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Original Research Article

Does fluorosis affect the intelligence profile of children? A cross sectional analysis of school children of district Una, Himachal Pradesh, India

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ABSTRACT

Background: The sub Himalayan region of the country does not fall in highly endemic region for fluorosis. Researchers over the world have hypothesized that high fluoride level in water is the cause of low intelligence level among children and adolescents. We aim to establish the association of high and low fluoride levels with intelligence level and oral health status of children aged 10-14 years in district Una, Himachal Pradesh.
Methods: The study was conducted in randomly selected 15 government high schools of district Una. Study population included 600 students of government run schools in age group 10-14years. This ICMR funded project was carried out from 2014 through 2017. Dean fluorosis index was used to study fluorosis level and Intelligence test was conducted on students by using Raven's standard progressive matrices questionnaire.
Results: The 60% of sites studied for fluoride levels were found to have >0.5 ppm fluoride level in water and none of them with level more than 1 ppm. Prevalence of dental fluorosis was 12.2%. Dental caries and high Dental Aesthetic Index were positively associated with high fluoride level in water. Low intelligence level of adolescents was not significantly associated with high fluoride level (OR;95% CI: 1.34; 0.72-2.49).
Conclusions: This sub Himalayan region is not endemic for fluorosis however lower level of fluoride is observed in many sites. Fluorosis was not significantly associated with intelligence hence indicating towards multifactorial causation of disease.

Keywords: IQ, Adolescents, Sub Himalayan, Fluoride, Water

INTRODUCTION

Fluorine is often called a double edged sword. Fluorosis is a public health problem caused by excess intake of fluoride through drinking water/food products/industrial pollutants over a long period. Its deficiency leads to dental caries. In India fluorosis is mainly due to excessive fluoride in water except in parts of Gujarat and Uttar Pradesh where industrial fluorosis is also seen. The desirable limit of fluoride as per Bureau of Indian Standards (BIS) is 1 ppm (parts per million or 1 mg per litre).[1]

In 2008-09, Ministry of Health and Family Welfare, Government of India launched a National Programme for Prevention and Control of Fluorosis (NPPCF) with the

aim for prevention, diagnosis and management of fluorosis in endemic areas. The first step by the programme was establishing a baseline surveillance of fluorosis in school children and community. This started with six districts with additions in subsequent years.[2]

Literature from across the country has mainly focused on the prevalence of fluorosis.[3] Apart from its effect on bones and teeth; evidences across the world hypothesize that children exposed to excessive fluoride in water tend to have lower intelligent quotient (IQ). Few researchers from endemic pockets in country have tried to establish association between fluoride levels and IQ among children.[4-11] The fluoride levels in water bodies differ from region to region and are not uniform. And there is paucity of evidence in reference to fluorosis from Himalayan states of country both from national programme and independent research.

Therefore, the present study aims to establish the association of high and low fluoride levels with intelligence level and oral health status of children of 10-14 year of age in district Una, Himachal Pradesh.

METHODS

Study area and setting

District Una is in South western part of Himachal Pradesh and is situated in east of outer Shivaliks. It lies within North latitude $31^0$17'52" and $31^0$52'0" and East longitude $75^0$58'2" and $76^0$28'25".Una district is bounded by the river Beas on the north and the river Sutlej in the east. The population of district according to census 2011 was 5,21,057 where 10-14 years of age contributed to 10.3% of population.[12]

Study population

This project was carried out in government high schools of district Una of Himachal Pradesh from July 2014 through 2017. There are total 42 high schools of district Una spreading over five blocks namely; Una, Amb, Haroli, Gagret, Dhundla. On an average 40-50 school children of 10-14 year age group were present in each school and a total of 15 schools were surveyed for the study purpose. It was hypothesized while planning the project that by the age of 5 years the teeth in oral cavity are deciduous and chances of detecting the fluorosis are lower as compared to higher age groups. Also the intelligence level of a child can be better assessed after 8 years of age. Those who did not consent to participate and children who were not enrolled in the school from last 5-8 years were excluded. Also children who have a history of congenital or acquired neurological disorder or head injury were excluded from the study.

In order to complete geographical coverage of study area, 3 schools were selected randomly (lottery method) from each of five blocks of the district (3×5=15).

Sample size

To detect 40% prevalence of malocclusion or 60.0% of prevalence of dental fluorosis, considering 1.5 relative risk at 95% confidence level and 80.0% study power, a sample size of 369 children is calculated.[9] Based on 10% non response 405 children of age 10-14 years were screened for oral hygiene, mal-occlusion and dental fluorosis. In order to keep reliable and relevant estimate a sample size of 600 school children will be kept. These children were selected from all the government high schools based upon population proportion to size.

Sampling

Written permissions were obtained from the Education department of district Una and the headmasters of concerned schools. Prior consent was taken from all the parents of the children to conduct the survey. Water samples were collected from the selected schools in polyethylene bottle. Water sample collection form was filled. Data regarding date and time of water sample collection, collection site name; global positioning system coordinates were recorded for exact location. A 200 ml of water sample was collected in sterile bottle and labelled with marker.

The dental checkup was performed by a dentist (principal investigator) and his team which consisted of a medical social worker, and a health worker. The schools were mostly visited on Saturdays after taking appointment with the Principal as the students had more of free classes on this day of week. The four classes of the school (5^{th}-8^{th}) were included in the study. On an average all the government schools included in the survey had around 15-16 children in each of the above mentioned classes. The dentist examined all the students of these classes, to achieve a sample size of 40 in each school. One school was visited twice to complete the sample size.

Study tools

The socioeconomic status of the study participants' families were assessed using Uday Preekh Scale. To assess the prevalence of Fluorosis we used Dean Fluorosis index.[13] Intelligence test was conducted on students by using Raven's standard progressive matrices questionnaire.[14] The children's scores were converted to percentile and specific grades were allotted, based on the following criteria:

Grade I: Intellectually superior − If the score lies at or above the 95^{th} percentile for that age group.

Grade II: Definitely above average − If the score lies at or above the 75^{th} percentile for that age group.

Grade III: Intellectually average − If the score lies between the 25^{th} and 75^{th} percentile for that age group.

Grade IV: Definitely below average in intellectual capacity − If the score lies at or below the 25th percentile for that age group.

Grade V: Intellectually impaired − If the score lies at or below the fifth percentile for that age group.

The grades and intelligence are inversely related in the Raven's Standard Progressive Matrices.

Ethical clearance

The ethical committee for biomedical research at Dr. Rajendra Prasad Government Medical College, Kangra at Tanda, H.P. approved the protocol for the project.

Water analysis

Water sample analysis was carried out in Department of Environment Science, Punjab University, Chandigarh. The water sample was tested with the help of ion exchange method using specific F-electrode method.

Data and statistical analysis

The level of fluoride in water was represented in the unit of parts per minute (ppm). The data on intelligence level and other outcomes were presented in form of proportions. The Chi square test and standard error of difference of proportion test was applied to detect significant difference between proportions. Level of significance was set at 5%.

RESULTS

In the present study area the source of the water supply was ground water and which was lifted with pump and stored in large reservoirs. This method for water supply was implemented under the state government scheme "*uthao pey jal pariyojna*" (lift water scheme) to the entire district. In these fifteen villages, fifteen water samples were tested for fluoride level. The water sample was collected from the school, from where the children were recruited. After water sample analysis, the study area was divided into two categories, fluoride content (>0.5 ppm) and fluoride content (<0.5 ppm) in drinking water source in schools. Among the study settings nine areas were considered as those with high level of fluoride (>0.5 ppm) (Table 1) (Figure 1).

Majority of study participants were males (56.8%) and belonged to middle class socioeconomic status (53.6%). Oral health status was examined for caries, Oral hygiene index, Gingival and periodontal assessment. The analysis showed the prevalence of caries was similar among males and females mentioning about half of student were affected with dental caries (53.8%). Proportion of good oral hygiene was observed to be higher among females (25.4%) as compared to males (17.0%). Gingival and periodontal health was good among 27.8% in males and 29.3% in females. Dental aesthetic index score in the examined students observed that majority 81.5% had score less than 25 indicating that these students do not require any treatment. Elective treatment was required only in 13.6% students with DAI 26-30, and mandatory treatment was indicated in 0.6% students only with DAI score of more than 36.

The risk assessment in terms of odd ratio demonstrated that the risk of dental caries is 1.5 times higher among children with high level of water fluoride, (OR: 1.49; 95%CI: 1.07- 2.07). High odds for DAI score of more than 25 was observed in children with high level of water fluoride with an OR of 1.77 (95% CI: 1.15-2.73) and was statistically significant. This denotes higher mal occlusion. Intelligence level was clubbed into grade (3-5) and (1-2) due to very small number in each cell. The comparison between low (3-5) and high (1-2) level of intelligence observed that risk of high fluoride level with relation to poor intelligence grade was insignificant (OR: 1.34; 95%CI: 0.72-2.49) (Table 2).

Table 1: Water samples and their fluoride content collected from selected government schools, Una, Himachal Pradesh.

Study setting from where water sample obtained	Fluoride content (ppm)	Study setting from where water sample obtained	Fluoride content (ppm)
1	0.57	9	0.63
2	0.42	10	0.66
3	0.40	11	0.67
4	0.68	12	0.44
5	0.63	13	0.32
6	0.41	14	0.67
7	0.52	15	0.52
8	0.31		

Source of water sample: Ground water for all.

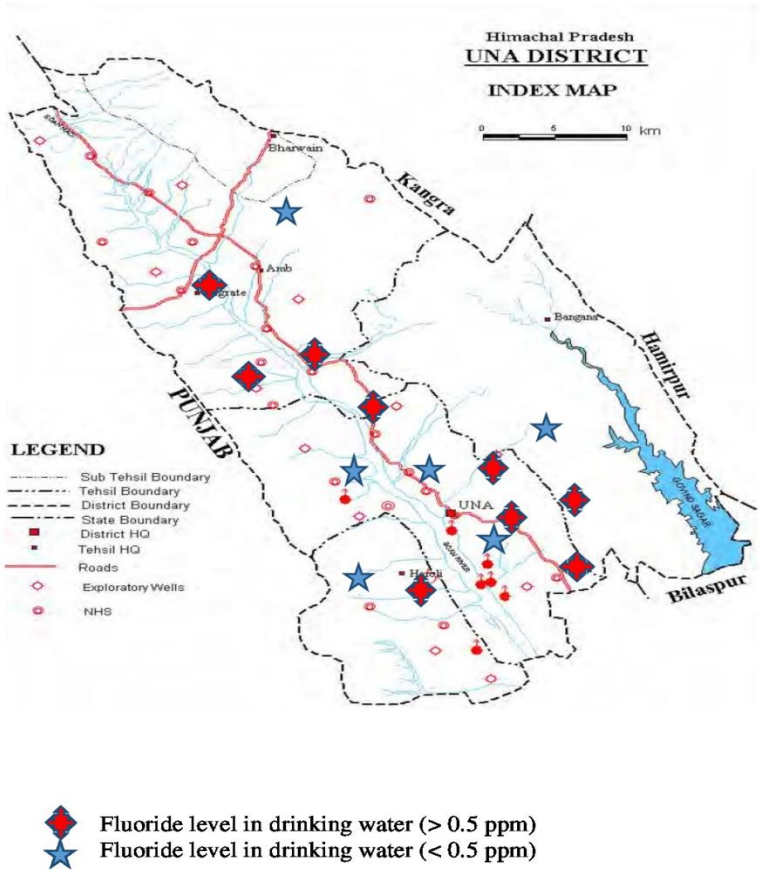

Figure 1: Map of district Una according to high (>0.5 ppm) and low (>0.5 ppm) level of fluoride in drinking water.

Table 2: Association between dental caries, DAI score and fluoride level among the school children of Government schools in Una district, Himachal Pradesh.

Fluoride value	Dental Caries present N (%)	Dental Caries absent N (%)	Total (%)	OR (95%CI), P value
>0.5 ppm	204(57.9)	148 (42.1)	352 (100)	1.49 (1.07 2.07), 0.01
<0.5 ppm	119 (44.4)	129 (55.6)	248 (100)	
Total	323 (53.8)	277 (46.2)	600 (100)	
Fluoride value	**DAI score >25 N (%)**	**DAI score <25 N (%)**	**Total (%)**	
>0.5 ppm	90 (24.2)	281(75.7)	371 (100)	1.77 (1.15- 2.73), 0.00
<0.5 ppm	35 (15.2)	194 (84.7)	229 (100)	
Total	125 (20.8)	475 (79.2)	600 (100)	
Fluoride value	**Intelligence grade 3-5 N (%)**	**Intelligence grade 1-2 N (%)**	**Total (%)**	
>0.5 ppm	355 (93.4)	25 (6.5)	380 (100.0)	1.34 (0.72-25.49), 0.35
<0.5 ppm	201 (91.3)	19 (8.6)	220 (100.0)	
Total	556 (92.7)	44 (7.3)	600 (100)	

Dental fluorosis was observed among 12.2% of students. Its prevalence was found to be 12.3% in males and 11.9% among females.(Table 3) None of children with grade 1 and grade 5 level of intelligence was observed. Intelligence level was majorly falling in grade II to grade III. Majority of children were having grade III level of intelligence (83.5%), it was observed as a dominant category across both high and low level of fluorosis. IQ level and gender did not show significant association. Different categories of fluorosis were compared among the levels of intelligence of study participants. Grade III and IV level intelligence are compared with grade II level. Significant difference was observed across level of intelligence with level of fluoride in water (Table 4).

Table 3: Severity of dental fluorosis in examined school children from government schools, Una, Himachal Pradesh.

Parameter	Male N (%)	Female N (%)	Total N (%)	P value
Normal	299 (87.6)	228 (88.0)	527 (87.8)	0.74
Questionable	23 (6.7)	16 (6.1)	39 (6.5)	
Very mild	10 (2.9)	11 (4.2)	21 (3.5)	
Mild	5 (1.4)	3 (1.1)	8 (1.3)	
Moderate	3 (0.8)	1 (0.3)	4 (0.6)	
Severe	1 (0.2)	0 (0)	1 (0.1)	
Total	341	259	600	

Table 4: Comparison of intelligence level grade II, III and IV across levels of fluorosis among government school children of district Una, Himachal Pradesh.

Fluorosis level	Intelligence level						
	Intelligence Grade II N (%)	Intelligence Grade III N (%)	P value	Intelligence Grade II N (%)	Intelligence Grade IV N (%)	P value	Total (%)
Normal	28 (63.6)	479 (95.6)	0.00	28 (63.6)	20 (36.3)	0.00	527 (87.8)
Questionable	9 (20.4)	14 (2.7)	0.00	9 (20.4)	16 (29.0)	0.32	39 (6.5)
Very mild	3 (6.8)	5 (0.9)	0.002	3 (6.8)	13 (23.6)	0.02	21 (3.5)
Mild	2 (4.5)	2 (0.3)	0.002	2 (4.5)	4 (7.2)	0.57	8 (1.3)
Moderate	2 (4.5)	1 (0.1)	0.00	2 (4.5)	1 (1.8)	0.43	4 (0.7)
Severe	0 (0.0)	0 (0.0)	N/A	0 (0.0)	1 (1.8)	0.37	1 (0.2)
Total	44 (100.0)	501 (100.0)		44 (100.0)	55 (100.0)		600 (100)

DISCUSSION

The fluoride level of the 15 sites studied revealed that 40% of the sites were below minimum level of fluoride that is 0.5 ppm. None of the sites had level more than 1 ppm. High levels of Fluoride were reported in 230 districts of 20 States. In the endemic States, the geological crust is heavily loaded with fluoride bearing minerals and this fluoride leaches out into the drinking water. The drinking water fluoride so far detected in the country ranges from 0.2 to 48 mg/ litre.[2]

There was no student in the study population in the current study that could be categorized as intellectually superior (grade I IQ). The proportion of average and below average IQ was marginally higher in high fluoride area (>0.5 ppm) as compared to low fluoride area in our study but the differences were not statistically significant. Broadbent et al., reported similar results as ours where there was no apparent difference in IQ because of fluoride exposure.[15] Aravind et al, conducted a similar study on adolescents of rural Kerala and demonstrated that the proportion of children with IQ grades II and III was larger in regions with low fluoride concentration level in drinking water (3.12%, 81.25%) and regions with medium fluoride concentration in drinking water (8.3%, 81.25%) compared to high fluoride areas (0, 40.62%), and the difference was statistically significant.[16] Sebastian et al, demonstrated a higher percentage of children with above the normal IQ range in the normal and low-fluoride group compared to high-fluoride group. But in our study the proportion of above average IQ was lower in low fluoride zone also as compared to average and below average group.[7] Saxena et al, Shivaprakash et al, and Razdan et al, in their study have also demonstrated that intellectual capacity of children decreases with increase in the fluorosis grade.[8,11,17] Trivedi et al, reported that an elevated fluoride level would affect higher levels of intelligence more vigorously than normal and low intelligence levels.[18] There was contrast reports presenting a statistically significant difference in IQ levels of children belonging to high, medium, and low fluoride areas, by Khan et al and Mondal et al.[5,6]

The functional and biochemical harm to the nervous system during the prenatal and development periods of infancy and childhood because fluoride can cross the blood brain barrier leading to lack of IQ in children exposed to high levels of fluoride is mainly; however, it is also due to factors involving variation in biological susceptibility, environmental conditions, and measurement errors.[19] Xiang et al, discussed about decreasing IQ with increasing age but reason is still not clear. Possibly, the total intake of fluoride/kg body weight per day or lifetime was the main cause; also adolescence is a sensitive period for the effect of fluoride on children's intelligence development.[20] The current study area lies in the foothills of Dhauladhar ranges, which are endemic for hypothyroidism. In a low iodine

area, impairment of intelligence could also occur through the development of hypothyroidism or clinical/subclinical cretinism.[21] Susheela et al also found in their study that elevated fluoride uptake may cause iodine deficiency in fluorotic individuals, even when they reside in non-iodine deficient areas.[22]

In the present study the overall prevalence of dental fluorosis among the study population was 12.2%. This estimate in our study is very less as compared to other studies conducted in other states of India in the same age group. A higher prevalence of 30%-94.9% was reported from the Haryana, 13%-100% from Karnataka, 71% from Nalgonda in Andhra Pradesh and 35.6% from Kerala.[10,23-25] Srikanth, in 2009, pointed out that in India about 62 million people are suffering from various levels of fluorosis, of which 6 million are children below the age of 14 years.[26] Rajasthan and Gujarat in North India and Andhra in South India are worst affected.

More than half of study population was diagnosed with dental caries. Similar prevalence was reported by Shekhar et al., from fluoride endemic belt of Andhra Pradesh.[10] In another study conducted in Vadodara District, the risk of dental fluorosis was higher in areas with high fluoride content in drinking water, but the rate of dental caries was low in the same area.[9] In our study in high fluoride zone the prevalence of caries was statistically higher than low fluoride zone. Goodarzi et al., in their systematic review reported the pooled prevalence of dental caries in low fluoride (<0.7 ppm) and moderate social class group as 76.6% (95% CI, 73.9%–79.3%) as compared to high fluoride group (69.1% (95% CI, 64.4%–73.9%). The prevalence increased in low social class group.[27]

Elective and mandatory treatment for malocclusion was required in 14.2% population in our study. The prevalence of malocclusion among 9-12 years from hilly terrain of same state was 12.5% and required orthodontic treatment.[28] Significant positive association of high DAI score of more than 25 was observed among children with high level of water fluoride (24.2% in high fluoride zone). Shekhar et al, from Nalgonda among 15 years old reported that 27.6% of the study subjects in areas with below optimal fluoride concentration, 13.6% in the areas having optimal fluoride concentration, and 8.8% in the areas with above optimal fluoride concentration had DAI score of more than 25.[29] Consistency of diet plays a vital role in the development of jaw musculature and dentition. It has been demonstrated in some animal studies that consumption of soft and refined foods results in less biting force and less biting duration which in turn affects stimulation of the jaw bones and oral musculature leading to inadequate development of jaws and oral musculature along with improper eruption of teeth.[30]

Interaction of fluoride with lead and arsenic has not been dealt with in this study hence one of the limitations. Iodine as a confounder also needs to be evaluated in future projects from Himalayan regions of the country. The nutrition status of children and of their mothers' during pregnancy also plays confounding roles. A cohort needs to be established and studied from this region which has potential to become endemic for fluorosis in coming decades.

CONCLUSION

This project to study association between intelligence and fluoride level was first of its kind from the Sub Himalayan region. The 60% of sites studied for fluoride levels were found to have >0.5 ppm fluoride level in water. But none of them with level more than 1 ppm. Prevalence of dental fluorosis was lower than other parts of country. Risk of dental caries and DAI were more prevalent in areas with high fluoride level in water. Low intelligence level of adolescents was not significantly associated with high fluoride level hence indicating towards multifactorial causation of disease.

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