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ORIGINAL ARTICLE

Prevalence of pneumonia and associated factors among indigenous children in Brazil: results from the First National Survey of Indigenous People's Health and Nutrition

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Background: Based on data from a nationally representative sample of indigenous villages in Brazilian indigenous reserves, the study sought to estimate the prevalence of pneumonia and evaluate associated factors among indigenous children under 5 years of age.

Methods: Sociodemographic, clinical and reported data on child respiratory health from the First National Survey of Indigenous People's Health and Nutrition in Brazil were collected for 6128 children. Prevalence of pneumonia was calculated for independent variables and hierarchical multivariate analyses were performed to assess associations.

Results: The overall prevalence proportions of cough, nasal congestion, pneumonia, and pneumonia with fever were 44.4%, 31.0%, 2.63%, and 1.28%, respectively. In the multivariate model, pneumonia was more frequent among children living in the South/Southeast and North regions of Brazil. Children living in larger households or houses with wood or thatch roofing, as well those with low birthweight or stunting, presented higher risk of pneumonia. Pneumonia was less prevalent among children living in houses with wood flooring and those presenting low weight-for-age.

Conclusions: The study results demonstrate that pneumonia is an important cause of illness among indigenous children throughout Brazil. The association between pneumonia and household characteristics suggests that indoor home environment is closely related to the respiratory health of indigenous children.

Keywords: Brazil, Children under 5 years, Indigenous peoples, Pneumonia, Respiratory illness, Risk factors

Introduction

Pneumonia is the leading cause of mortality in children under 5 years of age globally, accounting for about one in five deaths and surpassing two million deaths annually.[1,2] In Latin America, pneumonia accounts for 14.0% of all deaths in children under 5 years of age.[3] The adjusted incidence of pneumonia in children under 5 years of age is 0.29 episodes per child-year in developing countries, reaching 2.45 episodes per child-year, and 0.05 in developed countries.[1] The higher frequency of pneumonia observed in developing countries is often associated with malnutrition, inadequate sanitation, and low socioeconomic status.[1,4] This scenario is even worse among vulnerable segments of national populations, such as indigenous peoples.[5–7]

In Brazil, substantial reductions in morbidity and mortality among children under 5 years of age due to infectious diseases have been observed in recent decades. These improvements have been attributed to a significant decline in the prevalence of undernutrition, increased coverage of health and sanitation services, and overall improvement of socioeconomic and educational conditions.[8] Throughout the country, morbidity and mortality due to pneumonia have accompanied this downward trend.[9]

The few studies addressing the epidemiology of acute respiratory infection among indigenous peoples in South America have focused on specific regions or ethnic groups.[5,10,11] In Brazil, in contrast to the encouraging national trend, infectious and parasitic diseases (pneumonia in particular) and undernutrition remain among the leading causes of morbidity and mortality among indigenous children.[12–14]

The aim of this paper is to report results from the First National Survey of Indigenous People's Health and Nutrition in Brazil (henceforth, 'National Survey') regarding the prevalence of

pneumonia and associated factors among indigenous children under 5 years of age. The National Survey, one of the largest of its kind focusing on indigenous peoples in Latin America, was carried out in 2008–2009. It is the first health and nutrition survey to include a representative sample of the national indigenous population in Brazil.

Methods

The National Survey assessed the health and nutritional status of indigenous children under 5 years and women aged 14–49 years in Brazil. A representative sample stratified by four geopolitical regions was obtained by multi-stage sampling, as previously reported.[15] Probabilistic sampling was carried out for villages located in federally recognized indigenous reserves in each region. The final sample included 123 villages distributed by region as follows: 65 North, 14 Central-West, 23 Northeast and 21 South/Southeast. Households in selected villages were investigated by either census or sample depending on their estimated populations. In selected households, mothers, fathers, or other caretakers of indigenous children under 5 years of age were interviewed. Mothers and caretakers of children under 5 years of age were asked if they considered themselves 'indigenous' and if they had 'indigenous' children. For this paper, children of mothers who reported being indigenous (or having indigenous children) were considered indigenous. Additional information about variables employed and construction of nutrition, sanitation and socioeconomic indicators is available in previous publications reporting on the National Survey.[12,15,16]

As done in previous research carried out in dispersed rural populations without access to diagnostic equipment,[17,18] pneumonia was evaluated based on interviewee reports of child symptoms during the seven days preceding the interview: cough, respiratory distress, fever and nasal congestion. For analysis, two outcomes with different degrees of specificity were used as proxies for pneumonia: pneumonia when cough and respiratory distress were present without nasal congestion; and pneumonia with fever when cough, respiratory distress and fever were present without nasal congestion. An additional two outcomes, cough and nasal congestion, were also included in analyses.

Measures of associations were expressed as prevalence ratios (PR) and their corresponding 95% CIs. All estimates were corrected for the complex sampling design of the study.

Poisson regression with robust adjustment of variance was used in the multivariate analysis, which was carried out according to a hierarchical conceptual framework.[12] All estimates were adjusted by region. The first and most distal level included sociodemographic characteristics (regular income, household goods index, child's sex and age, and maternal schooling). The second hierarchical level included variables related to household characteristics and sanitation (type of flooring, walls, and roofing, source of drinking water, total number of residents, and number of residents under 5 years), indoor burning of wood for fuel, and maternal age. The third level included perinatal factors (place of delivery, type of

Table 1. Prevalence of cough, nasal congestion, presumed pneumonia, and presumed pneumonia with fever during the previous week among indigenous children under 5 years of age, with prevalence ratios and confidence intervals, by region. First National Survey of Indigenous People's Health and Nutrition, Brazil, 2008–2009

Indicator/Outcome	Region	n	Prevalence (95% CI)	Crude PR (95% CI)
Cough	All regions	6090	44.4 (41.0–47.9)	NA
	Northeast	1353	47.8 (44.0–51.6)	1.00
	North	2556	56.5 (51.6–61.3)	1.18 (1.05–1.33)
	Central-West	1302	34.4 (28.7–40.7)	0.72 (0.59–0.87)
	South/Southeast	879	40.6 (35.5–45.9)	0.85 (0.73–0.99)
Nasal congestion	All regions	6081	31.0 (28.1–34.0)	NA
	Northeast	1350	30.8 (27.7–34.1)	1.00
	North	2552	43.5 (38.1–49.1)	1.41 (1.20–1.66)
	Central-West	1300	21.8 (18.0–26.2)	0.71 (0.57–0.88)
	South/Southeast	879	29.1 (24.7–34.0)	0.94 (0.78–1.14)
Presumed pneumonia	All regions	6081	2.63 (2.08–3.33)	NA
	Northeast	1350	1.55 (0.99–2.24)	1.00
	North	2552	2.63 (1.98–3.48)	1.70 (1.01–2.87)
	Central-West	1300	2.96 (1.81–4.82)	1.92 (0.99–3.71)
	South/Southeast	879	3.25 (2.09–5.04)	2.10 (1.13–3.93)
Presumed pneumonia with fever	All regions	6081	1.28 (1.00–1.68)	NA
	Northeast	1350	0.95 (0.57–1.59)	1.00
	North	2552	1.21 (0.82–1.79)	1.27 (0.67–2.43)
	Central-West	1300	1.58 (0.92–2.72)	1.66 (0.78–3.52)
	South/Southeast	879	1.35 (0.78–2.33)	1.41 (0.66–3.00)

NA: not applicable; PR: prevalence ratio.

delivery, and birthweight of the newborn). Finally, the fourth and most proximal level encompassed child variables related to current nutritional status (height-for-age, weight-for-age, and weight-for-height), clinical history, and recent health outcomes (hospitalization due to acute respiratory infection or diarrhea during the previous 12 months, diarrhea in the previous week, and current anemia).

Multivariate analysis was conducted employing a backward selection procedure with $p<0.20$ for initial selection at each level, controlling for region and variables retained in previous levels (adjusted PR), and $p<0.05$ for retention in the final model. This multivariate analysis procedure has been described in previous studies based on the National Survey.[12,16] All analyses were conducted with the program STATA 10.0 (StataCorp LP, College Station, TX, USA).

Ethical approval

Upon arrival at each community, the research team held meetings with leaders and other community members, during which the objectives and procedures of the study were clearly presented. A Free and Informed Collective Consent form was presented and signed by leaders, as well as other community representatives. Any village, household, or caretaker could decline to participate at any time.

Results

The survey visited 5305 households and assessed 6128 children under 5 years old. Caretaker-reported data on all four respiratory symptoms investigated were obtained for 6081 children (99.2% of the 6128 children assessed).

Table 2. Prevalence of presumed pneumonia during the previous week among indigenous children under 5 years of age, with prevalence ratios and confidence intervals, according to sociodemographic (first level) characteristics. First National Survey of Indigenous People's Health and Nutrition, Brazil, 2008–2009

Variable	n[a]	Presumed pneumonia (%)	Crude PR (95% CI)	Adjusted PR (95% CI)
Sex			NS[b]	NS[b]
Female	2954	2.42	1.00	1.00
Male	3126	2.83	1.17 (0.88–1.55)	1.18 (0.88–1.57)
Age group (months)			NS[c]	NS[d]
0 to 11	1327	2.71	1.00	1.00
12 to 23	1199	2.47	0.91 (0.53–1.56)	0.92 (0.53–1.58)
24 to 35	1172	3.34	1.23 (0.77–1.97)	1.24 (0.77–1.99)
36 to 47	1248	2.09	0.77 (0.46–1.29)	0.78 (0.47–1.31)
48 to 59	1135	2.59	0.95 (0.53–1.72)	0.95 (0.52–1.71)
Maternal age (years)			NS[c]	NS[d]
<20	816	3.44	1.00	1.00
20 to 29	3116	2.66	0.77 (0.52–1.14)	0.79 (0.54–1.18)
30 to 39	1670	2.41	0.70 (0.42–1.15)	0.72 (0.43–1.18)
≥40	463	1.85	0.54 (0.24–1.21)	0.52 (0.23–1.19)
Maternal schooling (years)			NS[c]	NS[d]
None	1062	3.06	1.00	1.00
1 to 4	2651	2.36	0.77 (0.44–1.35)	0.81 (0.46–1.42)
5 to 9	1535	2.94	0.96 (0.55–1.68)	1.01 (0.59–1.74)
≥10	790	2.22	0.72 (0.37–1.44)	0.83 (0.42–1.64)
Regular household income			NS[b]	NS[b]
Yes	2520	2.17	1.00	1.00
No	3553	2.97	1.37 (0.98–1.92)	1.39 (0.99–1.95)
Household goods index[e]			NS[c]	NS[d]
1st tercile	2359	2.73	1.00	1.00
2nd tercile	2140	3.07	1.12 (0.77–1.64)	1.19 (0.81–1.74)
3rd tercile	1582	2.05	0.75 (0.46–1.22)	0.76 (0.44–1.29)

NA: not applicable; NS: p-value not significant; PR: prevalence ratio.
[a] Maximum n for each category may vary between variables due to missing data.
[b] χ^2 test of heterogeneity.
[c] χ^2 test for linear trend.
[d] Wald test.
[e] 1st tercile represents lowest socioeconomic status. The frequencies of children are not equal between terciles because categorization of this index was computed for households and attributed to individuals.

The overall prevalence of cough, nasal congestion, pneumonia, and pneumonia with fever were 44.4% (95% CI 41.0–47.9), 31.0% (95% CI 28.1–34.0), 2.63% (95% CI 2.08–3.33), and 1.28% (95% CI 1.00–1.68), respectively (Table 1). The highest prevalence proportions of cough (56.5%, 95% CI 51.6–61.3) and nasal congestion (43.5%, 95% CI 51.6–61.3) were recorded in the North region. For pneumonia and pneumonia with fever, the highest prevalence proportions were observed in the South/Southeast

Table 3. Prevalence of presumed pneumonia during the previous week among indigenous children under 5 years of age, with prevalence ratios and confidence intervals, according to household and sanitation (second level) characteristics. First National Survey of Indigenous People's Health and Nutrition, Brazil, 2008–2009

Variable	n[a]	Presumed pneumonia (%)	Crude PR[b] (95% CI[c])	Adjusted PR (95% CI)
Number of household residents			p=0.004[b]	p=0.004[c]
≤ 4	1448	1.86	1.00	1.00
5 to 8	2966	2.69	1.45 (0.95–2.21)	1.44 (0.94–2.21)
≥ 9	1645	3.53	1.90 (1.26–2.87)	1.93 (1.25–2.98)
Number of household residents <5 years			NS[b]	NS[c]
1	2066	2.25	1.00	1.00
2	2537	2.75	1.22 (0.78–1.90)	1.22 (0.78–1.90)
3	1007	3.50	1.55 (0.99–2.44)	1.57 (0.97–2.54)
≥ 4	412	2.26	1.00 (0.43–2.34)	1.03 (0.45–2.35)
Type of cooking fuel			NS[d]	NS[d]
Propane or natural gas	1475	2.32	1.00	1.00
Wood, coal, other	4602	2.75	1.18 (0.82–1.70)	1.17 (0.78–1.76)
Household heating			NS[d]	NS[d]
None	4634	2.36	1.00	1.00
Woodstove or other	275	2.47	1.05 (0.38–2.91)	0.84 (0.33–2.16)
Open fire	1157	3.77	1.60 (1.00–2.58)	1.47 (0.81–2.64)
Flooring			NS[d]	NS[d]
Ceramic	522	2.73	1.00	1.00
Cement	1780	1.97	0.72 (0.37–1.38)	0.74 (0.36–1.51)
Wood	1573	1.64	0.60 (0.29–1.23)	0.47 (0.22–1.02)
Dirt	2180	3.77	1.38 (0.73–2.59)	1.32 (0.63–2.76)
Walls			p=0.037[d]	NS[d]
Brick	2109	2.18	1.00	1.00
Mud	854	2.41	1.10 (0.62–1.98)	1.14 (0.66–1.98)
Wood	2209	2.90	1.33 (0.83–2.13)	1.16 (0.67–2.00)
Thatch	336	2.81	1.28 (0.56–2.97)	1.24 (0.51–3.02)
Canvas, plastic, other	567	3.78	1.73 (1.04–2.90)	1.48 (0.88–2.48)
Roofing			p=0.007[d]	p=0.023[d]
Clay tiles or concrete	1796	1.82	1.00	1.00
Zinc or asbestos sheet	2280	3.07	1.69 (1.05–2.71)	1.60 (0.95–2.69)
Wood or thatch	1947	3.08	1.69 (0.98–2.91)	1.87 (1.10–3.17)
Canvas, plastic, other	48	4.76	2.61 (0.40–17.0)	2.09 (0.33–13.11)
Source of drinking water			NS[d]	NS[d]
Faucet inside house	915	2.21	1.00	1.00
Faucet outside house	2980	2.91	1.32 (0.83–2.10)	1.27 (0.81–1.99)
Shallow well	489	2.72	1.23 (0.62–2.45)	1.25 (0.66–2.38)
River, lake, or reservoir	835	2.94	1.33 (0.73–2.44)	1.34 (0.70–2.59)
Other	858	1.74	0.79 (0.39–1.60)	0.92 (0.43–1.98)

NA: not applicable; NS: p-value not significant; PR: prevalence ratio.
[a] Maximum n for each category may vary between variables due to missing data.
[b] χ^2 test for linear trend.
[c] Wald test.
[d] χ^2 test of heterogeneity.

Table 4. Prevalence of presumed pneumonia during the previous week among indigenous children under 5 years of age, with prevalence ratios and confidence intervals, according to child perinatal (third level) characteristics. First National Survey of Indigenous People's Health and Nutrition, Brazil, 2008–2009

Variable	n[a]	Presumed pneumonia (%)	Crude PR (95% CI)	Adjusted PR (95% CI)
Birthplace			NS[b]	NS[b]
Hospital, healthcare units, other	3662	2.60	1.00	1.00
Village	2414	2.73	1.05 (0.68–1.61)	0.83 (0.53–1.30)
Type of birth			NS[b]	NS[b]
Vaginal	5367	2.65	1.00	1.00
Cesarean	628	2.59	0.98 (0.54–1.78)	1.26 (0.69–2.30)
Birthweight (grams)			p=0.005[b]	p=0.004[b]
≥2500	3664	2.54	1.00	1.00
<2500	300	5.29	2.08 (1.26–3.44)	2.17 (1.28–3.68)

NA: not applicable; NS: p-value not significant; PR: prevalence ratio.
[a] Maximum n for each category may vary between variables due to missing data.
[b] χ^2 test of heterogeneity.

(3.25, 95% CI 2.09–5.04) and Central-West regions (1.58, 95% CI 0.92–2.72), respectively (Table 1).

Table 2 shows prevalence proportions of pneumonia according to sociodemographic characteristics. No significant relationships were observed.

Pneumonia showed a statistically significant crude association with number of residents in the household (Table 3). The prevalence of pneumonia was higher in households with walls made of canvas, plastic or other materials (PR 1.73, 95% CI 1.04–2.90) and zinc or asbestos sheet roofing (PR 1.69, 95% CI 1.05–2.71), as well as in those that used firewood indoors for heating (PR 1.60, 95% CI 1.00–2.58).

Pneumonia was more prevalent in children with low birthweight (PR 2.08, 95% CI 1.26–3.44) and stunting (PR 1.57, 95% CI 1.03–2.39) (Table 4). Also, children who were hospitalized for acute respiratory infection during the previous year (PR 1.56, 95% CI 1.00–2.45) and those who had diarrhea during the previous week (PR 1.63, 95% CI 1.19–2.22) were more likely to present pneumonia (Table 5).

In the final multivariate model, pneumonia was more frequent among children living in the South/Southeast (PR 2.10, 95% CI 1.13–3.93) and North (PR 1.70, 95% CI 1.01–2.87) regions than in the Northeast. As can be seen in Figure 1, children living in households with more residents (PR 1.83, 95% CI 1.14–2.94) or in houses with wood or thatch roofing (PR 1.87, 95% CI 1.10–3.17), as well as children with low birthweight (PR 2.17, 95% CI 1.28–3.69) or stunting (PR 2.16, 95% CI 1.18–3.96), presented higher frequency of pneumonia. Pneumonia was less prevalent among children living in houses with wood flooring (PR 0.41, 95% CI 0.19–0.88) and those presenting low weight-for-age (PR 0.24, 95% CI 0.09–0.65).

Discussion

The findings presented here contribute to the literature on indigenous health in Brazil as it focuses on pneumonia, a major cause of disease and death of indigenous infants and children, based on a nationally representative sample. In one of the few previous studies carried out in Brazil, more than three-quarters of hospitalizations of indigenous Guarani children under 5 years old in the South/Southeast region were due to acute respiratory infection, thus exceeding the proportions of hospitalization for similar causes among other population segments in the region.[10] Several other studies of hospital morbidity and secondary datasets among indigenous peoples in Brazil similarly indicate that respiratory infection contributes importantly to disease load and abbreviates child survival.[14,19,20]

The prevalence of reported cough encountered for indigenous children nationally (44.4%) was similar to that reported for non-indigenous Brazilian children (43.5%),[25] but differences were observed between regions. Indigenous children in the North (56.5%) region presented greater prevalence of cough than those in all other regions. The prevalence proportions of nasal congestion and cough by region showed similar magnitude and distribution patterns, suggesting they reflected together the prevalence of common cold. The regional prevalence gradients of pneumonia and pneumonia with fever rates followed a different pattern than those observed for cough and nasal congestion, being most elevated in the South/Southeast (3.25% and 1.35%, respectively) and Central-West (2.96% and 1.58%, respectively), although differences with respect to the North were not significant. Unfortunately, we were unable to compare prevalence proportions of pneumonia and pneumonia with fever between indigenous and non-indigenous children because there are no comparable data from previous national surveys in Brazil.[21]

Disassociation between frequencies of respiratory symptoms (i.e., cough) and pneumonia have been attributed to inequity in the distribution of severe cases of the disease, which are more prevalent in populations with low income and restricted access to health services.[1,4] States in the South/Southeast and Central-West regions of Brazil are among those with the highest human

Table 5. Prevalence of presumed pneumonia during the previous week among indigenous children under 5 years of age, with prevalence ratios and confidence intervals, according to child nutrition and health (fourth level) characteristics. First National Survey of Indigenous People's Health and Nutrition, Brazil, 2008–2009

Variable	n[a]	Presumed pneumonia (%)	Crude PR (95% CI)	Adjusted PR (95% CI)
Weight-for-age (z-score)			NS[b]	NS[b]
≥−1	4173	2.59	1.00	1.00
<−1 and ≥−2	1402	2.89	1.12 (0.79–1.58)	0.95 (0.60–1.50)
<−2	439	1.94	0.75 (0.38–1.46)	0.38 (0.15–0.96)
Height-for-age (z-score)			p=0.034[b]	NS[b]
≥−1	2262	2.09	1.00	1.00
<−1 and ≥−2	1963	2.64	1.26 (0.83–1.91)	1.10 (0.65–1.86)
<−2	1747	3.30	1.57 (1.03–2.39)	1.57 (0.83–2.99)
Weight-for-height (z-score)			NS[b]	NS[b]
≥−1	5560	2.63	1.00	1.00
<−1 and ≥−2	336	1.98	0.75 (0.33–1.69)	0.71 (0.25–2.00)
<−2	82	0.71	0.27 (0.04–2.06)	0,00 (0.00–0.00)
Hospitalization during prior year			NS[c]	NS[c]
No	4931	2.48	1.00	1.00
Yes	1130	3.32	1.34 (0.91–1.96)	1.30 (0.89–1.90)
Hospitalization due to acute respiratory infection during prior year			p=0.05[c]	NS[c]
No	5530	2.51	1.00	1.00
Yes	531	3.94	1.56 (1.00–2.45)	1.29 (0.80–2.08)
Diarrhea during prior week			p=0.002[c]	NS[c]
No	4393	2.31	1.00	1.00
Yes	1658	3.76	1.63 (1.19–2.22)	1.28 (0.84–1.96)
Anemia			NS[b]	NS[b]
None	2417	2.33	1.00	1.00
Moderate	1957	2.72	1.17 (0.75–1.81)	1.12 (0.60–2.08)
Severe	991	3.31	1.42 (0.69–2.91)	1.81 (0.66–4.96)

NA: not applicable; NS: p-value not significant; PR: prevalence ratio.
[a] Maximum n for each category may vary between variables due to missing data.
[b] Wald test.
[c] χ^2 test of heterogeneity.

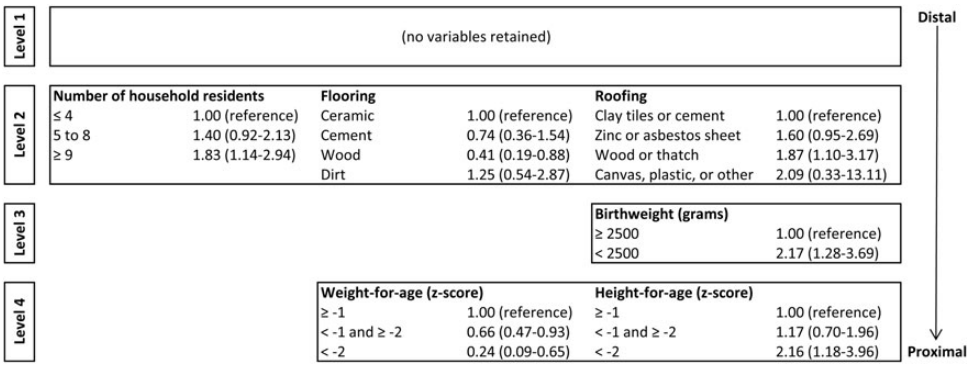

Figure 1. Final hierarchical model for presumed pneumonia during the previous week among indigenous children under 5 years of age. First National Survey of Indigenous People's Health and Nutrition, Brazil, 2008–2009. Values represent prevalence ratios with confidence intervals in parentheses. Geopolitical region was included as a control variable at all levels.

development indices for the general population. However, because these regions were colonized very early, are densely populated by non-indigenous peoples, and have a strong presence of commercial agriculture oriented towards national and international markets, many of their indigenous peoples suffer very adverse conditions in terms of land availability, subsistence, and dietary conditions.[15]

In this paper we address the relationships between pneumonia and socioeconomic and environmental factors among indigenous children in Brazil, a topic which has received little previous attention. The role of socioeconomic factors in the epidemiology of acute respiratory infection among children has been extensively investigated.[22,23] The only previous study of factors associated with respiratory infection among an indigenous population in Brazil showed that Guarani children living in households with monthly per capita income under US$30.00 were hospitalized 1.88 times more often than those living in households with higher income.[10] The National Survey did not show any association between income or maternal education and pneumonia.

The National Survey showed that pneumonia was associated with household size (number of residents) and physical characteristics of the house (roofing and flooring). The association with household size is consistent with research showing overcrowding to increase the likelihood of transmission of respiratory pathogens.[24,25] Similarly, associations between architectural aspects of the house and respiratory health are often attributable to certain construction materials and designs favoring indoor air pollution, dampness, and mold. Such conditions may increase the likelihood of respiratory allergies and infection, as was shown in studies carried out among indigenous peoples in South America[10,11,26] and elsewhere.[18,27]

Birthweight was inversely associated with pneumonia in the National Survey, a finding consistent with results from several other studies conducted among indigenous[10] and non-indigenous[25,28] children in Brazil. Children born underweight have higher risk of contracting or dying of pneumonia, as this condition is commonly associated with lowered immunity and structural and functional defects of the airways.

The role of undernutrition as a risk factor for death due to pneumonia has been reiterated in the results of various investigations.[1,29] In Brazil, greater fatality rates due to pneumonia have also been observed among undernourished children due to their greater susceptibility to infectious diseases.[28,30] In the National Survey, stunting was associated with higher risk of pneumonia even after controlling for environmental variables, a pattern consistent with a dose-response relationship, indicating that the disease prevalence increases with linear growth deficit.

The results of the National Survey revealed an unexpected protective effect of low weight-for-age for pneumonia, with a direct relationship between the two. Selective survivorship bias resulting from the transversal nature of the study may explain this finding. Because weight-for-age is more strongly associated with acute pneumonia, more severely undernourished children according to this index would have greater risk of contracting and dying from the disease. Consequently, these children would be excluded from prevalence calculations and, potentially, the direction of the association between low weight-for-age and the prevalence of pneumonia would be reversed. Offering support for this explanation, elevated mortality coefficients documented for indigenous children in Brazil, sometimes exceeding 100 deaths per 1000 live births, are closely associated with infectious, particularly respiratory, diseases.[13,14,20]

Several methodological limitations of the National Survey deserve attention. Pneumonia case definition based on reported symptoms could result in overestimation of pneumonia prevalence and consequent weakening of observed associations.[28,30] Furthermore, although data collection was not organized temporally by region, it occurred nationally over the course of one year, creating the possibility that some regional differences in prevalence of cough, nasal congestion, and pneumonia could result from seasonal variation. Another limitation derives from data regarding smoking in the child's domestic environment not having been collected by the National Survey. Finally, the cross-sectional design has important implications for the interpretation of results, since it is not possible to guarantee causal relationships between exposure and outcome. Nevertheless, the similarity between factors associated with pneumonia in our study and those reported in the literature,[1,23] except for the weight-for-age indicator, attests to the robustness of the data from the National Survey, which produced the first national and regional data on risk factors associated with pneumonia in indigenous children in Brazil.

In conclusion, the results of the National Survey presented here demonstrate that pneumonia is an important cause of illness among indigenous children in Brazil, with significant regional variation in prevalence. Demographic composition of households, materials used in constructing houses, and child nutritional status were the main factors associated with the disease. The association between pneumonia and household characteristics suggests that indoor home environmental quality is closely related to the respiratory health of indigenous children. Furthermore, the greater prevalence of pneumonia among children with stunting and born with low birthweight suggests that risk of pneumonia is increased by undernutrition, which in turn relates to broader sociodemographic and environmental conditions. Due to the epidemiological relevance of acute respiratory infection in indigenous populations in Brazil documented in this study, future investigations should be encouraged in order to more precisely and objectively identify pneumonia cases and associated factors, including in specific geographical and ethnic contexts.

Authors' contributions: AMC, BLH, RVS, JRW, ALE, and CEAC formulated the research concept and design. All authors participated in data collection. AMC, ALE, and RVS conducted the statistical analyses. AMC, CEAC, and JRW drafted the manuscript and all other authors read the paper and contributed to it. The final version was read and approved by all authors. AMC, BLH, and RVS are guarantors of the paper.

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