Chapter 6. Educational Interventions for Caregivers

Prepared by James Campbell, MD, MPH, and Michael Weitzman, MD

Table 6.1. Summary of Recommendations for Educational Interventions for Caregivers

General Considerations

- Tailor educational interventions to each child and caregiver.
- Repeat educational interventions as needed.

Environmental Interventions

- Provide information about potential sources of lead identified during environmental investigations.
- Explain that lead abatement should be conducted by certified professionals.
- Discuss and demonstrate the following methods that caregivers can use to reduce their child's lead exposure:
  - Create barriers between living/play areas and lead sources.
  - Regularly wash children's hands and toys.
  - Regularly wet mop floors and wet wipe window components.
  - Vacuum carpeted areas before wet mopping floors; cover carpeted floors with throw rugs.
  - Leave shoes at the door. Use entryway mats.
  - Prevent children from playing in soil. If possible, provide sandboxes.
  - Consider relocation if lead contamination is extensive and not easily remediable.
- Discuss with caregivers potential water hazards only if appropriate.
  - Do not cook with or allow children to drink hot tap water.
  - Run the tap water cold for 1-2 minutes in the morning and then fill a pitcher with the water for drinking, cooking, and formula preparation.
  - Use bottled water if drinking water is contaminated.

Nutritional Interventions

- Discuss dietary interventions.
- Encourage caregivers to provide children with foods rich in absorbable iron, vitamin C, and calcium.

Medical Care

- Discuss the importance of recommended medical follow-up, including the importance of notifying the case manager if the family moves.
- Review the nature of and risks associated with EBLLs.

Chapter 6. Educational Interventions for Caregivers

Introduction

The 1990s witnessed dramatic declines in children's mean blood lead levels (BLLs) and in the percent of children with elevated blood lead levels (EBLLs) (*1*). During that decade, we learned a lot about children's exposure to lead in and around their homes, and about how to reduce that exposure through environmental interventions and caregiver education and counseling. In this chapter, we provide current recommendations for educational interventions, review the quality of evidence that supports these recommendations, and identify research needed to improve the effectiveness of caregiver education. Much of the relevant research is discussed in more detail in Chapter 2, "Assessment and Remediation of Residential Lead Exposure."

The efficacy of most interventions has not been studied in isolation. Studies usually involved multiple interventions, thus limiting our understanding of the utility of individual recommendations.

Sources and Pathways of Residential Lead Exposure

Leaded paint is the most common high-concentration source of lead for children and is typically seen in homes built prior to 1950. Poorly maintained older homes with deteriorating paint or those undergoing renovation, whether they are the children's primary residences or secondary sites where children spend much time, pose the highest risk of lead exposure. The usual sites of deteriorating leaded paint are interior painted surfaces, particularly those subject to abrasion such as window components, and exterior surfaces like siding and porches. The paint chalks or chips off from normal wear-and-tear and deteriorates into dust. Leaded dust can also be created by improperly conducted abatement (*2*). Soil is another significant source of lead for some children (*3*). Exterior soil can become very contaminated with lead from deteriorating overlying leaded paint, driplines, or lingering fall-out from previously used leaded gasoline, especially along heavily traveled roads.

Children typically ingest leaded dust as a consequence of age-appropriate hand-to-mouth activity. Studies consistently show an association between the amount of lead on children's hands and their BLLs (*4, 5*). Children are also exposed by intentionally ingesting paint chips, dust, or soil. Housing and soil sources are the most common cause of EBLLs in children. Additional significant sources of lead in certain communities include water, industrial contamination, folk medicines, and imported cosmetics or pottery (*6-8*). In addition, as shown in Appendix I, numerous less common lead sources may be the cause of individual cases of EBLLs.

General Principles

Educational interventions are directed at helping caregivers reduce the exposure of children to residential and other sources of lead. While most children are exposed through the deterioration of leaded paint, they may also be exposed to lead from other sources; some of these exposures are a consequence of cultural practices or caregiver occupations or hobbies. Case managers should therefore select the information and interventions that are most appropriate to each child, family, and community and avoid overwhelming caregivers with interventions that may be of little or no benefit.

Although there is no risk-perception or risk-communication research specific to childhood lead poisoning, general principles of these fields can be applied to improve the effectiveness of educational interventions to reduce children's BLLs. Case managers must recognize that caregivers understand the "risk" of EBLLs in ways different from the ways that experts in lead poisoning understand them, and case managers should tailor their recommended interventions to caregivers' conceptions of risks. If interventions are not tailored to caregivers' conceptions of risks, then caregivers are less likely to act on the information they receive (*9, 10*).

In addition to educating caregivers about childhood lead poisoning, case managers may also need to provide detailed instructions on intervention techniques, actually demonstrate the techniques, and then ask caregivers to perform the techniques themselves. Such actions should increase caregivers' understanding of the interventions and consequently increase the chances that the interventions will be successful.

Studies of Various Interventions

Interventions to reduce children's lead exposure from residential deteriorating paint

Interventions to reduce children's exposure to deteriorating paint in their homes include the safe repair of non-intact leaded paint, the safe repair or replacement of windows or other building components to prevent abrasion of leaded paint, and the safe removal (stripping) of leaded paint from components left in the home. In a review of uncontrolled studies involving children with baseline BLLs greater than 25 Fg/dL, the EPA found that BLLs of children in homes where non-intact leaded paint was safely removed or repaired declined 20% to 30% over the following year (*11*). In one controlled study, the mean BLL of children in treated dwellings declined twice as much as that of children in untreated dwellings (*12*).

Interventions to reduce children's lead exposure from residential dust

Four clinical trials assessed the efficacy of household dust control by professional cleaners (*13-17*). Three trials assessed the effectiveness of household dust control done by the families of children with EBLLs: two randomized clinical trials (*18-20*), and one nonrandomized, retrospective analysis with a comparison group (*21, 22*).

Among the studies of professional house dust control, two (*13*, *17*) found that children in homes that underwent intensive dust-control (i.e., two trained cleaners wet mopping floors and wet wiping horizontal surfaces for 2 hours every 2-3 weeks) had a 17% - 18% decrease in their mean BLL 1 year after the initial test. In one of these studies (*17*), a subgroup of children whose homes were cleaned 20 or more times over the year (a mean of once every 2.6 weeks) had a 34% decrease in their BLLs. Since trained cleaners conducted the interventions, this effect size is probably the optimum that can be achieved. The remaining studies (*14-16*) failed to show that dust control is associated with a decrease in children's BLL. Two of these studies were of a one-time intervention (*14, 15*), and the other was of cleaning done every 6 weeks (*16*). However, one-time or infrequent interventions would most likely not prevent EBLLs, because household dust builds up again after a short time. This is suggested by Hilts et al., who found that children's lead loading returned to baseline levels 3 weeks after high-efficiency particulate air (HEPA) vacuuming (*16*). Similarly, Rhoads et al. found no change in the mean BLL of children whose homes were cleaned fewer than 10 times over the year (at most every 5.6 weeks) (*17*).

Lanphear et al. conducted two trials in which the cleaning was done by the caregivers (*18-20*). In the first, 104 children (aged 12 to 31 months; BLLs 1.7 to 30.6 Fg/dL) were randomly assigned to an intervention group (in which caregivers received cleaning supplies, were educated about areas likely to be contaminated with lead, and were instructed to clean monthly) or to a control group (in which caregivers received only a brochure about preventing EBLLs) (*18*). Seven months after enrollment, the median change in children's BLL was –0.05 Fg/dL in the intervention group and –0.60 Fg/dL in the control group (p=0.50). However, in this study, the researchers could not ensure that the families adhered to the recommended cleaning regimen.

The second trial involved 275 children with a mean baseline BLL of 2.8 Fg/dL (*19, 20*). These children were randomly assigned to either an intervention group that received education, cleaning supplies, and up to eight home visits by an advisor, or to a control group that did not receive any of these interventions. Again, researchers found no significant differences in the geometric mean BLLs of children in the two groups at 12, 18, 24 and 48 months of age. But again, they could not ensure that the families adhered to the recommended regimen.

Schultz et al. conducted a retrospective analysis of an in-home educational intervention (*21, 22*). Health department staff visited the homes of children (mean age 3.4 years) with BLLs 20 to 24 Fg/dL and conducted an educational session for caregivers regarding lead sources, methods to reduce children's exposure to these sources, and appropriate nutrition for children. The children in visited homes made up the study group. A reference group was made up of children (comparable with the study group by age, sex, race, and BLL) who did not receive the educational intervention. Follow-up BLLs were obtained about 6 months after the intervention. The study group children had a significantly greater mean decline in BLL (4.2 Fg/dL) than the reference group children (1.2 Fg/dL, P<0.001). The authors concluded that home educational visits may have helped lower children's BLLs (*22*). However, they also noted that "[t]he validity of this conclusion depends upon whether children who received the visits were comparable to reference group children whose families were often unavailable for outreach visits. Families that were unavailable…may have been more likely to exhibit behavior patterns responsible for the continued elevation of their children's blood lead levels" (*22*). Thus, with no randomization of subjects, the reference group may not have been comparable in at least one important way.

In a meta-analysis, the findings of several studies were combined to determine the effect of dust control on children's BLL (*23*). To be eligible for analysis, the studies had to be randomized controlled trials, cost less than $2,500, and be conducted in a community without a continual lead emission source, such as a lead smelter. Five studies were eligible (*15, 17-20*). Results of the meta-analysis showed no significant post-intervention differences in mean BLLs between children in the intervention and control groups. However, the intervention groups contained significantly fewer children with BLLs $ 15 Fg/dL and $ 20 Fg/dL than did the control groups. For example, only 1.8% of children in the intervention groups had BLLs $ 20 Fg/dL, whereas 5.3% of those in the control group did (OR=0.29, CI 0.01 - 0.85, p=0.024). This finding persisted even after the single study involving professional dust control (*17*) was removed from the analysis.

The aforementioned studies largely focused on cleaning dust on uncarpeted floors. Although the dust lead loading on uncarpeted floors has a higher correlation with children's BLLs than the dust lead loading on carpets, dust lead loading on carpets does correlate with children's BLLs (*24*). However, neither HEPA vacuums nor common household vacuums reduced carpet dust lead levels by clinically relevant amounts (*16, 25, 26*). Furthermore, in one study, children whose homes were HEPA vacuumed actually had higher levels of lead on their hands after the interventions although their BLLs did not change (*16*). The authors speculate this may have occurred because families who received the vacuuming "…may have relaxed their hygiene efforts…because of a perceived reduction in exposure risk" (*16*). A report that HEPA vacuuming increased the lead loading on the surface of the carpet by bringing lead from deep in the carpet to the surface (*25*) offers an alternative explanation for the increase in hand lead levels.

In summary, studies indicate that household dust control performed by professional cleaners is associated with decreases in children's mean BLL, although it appears that to be effective, such dust control must be conducted at least every 2 to 3 weeks. However, simply educating parents of the need to perform dust control has not proven effective in reducing children's mean BLL.

Interventions to reduce children's lead exposure by improving personal hygiene practices

We found no controlled studies that examined the effect of personal hygiene on BLLs of children, although studies of the correlation between the level of lead on children's hands and their BLLs have consistently found an association between the two (*6, 7, 27, 28*). Although the frequency of self-reported hand washing has not been associated with children's BLLs (*27, 28*), the validity of study results based on such self-reported hygiene measures is clouded by the possible effects of social desirability bias.

While there is no evidence that hand washing is associated with a decrease in children's BLLs, it is a simple intervention that poses no risks.

Interventions to reduce children's lead exposure from residential soil

The major study examining whether soil abatement is efficacious at reducing children's BLLs, the Urban Soil Lead Abatement Demonstration Project (*29*), was conducted in three cities: Boston, Baltimore, and Cincinnati.

In Boston, Weitzman et al. studied the effects of paint, dust, and soil lead abatement on the BLLs of 152 children (mean age: 31.6 months; mean baseline BLL: 12.5 Fg/dL; and median surface soil lead level: 2075 ppm) (*14*). Eleven months after soil lead abatement, the adjusted mean BLL of children in homes having the abatement dropped to 10.26 Fg/dL, and that of control children dropped to 11.54 Fg/dL (p=0.02). However, despite the statistical significance, the authors concluded that these differences were clinically irrelevant. In a follow-up of these children for an additional year, they found that soil lead abatement was associated with a 2.25 to 2.70 Fg/dL decline in the children's BLL, but that children who lived in dwellings with consistently elevated floor levels of leaded dust derived no benefit from the soil abatement (*30*).

In Baltimore, Farrell et al. randomly assigned 408 children (aged 6 to 72 months) to either an intervention group (whose homes underwent exterior paint stabilization followed by soil abatement) or a control group (whose homes underwent exterior paint stabilization but no soil abatement) (*31*). The children's mean BLL was about 11 Fg/dL. At baseline, only 54% of properties had soil samples with a lead concentration above 1000 ppm. Ten to 13 months after the intervention, the geometric mean BLL of the treatment group was unchanged, while that of the control group had fallen 0.7 Fg/dL (*29*). Results of multivariate analysis showed no significant difference in the mean BLL of the groups at follow-up.

In the Cincinnati trial, researchers studied the effects of soil lead abatement on the BLLs of 206 children (aged 9 to 72 months; median BLL 10 Fg/dL) by assessing changes in the children's median BLLs 9 to 10 months after the interventions. Through multivariate analysis, they found no significant difference in the mean BLL of children in households receiving and households not receiving soil lead abatement.

There are a number of possible explanations for why these studies of soil abatement showed no effect. First, most of the interventions were performed in scattered homes rather than contiguous blocks of homes, so continued exposure to lead from nearby properties may have limited the effectiveness of the interventions. Second, the studies enrolled children whose sources of lead exposure were primarily from their homes rather than children whose sources were primarily from soil (i.e., those who avidly played in or ingested soil). Finally, the release of lead from children's bones may have attenuated the impact of the interventions (*32*).

The EPA concluded that when soil is a significant source of lead for a child, the lead abatement of that soil is associated with a reduction in that child's BLL (*29*). However, the mean reductions in children's BLLs do not appear to be clinically relevant. Further, an economic analysis concluded that soil lead abatement was not cost-effective (*33*). Therefore, we do not recommend residential soil lead abatement in the secondary prevention of children's EBLLs. Nevertheless, because some children may experience significant lead exposure from soil either because they play in or ingest soil or because their soil has high levels of lead, we do recommend simple, safe measures such as providing sandboxes with covers or covering open soil with grass or mulch.

Nutritional Interventions

Although the effects of various nutritional interventions on children's BLLs are either limited or have not been studied, certain interventions are of value to the children's general health, because many children with EBLLs are at risk for poor nutrition. See Chapter 4, "Nutritional Assessment and Interventions," for a detailed discussion.

Recommendations

General Recommendations

Tailor educational interventions to each child and caregiver.
Select the interventions and information that are most appropriate to the child. Devise a written plan with specific recommendations to reduce the child's exposure to identified sources of lead in consultation with the caregivers and give a copy of the plan to them.

Continue educational efforts beyond a one-time intervention.
Monitor children's follow-up BLLs. If a child's BLL is not decreasing, discuss the case with the primary care provider (PCP) and, if appropriate, an environmental health specialist, to determine whether lead sources are being overlooked. Case managers may need to make further home visits to assess new lead sources and ensure that caregivers understand and are carrying out recommended interventions.

Environmental Recommendations

Prompt and effective control of the sources of children's lead exposure is the highest priority. Ensure that all sites lived in or regularly visited by a child with an EBLL are inspected jointly with the caregiver to identify potential sources of lead exposure.

Provide information about potential sources of lead.

If caregivers are informed of lead sources identified during the environmental inspection, as well as other potential sources (Appendix I), they may change their attitudes and behaviors in ways that result in secondary prevention. Therefore, encourage caregivers to examine their yards and homes for chipping paint, especially areas where their child spends a good deal of time, and to alert lead inspectors to areas that may be potential sources of exposure.

Explain that lead abatement should be conducted by trained workers.

Improperly conducted lead abatement (e.g., grinding or sanding lead-based paint and thus producing lead dust, or allowing children access to areas of abatement) may actually increase children's lead exposure (*34, 35*). Therefore, recommend that abatement be conducted by certified professionals. However, if caregivers choose to conduct lead abatement themselves, direct them to resources that will at least give them guidance in how to conduct lead abatement safely (Appendix II).

Discuss and demonstrate methods that caregivers can implement to reduce their children's lead exposure.

While verbal instructions and written materials are useful, it is important to demonstrate methods of reducing children's lead exposure whenever possible. Demonstrating these methods at the child's home can help in overcoming language and cultural barriers. Encouraging caregivers to practice the methods demonstrated and provide corrective feedback if necessary should help them better understand and adhere to the recommended interventions. Although many of these interventions have not been studied in isolation or shown to be effective, most are simple interventions that pose no risk and should help reduce children's risk for lead exposure.

- *Create barriers between living/play areas and lead sources*. Leaded paint tastes sweet, which may encourage children to ingest deteriorating paint. Until abatement is completed, caregivers should clean and/or isolate all sources of lead. Advise them to close and lock doors to keep children from deteriorated paint on walls and to use temporary barriers such as contact paper or duct tape to cover holes in walls or to block children's access to other sources of lead.
- *Regularly wash children's hands and toys.* Hands and toys can become contaminated from household dust or exterior soil, both known reservoirs of lead. Washing a child's hands may also enhance caregiver-child interaction and reduce the transmission of infectious diseases. Urge caregivers to buy toys that can easily be washed.
- *Regularly wet mop floors and wet wipe window components*. Because household dust is a major source of lead, advise caregivers to wet mop floors and wet wipe horizontal

surfaces every 2-3 weeks until all of their child's hand-to-mouth behaviors cease. Since windowsills and wells can contain high levels of leaded dust, they should be kept clean and, if feasible, shut to prevent abrasion of painted surfaces. Advise caregivers to use disposable cleaning materials or reusable materials used only for cleaning. The EPA recommends the use of a general-purpose, nonphosphate cleaner (*36*). In studies that found house dust control to be associated with a decrease in children's mean BLL, professional house cleaners used a powdered detergent rather than bleach or ammonia (*13, 17*).

- *Vacuum carpets before wet mopping floors; cover carpeted areas with throw rugs*. Vacuuming may increase children's lead exposure by bringing lead-contaminated dust from deep in the carpet to its surface. Therefore, advise caregivers to initially vacuum carpeted floors and subsequently wet clean the carpets. After cleaning the carpets, caregivers should wet mop noncarpeted floors to remove dust aerosolized by vacuuming. Advise caregivers to place throw rugs over carpeted children's play areas and to consider replacing the carpet if it is extremely contaminated with dust.
- *Leave shoes at the door; use entryway mats*. Contaminated exterior soil can be tracked into homes on shoes.
- *Prevent children from playing in soil; if possible, provide them with sandboxes*. Do not recommend residential soil abatement, but do advise caregivers to limit their children's play in bare soil. Also advise them to either plant grass on areas of bare soil or cover the soil with grass seed, mulch, or wood chips if possible. Until the bare soil is covered, advise caregivers to move play areas away from bare soil and away from the perimeter of the house. Sandboxes with covers can provide an alternative place for children to play; when not in use, sandboxes should be covered.
- *Consider relocation*. If lead contamination is extensive and not easily remediable, advise caregivers to consider moving to another home. Case managers should be knowledgeable about lead-safe housing where families can be temporarily or permanently placed.

Discuss the potential for lead-contaminated water, if appropriate.

Water sources can become contaminated with lead from household pipes made of lead or harboring leaded solder (*37*). The local health authority will know if this is a prevalent community-wide problem. See Chapter 2, "Assessment and Remediation of Residential Lead Exposure," for a detailed discussion of contamination in municipal or well water. If household water is a suspected source of lead exposure, advise caregivers to implement the following interventions pending the results of water testing:

- *Do not drink or cook with hot tap water*. Lead is more soluble in warm water.
- *Run the tap water cold for 1-2 minutes in the morning, and then fill a pitcher with the*

water. The water is then available that day for drinking, cooking, and formula preparation. Although the benefit of regularly running the tap before consuming water has not been studied in isolation, this is a simple intervention that poses no risk.

- *If drinking water in a child's home is contaminated with lead, advise caregivers to use only bottled water until household water lead levels have been corrected.* However, since most bottled water does not contain fluoride, fluoride supplementation may be necessary. For more information on bottled water, contact the United States Food and Drug Administration (301-443-4166); NSF International, an organization that certifies bottled water and water filters (313-769-5106); or the International Bottled Water Association (703-683-5213).

Nutritional Recommendations

Discuss dietary interventions.

- Recommend that caregivers provide children with foods rich in absorbable iron, vitamin C, and calcium. Foods such as red meat and iron-enriched cereals are good sources of absorbable iron. Adding foods to a meal that are rich in vitamin C (e.g., fruit juice) can dramatically increase iron absorption. Two servings per day of dairy products are recommended. Unless the child does not ingest dairy products because of lactase deficiency, do not suggest calcium supplements, as they can be contaminated with lead (*38*). Both iron deficiency and EBLLs are common among children of low-income families (*39, 40*), so providing iron-rich foods to children with EBLLs would contribute to the treatment of iron deficiency. (See Chapter 4, "Nutritional Assessment and Interventions," for details.)
- Recommend that caregivers provide regular meals and snacks. In one study of five adults, a higher proportion of lead was absorbed when it was given to people when they were fasting (*41*). Therefore, encourage caregivers to provide three meals and two snacks (during midafternoon and at bedtime) a day. Refer eligible families to food supplementation programs such as the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC).

Medical Recommendations

Discuss the importance of regular medical follow-up.

Follow-up blood tests are the best way to determine the success of environmental and other interventions. Therefore, remind caregivers to:

- Make and keep follow-up appointments for blood tests. When making appointments, follow the schedule in Table 3.4 of Chapter 3, "Medical Assessment and Interventions."
- Notify the case manager if the child moves to a new residence.

- Inform all current and future health care providers of the child that the child had an EBLL. This is important even when the child's BLL is no longer elevated.

Review the meaning and risks of EBLLs.
Remind caregivers that:

- Children with EBLLs are often asymptomatic.
- Knowing the source of lead is critical to preventing further exposure.
- Neurodevelopmental effects of EBLLs are usually not immediately identifiable. Because they may only become apparent after a child is in school, be aware of possible later effects. (See Chapter 5, "Developmental Assessment and Interventions.")

Recommendations for Caregivers Whose Children's Lead Exposure Is from Nonhousing Sources

Describe ways to eliminate work- and hobby-related exposure.
Household members who are exposed to lead from occupations or hobbies may bring lead into the home on lead-contaminated clothing, shoes, and hair (*42, 43*). A list of occupations and hobbies associated with home lead exposure can be found in Appendix I.
For work-related lead sources, advise the caregivers to:

- If possible, reduce their lead exposure in the workplace.
- Shower before leaving work.
- Change clothes before going home and leave soiled clothing at work to be laundered by the employer. If this is not possible, change clothes in an area at home that is inaccessible to children.
- Store street clothes in separate areas of the workplace to prevent contamination.
- Leave all lead-containing or lead-contaminated material at the workplace.
- Obtain a referral to an occupational health clinic if the caregiver has an EBLL.
- Prevent children from visiting the work area.

For hobby-related lead sources, advise the caregivers to:

- Separate hobby areas from living areas.
- Prevent children from visiting hobby areas.
- Have anyone engaging in "lead hobbies" change clothes either before entering the home or in an area that is inaccessible to children.
- Wash contaminated clothing separately from the rest of the family laundry.
- Properly store and dispose of toxic substances.

Discuss the hazards of food containers, folk remedies, or cosmetics contaminated with lead.
Items that may be associated with lead exposure are listed in Appendix I.

- Advise caregivers not to use containers, cookware, or tableware purchased abroad to store or cook foods or liquids unless they are shown to be lead-free.
- Advise caregivers not to use folk remedies and cosmetics purchased abroad unless they are shown to be lead-free.

Recommendations for Future Research

Although dust control performed by trained cleaners has been shown to reduce children's mean BLLs (*13, 17*), simply educating families on the need to perform dust control does not attain the same results. Further research on how to motivate families to perform regular and effective cleaning is important.

Reports indicate that, in the absence of interventions to reduce ongoing contamination of dust from disintegrating paint, the effect of dust control on children's BLLs is modest (*17, 18*, *20*, *44*). However, randomized trials examining the effects of a multifactor intervention involving dust control, nutritional supplementation, and behavioral modification on children's BLLs would be of value.

In other areas of environmental health, a great deal has been learned about ways in which different people view risks, methods of risk reduction, and barriers to addressing risks. Despite this increased understanding of the scientific basis of risk perception and communication in the past 20 years (*45*), no studies of risk perception or communication have been conducted among caregivers of children with EBLLs. In order to develop more effective educational and risk-reduction strategies to combat EBLLs in children, health officials need better information about what people think about lead hazards and why they think that way. Methods such as mental modeling (*46*) and value integration (*47*) would be very valuable approaches to obtaining such information.

Soil lead abatement is costly and has not been associated with clinically significant reductions in BLLs. However, studies are needed to assess the effectiveness and costs of using barriers such as grass, shrubbery, or cement to protect children with high soil lead exposures. Research is also needed on the efficacy of various barriers, such as wallpaper or paneling, in protecting children from exposure inside their homes.

Since the half-life of lead in the blood can be up to 38 months (*48*), children must be followed for prolonged periods to determine whether their BLLs are decreasing and whether interventions have been effective. Decreases in dust lead levels or hand lead levels might be used as intermediate, proxy measures of children's lead exposure if we could develop practical, inexpensive, and reliable methods of using such assays in a clinical setting.

References

1. Pirkle JL, Kaufmann RB, Brody DJ, et al. Exposure of the U.S. population to lead. Environ Health Perspect 1998;106:745-50.

2. Rey-Alvarez S, Menke-Hargrave T. Deleading dilemma: pitfall in the management of childhood lead poisoning. Pediatrics 1987;79:214-7.

3. Mielke HW, Reagan PL. Soil is an important pathway of human lead exposure. Environ Health Perspect 1998;106(Suppl 1):217-29.

4. Sayre JW, Charney E, Vostal J, et al. House and hand dust as a potential source of childhood lead exposure. Am J Dis Child 1974;127:167-70.

5. Lanphear BP, Matte TD, Rogers J, et al. The contribution of lead-contaminated house dust and residential soil to children's blood lead levels. Environ Res 1998a;79:51-68.

6. Matte TD, Proops D, Palazuelos E, et al. Acute high-dose lead exposure from beverage contaminated by traditional Mexican pottery. Lancet 1994;344:1064-5.

7. Ng R, Martin DJ. Lead poisoning from lead-soldered electric kettles. CMA 1977;116:508-12.

8. Jones TF, Moore WL, Craig AS, et al. Hidden threats: lead poisoning from unusual sources. Pediatrics 1999;104:1223-5.

9. National Research Council. Improving Risk Communication. Washington, DC: National Academy Press; 1989.

10. Bennett R, Calman K (eds). Risk Communication and Public Health. Oxford: Oxford University Press; 1999.

11. Environmental Protection Agency (EPA). Review of Studies Addressing Lead Abatement Effectiveness: Updated Edition. Washington, DC: EPA; 1998a. EPA 747-B-98-001.

12. Staes C, Matte T, Copley CG, et al. Retrospective study of the impact of lead-based paint hazard remediation on children's blood lead levels, St. Louis. Am J Epidemiol 1994;139:1016-26.

13. Charney E, Kessler B, Farfel M, et al. A controlled trial of the effect of dust-control measures on blood lead levels. N Engl J Med 1983;309:1089-93.

14. Weitzman M, Ashengrau A, Bellinger D, et al. Lead-contaminated soil abatement and urban children's blood lead. JAMA 1993;269:1647-54.

15. Aschengrau A, Hardy S, Mackey P, et al. The impact of low technology lead hazard reduction activities among children with mildly elevated blood lead levels. Environ Res 1998;79:41-50.

16. Hilts SR, Hertzman C, Marion SA. A controlled trial of the effect of HEPA vacuuming on childhood lead exposure. Can J Public Health 1995;86:345-50.

17. Rhoads GG, Ettinger AS, Weisel CP, et al. The effect of dust control on blood lead in toddlers: a randomized trial. Pediatrics 1999;103:551-5.

18. Lanphear BP, Winter NL, Apetz L, et al. A randomized trial of the effect of dust control on children's blood lead levels. Pediatrics 1996a;98:35-40.

19. Lanphear BP, Howard C, Eberly S, et al. Primary prevention of childhood lead exposure: a randomized trial of dust control. Pediatrics 1999;103:772-77.

20. Lanphear BP, Eberly S, Howard CR. Long-term effect of dust control on blood lead levels. Pediatrics 2000;106. Available at: http://www.pediatrics.org/cgi/content/full/106/4/e48. Accessed 12/19/01.

21. Schultz B, Pawel D, Murphy A. A retrospective examination of in-home educational visits to reduce childhood lead levels. Environ Res 1999;80:364-8.

22. Environmental Protection Agency (EPA). Effect of In-Home Educational Intervention on Children's Blood Lead Levels in Milwaukee. Washington, DC: EPA; 1996. EPA 747-R-95-009.

23. Haynes E, Lanphear BP, Tohn E, et al. The effect of interior lead hazard controls on children's blood lead concentrations: a systematic evaluation. Environ Health Perspect 2002 Jan;110(1):104-7.

24. Lanphear BP, Weitzman M, Winter NL, et al. Lead-contaminated house dust and urban children's blood lead levels. Am J Public Health 1996b;86:1416-21.

25. Ewers L, Clark S, Menrath W, et al. Clean-up of lead in household carpet and floor dust. Am Ind Hyg Assoc J 1994;55:650-7.

26. Yiin L, Rhoads GG, Rich DQ, et al. Comparison of lead reduction techniques on carpets and upholstery: the New Jersey assessment of cleaning techniques study (NJACT). Abstracts of the American Public Health Association 2000 Annual Meeting. Available at: http://apha.confex.com/apha/128am/techprogram/paper_10129.htm. Accessed 12/19/01.

27. Lanphear BP, Roghmann KJ. Pathways of lead exposure in urban children. Environ Res 1997;74:67-73.

28. Sargent JD, Dalton M, Stukel TA, et al. Evaluation of capillary collection methods for blood lead screening in children. Ambulatory Child Health 1995;1:112-22.

29. Environmental Protection Agency (EPA). Urban Soil Lead Abatement Demonstration Project. Volume I: EPA Integrated Report. Washington, DC: EPA; 1996. EPA 600/P-93/001aF.

30. Aschengrau A, Beiser A, Bellinger D, et al. The impact of soil lead abatement on urban children's blood lead levels: phase II results from the Boston Lead-in-Soil Demonstration Project. Environ Res 1994;67:125- 48.

31. Farrell KP, Brophy MC, Chisholm JJ Jr, et al. Soil lead abatement and children's blood lead levels in an urban setting. Am J Pub Health 1998;88:1837-9.

32. Rust SW, Kumar P, Burgoon DA, et al. Influence of bone-lead stores on the observed effectiveness of lead hazard intervention. Environ Res 1999;81:175-84.

33. Glotzer DE, Weitzman M, Aschengrau A, et al. Economic evaluation of environmental interventions for low-level childhood lead poisoning. Ambulatory Child Health 1997;3:255-67.

34. Amitai Y, Graef JW, Brown MJ, et al. Hazards of deleading homes of children with lead poisoning. Am J Dis Child 1987;141:758-60.

35. Aschengrau A, Beiser A, Bellinger D, et al. Residential leaded paint hazard remediation and soil lead abatement: their impact among children with mildly elevated blood lead levels. Am J Public Health 1997;87:1698-702.

36. Environmental Protection Agency (EPA). Lead-Cleaning Efficacy Follow-up Study. Washington, DC: EPA; 1998b. EPA 747-R-98-008.

37. CDC. Preventing lead poisoning in young children. Atlanta, GA: US Department of Health and Human Services, CDC; 1991.

38. Scelfo GM, Flegal AR. Lead in calcium supplements. Environ Health Perspect 2000;108:309-13.

39. Pirkle JL, Kaufmann RB, Brody DJ, et al. Exposure of the U.S. population to lead, 1991-1994. Environ Health Perspect 1998;106:745-50.

40. Looker A, Dallman PR, Carroll MD, et al. Prevalence of iron deficiency in the United States. JAMA 1997;277:973-6.

41. Rabinowitz MB, Kopple JD, Wetherill GW. Effect of food intake and fasting on gastrointestinal lead absorption in humans. Am J Clin Nutr 1980;33:1784-8.

42. Gerson M, Van den Eeden SK, Gahagan P. Take-home lead poisoning in a child from his father's occupational exposure. Am J Industr Med 1996;29:507-8.

43. Roscoe RJ, Gittleman JL, Deddens JA, et al. Blood lead levels among children of lead-exposed workers: a meta-analysis. Am J Ind Med 1999;36:475-81.

44. Lanphear BP. The paradox of lead poisoning prevention. Science 1998b;281:1617-8.

45. Fischhoff B. Risk perception and communication unplugged: twenty years of progress. Risk Analysis 1995;15(2):137-45.

46. Bostrom A, Fischhoff B, Morgan MG. Characterizing mental models of hazardous process: a methodology and an application to radon. J Social Issues 1992;48:85-100.

47. Gregory RS. Valuing environmental policy options: a case study comparison of multiattribute and contingent valuation survey methods. Land Economics 2000;76:151-73.

48. Manton WI, Angle CR, Stanek KL, et al. Acquisition and retention of lead by young children. Environ Res 2000;82:60-80.