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Children's Classroom Behavior and Lead in Taiwan

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Lead has long been recognized to cause adverse effects on children (Davis and Svendsgaard, 1987). A recent compilation of studies on the correlation of child intelligence and low-level lead exposure has demonstrated a robust dose-response relationship (Needleman and Gatsonis, 1990). Teeth have frequently been used as a retrospective marker of lead exposure. The pediatric neurotoxicity of lead is not limited to intelligence, but also effects other behaviors which are apparent to classroom teachers (Needleman et al, 1979).

The present study provided an opportunity to evaluate a range of relatively lower lead exposures, including those near smelters as well as those living in more typical urban and rural conditions. This may reveal help identify the lowestor no-effect levels.

SUBJECT AND METHODS

The children attended grades one through three of seven primary schools in Taiwan. These schools were chosen to represent a range of potential lead exposures but serving populations with broadly similar ethnic compositions. Details of the populations demographic traits, recruitment efforts, and tooth lead analysis and reliability have been presented elsewhere (Rabinowitz et al, 1991 a). A total of 940 teeth were collected from 764 children, but 78 were too decayed or small to analyze.

After tooth collections, the teachers were given a one page, 51 item questionnaire about the child's classroom behavior. This form includes three items (1) the 24 forced choice, yes-no item Boston Teachers Questionnaire (BTQ) (Guild, 1979), (2) a 26 question modified version of the Rutter's Child Behavior Check List (Rutter, 1967) with four options for reporting frequency instead of the usual 3 and (3) the score from Raven's Colored Progressive Matrices Test, which is routinely administered by the school to assess intelligence.

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Table 1. Probability values for the associations of lead and three learning handicap syndromes with candidate confounders.

	p-Value of Candidate vs Each *			
Candidate Confounding Variable	Lead	Task	Hyper	Read
Sex (1=girl,2=boy)	.4	.0002	.000	.3
Grade	.05	.18	.03	.09
Birth order	.06	.25	.23	.03
Total number of siblings	.0000	.009	.15	.0006
Number of adults at home	.15	.3	.01	.02
Fathers age now	.06	.6	.9	.9
Fathers education	.0000	.0001	.8	.0000
Fathers job classification	.0000	.05	.8	.0001
Mothers age	.005	.6	.2	.02
Mothers education	.0000	.003	.6	.0000
Mothers job classification	.0000	.5	.7	.01
Before birth, mother sick	.08	.3	.4	.2
Any pregnancy complication	.08	.4	.2	.02
Length of gestation	.6	.06	.7	.5
Delivery method	.0002	.01	.8	.15
Presentation	.1	.08	.2	.7
Incubator use	.8	.06	.8	.06
Jaundice	.02	.9	.4	.7
Fever more than 39 C	.003	.19	.19	.7
Child's longest hosp. stay	.4	.008	.04	.03
Handedness: left, right or ambi	.1	.8	.9	.3
Languages used by family	.0001	.004	.2	.002

These Variables have all p values > 0.15 (not significant)

When pregnant, any medicine	Condition of newborn
When pregnant, any bleeding	Any co-births
Hormone to halt miscarriage	Any birth defects
When pregnant, any drinking	Meningitis
When pregnancy, ever drunk	Head injury, not burns
When pregnant, any tobacco	Cerebral palsy
Weight of newborn	Seizures
Condition of newborn	Child ever seriously ill
Age when tooth shed	In past year, moved home

* Lead is the log of the incisor lead. Only three examples of the seven syndomes from the Boston Teachers Questionanaire are displayed.P values (2-tailed) are for Student-t Tests or correlations for categorical or continuous candidate variables.

Examinations of the role of lead and the outcomes of items 2 and 3 have been presented elsewhere. In this population the total and sub-scale scores from item 2 (Rutter Questionnaire) are not related to lead level. However, item 3 (Raven's test of intelligence) and lead are strongly associated, especially among girls, even after controlling for other factors (Rabinowitz et al, 1991a). This report addresses the association between lead and item 1, the Boston Teachers Questionnaire of learning handicap syndromes.

Over 97 % of the teacher forms were completed and returned. Then a two page form was given to the parents about their ages, home, education, employment, family composition, habits and health (90 % response rate). Both questionnaires and a tooth lead value were available for only 642 children. Because of the uncertainty of directly comparing incisors with molar or canine teeth, their having different mean lead levels and periods of growth (Rabinowitz et al 1991 b), only incisors are considered, yielding 515. Also, excluded were 22 children with cerebral palsy, meningitis, birth weight less than 2000 grams or hospitalization longer than 10 nights. The 493 cases with complete data sets were examined for any relationship between lead and the scores on the seven scales of the BTQ.

The teachers' responses regarding classroom behavior were grouped into seven clusters of dysfunction (reading, behavior, tasks, directions, mathematics, daydreaming, and hyperactivity) following the recommendations of Guild (1979). To be classified as positive for a cluster, the child must have been considered positive for all the items in the cluster. This requirement should help minimize misclassification into the dysfunctional group. Children with each cluster were compared to children with no individual items rated as problems, identified in Table 2 as "None".

To consider potential confounders, the relationship of the questionnaires' 40 separate variables with lead and with the learning handicap syndromes were assessed (Table 1). All potential confounders and lead were used in the initial logisitic regression model, and then individual variables with the highest p value were deleted until all of the retained variables had a significance level less than 0.20. Finally, the lead term was deleted, and the models with and without lead were compared for goodness of fit and any changes in each variables parameter estimate.

RESULTS AND DISCUSSION

In comparison to teeth collected in Boston from 1985 to 1987 and analyzed exactly the same way, the Taiwanese have a higher lead level. Mean (standard deviation) of incisor lead levels in Taiwan and Boston are 4.6 (3.5) and 3.3 (2.5) ug/g, $p<.001$. Boys and girls have very similar lead levels (4.5 and 4.7 ug/g). Twelve years ago, before the reduction of lead in gasoline in the United States, tooth lead levels in Boston were much higher, averaging 13 ug/g (Needleman et al 1979).

Only two clusters, both among boys, appear to increase with each quartile of lead: hyperactivity ($p=.009$, chi-sqr for trend 6.9) and task difficulties ($p=.004$, chi-sqr for trend 8.4) (Table 2). Compared to boys in the lowest quartile, boys with lead levels in the highest quartile are 4.2 times more likely to be hyperactive (95% confidence interval is 1.2 to 19.1) and 8.4 times more likely to have difficulty with tasks (1.9 to 31.8). Among the girls, the item closest to reaching significance is reading (chi-sqr for

Table 2. Number of cases of various learning handicaps among four quartile of lead.

GIRLS	Incisor Lead Levels (ppm)						
Cluster: items	<2.9	->3.9	->5.5	>5.6	Total	Chi-Sqrd	p
Behavior: easily frustrated, peer problems	3	3	0	5	11	4.7	.2
Hyperactive: hyperactive, impulsive	3	6	4	7	20	2.8	.4
Reading: slow/hard, not good speller	5	7	6	10	28	2.6	.5
Math: knows tables, uses tables	10	8	10	14	42	1.8	.6
Directions: difficulty with simple instruction, with sequence	2	2	2	1	7	.5	.9
Daydreaming: daydreamer, easily distracted	6	4	5	7	22	.6	.9
Tasks: persistent, dependent, inflexible approach	8	5	6	4	23	1.1	.8
None: no item of any cluster	23	22	14	14	73	5.4	.1
Total	73	59	62	66	260		

BOYS	Incisor Lead Levels (ppm)						
Cluster	<2.9	->3.9	->5.5	>5.6	Total	Chi-Sqrd	p
Behavior	1	7	4	7	19	5.2	.16
Hyperactive	4	11	13	14	42	6.2	.10 *
Reading	4	12	13	6	35	5.7	.13
Math	5	12	8	7	32	2.4	.5
Directions	4	1	4	4	13	2.7	.4
Daydreaming	5	7	9	7	28	0.8	.9
Tasks	1	9	16	12	38	13.5	.004**
None	11	17	10	11	49	2.3	.5
Total	53	63	62	56	234		

* chi squared for trend <.01
** chi squared for trend <.005

P value is for chi-squared test, 3 df. Clusters and individual component items are listed.

trend 2.8, p=.09, rel. risk 2.8, c.i. includes 1). A search for covariates of these dysfunctions among the available parental, pregnancy and childhood factors revealed only a few factors that were associated with a poor outcome. Six of the 8 ambidextrous boys (43%) had the task syndrome whereas only 26 of 196 who were not amibidextrous had the task syndrome (p=.01). Task difficulties were also related to parental education and work.

Table 3. Logistic models of three behavioral handicaps with and without the lead term.*

Task Syndrome: 31 with handicap out of 206 boys

	Without Lead Term			With Lead Terms		
Model Term	Beta	Std Err	p	Beta	Std Err	p
Intercept	-.33	.59	.58	-1.22	1.21	.31
Ambidextrous	1.71	.61	.005	1.66	.60	.006
Fathers' Educ	-.37	.14	.008	-.34	.14	.02
Tooth Lead High				1.12	1.15	.33
" " Middle				.77	1.06	.47
Model Chi-Square	14.3	p=.0008		15.45	p=.004	
r-square	6.6 %			8.1 %		

change in model chi-square 1.1, p=.57

Hyperactivity Syndrome: 47 with syndrome out of 399 children

	Without Lead Term			With Lead Terms		
Model Term	Beta	Std Err	p	Beta	Std Err	p
Intercept	-4.9	.71	.0000	-5.5	.92	.0000
Sex	1.2	.35	.0005	1.2	.35	.0005
Adults at Home	.35	.12	.004	.34	.12	.006
Tooth Lead High				1.04	.73	.16
" " Middle				.62	.64	.33
Model Chi-Square	21.3	p=.0008		23.5	p=.0001	
r-square	5.6 %			5.1 %		

change in model chi-square 2.2, p=.33

* Lead appears as two dummy variables: high (top decile, more than 7 ug/g) or middle (mid 80 percent, 2.3 to 7 ug/g).

Logistic models of these two dysfunction are shown in Table 3. Lead here is expressed as two dummy variables: high lead (top 10 percent, more than 7 ug/g) or middle lead (from 2.3 to 7 ug/g, middle 80 percent). As a rough guide to the blood lead corresponding to these tooth lead values, using the regression models from the Boston cohort, 7 ug/g corresponds to a blood lead of 26 ug/dl, and 2.3 ug/g to 3.8 ug/dl (Rabinowitz et al 1989). The logistic models for task and hyperactivity show no role for lead in predicting these learning handicaps. The p values for the lead terms never achieve significance, and adding the lead terms does not improve the model's goodness of fit. Also, the lead terms do not change the coefficients of the other variables, indicating no interaction effect among these risk factors. If models are constructed without the term for being ambidextrous, the addition of the lead terms does not improve the goodness of fit. The model r-squares are 2.5 percent without and 3.7 with lead terms (change in chi-square 2.8, p = .25). The vanishingly small role of lead in these models is not because the models are poor; they all fit their data with p values of less than .001, judged by the model chi-squares, albeit with small total explained variance.

Limiting analyses to subjects with a full data set poses potential problems. One of the limitations of this study was reliance on the students for their teeth and assistance in obtaining parental answers. Disorganized or troublesome children may not have been so helpful. This systematic exclusion of children with behavioral problems may have resulted in bias. Also, by selecting these public primary schools, we did not include severely handicapped or retarded children, who have separate schools.

Our findings are similar to a recent European multicenter study (Winneke et al 1990). At their levels (mean blood lead 17 ug/dl, mean tooth 6.4 ug/g) intelligence test scores, WISC, Bender-Gestalt, or Raven's correlate with lead, although a modification of the BTQ score does not.

Excessive childhood lead exposure is related to both reading difficulties (Needleman et al 1990) and hyperactivity (David et al 1983). However, in this study for these behavioral outcomes, the coefficient of the covariate adjusted lead term is not significantly different from zero and adding the lead term to models of these dysfunctions only marginally improves their predictive power. Thus, lead levels found in the teeth of children in Taiwan are not associated with learning handicap syndromes. This contrasts to earlier studies in other populations at higher lead levels (Needleman et al, 1979 and Yule et al, 1984). From this we infer that 7 ug/g of lead in teeth is a no effect level for learning handicap syndromes.

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