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Exposure sources and reasons for testing among women with low blood lead levels

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Previous research has focused on highly elevated blood lead (PbB). This study examined reasons for testing and potential sources of exposure among women with PbBs less than 0.72 μmol/l (15 μg/dl). A questionnaire was mailed to 18- to 49-year-old women in upstate New York, USA, who were PbB tested in 2007. The most common testing reason was pregnancy among 125 women who returned the questionnaire. Among women tested for PbB during pregnancy, doctors ordered approximately 80% of tests regardless of lead level. Few women with PbBs less than 0.24 μmol/l (5 μg/dl) reported a potential source of lead exposure. However, among women with PbBs of 0.24–0.71 μmol/L (5–14.9 μg/dl), 29.2% had a job and 21.2% had a hobby with potential lead exposure. There are systematic differences in reasons for testing and exposure sources among women with PbBs less than 0.72 μmol/l and these differences have implications for screening.

Keywords: low-level lead exposure; blood lead; lead screening; women

Introduction

With the banning or phasing out of lead-based gasoline and paint, blood lead (PbB) among the general population is declining steadily worldwide (Tong et al. 2000). However, the general population exposure to low levels of lead continues due to its widespread use and ubiquitous nature (Centers for Disease Control and Prevention [CDC] 2005). According to the 2003–2004 National Health and Nutrition Examination Survey, the mean PbB among women aged 18–49 years in the United States (US) was 0.06 μmol/l, with a 95th percentile of 0.13 μmol/l (CDC 2005). The mean PbB among adults aged 18–65 years was 0.38 μmol/l in 1995 in Barcelona, Spain (Torra 1997). Among 1,000 children aged 6–72 months tested in 1999 in Chiang Mai, Thailand, their average PbB was 0.20 μmol/l (Prapamontol 2010).

Previous research has focused on highly elevated PbBs. According to the 2005–2007 Adult Blood Lead Epidemiology and Surveillance (ABLES) by the US Centers for Disease Control and Prevention, the majority of adults with PbBs more

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than or equal to 1.21 μmol/l (25 μg/dl) were due to occupational exposures and less than 5% were from non-occupational exposures (CDC 2009). However, PbBs below 0.72 μmol/l (15 μg/dl) have been associated with adverse effects in humans including elevated blood pressure, impaired nervous system development, delayed sexual maturation, neurobehavioral effects, depressed renal glomerular filtration rate, and reduced heme synthesis (Agency for Toxic Substances and Disease Registry [ATSDR] 2007).

Limited epidemiologic surveys have been conducted to explore exposure sources and reasons for lead testing among women with PbBs less than 0.72 μmol/l (15 μg/dl) (Raja et al. 1996; Fletcher et al. 1999; Hertz-Picciotto et al. 2000; Klitzman et al. 2002). The current study was conducted to help address this issue. The objectives were to examine the reasons for lead testing, exposure sources, and socio-demographic characteristics between women with PbBs less than 0.24 μmol/l (5 μg/dl) and those with PbBs of 0.24–0.71 μmol/l (5–14.9 μg/dl).

Method

A self-administered questionnaire was mailed to upstate New York (New York State, exclusive of New York City), US women aged 18–49 years with reported PbBs below 0.72 μmol/l to the New York State Heavy Metals Registry (HMR) between 1 January 2007 and 31 August 2007. Women were stratified by PbB (< 0.24 μmol/l and 0.24–0.71 μmol/l) and 200 women were selected from each group using the simple random selection method in SAS PROC SURVEYSELECT (SAS® Institute Inc. 2005). We selected this cut-point because PbB less than 0.24 μmol/l accounts for over 95% of adult women (CDC 2005); PbB of 0.24–0.71 μmol/l contributes to less than 5% of adult women and is not considered sufficiently elevated to warrant clinical intervention (CDC 2005; ATSDR 2007).

The questionnaire asked reasons for the lead test, exposure sources during the past year including occupation, home renovation, housing condition, environment, hobbies, whether there was prenatal screening, and sociodemographics including age, education, race, and ethnicity. A letter explaining the study and a consent form were sent with the questionnaire.

The HMR maintains a statewide database and receives reports on exposure to heavy metals, including lead, mercury, arsenic, and cadmium from physicians and laboratories since 1982 (New York State [NYS] Department of Health Bureau of Occupational Health 2008). The reporting requirement was changed from 1.21 μmol/l to include all blood lead test reports regardless of level in 1992 (NYS Department of Health Bureau of Occupational Health 2008). In 2006, the HMR received nearly 100,000 reports for women with PbBs less than 0.72 μmol/l in 2006 – more than 99% of all records reported to the HMR (NYS Department of Health Bureau of Occupational Health 2008). The HMR has conducted telephone interviews for all women of childbearing age with PbBs 0.72 μmol/l and greater since September 2006 but does not interview women with lower levels.

The study was restricted to upstate New York women because our pilot efforts revealed very low response rates among women from New York City. For women with PbBs between 0.24 μmol/l and 0.71 μmol/l, the participant letter and the consent form stated that their PbBs were higher than 95% of the general population but still within the clinically normal range. To improve the overall response rate, the following strategies were further applied (Asch et al. 1997; Edwards et al. 2002):

Three mailings, one telephone call reminder, \$3 cash payment unconditional on response, and the inclusion of a self-addressed stamped envelope. This study was approved by the NYS Department of Health and the State University of New York at Albany Institutional Review Boards.

Statistical analysis

Initially, the study participants and non-respondents were compared regarding PbB and age to determine whether there were any systematic differences. Then reasons for testing, possible exposure sources, and sociodemographics were examined by lead level among participants. The χ^2 test was used to assess statistical difference with type I error rate of 5%. All analyses were conducted using SAS® version 9.1 (SAS Institute Inc. 2005).

Results

Sixty-one out of 400 questionnaires could not be delivered because of a change of address. Out of 339 delivered questionnaires, 125 women completed the questionnaire. The response rate was 36.9%. Table 1 indicates that response rates were similar between the two PbB groups, less than 0.24 μmol/l and between 0.24 and 0.71 μmol/l (34.7 and 39.1%, respectively). The response rate by age was borderline statistically significant ($p = 0.08$), with a higher percentage of those respondents being older (Table 1). Table 2 presents the sociodemographic characteristics by PbB among respondents. There were no differences in response by race, ethnicity, age, education, employment status, and residential characteristics.

As shown in Table 3, about 65.2% of women with PbBs between 0.24 and 0.71 μmol/l knew they were tested for blood lead, relative to only 45.6% for PbBs less than 0.24 μmol/l ($p = 0.03$). Among women with PbBs less than 0.24 μmol/l, virtually all of the women who knew they were being tested for lead reported that the reason was pregnancy-related. Pregnancy was also the most common reason for testing among women with PbBs between 0.24 and 0.71 μmol/l. However, this group also reported testing due to their own concern of being high risk (19.4%) or because of a company/workplace screening (12.9%). Among women tested for PbB during

Table 1. Characteristic distribution by response status.

Characteristic	Response		*P* value*
	Yes	No	
N	125	214	
Blood lead level (%)			0.41
0–0.23 μmol/l (0–4.9 μg/dl)	47.2	51.9	
0.24–0.71 μmol/l (5–14.9 μg/dl)	52.8	48.1	
Age (%)			0.08
18–19	5.6	11.7	
20–29	37.6	43.9	
30–34	26.4	22.9	
35–49	30.4	21.5	

**P* value is generated from Chi-square test.

Table 2. Sociodemographic characteristics by blood lead among respondents.

Characteristic	Blood lead (μmol/l) 0–0.23	0.24–0.71	P value*
n	59	66	
Race (%)†			0.46
White	71.4	79.3	
Black	16.1	8.6	
Other	12.5	12.1	
Ethnicity: Hispanic (%)	14.6	17.2	0.69
Age (%)			0.70
18–19	6.8	4.6	
20–29	39.0	36.4	
30–34	28.8	24.2	
35–49	25.4	34.9	
Education (%)			0.61
Less than high school graduate	5.2	10.8	
High school graduate	20.7	24.6	
Some college or bachelor degree	46.6	41.5	
Graduate study	27.6	23.1	
Working (%)	78.0	86.4	0.22
Type of residence (%)			0.97
House	77.6	76.6	
Apartment	17.2	17.2	
Mobile home	5.2	6.3	
Neighborhood (%)			0.33
Urban	22.8	30.2	
Suburban	59.7	46.0	
Rural	17.5	23.8	
Living near bridge (%)	20.3	25.8	0.47
Living near highway (%)	45.8	31.8	0.11

**P* value is generated from Chi-square test. †Race is missing for 8.8% of records.

pregnancy, doctors ordered 85% of tests for PbBs less than 0.24 μmol/l and 83% for PbBs between 0.24 and 0.71 μmol/l.

Table 4 displays potential sources of lead exposure by PbB level. Very few women (6.8%) with PbBs less than 0.24 μmol/l had jobs with potential exposure to lead within one year before the blood lead test, compared to 29.2% of those with PbBs between 0.24 and 0.71 μmol/l ($p < 0.01$). There were no significant differences in the proportion of women who lived in a residence built before 1978 by PbB level, nor was there a difference in painting-related renovation. Among 64 residences built before 1978, 12 (18.8%) were tested for home lead and three were positive (data not shown). Among residences built before 1978, 11 (17.2%) were tested for lead in water pipes and one tested positive (data not shown).

Table 4 also indicates that hobbies with potential for lead exposure other than home renovation were less common among women with PbBs less than less than 0.24 μmol/l compared to those with PbBs between 0.24 and 0.71 μmol/l (8.8% and 21.2%, respectively, $p = 0.06$). In addition, the use of glazed ceramics and/or pottery imported from outside the US was less frequent among women with PbBs less than 0.24 μmol/l than those between 0.24 and 0.71 μmol/l (2.1% vs. 12.8%, respectively, $p = 0.047$); however, the numbers were small.

Table 3. Reasons for lead testing by blood lead.

Characteristic	Blood lead (μmol/l) 0–0.23	0.24–0.71	*P* value*
Know lead testing			
n	57	66	0.03
Yes (%)	45.6	65.2	
Known reasons for lead testing			
n	58	62	<0.01
Doctor's advice – test during pregnancy (%)	75.9	48.4	
Doctor's advice – test before pregnancy (%)	1.7	1.6	
Doctor's advice – other (%)	3.5	1.6	
Self-request – concern of high risk (%)	1.7	19.4	
Self-request – planning to have a baby (%)	1.7	1.6	
Self-request – during pregnancy (%)	13.8	9.7	
Company/workplace routine check-up (%)	1.7	12.9	
Other (%)	0.0	4.8	
Reasons for lead testing during pregnancy			
n	52	36	0.87
Doctor's advice (%)	84.6	83.3	
Self-request (%)	15.4	16.7	

**P* value is generated from Chi-square test.

Table 4. Potential exposure sources by blood lead.

Characteristic	Blood lead (μmol/l) 0–0.23	0.24–0.71	*P* value*
Job with lead exposure			<0.01
N	59	66	
Yes (%)	4 (6.8%)	27 (29.2%)	
Residence built before 1978†			0.38
N	40	46	
Yes (%)	28 (70.0%)	36 (78.3%)	
Painting-related renovation for residences built before 1978			0.68
N	28	36	
Yes (%)	17 (60.7%)	20 (55.6%)	
Hobbies with lead exposure			
N	57	66	
Yes (%)	14 (24.6%)	24 (36.4%)	0.16
Hobbies with lead exposure excluding home renovation (%)**	5 (8.8%)	14 (21.2%)	0.06
Use of spices or herbs bought outside of the US			0.55
N	53	55	
Yes (%)	10 (18.9%)	8 (14.6%)	
Use of glazed ceramics or pottery bought outside of the US			0.047
N	48	47	
Yes (%)	1 (2.1%)	6 (12.8%)	
Use of traditional, folk or Ayurvedic remedies or medicines			0.45
N	56	56	
Yes (%)	2 (3.6%)	4 (6.7%)	

**P* value is generated from Chi-square test. †Year of residence built is missing or unknown for 31% of records. **Note that one woman could have several hobbies.

Discussion

According to the New York State Lead Poisoning Prevention Guidelines for Prenatal Care Providers by the New York State (NYS) Department of Health and American College of Obstetricians and Gynecologists (ACOG) District II, prenatal care providers should assess a woman's risk for current high-dose exposure using a standard questionnaire at the initial prenatal visit, and order lead tests for those at risk of current high-dose exposure (NYS Department of Health and ACOG District II 2009). Among women tested for PbB during pregnancy, prenatal care providers ordered 85% of tests for PbBs less than 0.24 μmol/l and 83% for PbBs between 0.24 and 0.71 μmol/l. Approximately 17% of pregnant women with PbBs between 0.24 and 0.71 μmol/l requested the test themselves. This suggests that prenatal care providers did not appropriately screen women's current exposure to determine whether or not to order the lead test. This would result in unnecessary tests among pregnant women with current low-dose exposure and inadequate tests among those with current high-dose exposure.

The contribution of occupational exposures varied according to PbB level. Few women with PbBs less than 0.24 μmol/l had a job with potential lead exposure, compared with a third of women with PbBs between 0.24 and 0.71 μmol/l in our study. Similarly, ABLES reported that 32% of women of childbearing age with PbBs more than or equal to 0.24 μmol/l had occupational exposure (CDC 2007). Fletcher et al. (1999) reported that approximately 46% of women with PbBs between 0.48 and 1.20 μmol/l had a job with potential exposure to lead. Furthermore, ABLES reported that the percentage of occupational exposure was 65% among women with PbBs more than or equal to 1.21 μmol/l (CDC 2007). Our data showed that the most frequent job among women with PbBs between 0.24 and 0.71 μmol/l was production and use of lead chemicals. This is different from the ABLES data showing that among women with PbBs more than or equal to 1.21 μmol/l, the most common industry was battery manufacturing (CDC 2007). The following jobs have been documented to be lead related: Lead abatement; removal of or painting with lead paint; lead soldering; lead smelting; lead-glazed pottery and glass making; and manufacturing of plastics, ammunition, lead chemicals, radiators and storage batteries (Avad et al. 1986; Zedd et al. 1993; Pant et al. 1994; Abudhaise et al. 1996; Alexander et al. 1996; Gidlow 2004; CDC 2005; ATSDR 2007). Women with these jobs may work directly with lead on a daily basis and personal protective equipment should be used to minimize the lead exposure to their body.

Renovation of houses built before 1978 in the US can be an exposure source for elevated PbB (Gardella 2001; Rastogi et al. 2007; Cleveland et al. 2008; McDiarmid et al. 2008). However, the percentage of home renovation was similar for PbBs less than 0.24 and 0.24–0.71 μmol/l in our study, approximately 17.5%. We speculate that: (i) People were aware of lead paint in old homes and protective device and cautions were used during home renovation; and (ii) some renovations were conducted for houses newer than 1978 without lead paint. Our percentage is slightly lower than 24% for women with PbBs between 0.48 and 1.20 μmol/l (Fletcher et al. 1999).

Women with PbBs between 0.24 and 0.71 μmol/l were approximately three times as likely to have a hobby with the potential for lead exposure excluding home renovation as those with PbBs less than 0.24 μmol/l in our study. The following hobbies can contribute to lead exposure: Recreational shooting, lead-glazed pottery and glass making, lead painting, lead soldering for jewelries and electronics (CDC 2005; ATSDR 2007). Women should avoid direct contact with lead during these activities, pay attention to the frequency of participating in these hobbies, and use personal protective equipment if they engage in these activities.

Imported pottery into the US can also be an exposure source for lead. In our study, 13% of women with PbBs between 0.24 and 0.71 μmol/l used imported pottery, which was higher than the 2% of women with PbBs less than 0.24 μmol/l. Klitzman et al. (2002) reported 21% of pregnant women with PbBs of 0.97 μmol/l or greater used imported pottery. It is recommended that women test whether the imported ceramics or pottery they use contains lead and avoid use of lead-glazed ceramics or pottery.

Our response rate was 37% despite the use of many strategies to maximize it. Although a higher rate would have been desirable, our rate is similar to the mean response rate of 35.3% (standard deviation 13.4%, minimum 7.5%, maximum 67.1%) for 64 mailed surveys conducted among the general public (Asch et al. 1997; Green et al. 1997; Edwards et al. 2002; Traina et al. 2005). Since this survey focused on reasons for lead testing and exposure sources, selection bias would be of concern if there had been the significant differences between respondents and non-respondents by PbB concentration. However, there was no appreciable difference in response rate between women with a PbBs less than 0.24 μmol/l and those between 0.24 and 0.71 μmol/l.

Another limitation was that because the questionnaire was self-administered, women may be reluctant to call us to clarify the questions and their answers, despite the offer to telephone the investigators toll-free. This would cause misclassification, but it would likely be non-differential according to PbB level. A small percentage of women answered unnecessary items, which were deleted by our logic-check programs.

Conclusion

The most frequent reason for lead testing was pregnancy-related. Among women tested for PbB during pregnancy, doctors ordered 80% of tests regardless of lead level. This suggests that the screening guideline for lead testing was not appropriately followed, which would result in unnecessary tests among pregnant women with current low-dose exposure and inadequate tests among those with current high-dose exposure.

Women with PbBs between 0.24 and 0.71 μmol/l were more likely to have lead exposure in their jobs, participate in hobbies that use lead, and use imported pottery. Maternal lead can readily cross placenta and enter fetus' blood circulation starting around the 12th–14th week of pregnancy, making fetus susceptible to lead poisoning (Lin et al. 1998). Women with PbBs 0.24 μmol/l and above could be reminded that some jobs, hobbies, or imported pottery can expose them to lead, and that they should avoid direct contact with lead during these activities and use personal protection equipment whenever possible.

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