Low Mercury Levels and Childhood Intelligence

Mike Marlowe, Ph.D.[1]; Charles Moon, Ph.D.[2]; John Errera, BLD.MT[3]; Jim Jacobs, Ph.D.[1]; Michael Brunson, M.A.[4]; John Stellern, Ed.D.[1], Cheryl Schroeder, M.S.[1].

Abstract

The present study investigated the relationship between mercury levels in children and their performance on an individual intelligence test. Hair mercury levels in 59 children were correlated with their performance on the Wechsler Intelligence Scale for Children - Revised. Low mercury levels correlated significantly and negatively with full scale, verbal, and performance IQ and six subtest scores of the intelligence test. A continuing reexamination of mercury exposure is needed because mercury levels previously thought harmless and routinely encountered in the environment may be associated with intellectual decrements.

It is well established that children who survive mercury poisoning are at risk for severe mental retardation resulting from damage to the central nervous system (Maurissen, 1981). Now recent research has suggested that children with a moderate increase in body burden of mercury, although clinically asymptomatic, may also be subject to impaired mental development, albeit a more difficult type to define. Low - moderate mercury levels previously thought harmless are now being correlated with mild mental retardation (Cameron, Wunderlich and Loop, 1980; Marlowe, Folio, Hall and Errera, 1982), learning disabilities (Cameron, Wunderlich and Loop, 1980; Capel, Pinnock, Dorrell, Williams and Grant, 1981; Marlowe, Cossairt, Welch and Errera, 1984), and behavior disorders (Marlowe, Moon, Errera and Jacobs, 1984).

The purpose of this study was to explore relationships between children's mercury levels and their performance on an individual intelligence test. It was hypothesized that as children's mercury levels increased their performance on an intelligence test would decrease. No previous studies have examined children's mercury levels in relationship to sensitive measures of psychometric intelligence.

In this study, children's mercury levels were determined via hair samples and atomic absorption spectroscopy. Scalp hair has several characteristics of an ideal tissue for epidemiologic study in that it is painlessly removed, normally discarded, easily collected, and its contents can be analyzed relatively easily. Heavy metal pollutants are accumulated in hair at concentrations generally higher than those present in blood serum and provide a continuous record of exposure. Numerous investigations worldwide have shown concentrations of mercury and other heavy metals in the hair provide an accurate and relatively permanent record of exposure, and there is a strong correlation between concentrations in hair and concentrations in internal organs (Laker, 1982; Passwater and Cranton, 1983).

1 Area of Special Education University of Wyoming department of Educational Foundations University of Wyoming

3 Doctor's Data Inc. West Chicago, Illinois 4 Department of Psychology University of Wyoming

METHODS

Subjects

The 59 subjects in this study were randomly drawn from elementary grades one through four at the University School, a teacher training laboratory school of the University of Wyoming, Laramie, Wyoming. Laramie is situated in the rural southeastern region of Wyoming at an altitude of 7,280 feet and has a population of 25,000.

Confounding Variables

Parents of subjects were interviewed via questionnaire and telephone in order to identify and control for the following confounding variables that affect intellectual development: subject's birthweight, birth order, history of immunizations against childhood diseases, history of pica, presence of father in the home, and father and mother's occupation and level of educational attainment. In addition, each child's school record was reviewed to determine whether there was a known or highly probable medical reason for an intellectual deficit, e.g., neurological disturbance, mercury poisoning. None of the children's school records contained a "probable cause".

Classification of Mercury Levels

After obtaining parental permission, children were asked to submit a small sample of hair (about 400 mg) for trace mineral analysis. Hair samples were collected from the nape of the child's neck, as close to the scalp as possible, by the researchers using stainless steel scissors. The hair samples were then submitted to Doctor's Data, Inc., a state licenced laboratory in West Chicago, where they were analyzed with three instruments - the atomic absorption spectroprotometer, the graphite furnace, and the induction coupled plasma torch -to determine the children's mercury levels.

Precise laboratory techniques are used by Doctor's Data, Inc., to assure reliability of results and to meet reproducibility requirement. These include:

1. A blind sample is run from the initial steps through the entire procedure to assure reproducibility of methods.
2. At least one of every three tests is a standard. Working standards are made to assure proper values.
3. The in-house pool is completely remade and analyzed monthly to eliminate the possibility of precipitating elements and to assure reproducibility.
4. Temperature and humidity are controlled to assure reliability and consistency of the testing instruments.
5. The hair samples are weighed to the thousandths of a gram (.001g is equal to approximately four hairs) 1 inch (.0254 m long); and only Volumetric Flasks, the most accurate available, are used for diluting the ashed sample.
6. Lot-number control sheets for all reagents are used to assure uniformity. Records are kept and available for inspection.
7. All glassware is acid washed in-house before use and between each use, including acid prewashed disposable test tubes.
8. The water used at Doctor's Data, Inc., is virtually mineral free, rated at 18 + MEG.
9. Upon receipt the hair sample is washed thoroughly with deionized water, a non-ionic detergent, and an organic solvent to remove topical contaminants.

Wechsler Intelligence Scale for Children - Revised (WISC-R)

Each subject was individually administered the Wechsler Intelligence Scale for Children - Revised (Wechsler, 1974). The following subtests were used in the WISC-R: information, comprehension, similarities, arithmetic, vocabulary and digit span in the verbal scale, and picture completion, picture arrangement, block design, object assembly, and coding in the performance scale. All WISC-R scores were age standardized.

The test administrators were a licenced psychologist, a certified school psychologist, and a psychometrist. All examiners were experienced in the administration of the WISC-R. Interscorer reliability was established on two occasions during the test period. Interscorer reliability coeffe-cients for full-scale IQ determinations ranged from .98 to 1.00.

RESULTS

Means and standard deviations for hair-mercury levels, WISC-R scales, and signifi-cant confounding variables are reported in **Table 1**. The 59 subjects' mean hair-mercury level was 1.04 parts per million (ppm), while the accepted upper limit of hair-mercury is 2.5 ppm according to the laboratory norms of Doctor's Data Inc. (1985). Thus, the group's hair-mercury mean was well below the accepted upper limit. No individuals evidenced hair-mercury levels above 2.5 ppm.

Table 1

Means and Standard Deviations for All Variables

Variable	X	SD
Mercury	1.050	.412
Age'	7.259	1.119
Mother's Education	15.833	1.891
WISC-R Scales		
Verbal	112.037	12.938
Performance	112.278	12.042
Full Scale	113.482	11.413
Information	11.389	2.310
Similarities	13.537	3.565
Mathematics	11.482	2.704
Vocabulary	12.130	3.133
Comprehension	11.741	2.863
Digit Span	10.833	2.409
Picture Completion	11.741	2.593
Block Design	12.537	2.847
Object Assembly	11.444	2.337
Coding	10.574	3.178

Note: n = 54
a Age is in years
b Mother's education is number of years

Average performance on the WISC-R scales was high and variability relatively low. All IQ and subtest scores were above the standardized normative means of 100 and 10 for IQ and subtest scores, respectively.

While age and mother's education were un-correlated ($r = .012$), each was positively correlated with several of the WISC-R scales, as shown in Table 2. In addition, mercury was not linearly related to age ($r = .053$) and only weakly linearly related to mother's education ($r = .212$, $p < .10$). All other confounding variables were un-corrected with WISC-R performance or hair-mercury levels.

Table 2

Pearson Correlations of Age and Mother's Education with WISC Scales

WISC Scales	Age	Mother's Education
Verbal	.386**	.275*
Performance	-.001	.057
Full Scale	.256*	.211
Information	.106	.292*
Similarities	.357**	.204
Mathematics	.282*	.105
Vocabulary	.335**	.297*
Comprehension	.357 * *	.041
Digit Span	.310*	.068
Picture Completion	.128	.156
Picture Arrangement	.094	-.158
Block Design	.169	.175
Object Assembly	-.067	.231
Coding	-.297*	-.182

*P<05 **P<01

Second-order Pearson correlation coefficients, holding both age and mother's education constant, revealed significant inverse linear relationships between mercury and 9 of the WISC-R scales, using a one-tailed test of the null hypothesis of zero correlation. The results are summarized in Table 3.

Table 3

Zero-order and Second-order Partial Correlations of Mercury With the WISC Scales

WISC Scale	Zero-order	Second-order
Verbal	-.216	-.341**
Performance	-.215	-.233*
Full Scale	-.281*	-.376**
Information	-.219	-.308*
Similarities	-.052	-.127
Mathematics	-.308*	-.370**
Vocabulary	-.215	-.338*
Comprehension	-.064	-.099
Digit Span	-.197	-.245*
Picture Completion	-.191	-.241*
Picture Arrangement	-.117	-.092
Block Design	-.210	-.269*
Object Assembly	-.112	-.166
Coding	-.106	-.057

*P<05 **P<01
a Age and mother's education are held constant

DISCUSSION

While not establishing an etiological relationship, the correlational data indicated an increase in mercury levels resulted in decreased full scale, performance, and verbal IQ, as well as decreased scores on six of the ten WISC-R subtests. The R^2 value between mercury levels and full scale IQ was .0789, thus indicating about eight percent of the variance of the full scale IQ scores may be attributed *to* the children's mercury levels. Psychometric intelligence is, of course, multifactorally determined, as there are a large number of genetic and environmental determinants, and for low mercury levels to account for even eight percent of the overall variance is noteworthy.

It is also important to reiterate that the mean hair-mercury level of the subjects fell well within the normal accepted range of exposure. Recent studies have pointed out, however, that there may be no such thing as a threshold level of metal pollutants, that is, a quantity below which there are no toxic effects (Landsdown, Yule, Urbanowicz and Millar, 1983; Marlowe, Moon, Stellern and Errera, 1984; Moon, Marlowe, Stellern and Errera, 1984; Needleman et al., 1979; Thatcher, Lester, McAlaster and Horst, 1982; Winneke et al., 1983). The data of this study also support this view.

It should also be noted that the ecological hazard of mercury is amplified in the young. This is clearly evident when examining epidemics of fetal and infant methylmercury poisoning occurring in the world over the past thirty or so years. In 1953 in Minamata, a small Japanese island fishing village, inhabitants were poisoned by methylmercury contamination of seafood due to effluents from a nearby factory. Twenty-two women who were clinically asymptomatic during pregnancy gave birth to infants with clinical signs of methylmercury poisoning. Autopsies performed on three who subsequently died revealed extensive neural damage and high levels of methylmercury in body tissues. Surviving infants displayed severe neurological defects, impaired intellectual and motor performance, and retarded speech. Ten years later all of the children were profoundly retarded. Doses that did not produce symptoms of poisoning in the pregnant women nevertheless had disastrous consequences for the unborn child.

A later methylmercury episode provided cogent confirmation of what had been suggested by Minamata. In the winter of 1971-72, Iraqi peasants ate seed grain treated with a methylmercury fungicide. Assessment of methylmercury exposure in 93 pregnant women and nursing mothers revealed that at relatively modest maternal blood levels, the offspring were often significantly retarded, showing delays in language and motor functioning and other developmental indexes (Clarkson et al., 1981).

The adverse effects of low level mercury on developmental processes may be of additional importance for several reasons. First, the effects may signal the early stages of an ongoing toxic process that becomes more disabling with age. In a well designed study, mice exposed prenatally to low levels of methylmercury were indistinguishable from untreated animals at birth. By one month (adolescence) exposed animals showed slight growth retardation and subtle behavioral deficits in open-field and swimming tests. By 6 to 12 months of age (adulthood) overt neurological impairment measured by the appearance of coordination problems became evident. As the animals approached middle age, central nervous system involvement became obvious, and behavioral tests were no longer needed to identify treated animals (Spyker, 1975).

Second, it is known that there is considerable individual variation to mercury, a variation that applies to most metal pollutants. A metal pollutant that produces subtle behavioral alterations in many children may produce a severe learning or behavioral disorder in those who are especially susceptible because of genetic or other factors, e.g., malnutrition. Third, for the child's caretakers, some mercury induced-behavioral effects (e.g., hyper- or hypo-activity) may make a child difficult to parent or instruct, leading to adult-child tensions that become aggravated over time.

Confidence in the study's findings depends on the validity of hair-mercury as a marker of exposure. The classification of mercury exposure *to* hair-mercury levels has been validated previously. Hair-mercury levels are elevated in individuals with chronic mercury poisoning and in individuals with increased blood mercury levels (National Research Council, 1978). Hair mercury levels also vary in relation to the consumption of mercury containing fish (Yamaguchi, 1971), occupational exposure to mercury (Lenihan, Smith and Harvey, 1973), use of mercury containing skin cream (Barr, 1973), and to "in utero" exposure to maternal body burdens of mercury (Fujita and Takabatke, 1977).

The biological and developmental significance of our findings is not clear. While warranting replication, the decreased IQ and subtest scores may be functional evidence of low-level mercury induced neuronal damage. The subtle subclinical effects of mercury on children are little understood, however, due to the absence of studies relating sensitive measures of psychologic performance to low levels of mercury. The developing central nervous system is especially vulnerable to mercury toxicity and future studies should examine the specificities of mercury exposure in the young in order to determine a minimal threshold (if there is one) for adverse developmental effects.

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