The Impact of Endemic Fluorosis Caused by the Burning of Coal on the Development of Intelligence in Children

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Objective: To explore the effect of endemic fluorosis caused by coal burning on the level of intelligence in children.

The Method: We randomly selected 20 school children from 4 areas between the ages of 8-12, whose characteristics fit the scope of our research. They were chosen from slight, moderate, and severe endemic fluorosis areas that were affected by regional fluoride poisoning brought on by the burning of coal, and a controlled, non-endemic area. We have used the used the CRT-RC to perform a test of the children's intelligence levels, and we have examined the condition of their dental fluorosis. Urine samples were collected in the morning, and the fluoride content in the samples was measured by the fluoride ion selective electrode method.

The Results: We have found that those more severely impacted by dental fluorosis had a higher level of fluoride in their urine samples ($P<0.01$). A significant difference in the children's levels of IQ could be observed amongst the different disease areas. The children's level of IQ tended to decrease as the severity of dental fluorosis increased. There was a negative correlation between the children's IQ level and urinary fluoride content ($P<0.01$). Significant differences could be seen in the abilities of comparative inference, serial relationship, and abstract inference between the different groups tested ($P<0.05$). In terms of cognition and analogical comparison abilities, the difference was not significant among the children from the different disease groups ($P>0.05$).

Conclusion: High exposure to fluoride most definitely has an adverse effect on the development of intelligence in children, in particular on the capability of abstract inference.

Keywords: Fluoride; Fluorosis; Children; Intelligence quotient; Coal-burning pollution

Fluoride poisoning is one of the major endemic diseases severely impacting the health of the human body. It is reported that more than 50 countries in the world have inhabitants suffering from chronic endemic fluorosis. Recent research on the fluorosis issue and its impact on the nervous system and, in particular, the development of intelligence and memory has prompted scientists and researchers from all over the world to place more focus on the disease and its impact on the human body. The journal Fluoride has also published an editorial, aptly named "Fluoride and level of intelligence", in its second issue published in 2000. In the article the author discussed the relationship between the intake of fluoride and the level of intelligence in children, and further emphasized the need for greater research on the negative impact of fluoride on intelligence level, as well as the need for more research on the effect of fluoride on the central nervous system (1). Presently, a lot of researchers from abroad and within China have performed relevant research on animal subjects and endemic fluorosis regions. However, little research has been conducted to assess the effect of demographics and the degree of pathological change in the fluorosis areas. The present report has therefore focused on the impact of fluoride poisoning, caused by coal burning, on children. Particular focus has been placed on the effect of fluoride poisoning on the level of intelligence in these young subjects, and if it varies based on the severity of the dental fluorosis encountered. A set of data has been provided as per this research to assist in the effective planning of preventive measures against the disease, so to ensure that children living in areas affected by fluoride poisoning can grow up in good health.

1. Content and Methodology

1.1 Subjects Researched

As per the natural environment, local economy, custom, lifestyle and eating habits of the region researched, we have selected one township as a point of research in the areas with slight, medium and severe fluorosis, and a

fluorosis-free area respectively, within Xinhua County, Hunan province, in November 2006. A group of children aged 8-12 years old from the grade 5 class of every central primary school from the four areas have been inspected. These are children who were born and raised in the area. We have excluded subjects who have been diagnosed with physical deformation, overall developmental disorders, delayed mental development, emotional/behavioral obstacles or challenges, or other forms of mental disorders. 20 children were then randomly selected from this group for the research, and thus a total number of 80 school children from the 4 points of research were examined. Regions and their level of endemic fluorosis were considered and confirmed based on "The standard of distinguishing regions with endemic fluorosis caused by coal burning", GB 17018-1997, as administered by the Ministry of Health of the People's Republic of China.

1.2 Inspection for Dental Fluorosis

For the inspection and examination of dental fluorosis in the subjects, we have used Dean's Method as recommended by the World Health Organization.

1.3 Intelligence Test for children

All subjects were asked to partake in a group testing as per the CRT-RC (Combined Raven's Test - For Rural regions in China method). Testing time was limited to 40 minutes. The test consists of 72 images, which are then divided into groups A, AB, B, C, D, E in accordance to their level of difficulty. Groups A and AB are primarily used to test the ability of cognitive discernment, image comparison, and imagination, whereas Group B primarily tests the ability of analogical comparison and image grouping. Group C primarily tests inference and image grouping. Group D primarily reflects serial relationship and the abilities of image registration and analogy. Group E tests abstract abilities such as exchanging and interchanging objects, etc. All children subjects were tested by the same administrative staff, and assisted by 3 other staff members. All instructional terms and conditions of testing strictly followed the requirements of the testing module. After the test was finished, the scores were calculated as per the standard answer cards. The actual level of intelligence (IQ) of the subject was then calculated as per the CRT-RC2 chart. The CRT-RC evaluates different levels of intelligence as per the following standard: IQ greater or equal to 130: outstanding; 120-129: excellent; 110-119: higher than average; 90-109: average; 80-89: lower than average; 70-79: subsistent intelligence; lower or equal to 69: low intelligence.

1.4 Inspection of Fluoride in Urine

We have used dry polyethylene bottles pre-treated by deionized water to collect urine samples in the morning. Once the sample was collected, we refrigerated it and took it back to our research site for further examination. The fluoride level in the urine samples was determined through the ion selective electrode method.

1.5 Statistical Analysis

We have used the SPSS 11.5 Statistics software to analyze the data, and have confirmed that the difference of $P<0.05$ has statistical significance in the analysis of data in this project.

2. Results of Investigation

2.1 Balance test

The results of the X^2 tests have shown that there is no statistical significance related to the difference in the distribution of gender found between subjects across the different groups (who have been selected from different endemic regions and were ailing at different levels of severity). ($x^2 = 0.201$, $P>0.05$; $x^2 = 1.870$, $P>0.05$). The results gathered from the single-element testing have shown that, likewise, there is no statistical significance related to the difference in the age found between subjects across the different groups who have been selected from different endemic regions and were ailing at different levels of severity. ($F=0.202$, $P>0.05$; $F=0.461$, $P>0.05$). This is representative of the fact that there is an equal representation of subjects from different age groups and gender class present in various endemic regions and were experiencing the symptoms of fluorosis at various levels of severity.

2.2 Comparison of the concentration of fluoride in urine samples from children from different endemic regions who were suffering from dental fluorosis at different levels of severity

For the data underlying this discussion, please refer to Table 1 and Table 2. There is no statistical significance related to the difference in the fluoride concentration across all of the endemic regions. (F=1.728, P>0.05). However, statistical significance is present for the difference between the fluoride concentration found in the urine samples of subjects who are, universally, suffering from dental fluorosis at the various degrees of severity. (F=5.104, P<0.01). By comparing these data, it is found that children suffering from severe dental fluorosis have a high level of fluoride in their urine samples, much higher than that of the other groups. This difference has a clear statistical significance (P<0.05). Urine samples of children suffering from moderate dental fluorosis are also found to contain fluoride at a level which is higher than that of the mild cases of dental fluorosis, suspected cases of dental fluorosis, and normal children. This difference also has statistical significance (P<0.05). Urine samples of children suffering from mild cases of dental fluorosis are found to contain fluoride at a level which is higher than that of normal children, and like the above cases, this difference has statistical significance (P<0.05). As for the children in the other groups tested, the difference found in the level of fluoride in their urine samples has no statistical significance (P>0.05).

Table 1 – IQ level and fluoride level in urine amongst children from different endemic regions (n=20)

Type of Endemic Region	Fluoride in Urine (x±s, mg/L)	IQ Level (x±s)
Severe endemic region	2.336±1.128	93.850±18.109
Medium endemic region	1.670±0.663	93.900±17.604
Mild endemic region	1.235±0.426	97.300±18.556
Comparative region	0.962±0.517	102.700±17.613

Table 2 - IQ level and level of concentration of fluoride in urine amongst children with varying degree of dental fluorosis

Degree of Fluorosis	Number of Subjects Examined	Fluoride in Urine (x±s, mg/L)	IQ level (x±s)
Normal	15	0.867±0.233	108.667±15.122
Suspected	13	1.094±0.355	102.077±15.058
Very mild	13	1.173±0.480	98.539±19.393
Mild	14	1.637±0.682 (a)	950428±14.685
Medium	12	2.005±0.796 (abc)	90.667±17.063
Severe	13	2.662±1.093 (abcd)	84.077±18.396 (a)

Note:
(a) In comparison to the normal group, P<0.05;
(b) in comparison to the suspected (cases of dental fluorosis) group, P<0.05;
(c) in comparison to the lightly impacted group, P<0.05;
(d) in comparison to the mild (cases of dental fluorosis group), P<0.05.

2.3 The comparison of intelligence among children from different regions and suffering different levels of dental fluorosis severity

There is no statistical significance found in relation to the difference in intelligence amongst children from the different endemic regions (F=0.862, P<0.05). However, statistical significance is present for the difference between the level of intelligence of the children who are universally suffering from dental fluorosis at various degrees (F=3.426, P<0.01). Children with severe dental fluorosis are found to have an IQ level which is lower than that of normal children (P<0.05), whereas the difference between the IQ levels of the other groups do not reach statistical significance (P>0.05). Looking at the distribution of IQ level amongst children suffering from dental fluorosis at various levels of severity, there is statistical significance in the difference of the rate of regression of IQ levels amongst the different groups (whose IQ measure at or less than 89). (X2=98.241,

P<0.05). When the level of severity of dental fluorosis increases, it is clear that the level of intelligence in the child decreases (or, put differently, children are seen to be lagging more and more behind the regular levels of IQ). See Table 3 for more details.

Table 3 - Percentage of lagging intelligence in children with varying degrees of dental fluorosis

Degree of Dental Fluorosis	Number of Subjects Examined	Number with Lagging Intelligence	Percentage (%)
Normal	15	1	6.67
Suspected	13	1	7.69
Very mild	13	3	23.07
Mild	14	5	35.71
Medium	12	6	50.00
Severe	13	7	53.85

There is no statistical significance related to the difference in the intelligence test results between the children from different endemic regions. (P>0.05). In terms of the ability of cognition and analogical comparison, there is likewise no statistical significance allocated to the difference between children with different degrees of dental fluorosis. (F=2.179, P>0.05; F=0.874, P>0.05). In terms of the ability of logical analysis, ability to relate, categorize, and abstract analysis, there is statistical significance to the difference between children with different degrees of dental fluorosis. (F=3.761, P<0.01; F=3.150, P<0.05; F=3.534, P<0.01). By comparing these data, it is found that children with different degrees of dental fluorosis (mild, medium, severe) were all found with results that are lower than the norm (P<0.05). As the disease progresses, the scores amongst these 3 groups continue to decrease. The results used to determine the subject's cognitive ability were calculated with the average score gathered from group A and group AB. See Table 4 for more details.

2.4 Correlation Analysis

By using Pearson's Correlation Analysis method, we have performed an analysis on the correlation between the level of intelligence in the children from the endemic regions, and the level of fluoride found in their urine samples. It is found that there is a considerable negative correlation between the intelligence level of children and the amount of fluoride found in their urine samples (r = -0.476, P<0.01).

4. Discussion

The most crucial period of development for the human brain is when one is still a fetus, and when one

Table 4 - Test results (various indicators) of children with varying degree of dental fluorosis

Degree of Fluorosis	No. Subjects Examined	Cognition	Group Comparison	Comparative Logic	Serial Relationship	Abstract Logic
Normal	15	9.600±1.692	8.533±2.997	8.133±2.997	7.333±2.870	3.067±2.052
Suspected	13	9.423±2.326	7.923±3.303	7.539±3.178	5.385±2.725	2.308±2.250
Very mild	13	8.231±2.743	7.154±3.805	6.692±3.449	4.923±2.842	1.231±1.235 a
Mild	14	8.143±2.804	6.786±3.068	5.143±2.958 a	4.214±2.424 a	1.143±1.167 a
Medium	12	8.083±3.096	6.583±2.999	4.750±3.646 a	3.750±3.306 a	0.667±0.779 a
Severe	13	6.654±3.085	5.539±3.126	3.461±2.222 ab	2.615±2.8444 a	0.539±0.660 ab
F value		2.179	0.874	3.761	3.150	3.534
P value		0.066	0.503	0.004	0.013	0.007

Note: (a) In comparison to the normal group, P<0.05; (b) in comparison to the suspected fluorosis group, P<0.05.

approaches infancy. An overdose of various types of elements, or lack thereof, in one's surrounding environment can have a highly negative impact on the development of the brain and nervous system. Research on the poisonous effect of fluoride in recent years has shown that an overdose of fluoride can be damaging to the central nervous system. If, during pregnancy, the mother ingests a higher than normal amount of fluoride, the fluoride can be transferred from the placenta to the actual body of the fetus and negatively affect its normal development. If, after birth, the child is continually subjected to living in an endemic environment, the child could be taking in more fluoride than needed. In particular, if the child has an overdose of fluoride between the time of birth up until the age of 8, the fluoride may penetrate the blood-cerebrospinal fluid barrier to affect the development of the child's brain in different phases. This will then cause different degrees of negative impacts on the child's intelligence level and functionality of his nervous system. (2, 3)

Another important indicator that bears on fluoride's ability to harm the subject's body and organs is the concentration of fluoride in urine. The present research has compared the difference between the urinary fluoride concentration in children with different degrees of fluoride poisoning. We have discovered that, if we do not consider the environmental impact of the endemic region on the subject's illness, the difference between the level of fluoride concentration in the urine samples from different children with various degrees of dental fluorosis does bear statistical significance ($P<0.01$). The more severe the symptoms of dental fluorosis in a subject, the higher the level of concentration of fluoride will be found in the subject's urine sample. This finding is consistent with the viewpoints of most published studies[4]. For this reason our research has focused on using the level of fluoride found in the children's urine as a way of inspecting the body's ability to withstand fluoride. Our research, however, did not find any difference in the level of fluoride in the urine samples of children affected by fluoride poisoning, despite their coming from different endemic regions. Such results seem to be in conflict with the results of previous research. This may be due to the method of analysis we used within the scope of this particular project.

Previously, researchers would not consider the impact of the actual disease on the subject as part of the controlled factors. Therefore, they would normally gather results that come up as positive. Our research is different in the sense that, while we use the random selection method, we had, simultaneously, looked into and analyzed the effect and impact of the actual disease (dental fluorosis), as well as that of other types of fluoride poisoning from the endemic region. This means that when we were analyzing the endemic regions, we had taken the bodily ailments of the subjects into consideration as a controlled factor. Similarly, we had taken the data associated with the endemic region into consideration when we were analyzing the actual symptoms and impact of the diseases. In using these controlled procedures, we have discovered that the differences between the IQ and urinary fluoride levels across the various endemic regions do not have statistical significance, whereas there is statistical significance when comparing the differences in these indicators across the varying levels of fluoride poisoning. These results indicate that changes in the level of intelligence, the fluoride concentration in urine, as well as other indicators, have an important correlation with the severity of dental fluorosis.

Researchers frequently use IQ as an indicator to measure the development of intelligence in a subject. There are numerous methods to test IQ. The one we have used for the present study is the CRT-CR. This test focuses on testing the basic elements of a child's intellectual ability, and the method is particularly suitable for group testing. The test results are not affected by factors such as culture, ethnicity and language, and can aptly demonstrate the way a child's intelligence moves from factual, intuitive/visual type of thinking to more abstract, logical thinking. This then reflects a child's intellectual development and level of maturity. We have therefore chosen this particular method to test our subjects' level of intelligence, as we believe this method to be reputable and effective.

The present research has also concluded that the difference in the level of intelligence between children suffering from various degrees of dental fluorosis does have statistical significance ($P<0.05$). As the disease progresses in severity, the child's IQ was seen to go

consistently downwards. Relevant research has shown that a child's level of intelligence (IQ) correlates with the fluoride level in urine ($P<0.01$). Such results are indicative of the fact that a high intake or overdose of fluoride has clear, negative impacts on the development of intelligence in children. This finding is most definitely consistent with the results of previous research on endemic fluorosis performed by other researchers[5,6].

The present investigation also focused on the impact of fluoride poisoning on the child's cognition and abstract logic. It was found that the difference of a subject's cognition and group comparison abilities are not statistically significant when comparing children with varying degrees of dental fluorosis. ($P>0.05$). These two indicators are primarily indicative of a subject's logical thinking. By contrast, the differences found in comparative logic, serial relationship, and abstract analysis capacities amongst children with varying degree of fluoride poisoning did reach statistical significance ($P<0.05$). As the disease progresses, scores attained for all 3 indicators decreased. These 3 indicators are therefore indicative of the harmful effect of fluoride poisoning on the children's mental development. It can be seen that such poisoning primarily effects the child's performance in abstract thinking, whereas it does little to effect the child's visual thinking ability. The likely reason for this is that as fluoride continues to build up inside the brain, the maturity of the brain (which is still undergoing development) would be affected. While children affected by fluoride poisoning are still capable to perform decently in simple neural exercises, they under-perform in more complicated neural activity.

It is worth mentioning that results presented here were gathered after excluding the factor of "regional influence". We believe such results, presented in this manner, are more reliable and reflect the truth of the situation. Additionally, our research has reinforced the finding that the severity of dental fluorosis (fluoride poisoning) directly correlates with a child's mental development. We therefore believe that this relationship merits greater acknowledgement from researchers and interested parties alike.

Looking at the results gathered from this study on the intelligence level of children with varying degrees of fluorosis, it is clear that fluoride's harmful impact on the central nervous system could be seen via the development of the subjects' intellect. In particular, said impact can be seen in the children's abstract thinking and logic. Accordingly, it is important that we raise our society's awareness of this issue.

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