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# LEAD ABSORPTION IN CHILDREN OF EMPLOYEES IN A LEAD-RELATED INDUSTRY

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**Morton, D. E., A. J. Saah, S. L. Silberg (School of Public Health, U. of Oklahoma Health Sciences Center, Oklahoma City, OK 73190), W. L. Owens, M. A Roberts and M. D. Saah. Lead absorption in children of employees in a lead-related industry. *Am J Epidemiol* 1982;115:549-55.**

**Children can be exposed to lead from a variety of environmental sources. It has been repeatedly reported that children of employees in a lead-related industry are at increased risk of lead absorption because of the high levels of lead found in the household dust of these workers. A case-control study was done in Oklahoma in 1978 to determine whether children of employees in a battery manufacturing plant had a higher prevalence of high levels of blood lead than children whose parents were not employed in a lead-related industry. The data obtained indicated that the blood lead levels of the study children were significantly greater than those of the control children. None of the control children had blood lead levels >30 μg/dl, while 53% of the exposed children had blood lead levels of >30 μg/dl. Trends indicated that the children whose fathers had higher lead exposure at work also had higher blood lead levels. However, the study children whose fathers had good personal hygiene had blood lead levels comparable to the control children. It appeared that only good personal hygiene, i.e., showering, shampooing and changing clothes and shoes before leaving work, was effective for lead containment. The mere changing of clothes and shoes appeared to be inadequate for lead containment.**

**blood specimen collection; hygiene; lead**

Exposure to lead of industrial origin may have a detrimental effect on the health of lead industry employees. It now appears that lead of industrial origin may also be a source of childhood exposure (1–3). These studies (1–3) have indicated that approximately 40–70 per cent of children of workers in a lead-related industry have blood lead levels in excess of 30 μg/dl. In a recent study by Baker et al. (1), 14 households of lead-smelter workers with children aged one to six years were matched with 14 neighboring households with children of similar age. The lead content of painted surfaces and household dust was determined for each pair of matched homes. Blood lead levels were determined for the children residing in

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the households of the lead-smelter workers. The homes of lead-smelter workers had significantly higher lead content in household dust than control homes, and the blood lead levels for the children of the lead-smelter workers were found to be elevated (>30 μg/dl). Therefore, Baker et al. (1) recommended that workers change their clothes and shower before leaving work in order to reduce the amount of lead apparently carried home.

The purpose of our study was to determine whether children of workers in a lead-related industry have significantly higher blood lead levels than neighborhood children of the same age whose parents are not employed in a lead-related industry. In addition, the personal practices of the lead workers such as showering, shampooing, changing clothes and shoes, and personal hobbies were assessed to determine whether these practices affected blood lead levels in their children.

## Materials and methods

The study was conducted during February and March, 1978, in Oklahoma. The study population consisted of children aged 12–83 months. To be included in the study group, a lead worker's child was required to have at least one year of potential exposure and to have lived in the same residence for at least six months. To be in the control group, a child had to be from a family in which no household member had been employed in a lead-related industry for the past five years, who had lived in their current residence for a minimum of six months, and who had not been exposed to a household lead worker.

The study group consisted of 34 children from households in which a family member was employed in a battery manufacturing plant in Oklahoma. Children were matched for neighborhood and age, plus or minus 12 months, and the blood lead levels were compared for each matched pair. Because no consistent difference between males and females between ages one and seven has been demonstrated (4), matching on the basis of sex was not necessary. Because a neighborhood control was selected, socioeconomic status was not considered as a matching variable. Informed consent was obtained from one or both parents of each child.

Control households were identified in a systematic fashion. Several considerations were necessary in choosing the neighborhood controls. When the residence of the lead worker was located along a major traffic street, the control child was selected from the same side of that street. This was done to balance for the potential confounding factor of lead pollution from automobile exhaust. If the worker's residence was located in an apartment complex, the control child was selected from the same complex. In three instances, workers lived in rural areas; the control children for these were selected from the same square-mile section as the individual worker's residence.

### *Laboratory methods*

Blood specimens were collected for each child in a matched pair concurrently. Lead-free materials were utilized for blood collection. A micro finger-stick method recommended by the Centers for Disease Control (CDC) was used to obtain the blood specimens from children. Blood lead determination by the micro method is highly susceptible to contamination from lead on the skin during collection by finger stick. To counter this problem, CDC recommended the use of a silicone spray which was applied to the child's finger just prior to the finger stick. In this manner, the blood rested on this inert silicone barrier instead of the skin. The blood lead levels were measured at CDC using a modification of the Delves cup atomic absorption technique. Blood lead levels for the past year for each employee were also compared to the blood lead levels for their children. The blood lead levels for the employees were provided by the company.

The results of the childrens' blood lead levels were reviewed by a physician, and letters were sent to the parents explaining the results and, if appropriate, follow-up by a pediatrician was recommended.

### *Assessment of lead exposure*

A questionnaire designed to obtain information about the family household environment, the parents' hobbies, the children's habits and the workers' hygienic practices was administered to matched households at the same time the blood was collected. Because of possible bias due to a worker's tendency to report hygiene practices recommended for lead workers, the questionnaire was directed toward the homemaker of the family. Most interviews were conducted during the workday when the workers were away from home. All questionnaires in this study were administered by the same interviewer and consisted of three main parts: 1) identifying information; 2) assessment of the children's potential exposure to lead other than from the father's occupation; and 3) a work history of the worker and assessment of personal hygienic practices.

The identifying information was obtained in order to carry out the systematic sampling procedure. To identify sources of lead other than those directly related to the father's occupation, a series of questions was asked in the second section concerning the habits of the child, hobbies of the family members and other miscellaneous items that have been demonstrated to be exogenous lead sources, e.g., pica, peeling paint or plaster, homemade or imported ceramics, pumping gasoline by family members, food supplements made from bone meal, homemade cider, automobile body repair or painting, lead casting and lead toys. Information was requested in the third section of the questionnaire concerning the types of jobs held and the length of time each job was held over the past five years. This information was asked on all persons in the household who were employed in any capacity whether full or part-time. In addition, questions were asked concerning frequency of the lead workers' showering, shampooing, changing work clothes and shoes and wearing work clothes home.

### *Worker population*

Since the potential for lead exposure varies by job function, the workers were stratified into three categories. A list of job functions was prepared, and the plant manager ranked the jobs in the plant according to high, medium or low exposure to lead dust and/or vapor. These rankings also represented the employee's potential for carrying lead from work to home. In addition, the company obtained permission from the employees to provide us with their blood lead levels for the past 12 months prior to this study.

The lead workers were also classified according to personal hygienic practices. The categories were developed using the information obtained from the questionnaire. An employee was considered to have good hygienic practices if he usually showered, shampooed and changed his clothes and shoes before leaving work. When an employee changed his clothes before leaving work, but did not shower, he was considered to have moderately good hygienic practices. If an employee did not practice any of the suggested lead containment procedures he was considered to have poor hygiene.

### *Statistical methods*

The Wilcoxon matched-pairs signed-ranks test was used to compare the blood lead levels of the two groups of children (5). The possible impact of the worker's personal hygiene habits on the blood lead level of his child was tested using the Kruskal-Wallis one-way analysis of variance (5). When multiple comparisons were made within a category, the Dunn distribution free test for ordered alternatives and unequal sample size, as presented in Hollander and Wolfe (6), was used to make the comparisons. The probabilities for the Kruskal-Wallis $H_t$ statistic were determined using tables generated by Alexander and Quade (7).

## Results

### *Children's blood lead levels*

Figure 1 illustrates the distribution of the children's blood lead levels for both groups. The actual blood lead levels in each matched pair and the difference between the blood lead levels are shown in table 1. One pair was discarded due to the loss of the specimen for the control child; the blood lead level in the study child was 29 μg/dl of whole blood. This blood lead level was included in analysis when matched pair analyses were not required.

The Wilcoxon matched-pairs signed-ranks test was used to compare the blood lead levels of the two groups of children (5). The two groups were found to have significantly different blood lead levels ($p \leq 0.001$). The results also indicate blood lead levels >30 μg/dl in 18 (53 per cent) of the 34 children of the lead workers; ≥40 μg/dl in eight children (23.5 per cent); and ≥60 μg/dl in two children (5.9 per cent). No child in the control group had a value >30 μg/dl.

### *Lead workers' blood lead levels*

The mean blood lead level for the employees in the Oklahoma plant was 49.2 μg/dl with a standard deviation of 8.3 μg. These data represent the average for each individual employee's blood lead tests over a one-year period. Three employees were found to have an average >60 μg/dl. The percentage of workers with blood lead levels >60 μg is lower than normally found in the industry; 11.5 per cent of all the workers in the plant had levels >60 μg compared to 26.5 per cent nationwide

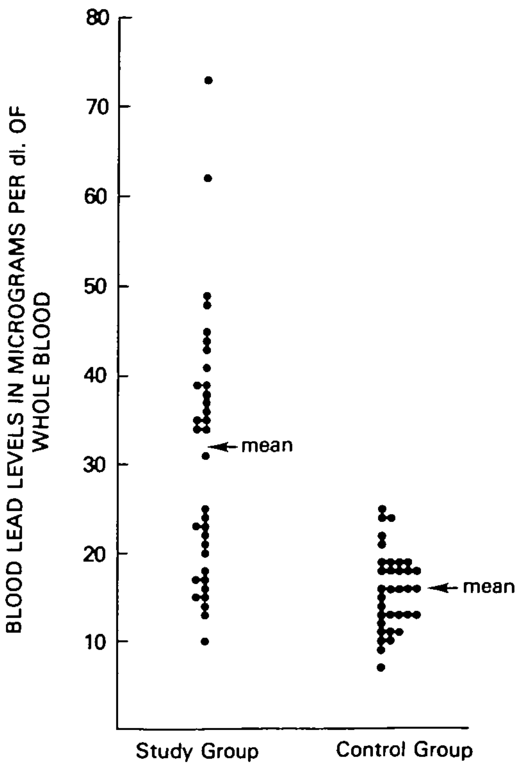


FIGURE 1. Distribution of the blood lead levels for the study children of lead-related industry employees and the control group, in μg/dl of whole blood.

(8). Of the eight children with blood lead levels ≥40 μg/dl, seven had fathers with blood lead averages over the past year of ≥50 μg/dl. However, no statistically significant correlation was found between the fathers' blood lead levels and that of their children.

### *Lead in the home*

Because a significant difference was noted between the blood lead levels of the study and control groups, the potential for lead exposure other than that related to the father's occupation was examined to eliminate confounding of the results caused by other lead exposures. Although the association could not be tested statistically, 11 pairs were found in which the study children had potential for lead ex-

TABLE 1

*Blood lead levels of study and control children and the difference between blood lead levels of the two groups by matched pairs, Oklahoma, 1978**

| Matched pair no. | Lead levels (μg/dl) Study | Control | Difference |
|---|---|---|---|
| 1 | 38 | 16 | 22 |
| 2 | 23 | 18 | 5 |
| 3 | 41 | 18 | 23 |
| 4 | 18 | 24 | −6 |
| 5 | 37 | 19 | 18 |
| 6 | 36 | 11 | 25 |
| 7 | 23 | 10 | 13 |
| 8 | 62 | 15 | 47 |
| 9 | 31 | 16 | 15 |
| 10 | 34 | 18 | 16 |
| 11 | 24 | 18 | 6 |
| 12 | 14 | 13 | 1 |
| 13 | 21 | 19 | 2 |
| 14 | 17 | 10 | 7 |
| 15 | 16 | 16 | 0 |
| 16 | 20 | 16 | 4 |
| 17 | 15 | 24 | −9 |
| 18 | 10 | 13 | −3 |
| 19 | 45 | 9 | 36 |
| 20 | 39 | 14 | 25 |
| 21 | 22 | 21 | 1 |
| 22 | 35 | 19 | 16 |
| 23 | 49 | 7 | 42 |
| 24 | 48 | 18 | 30 |
| 25 | 44 | 19 | 25 |
| 26 | 35 | 12 | 23 |
| 27 | 43 | 11 | 32 |
| 28 | 39 | 22 | 17 |
| 29 | 34 | 25 | 9 |
| 30 | 13 | 16 | −3 |
| 31 | 73 | 13 | 60 |
| 32 | 25 | 11 | 14 |
| 33 | 27 | 13 | 14 |

* The Wilcoxon matched-pairs signed-ranks test was used to compare the blood lead levels of the two groups; $p < 0.001$. Study group mean = 31.8, standard deviation = 14.4. Control group mean = 15.9, standard deviation = 4.5.

posure other than that due to the father's occupation, while their matched controls had no such exposures. Exogenous sources of lead found in the children's environment were automobile body painting, casting of lead and playing with spent gun shell casings in the home. Six children in the study group had fathers whose hobby was casting lead into fish sinkers; none of the control children's fathers did this. It was speculated that those who work with lead on the job are more accustomed to handling lead, thereby promoting its use in the home environment. In the majority of instances, multiple lead-related hobbies were found in a family if one hobby was present. Although these hobbies may not be likely sources of lead exposure for the child, any study/control matched pair in which one of these hobbies was present for the study child and not present for the control was eliminated from analysis. This conservative approach helped to assure that any difference between the blood lead levels of the two groups was due to the father's employment and hygienic practices. When these 11 children and their controls were eliminated, and the remaining 22 pairs were analyzed, the study and control groups continued to be statistically different ($p < 0.001$). The study group blood lead level mean was 29 μg/dl with a standard deviation of 4.4 μg.

### *Job function and containment practices*

Comparison of blood lead levels of the study children according to the potential lead exposure by father's occupation is shown in table 2. The high exposure job category included 55.9 per cent of the children, whose mean blood lead level was 37.1 μg/dl. The medium exposure category included 20.6 per cent of the children, with a mean blood lead level of 30.0 μg/dl. The low exposure category included 23.5 per cent of the children, whose mean blood lead level was 20.6 μg/dl.

Comparisons were made using the Kruskal-Wallis one-way analysis of variance. The three groups were found to be significantly different ($p < 0.02$). When compared at the 10 per cent level, children of the high exposure group were found to be significantly different from the low exposure group, but not from the medium exposure group. Furthermore,

TABLE 2

*Comparison of blood lead levels of the study children according to father's potential occupational exposure to lead, Oklahoma, 1978**

| Child's blood lead level† by father's potential exposure | | |
|---|---|---|
| High | Medium | Low |
| 14 | 39 | 16 |
| 13 | 29 | 36 |
| 25 | 31 | 23 |
| 41 | 34 | 21 |
| 18 | 20 | 17 |
| 49 | 22 | 27 |
| 38 | 35 | 15 |
| 23 | | 10 |
| 37 | | |
| 62 | | |
| 24 | | |
| 45 | | |
| 39 | | |
| 48 | | |
| 44 | | |
| 35 | | |
| 43 | | |
| 34 | | |
| 73 | | |
| Mean = 37.1 | Mean = 30 0 | Mean = 20.6 |

* Kruskal-Wallis one-way analysis of variance: $H_t = 8.5172, p < 0.02$

† Blood lead levels reported in μg/dl of whole blood

TABLE 3

*Blood lead levels of the study children by potential exposure and hygiene of fathers employed in the lead industry, Oklahoma, 1978*

| Employee's hygiene | Child's blood lead level* by father's potential exposure | | |
|---|---|---|---|
| | High | Medium | Low |
| Good | 14 | | |
| | 13 | 39† | |
| | 25 | | |
| | Mean = 17 3 | | |
| Moderately good | 41 | | |
| | 18 | 29 | 16 |
| | 49 | | |
| | Mean = 36 0 | | |
| Poor | 38 | 31 | 36 |
| | 23 | 34 | 23 |
| | 37 | 20 | 21 |
| | 62 | 22 | 17 |
| | 24 | 35 | 27 |
| | 45 | | 15 |
| | 39 | | 10 |
| | 48 | | |
| | 44 | | |
| | 35 | | |
| | 43 | | |
| | 34 | | |
| | 73 | | |
| | Mean = 41 9 | 28 4 | 21 3 |

Kruskal-Wallis one-way analysis of variance: within high exposure by hygiene, $H_t = 5\,611$, $p < 0\,05$ Kruskal-Wallis one-way analysis of variance: within poor hygiene by exposure, $H_t = 12\,5104$, $p < 0\,01$

* Blood lead levels reported in μg/dl of whole blood

† Hygiene category suspected to be in error; interviewer noted that the information on the questionnaire was inaccurate, based on personal observation of employee.

the medium exposure group was not significantly different from the low exposure group. When the medium and low exposure groups were combined and compared to the high exposure group using the Mann-Whitney $U$ test (5), a significant difference was found ($p < 0.01$). These findings indicate that the high exposure group of occupations resulted in higher lead levels in children when hygienic practices were not considered.

The father's compliance with recommended personal hygienic practices, which are assumed to minimize lead dust from being carried home on work clothes or on the body of workers, was analyzed within the work exposure categories. Blood lead levels for the study group by employee exposure category and hygiene are shown in table 3. Within the high exposure category, greater worker compliance with the recommended lead containment practices resulted in lower mean blood lead levels in their children; the mean blood lead level for the good hygiene, high exposure group was 17.3 μg/dl, which was close to the mean blood lead level of 15.9 μg/dl for the control group. In addition, the mean blood lead level for the good hygiene, high exposure group was less than the mean blood lead level of 21.3 μg/dl for the poor hygiene, low exposure group.

Statistical testing of blood lead levels in children of employees with high exposure indicates no significant difference between the poor hygiene and moderate hygiene groups ($p > 0.10$). However, a statistically significant difference was shown between the good hygiene and the poor hygiene groups at the 10 per cent level ($p < 0.10$).

## Discussion

The purposes of this study were to determine whether children of employees in a lead-related industry had increased absorption of lead as a result of their father's occupation, and to determine whether lead containment practices prevented lead absorption in children. Studies in Memphis (1, 2) and North Carolina (3) done in 1975–1977 indicated that such children were at increased risk of lead absorption. The prevalence of excessive lead absorption in these studies (1–3) was determined to be 41.8 per cent, 49 per cent and 72 per cent, respectively; however, concurrent neighborhood control children apparently were not used in these studies. Moreover, these studies concentrated on determining environmental lead in the household and did not actually use case-control methods. The present study, therefore, provides additional confirmation that increased risk of lead absorption occurs in children of employees in a lead-related industry and that the workers' personal hygienic habits do affect that risk.

## Summary

The results indicate that children of employees in a lead-related industry tend to have high blood levels of lead. There are distinct trends indicating that the risk of increased absorption is directly related to the lead exposure at work of the child's parent, and, more importantly, to personal hygienic habits. From this study, it appears that showering and shampooing, in addition to changing clothes before leaving work are necessary to effectively reduce the lead exposure to the children; only changing clothes did not reduce the risk of lead absorption to children. Apparently, in addition to their work clothing, an important source of lead may be the unwashed hands, hair and exposed skin of the employees.

The findings may help physicians identify factors that contribute to high blood lead levels in young children. We also feel that the data presented justify more stringent enforcement of lead containment practices, especially since the cost is low when compared to the detrimental effects of lead absorption in children.

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