Journal of Applied Clinical Pediatrics Vol. 20 No.9, September 2005; pp 897-898.

The Effects of Endemic Fluoride Poisoning Caused by Coal Burning on the Physical Development and Intelligence of Children

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Abstract: Goal: to investigate the effects of endemic fluoride poisoning caused by coal burning on the physical development and intellectual ability of children. Method: Using random sampling from the relevant population, 176 fluorosis sufferers aged 7-12 (the subjects) were drawn from a heavily fluoride poisoned area of Zhijin County, with 50 children without dental fluorosis (the control) selected from a less severely poisoned area, and then the children were subjected to tests to determine levels of urine fluoride, physical development, and intellectual ability, and the various measurements compared. Results: Compared to the control group, the fluorosis group showed retarded physical development, and the levels of urine fluoride and intellectual ability were both lower than the control ($P < 0.05$ for both). Conclusion: high fluoride burden has a definite effect on the intellectual and physical development of children.

Key Words: Fluoride Poisoning, Endemic Fluoride Poisoning, Coal Burning, Physical Development, Intelligence

Fluoride poisoning is endemic throughout the world. Its prevalence in many parts of China is undisputed, with Guizhou one of the provinces most seriously affected by the pernicious effects of fluoride poisoning due to the burning of contaminated coal. Guizhou's Zhijin County is classified as a severely affected, endemic area, and it has been shown that prolonged intake of excess fluoride can damage the central nervous system[1-3], therefore, in October and November 2004, with the goal of investigating the relationship between high fluoride exposure and

intellectual levels as well as physical development, we carried out a study of the physical development and intellectual ability of children from Zhijin County.

Subjects and Methods

1. Subjects

From a zone with severe fluoride poisoning, children aged 7-12 were selected by random sampling, with 57 subjects (33 boys, 24 girls) suffering from skeletal fluorosis and 119 subjects (59 boys, 60 girls) suffering from dental fluorosis alone; 50 subjects (31 boys, 19 girls) were drawn from a zone with relatively low fluoride. All of the subjects were registered students, and both zones were free from iodine deficiency, with the basic conditions, including standard of living, level of medical treatment available, sanitation, and cultural development all essentially the same. Diagnosis of skeletal fluorosis was made according to the standards for skeletal fluorosis diagnoses by X-ray (WS192-1999) and child bone X-ray diagnoses[4].

2. Methods

1. Dental fluorosis: measured using the Dean index as well as the Chinese "3 types, 9 classifications" index.

2. X-ray: two x-rays were taken, one of the pelvis and one of the right crus (when necessary, an x-ray of the tarsus was also taken).

3. Physical tests: Using standard measurement techniques, the height, chest measurement, weight, and abdominal skin thickness of subjects in each group were collected, with the readings accurate to the nearest 0.1 cm, 0.1 kg, and 0.5 mm. The skin thickness was determined using a Tixing brand skin thickness meter manufactured by the Chinese Physical Culture Administration's Scientific Research Department; the device was calibrated before use.

4. Intelligence testing: the collective testing of intellectual ability was conducted using the Chinese version of the Raven Standard Theoretical Intelligence Text developed by the Psychology Department of Beijing Normal University (the PTCS). For each group of 10 to 20, the test conditions and

instructions were kept rigorously uniform as per the requirements of the test.

5. Physical development ranking: Based on Chinese reference standards for growth, age-independent height, weight, and chest measurements scores were calculated, and the subjects were classified into five developmental categories: below $\overline{x}$ - 2s (low), between $\overline{x}$ - 2s and $\overline{x}$ - s (below average), $\overline{x}$ ± s (average), between $\overline{x}$ + s and $\overline{x}$ + 2s (above average), and above $\overline{x}$ + 2s (high). See Table 1 for the criterion used to rank intelligence.

Table 1: Criterion for Intelligence Rankings

Level	IQ Evaluation Standard	Rank
1	IQ Score greater than 95% of theoretical group of same age	High Intelligence
2	IQ score in the 75% to 95% range	Good
3	IQ score in the 25% to 75% range	Average
4	IQ score in the 5% to 25% range	Below Average
5	IQ score in the below 5% range	Intellectual Deficit

5. Quality control: the same forms, the same method of questioning, and the same recording system were used for testing, with the same training given to all testers prior to testing; an objective and professional attitude was maintained at all times. In order to be certain that results of the study were both correct and complete, all results were promptly rechecked, and any problems quickly remedied.

3. Statistical analysis

Using the statistical software package SPSS 10.0, the measured data was subjected to a *t*-test, a variance analysis, and *q*-test pair-wise comparison, while the categorical data was subjected to a chi-square test and a single factor correlative analysis.

Results

1. For the average fluoride level in the urine of Zhijin County children, see table 2

Table 2: Urine Fluoride of Children in Zhijin Country ($\bar{x}$ ± s, mg/L)

Group	*n*	Urine Fluoride	*T*	P
Endemic Zone	144	1.352±0.457	2.96	<0.01
Control Zone	35	1.611±0.467		

2. For the indicators of physical development for children of Zhijin County, see table 3. The proportions of children in each group with below average height, weight, and chest measurement show no significant difference (P>0.05).

Table 3: Results of the Physical Development Evaluation for Children in Zhijin County

Group	*n*	Height			Weight			Chest Measurement		
		Below Average	Average	Above Average	Below Average	Average	Above Average	Below Average	Average	Above Average
Skeletal Fluorosis	57	44	12	1	25	30	2	13	28	6
Dental Fluorosis	119	85	33	1	44	66	9	29	80	10
Control	50	35	12	3	18	26	6	12	32	6

3. For the results of the abdominal skin thickness measuring, see table 4. The results from the children within the endemic zone showed girls with a statistically significant thicker abdominal skin than boys (P <0.05). Comparing same sex subjects across the three groups, girls show no significant difference (P>0.05), however the differences among the boys are significant (P<0.05). The two groups from the endemic zone showed no significant differences (P > 0.05). The control group had thicker abdominal skin then both the dental fluorosis and skeletal fluorosis groups, and this result was significant (a variance analysis and *q*-test showed $q = 3.46$, P <0.05; $q = 3.75$ P <0.05); the subjects suffering from skeletal fluorosis had lower skin thickness than the subjects with only dental fluorosis, however the difference was not significant ($q = 0.23$, P > 0.05).

Table 4: Results of Abdominal Skin Thickness Measurement

Group	Boys	Girls
Control	4.620±0.835	4.760±0.632
Dental Fluorosis	3.660±1.650	4.440±1.910
Skeletal Fluorosis	3.960±1.690	5.090±2.520

4. For the distribution of intelligence rankings for each group of subjects, see table 5. Following a chi-square test, the difference in IQ between the two zones was found to have statistical significance (chi-square = 23.46, $P < 0.01$); IQs in the high fluoride zone are clearly lower than the control.

Table 5: Distribution of Intelligence Rankings in Children From Zhijin County

Group	*n*	<5%	5%-25%	25%-75%	≥75%
Control	49	2	4	29	14
Dental Fluorosis	97	6	24	59	8
Skeletal fluorosis	57	7	12	36	2

In total 157 students in the endemic zone were tested (3 tests were invalid); in the control zone 1 test was invalid.

5. The relationship between IQs scores and fluoride urine of children from both zones was investigated by subjecting the urine fluoride and IQ to a single factor correlative analysis. The results indicate a negative correlation between fluoride in urine and intelligence ($r = -0.494$, $P < 0.01$)

Discussion

The children from the fluoride endemic areas showed poor development with regard to the growth indicators used in this study, i.e height, weight, and chest measurement, with height being particularly low. In each group, the percentage of children with below average height was more than 70%, and the children with skeletal fluorosis were on average the shortest. This could be related to the

tendency of fluoride to collect in the bones and the resulting damage. Fluoride also seems to be harmful to the muscles, not only causing cells to lose their shape and muscle fibers to lose thickness, but also leading to a general drop in muscle energy metabolism[5]. The abdominal skin thickness of the subjects were tested, with the results indicating that fluoride poisoning has some effect on fat storage, with a corresponding effect on physical development. According to research, high body burden of fluoride can inhibit a wide range of enzymes[6], for instance inhibiting enzymatic hydrolysis of lipids, leading to insufficient amounts of essential fatty acids (linoleic acid, linolenic acid, arachidonic acid, etc.). This could be the cause of the differences in abdominal skin thicknesses seen in this study, but this mechanism needs to be researched further. The difference between the groups suffering from fluorosis and the control with regard to the various physical developmental indicators (height, weight, chest measurement) seen in this study was not statistically significant; this could be due to the fact that the control group was also drawn from an area that showed some fluoride contamination; they might also have also been, to a certain extent, fluoride poisoned. The indicators also showed no significant differences between the two groups suffering from fluorosis; this indicates that more research into the exact influence of varying degrees of fluoride poisoning on physical development is required.

This study used the PTCS IQ scale to measure intellectual ability; a testing method that minimizes the interference from ethnic, cultural, and linguistic factors. Recent research has demonstrated that excess fluoride uptake can damage the central nervous system, and can pass through the placental and blood-brain barriers to affect the synthesis and excretion of certain neurotransmitters and thus the various stages of child brain development, causing a retardation in the normal development of the nervous system and ultimately affecting the intellectual ability of the child[7-9]. This study found that the children from the severely endemic zone had higher urine fluoride than those from the control zone, and that urine fluoride and intelligence showed a clear negative correlation, results that are consistent with the findings of Liu Shusen et al[10,11]. The numbers of below-average IQ subjects from the two fluorosis groups were clearly higher than the control group,

further demonstrating that high fluoride intake has a damaging effect on intellectual ability. Even the control group had 16.3% of subjects in the low range, suggesting that even moderate levels of fluoride contamination such as were present in the control zone can still have a noticeable effect on the intellectual development of children. Our investigation did not discover a clear difference between the intellectual abilities of the two fluorosis groups; this might be related to certain characteristics of brain cell development. These results also suggest that, given the poisonous nature of fluoride with regard to the central nervous system, studying the intellectual ability of children in fluoride endemic areas can better reflect the overall harm that fluoride poises to the heath of children. Of course, fluoride is only one of many factors that influence the physical development and intelligence of children[12,13]; genetics, environment, economics, nutrition, and exercise are also related[14]. The region that was investigated in this study was underdeveloped in economic and cultural terms, and the children's regular diet showed nutrition deficits, including insufficient intake of animal protein, fat, calcium, and vitamins, which could also be playing a role in the retarded physical development of the children. In addition to lowering fluoride intake, other steps such as improving nutrition and increasing physical exercise should be taken to improve the health of children in such areas.

References

1. Guan Zhi, Wang Yanan, Gustav D 2004. Changes in the formation of phospholipids inside SH2SY5Y nerve cells caused by fluoride poisoning. *Journal of Guizhou Medical College*, 29(6), 471-474.
2. Li Junping, Wang Jundong, Liang Zhanxue et al 2004. The effects of high fluoride on the central nervous system. *Chinese Journal of Veterinary Drug*, 38(9); 38-47.
3. Xiang Quanyong, Wang Caisheng, Liang Youxin 2005. The poisonous effect of fluoride on the nervous system. *Chinese Journal of Endemiology*, 24(1): 114-116.
4. Chen Xuguang, Jiao Juan, Song Anxue, et al. Diagnosis of Skeletal Fluorosis

by X-ray. *Journal of Guizhou Medical College*, 14(3):179-182.

5. Jiang Qingwu 2003. *Epidemiology*. Beijing: Science Press, 156-158
6. Zhang Aijun 1992. The effects of fluoride on the endocrine system of organisms. *Chinese Journal of Endemiology*, 7(2), 102.
7. Shen Xiuying 2001. The effects of fluoride on the central nervous system. *Chinese Journal of Endemiology*, 16(6), 348.
8. Li Yongping, Jin Xiangyi, Chen De et al 2003. The effects of endemic fluoride poisoning on the intellectual development of children in Baotou. *Chinese Journal of Public Health Management*. 19(4), 337-338.
9. Chen Jun, Chen Xuemin 2002. Research on damage to the DNA of brain cells in rats caused by fluoride and the antagonism of fluoride with selenium and zinc. *Chinese Journal of Public Health Management*. 18(7), 774-775.
10. Liu Shusen, Lu Yan, Sun Zenrong et al 2000. Report on the intellectual ability of children living in high fluoride zones. *Chinese Journal of Control of Endemic Diseases*, 15(4):231-232
11. Wang Sanxiang, Wang Zhenghui, Cheng Xiaotian, et al 2005. Investigation and evaluation of the physical development and intellectual ability of children from areas with endemic arsenic and fluoride poisoning. *Chinese Journal of Control of Endemic Diseases*, 24(2):179-182.
12. Liu Weiming, Tang Jiulai, Wu De, et al. Research on the relationship between the IQ of urban schoolchildren and family background. *Journal of Applied Clinical Pediatrics*, 24(2), 179-182.
13. Shi Yanli, Li Lingzheng, Zang Huifang 2003. A longitudinal study of physical and intellectual development in children whose mothers had hypertension during pregnancy. *Journal of Applied Clinical Pediatrics* 18(10), 846-847.
14. Ye Guangjun 2000. *Child and Adolescent Health*, 5th ed. Beijing: People's Health Press, 212-214.

(Translated by Julian Brooke, 3/26/07)