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Lower respiratory tract infection in children younger than five years of age and adverse pregnancy outcomes related to household air pollution in Bariloche (Argentina) and Temuco (Chile)

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Abstract

Objective—To evaluate the association between household air pollution (HAP) with lower respiratory tract infection (LRTI) in children younger than 5 years old and adverse pregnancy outcomes.

Study Design and Setting—This retrospective cohort study took place in two cities in Patagonia. Using systemic random sampling, we selected households in which at least one child <5 years had lived and/or a child had been born alive or stillborn. Trained interviewers administered the questionnaire.

Results—We included 926 households with 695 pregnancies and 1,074 children. Household cooking was conducted indoors in ventilated rooms and the use of wood as the principal fuel for cooking was lower in Temuco (13% vs 17%). In exposed to biomass fuel use, the adjusted OR for LRTI was 1.87 (95% CI 0.98-3.55; $p = 0.056$) in Temuco and 1.12 (95% CI 0.61-2.05; $p = 0.716$) in Bariloche. For perinatal morbidity, the OR was 3.11 (95% CI 0.86-11.32; $p = 0.084$) and 1.41 (95% CI 0.50-3.97; $p = 0.518$), respectively. However, none of the effects were statistically significant ($p > 0.05$)

Conclusion—The use of biomass fuel to cook in traditional cookstoves in ventilated dwellings may increase the risk of perinatal morbidity and LRTI.

Keywords

Lower respiratory tract illness; household air pollution; adverse pregnancy outcomes; children; Latin America

Introduction

Globally, about 3 billion people depend on solid fuels for cooking (400 million people use coal and 2.6 billion use traditional biomass). Among this population, three percent live in Latin American countries (LAC). Households in developing countries commonly use wood as their primary cooking fuel, followed by charcoal and gas. Moreover, only five percent of the people who use biomass fuels for cooking have access to clean cookstoves (Legros et. al., 2009).

The use of biomass fuels in poorly ventilated dwellings results in high levels of household air pollution (HAP). In fact, HAP contributed to approximately 3.5 million deaths in 2010 and accounts for 4.5% of the global burden of disease (Lim et. al., 2012, Smith et. al., 2014).

There are different models of traditional cookstoves, ranging from three-stone open fires to closed models, and are made of various materials (i.e. bricks, metal, concrete). Stoves can include a chimney or a hood. Closed traditional stoves with chimneys enclose the fire and exhaust particulate matter and combustion byproducts, minimizing HAP (World Bank, 2011, Legros et. al., 2009).

Lower tract respiratory infection (LRTI) is a common cause of illnesses in children younger than five years of age and are the leading cause of global childhood mortality (Benguigui et. al., 1999, Nair et. al., 2010, Wardlaw et. al., 2006). In fact, in LAC, 12% of under-five deaths are caused by pneumonia (World Health Organization, 2010). Annually, 15 million preterm births occur worldwide and 32 million infants are born small for gestational age in low-income and middle-income countries (World Health Organization, 2011, Blencowe et. al., 2012, Lee et. al., 2013). These two neonatal conditions are well known causes of increased morbidity, mortality and lifetime disability.

HAP has been linked to an increased risk of LRTIs and adverse perinatal outcomes (Bruce et. al., 2000, Burki, 2011). Systematic reviews have reported 1.8, 1.4, and 1.5 fold increases in the odds of LRTIs, low birth weight (LBW), and stillbirths respectively, all of which are associated with HAP (Pope et. al., 2010, Dherani et. al., 2008). Since 1995, the reduction of HAP related to the use of solid fuels for cooking has been identified as a potential intervention for preventing pneumonia in children (Kirkwood et. al., 1995). In Latin America, a few studies have examined the association between HAP and LRTI or adverse perinatal outcomes. Those studies were conducted in Brazil (Fonseca et. al., 1996, Victora et. al., 1994), Guatemala (Smith et. al., 2010, Smith et. al., 2011, Smith et. al., 2000, Boy et. al., 2002) and Peru (Yucra et. al., 2011). Argentina contributed to a nine-country survey regarding biomass use among pregnant women; however, this study did not explore its association with health outcomes (Kadir et. al., 2010). To our knowledge, studies exploring the impact of HAP and child or maternal health have not been conducted in Argentina or

Chile or in any other upper-middle income countries with similar use of biomass fuel or sociodemographic characteristics.

Preliminary data from the PRISA study (Rubinstein et. al., 2011), which is an ongoing population-based cohort study conducted within four cities in Argentina, Chile and Uruguay, showed a higher than average exposure to HAP in Bariloche (Argentina) and Temuco (Chile) with 21% and 26% of households exposed, respectively. Figure S1 (supplementary data) shows the conceptual framework and the proposed relation between exposure, outcomes and other relevant variables.

The main objective of this study was to evaluate whether exposure to HAP in Bariloche and Temuco is related to LRTI in children less than 5 years old and adverse pregnancy outcomes.

Methods

Study Design

This retrospective cohort study aimed to explore the effect of HAP due to solid fuels in pregnant women and children under five years of age. Our primary objective was to estimate the effect of HAP on the incidence, hospital admissions, and deaths caused by LRTI (pneumonia and bronchiolitis) in children <5 years. Our secondary aim was to evaluate whether adverse pregnancy outcomes were associated with exposure to HAP.

Population and Sampling

The study was conducted in two cities, Bariloche (Argentina) and Temuco (Chile), with 134,000 and 245,000 residents, respectively, according to the most recent census data (Instituto Nacional de Estadística y Censos, 2010, Instituto Nacional de Estadísticas, 2002). Both cities are located in cold areas of the Argentine or Chilean Patagonia.

In the 2-stage sampling strategy, census radii were first selected according to the percentage of the population with high risk of HAP from cooking with biomass fuels in poorly vented dwellings, based on data from the PRISA study (Rubinstein et. al., 2011). Next, households within the chosen census radii were selected by systematic random sampling from a randomly selected starting point using a sampling interval proportional to the size of each census radius.

Households were eligible to participate in the study if at least one child under the age of five had resided in the home in the past five years and/or a child had been born alive or stillborn in the household in the last 3 years. Households were then included in the study if a key informant was able and willing to give written consent.

Questionnaire Design and Data Collection

Data were collected between January 2013 and February 2014 using a questionnaire designed for face-to-face verbal administration. During the household visit, a trained interviewer administered the questionnaire to the mother or, if this was not possible, to a key informant. We collected information related to LRTI, children's perinatal and health history, adverse pregnancy outcomes, history of pregnancies reaching more than six months

gestational age, exposure to biomass fuels for cooking and heating in the last five years, and socio-demographic characteristics. The interviewer registered all types of cookstoves (clean; traditional cookstoves with or without chimney) by direct observation. Birth weight and total number of pneumococcal vaccine doses were assessed from personal health records. Data related to deaths or hospitalizations due to respiratory causes were ascertained by examining medical records retrieved from the local health facilities.

Exposure

A standardized questionnaire was used to collect information related to the type of fuel used for cooking (wood, coal, gas, electricity, or other, such as crop waste), and the amount of time (per day, days per week, and total years) of use of each type of fuel. The number of hours of use for each type of fuel per year was then calculated. HAP exposure was subsequently defined as the use of wood or coal as the *primary* fuel used for cooking when the hours/year of use of wood or coal was higher than the hours/year for that of gas or electricity. We also explored the use of biomass fuel for cooking for more than 200 hours/year as the exposure variable (Perez-Padilla et. al., 1996).

Other variables related to HAP exposure were analyzed including: cookstove type; presence of ventilation (a window that can be opened in the kitchen); children or pregnant women sleeping in the same room used for cooking; and time spent by children in the kitchen while cooking was being done with biomass. Cookstove type was categorized as: clean cookstove (gas or electric); closed traditional cookstove with or without chimney, or open fire.

Outcomes

We collected information related to episodes of bronchiolitis and pneumonia diagnosed by a physician in the previous year. In addition, we asked about the number of treatments with $\beta 2$ agonist medications or antibiotics. Treatment was used as a cross-reference to verify the episode of bronchiolitis or pneumonia. We also gathered information about children's lifetime history of hospitalizations due to pneumonia or bronchiolitis. LRTI was defined as at least one episode of bronchiolitis or pneumonia in the last year. An LRTI-related hospitalization was defined as at least one event during the child's lifetime. Perinatal morbidity was a composite outcome that included LBW (birth weight less than 2500 g) or pre-term birth (less than 37 weeks of gestation).

Potential Confounders

Critical overcrowding was defined as when the number of inhabitants divided by the number of rooms (excluding bathroom/s and kitchen) was higher than three. Educational attainment of the mother or the primary caregiver of the child was analyzed as a categorical variable (primary, secondary, or tertiary education). Environmental tobacco exposure (ETS) was considered present if someone had smoked inside the house at least one day in the week prior to the survey.

The use of biomass for heating purposes was analyzed as a dichotomous variable and included in the models as a potential confounder.

Women who smoked at all during pregnancy were considered as “smokers during pregnancy”, whereas women who quit smoking when they found out about their pregnancy were considered as “non-smokers during pregnancy” for the analysis. Women also reported comorbidities pre-existing or during pregnancy (i.e. high blood sugar or high blood pressure).

According to national vaccination programs (the same in both countries), pneumococcal vaccine schedule was considered complete for child's age for three doses received in children over one year of age, two doses in children between 4 and 12 months, and one dose in children between 2 and 4 months. Complete vaccination for age was assessed by key informant report. Asthma in children <5 years is difficult to diagnose and can be categorized in different ways (i.e. wheezing children). For this reason, we also asked about the use of preventive treatment with inhaled corticosteroids and/or long acting β_2 agonists, which was included as a confounder in our analysis. Children's overall health status was assessed by means of proxy, using the SF-36 question.

Statistical Analysis

We estimated a sample size of 450 households per site, based on a statistically significant alpha level of 0.05 and a statistical power of 80% while assuming a LRTI incidence between 50/1,000 and 60/1,000 (Nair et. al., 2010), and an increased risk of LRTI in exposed children (OR) between 1.45 and 2.10 (Dherani et. al., 2008).

We described the frequency and distribution of population variables in each location. We used generalized estimating equations (GEE) models to examine the association between household exposure to biomass fuels (HAP) and development of LRTI, LRTI mortality, and adverse pregnancy outcomes, while accounting for potential correlation within households. Relevant variables considered to be potential confounders were added to the models. Additionally, we tested first-order interaction terms involving the exposure variable and other covariates of interest (educational attainment, overcrowding, and location). Because of the presence of a statistically significant interaction between location (Bariloche or Temuco) and exposure in LRTI models, they were analyzed separately. The statistical significance of these terms was evaluated using the log likelihood test at a 0.05 significance level. We assessed the overall goodness-of-fit of the final model through the Hosmer and Lemeshow test (Hosmer and Lemeshow, 2000) and performed model diagnostics, including deviance residuals and delta-beta statistics. Separate analyses were performed using children and pregnancies as the unit of analysis. Statistical analysis was performed using Stata Statistical Software version 11.0. (StataCorp., 2009).

Results

Population Characteristics

The study included 926 households (450 in Bariloche and 476 in Temuco), with information on 695 pregnancies (356 in Bariloche and 339 in Temuco) and 1,074 children (537 in each site); data on pregnancy outcomes were missing for one pregnancy. Information was obtained from a household key informant, though the mother always gave information

specific to pregnancy. The primary caregiver was the person who was primarily responsible for the care of the child, whether they were a family member or not. The refusal rate was lower than 10%.

Table 1 shows the main characteristics of households, pregnancies, and children. Compared to Temuco, households in Bariloche were of lower socioeconomic status, had primary caregivers who were less educated, were more overcrowded (26.7% vs 1.7%), and had children with a higher exposure to ETS (31.3% vs 9.1%).

The characteristics of the women and their pregnancies were different between the two locations. Bariloche had a slightly higher rate of adolescent pregnancies (22.3% vs 18.6%), more women who smoked during pregnancy (21.4% vs 13.6%), less cesarean delivery (30.1% vs 44.1%), and a lower mean birth weight by 140 grams. Women in Temuco reported higher rates of high blood sugar or diabetes (11.9% vs 2.8%) and lower rates of hypertension during pregnancy (6% vs 13%). In both places, more than 90% of pregnancies had four or more prenatal care visits.

The characteristics of children were similar between the two locations, with the exception of lower rates of LBW (3.3% vs 7.8%) and preterm birth (6.5% vs 8.8%) in Temuco, and a higher proportion of breastfed children in Bariloche. In both sites, 15% of children were receiving preventive asthma treatment and more than 95% had their immunization schedule complete. No child included in the study had a history of tuberculosis.

The different types of cooking fuels and cookstoves used are described in Table 2. In both cities, closed traditional cookstoves were used for cooking with biomass fuels (see Figure S2 in the supplementary data). In Temuco, 15.8% of traditional cookstoves did not have chimneys and the use of wood or charcoal as the *primary fuel* source for cooking was slightly lower than in Bariloche (13% vs 17%). The percentage of households using biomass for more than 200 hours/year was similar in both study sites (27.6% in Bariloche and 26.3% in Temuco). Also in both cities, more than 93% of households used gas or electricity for cooking and most households reported cooking indoors in ventilated rooms. Irrespective of the fuel used for cooking, most households in both sites used wood or coal to heat their homes.

LRTI and Exposure to HAP

The association between LRTI and exposure to HAP as well as to other factors, by location, is shown in Table 3. In Bariloche, 29.1% of children had at least one event of LRTI in the previous year. The unadjusted OR for LRTI in those exposed to HAP was 1.35 (95% CI 0.84-2.18; $p = 0.215$). After adjusting for the use of wood or charcoal as a heating fuel, kitchen without ventilation (a window that can be opened), overcrowding, educational attainment of the primary caregiver, TB exposure, ETS, prematurity, LBW, breastfeeding, age, any dose of pneumococcal vaccine, health status as reported by proxy, and asthma preventive treatment, the adjusted OR for LRTI remained non-significant at 1.12 (95% CI 0.61-2.05; $p=0.716$).

In Temuco, 58.7% of children had at least one LRTI event. The unadjusted OR for LRTI in those exposed to HAP was 1.50 (95% CI 0.88-2.56; $p = 0.136$). The adjusted OR of LRTI in exposed children (adjusted for the use of wood or charcoal as a heating fuel, overcrowding, educational attainment of the primary caregiver, TB exposure, ETS, prematurity, LBW, breastfeeding, age, any dose of pneumococcal vaccine, health status as reported by proxy, and asthma preventive treatment) was 1.87 (95% CI 0.98-3.55; $p = 0.056$).

Table 4 shows the association between hospital admissions due to LRTI with HAP and other factors. In Bariloche, 11.2% of children were hospitalized at any point during their lifetime due to a LRTI. The unadjusted and adjusted ORs for hospital admissions in exposed children were 1.01 (95% CI 0.49-2.10; $p = 0.977$) and 0.75 (95% CI 0.31-1.78; $p = 0.514$), respectively.

The prevalence of hospital admissions in Temuco was 6.2%. The unadjusted and adjusted ORs for hospital admission in children exposed to HAP were 1.74 (95% CI 0.73-4.14; $p = 0.210$) and 1.16 (95% CI 0.44-3.06; $p = 0.757$), respectively.

Only one death was reported in the study. Specifically, in Bariloche, a five-month baby, born prematurely, with respiratory problems a few days before death (maternal report).

Perinatal Morbidity and Exposure to HAP

For each location, the association between perinatal morbidity and exposure to HAP as well as to other factors is shown in Table 5. The prevalence of perinatal morbidity in Bariloche was 12.4%. The unadjusted OR in pregnancies exposed to HAP was 1.59 (95% CI 0.72-3.50). After adjusting for the use of wood or charcoal as heating fuel, overcrowding, ETS exposure, pre-existing high blood pressure or hypertension, history of preeclampsia/eclampsia, smoking during pregnancy, high blood sugar or diabetes during the pregnancy, educational attainment, and maternal age, the adjusted OR was 1.41 (95% CI 0.50-3.97; $p = 0.518$).

Temuco had a lower prevalence of perinatal morbidity (6.5%), but showed a significant association between pregnancies exposed to HAP and perinatal morbidity (unadjusted OR 2.94; 95% CI 1.07-8.03; $p = 0.036$). The adjusted OR for perinatal morbidity in pregnancies exposed to HAP was 3.11 (95% CI 0.86-11.32; $p = 0.084$) after adjusting for the use of wood or charcoal as heating fuel, ETS exposure, pre-existing high blood pressure or hypertension, pre-existing high blood sugar or diabetes, history of preeclampsia/eclampsia, smoking during pregnancy, high blood sugar or diabetes during the pregnancy, educational attainment, and maternal age.

As interaction between location and HAP was only found in the models in which LRTI was the outcome, we analyzed both sites jointly when perinatal morbidity was examined as the outcome of interest. We did not find a significant association between perinatal morbidity and HAP exposure (adjusted OR 2.10; 95% CI 0.93-4.74; $p = 0.076$).

In Temuco, one stillbirth was reported (sixth month of pregnancy; weight 420 grams); additional data related to this pregnancy were not available

Figure 1 shows all adjusted ORs for the associations between exposure to biomass fuels in the households with LRTI and adverse pregnancy outcomes.

Additional Analysis

We explored the variable of more than 200 hours/year of exposure to biomass fuel for cooking in the multivariate analysis, but did not find statistically significant results. The OR for LRTI was 1.25 (95% CI 0.70-2.22) for Bariloche and 1.20 (95% CI 0.75-1.93) for Temuco. For perinatal morbidity, the OR for Bariloche was 0.86 (95% CI 0.31-2.33) and for Temuco was 2.28 (95% CI 0.67-7.73).

Because Temuco had a prevalence of traditional cookstoves without chimney of 15.8%, we analyzed this variable as exposure, yielding an OR for LRTI of 1.29 (95% CI 0.70-2.40) and an OR of 1.05 (95% CI 0.21-5.21) for perinatal morbidity.

Finally, we conducted a sensitivity analysis comparing the most exposed (use of wood or charcoal as the *primary fuel*) and the non-exposed (exclusive use of gas). These results reinforce the directionality of the results shown above, as demonstrated through smaller changes in the ORs and narrower confidence intervals.

Discussion

The present study explored the relation between LRTI and adverse pregnancy outcomes with HAP in Bariloche and Temuco. The results of this study found no significant association between the exposure and the two outcomes. Even though the association between LRTI and HAP in Temuco was higher compared to Bariloche, it was not significant (OR 1.87; 95% CI 0.98-3.55; $p = 0.056$).

While the association between perinatal morbidity and exposure to HAP was not significant, the association in Temuco was stronger and at the margin of statistical significance, with OR 3.11 (95% CI 0.86-11.32; $p = 0.084$).

Our results in Chile were consistent with several observational studies conducted in low and middle-income countries with higher prevalence of biomass fuel use. However, previously published studies have found an association between the exposure to solid fuel smoke and the occurrence of LRTI in children younger than five years of age and adverse pregnancy outcomes (Tielsch et. al., 2009, Ramesh Bhat et. al., 2012, Mahalanabis et. al., 2002, Lakshmi et. al., 2013, Amegah et. al., 2012).

One of the possible factors contributing to the different results in Bariloche and Temuco is the higher use of traditional cookstoves without chimney in Temuco. This may explain the stronger association between the use of biomass fuels for cooking and LRTI and perinatal morbidity. The protective effect of chimneys in traditional cookstoves has been explored in other studies (Boy et. al., 2002, Thompson et. al., 2011). Another possible factor is the varying levels of ambient air pollution (Sanhueza H et. al., 2006).

The little or no effect of cooking with biomass fuels in Bariloche and Temuco may be related to the lower levels of exposure compared to other studies, given by the absence of

open fire cooking in the households included in the present study, and the high prevalence of cooking in ventilated rooms. For example, two case-control studies conducted in Brazil (Victoria et. al., 1994, Fonseca et. al., 1996) studied populations with low exposure to HAP and also did not find a significant association with LRTI. In addition, Murray et al. (2012) have shown an ameliorating effect of room ventilation on HAP exposure.

To our knowledge, this is the first study exploring the association between HAP and maternal and child health in the Southern Cone of Latin America. Our investigation reflects the actual use of biomass fuel in two cities from upper-middle income countries, which is very different from the patterns observed in poorer countries. These two Patagonian cities have a generalized use of biomass fuel for heating in fireplaces, high access to gas and a significant amount of households relying in biomass fuels for cooking. Interestingly, the characteristics of our population in terms of biomass fuel use and cookstove characteristics (vented combustion, the use of closed traditional cookstoves with chimneys, ventilated rooms) resemble the improvement interventions proposed by previous studies conducted in low-middle income countries (Smith et. al., 2010).

Some limitations of this study need to be discussed. First, given that the characteristics of the exposure and outcomes were obtained through interviews, participants are subject to recall bias. For instance, the exposure variable represents the average use of biomass fuel in the last five years and we cannot specify the temporal relationship between the exposure and the outcome. Also, in this regard the differences observed between study sites regarding LRTI events could be related to under-reporting of mild events in Bariloche, associated with the lower educational level of the caregivers. Previous studies have demonstrated that parents with lower educational level tend to provide less accurate reports, but become more reliable as the severity of the event increases (D'Souza-Vazirani et. al., 2005). Recall bias in our study could be also due to the seasonality of LRTI, particularly for Temuco as this data was collected throughout the winter season.

On the other hand, the interviews complemented with the direct observation of household kitchens in relation to the type of cookstove (traditional vs. clean) and ventilation (with and without chimney) which are known to be factors related to adverse health outcomes. Secondly, our exposure variable has not been used previously. In previous published studies (Regalado et. al., 2006, Ramirez-Venegas et. al., 2014, Ramirez-Venegas et. al., 2006), more than 200 hours per year of biomass fuel was used to define the threshold of exposure (Perez-Padilla et. al., 1996). Because we observed that households using more than 200 hours per year were also using gas as the primary fuel (for more hours than biomass), we decided to create a more conservative variable defining as principal fuel for cooking, the one with more hours per year of use. We believe this definition accurately reflects the reality in Temuco and Bariloche since the majority of households in these cities have access to clean fuels. Also, the results were similar and not significant with the two variables. Finally, both cities, particularly in Temuco, the general use of biomass for heating cannot be separated with one effect from the other, even though it was considered in the multivariate analysis.

In conclusion, our findings may support that cooking with biomass fuels in improved traditional cookstoves with ventilation appeared to have less adverse health outcomes than

open fire, and provided support to expand the use of clean cookstoves in low resource settings. While the use of clean fuels is widespread in Bariloche and Temuco, families continue to rely on the use of biomass fuel for cooking. The use of biomass fuel for cooking, even in ventilated dwellings, may increase the risk of perinatal morbidity and LRTI. These findings have important implications in the future interventions aimed at reducing HAP in countries in which the use of gas and electricity have not yet completely replaced the use of biomass fuels in household cooking.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Practical Implications

Despite the widespread availability of clean fuels in middle-income settings, many families still rely on the use of biomass fuel for cooking. The use of biomass fuel, even in ventilated dwellings, might increase the risk of perinatal morbidity and LRTI. These findings have important implications for the design of future interventions aimed at reducing HAP in countries, in which the use of gas and electricity have not fully replaced biomass fuels.

Figure 1. Adjusted OR (95% CI) for LRTI events, LRTI hospital admissions and perinatal morbidity per country. Temuco (Chile) in red and Bariloche (Argentina) in blue.

Table 1
Main Characteristics of Households, pregnancies and children in Bariloche (Argentina)
and Temuco (Chile)

		Number of households (%)		
		Overall sample n=926	Bariloche n=450	Temuco n=476
<i>Household Characteristics</i>				
Critical Overcrowding *		128 (13.8)	120 (26.7)	8 (1.7)
TB exposure		34 (3.7)	17 (3.8)	17 (3.6)
ETS [#] exposure		184 (19.9)	141 (31.3)	43 (9.1)
Educational attainment of the primary caregiver/mother:				
	Primary education	238 (25.8)	185 (41.2)	53 (11.2)
	Secondary education	466 (50.4)	242 (53.9)	224 (47.2)
	Tertiary education	220 (23.8)	22 (4.9)	198 (41.7)
		Number of pregnancies (%)		
		Overall sample n=695	Bariloche n=356	Temuco n=339
<i>Maternal and Pregnancy Characteristics</i>				
Maternal age				
	19	141 (20.5)	79 (22.3)	62 (18.6)
	20-34	478 (69.5)	250 (70.4)	228 (68.5)
	>35	69 (10.0)	26 (7.3)	43 (12.9)
Self-report of high blood sugar or diabetes		50 (7.2)	10 (2.8)	40 (11.9)
Self-report of high blood pressure or hypertension		76 (11)	43 (12.1)	33 (9.8)
Self-report of other chronic conditions (pre-existence) [‡]		73 (10.5)	30 (8.4)	43 (12.7)
4 or more antenatal care visits		650 (94.1)	337 (95.7)	313 (92.3)
Self-report of high blood sugar or diabetes during pregnancy		51 (7.3)	19 (5.3)	32 (9.4)
Self-report of hypertension during pregnancy		66 (9.6)	46 (13)	20 (6)
Self-report of Preeclampsia/Eclampsia		12 (1.9)	5 (1.6)	7 (2.2)
Smoke during pregnancy		122 (17.6)	76 (21.4)	46 (13.6)
Cesarean delivery		255 (36.9)	107 (30.1)	148 (44.1)
Birth weight, grams, (SD)		3.320 (0.520)	3.253 (0.557)	3.393 (0.466)
		Number of children (%)		
		Overall sample n=1074	Bariloche n=537	Temuco n=537
<i>Children Characteristics</i>				
Girls, n, (SD)		529 (49.3)	263 (49)	266 (49.5)
Mean Age, years (SD)		2.52 (1.47)	2.53 (1.42)	2.51 (1.52)
Birth weight, grams (SD)		3.314 (0.537)	3.246 (0.542)	3.386 (0.523)
Preterm birth		82 (7.7)	47 (8.8)	35 (6.5)
Low birth weight		59 (5.6)	42 (7.8)	17 (3.3)
Never breastfed		61 (5.7)	23 (4.2)	38 (7.1)
Complete immunization (referred)		986 (96.3)	484 (97.2)	502 (95.4)
Any dose of pneumococcal vaccine (by observation of records)		420 (39.1)	317 (59.0)	103 (19.2)
Regular or bad health reported by proxy		168 (15.7)	63 (11.8)	105 (19.6)

	Number of households (%)		
	Overall sample n=926	Bariloche n=450	Temuco n=476
Illnesses (referred)			
Bronchopulmonary dysplasia	4 (0.4)	2 (0.4)	2 (0.4)
Heart condition	15 (1.4)	9 (1.7)	6 (1.1)
Asthma	85 (7.9)	22 (4.1)	63 (11.7)
Preventive asthma treatment	160 (15.2)	75 (14.9)	85 (16.1)

* Number of inhabitants/number of rooms (excluding bathroom and kitchen)>3

Environmental tobacco smoke

¥ Anemia, Rheumatoid Arthritis, Asthma, Depression/Psychiatric Illness, Epilepsy, Scleroderma, Gastritis/Ulcer, Hypothyroidism/Hyperthyroidism, Insulin resistance, Lupus, Purple, Antiphospholipid syndrome and other hematologic disorders, Sinusitis, Cancer

Table 2
Characteristics of Exposure to biomass fuels at Households, pregnancies and children

	Number of households (%)		
	Whole sample n=926	Bariloche n=450	Temuco n=476
<i>Exposure at household level</i>			
Use of wood or charcoal as principal cooking fuel	138 (14.9)	76 (16.9)	62 (13)
Type of cookstove ^o :			
-Clean (only) [∞]	675 (73)	333 (74.2)	342 (71.9)
-Traditional cookstove with ventilation	174 (18.8)	115 (25.6)	59 (12.4)
-Traditional cookstove without ventilation	76 (8.2)	1 (0.2)	75 (15.8)
Kitchen without window that can be opened	196 (21.6)	152 (34.0)	44 (9.6)
Exclusive use of wood or charcoal for cooking	29 (4.1)	17 (4.9)	12 (3.4)
Cooking fuel used (more than one fuel per household)			
-Gas or electricity	900 (97.4)	436 (97.3)	464 (97.5)
-Wood or charcoal	312 (34.1)	164 (37.3)	148 (31.1)
-Kerosene	4 (0.4)	1 (0.2)	3 (0.6)
-Other	2 (0.2)	1 (0.2)	1 (0.2)
Heating fuel used (more than one fuel per household)			
-Gas or electricity	448 (49)	307 (69.9)	141 (29.6)
-Wood or charcoal	661 (72.3)	241 (55)	420 (88.2)
-Kerosene	59 (6.7)	0	59 (12.4)
-Other	1 (0.1)	0	1 (0.2)
Number of pregnancies (%)			
	Whole sample n=695	Bariloche n=356	Temuco n=339
<i>Exposure at individual level (pregnancies)</i>			
Use of wood or charcoal as principal cooking fuel	107 (15.4)	63 (17.7)	44 (13)
Exposure to biomass while sleeping during pregnancy	37 (5.4)	36 (10.3)	1 (0.3)
Number of children (%)			
	Whole sample n=1074	Bariloche n=537	Temuco n=537
<i>Exposure at individual level (children)</i>			
Use of wood or charcoal as principal cooking fuel	166 (15.5)	93 (17.3)	73 (13.6)
Average of biomass exposure during the day, hours (SD)	2.33 (2.94)	2.15 (1.65)	2.73 (4.76)
Exposure to biomass while sleeping	117 (10.9)	110 (20.6)	7 (1.3)

^o Direct observation, more than one cookstove per household

[∞] The only coookstove in the house is clean (gas or electricity)

Table 3

Exposure to IAP and other factors, and its association with LRTI events (bivariate analysis).

	Bariloche				Tenuco			
	n (%)	LRTI (%)	OR (95%CI)	p	n (%)	LRTI (%)	OR (95%CI)	p
All infants	537 (100)	156 (29.1)	-	-	537 (100)	315 (58.7)	-	-
Exposure to IAP								
Use of wood or charcoal as principal cooking fuel								
Yes	93 (17.3)	32 (34.4)	1.35 (0.84-2.18)	0.215	73 (13.6)	49 (67.1)	1.50 (0.88-2.56)	0.136
No	444 (82.7)	124 (27.9)	-	-	464 (86.4)	266 (57.3)	-	-
Traditional cookstove without ventilation								
Yes	1 (0.2)	1 (100)	1	-	86 (16.0)	53 (61.6)	1.16 (0.72-1.89)	0.537
No	535 (99.8)	155 (29.0)	-	-	451 (84.0)	262 (58.1)	-	-
Kitchen without ventilation								
Yes	193 (36.2)	76 (39.4)	2.13 (1.45-3.14)	0.000	48 (9.3)	26 (54.2)	0.81 (0.44-1.48)	0.496
No	340 (63.8)	80 (23.5)	-	-	471 (90.8)	277 (58.8)	-	-
Wood or charcoal as a heating fuel								
Yes	294 (56.1)	96 (32.7)	1.51 (1.03-2.25)	0.036	477 (88.8)	275 (57.7)	0.68 (0.39-1.21)	0.193
No	230 (43.9)	56 (24.4)	-	-	60 (11.2)	40 (66.7)	-	-
Average hours of biomass exposure during the day (SD)	2.15 (1.65)	2.58 (1.90)	1.24 (0.98-1.58)	0.076	2.73 74.76)	3.26 (5.66)	1.41 (0.70-2.83)	0.335
Exposure to biomass while sleeping								
Yes	110 (20.6)	32 (29.1)	1.00 (0.63-1.60)	0.984	732 (1.3)	5 (71.4)	1.75 (0.34-9.11)	0.506
No	424 (79.4)	123 (29.0)	-	-	529 (98.7)	310 (58.6)	-	-
Critical Overcrowding *								
Yes	159 (29.6)	49 (30.8)	1.13 (0.75-1.70)	0.554	13 (2.42)	7 (53.9)	0.78 (0.24-2.54)	0.683
No	378 (70.4)	107 (28.3)	-	-	524 (97.6)	308 (58.8)	-	-
TB exposure								
Yes	23 (4.3)	10 (43.5)	1.97 (0.84-4.63)	0.120	17 (3.2)	8 (47.1)	0.61 (0.23-1.61)	0.319
No	514 (95.7)	146 (28.4)	-	-	520 (96.8)	307 (59.0)	-	-
ETS# exposure								
Yes	169 (31.5)	58 (34.3)	1.44 (0.97-2.13)	0.069	49 (9.2)	28 (57.1)	0.92 (0.50-1.69)	0.791
No	368 (68.5)	98 (26.6)	-	-	486 (90.8)	286 (58.9)	-	-

	Bariloche				Temuco			
	n (%)	LRTI (%)	OR (95%CI)	p	n (%)	LRTI (%)	OR (95%CI)	p
Educational attainment of the primary caregiver:								
Primary education	223 (41.6)	62 (27.8)	1.30 (0.50-3.42)	0.594	59 (11.0)	35 (59.3)	0.98 (0.54-1.77)	0.938
Secondary education	287 (53.5)	88 (30.7)	1.49 (0.58-3.88)	0.410	258 (48.1)	149 (57.8)	0.90 (0.62-1.31)	0.595
Tertiary education	26 (4.9)	6 (23.1)	ref	-	219 (40.9)	131 (59.8)	ref	
Mean Age (SD)	2.53 (1.42)	2.49 (1.29)	0.97 (0.85-1.10)	0.627	2.51 (1.52)	2.82 (1.36)	1.38 (1.23-1.56)	0.000
Preterm birth								
Yes	47 (8.8)	13 (27.7)	0.93 (0.48-1.81)	0.829	35 (6.5)	21 (60.0)	1.14 (0.56-2.33)	0.715
No	490 (91.3)	143 (29.2)	-	-	501 (93.5)	294 (58.7)	-	-
Low birth weight								
Yes	42 (7.8)	15 (35.7)	1.40 (0.72-2.70)	0.324	17 (3.3)	7 (41.2)	0.48 (0.17-1.30)	0.150
No	495 (92.2)	141 (28.5)	-	-	492 (96.7)	293 (59.5)	-	
Never breastfed								
23 (4.3)	6 (26.1)	0.86 (0.33-2.23)	0.761	38 (7.1)	24 (63.2)	1.20 (0.61-2.37)	0.595	
Ever breastfed								
513 (95.7)	149 (29.0)	-	-	496 (92.9)	289 (58.3)	-	-	
Any dose of pneumococcal vaccine (records)								
317 (59.0)	95 (30.0)	1.12 (0.76-1.64)	0.564	103 (19.2)	62 (60.2)	1.08 (0.69-1.67)	0.738	
No pneumococcal vaccine								
220 (41.0)	61 (27.7)	-	-	434 (80.8)	253 (58.3)	-	-	
Regular or bad health reported by proxy								
63 (11.8)	42 (66.7)	6.31 (3.58-11.11)	0.000	105 (19.6)	93 (88.6)	8.22 (4.23-15.99)	0.000	
Good, very good or excellent health by proxy								
469 (88.2)	113 (24.1)	-	-	431 (80.4)	222 (51.5)	-	-	
Reference of asthma								
Yes	22 (4.1)	19 (86.4)	17.45 (5.08-59.87)	0.000	63 (11.7)	60 (95.2)	19.31 (5.57-66.99)	0.000
No	514 (95.9)	137 (26.7)	-	-	474 (88.3)	255 (53.8)		
Preventive asthma treatment								
Yes	75 (14.3)	62 (82.7)	18.54 (9.82-35.00)	0.000	85 (16.1)	76 (89.4)	7.72 (3.74-15.92)	0.000
No	451 (85.7)	93 (20.6)	-	-	444 (83.9)	234 (52.7)	-	-

* Number of inhabitants/number of rooms (excluding bathroom and kitchen)>3

Environmental tobacco smoke

Statistically significant results are shown in italic

Table 4

Exposure to IAP and other factors, and its association with LRTI hospital admissions (bivariate analysis).

	Bariloche			Temuco		
	n (%)	LRTI Admissions (%)	OR (95%CI)	p	n (%)	LRTI Admissions (%)
All	537 (100)	60 (11.2)			33 (6.2)	
Exposure to IAP						
Use of wood or charcoal as principal cooking fuel						
Yes	93 (17.3)	10 (10.8)	1.01 (0.49-2.10)	0.977	73 (13.6)	7 (9.6)
No	444 (82.7)	50 (11.3)	-	-	464 (86.4)	26 (5.6)
Traditional cookstove without ventilation						
Yes	1 (0.2)	0	1	-	86 (16.0)	6 (7.0)
No	535 (99.8)	60 (11.2)	-	-	451 (84.0)	27 (6.0)
Kitchen without ventilation						
Yes	193 (36.2)	26 (13.5)	1.45 (0.83-2.55)	0.197	48 (9.3)	1 (2.1)
No	340 (63.8)	34 (10.0)	-	-	471 (90.8)	30 (6.4)
Wood or charcoal as a heating fuel						
Yes	294 (56.1)	38 (12.9)	1.66 (0.91-3.00)	0.096	477 (88.8)	30 (6.3)
No	230 (43.9)	20 (8.7)	-	-	60 (11.2)	3 (5.0)
Average hours of biomass exposure during the day (SD)	2.15 (1.65)	3.00 (2.45)	1.35 (1.03-1.77)	0.029	2.73 (4.76)	1.33 (0.58)
Exposure to biomass while sleeping						
Yes	110 (20.6)	16 (14.6)	1.58 (0.84-2.99)	0.160	732 (1.3)	0
No	424 (79.4)	42 (9.9)	-	-	529 (98.7)	32 (6.1)
Critical Overcrowding *						
Yes	159 (29.6)	17 (10.7)	0.93 (0.50-1.73)	0.831	13 (2.42)	2 (15.4)
No	378 (70.4)	43 (11.4)	-	-	524 (97.6)	31 (5.9)
TB exposure						
Yes	23 (4.3)	2 (8.7)	0.85 (0.19-3.77)	0.833	17 (3.2)	1 (5.9)
No	514 (95.7)	58 (11.3)	-	-	520 (96.8)	32 (6.2)
ETS# exposure						
Yes	169 (31.5)	23 (13.61)	1.39 (0.79-2.46)	0.257	49 (9.2)	5 (10.2)
No	368 (68.5)	37 (6.39)	-	-	500 (90.8)	28 (4.8)

	Bariloche				Temuco			
	n (%)	LRTI Admissions (%)	OR (95%CI)	p	n (%)	LRTI Admissions (%)	OR (95%CI)	p
Educational attainment of the primary caregiver:								
No	368 (68.5)	37 (10.1)	-	-	486 (90.8)	28 (5.76)	-	-
Primary education	223 (41.6)	20 (9.0)	1	-	59 (11.0)	3 (5.1)	1.57 (0.40-6.25)	0.518
Secondary education	287 (53.5)	40 (13.9)	1.64 (0.93-2.9)	0.086	258 (48.1)	23 (8.9)	2.95 (1.26-6.93)	0.013
Tertiary education	26 (4.9)	0	-	-	219 (40.9)	7 (3.2)	ref	-
Mean Age (SD)	2.53 (1.42)	2.59 (1.22)	1.03 (0.85-1.24)	0.774	2.51 (1.52)	2.55 (1.53)	1.02 (0.81-1.28)	0.886
Preterm birth								
Yes	47 (8.8)	8 (17.0)	1.77 (0.79-3.97)	0.164	35 (6.5)	3 (8.6)	1.43 (0.41-4.94)	0.574
No	490 (91.3)	52 (10.6)	-	-	501 (93.5)	30 (6.0)	-	-
Low birth weight								
Yes	42 (7.8)	7 (16.7)	1.65 (0.69-3.93)	0.258	17 (3.3)	2 (11.8)	1.86 (0.41-8.53)	0.422
No	495 (92.2)	53 (10.7)	-	-	492 (96.7)	31 (6.3)	-	-
Never breastfed	23 (4.3)	2 (8.7)	0.70 (0.16-3.16)	0.645	38 (7.1)	3 (7.9)	1.36 (0.40-4.62)	0.623
Ever breastfed	513 (95.7)	58 (11.3)	-	-	496 (92.9)	30 (6.1)	-	-
Any dose of pneumococcal vaccine (records)	317 (59.0)	36 (11.4)	1.04 (0.61-1.80)	0.875	103 (19.2)	2 (1.9)	0.26 (0.06-1.08)	0.064
No pneumococcal vaccine	220 (41.0)	24 (10.9)	-	-	434 (80.8)	31 (7.1)	-	-
Regular or bad health reported by proxy	63 (11.8)	17 (27.0)	4.19 (2.18-8.03)	0.000	105 (19.6)	17 (16.2)	5.33 (2.59-11.00)	0.000
Good, very good or excellent health by proxy	469 (88.2)	39 (8.3)	-	-	431 (80.4)	15 (3.5)	-	-
Reference of asthma								
Yes	22 (4.1)	12 (54.6)	11.87 (4.85-29.04)	0.000	63 (11.7)	14 (22.2)	6.74 (3.19-14.21)	0.000
No	514 (95.9)	47 (9.14)	-	-	474 (88.3)	19 (4.0)	-	-
Preventive asthma treatment								
Yes	75 (14.3)	25 (33.3)	6.08 (3.34-11.04)	0.000	85 (16.1)	13 (15.3)	3.81 (1.82-7.96)	0.000
No	451 (85.7)	34 (7.5)	-	-	444 (83.9)	20 (4.5)	-	-

* Number of inhabitants/number of rooms (excluding bathroom and kitchen)>3

Environmental tobacco smoke

Statistically significant results are shown in italic

Table 5

Exposure to IAP and other factors, and its association with perinatal morbidity (bivariate analysis).

	Bariloche				Temuco			
	n (%)	Perinatal-morbidity (%)	OR (95%CI)	p	n (%)	Perinatal-morbidity (%)	OR (95%CI)	p
All pregnancies	356	44 (12.4)			339	21 (6.5)		
Exposure to IAP								
Use of wood or charcoal as principal cooking fuel								
Yes	63 (17.7)	11 (17.5)	1.59 (0.72-3.50)	0.248	44 (13)	6 (13.6)	2.94 (1.07-8.03)	0.036
No	293 (82.3)	33 (11.3)	-	-	295 (87.0)	15 (5.1)	-	-
Traditional cookstove without ventilation								
Yes	1 (0.3)	0	1	-	57 (16.8)	5 (8.8)	1.59 (0.56-4.54)	0.384
No	355 (99.7)	44 (12.4)	-	-	382 (83.2)	16 (5.7)	-	-
Kitchen without ventilation								
Yes	139 (39.2)	14 (10.1)	0.72 (0.36-1.44)	0.348	30 (9.2)	1 (3.3)	0.47 (0.06-3.65)	0.472
No	216 (60.9)	30 (13.89)	-	-	295 (90.8)	20 (6.8)	-	-
Wood or charcoal as a heating fuel								
Yes	197 (56.9)	24 (12.2)	0.91 (0.46-1.78)	0.782	306 (90.3)	19 (6.23)	1.03 (0.23-4.63)	0.970
No	149 (43.1)	19 (12.8)	-	-	33 (9.73)	2 (6.1)	-	-
Exposure to biomass while sleeping								
Yes	36 (10.3)	3 (8.3)	0.59 (0.15-2.27)	0.440	1 (0.3)	1 (100)	1	-
No	312 (89.7)	39 (12.5)	-	-	336 (99.7)	20 (6.0)	-	-
Critical Overcrowding*								
Yes	103 (28.9)	11 (10.7)	0.89 (0.42-1.87)	0.750	7 (2.1)	2 (28.6)	6.57 (1.20-36.10)	0.030
No	253 (71.1)	33 (13.0)	-	-	332 (97.9)	19 (5.7)	-	-
ETS# exposure								
Yes	106 (29.8)	13 (12.3)	1.09 (0.53-2.22)	0.821	23 (6.8)	1 (4.4)	0.67 (0.09-5.20)	0.698
No	250 (70.2)	31 (12.4)	-	-	314 (93.2)	20 (6.4)	-	-
Educational attainment								
Primary education	129 (36.3)	15 (11.6)	2.05 (0.32-19.96)	0.375	39 (11.5)	4 (10.3)	2.02 (0.56-7.31)	0.282
Secondary education	208 (58.6)	28 (13.5)	2.54 (0.25-16.71)	0.503	168 (49.7)	9 (5.4)	1.01 (0.37-2.79)	0.986
Tertiary education	19 (5.1)	1 (5.6)	ref	-	131 (39.8)	7 (5.3)	-	-

		Bariloche		Temuco		p	OR (95%CI)	p	OR (95%CI)
	n (%)	Perinatal-morbidity (%)	Perinatal-morbidity (%)	n (%)	Perinatal-morbidity (%)				
Maternal age		24.02 (6.10)		26.12 (7.04)					
>19	79 (22.3)	12 (15.2)	1.23 (0.57-2.62)	62 (18.6)	5 (8.2)	0.601	1.48 (0.51-4.32)	0.476	
>35	26 (7.3)	2 (7.7)	0.61 (0.14-2.72)	43 (12.9)	3 (7.0)	0.518	1.24 (0.34-4.55)	0.745	
20-34	250 (70.4)	30 (12.0)	ref	228 (68.5)	13 (5.7)	-	ref	-	
Self-report of high blood sugar or diabetes									
Yes	10 (2.8)	1 (10.0)	0.85 (0.10-6.95)	40 (11.9)	6 (15.0)	0.881	3.31 (1.20-9.09)	0.021	
No	345 (97.2)	43 (12.5)		297 (88.1)	15 (5.1)				
Self-report of high blood pressure or hypertension									
Yes	43 (12.1)	9 (20.9)	2.28 (1-5.22)	33 (9.8)	7 (21.2)	0.051	5.99 (2.20-16.31)	0.000	
No	313 (87.9)	35 (11.2)	-	303 (90.2)	13 (4.3)	-			
Self-report of other chronic conditions (pre-existence) [‡]									
Yes	30 (8.4)	6 (20.0)	1.94 (0.71-5.31)	43 (12.7)	4 (9.3)	0.199	1.68 (0.54-5.24)	0.374	
No	326 (91.6)	38 (11.7)	-	296 (87.3)	17 (5.8)	-	-	-	
Self-report of high blood sugar or diabetes during pregnancy									
Yes	19 (5.3)	3 (15.8)	1.40 (0.40-4.98)	32 (9.4)	4 (12.5)	0.599	2.43 (0.76-7.72)	0.133	
No	337 (94.7)	41 (12.2)	-	307 (90.6)	17 (5.6)	-	-	-	
Self-report of hypertension during pregnancy									
Yes	46 (13)	9 (19.6)	1.88 (0.82-4.31)	20 (6)	4 (20.0)	0.134	5.32 (1.57-18.02)	0.007	
No	307 (87.0)	34 (11.1)	-	313 (94.0)	14 (4.5)	-	-	-	
Self-report of Preeclampsia/Eclampsia									
Yes	5 (1.6)	1 (20.0)	2.04 (0.22-18.87)	7 (2.2)	3 (42.9)	0.528	15.96 (3.26-78.29)	0.001	
No	307 (98.4)	34 (11.1)	-	313 (97.8)	14 (4.5)	-			
Smoke during pregnancy									
Yes	76 (21.4)	12 (15.8)	1.33 (0.63-2.82)	46 (13.6)	3 (6.5)	0.452	1.06 (0.30-3.76)	0.926	
No	279 (78.6)	32 (11.5)	-	292 (86.4)	18 (6.2)	-	-	-	

* Number of inhabitants/number of rooms (excluding bathroom and kitchen)>3

Environmental tobacco smoke

[‡] Anemia, Rheumatoid Arthritis, Asthma, Depression/Psychiatric Illness, Epilepsy, Scleroderma, Gastritis/Ulcer, Hypothyroidism/Hyperthyroidism, Insulin resistance, Lupus, Purple, Antiphospholipid syndrome and other hematologic disorders, Sinusitis, Cancer

Statistically significant results are shown in italic

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