7.21, CI95%: 1.29–40.38) (Table 4).

Discussion

The prevalence rates for LBW (15.0%) and prematurity (16.1%) were high in the Guarani population in South and Southeast Brazil and exceeded the corresponding prevalence rates in most indigenous and non-indigenous populations. However, prevalence of IUGR (4.6%) was

Table 2 Crude associations between socioeconomic, household, and maternal characteristics (Hierarchical Level 1) andLBW, prematurity, andIUGR. Baseline of Guarani Birth Cohort, South and Southeast Brazil, 2014–2016

Hierarchical level, dimension, and variable	LBW		Prematurity		IUGR	
	OR (95%CI)	*p*-value	OR (95%CI)	*p*-value	OR (95%CI)	*p*-value
Level 1						
Socioeconomic characteristics						
Regular per capita income (U$)						
Extreme Poverty	1.21 (0.64–2.27)	0.552	1.22 (0.66–2.27)	0.519	1.55 (0.49–4.93)	0.454
Poverty	1.00		1.00		1.00	
Household characteristics						
Principal energy source for cooking						
Gas stove	1.00		1.00		1.00	
Wood burning stove	2.08 (0.87–4.96)	0.099*	3.87 (1.71–8.78)	0.001*	0.93 (0.19–4.5)	0.933
Bonfire	1.64 (0.84–3.20)	0.150*	2.57 (1.31–5.01)	0.006*	0.83 (0.27–2.54)	0.742
Brick and mortar housing						
No	1.00		1.00		1.00	
Yes	0.27 (0.08–0.89)	0.031*	1.14 (0.54–2.41)	0.739	–	
Additional covering on walls or ceiling						
No	1.00		1.00		1.00	
Yes	1.64 (0.88–3.04)	0.117*	0.62 (0.35–1.1)	0.104*	1.13 (0.4–3.18)	0.816
Maternal characteristics						
Maternal age (years)						
< 20	2.3 (1.25–4.24)	0.008*	1.58 (0.86–2.89)	0.141*	2.26 (0.78–6.5)	0.132*
20–34	1.00		1.00		1.00	
≥ 35	1.18 (0.38–3.68)	0.780	1.87 (0.73–4.78)	0.191*	0.98 (0.11–8.41)	0.984
Maternal height (cm)						
> 150	1.00		1.00		1.00	
≤ 150	1.6 (0.82–3.13)	0.170*	1.24 (0.66–2.33)	0.507	1.01 (0.34–3.03)	0.987
Maternal schooling						
Secondary or university	1.16 (0.41–3.26)	0.779	0.41 (0.13–1.26)	0.118*	2.66 (0.36–19.54)	0.337
Primary	1.16 (0.58–2.31)	0.679	0.57 (0.31–1.07)	0.082*	3.27 (0.71–15.04)	0.128*
No formal schooling	1.00		1.00		1.00	
Marital status						
With husband/partner	1.00		1.00		1.00	
Without husband/partner	1.24 (0.64–2.42)	0.522	1.17 (0.6–2.26)	0.648	2.18 (0.77–6.21)	0.143*

LBW Low birthweight, *IUGR* Intrauterine growth restriction
*Categories of independent variables associated with the outcome, with levelof significance $p < 0.20$, indicating that the variable was included in the multivariate analysis at its hierarchical level

similar to or lower than in other populations. These outcomes were associated with household conditions, lower maternal age, maternal nutritional status at the beginning of pregnancy, and obstetric causes.

Prevalence of LBW in the Guarani was almost double that of the corresponding prevalence rates in the non-indigenous Brazilian population (6.1–8.0%) [39], among indigenous peoples as a whole in Brazil (7.3%) [40], and in indigenous peoples in other regions of the world (6.1%) [41]. It was only exceeded by the reported prevalence rates among the Aboriginal peoples in remote areas of Australia (17.4%) [15]. Prevalence of prematurity in the Guarani was also higher than the corresponding rates in the non-indigenous Brazilian population (11.5%) [42] and in indigenous peoples in other regions of the world (10.8%) [41], and was only lower than the prevalence rates among the Aboriginal peoples of Australia (19.4%), which were the highest prevalence rates of prematurity reported in the literature [15]. Meanwhile, prevalence of IUGR in the Guarani was

Table 3 Crude associations between reproductive variables, quality and access to prenatal care, maternal morbidity, and habits in the pregnancy, place and type of delivery, and child's sex (hierarchical levels 2 and 3) and LBW, prematurity, and IUGR. Baseline of the Guarani Indigenous Cohort, South and Southeast Brazil, 2014–2016

Hierarchical level, dimension, and variable	LBW		Prematurity		IUGR	
	OR (95%CI)	*p*-value	OR (95%CI)	*p*-value	OR (95%CI)	*p*-value
Level 2[a]						
Reproductive variables						
Parity						
Multiparous	1.00		1.00		1.00	
Primiparous	1.58 (0.77–3.24)	0.216	1.73 (0.89–3.33)	0.104*	4.66 (1.68–12.95)	0.003*
Abortions and stillbirths						
No	1.00		1.00		1.00	
Yes	1.14 (0.5–2.64)	0.749	1.48 (0.65–3.38)	0.356	3.3 (0.43–25.57)	0.252
Quality of prenatal care						
Limited indicator						
Adequate	1.00		1.00		1.00	
Inadequate	1.69 (0.92–3.09)	0.091*	1.71 (0.94–3.11)	0.076*	0.82 (0.29–2.3)	0.702
Expanded indicator						
Adequate	1.00		1.00		1.00	
Inadequate	1.47 (0.8–2.69)	0.215	1.56 (0.85–2.85)	0.152*	0.82 (0.3–2.26)	0.702
Level 3[b]						
Maternal morbidity						
Hypertension						
No	1.00		1.00		1.00	
Yes	3.84 (0.88–16.74)	0.074*	0.80 (0.09–6.84)	0.839	5.21 (0.56–48.48)	0.147*
Urinary infection in pregnancy						
No	1.00		1.00		1.00	
Yes	1.18 (0.61–2.29)	0.624	1.23 (0.60–2.51)	0.575	0.53 (0.18–1.57)	0.254
Maternal nutritional status						
Chronic anemia before pregnancy						
No	1.00		1.00		1.00	
Yes	6.41 (1.7–24.16)	0.006*	1.56 (0.30–8.03)	0.598	7.21 (1.29–40.38)	0.025*
Pregestational nutritional status						
Underweight	1.32 (0.24–7.12)	0.753	2.53 (0.45–14.15)	0.289	2.22 (0.24–4.12)	0.486
Adequate	1.00		1.00		1.00	
Excess weight	0.54 (0.24–1.18)	0.12*	0.80(0.39–1.61)	0.524	1.17 (0.33–4.12)	0.805
Gestational weight gain						
Insufficient	1.71 (0.71–4.12)	0.228	0.85 (0.38–1.91)	0.691	0.38 (0.11–1.3)	0.123*
Adequate	1.00		1.00		1.00	
Excessive	1.37 (0.42–4.47)	0.599	0.99 (0.33–2.91)	0.979	0.53 (0.1–2.89)	0.123*
Maternal habits in pregnancy						
Smoking						
No	1.00		1.00		1.00	
Yes	1.35 (0.3–6.13)	0.701	2.72 (0.35–21.29)	0.34	0.75 (0.09–6.23)	0.791
Alcohol use						
No	1.00		1.00		1.00	

Table 3 Crude associations between reproductive variables, quality and access to prenatal care, maternal morbidity, and habits in the pregnancy, place and type of delivery, and child's sex (hierarchical levels 2 and 3) and LBW, prematurity, and IUGR. Baseline of the Guarani Indigenous Cohort, South and Southeast Brazil, 2014–2016 *(Continued)*

Hierarchical level, dimension, and variable	LBW		Prematurity		IUGR	
	OR (95%CI)	*p*-value	OR (95%CI)	*p*-value	OR (95%CI)	*p*-value
Yes	2.13 (0.77–5.87)	0.145*	1.83 (0.33–10.12)	0.489	0.77 (0.09–6.34)	0.805
Type of delivery (hospital)						
Vaginal	1.00		1.00		1.00	
Cesarean	0.76 (0.27–2.12)	0.597	1.66 (0.29–9.57)	0.569	0.39 (0.05–3.22)	0.385
Child's sex						
Female	1.52 (0.83–2.78)	0.174*	0.80 (0.44–1.45)	0.461	NA	NA
Male	1.00		1.00			

LBW Low birthweight, *IUGR* Intrauterine growth restriction, *NA* Not applicable
*Categories of independent variables associated with the outcome, with level of significance $p < 0.20$, indicating that the variable was included in the multivariate analysis at its hierarchical level
[a]OR of level 2 variables in the hierarchical model were adjusted for the variables that remained in level 1
[b]OR of level3 variables in the hierarchical model were adjusted for the variables that remained in levels 1 and 2

Table 4 Final hierarchical multivariate logistic regression model for risk factors for LBW, prematurity, and IUGR. Baseline of the Guarani Birth Cohort, South and Southeast Brazil, 2014–2016

Level	Domains	Variables	OR[a] (95%CI)	*p*-value
	Low birthweight			
1	**Household characteristics**	Brick and mortar housing		
		No	1.00	
		Yes	0.25 (0.07–0.84)	0.025
1	**Maternal characteristics**	Maternal age (years)		
		< 20	2.39 (1.29–4.44)	0.006
		20 to 34	1.00	
		≥ 35	1.15 (0.36–3.61)	0.815
3	**Maternal nutrition**	Chronic anemia before pregnancy		
		No	1.00	
		Yes	6.41 (1.70–24.16)	0.006
	Prematurity			
1	**Household characteristics**	Principal energy source for cooking		
		Gas stove	1.00	
		Wood burning stove	3.87 (1.71–8.78)	0.001
		Bonfire	2.57 (1.31–5.01)	0.006
	Intrauterine growth restriction			
2	**Reproductive variables**	Parity		
		Multiparous	1.00	
		Primiparous	4.66 (1.68–12.95)	0.003
3	**Maternal nutrition**	Chronic anemia before pregnancy		
		No	1.00	
		Yes	7.21 (1.29–40.38)	0.025

Note: [a]adjusted OR Each variable's effect on the outcome was adjusted for the other variables at the same hierarchical level that remained with $p < 0.05$ at the end of the multivariate analysis of the respective level and for the variables that remained from the previous levels. The odds ratios refer to the sizes of adjusted associations reached at entry level of each of these variables in the hierarchical model lower than the rates described in non-indigenous populations in Brazil that used the same reference curve as this study (9.3%) [43]. Prevalence was close to the rates reported in indigenous populations in different regions of the world (7.8%) [41], and lower than the prevalence rates in Aboriginal peoples in Australia (16.3%) [15]. However, the curves used to assess fetal growth in the latter two studies were different, which may limit direct comparisons of the results. No studies were found that describe the prevalence of prematurity or IUGR in indigenous peoples in Brazil.

Household per capita income, used as the socioeconomic indicator in our study, showed that all the liveborn Guarani infants lived in households below the poverty line, and that two-thirds were living in extreme poverty. This shows that the study population suffers unfavorable socioeconomic conditions when compared to the mean levels in the Brazilian population as a whole and among the non-indigenous population of the geographic regions of the study villages [35]. However, this indicator, household per capita income, was not associated with any of the three outcomes in the final model. This may be due to the relative socioeconomic homogeneity of the indigenous group when this dimension is measured by traditional indicators like per capita income. This indicator was used in order to allow comparisons with other studies and due to difficulties in building sensitive indicators for capturing intragroup socioeconomic differences [12]. However, the Guarani traditionally practice a barter system between family groups and rely on subsistence farming, the sale of traditional products and handicrafts, and donations [44]; the income indicator used here may thus not reflect their true socioeconomic situation.

Housing conditions have been identified in the literature as a factor associated independently with LBW and prematurity, reflecting socioeconomic conditions in urban populations in Brazil [45]. Living in brick and mortar housing was associated with 75% lower odds of LBW in the Guarani. Meanwhile, a study of indigenous people in Ecuador showed that less urbanized dwellings were more adequate in different aspects of their occupants' health when compared to more urbanized dwellings [46].

Although the Guarani villages showed some internal homogeneity in their housing standards, there is considerable heterogeneity between villages. The housing ranges from makeshift shacks, log-and-straw houses, packed-earth walls, and reed houses to brick and mortar houses, sometimes in different combinations of these types. Such housing standards are largely determined by characteristics of the respective villages, such as territorial extensions of (and proximity to) cities, availability of building materials in the local ecosystem, or access to targeted public housing policies [47]. Thus, housing standards in the Guarani are not a good socioeconomic indicator, but rather act as a proxy for exposure to environmental risks such as indoor pollution and crowding [23]. The interpretation of this association should thus consider the possibility that this indicator partly expresses the effect of other unmeasured socioeconomic variables or exposure to indoor pollutants [44]. There is no doubt that public housing measures are necessary for indigenous peoples, but they need to take into account more specific studies on the standards that can reduce environmental and health risks, necessarily considering the wishes and knowledge of the people.

The use of biomass as an energy source for cooking and heating is common among indigenous peoples and rural populations in Brazil and elsewhere in the world. The use of wood-burning stoves or bonfires in Guarani households was associated with an almost four-fold increase in the odds of prematurity, compared to children of mothers with gas stoves. Exposure to indoor pollution resulting from burning solid fuels has been associated with increased risk of adverse pregnancy outcomes such as LBW and prematurity [48]. The biological mechanisms involved in the association with fetal development appear to be related to placental alterations and reduced maternal lung function [48]. Smoke from burning biomass contains various pollutants that can lead to different pulmonary and placental inflammatory responses due to oxidative stress, influencing endothelial functions and triggering hemodynamic responses that limit fetal growth [48, 49].

Studies have reported higher prevalence of LBW and prematurity at the extremes of women's childbearing years [16, 50, 51]. These effects are assumed to be related to intrinsic age-related biological factors such as physiological immaturity for pregnancy in younger women, especially under 15 years of age, and higher prevalence of pregnancy-induced hypertension and hemorrhage in older women [52, 53]. Our study corroborated some of these results and found that LBW was associated with maternal age of less than 20 years. Oster and Toth [16], in a study of First Nations in Canada, reported a nearly twofold risk of LBW in mothers over 35 years of age. Kildea et al. [15] identified maternal age of less than 20 years as a risk factor for prematurity in the Australian Aboriginal population. Coversely, Heaman et al. [17] found a protective effect of maternal age of less than 19 years on prematurity in First Nations in Canada, and Oster and Toth [16] reported a protective effect of maternal age of less than or equal to 17 years on LBW, also in First Nations of Canada. Pregnancy in younger Guarani women does not appear to be a marker of social disadvantage since pregnancy in this age bracket is an event expected by the community [54]. We may thus assume that biological mechanisms are involved in the determination of LBW among the Guarani, indicating the importance of access to prenatal care, above all in this age bracket.

The odds of IUGR in primiparous Guarani women were 4.6 times those of multiparous mothers. This finding corroborates the findings from previous studies in both indigenous [15] and non-indigenous populations [50]. According to Bernabé et al. [50], the vascular maturation of uterine structures occurs in the first pregnancy, making the structures more sensitive to gestational stimuli. In subsequent pregnancies, the maturity of the reproductive structure allows more appropriate placental development and thus better fetal nutrition [50].

Anemia remains an important public health problem in indigenous women in Brazil, with prevalence rates ranging from 16.1% in non-pregnant women to 81.8% in pregnant women [55]. The First National Health and Nutrition Survey of Indigenous Peoples in Brazil confirmed for the first time on a national and regional scale, the high prevalence of anemia in indigenous women of childbearing-age (33.0% in the country as a whole and 30.8% in the South and Southeast, where the Guarani villages are located [56]. Anemia is known to begin or to be exacerbated in pregnancy due to the increased plasma volume and resulting plasma dilution [57]. Prevalence of chronic anemia before pregnancy in our study was considerably lower than these values, and may have been underestimated. Nevertheless, it was possible to detect a significant association between anemia and LBW and IUGR, as found in other studies [50, 57, 58]. Low hemoglobin levels favor alteration in placental angiogenesis, limiting the availability of oxygen to the fetus and thus causing potential IUGR and LBW [59]. This result emphasizes the importance of access to prenatal care and supplementation with ferrous sulfate and treatment of anemia diagnosed before and during pregnancy.

Despite the expansion of access and almost universal coverage of prenatal care in Brazil in recent decades, regional and social inequalities still exist in access to adequate care, which can be illustrated by differences in the trimester of prenatal care initiation, the number of consultations and the availability of testing for syphilis and HIV [36]. For indigenous peoples, there has also been a dramatic expansion of access to prenatal care in the last two decades, based on the implementation of the SASI-SUS, when primary health care started to be provided at village level. However, the quality of such prenatal care remains far short of the target and lower than in the non-indigenous Brazilian population, with later initiation, fewer consultations, poor clinical and laboratory monitoring and worse perinatal outcomes [26]. Better quality of prenatal care leads to better adoption of preventive measures and timely access to effective interventions for the control of biological and environmental risk factors associated with prematurity [36, 42]. This result reinforces the importance of expanding primary care in the villages and encouraging adherence to prenatal care.

Prevalence of induced labor in Brazil is one of the highest in the world, and Brazil thus also has one of the highest cesarean rates [42]. Induced labor has been identified as an iatrogenic risk in the determination of prematurity and LBW in Brazil. For the Guarani population in this study, the cesarean rate was low compared to overall rates in Brazil, and it was within the limits recommended by the World Health Organization (WHO) [60]. Thus, in the case of the Guarani population, although prematurity consisted predominantly of late premature infants (34 to 36 weeks), no association was seen between cesarean delivery and prematurity. While on the one hand this is a good indicator of the use of primary and hospital care by the indigenous population, on the other it indicates the need to both expand access to prenatal care and to improve the quality of such care. In addition, unexpectedly, Guarani children born by cesarean delivery showed significantly higher mean weight (3095.0 g) than children born by vaginal delivery (2890.5) ($p < 0.026$), which emphasizes adverse environmental conditions, maternal infections, and poor quality of prenatal care as determinants of prematurity in the Guarani.

Some limitations should be addressed in the interpretation of this study's findings. The first point is that the outcomes are prevalent by their nature, since liveborn infants are survivors of a conception cohort, while abortions and stillbirths may have occurred in this population. This is a common and almost insurmountable characteristic of studies on LBW, prematurity, and IUGR, and we can assume that the results are affected to some degree by survival bias. Studies indicate the possibility of birthweight measurement bias, especially in homebirths and populations with low socioeconomic status. Our study did not detect statistically significant differences in the prevalence rates of LBW ($p < 0.50$) or mean birthweight ($p < 0.85$) when comparing children born in the villages with those born in hospital. We also identified the occurrence of preferred digits (0 and 5) in the birthweight variable, but this occurred in both homebirths and hospital births and in all the ranges of weight measurement. Thus, possible errors in LBW classification appear to have occurred by chance.

The low prevalence of IUGR in comparison to LBW and prematurity could suggest that measurement bias has occurred. Clearly, gestational age could have been underestimated by recall bias related to the date of the last menstruation, or loss of precision of ultrasound at advanced gestational age. Weight could also be affected by measurement bias, as mentioned previously. On the other hand, both LBW and prematurity would be underestimated by these same potential biases, and this does not seem to have occurred. Since the prevalence of IUGR was significantly higher among non-recruited children, we suggest selection bias as the most likely explanation. In addition, some studies indicate that the INTERGROWTH 21st curve tends to underestimate the frequency of small for gestational age newborns, a proxy for IUGR [43]. Despite this, our study detected associations with anemia before pregnancy and primiparity. We believe that if the IUGR prevalence is underestimated, the real magnitude of the associations would be even greater, and additional unconfirmed associations could have been found.

Our results show biological plausibility and strong consistency with the literature. The analyses were performed at the baseline of the first indigenous birth cohort in Brazil and the recruitment level was high, without statistical differences in the prevalence rates of LBW and prematurity or in birthweight, gestational age at birth, and birthweight z-score for gestational age between recruited and unrecruited children, which reinforces the robustness of the study.

As mentioned previously, Brazil has one of the world's most socially diverse indigenous populations. The indigenous category encompasses extensive differences in culture, geographical and territorial occupation, degrees of contact with the surrounding society, exposure to environmental and climatic conditions, health standards and access to natural resources, goods and services, and public policies, such as health. Although this diversity imposes a certain limitation on the generalization of Guarani results to all indigenous peoples in the country, our study identified a common pattern marked by the social and health disadvantage of the indigenous people compared to their counterparts. Thus, these results can serve as a topic for debate about inequities in health and expanding access to public policies to guarantee the constitutional rights of indigenous peoples in Brazil.

Conclusions

As mentioned previously, the identification of populations at greater risk of LBW and that face barriers in access to health and nutrition policies is a global health priority. This study revealed high prevalence rates for LBW and prematurity in the Guarani indigenous population, higher than reported in most studies in indigenous and non-indigenous peoples in Brazil and elsewhere. The target outcomes were associated with environmental determinants such as quality of the household environment, maternal nutritional and health status before and during pregnancy, obstetric history, and access to and use of health services, most of which are modifiable through interventions by the health sector and by intersector policies on food security, housing, and the environment. Emphasis should be given to strengthening the Indigenous Healthcare Subsystem, allowing improved access to primary healthcare by indigenous peoples and the development of culturally sensitive health practices.

Interventions in these fields may result not only directly in the reduction of prevalence rates for LBW, prematurity, and IUGR in the population, but also indirectly in the reduction of the high burden of morbidity and mortality from infectious diseases, especially acute respiratory infections, and malnutrition in childhood. They could also minimize delays in cognitive development, preventing chronic noncommunicable diseases in adulthood, and interrupting the vicious circle of poverty and social exclusion that historically affects indigenous peoples in Brazil.

Supplementary Information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12884-020-03396-8.

Additional file 1 Supplementary file 1. The Guarani Birth Cohort - Perinatal Questionnaire Original Version (portuguese). The Perinatal questionnaire comprised 102 questions and some dependent subquestions, that were organized in blocks to be completed during the interview with the mother (33 items). Some information was extracted from secondary registries (69 items), to avoid unnecessarily long interviews for the participant. The total time for completing the questionnaire was about an hour, including a 30-min interview. The questionnaire was designed in digital format, operated on a handheld personal digital assistant (PDA), with subsequent online data transmission to the study coordinators. The perinatal questionnaire was designed by the research team and was based on questionnaires from the National Census, the First National Survey of Indigenous People's Health and Nutrition in Brazil, a population-based case-control study in the Guarani population, and other Brazilian reference studies on infant-maternal health, such as the four Pelotas Birth Cohorts (1982, 1993, 2004 and 2015) and the Birth in Brazil Study. We also added questions based on the forms routinely used in health services for prenatal care, the hospital discharge summary after birth, the health card of the child, and the birth certificate.

Additional file 2 Supplementary file 2. The Guarani Birth Cohort - Perinatal Questionnaire English version (translated). The PERINATAL questionnaire comprised 102 questions and some dependent subquestions, that were organized in blocks to be completed during the interview with the mother (33 items). Some information was extracted from secondary registries (69 items), to avoid unnecessarily long interviews for the participant. The total time for completing the questionnaire was about an hour, including a 30-min interview. The questionnaire was designed in digital format, operated on a handheld personal digital assistant (PDA), with subsequent online data transmission to the study coordinators. The perinatal questionnaire was designed by the research team and was based on questionnaires from the National Census, the First National Survey of Indigenous People's Health and Nutrition in Brazil, a population-based case-control study in the Guarani population, and other Brazilian reference studies on infant-maternal health, such as the four Pelotas Birth Cohorts (1982, 1993, 2004 and 2015) and the Birth in Brazil Study. We also added questions based on the forms routinely used in health services for prenatal care, the hospital discharge summary after birth, the health card of the child, and the birth certificate.

Abbreviations

95% CI: 95% confidence intervals; ARIs: Acute respiratory infections; DLM: Date of last menstruation; EMSI: Multidisciplinary Indigenous Health Teams; LBW: Low birthweight; INTERGROWTH-21st: International Fetal and

Newborn Growth Consortium for the twenty-first Century; IOM: Institute of Medicine; IUGR: Intrauterine growth restriction; OR: Odds ratios; PDA: Personal digital assistants; SASI-SUS: Indigenous Healthcare Subsystem; SUS: Unified National Health System; SD: Standard deviations; WHO: World Health Organization

Acknowledgements
Our thanks are due to the indigenous leaders and members of the participating villages, especially the mothers and children enrolled in the cohort, and to the Indigenous Health Subsystem managers of the Litoral Sul Sanitary District and the indigenous multidisciplinary health teams, which carried out the local surveillance system, and to Dr. Andrea Sobral de Almeida for collaborating on the production of the study area map.

Authors' contributions
CTGB and AMC - participated in the design of the study, interpretation of the data and writing of the article. FGT, YNF, LNP, MTF - interpretation of the data and writing of the article. All authors approved the final version of the manuscript.

Funding
This project was funded by the following institutions: National Research Council (CNPq - www.cnpq.br) Universal 14/2011–47.4008/2011–8 (Presentation of the objectives of the research project to the managers of the Indigenous Health Care Subsystem, visiting the villages to present the project and obtaining the free and informed collective consent form signed by the indigenous leaders, recruiting field interviewers, training workshops for field researchers, pilot testing of the interview questionnaires and the surveillance system, purchase of laboratory equipment and diagnostic supplies) and CNPq Universal 01/2016–428284/2016–7 (data collection, field supervision and retraining of field researchers); Oswaldo Cruz Foundation (Fiocruz - www.fiocruz.br) - INOVA ENSP II 2013–25388.000556/2013–52 (training workshops for field researchers, pilot testing of the interview questionnaires and the surveillance system), PAPES VII - Young scientist 2014–401789/2015–2 (programming of digital questionnaires, data collection, field supervision and retraining of field researchers) and ENSP 2016/2018–25388.000526/2017–70 (linkage of databases and final research database preparation, statistical analysis, funding for English review and costs for publication in open access scientific journals); Research Foundation of the State of Rio de Janeiro (FAPERJ - www.faperj.br) PPSUS FAPERJ/SES-RJ/MS-DECIT/CNPq 35/2013-E-26/110.275/2014 (data collection, field supervision and retraining of field researchers, statistical analysis); TED 175/2018 – Processo N° 25380.102279/2018–04 (Statistical analysis).

Availability of data and materials
The dataset generated in the Guarani birth cohort is not yet publicly available. Due to the relatively small size of the study population, the dataset may not be adequately anonymized to permit open access and protect the participants' identities. Proposals for access to data will be considered subject to ethical and legal restrictions, the terms of the original informed consent agreement with participant community, and Guarani community protocols for authorizing studies. Data requests may be sent to Dr. Ricardo Ventura Santos, leader of Health, Epidemiology and Anthropology Research Group, Departamento de Endemias Samuel Pessoa, Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz, located at Rua Leopoldo Bulhões 1480, Rio de Janeiro, RJ 21041–210, Brazil (http://www.ensp.fiocruz.br/portal-ensp/departamento/densp/grupos-de-pesquisa). Phone: + 55 (21) 2598–2654. Email: santos@ensp.fiocruz.br.

Ethics approval and consent to participate
The cohort study was approved by the National Research Ethics Commission (Comissão Nacional de Ética em Pesquisa – CONEP n. 719/2010) and the Research Committee of the National School of Public Health of Oswaldo Cruz Foundation (CEP/ENSP n. 160/10). The subproject of the Guarani Cohort was approved by the Institutional Review Board of the National School of Public Health of Oswaldo Cruz Foundation (CEP/ENSP), protocol number 1.821.137. The Guarani Cohort was authorized by the indigenous leaders who signed the free and informed consent form, in addition to individual verbal consent from the mothers or guardians and authorization by the Brazilian National Health Foundation to enter indigenous territories for purposes of scientific research.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Universidade do Estado do Rio de Janeiro (UERJ), Av. Marechal Rondon, 381. São Francisco Xavier, Rio de Janeiro, RJ CEP: 20950-000, Brazil. [2]Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz, Rio de Janeiro, RJ, Brazil. [3]Escola de Enfermagem Aurora de Afonso Costa. Faculdade de Enfermagem, Universidade Federal Fluminense, Niterói, RJ, Brazil.

Received: 8 June 2020 Accepted: 4 November 2020
Published online: 02 December 2020

References
1. World Health Organization. Global nutrition targets 2025: low birth weight policy brief. Geneva: WHO; 2014.
2. Barros FC, Victora CG, Matijasevich A, Santos IS, Horta BL, Silveira MF, et al. Preterm births, low birth weight and intrauterine growth restriction in three birth cohorts in southern Brazil: 1982, 1993 and 2004. Cad Saúde Pública. 2008;24(Suppl 1):390–8.
3. Shi T, Balsells E, Wastnedge E, Singleton R, Rasmussen ZA, Zar HJ, et al. Risk factors for respiratory syncytial virus associated with acute lower respiratory infection in children under five years: systematic review and meta–analysis. J Glob Health. 2015;5:2.
4. Lira PIC, Ashworth A, Morris SS. Low birth weight and morbidity from diarrhea and respiratory infection in Northeast Brazil. J Pediatr. 1996;128(4): 497–504.
5. Oudgenoeg-Paz O, Mulder H, Jongmans MJ, van der Ham IJM, Van der Stigchel S. The link between motor and cognitive development in children born preterm and/or with low birth weight: A review of current evidence. Neurosci Biobehav Rev. 2017;80:382–93.
6. Lansky S, Friche AA d L, Silva AAM d, Campos D, Bittencourt SD d A, Carvalho ML d, et al. Birth in Brazil survey: neonatal mortality, pregnancy and childbirth quality of care. Cad Saúde Pública. 2014;30(Suppl 1):192–207.
7. Risnes KR, Vatten LJ, Baker JL, Jameson K, Sovio U, Kajantie E, et al. Birthweight and mortality in adulthood: a systematic review and meta-analysis. Int J Epidemiol. 2011;40(3):647–61.
8. Bilgin A, Mendonca M, Wolke D. Preterm birth/low birth weight and markers reflective of wealth in adulthood: A meta-analysis. Pediatrics. 2018; 142:1.
9. Anderson I, Robson B, Connolly M, Al-Yaman F, Bjertness E, King A, et al. Indigenous and tribal peoples' health (the lancet–Lowitja Institute global collaboration): a population study. Lancet. 2016;388:131–57.
10. Gracey M, King M. Indigenous health part 1: determinants and disease patterns. Lancet. 2009;374(9683):65–75.
11. Montenegro RA, Stephens C. Indigenous health in Latin America and the Caribbean. Lancet. 2006;367(9525):1859–69.
12. Barreto CTG, Tavares FG, Theme-Filha M, Cardoso AM. Factors associated with low birth weight in indigenous populations: a systematic review of the world literature. Rev Bras Saúde Materno Infant. 2019;19:7–23.
13. Brazilian Institute of Geography and Statistics (IBGE). Os indígenas no Censo Demográfico 2010 primeiras considerações com base no quesito cor ou raça [online]. Rio de Janeiro; 2012. Available at: https://indigenas.ibge.gov.br/images/indigenas/estudos/indigena_censo2010.pdf Accessed Aug 16, 2020.
14. Kieffer EC, Alexander GR, Mor JM. Pregnancy outcomes of pacific islanders in Hawaii. Am J Epidemiol. 1995;142:674–9.
15. Kildea SV, Gao Y, Rolfe M, Boyle J, Tracy S, Barclay LM. Risk factors for preterm, low birthweight and small for gestational age births among Aboriginal women from remote communities in northern Australia. Women Birth. 2017;30:398–405.
16. Oster RT, Toth EL. Longitudinal rates and risk factors for adverse birth weight among first nations pregnancies in Alberta. J Obstet Gynaecol Can. 2016;38:29–34.
17. Heaman MI, Blanchard JF, Cupton AL, Moffatt MEK, Currie RF. Risk factors for spontaneous preterm birth among Aboriginal and non-Aboriginal women in Manitoba. Paediatr Perinat Epidemiol. 2005;19(3):181–93.

18. Panaretto K, Lee H, Mitchell M, Larkins S, Manessis V, Buettner P, et al. Risk factors for preterm, low birth weight and small for gestational age birth in urban Aboriginal and Torres Strait islander women in Townsville. Aust N Z J Public Health. 2006;30(2):163–70.
19. Sayers S, Powers J. Risk factors for Aboriginal low birthweight, intrauterine growth retardation and preterm birth in the Darwin health region. Aust N Z J Public Health. 1997;21(5):524–30.
20. Coughlin RL, Kushman EK, Copeland GE, Wilson ML. Pregnancy and birth outcome improvements for American indians in the healthy start project of the inter-tribal council of Michigan, 1998-2008. Matern Child Health J. 2013; 17(6):1005–15.
21. Graham S, Pulver LRJ, Wang YA, Kelly PM, Laws PJ, Grayson N, et al. The urban-remote divide for indigenous perinatal outcomes. Med J Aust. 2007; 186(10):509–12.
22. Cardoso AM, Horta BL, Santos RV, Escobar AL, Welch JR, Coimbra CEA. Prevalence of pneumonia and associated factors among indigenous children in Brazil: results from the first National Survey of indigenous People's health and nutrition. Int Health. 2015;7(6):412–9.
23. Cardoso AM, Coimbra CEAJ, Werneck GL. Risk factors for hospital admission due to acute lower respiratory tract infection in Guarani indigenous children in southern Brazil: a population-based case-control study. Trop Med Int Health. 2013;18(5):596–607.
24. Coimbra CE, Santos RV, Welch JR, Cardoso AM, de Souza MC, Garnelo L, et al. The First National Survey of Indigenous People's Health and Nutrition in Brazil: rationale, methodology, and overview of results. BMC Public Health. 2013;13:52.
25. Escobar AL, Coimbra CE, Welch JR, Horta BL, Santos RV, Cardoso AM. Diarrhea and health inequity among Indigenous children in Brazil: results from the First National Survey of Indigenous People's Health and Nutrition. BMC Public Health. 2015;15:191.
26. Garnelo L, Horta BL, Escobar AL, Santos RV, Cardoso AM, Welch JR, et al. Avaliação da atenção pré-natal ofertada às mulheres indígenas no Brasil: achados do Primeiro Inquérito Nacional de Saúde e Nutrição dos Povos Indígenas. Cad Saúde Pública. 2019;35(Suppl 3):e00181318.
27. Horta BL, Santos RV, Welch JR, Cardoso AM, dos Santos JV, Assis AMO, et al. 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(1):23.
28. Leite MS, Cardoso AM, Coimbra CE, Welch JR, Gugelmin SA, Lira PCI, et al. Prevalence of anemia and associated factors among indigenous children in Brazil: results from the first National Survey of indigenous People's health and nutrition. Nutr J. 2013;12(1):69.
29. Instituto Socioambiental (ISA). Mapa Guarani Continental 2016 [online]. São Paulo; 2016. Available at: https://www.socioambiental.org/pt-br/mapas/mapa-guarani-continental-2016. Accessed Aug 16, 2020.
30. Cardoso AM, Coimbra CEA Jr, Tavares FG. Morbidade hospitalar indígena Guarani no Sul e Sudeste do Brasil. Rev Bras Epidemiol. 2010;13(1):21–34.
31. Cardoso AM, Coimbra CEA Jr, Barreto CTG, Werneck GL, Santos RV. Mortality among Guarani Indians in southeastern and southern Brazil. Cad Saúde Pública. 2011;27(Suppl 1):222–36.
32. Cardoso AM, Santos RV, Coimbra CEA Jr, Garnelo L, Chaves MBG. Políticas Públicas de Saúde para os Povos Indígenas. In: Giovanella L, Escorel S, Lobato LVC, Noronha JC, Carvalho AI, editors. organizadores. Políticas e Sistemas de Saúde no Brasil. 2nd ed. Rio de Janeiro: Fiocruz; 2012. p. 911–32.
33. Pereira APE, Leal M d C, Gama SGN d, Domingues RMSM, Schilithz AOC, Bastos MH. Determinação da idade gestacional com base em informações do estudo Nascer no Brasil. Cad Saúde Pública. 2014;30(Suppl1):59–70.
34. Chatfield A, Caglia J, Dhillon S, Hirst J, Cheikh Ismail L, Abawi K, et al. Translating research into practice: the introduction of the INTERGROWTH-21st package of clinical standards, tools and guidelines into policies, programmes and services. BJOG. 2013;120:139–42.
35. Brazilian Institute of Geography and Statistics (IBGE). Síntese de indicadores sociais: uma análise das condições de vida da população brasileira. [online]. Rio de Janeiro; 2019. Available at: https://biblioteca.ibge.gov.br/visualizacao/livros/liv101678.pdf. Accessed Aug 16, 2020.
36. Domingues RMSM, Viellas EF, Dias MAB, Torres JA, Theme-Filha MM, da Gama SGN, et al. Adequação da assistência pré-natal segundo as características maternas no Brasil. Rev Panam Salud Publica. 2015;37(3):140–7.
37. Rasmussen KM, Yaktine AL, Institute of Medicine (U.S.), organizadores. Weight gain during pregnancy: reexamining the guidelines. Washington: National Academies Press; 2009. p. 854.
38. Victora CG, Huttly SR, Fuchs SC, Olinto MT. The role of conceptual frameworks in epidemiological analysis: a hierarchical approach. Int J Epidemiol. 1997;26(1):224–7.
39. Viana K d J, Taddei JA de AC, Cocetti M, Warkentin S. Peso ao nascer de crianças brasileiras menores de dois anos. Cad Saúde Pública. 2013;29(2):349–56.
40. Associação Brasileira de Pós-Graduação em Saúde Coletiva (ABRASCO). Inquérito Nacional de Saúde e Nutrição dos Povos Indígenas. Relatório Final (Análise dos Dados). Rio de Janeiro; 2009. Available at: http://ecos-redenutri.bvs.br/tiki-download_file.php?fileId=1284. Accessed Aug 16, 2020.
41. Shah PS, Zao J, Al-Wassia H, Shah V. Pregnancy and neonatal outcomes of Aboriginal women: A systematic review and meta-analysis. Womens Health Issues. 2011;21(1):28–39.
42. Leal M d C, Esteves-Pereira AP, Nakamura-Pereira M, Torres JA, Theme-Filha M, Domingues RMSM, et al. Prevalence and risk factors related to preterm birth in Brazil. Reprod Health. 2016;13(Suppl 3):127.
43. Kale PL, Lordelo CVM, Fonseca SC, da Silva KS, Lobato JCP, Costa AJL, et al. Adequação do peso ao nascer para idade gestacional de acordo com a curva INTERGROWTH-21st e fatores associados ao pequeno para idade gestacional. Cad Saúde Coletiva. 2018;26(4):391–9.
44. Pissolato E. A duração da pessoa: mobilidade, parentesco e xamanismo Mbya (Guarani). UNESP: São Paulo; 2007.
45. Vettore MV, Gama SGN. da, Lamarca G de A, Schilithz AOC, Leal M do C. housing conditions as a social determinant of low birth weight and preterm low birthweight. Rev Saúde Pública. 2010;44(6):1021–31.
46. Kroeger A. Housing and health in the process of cultural adaptation: a case study among jungle and highland natives of Ecuador. J Trop Med Hyg. 1980;83(2):53–69 PMID: 7381982.
47. Carrinho RG. Habitação de interesse social em aldeias indígenas: Uma abordagem sobre o ambiente construído Mbyá - Guarani no litoral de Santa Catarina [dissertation on the Internet]. Florianópolis: Universidade Federal de Santa Catarina; 2010. [cited 2020 Aug 16]. Available at: https://repositorio.ufsc.br/bitstream/handle/123456789/94054/289151.pdf?sequence=1&isAllowed=y.
48. Amegah AK, Quansah R, Jaakkola JJK. Household Air Pollution from Solid Fuel Use and Risk of Adverse Pregnancy Outcomes: A Systematic Review and Meta-Analysis of the Empirical Evidence. Nawrot TS, organizador. PLoS ONE. 2014;9(12):e113920.
49. Lee A, Kinney P, Chillrud S, Jack D. A systematic review of innate Immunomodulatory effects of household air pollution secondary to the burning of biomass fuels. Ann Glob Health. 2015;81(3):368.
50. Bernabé JV d, Soriano T, Albaladejo R, Juarranz M, Calle ME, Martínez D, et al. Risk factors for low birth weight: a review. Eur J Obstet Gynecol Reprod Biol. 2004;116(1):3–15.
51. Xu H, Dai Q, Xu Y, Gong Z, Dai G, Ding M, et al. Time trends and risk factor associated with premature birth and infants deaths due to prematurity in Hubei Province, China from 2001 to 2012. BMC Pregnancy Childbirth. 2015; 15(1):329.
52. Almeida AH do V de, Costa MCO, Gama SGN da, MTR A, Vieira GO. Baixo peso ao nascer em adolescentes e adultas jovens na Região Nordeste do Brasil. Rev Bras Saúde Materno Infant. 2014;14(3):279–86.
53. Mehari M, Maeruf H, Robles CC, Woldemariam S, Adhena T, Mulugeta M, et al. Advanced maternal age pregnancy and its adverse obstetrical and perinatal outcomes in Ayder comprehensive specialized hospital, northern Ethiopia, 2017: a comparative cross-sectional study. BMC Pregnancy Childbirth. 2020;20(1):60.
54. López GMA. A fecundidade entre os Guarani: um legado de Kunhankarai [master's thesis on the internet]. Rio de Janeiro: Escola Nacional de Saúde Pública /Fundação Oswaldo Cruz; 2000. [cited 2020 Aug 16]. Available at: https://www.arca.fiocruz.br/handle/icict/4582.
55. Lício JSA, Fávaro TR, Chaves CRM de M. Anemia em crianças e mulheres indígenas no Brasil: revisão sistemática. Ciênc Saúde Coletiva. 2016;21(8):2571–81.
56. Borges MC, Buffarini R, Santos RV, Cardoso AM, Welch JR, Garnelo L, et al. Anemia among indigenous women in Brazil: findings from the first National Survey of indigenous People's health and nutrition. BMC Womens Health. 2015;16(1):7.
57. Lin L, Zhu W, Wang C, Su R, Feng H, Yang H. Prevalence, risk factors and associated adverse pregnancy outcomes of anaemia in Chinese pregnant women: a multicentre retrospective study. BMC Pregnancy Childbirth. 2018;18(1):111.
58. Levy A, Fraser D, Katz M, Mazor M, Sheiner E. Maternal anemia during pregnancy is an independent risk factor for low birthweight and preterm delivery. Eur J Obstet Gynecol Reprod Biol. 2005;122(2):182–6.

59. Figueiredo ACMG, Gomes-Filho IS, Silva RB, Pereira PPS, Mata FAFD, Lyrio AO, et al. Maternal Anemia and Low BirthWeight: A Systematic Review and Meta-Analysis. Nutrients. 2018;10(5):601.
60. Batista Filho M, Rissin A. WHO and the epidemic of cesarians. Rev Bras Saúde Materno Infant. 2018;18(1):3–4.

Publisher's Note