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Association of Anemia, Child and Family Characteristics With Elevated Blood Lead Concentrations in Preschool Children From Montevideo, Uruguay

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ABSTRACT. Elevated blood lead levels (BPbs) have been identified in Uruguayan children in the La Teja neighborhood of Montevideo, but the extent of lead exposure in other city areas is unknown. Sources and predictors of exposure also remain understudied in this population. In 2007, the authors screened lead and hemoglobin levels in capillary blood of 222 preschool children from several areas of Montevideo, Uruguay, and identified predictors of elevated BPbs. Mean BPb was 9.0 ± 6.0 μg/dL and 32.9% of children had levels ≥10μg/dL. Mean hemoglobin level was 10.5 ± 1.5 g/dL, with 44.1% having levels <10.5g/dL. Older child age, hemoglobin <10.5g/dL, and putting fingers/toys in the mouth were associated with higher BPbs. Young maternal age, less education, father's job with potential risk of lead exposure, and fewer family possessions were also associated with higher BPbs. Pediatric lead exposure is a public health problem in Uruguay, with children experiencing elevated BPbs at a young age.

KEYWORDS: hemoglobin, lead, preschool, Uruguay

Lead exposure in children continues to be a problem in low- to middle-income countries,[1] and with cognitive deficits and behavioral problems shown at progressively lower blood lead concentrations,[2–4] public health concern is not limited to levels ≥10 μg/dL. Several Latin American countries produce, use, and emit lead and, as a consequence, large numbers of children are exposed.[5] Although Uruguay is not a lead producer, lead is imported for industrial use[5] and leaded gasoline was used until 2004. Other sources of lead exposure remain, including battery recycling in private residences, wire burning, and lead-containing water pipes.[6]

Most studies examining lead exposure in Uruguayan children have focused primarily on unregulated settlements in the Montevideo neighborhood of La Teja where, in 2001, the discovery of children with blood lead levels (BPbs) > 20 μg/dL resulted in a public and media outcry.[6] These settlements are informal residences, most often constructed by marginalized and poor members of society from metal or wood sheeting or cardboard on public or private land, with limited access to water, electricity, and other infrastructure. In La Teja, some settlements were constructed on land previously belonging to lead-using industries. The unfortunate result of the La Teja case is the general perception that lead exposure in Uruguay

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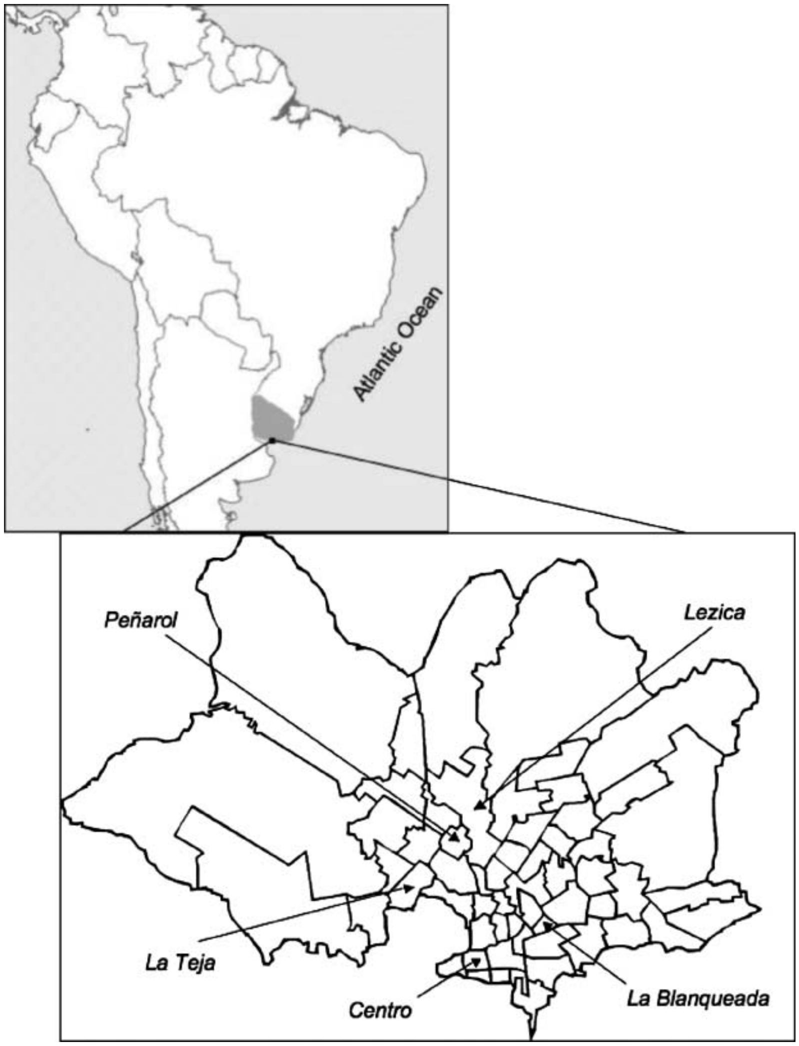

Fig. 1. Location of Montevideo neighborhoods that served as sources of the study population. Study participants were drawn mainly from 4 municipal areas of Montevideo: Peñarol (n = 101), La Teja (n = 84), Blanqueada (n = 15), Lezica (n = 14). Location of the city's center (Centro) is provided as a reference.

is found only among low-income populations and in unregulated urban or periurban settlements. In 2007, we conducted lead and hemoglobin screening in 222 children aged 5 to 45 months living in several areas of Montevideo to understand the extent of lead exposure in the city and to investigate family and child characteristics related to elevated BPbs.

METHODS

Setting and sample selection

The study was conducted on a convenience sample of children from Montevideo, the capital of Uruguay and home to 1.8 million inhabitants. Initially, children 6 to 36 months of age were invited for participation through posters, leaflets, radio announcements, and letters to childcare and health care centers. Participants came with their parents to the "lead clinic" at the Center for Research, Catholic University of Uruguay, or the researchers traveled to clinics set up specifically for this study in elementary schools and church or community centers. Due to community interest in the screening, the eligible age range was extended and the final sample included children aged 5 to 45 months. The participants lived mainly in 4 municipal areas of Montevideo: Peñarol ($n = 101$), La Teja ($n = 84$), Blanqueada ($n = 15$), Lezica ($n = 14$), others ($n = 8$) (Figure 1). The study was approved by Human Subjects Committees at the Cornell University, the Catholic University of Uruguay, and the Pereira Rossell Hospital for Women and Children.

Blood lead testing

After parents provided written consent, blood lead concentrations were tested in several drops of nonfasting capillary blood using the portable LeadCare Analyzer (ESA, Chelmsford, MA). The procedure was carried out by 2 trained pediatric nurses. The child's hand was washed with soap and water, and after air drying, the finger was gently massaged to stimulate blood flow. Blue Genie lancets (BD Microtainer, Franklin Lakes, NJ) were used for the finger stick. The first drops of blood were wiped off and the following 2 to 3 drops were used to completely fill a heparinized capillary tube (ESA). The entire contents of the capillary tube were transferred to the LeadCare test tube and mixed several times with the reagent. Fifty microliters of the liquid were used to obtain a blood lead reading. Quality control procedures were performed with each new test kit and at the beginning of each day of screening using standard controls.

Hemoglobin analysis

Hemoglobin was also measured in capillary blood, using additional drops of blood from the same finger-prick as BPb testing above. The HemoCue 201+ portable device was used to measure hemoglobin levels (HemoCue, Lake Forest, CA). Quality control was performed with standard HemoCue controls each time the instrument was used. Children with hemoglobin below 10.5 g/dL were referred to their pediatricians for follow-up.

Parental questionnaire

Parents completed a brief questionnaire asking about family size; socioeconomic status, including questions on number of possessions, house conditions (year of construction, presence of leaded pipes, last time the house was painted, number of rooms and bedrooms in the house, whether the family owned or rented the house), parents' education, and employment; pregnancy outcomes (birth weight and gestational age); breastfeeding history (duration of breastfeeding and child's age at the time liquids other than breast milk and solid foods were introduced); and the child's health (history of anemia, use of iron-fortified formula or cereals, whether the child uses a pacifier or puts fingers/toys in his/her mouth) and general diet (how many times in the past week did the child consume any fruits, vegetables, meat, eggs, legumes, and dairy products). The "family possessions" variable was constructed by summing the presence in the household of one or more of the following items: TV, video player, DVD player, computer, video games, radio, sound equipment, refrigerator, washer, house phone, cellular phone, or car. Because a large proportion of the mothers were not employed outside of the home, mother's occupation was collapsed into stay-at-home/unemployed versus employed. Father's occupation was coded as 1 if father engaged in jobs with potential lead exposure (print shop, informal recycling, construction, mechanic, driver, manufacture of plastics and metals) and 0 if employed otherwise.

Statistical analysis

All child and family characteristics were tested in bivariate regression models as potential predictors of BPb (continuous variable) and as the likelihood the child having a BPb ≥ 10 μg/dL. Next, all single factors with $p < .25$ were included in multiple linear and logistic regression models to investigate the most salient child and family predictors of blood lead concentrations and of the likelihood of children having BPb ≥ 10 μg/dL. Variables with $p > .15$ were removed in a backward stepwise fashion to establish the final parsimonious model.

RESULTS

Two hundred and forty-four children, including 20 sets of siblings, were screened between February and December 2007. Only one child from each set of siblings was randomly chosen for inclusion in the analysis, therefore the final study sample consisted of 222 children with blood lead and hemoglobin values. The majority of children came from 2-parent households (76% of parents either married or living together) and 33.8% of the families were of low socioeconomic status (defined as having 4 or less of the queried possessions). Almost 50% of the mothers did not have secondary education and the majority (76.8%) did not work outside of the home. The households with unemployed mothers were characterized by having, on average, fewer possessions (6.8 $\pm$ 2.7 versus 5.7 $\pm$ 2.4; $p < .05$) and higher crowding (2.4 $\pm$ 1.1 versus 3.2 $\pm$ 1.7 people/bedroom; $p < .01$) than households with employed mothers.

The mean capillary BPb of the children was 9.0 $\pm$ 6.0 (range 1–35.6) μg/dL, with 32.9% having BPb ≥ 10 μg/dL (Table 1). In turn, the mean hemoglobin concentration was 10.5 $\pm$ 1.5 g/dL, with 44.1% of the children being classified as anemic (hemoglobin < 10.5 g/dL). There was an association between blood lead and hemoglobin levels. In bivariate regression models, for each 1 g/dL increase in hemoglobin, capillary BPbs decreased by 0.65 μg/dL ($p < .05$). Children with hemoglobin < 10.5 g/dL had blood lead concentrations 2.5 $\pm$ 0.8 μg/dL higher on average ($p < .01$), and a 90% higher likelihood of a BPb ≥ 10 μg/dL ($p < .05$), than children without anemia. For children less than 18 months of age, the difference in BPbs between anemic and non-anemic children was 3.5 $\pm$ 1.1 μg/dL ($p < .01$); for older children the difference was 1.8 $\pm$ 1.2 μg/dL ($p > .1$).

Table 1 lists other characteristics that predicted children's blood lead in bivariate models. Younger mothers had children with higher BPb ($p < .05$), whereas mothers who had any secondary education had children with lower BPbs ($p < .01$) and lower likelihood of a BPb ≥ 10 μg/dL (odds ratio [OR] = 0.46, $p < .05$). Higher number of household possessions was also associated with lower BPbs. Finally, father's job with potential lead exposure was associated with higher BPb ($p < .05$) and a 2.3-fold higher likelihood elevated BPbs compared to other jobs.

Table 1.—Distribution of BPbs by Child and Demographic Characteristics

Child/family characteristic	N	Statistic	Blood lead (μg/dL)
		Child characteristics	
Age (months)	222	19.7 ± 8.9[a]	
<12		23.0%	7.6 ± 5.7
12–17.9		26.1%	9.0 ± 6.0
18–23.9		19.8%	9.3 ± 5.0
≥24		31.1%	9.9 ± 6.7[b]
Child sex	222		
Boys		53.2	9.0 ± 5.8
Girls		46.8	9.0 ± 6.3
Hemoglobin (g/dL)	222	10.5 ± 1.5	
≥10.5		55.9%	7.9 ± 5.1
<10.5		44.1%	10.4 ± 6.8**
Blood lead (μg/dL)	222	9.0 ± 6.0	—
≥10		32.9%	—
Puts fingers and toys in mouth	206		
No		35.4%	8.4 ± 5.4
Yes		64.6%	9.5 ± 6.3
Ever had anemia[c]	201		
No		84.1%	8.9 ± 6.1
Yes		15.9%	9.3 ± 5.5
Eats milk/dairy products daily	206		
No		11.2%	10.4 ± 6.9
Yes		88.8%	8.8 ± 5.9
		Parental/family characteristics	
Mother's age (years)	221	27.8 ± 7.3	
≥20		88.2	8.7 ± 5.6
<20		11.8	11.6 ± 8.2**
Mother's education	221		
Any primary		45.7%	10.4 ± 6.6
Any secondary		48.0%	8.1 ± 5.2*
Any postsecondary		6.3%	6.3 ± 5.0#
Mother unemployed/stay at home	220		
No		23.2%	7.1 ± 4.1
Yes		76.8%	9.5 ± 6.3**
Marital status	219		
Married		19.2%	8.9 ± 6.1
Divorced/separated		23.3%	9.5 ± 6.7
Living together		57.5%	8.9 ± 5.6
Family structure[d]	222		
2 parents		72.5%	8.9 ± 5.9
Single parent		27.5%	9.3 ± 6.4
Family's house	216		
Own		58.8%	9.0 ± 5.8
Rented		16.7%	7.2 ± 4.1
Family/other		24.5%	10.2 ± 7.2#
Crowding	215	3.0 ± 1.6	
≤3 people/bedroom		70.7%	8.8 ± 5.9
>3 people/bedroom		29.3%	9.5 ± 6.2
Family possessions	213	6.0 ± 2.5	
1–4		33.8	10.5 ± 6.1
5–8		47.4	8.9 ± 5.9
9–12		18.8	6.5 ± 5.1**
Father's job lead exposure risk	194		
No		67.0	8.2 ± 5.4
Yes		33.0	10.2 ± 5.8*

[a]Value given as $M \pm SD$.
[b]Significant trend test at $p < .05$.
[c]Based on the mothers report.
[d]The family structure does not reflect the number of adults living in the house; many households included other adults (for example grandparents).
#$p < .1$; *$p < .05$; **$p < .01$.

Table 2.—Child-Related Predictors of Mean Blood Lead Concentrations and the Likelihood of Elevated Blood Lead Concentrations (≥10 μg/dL) in Montevideo Preschoolers

	BPb (μg/dL)[a]	PbB ≥ 10 μg/dL[b]
Age (months)	0.11 [0.01, 0.20]**	1.02 [0.98, 1.05]
Hemoglobin < 10.5 g/dL	2.40 [0.77, 4.03]***	1.90 [1.08, 3.35]**
Fingers/toys	0.76 [−0.13, 1.65]	1.02 [0.74, 1.41]

[a]Predictors tested in multiple linear regression and included in the final model; values given as beta [95% confidence interval].
[b]Predictors tested in logistic regression and included in the final model; values given as OR [95% confidence interval].
*$p < .1$. **$p < .05$. ***$p < .01$.

To understand which child and family factors most strongly predicted the child's BPb and the likelihood of BPb ≥ 10 μg/dL, we conducted multiple linear and logistic regression models, with child and family-related predictors being tested separately. Age, hemoglobin, and putting fingers/toys in the mouth were the child-related characteristics that most strongly predicted the child's BPb. For each 1-month increase in age, BPb increased by 0.11 μg/dL, children with hemoglobin < 10.5 g/dL had BPb higher by 2.4 μg/dL, and children who put fingers or toys in their mouth had BPb higher by 0.76 μg/dL. Together, these characteristics explained 3.9% of variability in children's BPbs (Table 2). Hemoglobin < 10.5 g/dL remained the child characteristic most strongly predictive of BPb ≥ 10 μg/dL (Table 2). Furthermore, the likelihood of elevated BPbs was particularly pronounced in anemic children younger than 18 months (OR = 3.1, 95% confidence interval [CI; 1.3, 7.4], $p = .011$) but not in older children (OR = 1.4, 95% CI [0.6, 3.0], $p = .41$).

In multivariate modeling of the family characteristics, maternal age, schooling, and family possessions were the most salient determinants of child BPb. Children with very young mothers (<20 years) had higher BPbs by 2.74 μg/dL, children with mothers who had any secondary education tended to have BPbs lower by 2.61 μg/dL, and each additional household possession was associated with BPbs lower by 0.62 μg/dL (Table 3). Together, these predictors explained 14% of variability in children's BPbs. Mother's education, household possessions, and father's job were the strongest family predictors of elevated blood lead levels (Table 3).

COMMENT

We conducted blood lead and hemoglobin screening in 222 preschool children from Montevideo, Uruguay, to determine the extent of lead exposure and to understand the predictors of elevated BPb in this population. With a mean of 9.0 ± 6.0 μg/dL, over 30% of children having BPbs ≥ 10 μg/dL and almost 72% with BPbs ≥ 5 μg/dL, the extent of lead exposure among Montevideo preschoolers is similar to other Latin American countries. For example, in 0.5- to 11-year-old children from Lima Peru, the mean capillary BPb was 9.9 μg/dL, with 29% of the children having BPbs ≥ 10 μg/dL.[7] Also, in the State of Morelos, Mexico, children 1 to 12 years of age had mean BPb of 8.2 ± 5.6 μg/dL, with 29.7% having BPbs ≥ 10 μg/dL.[8] On the other hand, the BPbs in Uruguayan preschoolers are higher than in US children of similar age who experience population average BPb of approximately 1.6 μg/dL.[9] With detrimental effects on IQ and behavior found at BPbs previously thought to be "safe," this puts a large population of Uruguayan preschoolers at risk of potentially irreversible cognitive deficits.[10]

Low hemoglobin was a significant predictor of blood lead concentration and of the likelihood of a child having a BPb ≥ 10 μg/dL, particularly among children less than 18 months of age. Children experiencing both conditions at a young age could have increased susceptibility to later developmental consequences, thus our results underscore the urgency of lead and hemoglobin screening at an early age. The association between iron deficiency or anemia and elevated BPbs has

Table 3.—Family/Household-Related Predictors of Mean Blood Lead Concentrations and the Likelihood of Elevated Blood Lead Concentrations (≥10 μg/dL) in Montevideo Preschoolers

	BPb (μg/dL)[a]	PbB ≥ 10 μg/dL[b]
Mother's age < 20 years	2.74 [0.32, 5.15]**	1.96 [0.71, 5.41]
Mother's education		
Any primary	Ref. group	Ref. group
Any secondary	−1.48 [−3.11, 0.16]*	0.53 [0.27, 1.08]*
Any postsecondary	−3.74 [−6.98, −0.49]	0.37 [0.07, 1.94]
Possessions	−0.53 [−0.85, −0.22]***	0.79 [0.68, 0.92]***
Father's job lead exposure risk	1.28 [−0.33, 2.89]	1.96 [0.99, 3.90]*

[a]Predictors tested in multiple linear regression and included in the final model; values given as beta [95% confidence interval].
[b]Predictors tested in logistic regression and included in the final model; values given as OR [95% confidence interval].
*$p < .1$ **$p < .05$; ***$p < .01$.

been shown in some studies[11–13] but not others.[14] Iron deficiency is thought to predispose young children to BPbs ≥ 10 μg/dL,[15] whereas daily consumption of iron-fortified rice reduced the prevalence of elevated BPbs among iron-deficient Indian school children by 36%, compared to 13% reduction in the control group.[16] We did not measure direct indicators of iron deficiency, but anemia in this group is likely due to inadequacy of dietary iron. According to maternal reports, only 42.1% and 38.3% of children younger than 18 months received iron-fortified cereals within the previous week or month, respectively.

Other predictors of BPbs in this population included maternal age and education, family socioeconomic status, and father's employment in jobs with potential risk of lead exposure. Families with higher resources may be less likely to engage in activities (father's employment, for example) that will expose children to lead or live in areas with less industry. Similarly, families with higher maternal education may have better economic resources or engage in behaviors protective of child health, such as iron supplementation. In our study, women with any secondary education were twice as likely to give children iron-fortified cereals as women with primary education only (data not shown), but it is unclear if this is due to level of awareness or resources. We would caution, however, against interpreting our findings as demonstrating that lead exposure is only a problem in low-income Montevideo populations with lower levels of education. Although BPbs were higher among children whose mothers had only primary education and among families that had less than 5 of the possessions we queried, lead exposure was not absent in the more well off homes. Among children from families with higher socioeconomic status, the mean BPb was over 6 μg/dL and 15% had BPb greater than 10 μg/dL.

We used the LeadCare Analyzer to test lead levels in capillary blood because this method is portable and reliable. For approximately 80% of the sample, we carried out lead testing in the communities, which was greatly facilitated by using a device that did not require sample refrigeration, storage, or transport. LeadCare has previously been shown to correlate very well ($r^2 > .9$) with the atomic absorption spectrophotometry (AAS)[17] and, in validation studies, did not differ from AAS in classifying participants into the 10 to 19.9 μg/dL range of BPbs.[17] Most of the "high" values in our sample fell within this range. Thus, capillary blood lead screening is a valuable tool in community settings to identify populations exposed to lead and to alert public health authorities to potential problems.

In summary, we found a high prevalence of elevated BPbs in over 200 children in a variety of neighborhoods across Montevideo. Our study adds to the growing literature on pediatric lead exposure in Uruguay and provides evidence that elevated BPbs continue to be a problem despite the elimination of leaded gasoline in 2004. In addition, blood lead testing is not currently part of the routine pediatric visit, thus many lead-exposed children are not identified. These children represent a vulnerable population that may benefit from promising new interventions such as early environmental enrichment and behavioral/educational interventions. Thus, the issue of lead exposure in Uruguayan children needs to receive further attention from medical and public health professionals, scientists, and the government. For lead screening to become routine practice, lead exposure needs to be recognized as a mainstream problem and pediatricians need to be sensitized to its existence, prevalence, and consequences.

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