Journal of Exposure Science and Environmental Epidemiology (2012) 22, 198–203
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www.nature.com/jes

Lead powder use for skin care and elevated blood lead level among children in a Chinese rural area

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To investigate the association between lead powder use, as folk skin care, and blood lead level (BLL) in children, we studied 222 children up to 14-years old living in a Chinese rural area and administered a face to face interview with their parents to collect information on lead powder use and other potential exposure. We measured children's BLL at baseline and 2 years later after an intervention. The children were divided into three categories according to their use of lead powder: regular use, irregular use and never use. We applied multivariate linear regression to determine the association between lead powder use and elevated BLL. The average BLL of all children was 18 μg/dl; 56% of them had BLL of 10 μg/dl or higher. Lead powder use was significantly associated with elevated BLL. After adjusting for potential confounders the BLL of regular and irregular users was higher than non-users by 3.11 μg/dl and 1.47 μg/dl, respectively. Duration of lead powder use was positively associated with BLL, but the time since last use was inversely associated. A significant BLL reduction was observed 2 years later, and the greatest reduction (21 μg/dl) was seen in the youngest group of regular users. This study showed that traditional use of lead powder for a skin care purpose was a major contributor to elevated BLL in these children.
Journal of Exposure Science and Environmental Epidemiology (2012) **22,** 198–203; doi:10.1038/jes.2011.46; published online 14 December 2011

Keywords: *children, lead exposure, skin care, epidemiology, Chinese rural area.*

Introduction

Elevated blood lead level (BLL) in children is one of the most common, yet preventable, health problems worldwide. Elevated BLL in children poses great risks, not only to their physical functions, but also to their cognitive development, affecting their IQ, and even causing subsequent neurobehavioral impairment in later life (Chen et al., 2005; Meyer et al., 2008). Different sources of lead exposure could result in elevated BLL in children (Levin et al., 2008; Meyer et al., 2008; Grant, 2010). Deteriorated leaded paint and dust in old houses remain the most common sources of lead exposure for children in the United States (Gulson et al., 1995; Jones et al., 1999; Jacobs et al., 2002), whereas environmental lead pollution from industrial processes is often the leading source of lead exposure in many developing countries (Duzgoren-Aydin, 2007). In China, elevation of BLL in children is a serious public health problem (Wang and Zhang, 2006; Bian, 2008; He et al., 2009; Ji et al., 2011; Lin et al., 2011). A number of studies in China have indicated that lead exposure came from multiple sources (Wu et al., 2002; Wang and Zhang, 2006; Huo et al. 2007; Yan and Shen, 2008), and lead-containing Chinese Traditional Medicine (CTM) was one of the exposure sources, especially in remote rural areas (Shen et al., 1996; Auyeung et al., 2002; Peng et al., 2008). When sources of lead are elucidated, exposure science can have a crucial role in enabling protection of public health (Grant, 2010). Therefore, identifying an exact lead exposure source would be of utmost importance to reduce BLL and protect children's health.

In this study, we report an investigation of elevated BLL occurring among children in a rural area of Fujian Province, China, where "folk remedy" was a common practice. The investigation was triggered in 2006 by the discovery of elevated BLL in some children with unusual clinical symptoms and complaints. A child experiencing irregular abdominal pain, loss of appetite and constipation was found to have a BLL of 69.0 μg/dl. Other children had BLLs ranging from 13.5 to 41.0 μg/dl. When investigating possible environmental exposures, we discovered that lead powder

1. Abbreviations: BLL, Blood Lead Level; CDC, Center for Disease Control and Prevention; CTM, Chinese Traditional Medicine; IQ, Intelligence Quotient; US, United States; WHO, World Health Organization

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Received 13 April 2011; accepted 8 August 2011; published online 14 December 2011

was commonly used as a 'folk remedy' for skin care among children in this rural community. A lead powder sample was found to have a lead concentration of 196 000 mg/kg (~20%). The lead powder was homemade with litargirio (lead monoxide) and ordinary baby powder. On the basis of these preliminary findings, we hypothesized that the lead powder use was associated with the elevated BLL of the children. An intervention was then implemented in this rural community, including eliminating lead powder use and implementing health education among local residents. We re-examined the children's BLL after 2 years to document the effect of the intervention, and to further confirm the association between lead powder use and elevated BLL.

Subjects and methods

Study Subjects

According to official registry data, a total of 511 children aged 14 years or below lived in this rural community. We used a stratified random sampling method to select children in the three age strata: <3 years, >3 and <8 years, and >8 and <14 years. Based on the residence registry number, we randomly selected a total of 230 children (78, 65 and 87 children in the three age groups, respectively). The distributions of gender were similar in the three age groups, with 40 boys (51.3%) in the youngest age group, 35 boys (53.8%) in the medium age group and 46 boys (52.9%) in the oldest age group. We excluded 5 children who refused BLL measurements and another 3 without complete information, leaving 222 children in the data analysis. Among them, 208 (93.7%) had their BLLs re-measured after 2 years.

Measurements of Blood Lead Level

Venous blood was drawn from the cubital vein by trained nurses at a local hospital into metal-free heparinized tubes after the skin was properly cleaned and sanitized. Blood samples were stored at −20 °C or lower until analyzed. We used previously described methods of blood lead analysis and quality control (Miller et al., 1987). Briefly, BLL, expressed as μg/dl, was determined with graphite furnace atomic absorption spectrometry in an accredited laboratory. The lab adopted internal and external quality control measures to ensure accuracy. BLL was monitored using two concentrations of bench quality control materials, which were provided by the Chinese National Center for Disease Control and Prevention. The precision (coefficients of variation) for the quality-control levels at 6.8, 28.7 and 60.5 μg/dl was 7.3%, 3.5% and 4.9%, respectively. The same methods and procedures were used in retesting BLL 2 years later.

Personal Information Collection

Trained investigators conducted face to face interviews with the children's parents or care givers, while displaying a lead powder sample. A structured questionnaire was used to collect detailed information on children's lead powder use. If a child had ever used lead powder for skin care, further questions were asked about the frequency and duration of use, and time since last use. Inquiries were made about other potential lead sources including: lead pottery use, peeling paint, use of lead containing pesticides and parents' lead-related occupations. In addition, information on children's behaviors and hygiene habits, such as finger sucking habits, hand washing habits and canned food preference, were also collected.

Interventions

Soon after recognizing the possibility that lead powder use might have caused the children's elevated BLL in the area, local authorities prohibited all lead powder merchandises in local retails and drug stores and removed them from shelves. Local residents were strongly advised not to use lead powder or similar mixtures. Furthermore, the health department initiated a village-based health education program with a class every 3 months in the first year, focusing on the harmful effects of lead powder use and exposure prevention. Meanwhile, 18 children with BLLs reaching 45 μg/dl or above were hospitalized for treatment with chelation. We reevaluated the BLLs of all children 2 years later. The study was approved by the Institutional Review Board of Fujian Medical University.

Data Analysis

The frequency of lead powder use was adopted as an exposure index to estimate the degree of exposure among children, and was divided into three categories: never use, irregular use, and regular use. Irregular use was defined as using lead powder no more than three times per month, and regular use as more than three times per month. Duration of use and time since last use (in years) were examined as continuous variables. We used multiple linear regression models to determine the association between lead power use and BLL. The latter was log transformed to improve the normality of distribution in the children. Categorical variables, including lead powder use categories and age groups, were coded as dummy variables. Stepwise procedure was used with criteria of entry and removal at 0.05 and 0.1, respectively. Variables used in the regression included duration and frequency of lead powder use, time since last use and other variables (gender, parents' lead-related occupation, and age) meeting the selection criteria. Age and time since last use were included in two separate regression models because of their colinearity. To examine the changes in BLL 2 years later, we used a paired t-test among those successfully followed-up. We carried out all data analyses with the Statistical Package for the Social Sciences (SPSS) software version 15.0 for windows (SPSS, Chicago, IL, USA).

Results

Table 1 presents the children's characteristics and values of BLLs by lead powder use category. Among the children, 77.5% had reported using lead powder products, with a similar proportion of boys and girls. Age was significantly different across the powder use categories: the youngest mean age was in the regular users and the oldest mean age was in the never users. More than half of the mothers had not received any formal education, and only 3% had more than 6 years of education. There were no differences in the mother's education level among the lead powder use categories. Average duration of lead powder use was around 3 years in both irregular and regular users, while time since last use was longer in the irregular users (3.2 years) than the regular users (1.2 years). Fewer than 10% parents were involved in lead-related occupations, such as motor repairer, welder and vehicle driver, and no differences were found among the lead powder use categories. Other potential lead sources were found in several households: using lead pottery in six, peeling paint in five and using lead-containing pesticides in seven households.

Average BLL of the 222 children was 18.1 μg/dl (ranging from 0.19 to 69.0 μg/dl); 125 children (56%) having BLL of 10 μg/dl or above. BLL was significantly different among the powder use categories (Table 1): 32 μg/dl in the regular, 12 μg/dl in the irregular and 6 μg/dl in the never users. The majority of the children (92%) in the regular use category had BLL of 10 μg/dl or above, 47% in the irregular and 14% in the never use categories. Furthermore, 48% children in the regular use category had a BLL of 30 μg/dl or above.

Among children aged 3 years or younger, 62% were in the regular use category, whereas only 11% of those older than 8 years were in this category (Figure 1). Average BLL was 30 μg/dl in the youngest group and 8 μg/dl in the oldest; 86% and 25% of children in the two age groups had 10 μg/dl or

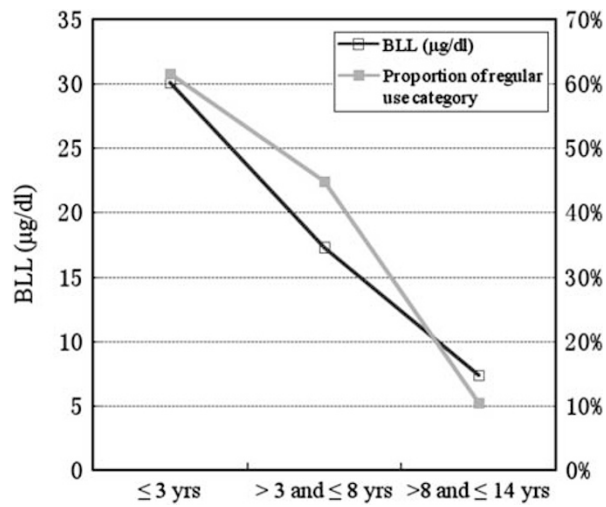

Figure 1. BLL and the proportion of the regular use category by age group. 61.5% of children at age ≤3 years were in regular use, 44.8% at age >3 years and ≤8 years, and 10.5% at age >8 years and ≤14 years. Average BLL was 30 μg/dl, 17 μg/dl, and 8 μg/dl in the three age groups, respectively.

Table 1. Children's characteristics and BLL (μg/dl) at baseline by lead powder use category ($n = 222$).

	Never use	Irregular use	Regular use	*P* value[a]
Total subjects[b]	50 (22.5)	89 (40.1)	83 (37.4)	
Boys[b]	26 (22.4)	49 (42.2)	41 (35.3)	0.758
Girls[b]	24 (22.6)	40 (37.7)	42 (39.6)	
Age (years), mean (SD)	8.08(4.54)	7.73 (4.54)	3.51 (3.26)	<0.001
Mothers' education				
Nil	29 (58.0)	46 (51.7)	44 (53.0)	0.950
≤6 years	20 (40.0)	40 (44.9)	37 (44.6)	
≥7 years	1 (2.0)	3 (3.4)	2 (2.4)	
Parents' lead related occupation	6 (12.0)	7 (7.9)	4 (4.8)	0.319
Potential other lead sources in household[c]	4 (8.0)	6 (6.7)	8 (9.6)	0.785
Duration of lead powder use (years), mean (SD)	—	2.96 (1.40)	2.84 (2.11)	0.313
Time since last use, years, mean (SD)	—	3.19 (1.13)	1.19 (0.96)	<0.001
BLL, mean (SD)	6.19 (3.86)	11.86 (6.79)	31.89 (17.93)	<0.001
Categories of BLL				
<10 μg/dl	43 (86.0)	47 (52.8)	7 (8.4)	<0.001
10∼	6 (12.0)	26 (29.2)	19 (22.9)	
20∼	1 (2.0)	15 (16.9)	17 (20.5)	
≥30	0 (0.0)	1 (1.1)	40 (48.2)	

The values represent number and percentage unless stated otherwise.
[a]Trend test for category variables and ANOVA for continuous variables for comparisons among lead powder use categories.
[b]Percentage in the summed row.
[c]Including lead pottery, paint peeling and lead pesticides in household.

above, respectively. The distributions of the powder use categories and age groups were similar in girls and boys.

In the linear regression analysis examining the risk factors for children's BLL (Table 2), potential lead sources in household, mother's education level, canned food preference, finger sucking habits and hand washing habits were considered in the initial model, but excluded from the final model because of no effects on the outcome variable. In the final model, lead powder use was significantly associated with BLL. Compared with the never use category, regular and irregular use were significantly associated with an elevated BLL. When BLLs were transformed back from log values, regular use was related to an increase of 3.11 μg/dl (95% CI, 2.24, 4.32 μg/dl), and irregular use to an increase of 1.47 μg/dl (95% CI, 1.05, 2.06 μg/dl). Children's BLL was also positively related to a longer duration of the powder use, but inversely related to age. When age was included in the model as a continuous variable, instead of age groups, an inverse association persisted, and lead powder use remained to be significantly associated with BLL. The time since last use was inversely related to BLL ($b = -0.059$, 95% CI: -0.102, -0.017), when the variable of age was taken out from the model. When the analysis was restricted to children 3-years old or younger ($n = 78$), the association between lead powder use and BLL became stronger, with an elevation of 9.25 μg/dl (95% CI: 4.63, 18.45 μg/dl) related to regular use, and 3.75 μg/dl (95% CI: 1.90, 7.41 μg/dl) to irregular use. In addition, girls were associated with an increased BLL, compared with boys, and parent involving in a lead-related occupation was related to a higher BLL, though neither of the associations was statistically significant.

Compared with children's BLLs measured at baseline, the values were significantly reduced after 2 years, irrespective of age group and powder use category (Table 3). The greatest reduction (21 μg/dl) was observed in the youngest group with regular use, followed by the age group of 4 to 8 years with regular use (9 μg/dl). As a whole, BLL was reduced by 15 μg/dl (37%) in the regular use category, 2 μg/dl (15%) in the irregular users and 1 μg/dl (12%) in the never users.

Table 2. Factors associated with children's BLL (μg/dl) ($n = 222$).

	B	*P*	95% CI
Constant	1.616	<0.001	1.518, 1.713
Gender, boys	−0.014	0.714	−0.089, 0.061
Parents' lead related occupation	0.074	0.306	−0.068, 0.215
Age group, years			
>8 ~ <14	—		
>3 ~ <8	0.171	0.001	0.071, 0.271
≤3	0.234	<0.001	0.131, 0.337
Lead powder use			
Never use	—		
Irregular use	0.168	0.024	0.023, 0.314
Regular use	0.493	<0.001	0.350, 0.635
Duration of use, years	0.068	0.023	0.009, 0.126

Using multiple linear regression analysis to fit the baseline data, in which BLL was log-transformed, $R^2 = 0.547$ for the model explanation.

Table 3. Comparisons of children BLL (μg/dl) between baseline and follow-up by lead use category and age group ($n = 208$).

Age group, yrs	BLL, (μg/dl)	Never use ($n = 45$)	Irregular use ($n = 83$)	Regular use ($n = 80$)
≤3	Baseline	4.46 (3.91)	17.08 (6.90)	41.57 (16.77)
	Follow-up	3.76 (3.31)	12.60 (4.97)	20.60 (7.38)
	Δ[a]	−0.81 (1.07)	−4.48* (3.01)	−20.98** (13.77)
	%Δ[b]	−6.94	−25.26	−45.34
> 3 ~ ≤8	Baseline	8.13 (4.92)	14.38 (8.02)	23.35 (10.06)
	Follow-up	7.12 (5.11)	11.66 (7.08)	14.72 (5.00)
	Δ	−1.01* (1.48)	−2.72** (2.96)	−8.63** (7.78)
	%Δ	−14.13	−21.33	−31.63
> 8 ~ ≤14	Baseline	6.01 (3.26)	8.91 (4.54)	11.67 (5.96)
	Follow-up	5.12 (2.93)	8.34 (4.51)	10.53 (5.76)
	Δ	−0.89** (0.93)	−0.57** (1.22)	−1.14* (1.20)
	%Δ	−13.12	−7.86	−10.88
Total	Baseline	6.76 (4.65)	12.03 (6.91)	32.66 (17.74)
	Follow-up	5.72 (4.07)	10.06 (5.49)	17.68 (7.41)
	Δ	−0.91** (1.10)	−1.98** (2.73)	−14.98** (13.45)
	%Δ	−12.39	−14.86	−37.44

Results are presented as mean (SD).
[a]Δ = follow-up BLL minus baseline BLL.
[b]%Δ = ΔBLL/baseline BLL × 100%.
*$P < 0.05$, ** $P < 0.01$, using pair *t*-test to compare follow-up BLL with baseline BLL.

Discussion

We observed a significant association between frequency of lead powder use and elevated BLL among the children. The lead powder (litharge, litargirio, or lead monoxide) used in this rural area was a fine red or reddish-orange powder. Local residents called it 'red powder' or 'yellow powder', and applied it as folk remedy for infant's eczema and other skin problems in children. In some remote rural areas of southern China, including the area under study, lead powder could be purchased from local drug stores, and then mixed with infant talcum powder. Parents usually applied the powder on children's neck, armpits and groin areas to prevent or treat skin diseases. Although we were not able to collect samples of the 'red powder' or 'yellow powder' used for all of the children, four samples were obtained and analyzed using graphite furnace atomic absorption spectrometry. The concentrations of lead in the samples were found to be 5210 mg/kg (0.5%), 42 000 mg/kg (4.2%), 196 000 mg/kg (20%) and 623 000 mg/kg (62%), respectively. On the other hand, acceptable lead concentrations were observed in the sampled soil, air and drinking water, with geometric means of 49.10 mg/kg, 0.018 μg/m^3 and 0.003 μg/l, respectively. Thus, environmental lead pollution could be ruled out in this area as a major source of the children's exposure.

The major finding obtained from the study was that regular powder use was significantly associated with elevated BLL in all age groups and particularly in the youngest children (≤ 3 years). Furthermore, we observed a significant reduction of BLL in the children after 2 years, with the greatest reduction in the regular users. This might be attributed to the health education program that persuaded the majority of the local residents to stop using the lead powder, and improve personal hygiene. Although an education approach alone might not be sufficient to prevent lead burden in some studies (Jordan et al., 2003), health education seemed to be of importance in this rural area. This was supported by a modest reduction (12%) in BLL in the never use category. Identifying lead powder use as a main source of exposure and the subsequent interventions targeting this exposure had a significant impact on the reduction of children's BLL. As 18 children with BLL above 45 μg/dl received chelation therapy, we repeated the data analysis after excluding these 18 children and found that significantly reduced BLL remained in both regular and irregular users. This demonstrated that reduction of BLL resulted from the abstinence of lead powder use alone, which further supported the hypothesis that lead powder use was primarily responsible for the elevated BLL among these children.

Lead powder could be partly absorbed through skin penetration when applied to children's skin (Sun et al., 2002; Filon et al., 2006). However, absorption of lead through ingestion is considered the most important pathway in children (US CDC, 2005). In this study, lead ingestion through hand-to-mouth activities after the children had contacted with lead powder or with contaminated surfaces was likely an important route of entry, which was similar to previously described environmental lead exposure in urban children (Lanphear and Roghmann, 1997). Hand-to-mouth activity was more common among younger children. This might partly explain their higher BLL in the same category of lead powder use. Another possible pathway might be through the parents' contaminated hands and clothes to food. This was supported by a lead level of 20.1 μg/kg in a food sample taken from a house in the area. It is worthwhile to note that 14% of children in the never use category had BLLs over 10 μg/dl. An under-reported lead powder use was possible. In addition, secondary exposure from touching and playing with other children on whom the lead powder was used might also occur. Although a high proportion of older children fell into the never use and irregular use categories, the possibility that lead powder use was more frequent and common than reported cannot be ruled out. Their parents might not be able to recall the frequency of lead power use reliably, especially if the use happened many years before administrating the survey when the children were very young. BLLs in these children could be much higher when they were younger, and then gradually decreased with cessation of use. The inverse association observed between the time since last use and BLL in the children supported this assumption.

Lead poisonings from folk remedies have been reported in other countries. Traditional medicines were estimated to account for up to 30% of all childhood lead poisoning cases in the United States (Rhor, 2010). Folk medicine was found to be a mainly unusual source for lead poisoning in children (Jones et al., 1999). Folk medicine associated lead poisoning often occurred in places where traditional medicines or folk remedies were popular (Mcelvaine et al., 1990; Woolf and Woolf, 2005). In Rhode Island, lead poisoning associated with use of litargirio in a pair of twin Hispanic boys from the Dominican community was reported (US CDC, 2005). The use of lead powder, as a cause of lead poisoning, has been occasionally reported in the southern part of China, such as in Fujian Province and Guangdong Province (Fan et al., 2002; Dong et al., 2009; Lin et al., 2010). However, previous reports of lead poisoning in children from unusual lead sources were either case reports or surveys with convenient samples. In the present study, we used a stratified random sampling method to select study subjects. The sampled children were similar to those who were not selected in terms of age, gender, and socioeconomic status. Furthermore, we were able to follow over 90% of the children after 2 years to determine the changes in BLL. These suggest that selection bias would not be a major concern in this study.

There are several limitations in this study. First, recalling past lead powder use could be subject to a recall error. As the lead powder use was more often in children under 3-years old, it was possible that parents of older children might not

be able to recall the frequency and duration of use reliably enough. This could have resulted in misclassification of exposure, likely leading to an underestimation of lead powder use in the older children. Another limitation was that only four powder samples were collected and determined. As there was lack of information on the actual lead concentration in the specified powder used, the exposure could only be estimated by the reported frequency and duration of lead powder use. After 2 years, 14 children were lost to follow-up, but 11 of them had BLL below 10 μg/dl. The result of the changes in BLL would not be affected substantially by the loss of these children.

In summary, this study revealed that lead powder use, as a traditional folk remedy, was significantly associated with elevated BLLs in these rural children. The results highlighted that the central and local government and public health agencies should ban the use of all forms of lead powder for children and adults alike. In addition, more stringent public health policy should be formulated to ensure that the use of lead-based products is minimized as much as possible throughout the country. At the same time, education programs should be initiated or strengthened in both urban and rural areas to raise the awareness of people and change their beliefs about folk medicines that contain harmful ingredients and risky behaviors.

Conflict of interest

The authors declare no conflict of interest.

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