

## • Field Survey •

**The Effects of Comprehensive Control Measures on Intelligence of School-Age Children in Coal-Burning-Borne Endemic Fluorosis Areas**

Wei Na, Li Yi, Deng Jie, Xu Shiqing, Guan Zhizhong

**The effects of comprehensive control measures on intelligence of school-age children in coal-burning-borne endemic fluorosis areas** Wei Na<sup>\*</sup>, Li Yi, Deng Jie, Xu Shiqing, Guan Zhizhong. <sup>\*</sup>Department of Pathology and Key Lab of Molecular Biology in Guiyang Medical College, Guiyang 550004, China

Corresponding author: Guan Zhizhong, Email: zhizhongguan@yahoo.com

**[Abstract]** **Objective** To investigate the incidence of dental fluorosis, urinary fluoride level and intelligence of children who lived in the coal-burning-borne endemic fluorosis areas and to reveal the effects of comprehensive control measures on intelligence of children in this area. **Methods** Children aged 8 – 12 who lived in coal-burning-borne endemic fluorosis areas in Bijie City of Guizhou Province were selected and divided into two groups according to the duration of comprehensive treatments given: long treatment group (Xiaba Village and Zhongtun Village, furnace stove was changed and comprehensive control measure of health education was carried out for more than 3 years) and short treatment group (Chadi Village and Maoliping Village, stoves were improved and health education time < 1 year). The children who lived in a non-fluorosis area were selected as controls in 2012. Dental fluorosis was diagnosed by the method of Dean; urinary fluoride was analyzed by the method of fluoride-ion selective electrode; and the intelligence quotient (IQ) was measured by Raven's Standard Progressive Matrices Test. **Results** The number of children surveyed in control group was 104, long treatment group was 298, short treatment group was 339, and the incidence rates of dental fluorosis were 0 (0/104), 72.5% (216/298) and 85.2% (289/339), respectively, and the incidence rates of dental fluorosis in children lived in the endemic fluorosis areas were significantly increased compared with that of control group; the difference of incidence rates between long

treatment group and short treatment group was statistically significantly ( $\chi^2 = 15.736$ ,  $P < 0.01$ ). Urinary fluoride content were  $(2.33 \pm 0.18)$  and  $(3.03 \pm 0.16)$  mg/L, respectively, compared with the control group [ $(1.34 \pm 0.64)$  mg/L], the values in endemic fluorosis areas were significantly higher ( $F = 306.53$ ,  $P < 0.01$ ). Above average IQ of children in the control group was 97.1% (101/104), which was significantly higher than that of long and short treatment groups; after a lengthy treatment, mental retardation detection rate was significantly lower in the low-age group, 8 – 10 year-old children ( $\chi^2 = 7.542$ ,  $P < 0.01$ ). Urinary fluoride content was negatively correlated with the level of IQ ( $r = -0.553$ ,  $P < 0.01$ ). **Conclusions** The intelligence development of children in coal-burning-borne endemic fluorosis area is significantly delayed. After a certain period of comprehensive treatment, the decreased level of cognition is inhibited and the mental retardation in the low-age group is improved.

**[Key words]** Fluorosis, dental; Coal; Children; Intelligence; Growth development

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Authors' organisation: Teaching Research Office of Department of Pathology, Guiyang Medical College, Guiyang 550004 [Wei Na, Guan Zhizhong (also attached to Key Lab of Guizhou Provincial Molecular Biology of Guiyang Medical College)]; Key Lab of Guizhou Provincial Molecular Biology of Guiyang Medical College [Li Yi, Deng Jie]; Qixinguan District CDC of Bijie City [Xu Shiqing]

Corresponding author: Guan Zhizhong, Email: zhizhongguan@yahoo.com

Endemic fluorosis is a relatively widespread and highly harmful epidemiological disease<sup>[1]</sup>, and coal burning induced fluorosis is a specific form of the disease found in China. Research studies have found that elevated levels of fluoride can accumulate in brain tissues by crossing the blood-brain barrier and the placental barrier<sup>[2-3]</sup>. Since children are undergoing a crucial period of brain differentiation and growth, any internal and external environmental change and stimulation can have adverse effects on the brain, resulting in lower intelligence for the child. China has adopted comprehensive control measures in the prevention of endemic fluorosis, such as upgrading water supplies and cooking stoves, as well as health education. In an effort to investigate changes in the effects on intelligence for children in areas affected by coal burning induced endemic fluorosis after comprehensive treatments and controls, the author conducted a survey in 2012 in Bijie City, Guizhou Province on the incidence of dental fluorosis, urinary fluoride content and intelligence of children living in coal-burning endemic fluorosis areas.

## 1 Subjects and Methodology

- 1.1 Sampling points and survey subjects: The Qixingguan District of Bijie City in Guizhou Province is a typical area affected by coal burning induced endemic fluorosis; it is also an area with non-iodine deficiency. With reference to epidemiology data on fluorosis in Bijie City, primary school students aged 8~12 were chosen from Xiaba Village and Qianxixiang Zhongtun Village of Yachi Township (where the furnace and stove upgrade program and health education have been running for more than 3 years) and Shadi Village of Haizijie Township and Maoliping Village of Bazai Township (where the stove upgrade program and health education have been running for less than 1 year) on the basis of comparable local geographical environments, socioeconomic conditions, living standards, and the duration of comprehensive endemic treatment and control measures involving cooking stove upgrade, health education and so on. The survey subjects were divided into a Long-term Treatment Group and Short-term Treatment Group, respectively; in addition, students from the No.8 Primary School of Qixingguan District in Bijie City were also selected to form a Control Group.
- 1.2 Sample content and sampling method: A random whole population sampling method was used to select a Control Group of 100 individuals, and 300 individuals for each of the Long-term Treatment Group and Short-term Treatment Group. Each group had comparable age and sex ratios.
  - 1.2.1 Dental fluorosis examination: the DEAN method was used in the diagnosis of dental fluorosis for all children in the survey.
  - 1.2.2 Urinary fluoride content: 50 children were selected from each of the Control Group, Long-term Treatment Group, and Short-term Treatment Group from 5 schools to collect 10 ml urinary samples to be tested for urinary fluoride content using the fluoride-ion selective electrode method.
  - 1.2.3 Intelligence test: Intelligence Quotient (IQ) tests were carried out on all children aged 8~12 in the survey by using the "Raven's Standard Progressive Matrices" (SPM) test method, revised by the School of Psychology of Beijing Normal University; each batch of tests had 20~30 subjects, with the test conditions and guiding instructions strictly in accordance with standardized test requirements. Moreover, strict QC was enforced: standardized forms, standardized Q&A format, standardized recording, all investigators underwent standardized training, while the survey was performed in an objective and methodical manner; the investigation results obtained during the survey were checked in a timely manner, and any issues found in the survey were corrected and remedied in a timely manner to ensure correctness and completeness of the investigation outcomes. In the case of comparison between same age groups, the test categories were  $\geq 95\%$ ,  $75\% \sim < 95\%$ ,  $25\% \sim < 75\%$ ,  $5\% \sim < 25\%$ ,  $< 5\%$ , and the intelligence levels were superior, good, average, below average, and intellectual deficiency.
- 1.3 Statistical analysis of data: The SPSS 16.0 statistics package was used to carry out statistical analysis on the data. The  $X^2$ -test was applied to the incidence of dental fluorosis and intelligence level in children; one-way ANOVA was used for comparison of urinary fluoride levels.

## 2 Results

- 2.1 Incidence of dental fluorosis in the children: the incidence of dental fluorosis was 0 in the Control Group of 104 subjects; dental fluorosis was found in 216 subjects in the Long-term Treatment Group of 298 subjects, giving an incidence of 72.5%; dental fluorosis was found in 289 subjects in the Short-term Treatment Group of 339 subjects, giving an incidence of 85.3%. The difference in incidence between the Long-term Treatment Group and the Short-term Treatment Group was statistically significant ( $X^2 = 15.736$ ,  $P < 0.01$ ).
- 2.2 Urinary fluoride levels in the children: 42, 51 and 72 children were tested in the Control Group, Long-term Treatment Group, and Short-term Treatment Group, respectively. Urinary fluoride levels were, respectively,  $(1.34 \pm 0.64)$ ,  $(2.33 \pm 0.18)$ ,  $(3.03 \pm 0.16)$  mg/L; both the Long-term Treatment Group and Short-term Treatment Group were higher than the Control Group ( $F = 306.53$ ,  $P < 0.01$ ).
- 2.3 Distribution of intelligence levels in the children: 97.1% of the children in the Control Group had average or above intelligence; 59.4% of the children in the Long-term Treatment Group had average or above intelligence; 55.2% of the children in the Short-term Treatment Group had average or above intelligence. The difference in intelligence between the Control Group, and the Long-term Treatment Group and Short-term Treatment Group was statistically significant ( $X^2 = 62.332$ ,  $P < 0.01$ ). The difference in intelligence between the Long-term Treatment Group and Short-term Treatment Group was statistically insignificant ( $X^2 = 1.161$ ,  $P > 0.05$ ). See Chart 1.
- 2.4 Distribution of the children's intelligence by age groups: The incidence of intellectual impairment for children aged 8 ~ 10 in the Long-term Treatment Group was lower than the Short-term Treatment Group ( $X^2 = 7.542$ ,  $P < 0.01$ ). See Table 2.

**Table 1 Distribution of the Children's Intelligence [cases, percentage (%)]**

Group	No. of cases	Intellectual Deficiency	Below Average	Average	Good	Superior
Control Group	104	0(0.0)	3(2.9)	35(33.7)	63(60.6)	3(2.9)
Long-term Treatment Group	298	25(8.4)	96(32.2)	118(39.6)	57(19.1)	2(0.7)
Short-term Treatment Group	339	33(9.7)	119(34.8)	138(41.0)	49(14.5)	0(0.0)

**Table 2 Distribution of Intelligence Quota by Age for Children in the Affected Areas [cases, percentage (%)]**

Age (Years)	Long-term Treatment Group		Short-term Treatment Group		$X^2$ value	P- value
	Below Average	Above Average	Below Average	Above Average		
8 ~ 10	25(24.8)	76(75.2)	67(41.4)	96(58.6)	7.542	< 0.01
11 ~ 12	96(48.7)	101(51.3)	85(48.0)	92(52.0)	0.019	> 0.05

- 2.5 The relationship between urinary fluoride content and intelligence: There is a negative correlation between urinary fluoride content and intelligence for children living in the affected areas ( $r = -0.553$ ,  $P < 0.01$ ).

### 3 Discussion

Coal burning induced endemic fluorosis is a cumulative systemic disease caused by the use of open furnaces and open stoves for heating, cooking or BBQ of food, chilies, etc. over a long period of time, resulting in air and food contamination by fluoride dusts and excessive intake of fluoride into the human body. Guizhou Province is a typical region affected by coal burning induced endemic fluorosis; it is also the worst affected region in this country, with Bijie City of Guizhou Province being the core endemic area. At present, the harmful effects of endemic fluorosis to human health are increasingly attracting serious attention by various sectors; and relevant governmental bodies have implemented models of prevention based on health education and health promotion, and regional control measures with furnace and stove upgrades<sup>[4-5]</sup>. The phenomenon of decreasing intelligence levels in regions affected by endemic fluorosis has been gaining more and more attention<sup>[6-7]</sup>. This present survey is conducted by the author to investigate the intelligence of children after comprehensive control measures were implemented in areas affected by coal burning induced endemic fluorosis.

The incidences of dental fluorosis in the Long-term Treatment Group and the Short-term Treatment Group are respectively 72.5% and 85.3% for children living in affected areas, far exceeding the national standard benchmark for core endemic regions with endemic fluorosis. In comparison to children in the Control Group, children living in the affected areas have appreciably elevated urinary fluoride levels. Urine is the principle means to eliminate absorbed fluoride, and elevated levels of urinary fluoride can indirectly reflect the intake, accumulation, and load of fluoride in the body. In view of the incidence of dental fluorosis in children living in the affected region, this would indicate the incidence of chronic fluorosis in children living in areas affected by endemic fluorosis remains a rather serious problem.

The SPM Chart is a non-textual intelligence test designed by the British psychologist J. C. Raven. It is suitable for use in a wide range of ages is unaffected by limitations of such factors as ethnicity, culture, language, etc., and it has important theoretical and practical significance<sup>[7-8]</sup>. The results of this present survey indicate that 97.1% of children in the Control Group without dental fluorosis have average or higher intelligence, and on the other hand, only 59.4% and 55.2% of children in the Long-term Treatment Group and Short-term Treatment Group have average or higher intelligence. In addition, the negative correlation between urinary fluoride levels and intelligence of the children indicates that elevated fluoride exposure and increases in internal fluoride load has harmful effects on a child's intellectual development, causing intellectual impairment. This shows the incidence of low intelligence in children living in areas affected by endemic fluorosis remains a rather serious problem.

There is no statistical significance in the difference in intelligence between children in the Long-term Treatment Group and the Short-term Treatment Group from an overall perspective. However, the picture is somewhat different when compared by age, with the indication that there is certain improvement to the incidence of developmental delay in intelligence for children of younger age after a longer period of treatment and control measures in the areas affected by endemic fluorosis. Moreover, there is also some reduction in the incidence of dental fluorosis and urinary fluoride levels, indicating the treatment and control measures centered on furnaces and stoves are starting to show some effects in children of younger age after a longer period of treatment and control measures in the areas affected by endemic fluorosis. Nevertheless, due to various general factors, such as the affected regions are relatively economically underdeveloped and the people living in these regions generally having insufficient health awareness while lacking the motivation for disease prevention, coupled with a narrowly focused model of prevention and so on, the progress and effectiveness of prevention are hampered to a certain extent. In view of the harm of elevated fluoride levels on children's growth and intellectual development and the need to consolidate the long term effectiveness of the comprehensive treatment and control measures, follow-up management of the furnace and stove improvement program should be strengthened. Local residents should be guided to change their unhealthy living style, paying more attention to child healthcare in regions with elevated fluoride levels, thus promoting the children's physical and intellectual development.

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