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Air pollution and low birth weight in an industrialized city in Southeastern Brazil, 2003-2006

Poluição do ar e baixo peso ao nascer em uma cidade industrial no Sudeste do Brasil, 2003-2006

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ABSTRACT: ***Introduction:*** Birth weight is an important indicator of several conditions that manifest earlier (as fetal and neonatal mortality and morbidity, inhibited growth and cognitive development) and later in life such as chronic diseases. Air pollution has been associated with adverse pregnancy outcomes. ***Objective:*** Retrospective cohort study investigated the association between low birth weight (LBW) and maternal exposure to air pollutants in Volta Redonda city, Rio de Janeiro, Brazil, from 2003 to 2006. ***Methods:*** Birth data was obtained from Brazilian Information System. Exposure information (O_3, PM_{10}, temperature and humidity) was provided by Governmental Air Quality Monitoring System. Linear and Logistic models, adjusted for sex, type of pregnancy, prenatal care, place of birth, maternal age, parity, education, congenital anomalies and weather variables were employed. ***Results:*** Low birth weight (LBW) represented 9.1% of all newborns (13,660). For an interquartile range increase in PM_{10} it was found $OR_{2ndTrimester}$ = 1.06 (95%CI 1.02 – 1.10), $OR_{3rdTrimester}$ = 1.06 (95%CI 1.02 – 1.10) and, in O_3 it was found $OR_{2ndTrimester}$ = 1.03 (95%CI 1.01 – 1.04), $OR_{3rdTrimester}$ = 1.03 (95%CI 1.02 – 1.04). The dose-response relationship and a reduction in birth weight of 31.11 g (95%CI -56.64 – -5.58) was observed in the third trimester of pregnancy due to an interquartile increase of O_3. ***Conclusion:*** This study suggests that exposures to PM_{10} and O_3, even being below the Brazilian air quality standards, contribute to risks of low birth weight.

Keywords: Air pollution. Birth weight. Environmental. Epidemiology. Maternal exposure. Ozone. Particulate matter. Sulfur dioxide.

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RESUMO: ***Introdução:*** O peso de nascimento é considerado como um indicador importante de várias condições que se manifestam mais cedo (como mortalidade fetal e neonatal e morbidade, inibição do crescimento e desenvolvimento cognitivo) e mais tarde na vida, tais como as doenças crônicas. A poluição atmosférica tem sido associada a efeitos adversos da gestação. ***Objetivo:*** Estudo de coorte histórica que associa o baixo peso ao nascer (BPN) e a exposição materna aos poluentes do ar em Volta Redonda, Rio de Janeiro, Brasil, entre 2003 e 2006. ***Metodologia:*** Dados sobre nascidos vivos foram obtidos no sistema de informação Brasileiro, e os de exposição (O_3, PM_{10}, temperatura e umidade) na rede pública de monitoramento do ar. Foram utilizados modelos lineares e logísticos, ajustados por sexo, tipo de gravidez, assistência pré-natal, local de nascimento, idade materna, paridade, educação, anomalias congênitas e variáveis meteorológicas. ***Resultados:*** A prevalência de BPN foi de 9,1% sobre 13.660 nascimentos. Para o aumento de um interquartil no nível de PM_{10} ($OR_{2^o trimestre}$ = 1,06; IC95% 1,02 – 1,10; $OR_{3^o trimestre}$ = 1,06; IC95% 1,02 – 1,10) e no nível de O_3 ($OR_{2^o trimestre}$ = 1,03; IC95% 1,01 – 1,04; $OR_{3^o trimestre}$ = 1,03; IC95% 1,02 – 1,04). Observou-se uma relação dose-resposta e uma redução do peso ao nascer de 31,11 g (95%IC -56,64 – -5,58) no terceiro trimestre da gravidez devido ao aumento de um interquartil de O_3. ***Conclusão:*** Este estudo sugere que exposições ao PM_{10} e O_3, mesmo abaixo de padrões de qualidade do ar, contribuem para os riscos de BPN.

Palavras-chave: Poluição do ar. Peso ao nascer. Epidemiologia. Exposição materna. Ozônio. Material particulado. Dióxido de enxofre.

INTRODUCTION

Air pollution has been associated with adverse pregnancy outcomes such as prematurity, low birth weight (LBW), intrauterine growth restriction (IUGR) and birth defects[1]. Several epidemiological studies have focused on the impacts of air contaminants on pregnancy outcomes, as reported in systematic reviews published by Nieuwenhuijsen et al.[2], Stieb et al.[3], Shah and Balkhair[4], and Olmo et al.[5].

Liu et al.[6] examined the relationship among preterm birth, low birth weight, intrauterine growth restriction and air contaminants in Vancouver, Canada; they evidenced that air gaseous pollutants (CO, SO_2, and NO_2), even at relatively low concentrations, were associated to deleterious adverse effects on birth outcomes. Salam et al.[7] found exposure to O_3 during second and third trimesters of pregnancy associated with LBW. A retrospective cohort study conducted by Dugandzic et al.[8] examined the association of LBW and the exposure to ambient air contaminants in a region of lower concentration levels and pointed to a dose-response relationship for SO_2, but no statistically significant effects were observed for ozone. Another study made clear the association among low levels or air contaminants ($PM_{2,5}$, NO_2 and O_3) and LBW[9]. Xu et al.[10] showed an association between the exposure to PM_{10} and LBW in the first and second pregnancy trimester in Pittsburgh, USA.

In Brazil, only few studies were published showing the association between air pollution and LBW. Gouveia et al.[11] reported birth weight reduction in São Paulo city due to exposure to CO and PM_{10} during the first trimester of pregnancy. The effects of CO and PM_{10} exposure on LBW were continued in another study developed in São Paulo, but with the inclusion of NO_2 among the risk factors for the outcome[12]. In Rio de Janeiro, Junger and Leon[13] have demonstrated a significant association between the fourth interquartile range of exposure to SO_2 in the third trimester and LBW. Nascimento and Moreira[14] found an association between LBW and exposure to SO_2 and O_3 during the 90 days prior to birth in a time-series study conducted in the city of São José dos Campos, São Paulo State.

Considering birth weight as an important indicator of several conditions that manifest early (as fetal and neonatal mortality and morbidity, inhibited growth and cognitive development) and later in life such as chronic diseases (hypertension, obesity and insulin-dependent diabetes mellitus)[9,15,16], this population-based study aimed to investigate the environmental determinant to low birth weight regarding the relationship between maternal exposure to specific outdoor air contaminants (PM_{10}, SO_2 and ground-level O_3) in Volta Redonda city.

METHODS

SETTING STUDY

Volta Redonda is an industrialized city situated in Southeastern Brazil, more specifically in Rio de Janeiro State. This city has a population of 257,803 inhabitants and an area of 182,48 km^2 [17]. It is observed a prevalence of the mesothermic climate, with a dry season in the winter and a rainy and hot season in the summer. The average annual temperature ranges between 16.5ºC and 27.8ºC and a relative humidity mean of 77%, even during the winter[18].

Since 1946, one of the largest integrated steel-making complex in Latin America is situated in the city center. This kind of industry emits a greater number of particles, gases and vapor than the other industrial plants. The major air contaminants emitted by the coke plant are CO, CO_2, hydrogen sulfide (H_2S), SO_2, ammonia (NH_3) and aromatic hydrocarbons, like benzene and polycyclic aromatic hydrocarbons (PAHs)[19]. Cement and lime plants also take part in the vicinity of the town, which contribute to the increase of some compounds emitted to atmosphere. Mobile sources contribute significantly to air pollution in Volta Redonda, due to the daily traffic of about 40,000 vehicles, most of which are lorries[20,21]. In 1999, the State Foundation of Engineering and Environment of Rio de Janeiro (FEEMA in portuguese) made public a report on air quality assessment in Volta Redonda, asseverating a considerable air pollution in the municipality[18].

BIRTH DATA

This retrospective cohort study included birth data obtained from the Information System on Live Births (SINASC) from the Brazilian Ministry of Health for all registered births for the municipality of Volta Redonda, Rio de Janeiro, from January 1st, 2003 to December 31st, 2006. Births whose data on birth weight were ignored, premature and multiple births were excluded. Live Birth Certificate is the source of data for SINASC with information about the newborn characteristics (date and hour of birth, sex, race/color, Apgar Score, birth weight and congenital anomalies); mother's characteristics (age, education, marital status, place of residence, parity); type of delivery; gestational age in weeks; prenatal care; and birth location[22].

LBW is considered when the weight of birth is less than 2,500 grams[23].

EXPOSURE ASSESSMENT

Air pollution data were obtained from outdoor stationary monitors operated by FEEMA, considering the period from January 1st, 2002 to December 31st, 2006. These data was generated by an air quality monitoring system composed by three automatic telemetric stations. Data on PM_{10} and SO_2 were reported as 24-hour averages, while O_3 was reported as maximum hourly during the 24-hour period. All pollutants and meteorological data were measured in each automatic station. For each atmospheric contaminant, it was calculated the mean of the municipality, considering daily mean values generated in each station. Arithmetic averages of temperature and relative humidity were calculated. All missing data on pollutants were completed by applying an imputation method[24].

In order to estimate maternal exposure for the study population, the birth date of each newborn was considered as basis to calculate the exposure to PM_{10}, SO_2 and O_3 over each gestational trimester. Thus, the estimate consisted of daily arithmetic means values of pollutant concentrations, temperature and relative humidity measured by the stations in the municipality of Volta Redonda, during the corresponding periods.

STATISTICAL ANALYSIS

Logistic and linear models were employed to assess the contribution of air pollution to LBW. In all models, birth weight was considered as a dependent variable. On the basis of logistic regression, the analyses were conducted comparing LBW and normal birth weight, employing a dichotomous variable to represent them, this method allowed the estimation of the crude and the adjusted odds ratio (OR) and 95% confidence interval (CI). The univariate and multiple logistic models were used in order to determine the factors related to LBW. First, the univariate model was tested for all variables contained in the SINASC, recognized as determinant risk factors for LBW. The variables with significance level smaller than 20% in the univariate models were included in the multiple models.

Among the variables made available in SINASC data we can emphasize the place of birth, maternal age, maternal marital status, maternal education, parity, type of delivery, prenatal care, child sex and congenital anomalies[15,23,25-30]. After determining this final multiple model, it was added the quartiles ($< 25^{th}$, 25 to 50^{th}, 50 to 75^{th}, and $> 75^{th}$) of pollutants, temperature and humidity.

For the linear model, birth weight was used as a continuous variable to demonstrate the reductions in birth weight due to prenatal exposures to air contaminants.

All analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 13.0 *for Windows*. We adopted a 5% significance level in all analyses.

RESULTS

This study covered 13,660 births occurred among mothers residing in Volta Redonda city from January 1st, 2003 to December 31st, 2006. After excluding premature child, multiple births and cases of infants without information on birth weight in SINASC, a total of 12,541 births were used in the analysis

The average (SD) birth weight was 3,162.2 g (561.8 g), and LBW represented 9.1% of all newborns. Low birth weight rates slightly decreased in the study period, it varied from 9.7% in 2003 to 9.3% in 2006. Overall, LBW rates were quite stable over the considered period. Table 1 shows descriptive characteristics of mothers and birth. Also, Odds Ratio (OR) estimates and 95% confidence interval of LBW for these variables are presented.

Table 1. Prevalence and Odds Ratio (OR) for low birth weight.

Variables relating to birth and mother	Low Birth Weight		OR (95%CI)
	n	%	
Maternal age (years)			
≤ 19	235	18.9	0.95 (0.77 – 1.17)
20–34	840	67.5	1.00
≥ 35	170	13.7	1.33 (1.06 – 1.67)
Maternal education (years)			
≤ 3	82	6.6	1.93 (1.44 – 2.60)
4–7	363	29.1	1.23 (1.04 – 1.46)
≥ 8	800	64.3	1.00
Maternal parity (children)			
None	478	38.4	1.72 (1.46 – 2.03)
1–2	660	53.0	1.00
≥ 3	107	8.6	1.09 (0.83 – 1.43)
Prenatal care (visits)			
< 7	558	44.8	2.08 (1.78 – 2.43)
≥ 7	687	55.2	1.00
Child's Sex			
Male	585	47.0	1.00
Female	660	53.0	1.41 (1.22 – 1.62)
Place of birth			
Hospital	1237	99.4	1.00
Others	8	0.6	5.00 (1.65 – 15.19)
Congenital abnormality			
Absence	1226	98.5	1.00
Presence	19	1.5	3.29 (1.70 – 6.36)

OR: Odds Ratio.

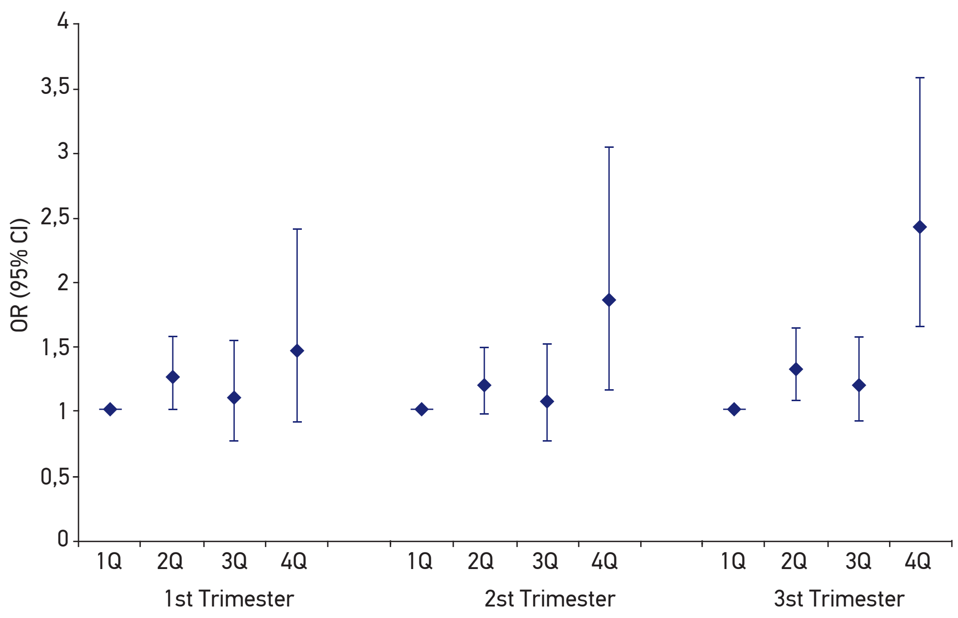
Infant sex, gestational length, prenatal care, place of birth, maternal age, maternal parity, maternal education and congenital anomalies have shown to be associated with LBW through adjusted OR.

Maternal marital status and type of delivery were not included in the analytic models with air pollutants, because their OR estimates showed no statistical significance.

In order to estimate the impact of air pollution during pregnancy, the arithmetic mean of pollutants concentrations was calculated for each trimester. Air pollutants mean (SD) levels were: O_3: first trimester = 58.22 μg/m³ (11.52), second trimester = 56.30 μg/m³ (10.46) and third trimester = 54.13 μg/m³ (10.35); PM_{10}: first trimester = 33.08 μg/m³ (3.56), second trimester = 32.22 μg/m³ (3.18) and third trimester = 31.62 μg/m³ (3.21); SO_2: first trimester = 9.45 μg/m³ (0.52), second trimester = 9.19 μg/m³ (0.75) and third trimester = 9.00 μg/m³ (0.87).

Risks of low birth weight for exposure to O_3, and PM_{10} during each trimester of pregnancy are showed in Figures 1 and 2. Regarding to trimester-specific exposures to O_3, we found that second and third trimesters exposure increased the risk for low birth weight ($OR_{2nd\ Trimester}$ = 1.03, 95%CI 1.01 – 1.04; $OR_{3rd\ Trimester}$ = 1.03, 95%CI 1.02 – 1.04). A positive association was also observed in first-trimester exposure, although it was not statistically significant.

In terms of exposures to PM_{10}, it was observed an increased risk for LBW related do maternal exposure during second and third trimesters ($OR_{2nd\ Trimester}$ = 1.06, 95%CI 1.02-1.10; $OR_{3rd\ Trimester}$ = 1.06, 95%CI 1.02-1.10). As observed in maternal exposure to ozone during



[a]Adjusted for infant sex, gestational length, type of pregnancy, prenatal care, place of birth, maternal age, maternal parity, maternal education, congenital anomalies, temperature and relative air humidity.

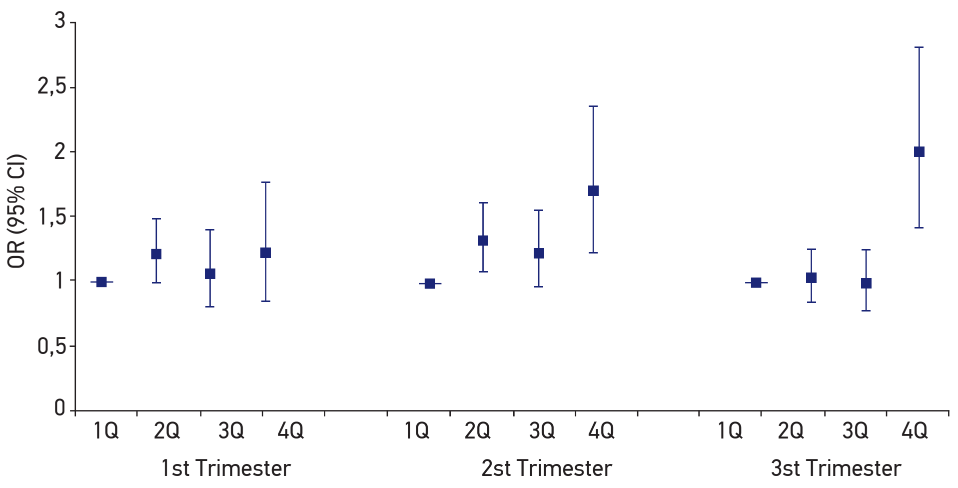
Figure 1. Odds Ratio and 95% confidence interval for low birth weight by quartiles of ozone (O_3) in trimesters of pregnancy analyzed from logistic regression models adjusted for covariates.

the first trimester, it was noticed a positive association between LBW and maternal exposure to PM_{10} in the same period of pregnancy, even though it was statistically not significant. Associations between LBW and maternal exposure to SO_2 were not found.

The dose-response relationships verified for low birth weight and concentrations of O_3 and PM_{10} are shown in Figures 1 and 2, respectively. The chances of LBW were increased in newborns due to maternal exposure to O_3 in each trimester of pregnancy. In the first trimester, it was observed an increase in the chance of LBW in the second interquartile range (OR = 1.27; 95%CI 1.01 – 1.58). In the highest interquartile range of the second trimester, it was also observed an increase of the chances for LBW (OR = 1.86; 95%CI 1.14 – 3.04). In the third trimester, maternal exposure to O_3 increased the chance of LBW in the second (OR = 1.34; 95%CI 1.09 – 1.65) and in the fourth (OR = 2.43; 95%CI 1.65 – 3.58) interquartile intervals.

Considering maternal exposure to PM_{10}, its contribution to the increased chance of LBW was verified, similar to what was observed to ozone: during the first trimester in the fourth interquartile (OR = 1.22; 95%CI 1.00 – 1.49); during the second trimester, in the second (OR = 1.32, 95%CI 1.08 – 1.61) and fourth interquartile (OR = 1.70, 95%CI 1.23 – 2.35), and during the third trimester in the highest interquartile (OR = 2.00, 95%CI 1.42 – 2.80).

We estimated the reduction on birth weight in relation to the interquartile range increase of pollutants. In this way, the reduction of birth weight was 31.11 g (95%CI - 56.64 – -5.58) for an interquartile increase of O_3 in the third trimester of pregnancy. All other pollutants showed no statistical reduction on birth weight.



[a]Adjusted for infant sex, gestational length, type of pregnancy, prenatal care, place of birth, maternal age, maternal parity, maternal education, congenital anomalies, temperature and relative air humidity.

Figure 2. Odds Ratio and 95% confidence interval for low birth weight by quartiles of particulate matter (PM_{10}) in trimesters of pregnancy analyzed from logistic regression models adjusted for covariates.

In multiple pollutants models, it was confirmed the robustness of O_3 exposure impact on birth weight reduction in the third trimester. In two pollutant models, considering O_3 and PM_{10}, the exposure to O_3 was responsible for a decrease in birth weight of 50.58 g (95%CI -90.78 – -10.21), meanwhile, exposure to PM_{10} presented non-significant results. The reduction on birth weight was 39.41g (95%CI -78.34 – -0.48) when considering exposure to O_3 and to SO_2, but the exposure to SO_2 was not significant. The model including three pollutants showed results in a similar way: decrease in birth weight related to exposure to O_3 was 71.64g (95%CI -129.87 – -13.24), and other pollutants did not show statistically significant results.

DISCUSSION

Birth weight is an important predictor of public health. It is not only associated to fetal and neonatal mortality and morbidity, inhibited growth or cognitive development, but it is also related to mortality and chronic diseases in adulthood[16]. In terms of populations, it reflects several social health determinants linked to the conditions in which people live and work[31].

LBW was associated with preterm birth, type of pregnancy, place of birth, prenatal care, infant sex, congenital anomalies, primiparity, maternal education and maternal age and these results have been replicated in several studies[10,25,26,28,29,32].

According to the Brazilian legislation of air quality[33], levels of primary (health-related) standards for O_3 and PM_{10} are, respectively, 160 $\mu g/m^3$ (1-hour average concentration) and 50 $\mu g/m^3$ (arithmetic mean). This legislation determines standards of annual arithmetic mean values for SO_2 as 80 $\mu g/m^3$ (primary standard). In Volta Redonda/Brazil, the annual average concentrations for these pollutants were lower than the annual National established during the studied period. Meanwhile, when considering World Health Organization Air Quality Guidelines[34], only SO_2 concentrations did not surpass its established standard value. However, considering physical environment as an important determinant of adverse pregnancy outcome, this study highlights some evidence about the association between maternal exposure to low-level concentrations of air pollutants during pregnancy and low birth weight occurrence.

Maternal exposure to such air pollutants concentrations during specific periods of pregnancy led to an increase in the risks of low birth weight. In second and third pregnancy trimesters, maternal exposure to ozone showed a positive and significant association with LBW, and when conducting the analyses considering interquartile concentrations of pollutants exposure, a dose-response relationship was suggested. In models based on continuous exposure variables, ozone exposures in third trimester showed evidence of reduction in birth weight; it was not attenuated, even when multiple pollutant models were employed. All these findings were seen after adjustment for other confounding variables to LBW and showed consistence with other epidemiological studies. Ha et al.[35] observed a significant increased risk of LBW associated with maternal exposure to O_3 during the third trimester of pregnancy for each interquartile concentration raise in Korea. Salam et al.[7] also ascertained the relationship between maternal exposure to ozone during the second and the third trimester in their study conducted with infants who were born in California between 1975-1987. Notwithstanding, some epidemiological studies have not found statistically association between LBW and maternal exposure to ozone. Brazilian studies, for instance, found no significant association between O_3 concentrations and low birth weight[9,11,13].

In terms of trimester-specific exposure to PM_{10}, this study showed a raised risk of LBW during second and third trimesters of pregnancy, reflecting a possible dose-response relationship. Several other studies yielded the association between maternal exposure to particulate matter and LBW[9,35]. A study developed in Connecticut and Massachusetts, in the USA, considering the period of 1999–2002, described an important association between LBW and maternal exposure to PM_{10} in the third trimester of pregnancy[9]. Lee et al.[36] conducted a study in Seoul, Korea, highlighting that maternal exposure to particulate matter during the second trimester increased the risk for LBW.

Associations were not found between trimester-specific maternal exposure to SO_2 and LBW. Bell et al.[9] did not find association for an interquartile increase in SO_2 concentration and LBW for the entire pregnancy period. However, Dugandzic et al.[8] found a significant increased risk of LBW and maternal exposure to SO_2 in the first pregnancy trimester.

Physiological mechanism in which air contaminants could affect birth weight needs further investigation[9]. Glinianaia et al.[37] pointed three mechanisms that could interfere in fetal growth and development. They are related to inflammatory response that alters blood coagulation, allergic immune response and altered cardiac function from changes in the heart rate variability. Smoking through pregnancy is concentrated among the socially disadvantaged, even in wealthier countries[38,39]. In Brazil, Nakamura et al.[40] found an association between maternal smoking and lower educational level in a hospital-based prospective study. Another hospital-based study correlated smoking during pregnancy with lower educational status (OR = 2.13; 95%CI 1.76 – 2.57) in six Brazilian cities[41]. Moreover, in relation to passive smoking, an association with lower educational status was found in Brazil[42].

A limitation of this study was the absence of some important variables in the SINASC database, like maternal active and passive smoking and maternal weight and height. Although the correlation between LBW and maternal smoking is extremely important, in Brazil, there seems to be a proportionally inverse correlation between maternal smoking and mother education[43]. We assumed that an indirect control to maternal smoking was done, as suggested by Junger and Leon[13]. They considered that maternal smoking is controlled indirectly including mother education status in the regression models.

CONCLUSION

This study highlighted the influence of physical environment on pregnancy, specifically the exposure to air pollution. As this study showed deleterious effects on newborns, we suggest a surveillance system on air pollution and its effects on vulnerable sub-populations in Volta Redonda, mainly in children and pregnant women. It is also strongly recommended the revision of the national air quality standards as it has been done in São Paulo state.

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