How, what, and why: housing, water & sanitation and wealth patterns in a cross-sectional study of the Guarani Birth Cohort, the first Indigenous birth cohort in Brazil

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Summary

Background Despite the importance of social determinants of health, studies on the effects of socioeconomic, sanitary, and housing conditions on Indigenous child health are scarce worldwide. This study aims to identify patterns in housing, water & sanitation, and wealth (HSW) in the first Indigenous birth cohort in Brazil–The Guarani Birth Cohort.

Methods Cross-sectional study using baseline data from The Guarani Birth Cohort. We used Multiple Correspondence Analysis and Cluster Analysis. The clusters identified were ordered in increasing degrees of access to public policies and wealth, defining the patterns of HSW. Finally, we explored the association between the patterns and one of the health outcomes, hospitalization, in the birth cohort.

Findings Three patterns were identified for housing and water & sanitation, and four for wealth status, resulting in 36 combinations of patterns (3 × 3 × 4). More than 62% of children in the cohort were found with the lowest wealth patterns. The distribution of children across patterns in one dimension was not fully determined by the other two dimensions. Statistically significant associations were found between precarious households and extreme poverty, and hospitalization.

Interpretation We observed substantial heterogeneity in the distribution of children across the 36 combinations. These findings highlight that, should the dimensions of HSW be associated with health outcomes, as seen for hospitalization, they should be considered separately in multivariable models, in order to improve the estimation of their independent effects.

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Keywords: Social determinants of health; Multivariate analysis; Housing; Sanitation; Health status disparities; Health indicators; Child; Indigenous peoples; Population groups; Brazil

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Research in context

Evidence before this study

We reviewed the evidence using PubMed and Web of Science for publications on Social Determinants of Indigenous Peoples' Health from November 2019 to December 2021. We use the keywords Social Determinants Health; Multivariate Analysis; Housing; Sanitation; Health Status Disparities; Indigenous Peoples; and Health Indicators, and searched for articles in English, Spain, and Portuguese. Indigenous Peoples are among the most marginalized population groups in both high-income and low- and middle-income countries. Despite the importance of social determinants of child health, traditional indicators such as income or education, might not be able to capture diversity within indigenous groups, as some public policies are adopted at the village level regardless of the socioeconomic diversity of the population. Furthermore, studies on the effects of socioeconomic, sanitary, and housing conditions on Indigenous child health are scarce in Brazil and elsewhere.

Added value of this study

The objective of this study was to identify patterns in housing, sanitation, and wealth using data collected from The Guarani Birth Cohort (Brazil), and two multivariate analysis techniques–Multiple Correspondence Analysis (MCA) and Cluster Analysis (CA). Between June 1, 2014, and May 31, 2016, 357/435 (82.0%) Guarani children who were eligible for the cohort were recruited from the 63 participating villages in the South and Southeast of Brazil. Baseline data were collected, which included questions on sociodemographic characteristics, maternal health status and behaviors, pregnancy and delivery conditions, access to prenatal care, birth conditions, and child characteristics. It is a challenge to collect a wide range of variables necessary not only to capture the variability of the ways of life of Indigenous populations but also to identify those that are sufficiently sensitive to distinguish strata that represent patterns of health risk. We expect to use the identified patterns as a proxy for living standards and socioeconomic vulnerability position to the occurrence of unwanted health outcomes in the first year of life of Indigenous children.

Implications of all the available evidence

The use of MCA and CA allowed the exploration and reduction of the dimensions of a great number of variables (129) present in the baseline of the Guarani Birth Cohort, identifying distinct patterns in different dimensions of the living conditions of Indigenous children. The Guarani children were concentrated in the combined strata with lower access to public policies and poverty. However, the distribution of children across patterns reveals substantial heterogeneity in the Guarani living conditions. Statistically significant associations were found between precarious households and extreme poverty, and one of the health outcomes, hospitalization. So far, our findings show that housing, water & sanitation, and wealth must be considered separately in multivariable models, hence adjusting for the independent effects of each dimension on children's health outcomes. The study represents an advanced methodology for future analyzes of Social Determinants of Health (SDH) of Indigenous populations. Although there is great ethnic diversity in Brazil, the methodology can be applied with specific data for different Indigenous ethnic groups.

Introduction

Among populations worldwide, disparities in health outcomes largely result from the way societies are organized and developed.[1,2] These dynamics and the so-called social determinants of health (SDH) are shaped through the complex interplay of money, power, and resources. The National Commission on Social Determinants of Health (CNDSS) of Brazil defines SDH as the social, economic, cultural, racial-ethnic, psychological, and behavioral factors that influence the occurrence of health problems and their risk factors in the population.[3] In human rights-based approaches that promote equity, health asymmetries, such as those associated with SDH (e.g., disparities across racial-ethnic groups), are considered unjust and avoidable.[1]

Effective planning for public policies to reduce health inequities presupposes a satisfactory assessment of socioeconomic status and other social determinants that impact health profiles and utilization of health services, particularly in the most vulnerable social groups.[4,5] Traditionally, socioeconomic status is measured in health surveys by collecting data on income and consumption expenditure, a task that is difficult both because of the financial and operational costs of the survey and because of the challenges of obtaining accurate and comprehensive data.[4–6] For example, seasonal variations or indirect sources of income (e.g., donations, sharing, and bartering) that contribute to subsistence, particularly for poorer, rural, or culturally differentiated populations, may not be adequately captured by the usual indicators.[4,7,8] Therefore, it is often considered more accurate to measure consumption or expenditure rather than income.[4,9] As an alternative approach to measure socioeconomic conditions in low- and middle-income countries,[7,9] several authors have proposed the construction of indices, usually employing multivariate statistical techniques such as Principal Component Analysis (PCA). Such indexes, which are typically derived from data on living standards (e.g., possession of durable goods, access to infrastructure, and housing characteristics) are less susceptible to short-term variations in income and, therefore, have greater stability and explanatory power for describing household wealth.[7,9]

Indigenous peoples are among the most marginalized population in both low- and middle- or high-income countries.[10] Despite significant ethnic diversity, wide geographic distribution, and diverse life contexts, Indigenous Peoples share common socioeconomic disadvantages, barriers to accessing social protection policies, and relatively poor health compared to their surrounding societies.[11] Increasingly, lifestyle changes, which are closer to those experienced by non-Indigenous western capitalist societies, are contributing to accelerated demographic, nutritional, and epidemiological transitions among Indigenous groups. Therefore, in addition to the persistently high burden of infectious diseases, particularly in childhood, Indigenous populations also face rising frequencies of non-communicable chronic diseases, diseases caused by environmental deterioration and contamination, and mental health problems, including those related to abuse of alcohol and other drugs.[10,11]

Since the early days of colonization in Brazil, Indigenous Peoples have been deeply affected by the installation of new economic regimes, the occupation of traditional territories, and changes in traditional subsistence systems, with direct consequences on their health patterns. Indigenous morbidity and mortality rates are substantially higher than national rates, while life expectancy at birth is lower.[12,13] Infant mortality is markedly higher in the post-neonatal period,[14–16] and pneumonia and diarrhea are important causes of hospitalization among Indigenous children.[17–19] Among Indigenous children under five years of age in Brazil, an estimated 25% experience chronic malnutrition, while approximately 50% have anemia.[20]

Despite the importance of social determinants of child health, studies on the effects of socioeconomic, sanitary, and housing conditions on Indigenous children's health are scarce in Brazil and elsewhere.

Furthermore, for Indigenous people in Brazil, housing and water & sanitation patterns may not be directly determined by socioeconomic conditions and driven by health needs, as public policies for housing and water & sanitation are generally implemented collectively at the village level, regardless of individual families' purchasing power.

To begin to address this gap in knowledge, this study aims to identify patterns in housing, water & sanitation, and wealth using data collected from the first Indigenous birth cohort in Brazil, The Guarani Birth Cohort, and two multivariate analysis techniques–Multiple Correspondence Analysis (MCA) and Cluster Analysis (CA).

Methods

Population and source of baseline data for the Guarani birth cohort

The last demographic census conducted in Brazil, in 2010, counted 896,900 Indigenous individuals, representing only 0.4% of the national population, but with more than 300 ethnic groups and 270 native languages.[21] The Guarani ethnic group numbers approximately 85,000 individuals, corresponding to 9.5% of the total Indigenous population in the country. The Guarani occupy territories in eight states, mostly in the Central-West, Southeast, and South regions, as well as areas in border countries, such as Argentina, Paraguay, and Bolivia.[22] The Guarani are divided into three ethnic subgroups, the Kaiowa, the Nhandéva, and the Mbya, based on religious, linguistic, and cultural differences.

The Mbya subgroup has the smallest population, with approximately 25,000 people, of whom one-third live on the southern coast of Brazil[23] in the geographical region where this study was conducted (Fig. 1). This region is part of the traditional territory of the Guarani population, and although our study did not select based on ethnicity, almost all participants are Mbya and Nhandéva. The Guarani population in this region maintain the use of their mother language and ritual practices and share high population mobility between communities. As the Guarani communities are located near the largest urban centers in Brazil (i.e., Sao Paulo and Rio de Janeiro), the proximity has resulted in restricted access and use of traditional territories, intense contact with the surrounding society, and a high degree of interaction with and dependence on regional markets.

In 1999, the Brazilian government implemented the Indigenous Healthcare Sub-System (SASI-SUS) as part of the Public Health System (SUS). Since then, Indigenous Health Multidisciplinary Teams (EMSI) have provided primary care in the villages, on a regular basis. SASI-SUS is organized in 34 Indigenous Health Special Sanitary Districts (DSEI). The area of investigation is the DSEI Litoral Sul and part of the DSEI Interior Sul (Fig. 1).

Between June 1, 2014, and May 31, 2016, 357/435 (82.0%) Guarani children who were eligible for the cohort were recruited from 63 (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 for implementing 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 to capture of several health outcomes of interest, including vital events, incident episodes of acute diseases, like acute respiratory infections and diarrhea, and perinatal outcomes, like low birth weight, prematurity, intrauterine growth restriction, and infant mortality. All eligible villages participated in the study.

Regarding the social determinants of health, according to Cardoso et al.[24] Guarani families tend to be large and usually live in houses with dirt floors, wood, wattle-and-daub, or adobe walls, and palm thatch roofs.

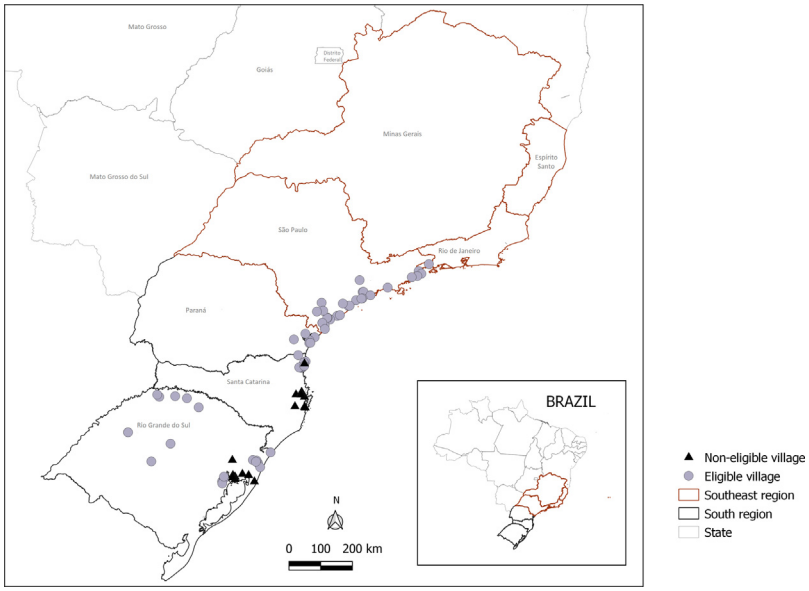

Fig. 1: **Geographic location of Indigenous villages according to eligibility to participate in Guarani Birth Cohort.**

Guarani villages often lack water & sanitation and suffer from unpredictable resource availability due to environmental degradation and peripheral participation in the regional economy. The non-eligible villages are similar to the eligible ones, although they tend to be more remotely located, smaller in population size, and have irregular visits from healthcare teams.

Baseline data were collected through a perinatal interview, conducted up to 15 days after birth. The perinatal interview was applied to the mother during postpartum by previously trained nurses from the Multidisciplinary Indigenous Health Team (EMSI). The perinatal questionnaire included questions on sociodemographic characteristics, maternal health status, and behaviors, pregnancy and delivery conditions, access to prenatal care, birth conditions, and child characteristics. The total time for completing the questionnaire was about an hour, including a 30-min interview, and 30 min to complete data from direct observation or collecting secondary data. Versions of the perinatal questionnaire and details on eligibility criteria, recruitment, follow-up, losses in the cohort, and demographic and socioeconomic characteristics of Guarani children were previously published.[23]

For the present analysis, 129 original variables (Housing: 21; water & sanitation: 7; wealth: 101) from the perinatal questionnaire were used to generate 33 derived variables (Housing: 8; water & sanitation: 5; wealth: 20) (Fig. 2), which were then applied in the MCA and CA. Derived variables that are not self-explanatory are detailed below.

The household's monthly *per capita* regular income was derived from the sum of all regular incomes (i.e., wages, retirement and pensions, and direct payments from the Bolsa Familia conditional cash transfer program) in the last month from all household residents aged 10 years or older, divided by the total number of residents in the household. The amounts received by each resident were measured by income class intervals, and the midpoint of the interval was considered the value for the purposes of summing household income. This variable was then categorized based on June 1, 2014, cut-off points used in the Bolsa Familia conditional cash transfer program: extreme poverty (≤BRL77.00); poverty (>BRL 77.00 and ≤BRL 154.00); and above the poverty line (>BRL 154.00)[25,26] and further converted to USD based on January 1, 2015, exchange rate.

Statistical analysis

MCA was conducted separately for each of the three dimensions of interest (housing, water & sanitation, and wealth), considering a matrix in which the rows correspond to the children and the columns to the variables that make up each dimension. The relationship between the categories of variables was analyzed by means of the correspondence map based on the distance between them; the closer they are to each other the higher the probability of association. Total inertia is the measure used to indicate the variability of the data in the space determined by the axes. The first two axes were considered because they are the most representative in terms of the association between the categories of variables.[27,28]

Next, we carried out a CA by means of the Partitioning Around Medoids (PAM) clustering method

HOUSING **Derived variable**/ Original variable[1]	WATER & SANITATION **Derived variable**/ Original variable	WEALTH STATUS **Derived variable**/ Original variable
Biomass use for cooking • Do you use open fire? • If affirmative, where is the location of the fire? • If indoors, where it is? • If outside the house, where it is? • Do you use a wood-burning stove? • If affirmative, where is the location of the fire? • If indoors, where it is? • If outside the house, where it is? **Gas stove used for cooking** • Do you use a gas stove? • If affirmative, where is the location of the fire? • If indoors, where it is? • If outside the house, where it is? **Fire most used for cooking** • Which type of fire do you most use for cooking? **Type of predominant dwelling floor** • The predominant material type of the dwelling floor. • Do you use any other material type to pad the dwelling floor? **Type of predominant dwelling walls** • The predominant material type of the dwelling walls. • Do you use any other material type to pad the dwelling walls? **Number of dwelling rooms?** • Whether the household has a single room or more than one room. **Electricity** • Whether the household has electricity. And if affirmative, what is the source of the electricity? **Number of residents** • How many residents live in the household, including the children?	**Defecation location** • Location where the residents usually defecate or evacuate. • In the case of a bathroom, where the sewage is discharged? **Household's main source of water for domestic use** • Where do the residents collect water for domestic use? • In the case of a tap or faucet, what is the source of supply? **Drinking water source** • Where do the residents collect drinking water? **Storage of drinking water** • Do the residents store drinking water in a bowl or canister or pan or another container? **Household waste disposal** What is the disposal of household waste?	**Possession of <goods>: Radio; Refrigerator; Freezer; DVD player; Gas stove; Washing machine; Semi-automatic washing machine; Cell phone; Personal computer; Television (TV); Car; Satellite dish; Bicycle** • Do you have <goods>? (a question for each type of the goods listed above) • If yes, how many <goods>? (a question for each type of the goods listed above) **Plantation or animal husbandry** • Do you practise plantation or animal husbandry? **Hunting and fishing/food gathering** • Do you practise hunting and fishing? • Do you practise food gathering? **Exchange or donation inside the village** • Do you practise exchange or donation inside the village? **Donations from outside the village?** • Have you received donations from outside the village in the last month? **Food purchase** • Do you use to purchase food? **Receipt of food baskets in the last month** • Have you received a food basket in the last month? • Number of food baskets. **Regular income** • Have you received any wage income in the last month? (one question for each of the residents aged 10 years or older in the household) • If affirmative, how many? • Have you received pension income (Social Security) in the last month? (one question for each of the residents aged 10 years or older in the household) • If affirmative, how many? • Have you received a cash transfer (Bolsa Família Program) in the last month? (one question for each of the residents aged 10 years or older in the household) • If affirmative, how many? • How many residents live in the household, including the children?

Fig. 2: **Dimensions of study and derived variables used in MCA and CA in Guarani Birth Cohort.** *Notes:* Derived variables are those created by the combination of the original variables collected during the interview through the Perinatal Instrument of the Guarani Birth Cohort. The derived variables are those in **bold**.

considering different numbers of partitions ($k = 2$, 3 and 4)[29] based on the matrix derived from the MCA, with the aim of obtaining the greatest homogeneity within each group and heterogeneity between the groups. The number of clusters (k) in each dimension was defined by partitioning the ellipses in the CA and the silhouette graph from MCA, considering the highest average silhouette. Silhouette value is a measure of how similar a category of a variable is to its own cluster (cohesion) compared to other clusters (separation). The silhouette value varies between –1 and 1.[30] The higher the silhouette value, the higher the degree of belongingness

of the category of the variable within the group. Negative silhouette values indicate that the category was not well classified (Supplementary Figures S1–S3).

The clusters identified in each dimension were ordered in increasing degrees of access to public policies and wealth, identifying patterns of housing, water & sanitation, and wealth. These patterns were named according to their characteristics. Finally, we calculated the absolute and relative frequency of children in each pattern. A bar graph was built to show the proportion of children in each of the possible combinations of wealth, water & sanitation, and housing patterns. The analyses were processed in the R statistical software using the FactoMineR package.[31] For exploratory purposes and with the aim of verifying the consistency of the patterns identified in the analyses, we evaluated the association between the patterns of each dimension generated with one of the outcomes measured in the birth cohort. For this analysis, we selected the outcome of hospitalization, defined as at least one admission for any cause during the first year of life, with a length of hospital stay equal to or greater than 24 h. Unadjusted relative risks were estimated with respective 95% confidence intervals (95% CI) using a log-binomial regression model.

Ethical 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.

Role of the funding source

The funding sources had no role in the study design, data collection, data analysis, interpretation, writing, or decision to submit.

Results

Of the 357 recruited children, 356 (99.7%) had complete data on housing and water & sanitation and were included in the analyses, while 353 (98.9%) were retained in the wealth dimension analysis. The variables used in the MCA and the respective categories and labels according to the dimensions studied, as well as the frequency of children in each category, are presented in Table 1.

In the housing dimension, we highlight the high proportion of children living in homes with the following characteristics: with a single room (37.4%), with a dirt floor (39.6%), using biomass as fuel for cooking inside the house (44.4%), with five or more residents (59.3%), and with electricity (84.3%). In the water & sanitation dimension, we highlight the high proportion of children living in homes without access to an inside toilet (25.6%), with access to a collective toilet outside the home (29.8%), without an inside tap (61.8%), using stored drinking water (43.8%), and where garbage is burned, buried, or discarded in the village (32.0%). In the wealth dimension, the frequencies of possession of durable goods varied from 4.0% for freezers to 74.5% and 76.2% for cell phones and televisions, respectively. The children's families also reported: a low frequency of self-production of food for subsistence, with only 17.3% reporting cultivation or animal husbandry and 10.8% reporting fishing, hunting, or gathering; a moderate frequency of external donations (35.1%) and receipt of basic food baskets (38.8%); and a high frequency of food purchases (88.4%), despite the significant proportion of families with incomes below the poverty line (71.7%).

In the MCA, the first two axes explained 34.5%, 43.0%, and 43.8% of the data variability (total inertia), respectively, in the housing, water & sanitation, and wealth dimensions. The subsequent cluster analysis identified three patterns for housing and water & sanitation, and four patterns for wealth (Fig. 3, ***a***: Housing, ***b***: Water & Sanitation, and ***c***: Wealth), based on the best statistical allocation of the silhouette values. The higher the silhouette value, the higher the degree of belongingness of the category within the group.

Based on the characteristics of the identified patterns, Housing and Water & Sanitation received the consecutive labels H1, H2 and H3 and S1, S2 and S3 corresponding, respectively, to the comparative lowest, intermediate, and highest degrees of access to public policies (Table 2, Housing and Table 3, Water & Sanitation). Wealth status received labels W1, W2, W3, and W4 corresponding, respectively, to the comparative lowest, intermediate-lowest, intermediate-highest, and highest degrees of wealth (Table 4, Wealth Status). The patterns were described as follows:

Housing

37.1% of children in the cohort were found to belong to pattern H1 (B): "Construction with local resources and biomass use", which included a predominance of houses built with materials from local resources (e.g., straw, logs, and wattle and daub house), comprised a single room, with a high number of residents (i.e., 10 or more); had no electricity, and had intra-household pollutant sources (like open fire for cooking). 28.1% were found to belong to pattern H2 (A): "Precarious alternative construction", which included a

Dimensions, derived variables, categories, and labels[a]	
Housing	n (%)
Biomass use for cooking	
No (fog_1)	101 (28.4)
Yes, indoors (fog_2)	158 (44.4)
Yes, outside the house (fog_3)	97 (27.2)
Gas stove used for cooking	
No (fga_0)	147 (41.3)
Yes, inside the house, single room (fga_1)	43 (12.1)
Yes, inside the house, separate room (fga_2)	142 (39.9)
Yes, out of the house, outdoor kitchen, closed (fga_3)	11 (3.1)
Yes, out of the house, outdoor kitchen, without walls (fga_4)	13 (3.7)
Fire most used for cooking	
Open fire (fgm_1)	112 (31.5)
Wood burning stove (fgm_2)	42 (11.8)
Gas stove (fgm_3)	180 (50.6)
Other (fgm_4)	22 (6.2)
Dwelling flooring	
Earthen (cha_1)	141 (39.6)
Earthen combined with other materials (cha_2)	39 (11.0)
Wood (cha_3)	56 (15.7)
Wood floor combined with other materials (cha_4)	4 (1.1)
Cement (cha_5)	63 (17.7)
Cement combined with other material (cha_6)	30 (8.4)
Ceramic (cha_7)	19 (5.3)
Ceramic combined with other materials (cha_8)	4 (1.1)
Dwelling walls	
Palm thatch (par_1)	16 (4.5)
Palm thatch combined with other materials (par_2)	51 (14.3)
Tree log (par_3)	34 (9.6)
Tree log combined with other materials (par_4)	32 (9.0)
Wooden board (par_5)	67 (18.8)
Wooden board combined with other materials (par_6)	37 (10.4)
Wattle and daub or adobe (par_7)	14 (3.9)
Wattle and daub combined with other materials (par_8)	20 (5.6)
Masonry walls/masonry walls combined with other materials (par_9)	69 (19.4)
Canvas/plastic/sheet/blanket/cloth (par_10)	12 (3.4)
Other materials (par_11)	4 (1.1)
Dwelling rooms	
Single room (nco_1)	133 (37.4)
More than one (nco_2)	223 (62.6)
Electricity	
No (eng_0)	38 (10.7)
Electrical network of distribution company (eng_1)	300 (84.3)
Solar plate or others (eng_2)	18 (5.1)
Nº residents dwelling	
1–4 (mfx_1)	145 (40.7)
5–7 (mfx_2)	185 (52.0)
10 or + (mfx_3)	26 (7.3)
Dimensions, derived variables, categories, and labels[a]	
Water & sanitation	n (%)
Defecation location	
Indoors household facility (evc_1)	70 (19.7)
Outdoor household facility, used only by household residents (evc_2)	89 (25.0)

(Table 1 continues on next page)

Dimensions, derived variables, categories, and labels[a]	
Water & sanitation	n (%)
(Continued from previous page)	
Outdoor household facility, collective (not exclusive of the household residents) (evc_3)	106 (29.8)
Rudimentary pit latrine, outdoors in the open or other (evc_4)	91 (25.6)
Household's main source of water for domestic use	
Household faucet from general or local public network sources (agd_1)	114 (32.0)
Household faucet from the river, waterfall, or other sources (agd_2)	22 (6.2)
Faucet outside the household, used just by residents, from the general or local public network (agd_3)	56 (15.8)
Faucet outside the household, used just by residents directly from the river, waterfall, and other sources (agd_4)	7 (2.0)
Faucet outside the household, used by residents and residents of other households (collective) from local general/public network sources (agd_5)	112 (31.5)
Faucet outside the household, used by residents and residents of other households (collective) directly from the river, waterfall, or other sources (agd_6)	28 (7.9)
No faucet, water directly from the river, waterfall, or other sources (agd_7)	17 (4.8)
Household's main source of drinking water	
Household faucet (agb_1)	141 (39.6)
Faucet outside the house, used just by the residents (agb_2)	57 (16)
Faucet outside used by residents and by residents of other households (agb_3)	139 (39.0)
Water directly from the spring or well in the village (agb_4)	6 (1.7)
Water directly from the waterfall, dam, lake, or river (agb_5)	6 (1.7)
Other sources (agb_6)	7 (2.0)
Store drinking water (inside bowl, canister, or pan)	
Yes (aga_1)	156 (43.8)
No (aga_2)	200 (56.2)
Waste removal	
Collected by cleaning service (lix_1)	37 (10.4)
Put in dumpster (lix_2)	205 (57.4)
Burned or buried in the village (lix_3)	95 (26.7)
Discarded in the village (lix_4)	19 (5.3)

Dimensions, derived variables, categories, and labels[a]	
Wealth	n (%)
Radio	
No (nra_0)	175 (49.4)
Yes, one (nra_1)	178 (50.6)
Refrigerator	
No (nge_0)	202 (57.2)
Yes, one (nge_1)	151 (42.8)
Freezer	
No (nfr_0)	339 (96.0)
Yes, one (nfr_1)	14 (4.0)
DVD player	
No (ndvd_0)	215 (60.9)
Yes, one (ndvd_1)	138 (39.1)
Gas stove	
No (nfo_0)	147 (416)
Yes, one (nfo_1)	206 (58.4)
Washing machine	
No (nma_0)	294 (83.3)
Yes, one (nma_1)	59 (16.7)
Semi-automatic washing machine	
No (nta_0)	236 (66.0)
Yes, one (nta_1)	120 (34.0)
Cell phone	
No (nce_0)	90 (25.5)

(Table 1 continues on next page)

Dimensions, derived variables, categories, and labels[a]	
Wealth	n (%)
(Continued from previous page)	
Yes, one (nce_1)	176 (49.9)
Yes, two or + (nce_2)	87 (24.6)
Personal computer/tablet	
No (nco_0)	327 (92.6)
Yes, one (nco_1)	26 (7.4)
Television	
No (ntv_0)	84 (23.8)
Yes, one (ntv_1)	227 (64.3)
Yes, two or+ (ntv_2)	42 (11.9)
Car	
No (nca_0)	331 (93.8)
Yes, one (nca_1)	22 (6.2)
Satellite dish	
No (nan_0)	262 (74.2)
Yes, one (nan_1)	91 (25.8)
Bicycle	
No (nbi_0)	289 (81.9)
Yes, one (nbi_1)	64 (18.1)
Plantation or animal husbandry	
Yes (pla_1)	61 (17.3)
No (plan_2)	292 (82.7)
Hunting and fishing/food gathering	
Yes (pco_1)	38 (10.8)
No (pco_2)	315 (89.2)
Exchange or donation inside the village	
Yes (tro_1)	52 (14.7)
No (tro_2)	301 (85.3)
Donations from outside the village	
Yes (doa_1)	124 (35.1)
No (doa_2)	229 (64.9)
Purchase food	
Yes (com_1)	312 (88.4)
No (com_2)	41 (11.6)
Food baskets	
No (ncb_0)	216 (61.2)
Yes, one (ncb_1)	115 (32.6)
Yes, two (ncb_2)	22 (6.2)
Regular income[b]	
≤US$ 29.03 (rend_1)	194 (55.0)
>US$ 29.03 and ≤58.05 (rend_2)	59 (16.7)
>US$ 58.05 (rend_3)	100 (28.3)

[a]Labels used in MCA and CA, are in parentheses. [b]The Cash Transfer Program (Program Bolsa Família), through Decree Nº 8232 of 2014, updated the values for extreme poverty when the monthly per capita family income is ≤US$29.03, while for poverty the monthly per capita family income is >US$29.03 and ≤US$58.05. Above the poverty line are individuals with an income >US$ 58.05.

Table 1: **Frequency of children according to categories of derived variables used for MCA and CA.**

predominance of houses made of improvised material, with a low number of residents (1–4), and no intra-household pollutant sources. 34.8% were found to belong to pattern H3 (C): "Urbanized masonry dwellings", which included a predominance of masonry buildings with internal room divisions, intermediate number of residents (5–9), various sources of electricity, no intra-household pollutant sources.

Water & sanitation

5.1% of children in the cohort were found to belong to pattern S1 (C): "No water & sanitation system, local

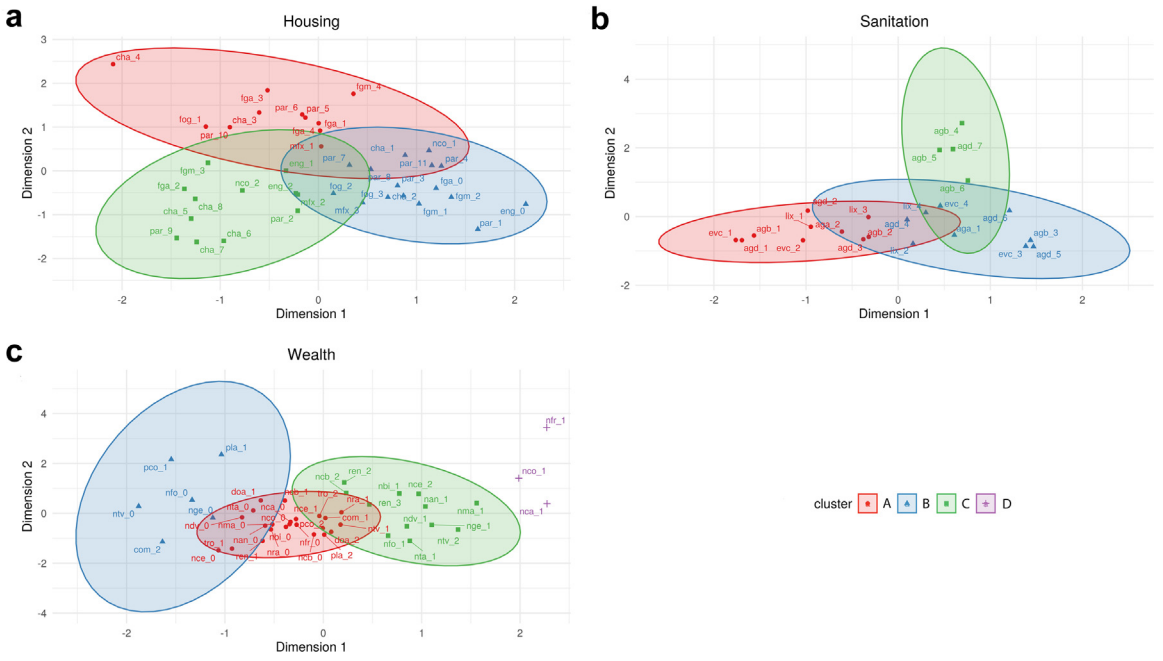

Fig. 3: **Clusters graphs showing patterns of housing, water & sanitation and wealth in the Guarani Birth Cohort.**

alternative solutions", with the predominance of water for drinking and for domestic use coming from natural sources such as a river, waterfall, lake, or dam. 44.9% were found to belong to pattern S2 (B): "Local water & sanitation system with facilities for collective/shared use", with the predominance of water sources for drinking and for domestic use outside the household, external toilet of shared use by more than one household. 50.0% were found to belong to pattern S3 (A): "General water & sanitation system or local system for individual use", with the predominance of drinking water and water for domestic use coming from a spout or tap inside the house, sanitary facilities inside the house or outside the house but for the exclusive use of the family, garbage collected by public cleaning services.

Wealth

30.0% of children in the cohort were found to belong to pattern W1 (B): "Local food production, no assets and income source", the predominance of households with no income or durable goods, subsistence based on local food production, such as fishing/hunting, gathering and planting. 32.6% were found to belong to pattern W2 (A): "Low income, dependent on donation", with a predominance of households with possession of some durable goods, such as radio, TV and cell phone, *per capita* income in the extreme poverty range, with some subsistence, food purchasing and basic food basket receipt. 25.2% were found to belong to pattern W3 (C): "Income above poverty line, medium value-added goods", predominance of households with ownership of some durable goods, such as gas stove, refrigerator, washing machine, two TVs, DVD player and *per capita* income range of poverty or above the poverty line. 12.2% were found to belong to pattern W4 (D): "High value-added goods", households with ownership of goods, such as car, computer, and freezer.

The distribution of children according to the combination of the three dimensions analyzed and the 10 patterns (H1–H3, S1–S3, and W1–W4) yielded 36 (3 × 3 × 4) categories (Fig. 4). The Guarani children of the cohort were concentrated in the combinations of lower degree of access to public policies and higher poverty across the dimensions studied. As one moves from the lowest (W1) to the highest (W4) wealth status pattern, there is also an increase in the proportion of children with higher degrees of access to housing and water & sanitation policies. However, we observed substantial heterogeneity in the distribution of Guarani children across the 36 combinations of the patterns identified. We found more than 62% of children in the cohort in the lowest wealth patterns (W1–W2).

During the cohort period, between June 2014 and May 2016, of the 351 children recruited, 102 (29%) were hospitalized at least once during the first year of life. In an exploratory analysis, we found statistically significant associations between such hospitalization and living in a precarious household (H2: 1.83; 95% CI: 1.24–2.77) and extreme poverty (W2:1.93; 95% CI: 1.06–4.15) (Table 5). The associations found with the other patterns, although statistically not significant, were in the expected direction.

Cluster	Variable categories (label)	Silhouette category	Average silhouette	Pattern name	Children N (%)
H1 (B)	Do not use gas stove for cooking (fga_0)	0.71	0.55	*"Construction with local resources and biomass use"*	132 (37.1)
	Fire most used for cooking: wood burning stove (fgm_2)	0.68			
	Tree log dwelling walls (par_3)	0.67			
	Earthen floor combined with other materials (cha_2)	0.66			
	Fire most used for cooking: open fire (fgm_1)	0.66			
	Tree log combined with other materials dwelling walls (par_4)	0.64			
	Other materials dwelling walls (par_11)	0.64			
	Biomass use for cooking, outside the home (fog_3)	0.61			
	No electricity (eng_0)	0.56			
	Palm thatch dwelling wall (par_1)	0.54			
	Single-room dwelling (nco_1)	0.52			
	Earthen floor (cha_1)	0.51			
	Wattle and daub combined with other materials dwelling walls (par_8)	0.50			
	Number of residents dwelling, 10 or + (mfx_3)	0.42			
	Wattle and daub or adobe dwelling walls (par_7)	0.30			
	Biomass use for cooking, indoors (fog_2)	0.13			
H2 (A)	Wooden board dwelling wall combined with other materials (par_6)	0.61	0.45	*"Precarious alternative construction"*	100 (28.1)
	Wooden board dwelling wall (par_5)	0.60			
	Gas stove, out of the house, outdoor kitchen, closed (fga_3)	0.60			
	Wood floor (cha_3)	0.58			
	Gas stove, inside the house, single room (fga_1)	0.52			
	Gas stove, outdoor kitchen, without walls (fga_4)	0.45			
	Canvas/plastic/sheet/blanket dwelling wall (par_10)	0.40			
	Fire most used for cooking, others (fgm_4)	0.39			
	Do not use biomass for cooking (fog_1)	0.31			
	Wood floor combined with other materials (cha_4)	0.28			
	Number of residents dwelling, 1–4 (mfx_1)	0.22			
H3 (C)	Cement floor (cha_5)	0.64	0.45	*"Urbanized masonry dwellings"*	124 (34.8)
	Ceramic floor (cha_7)	0.61			
	Masonry walls/masonry walls combined with other materials (par_9)	0.60			
	Ceramic floor combined with other materials (cha_8)	0.60			
	Cement floor combined with other materials (cha_6)	0.59			
	More than one room dwelling (nco_2)	0.54			
	Gas stove inside the house, separate room (fga_2)	0.52			
	Palm thatch combined with other materials (par_2)	0.31			
	Electricity from solar plate or others (eng_2)	0.31			
	Number of residents dwelling, 5–9 (mfx_2)	0.29			
	Fire most used for cooking: gas stove (fgm_3)	0.20			
	Electrical network of distribution company (eng_1)	0.16			

Table 2: **Distribution of the relative contribution of the variables categories according to the clusters for housing.**

Discussion

This study uses MCA and CA to identify distinct patterns of housing, water & sanitation, and wealth among Indigenous children participating in the Guarani Birth Cohort. The clusters reflect varying degrees of access to public policies and socioeconomic positions. Although there were correlations between the three dimensions, the distribution of Guarani children in one dimension is not fully determined by the other dimensions, e.g., children in each of the four wealth clusters are also represented across the three household clusters. Thus, the results revealed substantial heterogeneity in the distribution of Guarani children across the 36 combinations of the patterns identified. As already mentioned, in Indigenous Peoples communities in Brazil, housing and water & sanitation patterns may not be directly

Cluster	Variable categories (label)	Silhouette category	Average silhouette	Pattern name	Children N (%)
S1 (C)	Water for domestic use: no faucet, water directly from river, waterfall, other sources (agd_7)	0.75	0.58	*"No water & sanitation system, local alternative solutions"*	18 (5.1)
	Drinking water directly from waterfall, dam, or lake or river (agb_5)	0.74			
	Drinking water directly from spring or well in the village (agb_4)	0.65			
	Drinking water by other sources (agb_6)	0.19			
S2 (B)	Drinking water by faucet outside the house used by residents and by residents of other households (agb_3)	0.53	0.33	*"Local water & sanitation system with facilities for collective/shared use"*	160 (44.9)
	Outside household facility, collective (not exclusive of the household residents) (evc_3)	0.50			
	Water for domestic use by faucet outside household, used by residents and residents of other households (collective), from local general/public network sources (agd_5)	0.49			
	Water for domestic use by faucet outside household, used by residents and residents of other households (collective), directly from river, waterfall, other sources (agd_6)	0.44			
	Do store water inside the house (aga_1)	0.39			
	Rudimentary pit latrine, outdoors in the open or other (evc_4)	0.27			
	Waste discarded in the village (lix_4)	0.24			
	Water for domestic use by faucet outside household, used just by residents, directly from river, waterfall, other sources (agd_4)	0.07			
	Waste put in dumpster (lix_2)	0.01			
S3 (A)	Drinking water by household faucet (agb_1)	0.64	0.49	*"General water & sanitation system or local system for individual use"*	178 (50.0)
	Water for domestic use by household faucet, from general or local public network sources (agd_1)	0.62			
	Indoors household facility (evc_1)	0.61			
	Outdoor facility household, used just by household residents (evc_2)	0.61			
	Waste removal collected by cleaning service (lix_1)	0.59			
	Do not store drinking water (inside bowl, canister, or pan) (aga_2)	0.52			
	Water for domestic use by household faucet, from river, waterfall, other sources (agd_2)	0.40			
	Water for domestic use, by faucet outside the house, used just by residents, from general or local public network (agd_3)	0.37			
	Drinking water by faucet outside the house, used just by the residents (agb_2)	0.34			
	Waste burned or buried in the village (lix_3)	0.17			

Table 3: **Distribution of the relative contribution of the variables categories according to the clusters for water & sanitation.**

determined by socioeconomic conditions or wealth. Specifically, public policies for housing and water & sanitation are generally implemented collectively in a village, regardless of a given Indigenous family's purchasing power.

Risk factors described in the literature as potentially related to unfavorable health outcomes, such as biomass or solid fuel use for cooking, lack of electricity inside the house, the presence of many residents in a single room, limited access to water & sanitation, few assets and low income, and dependence on external food donations[18,19,23,24,32–35] were identified in the present study in the households of at least half of the children.

According to the World Health Organization (WHO), indoor air pollution was responsible for an estimated 3.2 million deaths per year in 2020, including more than 237,000 deaths of children under 5 years of age. The combined effects of air and indoor pollution are associated with 6.7 million premature deaths annually. Women and children, usually responsible for domestic tasks such as cooking and collecting firewood, are most affected by the burden of disease from the use of polluting fuels inside homes.[34]

In addition to affecting young children, indoor pollution from the burning of solid fuels for cooking and heating is a major risk factor for a wide range of cardiorespiratory and maternal-related diseases, as well as the global burden of disease in disability-adjusted life years (DALYs) in adults, with the highest prevalence in low- and middle-income countries.[35]

Several studies around the world, mostly carried out in Latina America, that investigated the determinants of Indigenous children's health indicated that living conditions, location in remote regions, limited access to public health policies, sanitation, and housing conditions, and schooling are shown to be a relevant context for the high frequencies of infectious diseases.[17,19,20,36–45] Thus, evidence indicates that housing conditions, access to water & sanitation, and socioeconomic characteristics have implications for health profile, especially in children.

The exploratory analysis of the association between the patterns of housing, water & sanitation and wealth, and hospitalization found that these dimensions are

Cluster	Variable categories (label)	Silhouette category	Average silhouette	Pattern name	Children N (%)
W1 (B)	No television (ntv_0)	0.39	0.19	*"Local food production, no assets and income source"*	106 (30.0)
	Do practice hunting and fishing/food gathering, (pco_1)	0.38			
	No gas stove (nfo_0)	0.29			
	Do plantation or animal husbandry (pla_1)	0.26			
	Do not purchase food (com_2)	−0.01			
	No refrigerator (nge_0)	−0.15			
W2 (A)	No bicycle (nbi_0)	0.70	0.50	*"Low income, dependent on donation"*	115 (32.6)
	No personal computer/tablet (nco_0)	0.69			
	No car (nca_0)	0.68			
	No freezer (nfr_0)	0.67			
	No washing machine (nma_0)	0.66			
	No radio (nra_0)	0.65			
	Cell phone, one (nce_1)	0.65			
	No satellite dish (nan_0)	0.62			
	No food basket (ncb_0)	0.56			
	Regular income, extreme poverty (ren_1)	0.56			
	Hunting and fishing/food gathering, do not practice (pco_0)	0.52			
	Plantation or animal husbandry, do not practice (pla_0)	0.49			
	Exchange or donation inside the village, do not practice (tro_2)	0.48			
	Do purchase food (com_1)	0.45			
	Donations from outside the village, do not receive (doa_2)	0.44			
	Food basket, receive one (ncb_1)	0.44			
	No semi-automatic washing machine (nta_0)	0.39			
	Do practice exchange or donation inside the village (tro_1)	0.37			
	No DVD player (ndv_0)	0.36			
	Television, one (ntv_1)	0.31			
	Do receive donations from outside the village (doa_1)	0.29			
	No cell phone (nce_0)	0.28			
	Radio, one (nra_1)	0.16			
W3 (C)	Satellite dish, one (nan_1)	0.57	0.35	*"Income above poverty line and medium value-added goods"*	89 (25.2)
	Refrigerator, one (nge_1)	0.53			
	Cell phone, two (nce_2)	0.51			
	Television, two or + (ntv_2)	0.49			
	Bicycle, one (nbi_1)	0.48			
	DVD player, one (ndv_1)	0.45			
	Semi-automatic washing machine, one (nta_1)	0.32			
	Regular income, above the poverty line (ren_3)	0.27			
	Gas stove, one (nfo_1)	0.23			
	Washing machine, one (nma_1)	0.16			
	Regular income, poverty (ren_2)	0.10			
	Food basket, receive two (ncb_2)	0.08			
W4 (D)	Freezer, one (nfr_1)	0.38	0.29	*"High value-added goods"*	43 (12.2)
	Personal computer/tablet, one (nco_1)	0.33			
	Car, one (nca_1)	0.15			

Table 4: **Distribution of the relative contribution of the variables categories according to the clusters for wealth.**

relevant social determinants of the Guarani children's health. Although these analyses include only one outcome, they reinforce the consistency of the patterns and dimensions identified in our analyses as a methodological advance in the investigation of the SDH in Indigenous Peoples. Future research should prioritize the investigation of other health outcomes using multivariable-adjusted analyses that account for potentially confounding medical and sociodemographic factors.

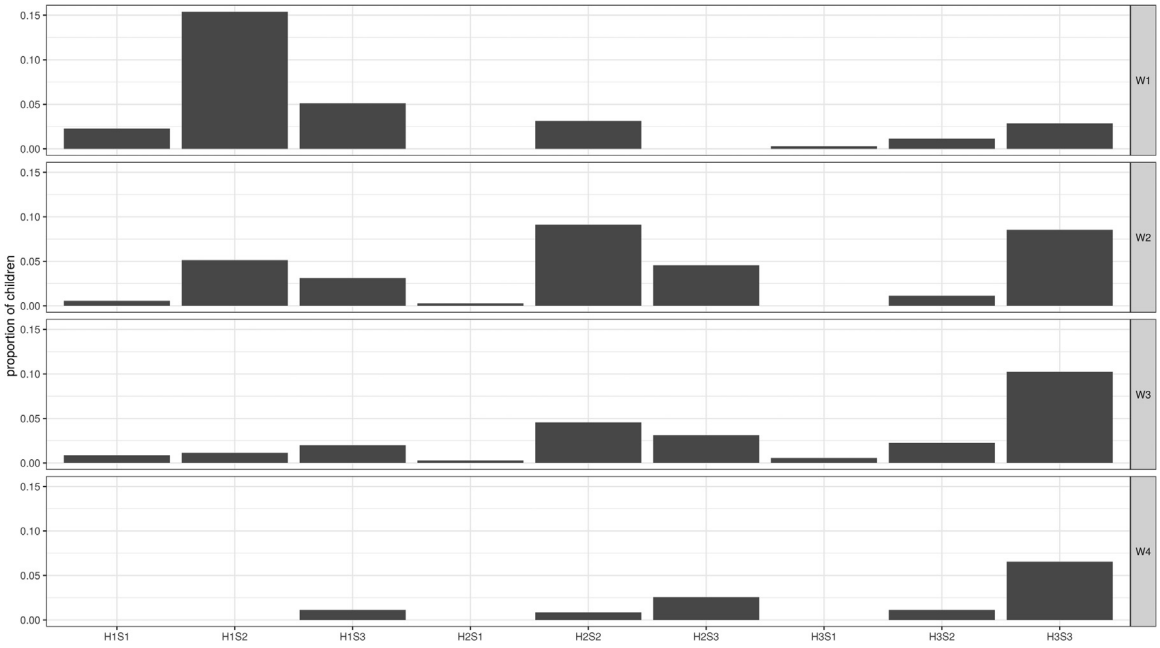

Fig. 4: **Distribution of children across 36 combinations of patterns in the Guarani Birth Cohort.**

Strengths of the study include the data source, the first Indigenous birth cohort in Brazil, and the identification of these patterns which will enable meaningful investigations concerning the potential effects of social determinants on health outcomes in Indigenous Guarani children. In addition, the analyses used variables that synthesized the explanation of socioeconomic position, and access to water & sanitation, and housing policies, which represents an advance in comparison with traditional indicators, used alone in many studies. In our study, the MCA and CA allowed the exploration and reduction of the dimensions of 129 variables (81 categorical and 48 numeric) present in the baseline of the Guarani Birth Cohort, identifying patterns on distinct aspects of the living conditions of Indigenous children. Eight variables and 39 categories of housing and seven variables and 23 categories of water & sanitation dimensions were reduced to three distinct patterns, while in the wealth dimension, 20 variables and 44 categories were

Dimension/Patterns	Number of children hospitalized	RR[a]	95% CI[b]
Housing			
H1 (Construction with local resources and biomass use)	32	1.08	0.69–1.70
H2 (Precarious alternative construction)	42	1.83	1.24–2.77
H3 (Urbanized masonry dwellings) (reference)	28	1.00	
Water & sanitation			
S1 (No water & sanitation system, local alternative solutions)	3	0.62	0.16–1.47
S2 (Local water & sanitation system with facilities for collective/shared use)	52	1.23	0.88–1.71
S3 (General water & sanitation system or local system for individual use) (reference)	47	1.00	
Wealth			
W1 (Local food production, no assets and income source)	27	1.37	0.71–3.01
W2 (Low income, dependent on donation)	41	1.93	1.06–4.15
W3 (Income above poverty line and medium value-added goods)	26	1.59	0.83–3.48
W4 (High value-added goods) (reference)	8	1.00	

The Guarani Birth Cohort, 2014–2017. [a]RR: Unadjusted Relative Risks. [b]CI: Confidence Interval.

Table 5: **Associations between housing, water & sanitation and wealth, and hospitalization during the first year of life.**

reduced to four distinct patterns. The MCA provides, therefore, synthetic patterns of living conditions and access to public policies, which can be used in theoretical and empirical models for investigating the social determinants of health of Guarani children, possibly with the greater explanatory power of adverse health outcomes compared to indicators commonly used for this purpose. The analysis strategy was able to capture the heterogeneity of socioeconomic and living conditions of Indigenous children due to the use of a large number of variables on different dimensions. Although the scope of the study does not extend to estimating any associations between health outcomes and the three identified dimensions, the exploratory analyses with the outcome hospitalization show a consistency of the indicators for investigation of SDH in the Guarani Indigenous children.

Our study also has some limitations such as the difficulty in capturing sources of income that are not stable and may not reflect the seasonality of income. Therefore, comparability between children is difficult, given that the collection of information referred to the month prior to the date of birth.

Conclusions

This work proposes a methodological advance in the investigation of the SDH in Indigenous populations. At the moment, our findings show that housing, water & sanitation, and wealth should be considered separately in multivariable models, hence fitting the independent effects of each dimension on children's health outcomes. Future work will more deeply assess the possible associations with other specific health outcomes and the separate patterns of housing, water & sanitation, and wealth. If confirmed, such associations should guide health care planning for Guarani children from South and Southeast Brazil and, more broadly, inform the development of intersectoral policies for improving living conditions in Indigenous villages. Overall, the patterns identified in this study among the Guarani children document severely compromised living conditions, as well as inequalities in the frequency of social and environmental risk factors between the Indigenous children. This study underscores the need to establish equitable and efficient policies to improve housing, water & sanitation, and wealth conditions.

Contributors

A.D.R.C., A.A.N., and A.M.C. were responsible for the study concept, design, for accessing and verifying the data, data analysis, and interpretation, and prepared the first draft. A.M.C., C.T.G.B., F.G.T, Y.N.F., L.N.P., and M.C.L.D. were responsible for the collection of data. E.B., N.A., and G.L.W. critically revised the manuscript for important intellectual content. All the authors gave final approval of the version to be published.

Data sharing statement

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 the participant community, and Guarani community protocols for authorizing studies. Data requests may be sent to Dr. Andrey Moreira Cardoso, 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) 2598–2661. Email: andrey.cardoso@fiocruz.br

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Declaration of interests

All authors declare that they have no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lana.2023.100496.

References

1 World Health Organization. Social determinants of health: Key concepts. https://www.who.int/news-room/questions-and-answers/item/social-determinants-of-health-key-concepts. 2013. Accessed April 26, 2023.
2 World Health Organization. A conceptual framework for action on the social determinants of health. https://apps.who.int/iris/handle/10665/44489. 2010. Accessed April 26, 2023.
3 Buss PM, Pellegrini Filho A. A saúde e seus determinantes sociais. *Physis*. 2007;17:77–93.
4 Vyas S, Kumaranayake L. Constructing socio-economic status indices: how to use principal components analysis. *Health Policy Plan*. 2006;21:459–468.
5 Barros AJD, Victora CG. Indicador econômico para o Brasil baseado no censo demográfico de 2000. *Rev Saude Publica*. 2005;39:523–529.
6 Cortinovis I, Vella V, Ndiku J. Construction of a socio-economic index to facilitate analysis of health data in developing countries. *Soc Sci Med*. 1993;36:1087–1097.
7 Kolenikov S, Angeles G. Socioeconomic status measurement with discrete proxy variables: is principal component analysis a reliable answer? *Rev Income Wealth*. 2009;55:128–165.
8 Pissolato E. Trabalho, subsistência e dinheiro: modos criativos na economia mbya (guarani) contemporânea. *Horiz Antropol*. 2016;22:105–125.
9 Fotso J-C, Kuate-Defo B. Measuring socioeconomic status in health research in developing countries: should we be focusing on households, communities or both? *Soc Indic Res*. 2005;72:189–237.
10 Gracey M, King M. Indigenous health part 1: determinants and disease patterns. *Lancet*. 2009;374:65–75.
11 King M, Smith A, Gracey M. Indigenous health part 2: the underlying causes of the health gap. *Lancet*. 2009;374:76–85.
12 Coimbra Junior CEA, Santos RV, Escobar AL, Associação Brasileira de Pós-Graduação em Saúde Coletiva, eds. *Epidemiologia e saúde dos povos indígenas no Brasil*. Rio de Janeiro, RJ: Editora Fiocruz: ABRASCO; 2003.
13 Pagliaro H, Azevedo MM, Santos RV, eds. *Demografia dos povos indígenas no Brasil*. Rio de Janeiro, RJ: Campinas, SP:

Editora Fiocruz; Associação Brasileira de Estudos Populacionais; 2005.
14 Cardoso AM, Santos RV, Coimbra CEA Jr. Mortalidade infantil segundo raça/cor no Brasil: o que dizem os sistemas nacionais de informação? *Cad Saude Publica*. 2005;21:1602–1608.
15 Cardoso AM, Coimbra CEA Jr, Barreto CTG, Werneck GL, Santos RV. Mortality among guarani Indians in southeastern and southern Brazil. *Cad Saude Publica*. 2011;27:s222–s236.
16 Caldas ADR, Santos RV, Borges GM, Valente JG, Portela MC, Marinho GL. Mortalidade infantil segundo cor ou raça com base no Censo Demográfico de 2010 e nos sistemas nacionais de informação em saúde no Brasil. *Cad Saude Publica*. 2017;33. https://doi.org/10.1590/0102-311x00046516.
17 Cardoso AM, Coimbra CEA Jr, Tavares FG. Morbidade hospitalar indígena Guarani no Sul e Sudeste do Brasil. *Rev Bras Epidemiol*. 2010;13:21–34.
18 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;7:412–419.
19 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.
20 Coimbra CE, Santos RV, Welch JR, 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.
21 Instituto Brasileiro de Geografia e Estatística. Censo Demográfico 2010. Características gerais dos indígenas. Resultados do universo. Rio de Janeiro: IBGE; 2012.
22 Guarani Mbya–povos indígenas no Brasil. https://pib.socioambiental.org/pt/Povo:Guarani_Mbya. Accessed March 18, 2021.
23 Barreto CTG, Tavares FG, Theme-Filha M, Farias YN, de Nazaré Pantoja N, Cardoso AM. Low birthweight, prematurity, and intrauterine growth restriction: results from the baseline data of the first Indigenous birth cohort in Brazil (Guarani Birth Cohort). *BMC Pregnancy Childbirth*. 2020;20:748.
24 Cardoso AM, Coimbra CEA, 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;18:596–607.
25 Tronco GB, Ramos MP. Linhas de pobreza no Plano Brasil Sem Miséria: análise crítica e proposta de alternativas para a medição da pobreza conforme metodologia de Sonia Rocha. *Rev de Adm Publica*. 2017;51:294–311.
26 Brasil, Presidência da República. Decreto no 8232, de 30de abril de 2014. Altera o Decreto no 5.209, de 17 de setembro de 2004, que regulamenta o ProgramaBolsa Família, e o Decreto no 7.492, de 2 de junho de 2011, *que institui o Plano Brasil Sem Miséria. 2014*.
27 Hair JF, ed. *Multivariate data analysis*. 7th. Upper Saddle River, NJ: Prentice Hall; 2010.
28 Greenacre MJ. *Correspondence analysis in practice*. 2nd. Boca Raton: Chapman & Hall/CRC; 2007.
29 Kaufman L, Rousseeuw PJ. *Finding groups in data: an introduction to cluster analysis*. Hoboken, NJ: Wiley; 2005.
30 Rousseeuw PJ. Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. *J Comput Appl Math*. 1987;20:53–65.
31 R: The R project for statistical computing. https://www.r-project.org/. Accessed January 27, 2021.
32 Cardoso AM, Horta BL, Coimbra CEA Jr, Follér ML, Souza MC. *Inquérito Nacional de Saúde e Nutrição dos Povos Indígenas no Brasil. Relatório Final (Análise dos Dados)*. Rio de Janeiro: Associação Brasileira de Saúde Coletiva (ABRASCO). Fundação Nacional de Saúde (FUNASA); 2009:494p.
33 Basnayake TL, Morgan LC, Chang AB. The global burden of respiratory infections in Indigenous children and adults: a review: respiratory infections in Indigenous people. *Respirology*. 2017;22:1518–1528.
34 World Health Organization. Household air pollution. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health. Accessed March 17, 2023.
35 Lee KK, Bing R, Kiang J, et al. Adverse health effects associated with household air pollution: a systematic review, meta-analysis, and burden estimation study. *Lancet Glob Health*. 2020;8:e1427–e1434.
36 Lozano O, Jair E. Epidemiología sociocultural de los padecimientos gastrointestinales en niños y niñas del pueblo Nasa, Colombia. *Rev Univ Ind Santander Salud*. 2018;50:328–340.
37 Pena JL, Heller L. Saneamento e saúde indígena: uma avaliação na população Xakriabá, Minas Gerais. *Eng Sanit Ambient*. 2008;13:63–72.
38 Santos AP, Mazzeti CMDS, Franco MDCP, et al. Estado nutricional e condições ambientais e de saúde de crianças Pataxó, Minas Gerais, Brasil. *Cad Saude Publica*. 2018;34:e00165817.
39 Brito RS. *Características Epidemiológicas e Estratégias para a Prevenção da Doença Diarreica em Crianças Indígenas: scoping review*. Epidemiological characteristics and strategies to prevent diarrheic disease in Indigenous children: a scoping review; 2016. published online Dec 21. http://tede2.pucgoias.edu.br:8080/handle/tede/4153. Accessed March 17, 2023.
40 Devera R, Blanco Y, Cabello E. [High prevalence of Cyclospora cayetanensis among Indigenous people in Bolivar State, Venezuela]. *Cad Saude Publica*. 2005;21:1778–1784.
41 Nisha M, Aiman M, Asyhira N, et al. Risk factors associated with soil transmitted helminth (STH) infection in two Indigenous communities in Malaysia. *Trop Biomed*. 2020;37:379–388.
42 Mohammed Mahdy AK, Lim YA, Surin J, Wan KL, Al-Mekhlafi MSH. Risk factors for endemic giardiasis: highlighting the possible association of contaminated water and food. *Trans R Soc Trop Med Hyg*. 2008;102:465–470.
43 McDonald E, Bailie R, Brewster D, Morris P. Are hygiene and public health interventions likely to improve outcomes for Australian Aboriginal children living in remote communities? A systematic review of the literature. *BMC Public Health*. 2008;8:153.
44 Saxton J, Rath S, Nair N, et al. Handwashing, sanitation and family planning practices are the strongest underlying determinants of child stunting in rural Indigenous communities of Jharkhand and Odisha, Eastern India: a cross-sectional study. *Matern Child Nutr*. 2016;4:869–884.
45 Bubak V, Sanabria M, Sánchez Bernal S, Medina N. Perfil nutricional de niñas y niños indígenas menores de cinco años del Paraguay y su asociación con factores socioeconómicos y otros determinantes sociales, Encuesta de Hogares Indígenas 2008. *Pediatr (Asunción)*. 2018;45:25–35.