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Original Article

Comparative Assessment of Intelligence Quotient among Children Living in High and Low Fluoride Areas of Kutch, India- a Pilot Study

***Ramesh NAGARAJAPPA, Piyush PUJARA, Archana J SHARDA, Kailash ASAWA, Mridula TAK, Pankaj AAPALIYA, Nikhil BHANUSHALI**

Dept. of Public Health Dentistry, Pacific Dental College and Hospital, Airport Road, Debari, Udaipur – 313024, Rajasthan, India

***Corresponding Author:** Email: rameshpcd@yahoo.co.in

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Abstract

Background: Long-term ingestion of large amounts of fluoride can lead to potentially severe skeletal problems and neurological consequences. The study was conducted to assess and compare intelligence quotient of children living in high and low fluoride areas in Kutch, Gujarat, India.

Methods: A cross-sectional descriptive survey was conducted among 100 school children aged 8 to 10 years, living in Kutch District, Gujarat, India during July 2012. Mundra (2.4 to 3.5 mg/L) and Bhuj (0.5mg/L) were the two villages randomly selected to represent the high and low water fluoride areas respectively. Seguin Form Board Test was used to assess the intelligence quotient (IQ) level of children. Descriptive statistics and independent sample t-test was used for analysis.

Results: Mean scores for average, shortest and total timing category were found to be significantly higher ($P<0.05$) among children living in Mundra (30.45±4.97) than those living in Bhuj (23.20±6.21). Mean differences at 95% confidence interval for these timings were found to be 7.24, 7.28 and 21.78 respectively. In both the villages, females had lower mean timing scores than males but the difference was not statistically significant ($P>0.05$).

Conclusion: Chronic exposure to high levels of fluoride in water was observed to be associated with lower intelligence quotient.

Keywords: Children, Cross sectional, Fluoride, Intelligence quotient, Seguin form board

Introduction

Fluoride, a double-edged sword, embraces beneficial effect, but excessive exposure can give rise to number of adverse effects. These may range from mild dental fluorosis to crippling skeletal fluorosis as the level and period of exposure increases. Apart from this, there are reports that excess fluoride consumption promotes cancer, hip fracture, leads to still birth or birth defects and has detrimental neurological effects. Research on fluoride poisoning in the last few years has revealed that high fluoride intake can damage the central nervous system, and that fluoride can pass through the placental barrier to damage the fetus. The negative effect of fluoride on children in the high fluoride area is mainly due to: (i) disruption of proper development in the womb due to the mother's intake of fluoride being passed to the fetus through the placenta, or (ii) childhood in a high fluoride environment. Either or both of these could lead to neuron damage, developmental difficulties, or neurotransmitter dysfunction (1, 2). In children, the most reported effect is on cognitive capacities, particularly intelligence reduction. Children who live in a fluorosis area were found to have five times higher odds of developing low IQ than those who live in a nonfluorosis area or a slight fluorosis area (3).

Elevated concentration of naturally occurring fluoride (F) in drinking water is a worldwide problem. Many Asian and Latin American countries have reported concentrations of F often exceeding the World Health Organization (WHO) guideline values of 1.5mg/L or their prevailing national standards (4). India lies in a geographical fluoride belt, which extends from Turkey to China and Japan through Iraq, Iran, and Afghanistan. Of the 85 million tons of fluoride estimated in the earth's crust, nearly 12 million tons are in India (5). About sixty million people are living in 200 districts of 20 states which are endemic of fluorosis and around two percent children suffer from dental fluorosis (6). Fifty to hundred percent districts are affected by fluorosis in Andhra Pradesh, Gujarat and Rajasthan (7).

Intelligence has been defined in many different ways including, but not limited to, abstract thought, understanding, self-awareness, communication, reasoning, learning, having emotional knowledge, retaining, planning, and problem solving. An intelligence quotient, or IQ, is a score derived from one of several standardized tests designed to assess intelligence. IQ scores are used as predictors of educational achievement, special needs, job performance and income. There is considerable relationship between a person's degree of intelligence and range of activities, the level of achievement and the depth of understanding possible to him (8).

There are many factors that influence intellectual development; besides the major influence of a high fluoride environment, the occupation and education of the parents also appears to play a definite role. Although the effect on the IQ of the child does not seem to be affected by the degree of fluorosis, nevertheless there is a correlation between dental fluorosis and the intellectual ability. In a meta-analysis performed in China to review studies on fluoride and IQ between 1988 and 2008, a consistent and a strong association between exposure to fluoride and low IQ was found (3). Mundra is a port town located on the south coast of Kutch, Gujarat. Fluoride level in drinking water in Mundra was found to be 2.4 to 3.5 ppm which was highest in the entire Kutch District (9). Since environmental factors related to health can lead to significant cognitive impairment, particularly if they occur during childhood when the brain is growing (8) and owing to the paucity of literature (1, 2) the present pilot study has been undertaken with an objective to assess and compare the intelligence quotient of children living in high and low fluoride water area of Kutch, Gujarat.

Methods

Study design, study setting and study population

A descriptive cross-sectional study was conducted among 8 to 10 years old school children living in Kutch District, Gujarat, India, during July 2012.

Ethical considerations:

Before the beginning of the study, ethical approval was obtained from the ethical committee of Pacific Dental College, Udaipur. Official permission to examine the school-children was obtained from the school authorities of both schools and written informed consent was obtained from parents of children who participated in the study.

Sample selection

Prior to instigation of the study, list of all villages in the Kutch District was obtained from municipality of Kutch. Information about fluoride level in drinking water was obtained from Water and Sanitation Management Organization, Gujarat. Villages were categorized according to fluoride level in water as high fluoride area (≥ 1.5 mg/L) and low fluoride area (<0.7 mg/L). After that, one village each from high fluoride area (Mundra having fluoride level 2.4 to 3.5mg/L) and low fluoride area (Bhuj having fluoride level 0.5mg/L) with similar socioeconomic conditions and level of education were selected. The information on the list of Primary schools in Mundra and Bhuj was obtained from the district education officer. One school from both the villages having same medium of education (Hindi) and parents with middle social class having undergraduate level of education only were selected and fifty children were selected from each school between 8 to 10 years of age (Data not shown).

Inclusion criteria for the Mundra children were: (i) Signs of Moderate fluorosis (according to Dean's Fluorosis index) (ii) Those born and brought up in the study areas. Exclusion criteria: (i) Children who had a change in source of water since birth (ii) Those suffering from genetic, congenital or acquired diseases related to nervous systems in past or present.

Study instrument

IQ was tested using Seguin Form Board Test to assess visual discrimination, matching and eye-hand coordination. Test materials consisted of ten differently shaped wooden blocks and a large form board with recesses corresponding to these shapes (10). The testing was administered individually to each child, in compliance with the guidelines and direction of the Seguin form board test manual. Retesting was done on 10 children after a day so as to check the reliability of the testing protocol (Kappa=0.8).

Methodology

On the pre decided days, the investigator visited both the schools. With the help of school authorities a class room was arranged. Fifty children were selected randomly and they were made to sit in the classroom. IQ testing kit was placed on the table and children were asked to come one by one and perform the test. While administering the test, these blocks were taken out by the examiner and stacked in front of the subject who had to put them back as quickly as he/she could. The following instructions were given to the students: "Here are ten wooden blocks which have to be put by you in the appropriate space. Be as fast as you can. You will be allowed only three trials." Prior to starting the test proper, a 'ready' signal was given and at the second signal 'start', child started placing the wooden blocks. The timing with stop watch was matched with the child picking up the first block. The task was repeated three times. Time, in seconds was obtained for each trial by investigator, who seated beside and slightly to the back of the subject to be tested. The total time score of each subject in three trials, their average and the shortest time score were obtained.

Statistical analysis

The data was coded and entered into Microsoft Excel spreadsheet. Analysis was done using SPSS version 15 (SPSS Inc. Chicago, IL, USA) Windows software program. The variables were assessed for normality using the Kolmogorov-Smirnov test. Descriptive statistics were calculated. Means of both groups were compared by independent student *t*-test. Level of significance was set at P=0.05.

Results

Among all, there were 26 males and 24 females from the each village. Mean scores for average timing of males and females at Mundra were 31.24±4.45 and 29.59±5.44 respectively and at Bhuj were 23.53±7.53 and 22.84±4.51 respectively. In both the villages, females had lower mean timing scores than males but the difference was not statistically significant (P>0.05) (Table 1).

Mean scores for average timing category was found to be significantly higher (P<0.05) among children living at Mundra (30.45±4.97) than among children living at Bhuj (23.20±6.21). Similarly statistically significant difference were evident with respect to shortest (P<0.05) and total (P<0.05) mean timing scores among children of both regions (Table 2).

Discussion

Research conducted in recent years has demonstrated conclusively that fluoride can cause direct damage to central nervous system function.

Table 1: Comparison of the mean scores for average timing by gender

Villages	n = 100		Males average timing (sec) [Mean±SD]	Females average timing (sec) [Mean±SD]	p value	Mean difference ± Standard. error difference	Confidence interval of the difference		Level of fluoride in drinking water
	Males	Females					Lower	Upper	mg/L
Mundra	26	24	31.24±4.45	29.59±5.44	0.246	1.64±1.40	-1.17	4.46	0.5
Bhuj	26	24	23.53±7.53	22.84±4.51	0.250	1.64±1.41	-1.20	4.49	2.4-3.5

Statistically significant difference at $P<0.05$
Test of significance- Student *t* test, SD: Standard Deviation

Table 2: Comparison of the mean timing scores of the Mundra (n=50) and the Bhuj (n=50) children

Timing	Villages (fluoride level mg/L)	Mean±SD (sec)	Mean difference ± Standard. error difference	*P* value	Confidence interval of the difference	
					Lower	Upper
Average	Mundra (2.4 to 3.5)	30.45±4.97		0.002*	5.01	9.48
	Bhuj (0.5)	23.20±6.21	7.246±1.12		5.01	9.48
Shortest	Mundra (2.4 to 3.5)	28.86±5.33		0.003*	4.99	9.57
	Bhuj (0.5)	21.58±6.17	7.280±1.15		4.99	9.56
Total	Mundra (2.4 to 3.5)	91.40±14.97		0.005*	15.06	28.49
	Bhuj (0.5)	69.62±18.65	21.78±2.28		15.06	28.49

* indicates statistically significant difference at $P<0.05$
Test of significance- Student *t* test, SD: Standard Deviation

The rate of Down's syndrome in regions with endemic fluoride poisoning is also found to be high (11). The present study conducted among two villages with high (Mundra) and low (Bhuj) fluoride levels in drinking water matched for variables such as standards of living, medical facilities, levels of development and educational quality. In total, hundred school students between the ages of 8 to 10 years were tested to investigate the intellectual ability of children. The results indicated that the mean scores for average, shortest and total timing category were found to be significantly higher ($P<0.05$) among children living at Mundra than among children living at Bhuj.
IQ has been used to measure intellectual ability for almost one hundred years, and there are many standards of measuring IQ (3). In the present study investigators have used Seguin Form Board Test which finds application in assessment of general intelligence of children in pre-primary and primary school years (12); or for measuring visual discrimination and matching, eye-hand coordination and cognitive-perceptual abilities in children (13). It was observed that Mundra children were slower in performing this test than Bhuj children. This finding was in accordance with other study where it was discovered that kids in low fluoride area were much faster on the Form board (10).
An analysis of performance on the SFB based on gender variable indicated that girls had faster and better performance than boys of same age levels ($P<0.001$). Similar observations were reported by David and Virginia (1972), where girls took on an average four seconds less to complete the board than boys (13).
The impact of fluoride on IQ has been reported in several studies by Chinese researchers (3, 14). The average IQ of children living in the area with high fluoride content in the drinking water was significantly lower than children with standard water fluoride levels (15). These results are consistent with findings reported by Xiang et al., (2003) who confirmed a decrease in children's neurobehavioral ability when exposed to elevated fluoride levels (16). This association was attributed to following reasons- high levels of fluoride absorbed in

the blood forms lipid soluble complexes which cross the blood-brain barrier and accumulate in cerebral tissues. The penetrated fluoride complexes adversely affect the CNS development by different neurotoxic and exciotoxic mechanisms, such as free radical generation, inhibition of antioxidant and mitochondrial energy enzymes and inhibition of glutamate transporters (17). The structural and functional alterations in CNS, specifically in the fetal period and the first 8 years of life, may lead to learning and intellectual deficits and cognitive dysfunctions (17). In addition, fluoride interferes with the activity of the thyroid gland, which has a deleterious effect on brain development and function in children (18). It is well accepted that the neurobehavioral development may be influenced by many genetical, socioeconomical and geographical factors (19). Thus, we have recruited our samples from a homogenous rural population in Mundra and Bhuj, diminishing the effect of some environmental and inherited factors, yet it is obvious that complete exclusion of such factors is impossible. The occupation and education of the parents also appears to play a definite role. Yongxiang et al., 1991 discovered that the IQs of children born into an "employed" household was higher than those born into a farming household, and that the IQ levels of the children increased along with the education level of their parents (20). This indicates that a positive educational influence from the family is a benefit to child intellectual development. Therefore, strict uniformity requirements must be enforced when selecting an area for study, determining the test subjects, etc. The present study paid special attention to this aspect; and the occupation and education levels were basically matched in both the endemic and control area.

In the present study, the effect of fluoride concentration on the child's IQ was assessed; however, it is possible that other trace elements in drinking water may have some neurological side effects (21). One of the limitations of this study was that Seguin Form Board Test may not give us a complete picture of mental development. It must be supplemented by other comprehensive tests such as Stanford-Binet or Wechsler Intelligence Scale. As regression analysis of IQ level with the amount of fluoride in water was not done, exact correlation between IQ and fluoride level could not be established in this study. Apart from these shortcomings, other factors like emotional tension, anxiety, and unfamiliarity with the testing process might also have greatly affected test performances. Considering these factors and the fact that this was a preliminary study done on a small scale with small sample size we cannot generalized these results to other communities. Therefore further investigation to clarify the nature of the relationship between fluoride and intelligence are clearly desirable.

Conclusion

The comparison of both areas in the present study showed clear differences in IQ which may support the hypothesis that excess fluoride in drinking water has neurological toxic effects. Therefore, a close monitoring of fluoride levels in local water supplies from areas with endemic fluorosis and implementing public health measures to reduce the fluoride exposure levels in high fluoridated regions seem necessary.

Ethical Considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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