NIH Public Access
Author Manuscript
Paediatr Perinat Epidemiol. Author manuscript; available in PMC 2013 January 1.

Published in final edited form as:
Paediatr Perinat Epidemiol. 2012 January ; 26(1): 61–69. doi:10.1111/j.1365-3016.2011.01234.x.

Blood Lead Levels and Associated Socio-demographic Factors among Preschool Children in the South Eastern region of China

Jianghong Liu[a,*], **Yuexian Ai**[b,*], **Linda McCauley**[c], **Jennifer Pinto-Martin**[a], **Chonghuai Yan**[d], **Xiaoming Shen**[d], and **Herbert Needleman**[e]

[a]University of Pennsylvania, School of Nursing

[b]Jintan People's Hospital, Jintan, Changzhou City, China

[c]Emory University, Nell Hodgson School of Nursing

[d]Shanghai Jiaotong University School of Medicine, Shanghai Key Laboratory of Children's Environmental Health

[e]University of Pittsburgh, Department of Psychiatry and Pediatrics

Summary

Children are especially vulnerable to lead toxicity, and exposure to lead has been linked to poor school performance and delinquency in children and adolescents. Even low-level lead exposure (blood lead level [BLL] lower than 10 μg/dL) can cause intelligence deficit. In China, BLLs in children decreased slightly after the phase-out of lead in gasoline, but few studies have examined the socio-demographic factors associated with BLL above 10 μg/dL. In thus study, we sought to examine the hypothesis that socio-demographic factors predict BLLs. We measured BLLs of 1,344 preschool children (3–5 years old) from the China Jintan Child Cohort Study. Children's socio-demographics and health statuses, as well as parental socio-demographics, were collected through questionnaire. Multiple regression models were used to explore the association between socio-demographic factors and log-transformed BLLs as well as the relationship between socio-demographic factors and the risk of BLL above 10 μg/dL. We found the median BLL to be 6.2 μg/dL (range: 1.8–32.0 μg/dL), and 8% of children had BLLs above 10 μg/dL. Boys had a higher median BLL (6.4 μg/dL) than girls and were more likely to have BLL above 10 μg/dL (OR=1.77, 95% CI 1.14 –2.74). BLLs increased as children aged, with a median BLL of 6.6 μg/dL among 5-year old children. Children with sibling(s) had higher average BLL and prevalence of BLL above 10 μg/dL than those without sibling(s). Living in a crowded neighborhood was also associated with increased BLLs. Mother's lower education, father's occupation (as professional worker), and parental smoking at home were associated with increased BLLs. This study shows that children in this area still have relatively high BLLs after the phase-out of leaded gasoline. Both children's and parental factors and community condition are associated with increased BLLs. Future efforts are needed to identify other exposure sources and develop targeted prevention strategies.

Corresponding Author, Dr. Jianghong Liu, PhD, RN, University of Pennsylvania Schools of Nursing and Medicine, 418 Curie Blvd., Room 426, Claire M. Fagin Hall, Philadelphia, Pennsylvania 19104-6096, Tel: (215) 898-8293, jhliu@nursing.upenn.edu.
*Note: Please list both Jianghong Liu and Yuexian Ai as first co-authors

Competing Interests
The authors have declared that no competing interests exist.

Authors' Contribution
JL conducted data collection, data analysis, data interpretation, and manuscript preparation. Ai Yuexian involved in research design and data collection. LM and JP conducted data interpretation and manuscript preparation. CY and XS conducted blood lead analysis. HN conducted data interpretation and manuscript preparation. All authors read and approved the final manuscript.

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Keywords

Blood lead level; Children; Socio-demographic factors

Introduction

Lead exposure is a child health concern around the world, especially in developing countries. Children's developing neurological systems are vulnerable to lead toxicity, as it can cause intellectual dysfunction[1,2] and increase negative behavior outcomes. [3–6] Even low-level lead exposure can cause intelligence deficits. [7–9] As of yet, no threshold for lead toxicity has been established. A point of concern for levels at or above 10μg/dL was established in 1991 by the US Centers for Disease Control and Prevention, and it was adopted by the Ministry of Health of China in 2006. While average blood lead levels (BLLs) and the prevalence of BLLs above 10 μg/dL have declined, it has been argued that even the level of 10μg/dL is too high and should be lowered further. [7, 10–12]

In China, reductions in both mean BLLs and the prevalence of BLL above 10 μg/dL have been reported since the ban of leaded gasoline in 2000.[13,14] Still, from 2001–2007, the mean BLL of children in China remained high at 8.1 μg/dL, and 23.9% of children had BLLs above 10 μg/dL.[15] This suggests that other important sources contribute to children's lead exposure in China. While a number of studies have measured BLLs in urban children, limited data exists for children who live in rural and suburban areas and may be exposed to high levels of lead discharged from small-scale industrial facilities due to poor hazard controls.[16] Indeed, after the phase-out of leaded gasoline, the prevalence of BLLs over 10 μg/dL was found to be higher among children living in suburban areas than that of children living in urban areas.[15] This could be due to industries shifting from urban to suburban areas, as well as poorer environmental and socioeconomic levels in suburban areas.[15]

Studies in developed countries have shown that BLLs above 10 μg/dL were associated with age, gender, race/ethnicity, use of ethnic remedies, cosmetics, or goods, immigrant and refugee status, income level, age of housing, location of residence, parental occupation, and exposure to tobacco smoke.[17,18] However, few studies in China have examined the determinants of BLLs after the phase-out of leaded gasoline. The majority of these studies in China have focused on gender and age differences, showing that BLLs were higher in boys and increased with age.[15,19] However, investigations in other countries have shown the opposite trend, where BLL was highest among toddlers and then declined with age.[20] We hypothesize that in addition to gender and age, other socioeconomic factors such as parental characteristics and community conditions predict BLL among young children in China as well. In the present study, we investigated the associations between socio-demographic factors and increased BBLs among preschool children from The China Jintan Child Cohort Study. [21]

Methods

Subjects

All subjects were from The China Jintan Child Cohort Study, which consists of 1,656 preschool children accounting for 24.3% of all children in the 3–5 age range in Jintan, Jiangsu, China. Study design, purpose, subject enrollment, and laboratory and health measures have been described previously.[21] Four pre-schools (Jianshe, Huacheng, Xuebu, and Huashan) were chosen to be representative of the geographic, social and economic profile of the whole city (Figure 1). Jianshe, Huacheng, and Huashan were chosen to represent urban, suburban, and rural areas, respectively. Xuebu was selected because of lead

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

pollution from a cement factory in this mining area.[22] Between Fall 2004 and Spring 2005, all children (ages 3–5 years) attending the four preschools were invited to participate in this study. Signed consent forms for children's participations were obtained from parents. Institutional review board approval was obtained from the University of Pennsylvania and the ethical committee for research at Jintan Hospital in China.

BLL measurement

Blood specimens of 1,344 children were collected by trained pediatric nurses using a strict research protocol to avoid lead contamination and were frozen and shipped to the Research Center for Environmental Medicine of Children at Shanghai Jaotong University for lead and micronutrient (iron, copper, zinc, calcium, and magnesium) analyses. We were not able to successfully collect blood samples from other children due to a variety of reasons, but there were no differences in demographics between children with and without blood samples. BLLs were measured by a graphite furnace atomic absorption spectrophotometer (AA100 - Perkin-Elmer Company). This laboratory has participated successfully in a CDC-administered quality-control program (Blood Lead Proficiency Testing Program) for the measurement of lead in whole blood. The detailed analytic procedures and performances have been described previously.[23,24] Analysis of each specimen was conducted using a replication procedure, and the mean of the repeated measurements was taken as the final measure. Blood lead reference materials for quality control (QC) were provided by Kaulson Laboratories, New Jersey. QC samples were inserted blindly among the study samples (one QC sample in every 10 study samples). The limit of detection (LOD) was 1.8 μg/dL and a half of LOD was imputed for samples under LOD.

Socio-demographic Information

Socio-demographic information obtained from the questionnaire include sex, age, parental educations and occupations (unemployed, general labor, skilled labor, professional worker), neighborhood condition such as whether living in a crowed neighborhood, person directly raising the child, having sibling(s) or not, parental smoking at home, and the mother's age when the child was born. Parents filled out the socio-demographic questionnaire during their meeting at the pre-schools, which happened at the end of the school year when blood samples were collected. While this questionnaire was self-administered, research assistants were on-site to assist any parents in filling out the forms.

Data analysis

Means with standard deviations (SD) and medians with minimum and maximum values were calculated to describe the distributions of BLLs. Since BLLs were not normally distributed, we used one way nonparametric analysis of variance (Wilcoxon or Kruskal-Wallis test) to compare BLLs. The multivariable linear regression model was fitted to identify independent predictors of BLLs (log-transformed). Multivariable logistic regression analysis was also performed to explore the associations between these factors and BLL above 10 μg/dL (≥10 μg/dL vs. <10 μg/dL) and above 5μg/dL (≥5 μg/dL vs. <5 μg/dL). Blood micronutrient levels and health states were controlled as potential confounders. All analyses were done in SAS 9.2 (SAS Institute, Cary, NC).

Results

Figure 2 shows the distribution of BLL. The median BLL was 6.2 μg/dL (range 1.8–32.0 μg/dL), with 7.8% of children having BLL above 10 μg/dL and 72.2% of children having BLL above 5 μg/dL. In univariable analysis (Table 1), statistically significant differences in BLLs were found between subgroups for all factors except for father's occupation (p=0.26) and person directly raising the child (p=0.96). The median BLL in boys was 10% higher

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

than that in girls. Median BLLs increased with increasing age of the children. Children with sibling(s) had higher median BLLs (6.7 μg/dL) than those without (6.1 μg/dL). Parental factors associated with increased BLLs include mother's age (<25 years), lower education levels, mother's occupation (unemployed or general labor woker), and smoking at home. Those living in houses or attending schools in rural area had the highest median BLLs. Living in crowed neighborhood was also associated with higher BLLs.

In multivariable linear regression analysis (Table 2), children's sex and age, mother's age when the child was born, having sibling(s), living in a crowded neighborhood (defined as having a lot of neighbors), and parent's smoking at home are the predictors of log-transformed BLLs. The estimated coefficient (beta) for boys was 0.096 units of log BLL, resulting in a 10% increase of BLL when transforming back to original scale. Compared with 3-year-old children, BLLs of 4- and 5 year-old children increased by 11% (beta=0.103 units of log BLL, P<0.0001) and 38% (beta=0.318 units of log BLL, P<0.0001), respectively. Mothers who were younger than <25 years old when the child was born had a 9% increase (beta=0.084 units of log BLL, P=0.02) when compared with those aged older than 30. Those children living in crowed neighborhood had an 8% increase compared with those living in less crowed neighborhood (beta=0.066 units of log BLL, P=0.01). Parental smoking at home increased children's BLLs by 10%. Children of parents as profession workers tended to have higher BLLs.

As shown in Table 3, boys are more likely to have BLLs above 10 μg/dL than girls (OR=1.77, 95% CI 1.14 –2.74). Compared with 3-year old children, 4- and 5-year old children had twice the odds of having BLLs above 10 μg/dL. Both father's education level and occupation were associated with a higher risk of BLL above 10 μg/dL among children. Compared with fathers who were college graduates, ORs ranged from 2.5 to 3.8 for fathers without a college education. Fathers as professional workers were more likely to have children with BLL above 10 μg/dL (OR=2.21, 95% CI 1.05 –4.66). Having sibling(s) was also associated with higher prevalence of BLL above 10 μg/dL (OR=2.18, 95% CI 1.12 – 4.24). None of the mothers' characteristics were associated with BLLs above 10 μg/dL among children. The findings were somewhat different when the model was fitted for BLL above 5 ug/dL. Living in a crowed neighborhood was associated with the prevalence of BLL above 5 ug/dL (OR=1.56, 95% CI 1.15–2.13), but neither father's degree nor having sibling(s) were associated the risk.

Discussion

Findings from this study indicate that despite the elimination of leaded gasoline, children in Jintan, China are still exposed to high levels of lead, with an average BLL greater than 6 μg/dL. This phenomenon has also been observed in other areas of China. Up to 6 years after the phase-out of leaded gasoline, mean BLLs among children aged 0–6 years from 14 Chinese cities during 2004–2006 varied around 5 μg/dL, with 7–10% of children having BLLs above 10 μg/dL.[19] Besides leaded gasoline, other important sources of lead exposure among children in China might include industrial emissions, lead-contaminated paints (e.g. in houses, toys, and stationeries), parents' take-home lead from work, coal combustion, food, and traditional medications.[25, 26, 27] In our study, preschool boys and girls living in rural areas (Xuebu and Huashan) had higher mean BLLs and a higher rate of BLL above 10 μg/dL than children living in urban and suburban areas due to lead emission from a cement factory, the biggest employer in this community with about 800 employees. Diet has been postulated as another important contributor of lead exposure in this area, since lead emitted from the factory may have contaminated the locally grown food. Wang and colleagues (2009) found that the weekly lead intake per body weight in children living in this area was higher than that in adults and 30% of children's weekly intake was greater than the

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

provisional tolerable weekly intake (PTWI) of the Joint FAO/WHO Expert Committee on Food Additives.[28] In the future, identifying the sources and quantifying their relative contributions to BLLs in these preschool children would help health agencies develop lead prevention strategies. Future investigations could include analysis of soil and dust samples of our study's three locations.

In this study, we found that BLLs increased with the increasing age of children, and this is consistent with findings in other studies both in China and India.[15, 29] This trend might be due to the fact that children are more mobile and thus are exposed to more sources of lead while they grow up. The increase in BLL may not continue after a certain age. Rabinowitz and colleagues (1985) found that BLLs increased up to age 5 and declined thereafter. Although we were not able to test this trend in the current analysis, the longitudinal design of this study will allow us to follow the temporal trend (with age increasing) in future analyses.[30]

The higher BLLs among boys might be explained by the differences in behaviors related to lead exposure. Compared to girls, boys spend more time doing outdoor activities and have more hand-to-mouth and object-to-mouth activities,[31] which have been associated with higher BLLs.[32] We did not collect information on physical activity and hand-to-mouth activity in our cohort, so the factors associated with our observed age and gender differences can only be postulated. Other factors such as physical activity and dietary intake may also influence the toxicokinetics of lead in the body and contribute to this difference. A recent study showed that the association of gender and BLL was modified by physical activity and race/ethnicity.[33] For the first time in China, we were able to compare BLLs between children with and without sibling(s) and found that children with sibling(s) had higher BLLs than those without sibling(s). This is consistent with findings such as those by Jarosińska et al. (2004), who found that children in Poland with two or more siblings had higher BLLs than those without siblings,[34] as well as a number of other studies that have found an association between the number of siblings and increased BLLs in children.[35–37] This association may result from the fact that children with siblings have more activities (especially outdoor activities) and live in a more crowded house, which was shown as a predictor of BLL.

Several parental factors were associated with BLLs in this study. Children of factory workers are more likely to have BLLs above 10 μg/dL. In Jintan, the majority of factory jobs are in manufacturing industries (such as smelter and cement) with lead exposure. In this area, while less educated persons are more likely to do general labor jobs, more-educated persons are more likely to have factory jobs and become smelter workers and cement workers, who are exposed to higher levels of lead. Lead taken home by parents has been recognized as an important source of children's exposure.[17] Lead dust from parents' surfaces and work clothing can be digested or inhaled by children at home. Lower education levels in fathers were also associated with increased BLLs as shown previously.[38–40] The association between mother's education and BLLs observed in univariable analysis disappeared in the multivariable analysis, indicating that education level may be a proxy for the combination of socioeconomic factors (e.g., occupation, home income, nutrition, location of residence) that more directly impact children's lead exposure and toxicokinetics.

Parental smoking at home has been associated with higher BLLs in children,[41–44] but a limited number of studies have been done to evaluate this association in China. This study, along with two previous studies,[23,45] verified this association. Children could be exposed to lead by inhaling tobacco smoke and by digesting floor dust containing lead that may be partially from indoor smoking. Studies showed that indoor smoking is one of the predictors for lead level in floor dust, which is associated with higher BLLs.[42,46] In China, 45% to

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

65% of children were exposed to environmental tobacco smoking, mainly in the home, and lead has been detected in all 15 randomly selected cigarette products in the Chinese market.[47] In the United States, 25% of children aged 3–11 years live with one or more smokers in the household.[48] Children with high cotinine levels were more likely to have BLLs above 10 μg/dL.[44] These data suggest that the control of parent smoking might be especially important for children in China.

Findings in this study have several implications for government policy regarding lead prevention. First, after the implementation of lead-free gasoline and regulations on lead levels in paint and industrial emissions, children in urban and suburban areas still had relatively high BLLs, suggesting that a broader national policy is necessary to control lead exposures from other sources. In 2006, the Ministry of Health of China issued its first guide for the prevention of children's lead poisoning through health education (knowledge, behavior, and nutrition) and blood lead level monitoring strategies. This guidance outlines comprehensive interventions including not smoking at home, no taking-home lead, no food with lead as additive. However, to our knowledge, there is no data showing how these recommendations have been implemented or the effectiveness of the prevention. Both children's factors and parental factors were associated with BLLs, suggesting the need of both school-based and community-based lead prevention programs.

This study has several limitations. First, despite accounting for many factors associated with BLLs, our multivariable model explained a small portion of variance, suggesting that other important contributors have not been identified. Second, blood lead is a biomarker of the most recent exposure to lead due to the short half-life (about one month in blood). All associations were analyzed using one measurement which may not represent the children's average exposure. Seasonal variations of BLLs have also been reported.[29] Third, we were not able to collect information about family income, drinking water sources, and traditional medications which have been associated with BLLs in previous studies.[17] Despite the association observed between father's occupations and BLLs above 10 μg/dL, we were not able to exactly know father's lead exposure status and some of them had multiple jobs which makes exposure assessment harder.

List of Abbreviations

BLLs	blood lead levels
CDC	Centers for Disease Control and Prevention
QC	Quality Control
SD	Standard deviations

Acknowledgments

National Institute of Environment Health Sciences (NIEHS, K01-ES015 877; R01-ES018858) US; UPenn CEET P30 ES013508; The Wacker Foundation US; Jintan City Government; Jintan Hospital, China.

Thanks are extended to the participating children and their families from Jintan City, and to the Jintan Cohort Study Group. This group consists of the Jintan Maternal Child Health Center, Jintan Hospital (Dr Liping Zhang, Yue Xian Ai and Liudi Han), China Southern Eastern University (Dr Guiju Sun and Honglei Peng), Nanjing Brain Hospital (Dr Tunong Chen) and The Chinese University of Hong Kong (Patrick W.L. Leung). We are very grateful to the Jintan city government and the Jintan Hospital for their support and assistance.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

References

1. Canfield R, Henderson C, Cory-Slechta D, Cox C, Jusko T, Lanphear B. Intellectual impairment in children with blood lead concentrations below 10 microgram per deciliter. New England Journal of Medicine. 2003; 348:1517–1526. [PubMed: 12700371]
2. Hubbs-Tait L, Nation J, Krebs N, Bellinger D. Neurotoxicants, Micronutrients, and Social Environments. Individual and Combined Effects on Children's Development. Psychological Science in the Public Interest. 2005; 6:57–121.
3. Needleman H, Riess J, Tobin M, Biesecker G, Greenhouse J. Bone Lead Levels and Delinquent Behavior. Journal of the American Medical Association. 1996; 275:363–369. [PubMed: 8569015]
4. Dietrich K, Ris M, Succop P, Berger O, Bornschein R. Early exposure to lead and juvenile delinquency. Neurotoxicology and Teratology. 2001; 23:511–518. [PubMed: 11792521]
5. Chen A, Cai B, Dietrich K, Radcliffe J, Rogan WJ. Lead exposure, IQ, and behavior in urban 5- to 7-year-olds: does lead affect behavior only by lowering IQ? Pediatrics. 2007; 119:e650–e658. [PubMed: 17332184]
6. Braun J, Froehlich T, Daniels J, Dietrich K, Hornung R, Auinger P, Lanphear B. Association of environmental toxicants and conduct disorder in U.S. children: NHANES 2001–2004. Environmental Health Perspectives. 2008; 116:956–962. [PubMed: 18629321]
7. Bellinger DC. Very low lead exposures and children's neurodevelopment. Current Opinion in Pediatrics. 2008; 20:172–177. [PubMed: 18332714]
8. Shen XM, Wu SH, Yan CH. Impacts of low-level lead exposure on development of children: Recent studies in China. Clinica Chimica Acta. 2001; 313:217–220.
9. Lanphear BP, Hornung R, Khoury J, Yolton K, Baghurst P, Bellinger DC, et al. Low-Level Environmental Lead Exposure and Children's Intellectual Function: An International Pooled Analysis. Environmental Health Perspectives. 2005; 113:894–899. [PubMed: 16002379]
10. Gilbert S, Weiss B. A rationale for lowering the blood lead action level from 10 to 2 μg/dL. NeuroToxicology. 2006; 27:693–701. [PubMed: 16889836]
11. Jones RL, Homa DM, Meyer PA, Brody DJ, Caldwell KL, Pirkle JL, et al. Trends in blood lead levels and blood lead testing among US children aged 1 to 5 years, 1988–2004. Pediatrics. 2009; 123:e376–e385. [PubMed: 19254973]
12. Needleman H, Riess J, Tobin M, Biesecker G, Greenhouse J. Low level lead exposure: history and discovery. Annals of Epidemiology. 2009; 19:235–238. [PubMed: 19344860]
13. Shen X, Yan C, Zhang Y. Comparison of children's blood lead levels in Shanghai before and after the introduction of lead free gasoline. China Medical Journal. 1999; 79:739–741.
14. Luo W, Zhang Y, Li H. Children's blood lead levels after the phasing out of leaded gasoline in Shantou, China. Archives of Environmental Health. 2003; 58:184–187. [PubMed: 14535579]
15. He K, Wang S, Zhang J. Blood lead levels of children and its trend in China. Science of the Total Environment. 2009; 407:3986–3993. [PubMed: 19395068]
16. Ye X, Fu H, Guidotti G. Environmental Exposure and Children’s Health in China. Archives of Environmental and Occupational Health. 2009; 62:61–73. [PubMed: 18316263]
17. Levin R, Brown MJ, Kashtock ME, Jacobs DE, Whelan EA, Rodman J, et al. Lead exposures in U.S. children, 2008: Implications for prevention. Environmental Health Perspectives. 2008; 116:1285–1293. [PubMed: 18941567]
18. Meyer PA, Pivetz T, Dignam TA, Homa DM, Schoonover J, Brody D. Surveillance for elevated blood lead levels among children--United States, 1997–2001. Morbidity and Mortality Weekly Report. 2003; 52:1–21.
19. Zhang SM, Dai YH, Xie XH, Fan ZY, Tan ZW, Zhang YF. Surveillance of childhood blood lead levels in 14 cities of China in 2004–2006. Biomedical and Environmental Sciences. 2009; 22:288–296. [PubMed: 19950523]
20. Baghurst PA, Tong S, Sawyer MG, Burns J, McMichael AJ. Sociodemographic and behavioural determinants of blood lead concentrations in children aged 11–13 years. The Port Pirie Cohort Study. The Medical Journal of Australia. 1999; 170:63–67. [PubMed: 10026685]
21. Liu J, McCauley LA, Zhao Y, Zhang H, Pinto-Martin J. Cohort profile: The China Jintan Child Cohort Study. International Journal of Epidemiology. 2010; 39(3):668–674. [PubMed: 19433517]

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

22. Jintan Bureau of Environmental Protection. New efforts to reduce environmental lead pollution. Jintan, China: http://www.jthbj.gov.cn/8fo-ReadNews.asp?NewsID=783.
23. Yan C, Shen X, Zhang Y. An epidemiological survey on blood lead level and high risk factors for lead poisoning of children in Shanghai. Chinese Journal of Pediatrics. 1998; 36:142–144.
24. Shen X, Zhou J, Yan C. The methodology of BPb level measurement by flamele GF-AAS. Journal of Trace Elements and Health Research. 1994; 11:43–48.
25. Shen X, Rosen JF, Guo D, Wu S. Childhood lead poisoning in China. Science of the Total Environment. 1996; 181:101–109. [PubMed: 8820381]
26. Lin GZ, Peng RF, Chen Q, Wu ZG, Du L. Lead in housing paints: An exposure source still not taken seriously for children lead poisoning in China. Environmental Research. 2009; 109:1–5. [PubMed: 18976991]
27. Clark CS, Rampalb KG, Thuppilc V, Chend CK, Clarka R, Roda S. The lead content of currently available new residential paint in several Asian countries. Environmental Research. 2006; 102:9–12. [PubMed: 16782088]
28. Wang F, Gao Q, Shao J, et al. Dietary lead intake among children and adults in Jinhu, Jiangsu. Chinese Journal of Public Health. 2009; 25:1–3.
29. Roy A, Hu H, Bellinger DC, Palaniapan K, Wright RO, Schwartz J, et al. Predictors of blood lead in children in Chennai, India (2005–2006). International Journal of Occupational and Environmental Health. 2009; 15:351–359. [PubMed: 19886345]
30. Rabinowitz M, Leviton A, Needleman HL, Bellinger DC, Waternaux C. Environmental Correlates of infant Blood Lead Levels in Boston. Environmental Research. 1985; 38:96–107. [PubMed: 4076115]
31. Freeman NCG, Jimenez M, Reed KJ, Gurunathan S, Edwards RD, Roy A, et al. Quantitative analysis of children's microactivity patterns: The Minnesota Children's Pesticide Exposure Study. Journal of Exposure Analysis and Environmental Epidemiology. 2001; 11:501–509. [PubMed: 11791166]
32. Ko S, Schaefer PD, Vicario CM, Binns HJ. Relationships of video assessments of touching and mouthing behaviors during outdoor play in urban residential yards to parental perceptions of child behaviors and blood lead levels. Journal of Exposure Science and Environmental Epidemiology. 2007; 17:47–57. [PubMed: 16941017]
33. Theppeang K, Glass TA, Bandeen-Roche K, Todd AC, Rohde CA, Schwartz BS. Gender and race/ethnicity differences in lead dose biomarkers. American Journal of Public Health. 2008; 98:1248–1255. [PubMed: 18511728]
34. Jarosińska D, Peddada S, Rogan WJ. Assessment of lead exposure and associated risk factors in urban children in Silesia, Poland. Environmental Research. 2004; 95:133–142. [PubMed: 15147918]
35. Cikrt M, Smerhovsky Z, Blaha K, Nerudova J, Sediva V, Fornuskova H, et al. Biological Monitoring of Child Lead Exposure in the Czech Republic. Environmental Health Perspectives. 1997; 105:406–411. [PubMed: 9189705]
36. Osman K, Zejda JE, Schütz A, Mielzynska D, Elinder CG, Vahter M. Exposure to lead and other metals in children from Katowice district, Poland. International Archives of Occupational and Environmental Health. 1998; 71:180–186. [PubMed: 9591159]
37. Jain NB, Hu H. Childhood Correlates of Blood Lead Levels in Mumbai and Delhi. Environmental Health Perspectives. 2006; 114:466–470. [PubMed: 16507473]
38. Morales LS, Gutierrez P, Escarce JJ. Demographic and socioeconomic factors associated with blood lead levels among Mexican-American children and adolescents in the United States. Public Health Reports. 2005; 120:448–454. [PubMed: 16025725]
39. Albalaka R. Blood lead levels and risk factors for lead poisoning among children in Jakarta, Indonesia. The Science of the Total Environment. 2003; 301:75–85. [PubMed: 12493187]
40. Kaiser R, Henderson AK, Daley WR, Naughton M, Khan MH, Rahman M, et al. Blood lead levels of primary school children in Dhaka, Bangladesh. Environmental Health Perspectives. 2001; 109:563–566. [PubMed: 11445508]

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

41. Ordóñez Iriarte JM, Aparicio Madre MI, Aránguez Ruiz E, Rivero Cuadrado A. Determinant factors of blood lead levels in children of 7–8 years old in the Autonomous Community of Madrid, Spain. Acta Pediatrica Espanola. 2009; 67:173–181.

42. Dixon SL, Gaitens JM, Jacobs DE, Strauss W, Nagaraja J, Pivetz T, et al. Exposure of U.S. children to residential dust lead, 1999–2004: II. The contribution of lead-contaminated dust to children's blood lead levels. Environmental Health Perspectives. 2009; 117:468–474. [PubMed: 19337524]

43. Baghurst PA, Tong SL, McMichael AJ, Robertson EF, Wigg NR, Vimpani GV. Determinants of blood lead concentrations to age 5 years in a birth cohort study of children living in the lead smelting city of Port Pirie and surrounding areas. Archives Of Environmental Health. 1992; 47:203–210. [PubMed: 1596103]

44. Mannino DM, Albalak R, Grosse S, Repace J. Second-hand Smoke Exposure and Blood Lead Levels in U.S. Children. Epidemiology. 2003; 14:719–727. [PubMed: 14569189]

45. Liu J, Jing J, Yi H, Wang M, Chen X, Liu D. Passive Smoking and Blood Lead Level. Chinese Journal of Public Health. 2000; 16:1–3.

46. Gaitens JM, Dixon SL, Jacobs DE, Nagaraja J, Strauss W, Wilson JW, et al. Exposure of U.S. children to residential dust lead, 1999–2004: I. Housing and demographic factors. Environmental Health Perspectives. 2009; 117:461–467. [PubMed: 19337523]

47. Zhang Y, Zhou H. Summary on Study of Heavy Metal Elements in Tobacco. Tobacco Science & Technology. 2004; 209:20–24.

48. CDC. 2006 Surgeon General's Report—The Health Consequences of Involuntary Exposure to Tobacco Smoke. Atlanta, GA: Centers for Disease Control and Prevention; 2006.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

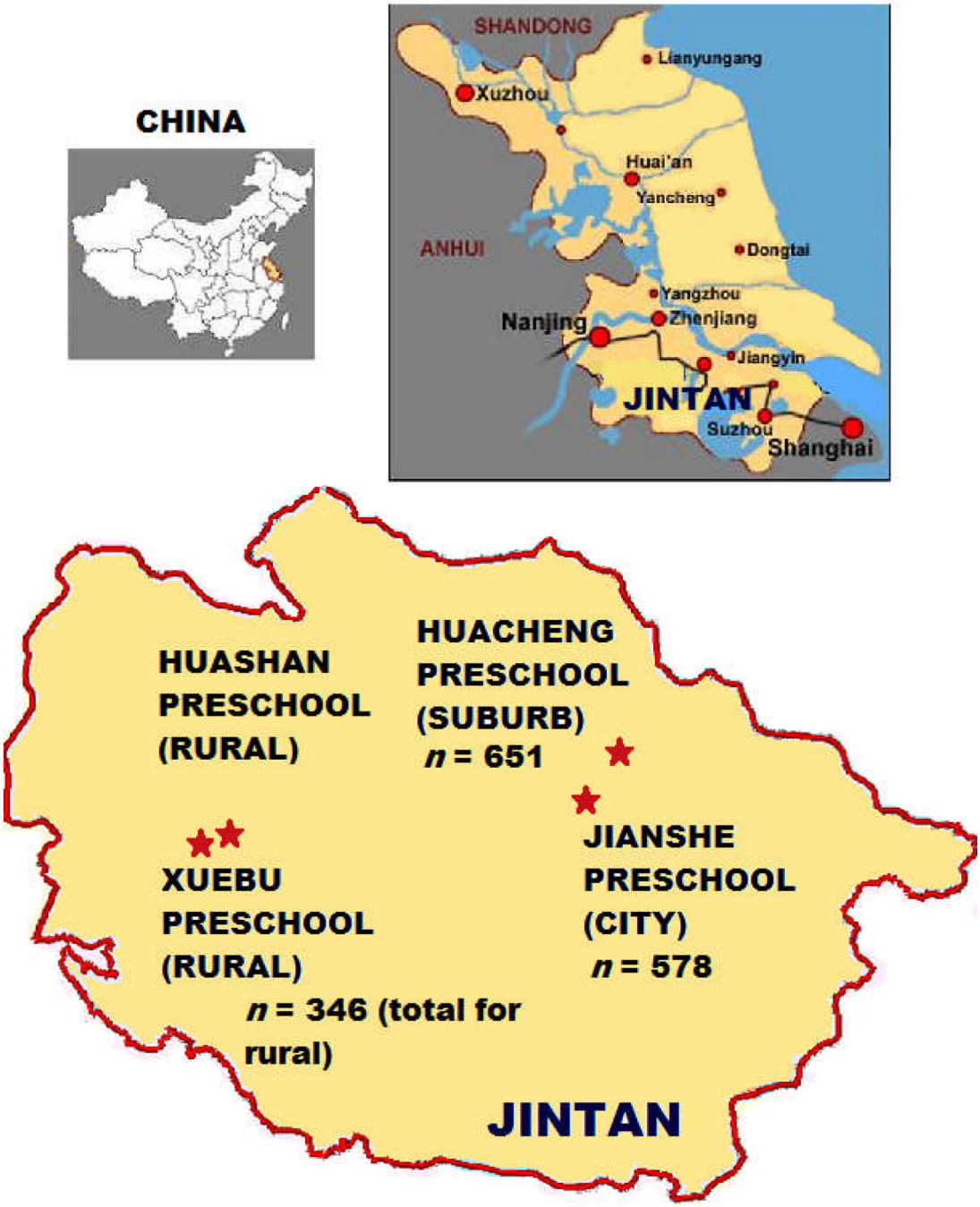

Figure 1.
Preschools selected in the China Jintan Child Cohort Study

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

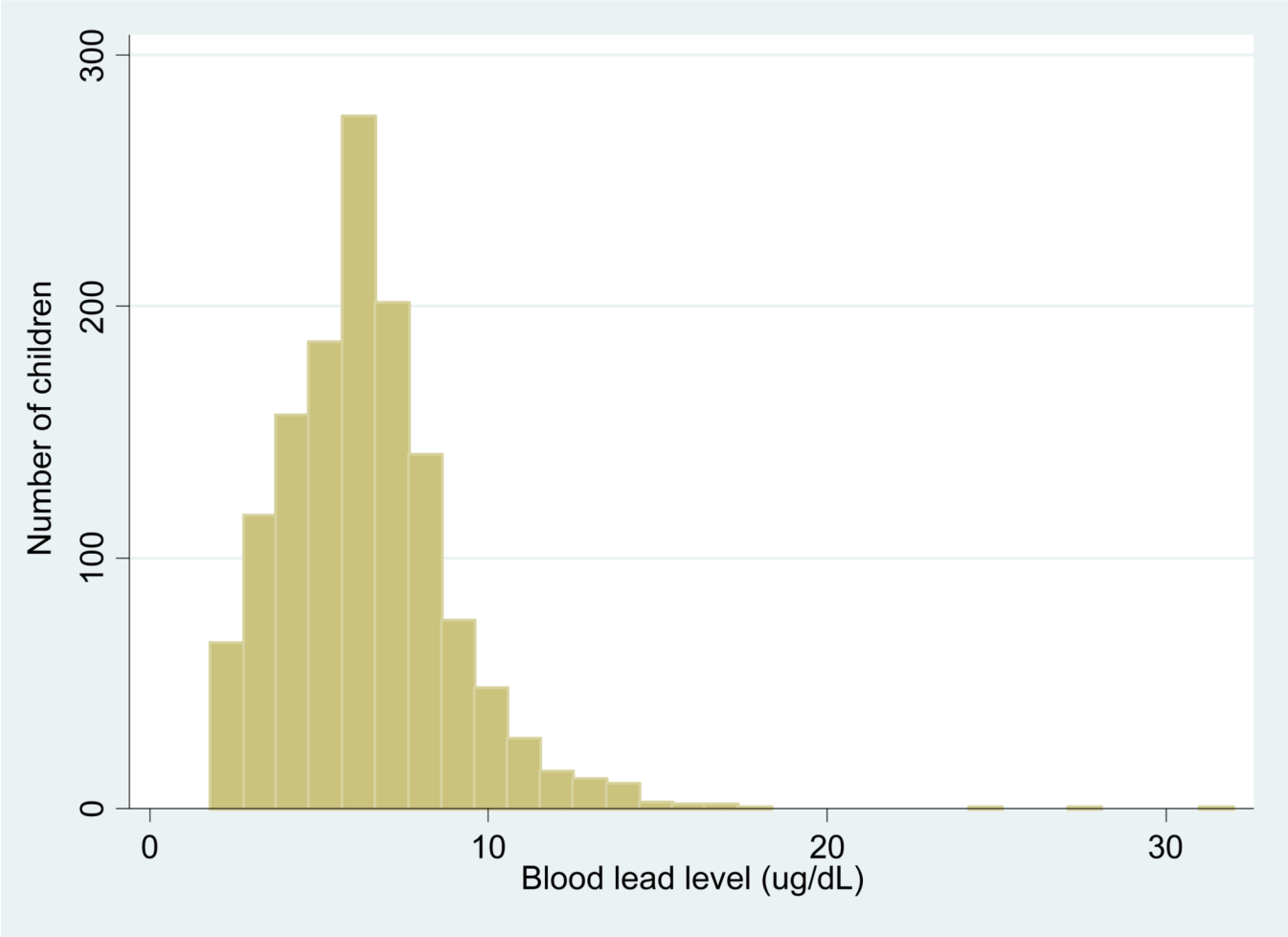

Figure 2.
The distribution of blood lead levels among preschool children from China Jintan Child Cohort Study

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

Table 1

Blood lead levels in pre-school children by social-demographic characteristics in Jintan, China

Characteristics		N (%)	Median (min.,max.)	Mean(SD)	P value*	% 5–10 μg/dL	% ≥10μg/dL
Total		1344 (100)	6.2 (1.8, 32.0)	6.4 (2.6)		865 (64.4)	105 (7.8)
Sex	Boys	740 (55.1)	6.4 (1.8,32.0)	6.7 (2.8)	<.0001	490 (66.2)	72 (9.7)
	Girls	604 (44.9)	5.9 (1.8,18.1)	6.0 (2.3)		375 (62.1)	33 (5.5)
Age (years)	5	596 (44.4)	6.6 (2.3, 24.0)	7.1(2.4)	<.0001	450 (75.5)	60 (10.1)
	4	438 (32.6)	6.1 (1.8, 32.0)	6.4 (2.8)		275 (62.8)	34 (7.8)
	3	308 (23.0)	4.9 (1.8,17.0)	5.2 (2.3)		138 (44.8)	11 (3.6)
Mother's age when the child was born	<25	380 (30.1)	6.4 (1.8,24.6)	6.8 (2.6)	<0.0001	261 (68.7)	37 (9.7)
	25–29	723 (57.3)	5.9 (1.8,32.0)	6.2 (2.6)		442 (61.1)	52 (7.2)
	30-	159 (12.6)	6.2 (1.8,18.1)	6.3 (2.8)		107 (67.3)	9 (5.7)
Father's highest degree	Primary school	40 (3.1)	7.1 (2.6,14.4)	7.3 (2.9)	<0.002	25 (62.5)	7 (17.5)
	Middle school	448 (35.2)	6.3 (1.8,32.0)	6.7 (2.8)		302 (67.4)	41 (9.2)
	High school	409 (32.2)	6.1 (1.8,27.5)	6.4 (2.9)		248 (60.6)	37 (9.0)
	College/University	375 (29.4)	5.9 (1.9,14.8)	6.0 (2.0)		239 (63.7)	14 (3.7)
Mother's highest degree	Primary school	145 (10.8)	6.9 (2.3,32.0)	7.1 (3.2)	<.0001	101 (69.7)	17 (11.7)
	Middle school	566 (42.1)	6.3 (1.8,24.6)	6.6 (2.7)		379 (67.0)	50 (8.8)
	High school	377 (28.1)	6.0 (1.8,14.8)	6.1 (2.4)		224 (59.4)	27 (7.2)
	College/University	256 (19.3)	5.9 (2.1,27.5)	6.1 (2.6)		161 (62.8)	11 (4.3)
Father's occupation	Unemployed/unskilled labor	156 (12.7)	6.3 (2.1,15.2)	6.7 (2.4)	0.260	113 (72.4)	12 (7.7)
	Skilled labor	559 (45.5)	6.3 (1.8,17.0)	6.4 (2.5)		354 (63.3)	43 (7.7)
	Professional workers	514 (41.8)	6.0 (1.9,32.0)	6.4 (3.0)		320 (62.3)	42 (8.2)
Mother's occupation	Unemployed/house wife	328 (26.5)	6.3 (1.9,14.4)	6.5 (2.2)	0.020	233 (71.0)	22 (6.7)
	Labor/assistant/secretary	540 (43.6)	6.3 (1.8,32.0)	6.5 (2.9)		338 (62.6)	51 (9.4)
	Professional workers	370 (29.9)	5.9 (1.9,27.5)	6.1 (2.6)		224 (60.5)	23 (6.2)
Having sibling(s)	Yes	107 (9.2)	6.7 (1.8,16.3)	7.0 (2.8)	0.010	69 (64.5)	15 (14.0)
	No	1055 (90.8)	6.1 (1.8,32.0)	6.4 (2.7)		673 (63.8)	75 (7.1)
Person directly raising the child	Biological parents	1184 (93.3)	6.1 (1.8,32.0)	6.4 (2.7)	0.960	758 (64.0)	91 (7.7)
	Others	86 (6.7)	6.0 (1.9,12.5)	6.4 (2.3)		54 (62.8)	8 (9.3)
Current living place	Urban	933 (73.5)	6.0 (1.8,32.0)	6.2 (2.7)	<0.001	574 (61.5)	61 (6.5)

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

Characteristics		N (%)	Median (min.,max.)	Mean(SD)	P value*	% 5–10 μg/dL	% ≥10μg/dL
	Suburban	187 (14.7)	6.3 (1.9,17.0)	6.7 (2.5)		129 (69.0)	20 (10.7)
	Rural	150 (11.8)	6.6 (2.3,18.1)	7.0 (2.6)		109 (72.7)	18 (12.0)
School location	Suburban	525 (39.1)	6.0 (1.8,32.0)	6.3 (2.9)	<0.005	315 (60.0)	43 (8.2)
	Urban	534 (39.7)	6.1 (1.9,24.6)	6.3 (2.5)		345 (64.6)	31 (5.8)
	Rural	285 (21.2)	6.4 (2.6,18.1)	6.9 (2.4)		205 (71.9)	31 (10.9)
Living in crowded neighborhood	Yes	504 (46.3)	6.4 (1.8,24.6)	6.7 (2.6)	<0.005	342 (67.9)	48 (9.5)
	No	585 (53.7)	6.1 (1.8,17.0)	6.3 (2.4)		371 (63.4)	41 (7.0)
Parental smoking at home	Yes	95 (11.2)	6.7(1.9,32.0)	7.4(4.2)	<0.005	67 (70.5)	9(9.5)
	No	752 (88.8)	5.9(1.8,24.6)	6.2(2.5)		453 (60.2)	57 (7.6)

*p values of one-way nonparametric analysis of variance (Wilcoxon or Kruskal-Wallis test)

NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 2

Predictors of log-transformed blood lead levels (μg/dL) among children in Jintan, China

Characteristics		Coefficient (beta) estimate	95% CI	p-value
Sex	Boys	0.096	[0.055, 0.137]	<.0001
	Girls	Reference		
Age (years)	5	0.318	[0.263, 0.373]	<.0001
	4	0.103	[0.054, 0.152]	
	3	Reference		
Mother's age when the child was born	<25	0.084	[0.011, 0.157]	0.023
	25–29	0.024	[−0.043, 0.091]	
	30-	Reference		
Father's highest degree	Primary school	0.028	[−0.115, 0.171]	0.879
	Middle school	0.009	[−0.060, 0.078]	
	High school	0.007	[−0.054. 0.068]	
	College/University	Reference		
Mother's highest degree	Primary school	0.05	[−0.079, 0.179]	0.092
	Middle school	−0.013	[−0.093, 0.067]	
	High school	−0.065	[−0.138, 0.008]	
	College/University	Reference		
Father's occupation	Professional workers	0.106	[−0.017, 0.229]	0.486
	Skilled labor/driver	0.061	[−0.057, 0.179]	
	Unemployed/unskilled labor	Reference		
Mother's occupation	Professional workers	−0.082	[−0.192, 0.028]	0.575
	Skilled labor/driver	−0.027	[−0.125, 0.071]	
	Unemployed/unskilled labor	Reference		
Having sibling(s)	Yes	0.071	[−0.007, 0.149]	0.045
	No	Reference		
Living in a crowded neighborhood	Yes	0.066	[0.021, 0.111]	0.003
	No	Reference		
Parental smoking at home	Yes	0.093	[0.013, 0.173]	0.062
	No	Reference		

95% CI: 95% confidence interval.

NIH-PA Author Manuscript NIH-PA Author Manuscript NIH-PA Author Manuscript

Table 3

Logistic regression analysis of BLL above 10 μg/dL and 5 μg/dL among preschool children in Jintan, China

Characteristics		≥ 10 μg/dL		≥ 5μg/dL	
		ORs and 95% CI	p-value	ORs and 95% CI	p-value
Sex	Boys	1.77 (1.14 –2.74)	0.011	1.55 [1.20, 2.01]	0.001
	Girls	Reference			
Age (years)	5	2.28 (1.10 –4.70)	0.018	2.65 [1.91, 3.68]	<0.0001
	4	2.73 (1.36 –5.46)		6.20 [4.36, 8.81]	
	3	Reference			
Mother's age when the child was born	<25	1.80 (0.78 –4.15)	0.545	1.28 [0.79, 2.07]	0.020
	25–29	1.61 (0.72 –3.58)		0.80 [0.53, 1.26]	
	30-	Reference			
Father's highest degree	Primary school	3.81 (1.10 –13.19)	0.069	0.79 [0.29, 2.11]	0.886
	Middle school	2.45 (1.10 –5.43)		0.96 [0.61, 1.48]	
	High school	2.81 (1.37 –5.78)		0.85 [0.59, 1.25]	
	College/University	Reference			
Mother's highest degree	Primary school	1.58 (0.46 –5.44)	0.858	1.07 [0.43, 2.64]	0.212
	Middle school	1.28 (0.51 –3.22)		0.93 [0.57, 1.52]	
	High school	1.10 (0.46 –2.63)		0.69 [0.44, 1.07]	
	College/University	Reference			
Father's occupation	Skilled labor/driver	1.25 (0.62 –2.51)	0.086	1.49 [0.69, 3.21]	0.821
	Professional workers	2.21 (1.05 –4.66)		1.86 [0.83, 4.21]	
	Unemployed/unskilled labor	Reference			
Mother's occupation	Skilled labor/driver	1.60 (0.92 –2.76)	0.380	0.71 [0.35, 1.41]	0.418
	Professional workers	1.32 (0.63 –2.78)		0.50 [0.23, 1.07]	
	Unemployed/unskilled labor	Reference			
Having sibling	Yes	2.18 (1.12 –4.24)	0.021	1.30 [0.76, 2.22]	0.341
	No	Reference			
Living in a crowded neighborhood	Yes	1.31 (0.83 –2.08)	0.250	1.56 [1.15, 2.13]	0.004
	No	Reference			
Parent smoking at home	Yes	1.03 (0.47 –2.23)	0.946	1.52 [0.86, 2.70]	0.145

NIH-PA Author Manuscript
NIH-PA Author Manuscript
NIH-PA Author Manuscript

Characteristics	≥ 10 μg/dL		≥ 5μg/dL	
	ORs and 95% CI	p-value	ORs and 95% CI	p-value
No	Reference			

ORs, odds rations; 95% CI, 95% confidence interval.