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PSYCHOLOGICAL ALTERATIONS IN CHILDREN EXPOSED TO A LEAD-RICH HOME ENVIRONMENT[1]

Gilberto Molina,[2] Miguel A. Zúñiga,[3] Adolfo Cárdenas,[4] Rolando Medina Alvarez,[5] Pedro Solís-Cámara Jr.,[6] and Pedro Solís-Cámara[7]

Children with high blood-lead concentrations (over 40 μg/dl) belonging to pottery-making families in a Mexican village were tested for psychological abnormalities. The results suggest that lead intoxication contributed to these children's delayed mental development.

Introduction

Exposure to high lead concentrations produces severe alterations in central nervous system development and, consequently, in the behavior of both experimental animals and children *(1-5)*. However, in asymptomatic children exposed to lead intoxication the resulting intellectual and behavioral abnormalities may be expressed in different ways—i.e., as hyperactivity *(6)*, fine motor incoordination *(7)*, or various shortcomings revealed by various psychological tests *(2, 7, 8)*.

Previous work by the authors that was carried out in the town of Tonalá (located in a pottery-producing area of Jalisco, Mexico) found higher blood-lead levels in children of families manufacturing pottery than in children whose families worked in other unrelated activities *(9)*. This made it important to investigate whether or not the former group of children had psychological abnormalities (manifested in either the psychomotor or cognitive domains) that could have resulted from their high blood-lead concentrations. The purpose of the study reported here was to determine the intelligence quotients and Bender-Gestalt test results of a group of these Tonalá children with high blood-lead concentrations and to compare them with those obtained by Tonalá children whose blood-lead levels were relatively low.

Materials and Methods

Subjects

Two groups of children were selected. As shown in Table 1, the first (Group 1) consisted of 33 children (17 boys and 16 girls) with an average age of 10 years 7.4 months (± 2 years 7.4 months), randomly selected from 64 schoolchildren with blood-lead levels above 40 μg per decaliter. (These 64 children had in turn been selected from among a larger group of 153 children belonging to pottery-making Tonalá families in close contact with lead-bearing materials, as previously reported—*9.)* All of the Group 1 children, who were attending the town's elementary school, were interviewed briefly and given physical examinations in order to determine their health status.

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[2]Chief of the Research Services Subdivision, Northeastern Biomedical Research Unit, Mexican Social Security Institute (IMSS).

[3]Investigator, Northeastern Biomedical Research Unit, IMSS.

[4]Chief of the Clinical Analysis Laboratory, Western Biomedical Research Unit, IMSS.

[5]Chief of the Department of Program Control, Division of Teaching and Research, National Medical Center, IMSS.

[6]Psychologist, Western Biomedical Research Unit, IMSS.

[7]Director, Western Biomedical Research Unit, IMSS.

Table 1. Verbal, performance, and full-scale IQ scores of the 33 Group 1 (high blood-lead) children.

No. of subject	Sex	Blood-lead concentration (μg/dl)	Age in months		IQ scores		
			Chronological	Mental	Full-scale	Verbal	Performance
1	F	63	100	82	74	81	71
2	F	78	162	109	72	86	63
3	F	62	159	133	87	80	96
4	F	43	101	94	85	88	84
5	F	42	118	80	61	67	61
6	F	56	98	74	40	45	45
7	F	42	151	95	68	67	72
8	F	59	78	74	76	79	77
9	F	49	119	86	70	68	75
10	F	79	150	79	45	51	48
11	F	77	109	78	57	49	72
12	F	80	145	104	71	86	60
13	F	43	127	99	75	74	80
14	F	79	120	48	40	40	40
15	F	59	114	79	63	68	63
16	F	45	161	110	72	79	70
17	M	56	118	105	92	97	90
18	M	57	156	87	50	51	57
19	M	45	79	79	93	95	93
20	M	51	103	73	71	74	72
21	M	58	91	76	70	77	67
22	M	48	91	78	84	88	82
23	M	52	95	77	72	81	67
24	M	72	97	77	58	67	55
25	M	78	145	86	50	47	61
26	M	78	185	82	41	47	45
27	M	85	109	43	40	46	45
28	M	85	136	81	57	60	61
29	M	43	111	79	52	65	46
30	M	70	180	72	40	40	40
31	M	79	197	119	68	67	71
32	M	89	173	135	83	96	72
33	M	90	135	98	62	59	70
Mean		63.39	127.67	87.01	64.81	68.64	65.79
Standard deviation		15.84	31.97	19.80	15.78	16.72	14.94

The results indicated that all the children seemed to be in good health. The second sample of children (Group 2) consisted of 30 subjects (11 boys and 19 girls) with an average age of 10 years 1.9 months (±2 years 6.6 months) with blood-lead levels below 40 μg/dl. These children were selected from among 80 children belonging to a group of Tonalá families employed in occupations other than pottery-making but having about the same socioeconomic background as the families of the other children. The children in this group (who are listed in Table 2) were also attending the public elementary school and appeared clinically healthy *(9)*.

Procedures

Both groups of children were given the Revised Wechsler Intelligence Scale for Children (R-WISC), including its 12 subtests. This test has been translated into Spanish, adapted to our country's environment, and partially validated by Mexico's Autonomous University of Nuevo León. The results yielded scores for each child's full-scale intelli-

Table 2. Verbal, performance, and full-scale IQ scores of the 30 Group 2 children.

No. of subject	Sex	Blood-lead concentration (μg/dl)	Age in months		IQ scores		
			Chronological	Mental	Full-scale	Verbal	Performance
1	F	27	84	80	77	86	71
2	F	30	102	80	70	72	72
3	F	28	162	71	40	46	45
4	F	37	102	101	103	103	104
5	F	23	118	76	64	67	67
6	F	22	83	83	91	106	78
7	F	21	182	133	74	72	81
8	F	16	148	101	69	75	65
9	F	35	100	82	72	72	77
10	F	27	161	121	82	86	81
11	F	35	134	132	96	100	92
12	F	36	108	79	59	60	65
13	F	37	133	108	76	75	80
14	F	28	104	87	81	87	78
15	F	39	97	88	92	95	91
16	F	18	98	93	91	90	93
17	F	29	128	72	56	70	48
18	F	24	90	66	72	74	74
19	F	17	116	76	54	57	60
20	M	27	138	100	67	66	71
21	M	34	164	131	76	84	71
22	M	17	75	77	101	113	88
23	M	15	132	100	76	73	84
24	M	34	163	117	78	82	77
25	M	14	146	89	59	65	61
26	M	13	100	79	58	72	49
27	M	17	89	74	59	69	55
28	M	37	184	114	62	64	67
29	M	25	99	104	103	108	98
30	M	26	118	115	96	101	91
	Mean	26.27	121.93	94.30	75.13	79.67	74.47
	Standard deviation	7.99	30.68	19.69	16.13	16.53	14.82

gence quotient (IQ), verbal IQ, performance IQ, and mental age. The children were also given the Bender-Gestalt test and evaluated on the basis of the results. No information about the children's schoolwork or achievements, provided by either the parents or the school, was recorded.

All the psychological testing was carried out in a special room with adequate lighting and ventilation in the town of Tonalá, following an interview with both of the test child's parents in their own home. In the case of Group 1 children, the number of years the parents had worked at manufacturing pottery was recorded.

A single venous blood sample was obtained from each child after a 10-12 hour overnight fast. This sample was subjected to duplicate determinations of lead levels by means of atomic absorption spectrophotometry *(10)*. To confirm the higher absorption of lead by Group 1 children, levels of urinary excretion of delta-aminolevulinic acid were determined *(11)*, and blood levels of zinc protoporphyrin were measured using a hematofluorometer (Hemafluor ZP, Model 4,000) *(12)*. In every case the nature and goals of the research were carefully explained to the child's parents, and their written consent was obtained before initiation of the study.

The results were analyzed statistically by applying the two-tailed Student's "t" test for independent samples and the Mann-Whitney U test. Pearson's correlation coefficient was employed to test the relationship between blood-lead concentrations and IQ.

Results

As the averaged data at the bottom of Tables 1 and 2 show, the Group 1 children, with higher blood-lead concentrations, were found to have a lower average full-scale IQ ($p<0.01$), verbal IQ (<0.01), and performance IQ ($p<0.025$) than did the Group 2 children.

Both groups were found to have significant differences between their chronological and mental ages. This was true for each group taken as a whole ($p<0.001$ in each case), as well as for Group 1 boys ($p<0.001$), Group 1 girls ($p<0.001$), Group 2 boys ($p<0.05$), and Group 2 girls ($p<0.005$). However, when the differences between each individual's chronological age and apparent mental age were tallied for members of both groups, the average difference for Group 1 members (3.4 years) was found to be larger than the average difference for Group 2 members (2.3 years). This disparity was found to be statistically significant ($p<0.05$, $Z=1.87$) when analyzed by applying the Mann-Whitney U test.

Regarding the R-WISC subtests (Table 3), relatively large percentages of Group 1 children were found to have low scores (over three standard deviations below the mean control value) on the subtests for coding, arithmetic, and information. The specific percentages with low scores were 78.7 per cent for coding (versus 60.0 per cent in Group 2), 54.5 per cent for arithmetic (versus 26.0 per cent in Group 2), and 75.7 per cent for information (versus 66 per cent in Group 2).

A significant negative linear correlation was observed between blood-lead concentrations in the Group 1 children and full-scale IQ ($r=-0.386$, $p<0.05$), verbal IQ ($r=-0.355$, $p<0.05$), and performance IQ ($r=-0.390$, $p<0.05$) (Figure 1). No such correlation was observed in data from the Group 2 children. On the other hand, no correlation was found in Group 1 between the number of years the family had been handling lead-containing materials (4 to 41 years) or the number of years the child had been exposed to a lead-rich family environment (2 to 15 years) and the child's IQ scores (full-scale, verbal, or performance) or blood-lead concentration.

Table 3. Scores by Group 1 and Group 2 children on the Revised Wechsler Intelligence Scale verbal and performance subtests. The scores shown are the mean plus or minus one standard deviation.

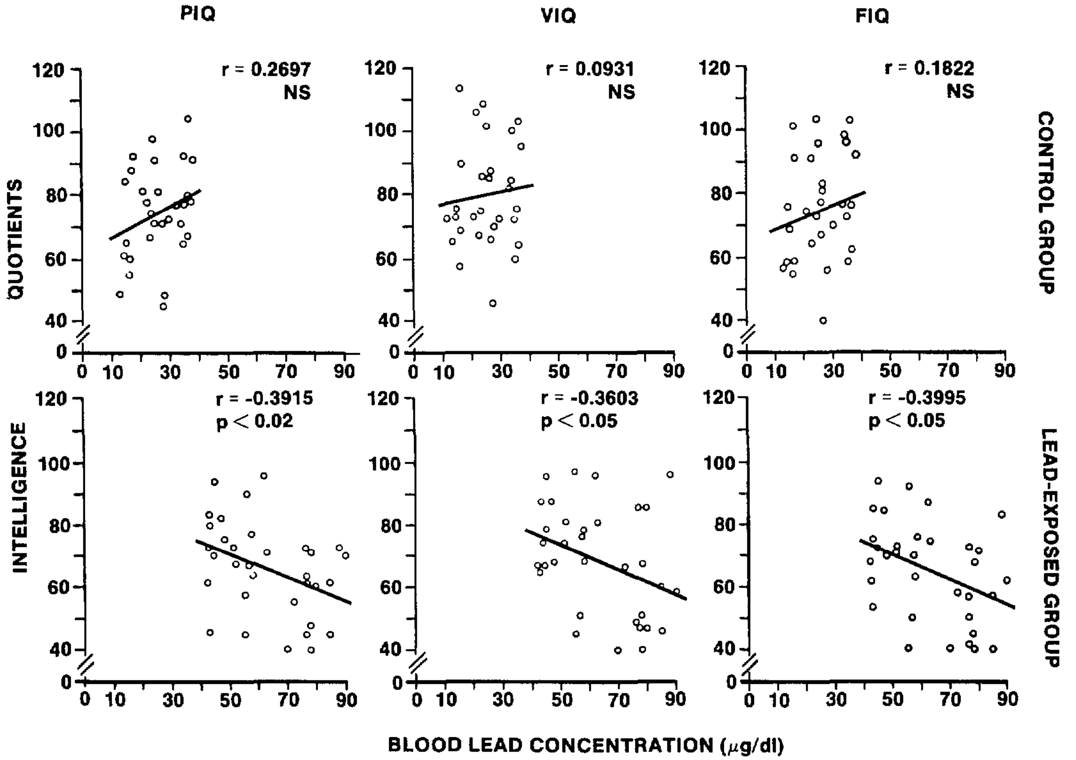
Verbal subtests		Performance subtests	
Information:		Picture completion:	
Group 1	4.27 ± 2.76	Group 1	4.94 ± 2.65
Group 2	5.87 ± 3.60	Group 2	5.30 ± 3.15
Comprehension:		Picture arrangement:	
Group 1	5.27 ± 2.98	Group 1	4.09 ± 3.52
Group 2	6.30 ± 2.97	Group 2	6.53 ± 3.57
Arithmetic:		Block design:	
Group 1	6.00 ± 3.18	Group 1	4.97 ± 2.85
Group 2	8.30 ± 3.03	Group 2	5.73 ± 2.97
Similarities:		Object assembly:	
Group 1	4.06 ± 2.57	Group 1	5.60 ± 2.95
Group 2	6.00 ± 3.39	Group 2	7.40 ± 2.34
Vocabulary:		Coding:	
Group 1	5.42 ± 3.80	Group 1	4.45 ± 3.40
Group 2	7.13 ± 3.95	Group 2	6.10 ± 3.51
Digit:		Mazes:	
Group 1	4.36 ± 2.75	Group 1	6.12 ± 2.99
Group 2	5.73 ± 2.57	Group 2	8.43 ± 3.27

The results of the Bender-Gestalt test were analyzed only from a qualitative viewpoint *(13)*. The drawings showed moderate perceptual deficiencies in 33.9 per cent of the Group 1 children but in only 7.4 per cent of the Group 2 children. Also, Group 1 showed a greater tendency to rotate the drawings and more perseverance than Group 2. In all, four Group 1 children were diagnosed as having probable brain damage.

Discussion

The fact that the R-WISC test has only been partially validated in our country sug-

Figure 1. Linear correlations between the 63 test children's blood-lead concentrations and their IQ performance (PIQ), verbal (VIQ), and full-range (FIQ) test scores. The results for the lead-exposed children (Group 1) are shown at the bottom and those for the control children (Group 2) at the top.



gests a possible shortcoming of our study and shows that the absolute values obtained for the different IQ scores need to be regarded with caution. Nevertheless, the test did reveal lower IQ scores in Group 1 as compared to Group 2, and also showed a trend toward lower IQ scores among Group 1 children with higher blood-lead concentrations.

The mean full-scale IQ score of Group 1 (64.52) can be considered indicative of mild mental deficiency, while that of Group 2 (76.42) can be considered borderline. The main point, however, is that the mean disparity between chronological and mental age (3.4 years for Group 1 and 2.3 years for Group 2) differed significantly from one group to the other ($p<0.05$, $Z=1.87$), a finding which appears to establish that the Group 1 children on the whole had experienced delayed intellectual development.

The relatively low verbal IQ scores of the Group 1 children suggest the existence of cognitive abnormality, while their relatively low performance IQ scores could have resulted from motor hyperactivity. Both abnormalities seem to be at least partially related to chronic lead intoxication. These results agree with the observed deleterious influence of lead intoxication upon the learning capabilities of rats exposed to low lead concentrations *(14, 15)*. However, it should be emphasized that the cognitive learning deficits detected in these children need to be judged in terms of the particular affected component (memory, perception, attention, visual-motor integration, etc.), as the R-WISC test permits *(14, 16, 17)*.

Concluding Remarks

Besides lead intoxication, educational and socioeconomic factors have undoubtedly played a role in development of the cognitive abnormalities observed in these children, and so no exclusive cause-and-effect relationship between lead intoxication and these cognitive deficiencies can be established. However, the existence of a higher percentage of children in Group 1 with low scores on the coding, arithmetic, and information subtests can be related to a poor attention span, and so the results indicate that these children could be expected to exhibit relatively poor intellectual performance and slow school progress *(8, 18)*.

It has recently been suggested that acute lead intoxication mainly affects the psychomotor area, while chronic intoxication mainly alters the cognitive area *(4, 14, 16)*. Thus, the observation that the difference between the average Group 1 verbal (cognitive) and performance (psychomotor) IQ scores was not large could indicate that the group encompassed a mixed population of children exposed to a lead-rich environment for varying lengths of time.

Qualitative analysis of the Bender-Gestalt test indicated the presence of more marked perceptual deficiencies in Group 1 than in Group 2. Also, the greater frequency of drawing rotation suggested spatial orientation abnormalities in younger children and probable organic damage in older children. However, no further conclusions could be drawn due to the qualitative nature of the analysis.

Overall, these findings demonstrate a need to study a larger number of children and to include a control group of clinically and psychologically healthy children in order to determine the degree of influence that socioeconomic and educational factors may have in bringing about the observed psychological abnormalities in children chronically exposed to a lead-rich home environment.

SUMMARY

Previous work by the authors *(9)* indicated that children belonging to pottery-making families in the town of Tonalá, Mexico, tended to have higher blood-lead levels than Tonalá children whose parents had other occupations. The study reported here sought to determine, through the Revised Wechsler Intelligence Scale and Bender-Gestalt tests, whether a group of Tonalá children with high blood-lead levels (over 40 μg/dl) showed psychological abnormalities, as compared to another group of children whose blood-lead levels were relatively low.

The results indicated that the high-lead group had lower average verbal, performance, and full-scale IQ scores than the control group, and also that the average deficit between mental and chronological age was greater in the high-lead group. In addition to lead intoxication, socioeconomic factors undoubtedly played a role in development of the observed abnormalities. Nevertheless, comparison of the two groups' test results appears to establish that children in the high-lead group tended to experience delayed mental development.

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