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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

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Abstract

OBJECTIVE To assess risk factors associated with hospital admission due to acute lower respiratory tract infection (ALRTI) in indigenous Guarani children <5 years of age in southern Brazil.
METHODS Population-based matched case–control study from May 2007 to June 2008 in 81 Guarani villages. Cases were defined as hospital admissions due to confirmed ALRTI. Two controls free from acute respiratory infection, matched according to age, sex and place of residence, were selected for each case at the time of the case's hospitalisation. Both cases and controls were recruited by a surveillance routine established for the study.
RESULTS The analysis was performed on 120 cases and 201 controls. The risk factors that remained significantly associated with hospitalisation due to ALRTI in the hierarchical multivariate conditional logistic regression were: low stable monthly per capita household income (<US$30.00 = OR: 2.77, $IC_{95\%}$: 1.51–5.10; no income= OR: 1.88, $IC_{95\%}$: 1.02–3.47); large number of persons in the household (6–9 = OR: 2.03, $IC_{95\%}$: 1.06–3.88; 10–16 = OR: 5.00, $IC_{95\%}$: 1.81–13.86); indoor exposure to fumes from burning firewood used for cooking (OR: 3.08, $IC_{95\%}$: 1.39–6.84);low maternal age (OR: 2.77, $IC_{95\%}$: 1.42–5.39); and low birthweight (OR: 6.12, $IC_{95\%}$: 1.44–26.13).
CONCLUSION Acute respiratory infections are a major cause of morbidity and mortality among Guarani children. Our study provides the first evidence about their determinants in indigenous peoples in Brazil that can help to better understand the epidemiology of respiratory infections in indigenous children.

keywords acute respiratory infection, pneumonia, indigenous peoples, children, population, case-control study

Introduction

Acute respiratory infection (ARI) remains a leading cause of morbidity and mortality worldwide, disproportionally affecting younger children (Fuchs *et al.* 2005; Rudan *et al.* 2008). Recent assessments of epidemiological trends in Brazil point to major achievements in reduction in morbidity and mortality due to infectious diseases (Barreto *et al.* 2011). The overall epidemiological picture documented for indigenous peoples in Brazil, however, suggests a very different pattern. ARI ranks high as cause of disease and death among indigenous groups, especially among children. Pneumonia constitutes the leading cause of hospitalisation in indigenous children in Brazil, often accounting for over 50% of all cases recorded (Coimbra *et al.* 2013; Lunardi *et al.* 2007; Orellana *et al.* 2007). Research conducted among Guarani Indians reported an even higher proportion of hospitalisations due to ARI, reaching 71.9% in children under 5 years of age and 78.4% in infants (Cardoso *et al.* 2010). Moreover, ARI accounts for more than two-thirds of all deaths of Guarani children under 5 years of age (Cardoso *et al.* 2011).

The identification of risk factors associated with ARI in different populations is paramount for the formulation of more effective policies and strategies to improve health globally (WHO 2009). Despite scientific advances in ARI epidemiology in Brazil (Victora *et al.* 1989, 1994; Fonseca *et al.* 1996a,b; César *et al.* 1997, 1999; Albernaz *et al.* 2003; Macedo *et al.* 2007; Prietsch *et al.* 2008), there is no available information about risk factors for ARI among indigenous peoples. This study reports the results of a population-based matched case–control study carried out among the Guarani Indians of southern Brazil to assess risk factors for hospital admission due to acute lower respiratory tract infection (ALRTI) in children under 5 years of age.

Population and methods

The Guarani constitute one of the most numerous indigenous groups in Brazil. The Guarani subgroups investigated in this study included the Mbyá and the Nhandeva, who inhabit a discontinuous territory with numerous villages in southern Brazil (Ladeira 2007). Families tend to be large and usually live in houses with dirt floors, wood or wattle-and-adobe walls, and palm thatch roofs. Guarani villages often lack sanitation and suffer from unpredictable resource availability due to environmental degradation and peripheral participation in the regional economy.

A matched case–control study was performed between 1 May 2007 and 30 June 2008 to investigate risk factors associated with hospitalisation due to ALRTI in Guarani children <5 years old residing in 83 villages in southern Brazil, in the following states: Rio Grande do Sul (32 villages), Santa Catarina (16), Paraná (4), São Paulo (26) and Rio de Janeiro (5). During the study period, two villages in the state of São Paulo were excluded from the study due to operational difficulties in collecting data. The total Guarani population in the remaining 81 villages included in this study was approximately 6000 individuals (20% under 5 years of age).

Cases were defined as Guarani children <5 years old residing in a participating village hospitalised for ALRTI within the study period. *Controls* were defined as Guarani children <5 years old free from acute respiratory signs and symptoms or other acute infections requiring the use of antibiotics 15 days before and 7 days after the date of hospital admission of the matched case.

Hospitalisation due to ALRTI was defined as in-hospital care $\geq$24 h, when the child presented chest indrawing and/or tachypnea in the presence of cough or difficult breathing, complemented by information on other clinical signs (crepitation, wheezing, stridor) and/or radiological evidence of lung disease (infiltrate), whenever available in the hospital records (PAHO 2001). Two controls with matching age, sex and place of residence were selected for each case. Controls were not previously hospitalised for ALRTI or resided in the same house as the matched case. Children selected as *controls* could subsequently become a *case* if they were hospitalised for ALRTI.

A surveillance routine was established to report hospitalisations possibly due to ARI in children and to recruit controls. Immediately after the identification of a case, the fieldworker responsible for monitoring a given village selected two controls based on a list of eligible children. All hospital records were reviewed by a paediatrician. Hospitalisations that could not be confirmed as ALRTI were excluded from the study.

A culturally adapted questionnaire focusing on known risk factors for ALRTI was administered to parents of cases and matched controls within 15 days of hospitalisation of the case. Data extracted from secondary medical records in the village included children's medical history, use of health services, birthweight, height and weight. The study variables and their corresponding categories of analysis are described in Figure 1 and Tables 1–3. Variables requiring further clarification are detailed below.

For the purposes of this study, *income* was defined as monetary earnings (e.g. salaries, pensions, government donations and craft sales) obtained during the month prior to hospitalisation of the case. *Income* was transformed into two indicators: (a) *stable household income per capita* (total household salaries and pensions divided by the number of household residents) and (b) *total household income per capita* (total household stable and unstable monetary earnings divided by the number of household residents). The *number of household goods* (refrigerator, gas stove, television, fan, DVD or VCR player, radio, mobile phone) was used as an indicator of the household's capacity to purchase.

The index *physical characteristic of the house* considered six items. For each item, a score of 0 or 1 was assigned as follows: flooring (dirt/wood = 0; others = 1), roofing (thatch/clapboard = 0; others = 1), type of walls (wood/wattle-and-daub = 0; others = 1), number of windows (none = 0; $\geq$ 1 = 1), bathroom with latrine and piped water (no=0, yes=1) and cooking fire (indoors without partitions = 0; outside or indoors in a partitioned kitchen = 1). This index was calculated as the ranked sum of all variables as follows: level 1 (score 0 to 2), level 2 (score 3 to 4) and level 3 (score 5 to 6), corresponding to putative decreasing risk of ALRTI (high, intermediate and low, respectively).

The nutritional assessment indexes weight-for-age (W/A), weight-for-height (W/H) and height-for-age (H/A) were calculated, and children were classified as well nourished (z-scores for W/A, W/H and H/A $\geq$ -1.00) or undernourished (any of the z-scores <-1.00) (WHO 2006).

Associations between variables were expressed as odds ratios (OR) and their corresponding confidence intervals (95% CI), estimated using conditional logistic regression.

Table 1 Distribution of cases and controls according to household socio-economic and paternal characteristics, with respective odds ratios (OR), confidence intervals (95% CI) and significance level (*P*)

Characteristics	Cases *n* (%)	Controls *n* (%)	Crude OR (95% CI)	*P*-value
Level 1				
Salary				
Yes	32 (26.9)	81 (40.5)	1.00	
No	87 (73.1)	119 (59.5)	1.97 (1.17–3.32)	0.01*
Retirement				
Yes	12 (10.1)	23 (11.4)	1.00	
No	107 (89.9)	178 (88.6)	1.13 (0.53–2.37)	0.75
Supplementary income from government				
No	69 (58.0)	129 (64.2)	1.00	
Yes	50 (42.0)	72 (35.8)	1.39 (0.80–2.42)	0.24
Earning from handcrafts sale				
Yes	61 (51.3)	103 (51.2)	1.00	
No	58 (48.7)	98 (48.8)	0.98 (0.58–1.64)	0.93
Food production				
Yes	58 (48.3)	87 (43.3)	1.00	
No	62 (51.7)	114 (56.7)	0.65 (0.35–1.20)	0.17*
Basic food baskets				
No	62 (51.7)	110 (54.7)	1.00	
Yes	58 (48.3)	91 (45.3)	1.18 (0.68–2.06)	0.54
Stable household income per capita (US$)			Linear trend	$P = 0.035$
≥ 30.00	28 (24.3)	80 (40.8)	1.00	
<30.00	51 (44.4)	61 (31.1)	2.77 (1.51–5.10)	0.001*
No income	36 (31.3)	55 (28.1)	1.88 (1.02–3.47)	0.043*
Total household income per capita (US$)			Linear trend	$P = 0.024$
≥ 30.00	38 (33.3)	87 (45.8)	1.00	
< 30.00	56 (49.1)	82 (43.2)	1.60 (0.95–2.70)	0.078*
No income	20 (17.6)	21 (11.0)	2.13 (0.98–4.61)	0.056*
Number of household goods			Linear trend	$P = 0.683$
≥ 5	28 (23.7)	62 (31.5)	1.00	
3–4	35 (29.7)	47 (23.9)	1.65 (0.80–3.40)	0.174*
1–2	33 (28.0)	44 (22.3)	1.82 (0.84–3.93)	0.128*
None	22 (18.6)	44 (22.3)	1.21 (0.53–2.77)	0.645
Paternal schooling (higher level in years)			Linear trend	$P = 0.159$
≥ 7	19 (26.4)	41 (31.3)	1.00	
1–6	44 (61.1)	48 (36.6)	2.18 (0.83–5.76)	0.11*
No schooling	9 (12.5)	42 (32.1)	0.32 (0.08–1.30)	0.11*
Paternal age (years)			Linear trend	$P = 0.441$
≥ 40	12 (11.8)	15 (8.2)	1.00	
30–39	18 (17.6)	47 (25.5)	0.54 (0.20–1.47)	0.23
20–29	50 (49.0)	97 (52.7)	0.67 (0.27–1.63)	0.37
<20	22 (21.6)	25 (13.6)	1.14 (0.42–3.11)	0.80

*Variables with $P < 0.20$ were included in the multivariate conditional logistic regression.
There is no adjusted OR for the level, because this is the first level of analysis, and only a single variable had $P < 0.05$ at the end of the multivariate conditional logistic regression.

Statistical analysis was performed using STATA software 9.0 (Stata Corp., College Station, TX).

The modelling strategy was based on a conceptual hierarchical model for the determination of ALRTI specifically proposed for Guarani children <5 years of age (Figure 1), following Victora *et al.* (1997). Variables situated in level 1 with a significance level of $P < 0.20$ in the univariate analysis were jointly included in a multivariate regression model for this level. A backward procedure was then used to progressively exclude variables, retaining only those with a significance level of $P < 0.05$.

An adjusted OR for each variable in level 2 was determined by conditional logistic regression including the variables retained in the previous hierarchical level. Those

Table 2 Distribution of cases and controls according to house, maternal and gestational characteristics, with respective odds ratios (OR), confidence intervals (95% CI) and significance level (*P*)

Characteristics	Cases *n* (%)	Controls *n* (%)	OR (95% CI) *P*-value Crude		Adjusted*	
Level 2						
Type of walls						
Brick	17 (14.3)	32 (16.2)	1.00		1.00	
Wooden plank	64 (53.8)	100 (50.8)	1.45 (0.69–3.05)	0.33	0.77 (0.33–1.78)	0.54
Baulk	15 (12.6)	23 (11.7)	1.50 (0.54–4.14)	0.44	0.78 (0.26–2.33)	0.66
Wattle and daub	15 (12.6)	27 (13.7)	1.27 (0.48–3.37)	0.63	0.89 (0.32–2.48)	0.82
Mixture	8 (6.7)	15 (7.6)	1.21 (0.40–3.66)	0.74	0.79 (0.25–2.56)	0.70
Roofing						
Clay tile	32 (26.7)	56 (27.9)	1.00		1.00	
Zinc/asbestos tile	61 (50.8)	112 (55.7)	0.91 (0.43–1.90)	0.80	0.74 (0.34–1.65)	0.47
Thatch/clapboard	19 (15.8)	21 (10.4)	2.02 (0.80–5.10)	0.14	1.68 (0.63–4.51)	0.31
Mixture	8 (6.7)	12 (6.0)	1.46 (0.49–4.73)	0.53	1.69 (0.47–6.05)	0.42
Flooring						
Ceramics	8 (6.7)	11 (5.6)	1.00		1.00	
Cement	19 (16.0)	36 (18.3)	0.73 (0.24–2.16)	0.57	0.59 (0.17–1.20)	0.40
Wood	19 (16.0)	33 (16.7)	0.81 (0.24–2.78)	0.74	0.48 (0.12–1.92)	0.30
Dirt	73 (61.3)	117 (59.4)	0.90 (0.33–2.45)	0.84	0.52 (0.16–1.67)	0.28
Faucet at home						
Yes	24 (21.4)	52 (27.2)	1.00		1.00	
No	88 (78.6)	139 (72.8)	1.59 (0.82–3.09)	0.17	1.18 (0.58–2.41)	0.64
Bathroom						
Yes, indoor	28 (23.3)	59 (29.6)	1.00		1.00	
Yes, outdoor	70 (58.3)	116 (58.3)	1.38 (0.75–2.53)	0.30	1.03 (0.54–1.97)	0.93
No	22 (18.4)	24 (12.1)	2.92 (1.18–7.22)	0.02	2.28 (0.85–6.11)	0.10†
Number of doors					Linear trend	*P* = 0.160
≥3	14 (11.8)	30 (15.0)	1.00		1.00	
2	46 (38.7)	59 (29.5)	1.58 (0.73–3.45)	0.24	1.52 (0.67–3.49)	0.32
1	59 (49.5)	111 (55.5)	1.08 (0.51–2.29)	0.83	0.78 (0.35–1.74)	0.54
Number of windows					Linear trend	*P* = 0.964
≥4	26 (22.0)	45 (22.5)	1.00		1.00	
2–3	35 (29.7)	62 (29.7)	0.96 (0.48–1.92)	0.92	1.13 (0.54–2.38)	0.74
1	11 (9.3)	31 (15.5)	0.62 (0.24–1.58)	0.32	0.63 (0.23–1.75)	0.38
None	46 (39.0)	62 (31.0)	1.30 (0.64–2.64)	0.48	1.10 (0.51–2.40)	0.80
Physical characteristics of the house Index					Linear trend	*P* = 0.096
Level 3	20 (22.5)	47 (33.6)	1.00		1.00	
Level 2	15 (16.8)	32 (22.9)	1.24 (0.50–3.06)	0.64	0.87 (0.31–2.45)	0.79
Level 1	54 (60.7)	61 (43.6)	2.22 (1.09–4.53)	0.03	1.74 (0.78–3.89)	0.18†
Place where child sleeps						
Bed/stage/lace	80 (69.6)	161 (82.6)	1.00		1.00	
Floor	35 (30.4)	34 (17.4)	2.74 (1.41–5.30)	0.003	2.80 (1.38–5.71)	0.005†
Number of persons in household					Linear trend	*P* = 0.006
2–5	55 (45.8)	123 (61.2)	1.00		1.00	
6–9	43 (35.8)	66 (32.8)	1.51 (0.92–2.48)	0.10	1.40 (0.82–2.40)	0.214
10–16	22 (18.3)	12 (6.0)	4.40 (1.92–10.08)	0.000	3.47 (1.47–8.16)	0.004†
Number of other children <5 in household					Linear trend	*P* = 0.023
≤ 1	32 (28.3)	86 (45.3)	1.00		1.00	
2	58 (51.3)	81 (42.6)	2.14 (1.22–3.79)	0.008	2.10 (1.15–3.83)	0.016†
3–6	23 (20.4)	23 (12.1)	2.88 (1.34–6.21)	0.007	2.25 (1.01–4.99)	0.047†
Number of other persons sleeping in the same room					Linear trend	*P* = 0.03
≤2	31 (26.7)	77 (38.9)	1.00		1.00	
3–6	62 (53.4)	107 (54.0)	1.33 (0.76–2.31)	0.315	1.19 (0.67–2.10)	0.554
7–15	23 (19.8)	14 (7.1)	6.85 (2.42–19.2)	0.000	4.18 (1.40–12.52)	0.011†

Table 2 (*continued*)

Characteristics	Cases n (%)	Controls n (%)	OR (95% CI) P-value Crude		Adjusted*	
Number of other children < 5 sleeping in the same room					Linear trend	P = 0.183
None	42 (37.8)	97 (51.3)	1.00		1.00	
1	53 (47.8)	75 (39.7)	1.71 (0.99–2.92)	0.05	1.47 (0.84–2.58)	0.177†
2–5	16 (14.4)	17 (9.0)	2.38 (1.03–5.48)	0.042	1.62 (0.66–4.00)	0.290
Number of other persons sleeping in the same bed					Linear trend	P = 0.221
≤ 1	17 (15.9)	53 (28.5)	1.00		1.00	
2	51 (47.7)	65 (34.9)	2.75 (1.35–5.59)	0.005	3.16 (1.48–6.73)	0.003†
2–10	39 (36.4)	68 (36.6)	1.96 (0.92–4.14)	0.08	1.89 (0.85–4.21)	0.118†
Number of other children <5 sleeping in the same bed						
None	60 (57.1)	128 (70.3)	1.00		1.00	
1–4	45 (42.9)	54 (29.7)	1.84 (1.07–3.16)	0.03	1.62 (0.92–2.88)	0.097†
Location of the main fire						
Kitchen indoor/outdoor	80 (74.1)	166 (87.4)	1.00		1.00	
Indoor, household without partitions	28 (25.9)	24 (12.6)	2.25 (1.15–4.41)	0.02	2.17 (1.09–4.33)	0.028†
Cooking inside the house with gas stove						
Always	33 (29.0)	69 (35.4)	1.00		1.00	
Sometimes, never	81 (71.0)	126 (64.6)	1.26 (0.72–2.23)	0.42	1.20 (0.65–2.19)	0.56
Cooking inside the house with wood stove						
Sometimes/never	87 (75.0)	156 (80.0)	1.00		1.00	
Always	29 (25.0)	39 (20.0)	1.47 (0.81–2.67)	0.20	1.28 (0.68–2.39)	0.44
Domestic heating						
No	62 (52.5)	105 (52.8)	1.00		1.00	
Open fire/wood stove	56 (47.5)	94 (47.2)	1.01 (0.57–1.80)	0.96	0.79 (0.42–1.50)	0.48
Alternative source of light (lamp/candle)						
No	35 (30.2)	72 (37.5)	1.00		1.00	
Yes	81 (69.8)	120 (62.5)	1.73 (0.92–3.28)	0.09	2.05 (1.02–4.11)	0.042†
Smokers at home (cigarette)						
No	69 (57.5)	121 (60.2)	1.00		1.00	
Yes	51 (42.5)	80 (39.8)	1.17 (0.72–1.92)	0.53	1.11 (0.66–1.86)	0.70
Smoker caregiver						
No	104 (87.4)	175 (87.9)	1.00		1.00	
Yes	15 (12.6)	24 (12.1)	1.14 (0.56–2.35)	0.71	1.05 (0.50–2.22)	0.89
Maternal age (years)						
26–45	32 (27.3)	89 (44.9)	1.00		1.00	
12–25	85 (72.7)	109 (55.1)	2.25 (1.34–3.78)	0.002	2.19 (1.27–3.78)	0.005†
Maternal schooling (higher level in years)					Linear trend	P = 0.672
≥ 7	14 (12.7)	37 (19.1)	1.00		1.00	
1–6	53 (48.2)	71 (36.6)	1.79 (0.82–3.89)	0.14	1.32 (0.58–2.99)	0.506
None	43 (39.1)	86 (44.3)	1.32 (0.60–2.92)	0.49	0.97 (0.41–2.26)	0.94
Maternal smoking during pregnancy						
No	83 (78.3)	131 (73.2)	1.00		1.00	
Yes	23 (21.7)	48 (26.8)	0.82 (0.44–1.53)	0.53	0.68 (0.34–1.36)	0.278
Maternal alcohol use during pregnancy						
No	101 (91.8)	171 (92.4)	1.00		1.00	
Yes	9 (8.2)	14 (7.6)	1.14 (0.47–2.77)	0.76	0.96 (0.37–2.47)	0.93

*The effect of each variable on the outcome was adjusted for the variable that remained with $P < 0.05$ in the multivariate analysis of the Level 1.

†Variables with $P < 0.20$ were included in the multivariate conditional logistic regression of the Level 2, together with the variable retained in the previous level.

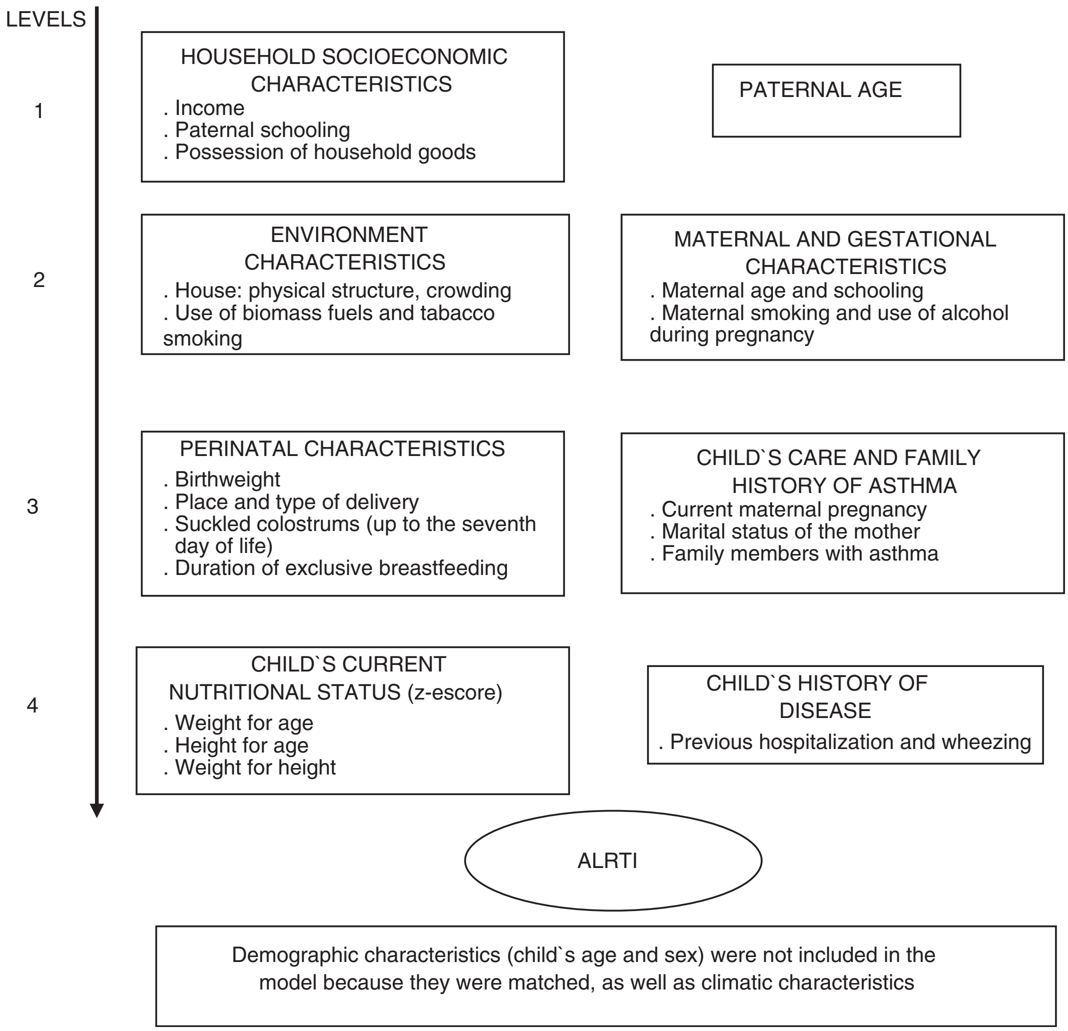

Figure 1 Conceptual hierarchical approach of acute lower respiratory tract infection (ALRTI) proposed for the Guarani indigenous children under 5 years old, Brazil.

variables exhibiting an OR with $P < 0.20$ for this level were jointly included in a conditional multivariate logistic regression model with the variables retained from level 1. As before, a backward procedure was used to retain those variables of level 2 showing statistically significant association with ALRTI ($P < 0.05$).

Analysis of subsequent hierarchical levels followed the same procedures as described for level 2. In the final model, the adjusted OR values for each variable were those mutually adjusted for the variables in the same hierarchical level and also for the variables retained from the previous hierarchical levels. The jackknife sampling–resampling procedure was used as a way to avoid potential unduly influence of certain observations on the results of the multivariate analyses (Abdi & Williams 2010).

The study was authorised by the Ethics Committee of the National School of Public Health (ENSP), the Brazilian National Committee for Research Ethics, the National Indian Foundation, the local Indigenous Health District Council, the community leaders of participating villages and the parents of each case and control child.

Results

We recorded 293 hospitalisations of children <5 years old with suspected ALRTI as the primary cause in the 81 villages participating in the study. Of these, 105 (35.8%) cases could not be contacted for subsequent interviews and 68 (23.2%) did not meet eligibility criteria during the revision of hospital records or could not be matched to controls. Thus, matched analysis was performed on 120 cases and 201 controls (81 trios and 39 pairs). This sample conferred a 90% power to detect an OR ≥ 2.5 with a 5% level of significance, if the prevalence of exposure varied between 14 and 71%. In 82.5% of cases and 73.1% of controls, interviews were performed within 7 days of the date of hospitalisation of the case.

No statistically significant differences were observed for either sex or age between the cases included in the analysis and those that were lost or excluded. However, an excess of hospitalisations due to pneumonia and to multiple hospitalisations for ALRTI in the same child was identified among the lost and excluded cases.

The distribution of cases and controls according to different categories of the variables investigated in this study, along with their corresponding OR, 95% CI and *P*-values are described in Tables 1–3. A protective crude effect against hospitalisation due to ALRTI was observed in children who lived in households with at least one salaried member (Table 1). Children living in households with stable or total income per capita <US$30.00 were hospitalised at least 1.6 times more frequently than their better off counterparts. Supplementary earnings, including government's social benefits, as well as local food production, did not prevent hospitalisations due to ALRTI.

Children living in households without bathrooms, in households classified at level 1 of the physical characteristics index or in households where children slept on the floor showed higher odds ($P < 0.20$) for hospitalisation due to ALRTI, after adjustment for stable household per capita income (Table 2). All indicators of overcrowding were directly associated with hospitalisation for ALRTI, as were indoor cooking fires in houses without partitions and use of smoke-producing light. The OR of hospitalisation was higher when the mother was younger. Maternal smoking, alcohol drinking during pregnancy or child's cohabitation with adult smokers did not show significant association with hospitalisation for ALRTI.

Children with low birthweight were more than six times as likely to be hospitalised due to ALRTI as children with adequate birthweight after adjusting for variables retained from previous hierarchical levels (Table 3). To a lesser degree, the same pattern was observed for baby bottle-feeding, family history of asthma and maternal pregnancy. No significant association was found with other perinatal factors, duration of exclusive breastfeeding or marital status of the mother. Among the variables considered in the proximal level of determination, undernourished children and children with previous hospitalisation and wheezing showed significantly higher odds for hospitalisation after adjusting for variables retained from previous hierarchical levels (Table 3).

Table 4 describes the final model of hierarchical multivariate conditional logistic regression of risk factors for hospitalisation. The lack of stable per capita household income was the only indicator in level 1 that remained significantly associated with higher odds of hospitalisation. Moreover, hospitalisation was significantly associated with number of persons in the household, cooking with firewood, young maternal age and low birthweight. Low W/A and previous hospitalisations, which were significantly associated with hospitalisation for ALRTI, lost statistical significance and were excluded from the final model, after jackknife procedure (low W/A: OR: 6.23, $IC_{95\%}$: 0.02–2111.75, $P = 0.53$; previous hospitalisations: OR: 12.27, $IC_{95\%}$: 0.00–31748.77, $P = 0.52$).

Discussion

Approximately 156 million cases of pneumonia are estimated to occur in children <5 years of age worldwide each year, with roughly 96% occurring in developing countries. Of this total, 7–13% of cases require hospitalisation, and the death toll is high (Rudan *et al.* 2008).

The role of socio-economic factors as determinants of ALRTI morbidity and mortality is well established (Victora *et al.* 1994; Graham 2001). Notwithstanding, the only socio-economic indicator shown in this study to have a significant and independent protective effect against hospitalisation due to ALRTI among Guarani children was stable household income per capita. Other socio-economic indicators used in this study were probably not specific enough due to important aspects of Guarani social organisation (e.g. reciprocity) that might blur eventual interhousehold economic differences (Ladeira 2007).

It has been reported that children living in houses constructed from non-industrialised materials are at higher risk of contracting ALRTI, probably because earth floors favour accumulation of domestic residues and dust (López-Bravo *et al.* 1997, Prietsch *et al.* 2008; Savitha *et al.* 2007). The combination of materials used in house construction and architectural style contributes to indoor air quality. One study addressing housing pattern and health among indigenous peoples in Ecuador showed that, in contrast with traditional housing that ensured more constant temperatures and provided better overall protection, many new houses were built with lower ceilings, had less air circulation and were built with a mix of materials of questionable quality (Kroeger 1980). Present-day Guarani houses differ greatly from those constructed with traditional indigenous architectural techniques, more closely resembling those commonly observed in poor rural areas throughout Brazil. The relatively homogeneous

Table 3 Distribution of cases and controls according to perinatal and nutritional characteristics, family history of asthma, disease history and aspects related to child care, with respective odds ratios (OR), confidence intervals (95% CI) and significance level (*P*).

Characteristics	Cases *n* (%)	Controls *n* (%)	OR (95% CI) *P*-value			
			Crude		Adjusted*	
Level 3						
Birthweight (grams)						
≥2500	70 (80.5)	132 (91.7)	1.00		1.00	
<2500	17 (19.5)	12 (8.33)	4.22 (1.52–11.75)	0.006	6.12 (1.44–26.13)	0.014†
Place of delivery						
Outside the village	76 (64.4)	124 (63.9)	1.00		1.00	
Village	42 (35.6)	70 (36.1)	1.03 (0.63–1.70)	0.9	0.87 (0.46–1.66)	0.67
Type of delivery						
Vaginal	108 (92.3)	169 (85.8)	1.00		1.00	
Caesarean	9 (7.7)	28 (14.2)	0.52 (0.24–1.15)	0.11	0.58 (0.22–1.51)	0.27
Child was fed with colostrum						
Yes	114 (96.6)	191 (98.4)	1.00		1.00	
No	4 (3.4)	3 (1.5)	2.21 (0.48–10.03)	0.3	1.67 (0.22–12.89)	0.622
Exclusive breastfeeding (in months)						
≤3	42 (41.6)	65 (37.1)	1.10 (0.54–2.20)	0.80	0.78 (0.31–2.00)	0.61
4–7	50 (49.5)	83 (47.4)	1.00		1.00	
≥8	9 (8.9)	27 (15.4)	0.62 (0.24–1.56)	0.31	0.50 (0.15–1.68)	0.26
Bottle use						
No	61 (52.1)	124 (62.3)	1.00		1.00	
Yes	56 (47.9)	75 (37.7)	1.76 (1.03–3.01)	0.04	1.89 (0.98–3.62)	0.055†
Family members with asthma						
No	103 (87.3)	187 (94.0)	1.00		1.00	
Yes	15 (12.7)	12 (6.0)	2.37 (1.01–5.56)	0.05	2.39 (0.74–7.79)	0.147†
Ongoing maternal pregnancy						
No	104 (92.0)	187 (95.4)	1.00		1.00	
Yes	9 (8.0)	9 (4.6)	1.78 (0.68–4.70)	0.24	2.32 (0.71–7.59)	0.163†
Marital status of the mother						
With partner	85 (74.6)	163 (82.3)	1.00		1.00	
Alone	29 (25.4)	35 (17.7)	1.56 (0.89–2.74)	0.12	0.93 (0.47–1.88)	0.849
Level 4						
Weight–for-age (z-score)						
≥−1	28 (36.4)	95 (70.9)	1.00		1.00	
<−1	49 (63.6)	39 (29.1)	4.14 (2.09–8.22)	0.000	5.65 (1.43–22.37)	0.014†
Weight-for-height (z-score)						
≥−1	50 (84.8)	96 (92.3)	1.00		1.00	
<−1	9 (15.2)	8 (7.7)	1.5 (0.48–4.73)	0.49	0.41 (0.05–3.59)	0.42
Height-for-age (z-score)						
≥−1	8 (11.8)	28 (26.4)	1.00		1.00	
<−1	60 (88.2)	78 (73.6)	2.98 (0.95–9.34)	0.06	12.83 (0.97–170.28)	0.053†
Previous hospitalisation						
No	47 (40.2)	178 (89.0)	1.00		1.00	
Yes	70 (59.8)	22 (11.0)	15.9 (6.86–36.88)	0.000	17.27 (3.98–75.02)	0.000†
Previous wheezing in the lifetime						
No	31 (25.8)	136 (68.0)	1.00		1.00	
Yes	89 (74.2)	64 (32.0)	9.54 (4.72–19.28)	0.000	40.51 (6.32–259.41)	0.001†

*The effect of each variable on the outcome was adjusted for the variables that remained with $P < 0.05$ in the multivariate analysis of the previous levels.

†Variables with $P < 0.20$ were included in the multivariate conditional logistic regression of their hierarchical level, together with the variables retained in the previous levels.

Table 4 Final model of hierarchical multivariate conditional logistic regression of risk factors to hospitalisation due to ALTRI in Guarani indigenous children under 5 years of age from southern and southeastern Brazil, 2007–2008.

Level	Characteristics	OR* (95% CI)	*P*-value
1 Socio-economic		Linear trend	$P = 0.035$
Stable household income per capita (US$)	≥ 30.00	1.00	
	<30.00	2.77 (1.49–5.16)	0.001
	No income	1.88 (1.01–3.50)	0.047
2 Environmental		Linear trend	$P = 0.001$
Number of persons in household	2–5	1.00	
	6–9	2.03 (1.02–4.03)	0.044
	10–16	5.00 (1.76–14.22)	0.003
Location of the main fire	Kitchen indoor/outdoor	1.00	
	Indoor, household without partitions	3.08 (1.28–7.45)	0. 013
Maternal			
Maternal age (years)	26–45	1.00	
	12–25	2.77 (1.34–5.71)	0.006
3 Perinatal			
Birthweight (grams)	≥ 2500	1.00	
	< 2500	6.12 (1.18–31.73)	0.031
4 –			

*The effect of each variable on the outcome was adjusted for the other variables of the same hierarchical level, which remained with $P < 0.05$ at the end of the multivariate analysis of the respective level, and for those variables retained in the previous levels.
The OR presented refer to the magnitudes of adjusted associations achieved on the input level of each of those variables in the hierarchical model.
The OR, confidence intervals (95% CI) and significance level (*P*) presented in the final model were corrected by jackknife approach.

pattern of contemporary Guarani housing could explain the absence of an association between house type and hospitalisation due to ALRTI.

Another relevant feature of Guarani houses is that they are usually inhabited by large numbers of individuals. In this study, overcrowding was associated with higher rates of hospitalisation for ALRTI among Guarani children. This association might imply a rising probability of interpersonal transmission of respiratory pathogens with a rising number of household occupants, as has been shown elsewhere (Victora *et al.* 1994; Simoes 2003).

The Guarani usually use firewood for indoor cooking and heating. Guarani children living in households with no partition and indoor fire were at significantly higher risk of hospitalisation for ALRTI. The relationship between suspended particulate matter from biomass burning indoors and risk of ALRTI, particularly severe pneumonia, has been described for various communities and is likely to negatively affect the general defence mechanisms of the lungs, including its mucociliary function, which leads to increased susceptibility to respiratory diseases (Banerji *et al.* 2009, Dherani *et al.* 2008; Simoes 2003). Children are particularly susceptible to domestic air pollution.

Previous hospitalisation and history of wheezing were associated with risk of hospitalisation for ALRTI among Guarani children, although both did not remain in the final model. Wheezing in particular often correlates with ALRTI in young children. In the case of Guarani children, this association is probably related to domestic environmental conditions that chronically expose children to airborne pathogens and pollutants from early age (Victora *et al.* 1994; Kusel *et al.* 2007; Castro-Rodrigues *et al.* 2008). Indoor smoke produced by firewood and overcrowding are likely the most significant environmental and demographic factors that might explain risk of hospitalisation due to ALRTI in Guarani children. More research is needed to assess the role played by the overall structural and environmental characteristics of Guarani houses and their effects on child respiratory health.

The protective effect of older maternal age on children's respiratory health has been noted previously in Brazil (Victora *et al.* 1994; César *et al.* 1997; Prietsch *et al.* 2008) and was further substantiated in this study. Although most authors explain this association based on common sense arguments (i.e. the older the mother, the more experienced she should be in caring for her child), little is known from a sociocultural perspective about mothering and childcare in Guarani society.

Different from what has been observed in non-indigenous Brazilian populations (César *et al.* 1997; Prietsch *et al.* 2008), we did not find maternal schooling to have a protective effect. Maternal schooling correlates inversely with maternal age in Guarani women. It is possible that the effect of schooling in Guarani mothers on the odds of hospitalisation due to ALRTI will become relevant as more women have access to elementary school. Birthweight was found to be inversely associated with hospitalisations for ALRTI, thus agreeing with several other studies of risk factors for ARI (Victora *et al.* 1994; Fonseca *et al.* 1996a,b; Simoes 2003). This is because young children born with low birthweight are at higher risk of contracting and dying from pneumonia, as this condition is commonly associated with shortened breastfeeding, undernutrition and impaired biological immunity.

The association between undernutrition (low W/A) and hospitalisation for ALRTI reported by several studies carried out in Brazil emphasise the mutual effect of undernutrition and increased susceptibility to infectious diseases, as the child's cell-mediated immune response may be compromised due to thyme lymphocyte depression (Victora *et al.* 1994; López-Bravo *et al.* 1997, Fonseca *et al.* 1996a,b). Such association was not observed in Guarani children. This may have resulted from the hierarchical approach undertaken, in which the effects of more proximal variables were adjusted for a large number of potentially explanatory variables from more distal levels.

Although the protective effect of breastfeeding against hospitalisation due to ALRTI is widely accepted (Bachrach *et al.* 2003; Victora *et al.* 1994; López-Bravo *et al.* 1997, Dharmage *et al.* 1996), this association was not found for Guarani children. More research on this topic in needed as little is known about breastfeeding and other baby feeding practices among the Guarani.

Some methodological features of the present study deserve additional comments. The potential cases of ALRTI that could not be included in the analyses due to lack of interviews or matched controls showed higher frequencies of pneumonia and severe pneumonia and were younger than the cases included in the study. As younger children with these outcomes probably have higher levels of exposure to risk factors, this may have resulted in underestimations of the association. The inclusion criteria adopted in this study were sufficiently specific for the diagnosis of ALRTI. Nevertheless, due to the different levels of hospital complexity to which Guarani children are referred, and because the quality of records in these institutions varies greatly, some Guarani children suffering from recurrent bronchial hyperactivity and asthma may have been included among our cases. Previous hospitalisation by ALRTI, considered an ineligibility criterion for controls, could have resulted in overestimated OR. Otherwise, our criteria did not exclude controls who were hospitalised for any other reason or who suffered from ARI as outpatients, which possibly attenuated such potential bias.

Some methodological advances of the study design warrant highlighting. The study clearly defined a population from which to recruit cases and controls, thus minimising selection bias; established a specific village-based surveillance system, which allowed for the identification of the local reference hospital network and improved recruitment; collected data for more than 1 year, thus covering all seasons; and conducted the interviews within a short period of time to minimise recall bias.

References to the Guarani people first appeared in the 16th century narratives of early European travellers to coastal Brazil and neighbouring countries in southern South America. Since then, their various groups suffered from direct persecution, enslavement and infectious disease epidemics, leading to depopulation and significant changes in their economic system and social organisation (Souza 2002; Lugon 2010). Today, they live in villages within small federal reserves, in camps of various sizes along highways, and on the periphery of major cities, where they suffer from precarious to hazardous living conditions. Despite the fact that the southern Brazilian states are considered the most developed in the country, indigenous children living in this region face disproportionate risk of early death and high prevalence rates of undernutrition and infectious and parasitic disease (Scolari *et al.* 2000; Pícoli *et al.* 2006; Cardoso *et al.* 2010, 2011; Brandelli *et al.* 2012). Recent epidemiological analyses of hospital morbidity and mortality among the Guarani Indians in Brazil confirm their vulnerability to acute respiratory infections, with smaller children carrying the heaviest disease burden.

The hierarchical conceptual model that oriented the present analysis allowed for the identification of absence of stable per capita household income, number of persons in the household, indoor exposure to firewood smoke, young maternal age and low birthweight as risk factors for ALRTI in Guarani children. These findings are of great relevance for critically analysing the preventive strategies and treatment protocols currently used by the local health services attending Guarani children.
Although the primary focus of the study was not Guarani sanitation, housing or economic conditions, the findings clearly underscore their marginal living conditions and thus call attention to the accentuated social and health inequities that continue to exist in Brazil despite governmental efforts to bridge such gaps. The study also indicates that more research is needed to assess ARI in this indigenous population, including the investigation of other possible risk factors that were not assessed here,

the aetiology of the disease, plus new avenues for the analysis of the role played by food and nutrition, the environment and indoor air pollutants in respiratory health.

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