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RESEARCH ON THE EFFECTS OF FLUORIDE ON CHILD INTELLECTUAL DEVELOPMENT UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

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SUMMARY: *Goal:* **To study the effects of the fluoride and iodine content of drinking water on child intellectual development and the interaction between the two factors and also the relationship of educational factors to such development.** *Methods:* **The subjects of the investigation were 8- to 14-year-old children randomly selected from endemic areas as well as a control area, with the subjects tested for fluorosis, goiter, and IQ.** *Results:* **In endemic areas with high fluoride and high iodine, there was greater prevalence of both fluorosis and goiter than in the areas with only one of these two factors. Although the high fluoride and high fluoride/high iodine groups showed no significant drop in average IQ compared to the control ($p>0.05$), in both cases this tendency was present. There was also no significant difference in IQ between the high fluoride and high fluoride/high iodine groups ($p>0.05$). The IQ scores of the high fluoride/low iodine and low fluoride/low iodine groups each showed significant differences compared to the control ($p<0.01$). With regard to average IQ, high fluoride and low iodine show significant interaction ($p<0.01$). In terms of IQ ranking, the high fluoride groups showed significant deficits compared to the control ($p<0.01$). The average IQ was also significantly linked to the educational level of the parents as well as preschool attendance($p<0.01$).** *Conclusion:* **When fluoride and iodine not meeting national standards for drinking water are present in the same area and ingested together, the harmful effects of fluoride are more pronounced, and the resulting damage compounded. However, the damage caused independently by either high or low iodine is greater than that caused by fluoride. Environmental effects related to education also have a direct influence on child intelligence.**

[Keywords: Children's IQ; Education and IQ; Environment and IQ; Goiter; High fluoride water; Iodine in drinking water; IQ study in China; Standardized Raven Test (Chinese Rural Edition CRT-R), Yellow River.]

INTRODUCTION

The region of China selected for this study is a high fluoride, high iodine area in the lower reaches of the Yellow River on the flood plain near the Bohai Sea.[1] Because the residents of the region consume drinking water that has a higher content of fluoride and iodine than the national standard, the prevalence of dental fluorosis and goiter is high. This study investigated the effects of different levels of fluoride and iodine on the intellectual development of school-age children with the results that are presented here.

MATERIALS AND METHODS

Selection of location and subjects: Three counties (Wukang, Boxing, Zouping) in Shangdong Province with approximately the same geographical features and standard of living were chosen as the region for study; areas within the region whose drinking water had concentrations of fluoride or iodine not conforming to

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national standards were considered affected (endemic) zones, and those that were within the acceptable range of the national standards were the control (see Table 1). From each population, children 8 to 14 years old currently attending school were randomly selected and tested to determine the rates of dental fluorosis and goiter as well as IQ level.

Investigation of factors related to educational environment: Subjects were grouped according to whether their parents had a post-middle school education and whether they had received pre-school education, and they were then tested for IQ level.

Standards for diagnosis of dental fluorosis and goiter: The diagnosis of children with dental fluorosis was based on the WHO-recommended Dean's index. Goiter was diagnosed according to the international two-grade (I and II) classification system.

IQ testing procedures and standards: The procedures and standards for testing were taken from the *Guide to the Standardized Raven Test (Chinese Rural Edition CRT-R)* edited by Wang Dong. The IQ scores were classified as follows: outstanding (IQ>130), excellent (120–129), above average (110–119), average (90–109), below average (80–89), borderline (70–79), and low (IQ<69).

Determination of fluoride and iodine levels: Conventional chemical assay methods were used.

Quality control: To ensure the quality of their work, personnel participating in the study were given rigorous training, tested for competence, and given practice prior to carrying out their duties.

Statistical methods: The data collected were subjected to t-test and chi-squared statistical analysis.

RESULTS

Fluoride and iodine levels in the drinking water of investigated areas: For the levels of iodine and fluoride in the water of the endemic and control areas, see Table 1.

Table 1. Fluoride and iodine content of drinking water in various subject areas

Group	Fluoride (mg/L)[a]	% Above standard	Iodide (µg/L)[b]	% Above standard
Control	0.75	-	150	-
High F only	2.90	190%	-	-
High F, High I	2.85	185%	1150.0	283%
High F, Low I	2.94	194%	0.91	-
Low F, Low I	0.48	-	0.75	-

[a]The standard range for water fluoride content is 0.5–1.0 mg/L; <0.5 mg/L is classified as low fluoride, >1.0 mg/L is classified as high fluoride. [b]The standard range for water iodide content is 50–300 µg/L; <10 µg/L is classified as low iodide, >300 µg/L is classified as high iodide.

Comparison of IQ levels between the endemic areas and the control: Table 2 shows no significant difference when the IQs of children in the high fluoride only

and high fluoride/high iodine areas are compared with the control. In each case, however, the IQ scores show a negative tendency. There is no significant difference between the high fluoride only and the high fluoride, high iodine areas ($t = 1.763$, $p>0.05$). The high fluoride/low iodine and the low fluoride/low iodine areas are each significantly different compared with the control ($p<0.01$) and are also significantly different compared to each other ($t = 8.79$, $p<0.01$).

Table 2. Comparison of dental fluorosis, goiter, and IQ in the various areas

Group	Rate of dental fluorosis			Rate of goiter		IQ (mean±SD)	t	p[a]
	n	Sufferers	%	Sufferers	%			
Control	32	2	6.25	1	3.13	82.79±8.98	-	-
High F only	85	79	92.94	1	1.18	80.58±2.28	1.12	>0.05
High F, High I	32	31	96.88	4	12.50	79.39±6.92	1.23	>0.05
High F, Low I	28	26	92.86	12	42.86	68.38±19.12	7.85	<0.01
Low F, Low I	28	2	7.14	9	32.14	75.53±6.92	8.26	<0.01

[a]Compared to the control.

IQ ranking distribution for the endemic areas and the control: As shown in Table 3, there were higher numbers of low IQ subjects in each of the high fluoride only, high fluoride/high iodine, and high fluoride/low iodine groups as compared to the control.

Table 3. Child IQ ranking distributions for the high fluoride and control groups

IQ	Control		High F only		High F, High I		High F, Low I	
	n	%	n	%	n	%	n	%
>130	2	2.38	0	-	0	-	0	-
129-120	3	3.57	1	2.22	1	2.13	0	-
119-110	6	7.14	0	-	2	4.26	1	1.22
109-90	28	33.33	14	3.11	14	29.79	22	26.83
89-80	28	33.33	16	35.56	13	27.66	29	35.37
79-70	15	17.87	10	22.22	12	25.53	19	23.17
69<	2	2.38	4	8.89	5	10.63	11	13.41
Total	84	-	45	-	47	-	82	-

Investigation of education environment factors:

(i). Relationship between the educational level of parents and child IQ: Table 4 shows that for the IQs of 30 children in the high fluoride group and 31 in the control group, the educational level of the parents is extremely significant ($p<0.01$). However, when educational level is held constant there is no significant difference between the groups ($t = 1.01$, 1.95, $p>0.05$).

Table 4. Relationship of child IQ and parental education for high fluoride exposed group vs. control group IQ (mean ±SD)

Group	n	High school or above	Middle school or below	t	p
High fluoride	30	82.23±2.98	77.16±2.24	5.17	<0.01
Control	31	83.98±2.29	78.75±2.23	6.32	<0.01

(ii). Effect of pre-school education on child intellectual ability: Table 5 shows that for the IQs of 30 children in the high fluoride group and 32 in

the control group, it is extremely significant whether or not the child went to preschool ($p<0.01$). However, there is no significant difference between the two groups when preschool attendance is held constant ($t = 1.09, 1.78, p>0.05$).

Table 5. Relationship of child IQ and preschool education for high fluoride exposed group and control group IQ (mean±SD)

Group	n	Had preschool education	No preschool education	t	p
High fluoride	30	82.22±1.53	75.11±1.38	6.27	<0.01
Control	32	83.18±1.68	77.21±1.58	5.68	<0.01

Tables 4 and 5 indicate major IQ differences are attributable to environmental factors such as parental educational level and preschool education in children from both endemic and non-endemic areas.

DISCUSSION

The relation between high fluoride and the rate of goiter: The standards for the drinking water fluoride content used in this study are based on the national regulatory standards (GB5749-84) where >1.0 mg/L is considered high fluoride water and >300µg/L is considered high iodide water. These standards are based on evidence from the literature.[2] As seen in Table 2, the high fluoride/high iodine group shows increased prevalence of goiter associated with the presence of high iodide, but the high fluoride only group shows no increase in the cases of goiter. The high fluoride/low iodine group had an increased rate of goiter as compared to low fluoride/low iodine group, possibly stemming from the toxic effects of fluoride interacting with and aggravating the damage caused by a low iodine environment. According to national standards for disease, each of these areas can be classified as an endemic area.

The effects of fluoride on child intellectual ability: The IQ results of this study show no significant difference between the average IQs of those children from the high fluoride only areas and the high fluoride/high iodine areas, however the result from the high fluoride/low iodine group show statistically significant differences as compared to that of the low fluoride/low iodine group. In short, it appears that the presence or lack of iodine is a more significant factor in both the prevalence of goiter and average IQ.

Looking at the IQ ranking distributions, children classified as having “low” IQ in each of the high fluoride only, high fluoride/high iodine, and high fluoride/low iodine groups were higher than the control; children having IQs of 69 or less make up 8.89%, 10.63%, and 13.41%, respectively, with only 2.38% of children in the control similarly classified. It has already been conclusively shown that the lack or excess of iodine affects intellectual development. With regard to the question of whether fluoride directly affects intellectual ability, reports in the literature state that fluoride concentrations are clearly related to the function of adenohypophysis cells, with high concentrations showing toxic effects. Siddiqui found that most fluoride-poisoned patients show clear nerve damage, in particular deficits in the

eighth cranial nerve. When high fluoride and low iodine co-occur, there appear to be compounding effects on the population in endemic areas, with a negative influence on child intellectual development that is more pronounced than the case of low iodine alone.[4] This intellectual deficit is likely to be caused by the effect of excess fluoride on the normal function of central nervous system. In the first 10 to18 weeks after birth, cells in the human brain are dividing rapidly; if there is excess fluoride present, its toxicity can disrupt active enzyme metabolism, inhibiting the production of cell-forming proteins and the synthesis of nucleic acids, affecting the structure and ultrastructure of cell membranes, ultimately causing various degrees of damage to the nerve cells. Iodine deficiency has a direct negative influence on the function of the thyroid as well as brain development; during pregnancy and the first year or two after birth, iodine deficiency increases the damage caused by fluoride toxicity.[5,6]

The effects of education-related environmental factors on intelligence: As shown in Tables 3 and 4, in the high fluoride,[7] high fluoride/high iodine, and control areas, the educational level of the parents and the presence or lack of preschool education both had a marked effect on the IQ of the child subjects. The results demonstrate that, putting aside the effects from trace elements like fluoride and iodine, these educational factors are also strongly relevant to child intellectual development. During our investigation we noted that, among the environmental factors that affect IQ, the most significant appears to be the educational level of the mother.

The conclusions of this study: (1) When fluoride and iodine levels are outside of national standards for drinking water are present in the same area and ingested together, the harmful effects of fluoride are more pronounced, and the resulting damage compounded. However, the damage caused independently by either high or low iodine is greater than that caused by fluoride. (2) In both the control and endemic areas, environmental factors such as education and child-rearing showed a direct influence on intellectual development.

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