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Intellectual Capacity of Children Exposed to Environmental Pollution in the Extreme South of Brazil

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Abstract: Objective: The study evaluated the intellectual capacity of children who live in areas that were E (exposed) or NE (not exposed) to environmental pollution. Method: 246 students between the ages of 8 and 11 years and 8 months were evaluated. Data were collected between May and June 2010 using a semi-structured questionnaire to examine factors that were related to compromised intellectual capacity. Intellectual capacity was evaluated with Raven's Colored Progressive Matrices Scale. The intellectual capacity of children who live in areas that were exposed or not exposed was compared using chi-squared tests and raw and adjusted analyses were conducted using Poisson regression. Results: The general occurrence of intellectual impairment was 28.9%, with 22.0% in the non-exposed area and 36.1% in the exposed area (p = 0.01). The outcome was associated with the following: a lack of companionship (RP = 2.77; $p < 0.00$), maternal education of less than five years (RP = 2.13; $p < 0.00$), the mother not being Caucasian (RP = 1.57; $p < 0.00$), residing in an exposed area (RP = 1.88; $p < 0.00$), and nutritional risk/malnutrition (RP = 2.83; $p < 0.00$). Conclusions: The results showed a high occurrence of intellectual impairment and a significant difference between the environmental areas. Additional research is needed to improve the understanding of several results. The town's priorities should include efforts related to environmental health.

Key words: Children's intellectual capacity, environmental pollution, determining factors, Raven.

1. Introduction[1]

Intelligence is understood as multiple capacities that are susceptible to stimulation [1]. Children who have difficulty developing these abilities constitute 12% to 16% of the child population [2]. Several factors can influence their growth and development [3].

Combined genetic, biological, psychological and environmental factors impact children's development, and interactions between factors can lead to difficulty expressing children's intellectual capacity [4].

In the context, research has examined factors such as maternal education and family environment [5], socioeconomic factors [6], and exposure to environmental factors [7].

The present study occurred in the town of Rio Grande/RS, which is located in the extreme south of Brazil. Its urban area houses a fertilizer industrial site and a petrochemical company, which are responsible for emitting pollutants that contaminate the air, water and soil. Environmental studies conducted in this town have identified pollutants, such as lead, mercury, arsenic, fluorides and aromatic polycyclic hydrocarbons in different environmental compartments [8-10]. Research is currently examining several of these pollutants to examine the effect of exposure or

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contamination on children's intellectual capacity [11-14].

Other studies in this region have found significant associations between the proximity of residences' location to the industrial site, and concluded that proximity affects low birth weight [15], delays in neurological and psychomotor development [16-17] and high rates of spontaneous abortion [18].

Therefore, the study evaluated the intellectual capacity of residents who live in areas exposed and not exposed to environmental pollution in Rio Grande/RS.

2. Methods

2.1 Participants

The study recruited 246 children who were between 8 and 11 years and 8 months were evaluated, residing in two areas of Rio Grande/RS: regions E (exposed) and NE (not exposed) to environmental pollutants. Both areas were identified by a previous study that analyzed the prevalence of high winds in the town, accounting for proximity to the town's industrial site [18].

2.2 Instruments

Two measures were used for data collection: a semi-structured questionnaire, which measured pre-, peri- and post-natal issues related to the child's education; and Raven's Colored Progressive Matrix Scale, which evaluated children's intellectual capacity [19].

The outcome variable was impairment in children's intellectual capacity, which was identified by a score of less than 49 on the Raven's Colored Progressive Matrix Scale.

According to the literature review, variables in the authors' theoretical model that increase risk for deficits in intellectual capacity are the following: Level 1—family socioeconomic conditions and maternal demographics (i.e. family income, parental education, parental occupational status, the presence of companionship, age and mother's race); Level 2—housing conditions (i.e., house type, bathroom type,

and the presence of plumbing water); and environmental factors (i.e., a house located in E or NE areas, pre-natal and current exposure to smoking, parental exposure to area E during pregnancy due to housing and/or work); Level 3—maternal reproductive history (i.e., the number of children, number of children under 5 years old, a history of deceased children); medical care during pregnancy (i.e., pre-natal); Level 4—birth conditions (i.e., birth type, gestational age, birth weight, breathing assistance after birth) and child characteristics (i.e., gender and race); Level 5—attention given to the child during life (i.e., breastfeeding and its duration), paternal care (e.g., full participation: participation in more than 5 care procedures; partial participation: participation in 3 to 5 care procedures; and small participation: participation in fewer than 3 care procedures), daycare or children's school attendance, and animal pets present; Level 6—growth, morbidity and children's habits (i.e., chronic diseases, hospitalizations, visits to Emergency Care Centers, nutrition, consuming fish from the existing town lake).

A height/age index was used to define nutrition and calculate Z scores (Epi info 6.0). The World Health Organization classification was employed to interpret nutrition. Children's nutrition was categorized as one of the following: a Z score between -0.99 and 1.99 (eutrophic), $Z >$ than 2.0 (overweight/obesity), or $Z \leq$ -1.00 (nutritional risk/malnourished).

2.3 Recruitment and Selection

The first step in identifying children for the study included a survey of schools that were located in the two areas, followed by a random raffle to select children for participation. The sample size was determined using the following criteria: an alpha error rate of 0.05, relative risk of 2.0, and 80% power. The authors used 34% as the total prevalence rate of developmental delay [21]; thus, non-exposed children's prevalence was 23%. Therefore, after adding 10% for analyzing confounding factors, 15% for

dropout and maintaining a 3:1 ratio, 240 children were identified as the total sample size.

2.4 Data Collection

Data collection occurred between May and July 2010. Quality control included continuously supervised fieldwork and daily questionnaire revisions. All data were collected in the schools where the child studied.

Questionnaires were administered by trained university students and a trained psychologist used the Raven's Colored Progressive Matrices to evaluate children's intellectual capacity.

2.5 Ethical Considerations

The present study adhered to ethical guidelines for research involving human subjects as defined by Resolution N° 196/1996. Children's parents or responsible adults signed two copies of the Free and Informed Agreement Term (TCLE), which explained the research objectives and the anonymity of data collection. This study was submitted to and approved by the Research Ethics Committee of the Rio Grande Santa Casa (Report N° 003/2007).

2.6 Data Analyses

After the data were entered and analyzed for consistency, statistical analyses was performed using STATA 10.0 software. The initial analysis examined variable distributions and frequencies, followed by comparisons between the two areas using Chi-square tests. A Poisson regression with estimates of robust variance estimated the ratio of gross and adjusted prevalence rates and their confidence intervals (95%) and p values (Wald's test).

Multivariate analyses were conducted using the hierarchy that was established in the theoretical model that was presented earlier. Stepwise backward analyses were performed on the six levels of variables, beginning with Level 1. To avoid confounding factors, variables that that had $p \leq 0.2$ were retained in the model as other variables from the hierarchy were introduced into the model. For all analyses, p values < 0.05 were considered significant.

3. Results

The study evaluated 246 children. Intellectual capacity impairment was identified in 28.9% of the children. Across study areas, 36.1% of the children that live in the E area and 22.0% of the children in the NE area had intellectual capacity impairment (p = 0.01).

3.1 Sample Characterization

In terms of socioeconomic status, 37.4% of families had an income less than the 02 minimum salary. Most mothers (46.3%) and fathers (47.9%) had completed between 5 and 8 years of education. In regard to occupational status, 61.7% of mothers and 18.0% of fathers were not working at the time of the interview. Most mothers had companions (81.7%), were more than 35 years old (49.4%), and were white (67.4%).

Regarding housing conditions, most children lived in masonry houses (79.8%) that had flushing toilets (95.5%) and plumbing inside the house (96.7%).

The remaining environmental influences indicated that 25.1% of the children were exposed to maternal smoking during pregnancy and 59.1% were currently exposed to smoking because smokers were present in the house. Parental exposure to residing or working in the E area during pregnancy was 35.0% for mothers and 22.8% for fathers.

In regard to maternal reproductive history, most mothers had more than two children (48.1%), did not have children under 5 years of age (71.6%) and 12.9% of mothers had deceased children. Most mothers (93.3%) reported to have pre-natal follow-ups completed, which reflected care during pregnancy.

Regarding children's birth conditions, most had normal births (68.4%), 14.5% were premature, 11.4% had a low birth weight, and 5.8% needed breathing assistance immediately after birth.

Most children were female (53.7%) and white

(67.2%). Most children had been breastfed (86.4%), and 57.4% had been breastfed for a maximum of six months. Children's attendance in daycare was reported by 35.4% of mothers. Paternal participation in childcare was also investigated, and most had little participation (64.7%). Most mothers reported that pet animals were present in the house (78.9%).

In terms of birth, morbidity and children's habits, 17.1% of children had a history of chronic disease. Regarding health service utilization, 44.7% had sought medical assistance from the Health Care Unit in the 12 months prior to the study. A nutritional analysis showed that 12.0% of the children had a height/age index with a $Z < -1.00$ score that indicated a risk for nutritional/malnourishment.

Consuming fish from the town lake three or more times per month was reported by 34.6% of the mothers.

3.2 Comparative Analyses between Areas Exposed and Non-exposed to Environmental Pollution

Comparative analyses between E and NE areas indicated that family income significantly differed ($p <$ 0.00) for socioeconomic and demographic conditions. The percentage of families with an income less than twice the minimum wage in area E was higher (51.2%) than in the NE area (74.8%) (Table 1).

Maternal and paternal education also significantly differed between the areas (p = 0.02). The percentage of mothers and fathers with more than eight years of education was higher in the NE area (mother: 45.9%; father: 39.8%) than in the E area (mother: 28.4%; father: 28.7%). The mother's race also significantly differed between the areas ($p < 0.00$), as there were a higher percentage of non-white mothers in area E (44.9%) than in the NE area (20.7%; Table 1).

In regard to housing conditions and other environmental factors, the percentage of mothers who were exposed to the area during pregnancy due to housing and/or work was higher ($p < 0.00$) among children from area E (70.6%) than the NE area (1.6%). Passive smoking in the house also significantly differed between areas ($p < 0.00$) and was higher in area E (69.6%) than area NE (49.2%; Table 1).

Table 1 Family socioeconomic conditions, motherhood, housing and environmental demographics of children (n = 246) residing in areas considered to be exposed (E) or non-exposed (NE) to environmental pollution. Rio Grande—RS, 2011.

VARIABLE	Total		Area NE	Area E	P
	N	%	%	%	
Family income					0.00*
< 2 SM*	154	62.6	51.2	74.8	
≥ 2 SM	92	37.4	48.8	25.2	
Maternal education					0.02*
> 8 years	87	37.7	45.9	28.4	
5-8 years	107	46.3	41.8	51.4	
≤ 4 years	37	16.0	12.3	20.2	
Paternal education					0.02*
> 8 years	66	34.7	39.8	28.7	
5-8 years	91	47.9	38.8	58.6	
≤ 4 years	33	17.4	21.4	12.6	
Mother's race					0.00*
White	161	67.4	79.3	55.1	
Non-white	78	32.6	20.7	44.9	
Children's exposure to tobacco in the home					0.00*
Yes	139	59.1	49.2	69.6	
No	96	40.9	50.8	30.4	
Maternal permanence in the exposed area during pregnancy					0.00*
Yes	86	35.0	1.6	70.6	
No	160	65.0	98.4	29.4	

For reproductive history and pregnancy, the variables that significantly differed between areas were the following: birth type ($p < 0.00$), with a higher number of cesarean births in the NE area (39.2%) than the E area (23.5%); child gender ($p = 0.02$), with a higher number of male children in area E (53.8%) than in area NE (39.4%); and child race, with a higher percentage of non-white children in area E (45.0%) than in area NE (21.8%) (Table 2).

There was also a higher percentage of chronic disease ($p < 0.00$) in area NE (28.3%) than in area E (5.0%). The percentage of children taken to the Emergency Care Unit in the last 12 months significantly differed between areas ($p < 0.00$), as there were more visits in the NE area (54%) than in the E area (34.7%) (Table 2).

3.3 Factors Associated with Children's Intellectual Capacity Impairment

Table 3 shows the data for bivariate and multivariate analyses. The overall analysis showed relationships between the outcomes and the following conditions related to socioeconomic and demographic variables:

maternal education of less than 5 years (RP = 2.12; $p < 0.00$), paternal unemployment (RP = 1.84; p = 0.01), and having a non-white mother (RP = 1.57; p = 0.03).

For housing conditions and other environmental factors, absence of a flushing toilet (RP = 1.97; p = 0.02) and children's exposure to passive smoking in the house (RP = 1.66; p = 0.03) were significantly associated with the outcome. Similarly, the child living in area E was also related to intellectual capacity deficits (RP = 1.64; p = 0.02).

For reproductive history and care during pregnancy, no pre-natal care was associated with the outcome (RP = 1.81; p = 0.03). For birth conditions and child characteristics, two variables were significantly associated with the outcome: the need for breathing assistance after birth (RP = 1.85; p = 0.03), and being a non-white child (RP = 1.71; p = 0.01).

For the child's health, the variable that was significantly associated with impairment in intellectual functioning was a lack of breastfeeding (RP = 1.85; $p < 0.00$). For child growth and morbidity, there was a significant association between intellectual functioning impairment and the child's nutritional situation as

Table 2 Maternal reproductive history, care during pregnancy, characteristics and birth conditions, attention to health, growth, morbidity and habits of children (n = 246) residing in the areas considered E (exposed) and NE (non-exposed) to environmental pollution. Rio Grande—RS, 2011.

VARIABLE	Total		Area NE	Area E	P
	N	%	%	%	
Birth type					0.01*
Normal	167	68.4	60.8	76.5	
Cesarean	77	31.6	39.2	23.5	
Child's gender					0.02*
Male	114	46.3	39.4	53.8	
Female	132	53.7	60.6	46.2	
Child's race					0.00*
White	158	67.2	78.2	55.0	
Non white	77	32.8	21.8	45.0	
History of chronic diseases					0.00*
No	204	82.9	71.7	95.0	
Yes	42	17.1	28.3	5.0	
Emergency care in the 12 months prior to this research					0.00*
No	135	55.3	46.0	65.3	

Yes		109	44.7	54.0	34.7

Table 3 Gross and adjusted effects of different variables that influence children's intellectual capacity. Rio Grande—RS, 2011.

Variable	Bivariate analysis RP (IC 95%)		p	Multivariate analysis RP (IC 95%)		P
Presence of maternal partner			0.19			0.00*
Yes	1.00			1.00		
No	1.35	(0.86-2.13)		2.77	(1.60-4.77)	
Maternal education			0.00*			0.01*
> 8 years	1.00			1.00		
5-8 years	1.06	(0.63-1.76)		1.02	(0.59-1.78)	
≤ 4 years	2.12	(1.27-3.52)		2.13	(1.21-3.77)	
Paternal education			0.19			0.61
> 8 years	1.00			1.00		
5-8 years	1.78	(1.02-3.13)		1.60	(0.91-2.82)	
≤ 4 years	1.38	(0.66-2.91)		0.61	(0.27-1.35)	
Paternal work			0.01*			0.48
Yes	1.00			1.00		
No	1.84	(1.14-2.97)		1.25	(0.67-2.35)	
Housing type			0.55			0.05*
Masonry	1.00			1.00		
Others	1.15	(0.73-1.83)		0.57	(0.33-1.01)	
Mother's race			0.03*			0.04*
White	1.00			1.00		
Non-white	1.57	(1.05-2.85)		1.57	(1.01-2.16)	
Bathroom type			0.02*			0.59
With flushing device	1.00			1.00		
Without flushing device	1.97	(1.10-3.52)		1.37	(0.43-4.38)	
Housing location			0.02*			0.01*
Non-exposed	1.00			1.00		
Exposed	1.64	(1.09-2.46)		1.88	(1.14-3.09)	
Maternal smoking during pregnancy			0.45			0.193
No	1.00			1.00		
Yes	1.19	(0.75-1.89)		0.66	(0.36-1.23)	
Child exposure to smoking in the house			0.03*			0.15
No	1.00			1.00		
Yes	1.66	(1.05-2.61)		1.48	(0.87-2.53)	
Children under 5 years			0.96			0.14
No Sim	1.00			1.00		
Yes	0.99	(0.64-1.53)		1.42	(0.89-2.28)	
Child's gender			0.09			0.20
Male	1.00			1.00		
Female	0.71	(0.48-1.05)		0.72	(0.43-1.19)	
Child's race			0.01*			0.44
White	1.00			1.00		
Non-white	1.71	(1.14-2.55)		1.58	(0.50-4.98)	
Prenatal care			0.03*			0.66

| Yes | 1.00 | | | 1.00 | | |
| No | 1.81 | (1.06-3.08) | | 1.20 | (0.52-2.77) | |

Table 3 continued

Variable	Bivariate analysis RP (IC 95%)		p	Multivariate analysis RP (IC 95%)		P
Birth type			0.37			0.11
Normal	1.00			1.00		
Cesarean	1.20	(0.80-1.81)		1.48	(0.91-2.40)	
Breathing assistance after			0.03*			0.36
Birth						
No	1.00			1.00		
Yes	1.85	(1.05-3.27)		1.39	(0.68-2.84)	
Breastfeeding			0.04*			0.78
Yes	1.00			1.00		
No	1.85	(1.22-2.82)		1.10	(0.56-2.14)	
height/age index (Z) score			0.00*			0.00*
-0.99 a 1.99	1.00			1.00		
< -1.00	2.75	(1.82-4.17)		2.83	(1.43-5.57)	
> 2.0	0.53	(0.14-2.00)		0.88	(0.27-2.85)	

shown by the variable height/age index (RP = 2.75; $p < 0.00$). None of the remaining variables in the bivariate analyses were associated with the outcome.

When the variables were adjusted to account for the hierarchy of different blocks of variables, they remained significantly related to the final result. The following variables were identified as risk factors for impairment in children's intellectual capacity: a mother without a companion (RP = 2.77; $p < 0.00$), maternal education less than 5 years (RP = 2.13; $p < 0.00$), non-white maternal race (RP = 1.57; p = 0.04), the child residing in area E (RP = 1.88; p = 0.01) and a nutritional situation indicating risk (RP = 2.83; $p < 0.00$). In addition, the multivariate analysis indicated that residence in a non-masonry home was a protective factor (RP = 0.57; $p < 0.05$).

After adjusting the variables in the hierarchy, several factors were not related to the outcome, including paternal education less than or equal to 4 years, maternal smoking during pregnancy, a mother with children under 5 years of age, female gender of the child, and cesarean birth.

4. Discussion

The study evaluated the intellectual capacity of children residing in two areas located in the town of Rio Grande in southern Brazil, which were differentiated by exposure to environmental pollution, which was defined as the geographic distance from the industrial site as described by a prior study on wind direction [18].

Comparative analyses between the areas were initially presented and the variables that differed between areas were discussed. These analyses can help to interpret the effects of several factors on children's intellectual capacity.

In terms of the maternal socioeconomic and demographic conditions in the E area, there were more families that earned less than two minimum wage salaries, mothers with little education and mothers who were non-white. Among children in the NE area, there were more parents with less than five years of education. Although there was no significant difference for this variable between areas [16, 17], a recent study on breathing function in children of the same age range identified a difference between the areas [22].

Economic situations, represented by income, has been viewed as very important for developing children's intellectual capacity, as poverty is frequently

associated with lower IQ scores [23]. Researchers confirm that socioeconomic conditions affect child development and this effect is stronger when paired with unfavorable nutritional situations [6]. Therefore, family income represents a very important characteristic in studies that investigate child development, especially in Brazil, where there are many social inequalities [24]. In another study, researchers found that children who had the lowest IQ scores also belonged to lower social strata [6].

Research has suggested that mothers with more education provide more stimulation to their children by making material resources available, engaging in more adequate activities and having a stronger emotional connection between mother and child. More adequate stimulation appears to contribute to children's intellectual development [5]. Studies have examined the association between maternal education and cognitive delays [25, 26].

Regarding maternal race, it is important to consider the differences in opportunities between white and non-white women. There are many known differences between minorities and whites, and the educational conditions of black people are inferior to those of non-black people. The educational differences between white and black parents are often reflected by the stimulation that is provided to develop their children's intellectual capacity. The family plays an important role in transferring knowledge, and this helps to develop intellectual capacity in relation to psychosocial stimulation and participation in education [27-29].

In regard to the set of variables on housing condition and other environmental factors, the mothers of the children from area E remained in this area during their pregnancies, either because they resided in and/or worked in this area. Research has suggested that fetuses and newborns are more susceptible than adults to environmental toxic substances [30].

The study also found that children from area E suffered more from passive smoking resulting from the presence of smokers in the house. It has been suggested

that pre- or post- natal exposure to tobacco is associated with lower IQ scores compared with children who were not exposed [31].

The analyses of birth condition variables found that birth type differed between the areas and that cesarean births were more prevalent in the NE area. Independent of this difference between the areas, the percentage of cesarean births is high compared to one decade ago; children's cesarean births were 31.6% in 1999 compared to 53.8% in 2009, according to DATASUS information [32].

Cesarean births are frequently associated with premature birth, which can be crucial to developing children's intellectual capacity [33, 34]. In addition, cesarean births sometimes result in less contact between the mother and baby immediately after birth, which can lead to difficulties in developing a mother-baby connection. This factor can compromise the child's development and intellectual functioning [35].

When children's race and gender were analyzed, it was found that there was a higher prevalence of male and non-white children in area E. Children's intellectual capacity did not appear to be influenced by gender [36]. The influence on intellectual capacity based on the skin color of children and their parents has been characterized in an indirect manner by identifying that non-white individuals have less access to education and, consequently, fewer opportunities to develop cognitive abilities.

Official data on educational attainment in the Brazilian population by race characterizes the uneven distribution of educational opportunity for white and non-white individuals and the accumulated effects of racial discrimination on formal education [27]. In a socioeconomic study, there were differences in children's school performance when separated by racial group, with a smaller difference between white and brown in relation to white and black [37].

In terms of growth, morbidity and children's habits, children from area NE had higher prevalence rates of

chronic disease history and Emergency Care Unit visits in the 12 months prior to the study. Pain and other symptoms from chronic diseases can generate anguish and impotence in families and can make it difficult to stimulate the child [3]. Childhood chronic diseases have been identified as a factor that may influence children's intellectual development. One study found that there were fewer educational practices employed by mothers of children with chronic diseases [38]. However, it is worth mentioning that a history of chronic disease can be characterized by special attention to the child from parents and the health team. In this situation, parents may display overprotective behaviors, which may be more stimulating for the child [39].

In the present study, schooling children's general intelligence was evaluated by the Raven test. Of the children that participated in the study, 28.9% had impairments in intellectual capacity, which indicated that there is a high prevalence of unfavorable cognitive alterations. Similarly, another study using the same evaluation scale detected that 30% of the children had intellectual levels that were considered unsatisfactory [6].

To identify different factors that were associated with children determined to be intellectually impaired, this study examined family socioeconomic status and maternal demographics, including housing conditions and other environmental factors, maternal reproductive histories and care during pregnancy, characteristics, child birth conditions, and health care, as well as growth, morbidity and nutritional habits.

The evaluation of children using the Raven test identified several risk factors that were significantly associated with impairment in children's intellectual function in the overall and adjusted analyses. These variables were a maternal education less than 5 years, non-white maternal race, residing in the E area and a nutritional situation indicating nutritional/malnourishment risk. After adjusting for all variables, having a mother without companions was

also a risk factor for intellectual deficits.

Higher maternal education has been associated with children's intellectual impairment, and is considered to be a protective factor for global and specific health development, for example, in extending vocabulary and intelligence scores [5].

In the study, having a non-white mother was also a risk factor for developing intellectual functioning deficits. Because non-white mothers often have non-white children, socioeconomic control suggests that there are differences in school performance between students when divided into racial groups, with differences being significantly smaller between white and brown children than between white and black children [37].

Another factor that was related to the outcome was the mother not living with a companion. This draws attention to the importance of the paternal figure, a male figure in the house. This relationship reinforces the importance of the paternal figure in the child's life in growth and development. It is important to emphasize that family economic stability is often guaranteed or mainly provided by the father or companion's income. The absence of this contribution can damage the child's full development and intellectual capacity [5].

Environmental factors, specifically the child's residence in area E, was a risk factor for impairment in intellectual functioning. The Raven test showed that 36.1% of children in area E, compared to 22.0% in area NE, were classified in the inferior medium category or lower.

The smaller the child, the greater his vulnerability to pollutant exposure, because the nervous system has not yet completely developed, which can increase neurological effects, including mental retardation and language and behavior deficits. Exposed children often have higher indices of blood contamination because they ingest more water and food and breathe more air per unit of body weight compared with adults. Additionally, children play next to contaminated soil

and often put their hands in their mouths, which increases the ingestion of these pollutants [40].

Research conducted in Rio Grande has found high concentrations of pollutants, including metals such as lead, mercury, arsenic and HPAs (aromatic polycyclic hydrocarbons) in different environmental compartments, such as in air, water, soil and sediment [8-10, 41]. The effects of these pollutants on children's intellectual functioning are well known.

A study done in the city of Bauru (São Paulo-Brazil) with 40 participants of both genders who were between 7 and 10 years old and divided into two groups (e. g. children contaminated by lead and non-contaminated children). Larger deficits were detected in the intellectual capacity of contaminated children compared with the non-contaminated group [12]. A longitudinal study in the same city re-evaluated the intellectual capacity of these contaminated children and found that they had significant IQ losses, compared with the earlier evaluation [13].

Researchers suggest that lead exposure in childhood predicts adult intellectual functioning and that school-aged children may be in a period of higher susceptibility [42]. In children's health, research has shown that high lead concentrations in the blood are associated with a higher risk for fetal malformation [43]. One study found that blood levels of up to 10 µg/g of lead were related to reductions in children's cognitive functioning [44].

Studies have also found a significant association between arsenic exposure and children's intellectual capacity [11-14]. One group of researchers identified that verbal skills are most affected by the relationship between intellectual capacity and pollutant exposure [11]. Thus, it is important to emphasize that the test used in the present study is non-verbal.

A study done in Poland with 5-year-old children used the Raven test to evaluate the intellectual capacity of children who were exposed to high concentration of HPAs and found that more pre-natal exposure to these compounds was associated with significant reductions in non-verbal intelligence scores, even after controlling for confounding factors [45].

A child needs balanced nutrition for healthy development, as it is indispensable for physical growth and intellectual development [46]. In terms of the child's nutritional conditions, nutritional risk/malnourishment was a risk factor for the outcome variable. Children who are at any level of nutritional risk need more attention and differentiated education. Global treatment and the pedagogic methods used to educate these children, malnourished or not, should account for their environmental situations [6].

Lack of residence in a masonry house was a protective factor on the outcome variable. The town's humid weather and the lack of insulation in many masonry houses facilitate mold development in most residences, which can become hostile environments for children's health. Cases of respiratory problems are frequent, especially in the winter, and are responsible for causing absences from school [47].

In the bivariate analysis, several variables were risk factors for impaired intellectual function in children, such as the father's unemployment, having a non-flushing toilet in the house, children's passive exposure to smoking from house residents, being non-white, no pre-natal follow-up care, needing respiratory assistance after birth, and if the child was not breastfed. However, these variables were not significant after adjusting the remaining variables to different levels of the hierarchy.

As observed in the study, there was a high prevalence of children with intellectual capacity impairment. The instrument employed appeared to be adequate for evaluating intellectual functioning, especially because evaluations were performed on a large number of children.

The results allowed the authors to identify several factors that interfere with the development of intellectual capacity. Identification of these factors indicates a need for individual and collective interventions. As such, it is important to emphasize

education and health sector management and to adopt surveillance measures to assess the growth, and physical and intellectual development of these children. Additionally, adequate interventions should allow for good school performance and the full development of children's potential.

5. Limitations

Although the role of pollution in intellectual capacity cannot be overlooked in this study, there are limitations in research that house location as an exposure factor.

6. Conclusion

The study found an association between children residing and studying in an area next to an industrial site, resulting in exposure to pollution and impairment in intellectual functioning. There are known limitations in using residence location as an exposure factor [20, 48, 49], however, the role of environmental pollution on children's intellectual functioning cannot be overlooked in this study, especially because environmental pollution in the town has already been discussed by other researchers.

Given the results from the study, it is important to take action to improve the quality of life for the population in the town.

Additional research is needed that uses other evaluation instruments to examine children's intellectual capacity to better understand the profiles of children's exposure to environmental pollutants, including analyses of body fluids, such as blood and urine.

7. Abbreviations

E: Exposed area; NE: Non exposed area; TCLE: Free and Informed Agreement Term; RAVEN: Raven's Colored Progressive Matrices; RP: Prevalence ratio.

8. Competing Interests

The authors declare they have no competing interests.

9. Author's Contributions

MDS performed the cognitive evaluations and wrote the first version of this manuscript with guidance from MCFS and ALMB, who made revisions and offered critical evaluation. MDS, MCFS and ALMB performed the statistical analyses. All authors approved the final version of the manuscript.

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