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Association of Hypertension, Body Mass Index, and Waist Circumference with Fluoride Intake; Water Drinking in Residents of Fluoride Endemic Areas, Iran

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Abstract

Hypertension is becoming a global epidemic for both rural and urban populations; it is a major public health challenge in Iran. Fluoride can be a risk factor for hypertension**.** Cross-sectional analysis was conducted in two study areas to assess the relation of fluoride with blood pressure prevalence, BMI, waist circumference, and waist-to-hip ratio (WHR) among different age groups in both sexes. The mean value of fluoride concentration in the drinking water from the four study villages varied from 0.68 to 10.30 mg/L. The overall prevalence of HTN and prehypertension in all subjects was 40.7%. The prevalence of isolated systolic hypertension, isolated diastolic hypertension, systolic-diastolic hypertension, and prehypertension in the total sample population was 1.15, 0.28, 9.53, and 29.76%, respectively. The odd ratio of hypertension in residents who drank water with high fluoride levels was higher than that in residents who drank water with lower level of fluoride (OR 2.3, 1.03–5.14). Logistic regression results showed that age ($P < 0.001$), sex ($P = 0.018$), BMI ($P = 0.015$), and the fluoride level in drinking water ($P = 0.041$) had a significant relationship with increased blood pressure. There were no statistically significant correlations between fluoride and BMI, hip circumference, and waist to hip ratio (WHR). The findings of this study are important for health care personnel and policymakers.

Keywords Drinking water · Fluoride endemic · Hypertension · BMI · Poldasht · Iran

Abbreviations

ISH	Isolated systolic hypertension
DBP	Diastolic blood pressure
IDH	Isolated diastolic hypertension
WHR	waist-to-hip ratio
SDH	Systolic-diastolic hypertension
MAP	Mean Arterial Pressure
HTN	Hypertension
TDS	Total dissolved solids
F	Fluoride
TH	Total hardness
ALK	Alkalinity
BMI	Body mass index
SBP	Systolic blood pressure
WHO	World Health Organization

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Introduction

Today, the concerns of human societies are increasing in relation to a variety of diseases associated with environmental factors [1, 2] Although there are limitations in the direct connection of diseases with environmental factors, there has been a lot of research in this area that indicate this association and increase existing concerns [3–5].

According to the World Health Organization (WHO), 23% of deaths in 2012 were due to environmental factors, with 12.6% of deaths occurring annually because of unhealthy environment. Environmental risk factors, such as air, water, soil pollution, exposure to chemicals, and ultraviolet radiation, play a role in causing hundreds of diseases and injuries [6]. Fluoride is an element that is widely distributed in all sources of water, air, and soil, so humans can receive this ion in many ways. Some of these ways are through breathing, skin contact, soil, food, dental products, and drinking water. One of the main issues is fluoride in drinking water because fluoride concentration in drinking water has been constant for many years, and humans daily consume 2–3 L of water [7–11]. Although it has been reported that concentrations of less than 1 mg/L of fluoride in drinking water can have a positive effect on the health of teeth and bones at young ages, fluoride concentrations above 4 mg/L in the long run can have harmful effects on human health [12–15]. Examples of the acute effects of contact with fluoride that have been reported include the following: genetic mutations, birth defects, disorders of weight and height in infants, effect on fertility, the kidney, and the liver, and neurological effects. In children, it affects intelligence, causes pre-acne and affects the thyroid hormone. Increasing allergy in humans and diseases have been traced to fluorosis, which also causes skeletal disease in endemic areas where drinking water sources have a high fluoride content, such as in parts of India, Africa, China, and Iran [15–23]. In China, India, and Africa, 40 million, 45 million, and 70 million people respectively are reported to be affected by fluoride-related diseases and skeletal illness [24–26]. One of the other diseases associated with excessive intake of fluoride is increase in blood pressure. Obesity has been reported in Iran, China, and other parts of the world [27–32]. Studies have shown that accumulation of fluoride in the hard and soft tissues causes problems in the cardiovascular system, which increases heart beat [33, 34]. Although studies have shown that fluoride poisoning causes hypertension, chronic ischemic heart disease, and increase of heart rate, there is no clear evidence that an increase in the incidence of high blood pressure is associated with exposure to fluorine in water, food, and air. There are limited epidemiological studies regarding the effects of fluoride on blood pressure and obesity. Today, the problem of obesity has reached epidemic proportions worldwide and is growing in developing countries. High blood pressure is associated with obesity. Among the indicators of obesity, we can mention BMI and WHR [35]. Few studies of blood pressure, BMI, and WHR exist in connection with the environmental parameters such as fluoride. Most studies have been done in advanced countries and there is insufficient information about the less-developed countries [36–39]. Therefore, the main purpose of this study was to investigate the relationship between blood pressure, BMI, and WHR in people living in two regions of the West Azerbaijan Province in northwest Iran. One region has high fluoride content in drinking water and the other area has low fluoride content.

Material and Methods

Study Area

Two study areas were selected in West Azerbaijan Province in the northwest part of Iran, (Agh otlogh and Sarisoo with a high level of fluoride, and Shiblou Olia and Shiblou Sofla with low fluoride levels) with almost the same socio-economic status and dietary habits but different natural concentrations of fluoride in drinking water (Fig. 1).

Determination of Fluoride in Drinking Water

The samples of this study were taken from drinking water resources, including wells and springs, from four villages of the city of Poldasht in West Azerbaijan province. A total of 24 samples were collected every 3 months over two consecutive years from March 2014 to March 2016. The water samples were collected in sterile plastic containers and then transported to the laboratory. Fluoride concentration in the water samples was determined using SPADNS method according to the standard analytical method for fluoride determination in the range of 0.0625–1.75 mg/L^{-1} ($r = 0.9993$), and the higher concentrations of this range were diluted and measured. The fluoride concentration was assessed by spectrophotometer (DR/5000, USA) and the obtained limits of determination (LOD) and quantification (LOQ) were 0.12 and 0.37 ppm, respectively.

Study Population

The populations studied in the villages of Agh otlogh, Sarisoo, Shiblou Olia, and Shiblou Sofla were 462, 272, 278, and 277 respectively. The data on the incidence was derived from the health records of the areas being investigated. According to the health records, 190 (85 males and 105 females, mean age 43–29 years old) were residents of the region with a high F level and 156 (73 males, 83 females, mean age 42–27 years) were in the low F region.

Data Collection

Data on weight, BMI, waist circumference and WHR, and blood pressure prevalence in the health records of people who lived in the area for at least 10 years were extracted. There were cases with factors known to cause high blood pressure, such as smoking, age > 65 years, family history of

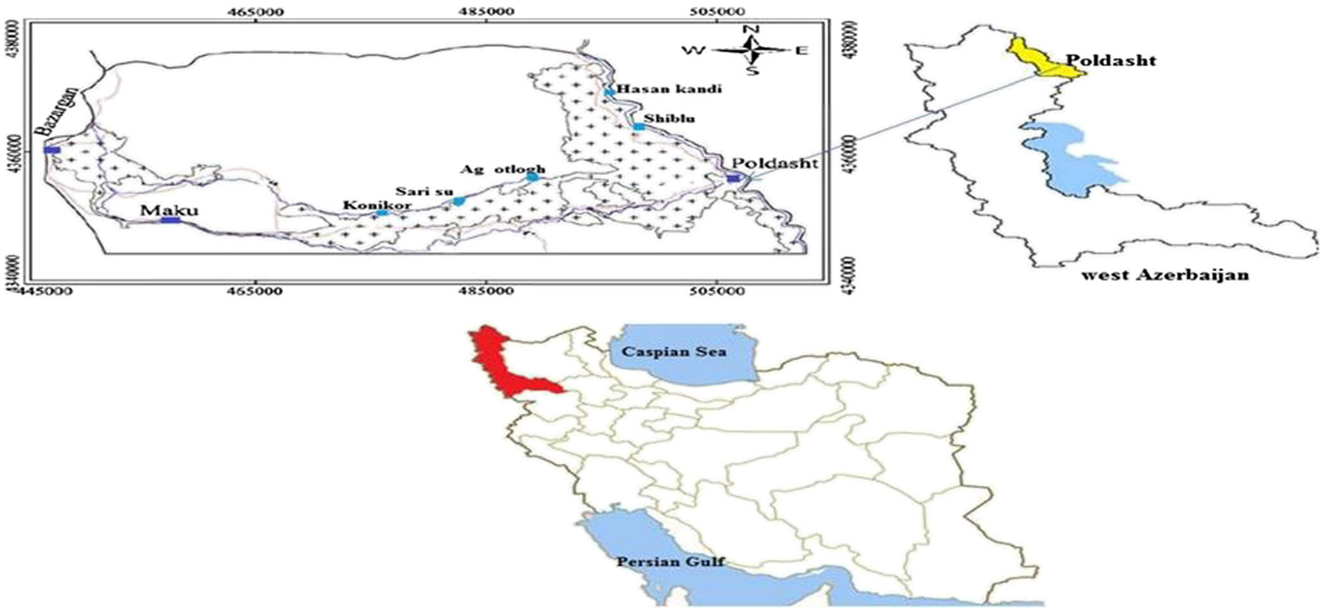

Fig. 1 Location of the study areas in Poldasht city, West Azerbaijan, Iran

high blood pressure, immobility, and cardiovascular disease according to the interview history and monthly progress reports in health centers. These were excluded.

Blood Pressure Blood pressure was measured in two groups according to the instructions of the ministry of health. Participant blood pressure was measured three times in the morning, using a mercury sphygmomanometer. Subjects had to be in a seated position and quietly rest for at least 5 min before this measurement. The presence or absence of HTN was identified when any of the following conditions already existed: when the systolic blood pressure (SBP) was higher than 140 mmHg, and when subject's diastolic blood pressure (DBP) was higher than 90 mmHg.

Category of Blood Pressure

The hypertensive patients were further classified into three types: those with isolated systolic hypertension (ISH: SBP ≥ 140 mmHg and DBPb 90 mmHg), isolated diastolic hypertension (IDH: DBP ≥ 90 mmHg and SBPb 140 mmHg), or systolic-diastolic hypertension (SDH: SBP ≥ 140 mmHg and DBP ≥ 90 mmHg).

Category of BMI

The subjects' BMI was calculated using the following formula: BMI = weight/height (kg/m2). The participants were classified by BMI into three groups: normal (BMI 18.50–24.99 kg/m2), overweight (BMI 25.99– < 29.99 kg/m2), and obese (BMI > 30 kg/m2), according to the obesity criteria for Asian people recommended by the World Health Organization [34].

Statistical Method

To present the data, we used mean, standard deviation, median, and range. To compare the results between two groups, we used independent sample *t* test and Mann-Whitney test as well as chi-square test. To evaluate the relation of different parameters with the fluoride, we used Spearman correction. To evaluate the simultaneous effect of variables on the HTN, we used logistic regression analysis. The precision of the statistics was presented by 95% CI. All the statistical methods were performed by SPSS software (Version 24.0). *P* values less than 0.05 considered statistically significant.

Result

Data presented here deal with monitoring of physical and chemical properties, including pH, EC, TDS, HCO_3, CO_3, SO_4, Cl, NO_3, and fluoride in Table 1. As in Poldasht County, West Azerbaijan, Iran, Fig. 1 shows the study area and the sampling points. Fluoride ion varied from 0.68 to 10.30 mg/L. This is given in Table 1. Minimum 0.68 mg/L and maximum 10.3 mg/L concentration of F were observed from Hasan kandi and Agh otlogh villages, respectively. And also, according to data, 45% of the villages are located in the desirable range, and in 55 of them, the amount of fluorine was more than the standard level.

Anthropometric characteristics and systolic and diastolic blood pressure of both groups with high and low fluoride levels in drinking water are presented in Table 2. Based on the result, the mean systolic and diastolic blood pressure was found to be significantly higher in rural areas with high levels

Table 1 Average of physical-chemical parameters in drinking water samples in the study area

Chemical parameters	Number of sample	Village				W.H.O guideline
		Sarisu	Agh otlogh	Shiblou Olia	Shiblou Sofla	
pH	60	7.48	7.68	7.32	7.76	6.5–8.5
EC (μS/cm)	60	1523.6	1059.2	1960	1561.8	
TDS (mg/L)	60	591	740.2	948	1012.8	500
NO_3^- (mg/L)	60	7.63	2.1	3.9	20.48	10
SO_4^{2-} (mg/L)	60	70.6	101	202	77.2	200
TH (mg/L as $CaCO_3$)	60	173.8	169	417	243	200
Chloride (mg/L)	60	48	47	235.4	44.1	200
HCO_3^- (mg/L)	60	773.6	761.4	384	770.4	–
F (mg/L)	60	7.63	10.15	0.79	4.02	1.5–2

EC electrical conductivity, *TDS* total dissolved solids, NO_3^- nitrate, SO_4^{2-} sulfate, *TH* total hardness, *CL* chloride, HCO_3^- bicarbonate *F* fluoride

of fluoride in drinking water (Table 2). There were no statistically significant correlations between fluoride and BMI, hip circumference, and waist to hip ratio (WHR) (Table 2). The overall prevalence of HTN and prehypertension in all subjects was 40.7%. The prevalence of ISH, IDH, SDH, and prehypertension in the total sample population was 1.15, 0.28, 9.53, and 29.76, respectively (Table 3). There was a statistically significant positive correlation between the mean concentrations of F in the sample drinking water and the hypertension prevalence (Spearman correlation = 0.165, P = 0.002). Logistic regression results showed that age, sex, BMI, and fluoride levels in drinking water had a significant relationship with increased blood pressure. So the odd ratio of hypertension in residents who drank water with high fluoride levels was higher than in residents who drank water with lower level F (OR 2.3, 1.03–5.14) (Table 4).

Discussion

In this study, the relations of F in the two study areas with blood pressure prevalence, BMI, waist circumference, and WHR in different age and sex groups were investigated. We found statistically significant positive correlation between

Table 2 Association between hypertension, BMI, and WHR in the different groups in the two areas with different drinking water fluoride levels

Characteristics		Fluoride		P *P* value
		Low	High	
Sample size (*N*)	346	156 (45.1%)	190 (54.9%)	
Age (year)	≤ 30.0	13 (44.8%)	16 (55.1%)	0.300
	31–40	56 (48.7%)	59 (51.3%)	
	41–50	62 (47.3%)	69 (52.6%)	
	51–75	25 (35.2%)	46 (64.7%)	
Sex	Male	73 (46.2%)	85 (53.8%)	0.702
	Female	83 (44.1%)	105 (55.8%)	
BMI (kg/m^2)	18.50–24.99	30 (30.3%)	69 (69.7%)	0.002
	25.00–29.99	82 (51.5%)	77 (48.4%)	
	≥ 30	43 (49.4%)	44 (50.5%)	
Waist (cm)	Normal	85 (51.8%)	79 (48.1%)	0.019
	Abnormal	71 (39.2%)	110 (60.7%)	
Hip (cm)	Mean ± SE	102 ± 3.9	104 ± 0.76	0.715
WHR	Mean ± SE	0.95 ± 0.007	0.95 ± 0.006	0.984
SBP (mmHg)	Mean ± SE	111.6 ± 1.33	118.7 ± 1.06	< 0.001
DBP (mmHg)	Mean ± SE	71.4 ± 0.622	74.3 ± 0.787	0.005
MAP	Mean ± SE	98.2 ± 1.056	103.9 ± 0.945	0.0001

BMI body mass index, *WHR* waist-hip ratio, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *MAP* mean arterial pressure

Table 3 Comparison of the prevalence of ISH, IDH, SDH, prehypertension, and HTN in the two areas with different drinking water fluoride levels

Fluoride	Number	ISH	IDH	SDH	Prehypertension	Total	*P* value
Low	156	3 (1.92%)	–	8 (5.13%)	10 (6.41%)	21 (13.46%)	< 0.001
High	190	1 (0.53%)	1 (0.53%)	25 (13.15%)	93 (48.94%)	120 (63.5%)	
Total	346	4 (1.15%)	1 (0.28%)	33 (9.53%)	103 (29.76%)	141 (40.7%)	

HTN hypertension, *ISH* isolated systolic hypertension, *IDH* isolated diastolic hypertension, *SDH* systolic-diastolic hypertension

hypertension prevalence and mean concentrations of F in the sample drinking water in the two study areas. Also, results showed that age, sex, BMI, and fluoride levels in drinking water had a significant relationship with increased blood pressure. So the odd ratio of hypertension in residents who drank water with high fluoride levels was higher than in residents who drank water with lower level F (OR 2.3, 1.03–5.14). Many articles have shown the relationship between excessive fluoride intake from drinking water and HTN, and similar results were reported by Singh. There were higher systolic blood pressure and increased left atrial diameter in patients with endemic skeletal fluorosis [39]. In 2012, Sun et al. showed that high levels of fluoride in drinking water can increase blood pressure and plasma ET-1 levels in subjects living in fluorosis endemic areas [29]. In 2011, Amini et al. conducted an ecological study on the relationship between fluoride levels in ground water and blood pressure in an Iranian population. The result showed an overall statistically significant positive correlation between the mean level of fluoride in the ground water samples and the prevalence of HTN. They also found a statistically significant positive correlation between the mean level of fluoride in the groundwater sources and the mean systolic blood pressure of men, and a borderline correlation with that in women [27]. However, Sun et al. reported that the effect is similar in both men and women [29]. Varol et al. indicated that excess fluoride intake from drinking water appears to exert an increase in primary HT. [40]. Aghai et al. studied the correlation between hypertension and fluoride in drinking water, and declared that no significant difference in the prevalence of hypertension related to F exposure was found in any of the male only groups [28]. Our results from the multivariable logistic regression also showed that age, sex, BMI, and the fluoride level in drinking water had a significant relationship with increased blood pressure. So, the odd ratio of hypertension in residents who drank water with high fluoride levels was higher than in residents who drank water with lower F level. In the present study, we only investigated if the subjects were drinking water, and we did not investigate the type of drinks or beverage. These may be the reason why our finding was inconsistent with other results. In summary, from what is now known, excess fluoride intake from drinking water appears to be responsible for an increase in primary HTN. However, it is also clear that the relation of fluoride with blood pressure needs more experimental and epidemiological studies, such as other etiological factors.

Table 4 Multivariate logistic regression on hypertension of study subjects in different fluoride exposure groups

Parameter	OR	95% CI		*P* value
Group				
Low fluoride	1			
High fluoride	2.3	1.03	5.14	0.041
Age (each 10 years)	3.77	2.21	6.47	< 0.001
Sex				
Male	1			
Female	2.69	1.18	6.11	0.018
BMI (kg/m^2)				
18.50–24.99	1			
25.00–29.99	2.42	0.84	6.89	0.099
≥ 30	3.91	1.31	11.68	0.015
WaistC				
Normal	1			
Abnormal	1.5	0.8	0.3	0.226

BMI body mass index

Conclusion

In summary, this study declared a significant correlation between exposure to excess fluoride in drinking water and the prevalence of hypertension in people living in fluoride endemic areas.There were no statistically significant correlations between fluoride and BMI, hip circumference, and waist to hip ratio (WHR).

The results also demonstrated that BMI age and sex had a significant relationship with increased blood pressure. The findings of this study showed that it is important for health care personnel and policymakers, such as the ministry of health, to raise awareness and make appropriate interventions in nutrition. They play an important role in dealing with the problem of hypertension. The department of water should provide fluoride-safe water supply or effective defluorodation of the existing water supply systems by maintaining a strict water quality control in order to eliminate the fluoride toxicity in all fluoride endemic areas.

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Compliance with Ethical Standards

Competing Interests The authors declare that they have no competing interests.

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