Subclinical Effects of Chronic Increased Lead Absorption — A Prospective Study

I. Study Design and Analysis of Symptoms

Gary H. Spivey, M.D., M.P.H.; C. Perry Brown, M.S.P.H.; Robert W. Baloh, M.D.; David S. Campion, M.D.; Jane L. Valentine, Ph.D.; Frank J. Massey, Jr., Ph.D.; Ben L. Browdy, Ph.D.; and B. Dwight Culver, M.D.

Seventy workers exposed to lead for at least one year and 35 control workers have been enrolled in a prospective study of possible neurologic effects of chronic lead absorption at or below the current standard of 80 μg per 100 ml whole blood. The study design is described in detail. Initial results of analysis of lead-related symptoms from baseline studies indicate few differences between the exposed and nonexposed workers. The majority of differences were for central nervous system (CNS) symptoms and muscle or joint pain. Little correlation was found between symptom reporting and indices of lead absorption. The evidence suggests that factors other than lead absorption itself may be important in symptom reporting.

Lead has been recognized as an occupational hazard since the time of Hippocrates.[1] Symptoms of overt poisoning are well known.[2] Since acute lead poisoning does not generally develop in the adult at blood lead values less than 80 micrograms per 100 milliliters (μg/ml) whole blood,[3,4] this blood lead level has been set as the upper limit of safe occupational lead absorption by the National Institute for Occupational Safety and Health (NIOSH).[5] Recently, however, investigators have raised doubts about the adequacy of this standard,[6-9] and levels of 50 μg/100 ml,[8] 60 μg/100 ml,[10] and 70 μg/100 ml[11] have been proposed.

Chronic lead absorption at levels below 80 μg/100 ml whole blood is known to produce measurable metabolic changes such as inhibition of erythrocyte δ-aminolevulinic acid dehydratase (ALAD) activity.[11-16] Effects on other systems are not so clear. However, there is growing evidence of both clinical and subclinical effects on the nervous system[17] including development of motor neuron disease[18] and peripheral neuropathy;[19,20] nerve conduction and electromyographic (EMG) abnormalities;[21-25] subclinical behavioral impairment;[26,27,28] and eighth nerve deficits.[29-32] The authors are not aware of reported evidence concerning the progression or reversibility of such effects.

Editor's Note: The 1978 NIOSH Lead Criteria (Revision) document recommends a safe blood lead level of 60 μg/100 g whole blood. The recently promulgated OSHA lead standard prescribes a blood lead maximum of 40 μg/100 g, to take effect in five years, with a schedule for progressive reductions to this level during the interim.

This study was designed to investigate the possible existence of subclinical neurologic alterations in apparently healthy lead workers with blood lead values below 80 μg/100 ml, and the progression or reversal of any such neurologic alterations in relation to changes in biochemical measures associated with elevated body lead content. This cohort study was designed to be carried out over a three-year period in three phases: a baseline examination; a follow-up period with monitoring of biochemical indices; and a final retesting phase with a repeat of all baseline measurements. The study is unique because of the prospective design which has not previously been used to evaluate the 80 μg/100 ml blood lead safety level, and because of the availability of longitudinal blood lead measurements for all exposed workers. Thus workers could be selected with better knowledge of their lead absorption history than has been possible in the past. The purposes of this article are to describe in detail the study design, to examine the comparability of the study and control groups, and to present initial findings from an examination of reported symptoms in the baseline studies.

From the School of Public Health (Drs. Spivey, Valentine, Massey, Browdy, and Mr. Brown) and the School of Medicine (Drs. Baloh and Campion), the University of California at Los Angeles (UCLA), Los Angeles, CA 90024, and the University of California, Irvine, CA 92664 (Dr. Culver).

This investigation was supported by Grant No. OH00616-03 from the National Institute for Occupational Safety and Health, U.S. Department of Health, Education and Welfare. Computing assistance was obtained from the Health Sciences Computing Facility, UCLA, supported by NIH Special Research Resources Grant RR-3.

Methods

Selection of Study Groups. — The study group was derived from a secondary lead smelter in southern California. This plant smelts, refines and recasts lead, mostly from automobile storage batteries. Approximately 250 men are employed in the plant. Two-thirds are day-shift employees and one-third are swing or graveyard shift workers. Although the production is lower during swing and graveyard shifts, all departments operate around the clock. Because of the high turnover rate of workers in this industry, only employees with at least one year of employment were eligible for inclusion in the study.

Longitudinal blood lead measurements from the company's medical surveillance program were available on 136 potential study group workers. All workers with the majority of their past blood lead values between 60 and 80 μg/100 ml were invited to participate. A small random sample of those with the majority of past values above 80 μg/100 ml or below 60 μg/100 ml were also invited to participate. Thus the selected sample included a wider range of blood lead values but emphasized values between 60 and 80 μg/100 ml. Eleven of 82 workers (13%) invited to participate refused.

The control workers were obtained from three separate facilities within Los Angeles. One group was employed in an aluminum cutting and warehousing facility. Another group originated in an aluminum casting and cutting plant. The third group was obtained from an aluminum smelting and casting facility. These plants were chosen for the similarity to the study group plant in work force characteristics, noise exposure, types of industrial operations and physical activity of the employees, and for lead, arsenic, or cadmium exposures comparable to those in the general community. Where possible, only those workers who had at least a one-year history with the company were selected for the control group. (Thirty-two of the 35 controls met this criterion.) Nine of 13 eligible workers from the cutting and warehousing facility, 16 of 17 eligible workers from the casting and cutting plant, and a small volunteer group of 10 workers from the aluminum smelter participated in the study. It was not possible to match control workers to study workers individually for age or race, but an attempt was made to group match on these parameters.

Examinations. — Baseline studies were conducted in the UCLA Center for the Health Sciences. These studies consisted of an interviewer administered questionnaire; measurement of height, weight, and blood pressure; standard neurologic examination; blood measurements for lead, arsenic, and cadmium; quantitative oculomotor function tests; nerve conduction measurements; and audiology. The measurements took place between February and August 1977. At all times the group of workers examined included both study and control group workers so that the examiners were unaware of the study or control group status of any individual they tested.

Questionnaire. — The questionnaire developed for the study was based upon that used in the University of Louisville[28] study of behavioral effects of lead exposure. It includes a detailed symptom history, history of exposure to other chemicals which could produce similar symptoms, and questions about work habits. The symptom list included reported lead poisoning related symptoms. This questionnaire was modified for interviewer administration and was expanded to include demographic data, illness and medication histories, and possible other sources of lead exposure. Two nonsense symptoms, tingling navel and itchy gums, were added to the symptom list as a check on respondent reliability. The questionnaire was pretested, but no attempt at validation was made. The questionnaire was translated into Spanish for use with non-English speaking workers. The interviewers were bilingual. A copy of the questionnaire is available from the authors upon request.

Neurologic Examination. — A standard neurologic examination was conducted by a neurologist with particular emphasis on identifying subtle signs of a peripheral neuropathy.

Oculomotor Function Tests. — Electro-oculographic recorded eye movements were quantified by having each subject follow on a modified TV set a slit of light as it moved through a series of random jumps and sinusoidal oscillations. The characteristics of the saccadic and pursuit eye movements are determined by laboratory digital computer.[33,34]

Nerve Conduction. — Motor latencies and conduction velocities of the ulnar and peroneal nerves and sensory latencies of the ulnar and sural nerves on one side were determined by standard methods.[35] Conduction velocities of slower fibers of the ulnar nerve were determined by the techniques of Seppäläinen.[36]

Audiology. — Audiometric testing in the UCLA Clinical Audiology Laboratory consisted of standard pure-tone air and bone conduction, performance intensity functions for phonetically balanced words,[37] and impedance studies including typanometry and measurement of the acoustic reflex.[38,40]

Biochemistry. — Blood from each participant was collected into lead-free vacutainers. A hematocrit determination was made for each sample. Whole blood lead and cadmium were determined by atomic absorption spectrophotometry[41] using a Perkin-Elmer Model 303 atomic absorption spectrophotometer. Red blood cell (RBC) δ-aminolevulinic acid dehydratase (ALAD), and RBC protoporphyrin (FEP) were determined by methods of Burch and Siegel[42] and Piomelli,[43] respectively. Blood arsenic was determined by the method of Kang and Valentine.[44]

Each laboratory was given a series of split samples for reliability measurement. In addition, a series of split samples was sent to Environmental Science Associates in Bedford, Massachusetts, for independent whole blood lead determination.

Environmental Assessment. — Health Science Associates, a private industrial hygiene firm, performed air sampling for lead, arsenic, and cadmium in the study and control plants. Noise levels were also recorded. Sampling was performed by work area within each plant to establish the range of typical exposure levels.

During the follow-up phase of the study, the biochemical measurements will be repeated. In addition, any worker who leaves the employment of either the study or control companies will be asked to return to UCLA for a repeat of the baseline studies. During the final phase of the study, the workers from both groups will return to UCLA for a repeat of the full complement of baseline

Table 1. — Demographic Characteristics of Lead Workers and Controls.

	Lead Group (69)	Control Group (35)
Age		
<29	12 (17.4)*	8 (22.9)
30-39	17 (24.6)	7 (20.0)
40-49	18 (26.1)	14 (40.0)
>50	22 (31.9)	6 (17.1)
Mean and standard deviation	42.5 ± 10.9	39.7 ± 11.1
Race		
White	9 (13.0)	10 (28.6)
Black	29 (42.1)	15 (42.8)
Spanish surnamed	31 (44.9)	10 (28.6)
Educational level (mean number of years and standard deviation)	8.7 ± 3.5	10.4 ± 2.8
Length of employment (mean number of years and standard deviation)	11.3 ± 9.2	8.4 ± 7.0

*Number in parentheses is percent of group

studies. The workers will be retested in approximately the same order as in the initial testing so that each worker will have about 15 months follow-up between testing periods.

Results

A total of 70 lead workers and 35 control group workers were admitted to the study. One study group worker was subsequently found to have been employed for less than one year and is excluded from the following analysis, leaving a total of 69 lead workers. Four of 69 lead workers (5.8%) had blood lead levels greater than 80 μg/100 ml at the time of examination. One lead worker responded positively to 42 of 47 symptoms including the two nonsense symptoms. His responses are considered unreliable and he is excluded from the symptom analyses. Although a history of lead poisoning as defined by hospitalization was an exclusion criterion for the lead group, nine workers were subsequently found to have been hospitalized. The results of analyses of these nine workers to date do not appear to form a unique pattern even though they had a higher mean blood lead level (71.4 μg/100 ml) and reported more symptoms (mean = 13.3) than the rest of the lead workers. These workers are included in the following analyses, except where indicated. For comparisons of proportions between the lead exposed and control groups, Fisher's exact test was used because of the small expected numbers in some cells.

Table 1 gives a comparison of demographic characteristics in the two groups. The mean ages of the two groups are similar. However, the table does indicate a slight difference in the age distribution in the two groups with a higher proportion of workers over 50 years of age in the lead group. The control group has a higher proportion of white and a lower proportion of Spanish surnamed workers than the lead group. The age distribution did not differ among the racial groups. The control group had a slightly higher mean educational level than the lead group. Mean length of employment was similar in both groups.

Table 2 shows environmental data derived from area surveys for the four involved plants. The elevated lead levels in the smelter are clearly shown as well as the elevated arsenic levels which were known to exist in localized areas of the plant. All cadmium levels are below the Occupational Safety and Health Administration (OSHA) standard of 200 micrograms per cubic meter (μg/m³) air.[45] The only area of the lead smelter with even moderately elevated cadmium levels was the area immediately adjacent to the furnace (171 μg/m³). The noise exposures in the four facilities are similar.

Table 3 indicates that reported past exposure histories of the two groups were similar except for the high level of reported cadmium, lead, and arsenic exposure in the lead group. Table 4 shows the expected differences between the lead exposed and control workers in blood lead, FEP, and ALAD measurements. None of the control workers had blood lead values above those expected for normal urban dwellers.[46] The difference between the lead workers and controls in blood arsenic is very small although statistically significant ($p < 0.01$). The arsenic values for both groups are well within normal limits.[47]

Table 2. — Background Environmental Data (Range of Values from Area Samples).

Exposure	Lead Plant	Control Plant 1	Control Plant 2	Control Plant 3
Pb (μg/m³ air)*	10-4840	3.9-51.0	5.4-32.2	0.3-35.2
Cd (μg/m³ air)*	<0.3-171	0.3-0.4	<0.3	0.3-0.5
As (μg/m³ air)*	3.0-250	0.3-0.4	<0.3	0.3-0.5
Sound (dBA)	82-105	79-103	60-99	69-102

*8-hour time weighted averages

Table 3. — Responses to Exposure Questions.

	Lead Group (69) % Yes	Lead Group (69) % DK*	Control Group (35) % Yes	Control Group (35) % DK*	P†
Cadmium	26.1	2.9	2.9	2.9	0.003
Metal mercury	2.9	5.8	2.9	0.0	1.000
Methyl mercury	1.5	5.8	0.0	0.0	1.000
Carbon disulfide	7.3	5.8	2.0	0.0	0.662
Lead	95.7	0.0	22.9	0.0	<0.001
Manganese	13.0	5.8	11.4	0.0	1.000
Arsenic	55.1	1.5	2.9	0.0	<0.001
Thallium	1.5	5.8	2.9	0.0	1.000
Acrylamide	2.9	8.7	2.9	0.0	1.000
Trichloroethylene	23.2	4.4	11.4	2.9	0.189
Methyl bromide	0.0	4.4	5.7	2.9	0.113
Carbon monoxide	18.8	1.5	14.3	2.9	0.784
Pesticides	5.8	1.5	2.9	0.0	1.000
Methyl chloride	8.7	4.4	5.7	2.9	0.713
High noise levels	73.9	0.0	77.1	0.0	0.813
Military noise	8.7	0.0	8.6	0.0	1.000

*Don't know, didn't answer
†Significance level determined from Fisher's test (2-tail)

Table 4. — Blood Lead, Arsenic, and Cadmium Levels in Lead Workers (69) and Controls (35).

Blood Determination	Lead Group*	Control Group*
Lead (μg/dl)	61.3 ± 12.8	22.0 ± 5.9
FEP (μg/dl)	235.5 ± 155.7	32.5 ± 9.5
ALAD (units/ml RBC)	123.8 ± 39.7	252.6 ± 71.7
Arsenic (μg/dl)	0.32 ± 0.18	0.20 ± 0.17
Cadmium† (μg/dl)	0.36 ± 0.10	—

*Mean ± standard deviation
†N = 20

Table 5. — Illness and Injury History.*

	Lead Group (69)		Control Group (35)	
	% Yes	% DK†	% Yes	% DK†
Kidney disease	1.5	1.5	2.9	0.0
Liver disease	1.5	0.0	0.0	0.0
Hypertension	18.8	1.5	8.6	0.0
Diabetes	2.9	0.0	0.0	0.0
Currently seeing a physician	10.0	0.0	11.4	0.0
Work related injury	66.7	0.0	54.3	0.0
Non-work injury	17.4	0.0	22.9	0.0
Head or neck injury	30.4	0.0	22.9	0.0

*None of the differences are statistically significant at a level of p = 0.10 (Fisher's)
†DK = "don't know"

Since there was no potentially significant cadmium exposure in any of the control plants, blood cadmium levels were not done on control workers. A random sample of 20 lead workers which included several workers working near the furnace was checked for blood cadmium levels. As shown in Table 4, all blood cadmium levels were within normal expected values.[48]

Table 5 shows that the two groups were very similar in prior medical history. Fifty-seven percent of workers in each group are current smokers. Among current smokers, 21% of the lead workers and 25% of the control workers smoke more than one pack per day. Alcohol was used by 84% of the lead group and 80% of the control group. There were no racial differences in alcohol consumption.

Table 6 presents the number and percentage of each group responding positively to the symptoms included in the questionnaire. All but two of the symptoms were reported more frequently by lead workers than by control workers. For 11 symptoms the differences were statistically significant at $p \leq 0.05$, and p values were between 0.10 and 0.05 for four additional symptom differences. The lead workers on the average reported 8.1 ± 6.7 symptoms while the control workers reported 3.8 ± 3.9 symptoms ($p < 0.01$, t-test). The previously hospitalized workers reported an average of 13.3 ± 7.4 symptoms, while the rest of the lead workers reported 7.4 ± 6.4 symptoms. These means were significantly different from each other and from the control group ($p < 0.01$ for all comparisons).

Table 7 shows weak correlations between the number of reported symptoms and three measures of lead absorption when the study and control groups are combined. There is also a negative correlation between the number of symptoms and years of education for the combined group. In the lead group only there is a negative correlation between length of employment and number of symptoms. This negative correlation held when CNS symptoms were analyzed separately. The pattern of findings did not change when the previously hospitalized cases were excluded from the analysis.

Table 6. — Responses to Questionnaire Symptom Queries.

Symptom	Lead Group (n = 68) Number Reporting*	Control Group (n = 35) Number Reporting	P†
Neurologic symptoms			
Tire easily	23 (33.8)	7 (20.0)	0.107
Lose temper	22 (32.4)	7 (20.0)	0.138
Personality change	16 (23.5)	3 (8.6)	0.052
Nightmares	13 (19.1)	4 (11.4)	0.241
Sleepy	29 (42.7)	9 (25.7)	0.069
Difficulty with memory	19 (27.9)	6 (17.1)	0.167
Blackouts	1 (1.5)	0 (0.0)	0.660
Difficulty with math	7 (10.3)	0 (0.0)	0.049
Difficulty with reading	10 (14.7)	3 (8.6)	0.290
Depressed (blue)	15 (22.1)	1 (2.9)	0.008
Difficulty with concentration	14 (20.6)	2 (5.7)	0.040
Tingling hands	8 (11.8)	1 (2.9)	0.123
Seizures	1 (1.4)	0 (0.0)	0.660
Disorientation	2 (2.9)	0 (0.0)	0.434
Dizziness	16 (23.5)	2 (5.7)	0.019
Difficulty with hearing	11 (16.2)	8 (22.1)	0.284
Shaky handwriting	13 (19.1)	0 (0.0)	0.003
Difficulty saying words	5 (7.4)	2 (5.7)	0.555
Numbness in arms/legs	6 (8.8)	2 (5.7)	0.448
Unsteady walk	11 (16.2)	2 (5.7)	0.112
Weakness in hands	18 (26.5)	3 (8.6)	0.026
Headaches	15 (22.1)	5 (14.3)	0.251
Eyesight worsened	16 (23.5)	6 (17.1)	0.315
Treated for loss of consciousness	0 (0.0)	1 (2.9)	0.340
Tremor of:			
Hands	8 (11.8)	1 (2.9)	0.123
Lips	0 (0.0)	0 (0.0)	—
Arms	1 (1.5)	0 (0.0)	0.660
Legs	2 (2.9)	0 (0.0)	0.434
Sleep poorly	10 (14.7)	3 (8.6)	0.290
Gastrointestinal symptoms			
Weight loss	11 (16.2)	3 (8.6)	0.227
Constipation >24 hr	14 (20.6)	3 (8.6)	0.098
Diarrhea >24 hr	3 (4.4)	1 (2.9)	0.581
Abdominal pain	11 (16.2)	3 (8.6)	0.227
Appetite poor	4 (5.9)	4 (11.4)	0.265
Other symptoms			
Muscle pain	31 (45.6)	11 (31.4)	0.120
Joint pain	36 (52.9)	9 (25.7)	0.007
Chest pain	12 (17.7)	3 (8.6)	0.174
Metallic taste in mouth	26 (38.2)	5 (14.3)	0.009
Legs/feet swelling	4 (5.9)	0 (0.0)	0.184
Night urination	26 (38.2)	4 (11.4)	0.003
Rapid heartbeat	16 (23.5)	2 (5.7)	0.019
Peeling of palms/soles	10 (14.7)	1 (2.9)	0.059
Itchy gums >2 days	0 (0.0)	0 (0.0)	—
Navel tingling	0 (0.0)	0 (0.0)	—
Watering/itchy eyes (nonallergy)	15 (21.7)	1 (2.9)	0.013
Bad health	7 (10.3)	2 (5.7)	0.353

*Number in parentheses is percentage of total group
†Significance level determined by Fisher's (1-tail) test

Discussion

The original study design called for pairwise matching of cases and controls on race and age. Difficulty in obtaining the control group allowed only limited group matching on these characteristics. The age, race, smoking, alcohol use, and education comparisons indicate that the group matching process was largely successful in achieving group comparability. However, the differences observed suggest that some adjustment for these variables may still be necessary in the analysis of study results. The nine previously hospitalized lead workers will be examined as a separate group as further analyses are completed.

While some control plant locations were found to have airborne lead levels higher than expected (Table 2), all

Table 7. — Correlation of Number of Reported Symptoms with Demographic Variables and Lead Absorption Measures.

Variable	Correlation Coefficient Lead Group (68)	Control Group (35)	Both Groups (103)
Age	-0.277*	0.076	-0.140
Years of schooling	-0.106	-0.187	-0.207*
Alcohol consumption	0.047	0.100	0.093
Length of employment	-0.251*	0.037	-0.133
FEP	0.043	0.076	0.222*
ALAD	0.200	-0.103	-0.199*
Whole blood lead	0.032	-0.103	0.280†

*Statistically significant $p < 0.05$
†Statistically significant $p < 0.01$

levels were well below the current OSHA occupational standard of 200 μg/m³.[45] As indicated in Table 4, none of the control workers had blood lead levels higher than expected for normal urban dwellers.[46]

The lead group differed from the control group in exposure to arsenic and cadmium as well as lead. This was expected due to the smelter's process of recovering lead mostly from old automobile batteries. Environmental data (Table 2) indicates that cadmium levels are not high enough to be of concern, and indeed the blood cadmium levels (Table 4) confirm the lack of significant exposure. Since arsenic, which is present in some areas of the lead smelter, can cause neurologic damage similar to lead,[49] assessment of arsenic absorption is important. While the blood arsenic levels of the lead workers tended to be higher than the control workers, the differences were small. Blood arsenic levels did not correlate with symptom reporting.

The high frequency of reported symptoms in a presumably healthy population of lead workers is consistent with the findings of Lilis.[10 50] Whether this finding is an indication of real differences between the groups or at least partly a reflection of the company educational program, which teaches the workers what symptoms to expect, is not clear. The higher proportion of Spanish surnamed workers in the lead group suggests the possibility that the symptom reporting differences might be the result of communication problems, even though the questionnaire was administered in Spanish when requested. However, examination of the symptom reporting revealed no differences in either group by race. Furthermore, Spanish surnamed workers did not differ in symptom reporting between those who elected Spanish questionnaires and those who elected English questionnaires.

Lilis examined a group of lead workers who had single blood lead determinations less than 80 μg/100 ml, and who gave no history of notification of blood lead over 80 μg/100 ml. Fifty-six percent of these workers reported one or more CNS symptoms, while 39% reported either muscle or joint pain or both. Unfortunately, no control group values were reported for these symptoms.

One or more CNS symptoms were reported by 75% of our lead group, and by 60% of our control group. This difference is not statistically significant ($p = 0.05$ level). It is interesting that our control group reported more CNS symptoms than Lilis' lead group, but since Lilis did not report the number of CNS symptoms on her questionnaire, our results cannot be adequately compared to hers because of a probable difference in the number of symptoms asked about. The findings of the two studies can be directly compared for the muscle/joint pain symptoms where the number of questions is the same. Sixty-five percent of the lead workers and 40% of the control workers in this study reported one or both of these symptoms (difference statistically significant at $p<0.05$). It is interesting that our control group again reported these symptoms as frequently as Lilis' study group. These two symptom comparisons point up the danger of not properly using a control group in such studies.

Lilis also comments that the greater reported frequency of CNS symptoms than other organ system symptoms observed in her study is very common in lead workers. Our results also show a higher frequency of CNS symptoms (75%) than muscle/joint pain symptoms (65%) or gastrointestinal (GI) symptoms (19%). However, the control group showed a similar pattern (CNS 60%, muscle/joint pain 40%, GI 17%). The greater reported frequency of CNS symptoms is most likely a result simply of combining multiple symptoms. There are more CNS symptoms to ask for, therefore, the chances of at least one being reported are higher. The individual symptoms most frequently reported were muscle pain and joint pain (Table 6).

The higher reported frequency of depression, difficulty in concentrating, personality change, and rapid heartbeat in the lead group is consistent with the findings of hostility, depression, and dysphoria in the Louisville Study.[28] The reported dizziness, shaky handwriting, and weakness in the hands may be consistent with the difficulties with neuromuscular function also found in the Louisville Study. The reported watering or itching of the eyes in this study may be the result of sulfate exposure in the lead smelter.

The negative correlation between number of reported symptoms and length of employment in the lead group suggests the possibility that workers who remain employed for long periods of time are biologically more resistant to the effects of lead than the average worker. This result may also be explained by greater stoicism or by better hygiene among the longer-term workers. The negative correlation with age is presumably caused by the correlation between age and length of employment. The negative correlation between years of education and number of symptoms may mean that some of the reported symptoms are unrelated to lead. This finding might also be explained by differences in personal hygiene, job classification, or other factors. As pointed out earlier, the differences in educational levels of the lead and control groups do not appear large enough to account for the differential symptom reporting between the two groups. In fact, the correlation between blood lead and symptoms, holding the effect of education fixed, is still significant for the combined group. This suggests that education is not a confounding variable in this analysis.

The positive correlation of number of symptoms with FEP and whole blood lead, and the negative correlation with ALAD (which goes down with increased lead absorption) are in the expected direction. These three biochemical indices are largely a reflection of relatively short-term exposures (months rather than years). Thus,

their lack of correlation with number of symptoms in the lead group is not surprising since symptoms seem more likely to be a result of chronic exposure. Finding the correlations only when the study and control groups are combined is consistent with this hypothesis and suggests that the fact of exposure is important. However, the small size of the correlations by what is statistically a somewhat artificial mechanism (combining a low blood lead/low symptom group with a higher blood lead/higher symptom group — each group individually without significant correlation between blood lead and number of symptoms), seems to indicate that lead absorption alone may not be a very important variable in determining the development or reporting of symptoms. This conclusion is also supported by the fact that when we divided the lead group into those with no past blood lead value greater than 80 μg/100 ml and those with past values greater than 80 μg/100 ml, we found no differences between the groups in symptoms reported or in symptom frequency. Factors such as educational level, knowledge of possible symptoms, and biologic susceptibility may be as important variables as absorption itself.

As baseline analyses are completed, we will report further on specific portions of the baseline studies. Although analysis of objective portions of the baseline studies is not yet completed, the findings presented here do provide some subjective evidence of an effect on at least two organ systems — CNS and musculoskeletal — from lead absorption at levels below 80 μg/100 ml. An apparent need exists for more detailed research into variables other than lead exposure (or absorption) which may be important in determining the effect of that exposure.

References

1. Purdom PW: Environmental Health. New York: Academic Press, 1971, p 432.
2. Johnstone RT: Clinical inorganic lead intoxication. *Arch Environ Health* **8**:250-255, 1964.
3. Kehoe RA: Standards with respect to atmospheric lead. *Arch Environ Health* **8**:348-354, 1964.
4. Kehoe RA: The Harben Lectures, 1960. The metabolism of lead in man in health and disease. Lecture 2, Part 2: The metabolism of lead under abnormal conditions. *J R Inst Public Health Hyg* **24**:129-143, 1961.
5. NIOSH: Occupational exposure to inorganic lead. U.S. Dept. Health, Education and Welfare, Health Services and Mental Health Administration Publ. No. (HSM) 73-11010, Cincinnati, 1972.
6. Editorial: Subclinical lead poisoning. *Lancet* **1**:87, 1973.
7. Guinee VF: Lead poisoning. *Am J Med* **52**:283-288, 1972.
8. Waldron HA: The blood lead threshold. *Arch Environ Health* **29**:271-273, 1974.
9. Zielhuis RL: Interrelationship of biochemical responses to the absorption of inorganic lead. *Arch Environ Health* **23**:299-311, 1971.
10. Lilis R, Blumberg WE, Fishbein A, et al: Lead effects among secondary lead smelter workers with blood lead levels below 80 μg/100 ml. *Arch Environ Health* **32**:256-266, 1977.
11. Morgan BB Jr. and Repko JD: Evaluation of behavioral functions in workers exposed to lead, in Behavioral Toxicology, Early Detection of Occupational Hazards, C. Xintaras, B. L. Johnson, and I. de Groot (Eds.). HEW Publication No. (NIOSH) 74-126, 1974, pp 248-266.
12. Gusev MI: The maximum permissible concentration of lead in the air in centers of population, in Limits of Allowable Concentrations of Atmospheric Pollutants, V. A. Rjazanov (Ed.) and B. S. Levine (Trans.). Moscow: Medzeg, 1960, pp 5-31.
13. Hernberg S, Nikkanen J, Mellin G, and Lilius H: δ-aminolevulinic acid dehydrase as a measure of lead exposure. *Arch Environ Health* **21**:140-145, 1970.
14. Morgan JM and Burch HB: Comparative tests for diagnosis of lead poisoning. *Arch Intern Med* **130**:335-340, 1972.
15. Weissberg JB, Lipschutz F, and Oski FA: δ-aminolevulinic acid dehydratase activity in circulating blood cells. A sensitive laboratory test for the detection of childhood lead poisoning. *N Engl J Med* **284**:565-569, 1971.
16. Haeger-Aronsen B, Abdulla M, and Fristedt BI: Effect of lead on δ-aminolevulinic acid dehydrase activity in red blood cells. *Arch Environ Health* **23**:440-445, 1971.
17. Baloh RW: The effects of chronic increased lead absorption on the nervous system — A review article. *Bull Los Angeles Neurol Soc* **38**:91-99, 1973.
18. Campbell AMG, Williams ER, and Barltrop D: Motor neurone disease and exposure to lead. *J Neurol Neurosurg Psychiatry* **33**:877-885, 1970.
19. Fullerton PM: Toxic chemicals and peripheral neuropathy: Clinical and epidemiological features. *Proc R Soc Med* **62**:201-204, 1969.
20. Fullerton PM: Chronic peripheral neuropathy produced by lead poisoning in guinea pigs. *J Neuropathol Exp Neurol* **25**:214-236, 1966.
21. Catton MJ, Harrison MJG, Fullerton PM, and Kazantzis G: Subclinical neuropathy in lead workers. *Br Med J* **2**:80-82, 1970.
22. Seppäläinen AM and Hernberg S: Sensitive technique for detecting subclinical lead neuropathy. *Br J Ind Med* **29**:443-449, 1972.
23. Feldman RG, Haddow J, Kopito L, and Schwachman H: Altered peripheral nerve conduction velocity. Chronic lead intoxication in children. *Am J Dis Child* **125**:39-41, 1973.
24. Cupcea S, Raucher C, Derevenco R, et al: Contributions au problème de l'examen de la reactivité dans le saturnisme. (Examination of reactivity in plumbism.) *Rev Sci Med Bucharest* **2**:106-115, 1954.
25. Boyadzhiev V, Stoev V, and Petkov G: Diagnostichno znachenie na nyakoi pokazateli za promentie vuv visshata nervna deinost pri olovnoto otravyane. (The diagnostic importance of the higher nervous system in case of lead intoxications.) *Nauchni Tr Vissh Med Inst Sofiia* **41**:99-113, 1962.
26. Hernberg S: Biological effects of low lead doses, in Proceedings of International Symposium on Environmental Health Aspects of Lead. Amsterdam, October 2-6, 1972, pp 617-629.
27. Stöfen D: Less noted European papers on lead, in Proceedings of International Symposium on Environmental Health Aspects of Lead. Amsterdam, October 2-6, 1972, pp 441-448.
28. Repko JD, Morgan BB Jr., and Nicholson J: Behavioral effects of occupational exposure to lead. U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, Division of Laboratories and Criteria Development, HEW Publication (NIOSH) 75-164, 1975.
29. Rieke FE: Lead intoxication in shipbuilding and shipscrapping 1941 to 1968. *Arch Environ Health* **19**:521-539, 1969.
30. Bordley JE and Hardy WG: The etiology of deafness in young children. *Acta Otolaryngol (Stockh)* **40**:72-79, 1951.
31. Harvey SC: Heavy metals, in The Pharmacological Basis of Therapeutics, L. S. Goodman and A. Gilman (Eds.). New York: MacMillan, 1965, pp 943-975.
32. Gozdzik-Zolnierkiewicz T and Moszynski B: VIII nerve in experimental lead poisoning. *Acta Otolaryngol (Stockh)* **68**:85-89, 1969.
33. Baloh RW, Kumley WE, and Honrubia V: Algorithm for analyses of saccadic eye movements using a digital computer. *Aviat Space Environ Med* **47**:523-527, 1976.
34. Baloh RW, Sills AW, Kumley WE, et al: Quantitative measurement of smooth pursuit eye movements. *Ann Otol Rhinol Laryngol* **85**:111-120, 1976.
35. Lenman JAR and Ritchie AE: Clinical Electromyography. London: Pitman Medical and Scientific Publishing Company, Ltd., 1970, pp 1-57.
36. Seppäläinen AM: The conduction velocity of slower fibers of the ulnar nerve in adults (Abstract). *Scand J Clin Lab Invest* **27**(116):70, 1971.
37. Jerger J and Jerger S: Diagnostic significance of PB word functions. *Arch Otolaryngol* **93**:573-580, 1971.
38. Jerger J: Diagnostic audiometry (Chapter 3), in Modern Developments in Audiology, J. Jerger (Ed.). New York: Academic Press, 1973, pp 75-115.
39. Jerger J, Harford E, Clemis J, and Alford B: The acoustic reflex in eighth nerve disorders. *Arch Otolaryngol* **99**:409-413, 1974.
40. Anderson H, Barr B, and Wedenberg E: Intra-aural reflexes in retrocochlear lesions, in Proceedings of the Tenth Nobel Symposium, Stockholm, August 1968: Disorders of the Skull Base Region, C.

Hamberger and J. Wersall (Eds.). Stockholm: Almqvist & Wiksell Förlag AB, 1969, pp 49-55 (New York: Wiley).

41. Hessel DW: A simple and rapid quantitative determination of lead in blood. *Atomic Absorption News Letter* 7:55-56, 1968.

42. Burch HB and Siegel AL: Improved method for measurement of δ-aminolevulinic acid dehydratase activity of human erythrocytes. *Clin Chem* **17**:1038-1041, 1971.

43. Piomelli S: A micromethod for free erythrocyte porphyrins: The FEP test. *J Lab Clin Med* **81**:932-940, 1973.

44. Kang HK and Valentine JL: Acid interference in the determination of arsenic by atomic absorption spectrophotometry. *Anal Chem* 49:1829-1832, 1977.

45. NIOSH: Registry of Toxic Effects of Chemical Substances, 1976. Rockville, Md: NIOSH.

46. Zielhuis RL, Stuik EJ, Herber RFM, et al: Smoking habits and levels of lead and cadmium in blood in urban women. *Int Arch Occup Environ Health* **39**:53-58, 1977.

47. Valentine JL, Kang HH, and Spivey GH: Arsenic levels in human blood, urine and hair in response to exposure via drinking water. Submitted for publication.

48. Kubota J, Lazar VA, and Losee F: Copper, zinc, cadmium and lead in human blood from 19 locations in the United States. *Arch Environ Health* **16**:788-793, 1968.

49. Heyman A, Pfeiffer JB, Willett RW, and Taylor HM: Peripheral neuropathy caused by arsenical intoxication. A study of 41 cases with observations on the effects of BAL (2,3, Dimercapto-Propanol). *N Engl J Med* **254**:401-409, 1956.

50. Lilis R, Fischbein A, Eisinger J, et al: Prevalence of lead disease among secondary lead smelter workers and biological indicators of lead exposure. *Environ Res* **14**:255-285, 1977.

Fairness in Pursuit of Equality

The antis have continually described feminists as "anti-male," if not downright "rabid man-haters." But it is the anti-feminists who start hyperventilating with rage when men make advances in the arenas of Social Security, parenthood and alimony rights . . .

There is, all in all, a kind of stinginess about the anti-rights movement, a real deep-seated reluctance to "let men off the hook."

— From "Look Who's Outraged at the Supreme Court's Alimony-for-Men Decision" by Ellen Goodman, in *Pittsburgh Post-Gazette*, March 10, 1979.