

The Relationship of Fluorosis and Brick Tea Drinking in Chinese Tibetans

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Brick tea-drinking fluorosis is an unusual environmental problem. As a result of an investigation of tea-drinking habits, total fluoride intakes, dental fluorosis, and skeletal fluorosis, this disease has been found in the Sichuan Province of China in Tibetans with a long history of drinking brick tea. The dental fluorosis investigation of 375 Tibetan children (213 males, 162 females) and 161 Han children (86 males, 75 females), 8–15 years of age, was carried out in Daofu County, Sichuan Province. According to the standard of the Chinese Health Ministry, a skeletal fluorosis survey of 658 Tibetans (264 males, 394 females) and 41 Hans (20 males, 11 females), all over 16 years old, was performed. The total fluoride intake and fluorosis were determined from a question–calculation method in all participants. The morbidities of dental fluorosis in Tibetan and Han children are 51.2% and 11.05%, respectively, and the indexes of dental fluorosis are 1.33 and 0.17 ($\chi^2 = 75.7$, $p < 0.01$) respectively. The morbidity of skeletal fluorosis is 32.83% for Tibetan children and zero for the Han children. The fluoride intakes of Tibetan children and adults were 5.49 mg/person/day and 10.43 mg/person/day, respectively, in this area. Of total everyday fluoride intake, 94.2% by children and 94.4% by adults was from brick tea and zanba ($r = 0.99$). *Key words:* dental fluorosis, epidemiology, fluorine, fluorosis, tea. *Environ Health Perspect* 104:1340–1343 (1996)

According to the biological characteristics of the tea tree, fluorine can be selectively absorbed from soil by trees and accumulated in the leaves. When the growth period of tea trees is longer, the fluorine concentration in leaves is higher (1,2). Brick tea is considered to be one of life's necessities by Tibetans and other minority nationalities in western China. The fluorine concentration of brick tea is 200–300 times higher than ordinary green tea and black tea (3,4) because brick tea is made from old stems and leaves of the tea tree, but ordinary green tea and black tea are made from tender leaves and buds. It has been shown that the fluorine concentration of brick tea has no relationship with its method of preparation (5).

In some countries, fluorosis may be caused by excess fluoride in drinking water or by coal pollution (6–8); however, it has seldom been reported that tea drinking leads to fluorosis (9). To investigate the influence of fluorine on the human body after long-time drinking of brick tea, we performed an epidemiological survey in Daofu County, Ganzhi Autonomous Prefecture, Sichuan Province, China.

Methods

Investigation of total fluorine intake. We surveyed Daofu Tibetan and Han residents to collect ecological, economical, cultural, and tea-drinking habit information. We used a question and calculation method to count total fluorine intake (10), according to the *Guideline for the Study of Dietary Intake of Chemical Contaminants* (11). For

each investigated adult and child, everyday intake of foods and tea were recorded. To prove the accuracy of this method, the everyday food intake of 15 Tibetan and Han families, both adults and children, were weighed. After measuring the fluorine concentrations in food and tea samples collected from the 15 Tibetan and Han families, each person's daily total fluorine intake was determined. Also, the fluorine concentrations were measured in three drinking-water samples from each Tibetan and Han living area.

Examination of dental fluorosis. All 8–15-year-old Han and Tibetan students at the Daofu County Primary School and the Forest Bureau Primary School were investigated. The examinations were performed by two dentists according to Horowitz's TSIF standard (12). Mouth mirrors, pliers, and dental probes were used under natural light.

Examination of skeletal fluorosis. At a Tibetan herd area, a Tibetan Buddhist Temple, and a Forest Bureau Han area, random cluster sampling was used to sample Tibetan and Han residents, both male and female, over 16 years of age. Clinical symptoms and signs of skeletal fluorosis were investigated.

According to the standard of the Chinese Health Ministry (13), clinical symptoms and signs were classified either mild (I), medium (II), or severe (III). The investigation included five symptoms and nine signs.

According to the standards of the Chinese Health Ministry (13), X-ray diag-

nosis of skeletal fluorosis was classified extremely mild, mild, medium, or severe. Among the persons who had three signs of skeletal fluorosis, 30% were sampled randomly to take X rays. X-ray examinations included pelvis, right upper arm, and right femur including the knee joint.

Fluorine measurement. Water, tea with milk, tea alone, and urine were measured by fluorine selective electrodes. Urinary samples were collected (in the morning) from 30 Tibetan and Han children. Food and vegetable samples were collected and measured by acid treatment and fluorine selective electrodes (14). A 1.00 g food sample, which had been passed through a 0.45 mm sieve, was put into a 50-ml volumetric flask with 10 ml of 1N hydrochloric acid for 1 hr and shaken gently. After 1 hr, 25 ml general ionic strength buffer (3 M sodium acetate and 0.75 M sodium citrate, v/v) was added; double deionized H₂O was then added to reach a final volume of 50 ml.

Statistical analysis. We used SAS software (SAS, Cary, NC) to analyze and calculate total fluorine intake, method of fluorine intake, correlation coefficient of total fluorine intake, and the relationship of fluorine intake with dental fluorosis and skeletal fluorosis.

Results

Daofu County is located southeast of the Qing-Tibet Plateau, its altitude is 2,900–5,800 m, and the annual average temperature is 3.9–7.8°C. The total area of the county is 7,546 km². The population is over 40,000, and 90% are Tibetan; the population density is 5.6 persons/km². There is only one highway that connects Daofu County with Tibet, and there is no industry. Brick tea is considered necessary for the Tibetans who live there. The proverb "Tibetans would rather have no food for three days than no tea for a day," is still popular. The brick tea drunk by Tibetans is broken into pieces and then boiled in water to make tea. When Tibetans drink brick tea, they put milk or butter into the tea. Their

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main food is zanba (roasted qingke barley flour). After breast-feeding, Tibetan children begin to drink tea and eat zanba at once.

The Han population living in Daofu County has a separate water system and also keeps Han customs. The basic information for the investigated area is shown in Table 1. The main differences between Hans and Tibetans are that Tibetans eat zanba and drink brick tea and the Hans drink green tea and do not eat zanba. The fluorine concentration in water in the Tibetan living area is 0.11mg/l, the same as the level for the Han living area; water from both areas is typically low in fluorine concentration.

The results of total fluorine intake in main foods are shown in Table 2. The fluorine concentration was much higher in zanba and brick tea than in other Tibetan foods, and the fluorine concentration in Tibetan brick tea was four times higher than that in ordinary green tea, drunk by the Hans.

Both questionnaires and quantitative methods were used to estimate food intake of adults and children. These two methods were compared with a matched pair and question method. The errors between the methods ranged between 0 and 24%.

The intake of food (grams per person per day) and fluorine (milligrams per person per day) are presented in Table 3. In the Sichuan Province, there are no recommendations for daily fluorine intake. The National Research Council in the United States published recommended daily allowances (RDA) of fluo-

Table 2. The concentrations of fluorine in main foods

Area	Food	Fluorine concentration (mean \pm SD) ^a
Tibetan	Zanba (n = 3)	5.12 \pm 2.80
	Rice (n = 3)	0.85 \pm 0.25
	Flour (n = 3)	0.66 \pm 0.21
	Vegetables (n = 6)	0.56 \pm 0.019
	Brick tea with milk (n = 5)	2.59 \pm 1.73 (mg/l)
Han	Rice (n = 3)	0.85 \pm 0.25
	Flour (n = 3)	0.66 \pm 0.22
	Vegetables (n = 6)	0.56 \pm 0.19
	Green tea (n = 5)	0.55 \pm 0.16 (mg/l)

SD, standard deviation.

^aValues are given in milligram per kilogram except where noted.

Table 3. The intake of food (I)^a and fluorine (F)^b

Population	Age (years)	Zanba		Rice		Flour		Vegetables		Brick tea (milk)		Green tea		Total F
		I	F	I	F	I	F	I	F	I	F	I	F	
Tibetan	8-15	250	1.28	100	0.085	150	0.099	250	0.14	1500	3.89	—	—	5.49
	>15	400	2.05	200	0.17	200	0.132	500	0.28	3000	7.80	—	—	10.43
Han	8-15	—	—	400	0.34	200	0.132	250	0.14	—	—	1500	0.83	1.44
	>15	—	—	400	0.34	600	0.40	750	0.42	—	—	2500	1.38	2.54

^aIntake is given in grams per person per day.

^bFluorine is given in milligrams per person per day.

^cTea intake is given in milliliters per person per day.

Table 1. Basic information of investigated area

Area	Altitude (m)	Fuel	Main foods	Tea
Tibetan	2,900-3,100	Wood, electricity	Zanba, rice, flour, vegetables	Brick tea
Han	2,900	Wood, electricity	Rice, flour, vegetables	Green tea

rine intake of 2.5 mg/day for children and 1.5-4.0 mg/day for adults (15). Therefore, the daily intake of fluorine for Tibetan children was 2.2 times higher and for Tibetan adults, the level of fluorine was 2.6 times higher than the maximum suggested values.

Table 4 shows the correlation between the total intake of fluorine and the source of fluorine. The stepwise analyses show that the fluorine in brick tea and zanba was the main factor influencing the total intake of fluorine; their correlation coefficients were 0.99 and 0.96, respectively.

Dental fluorosis and urinary fluorine concentration of children. The morbidity rate and the index of dental fluorosis in children is presented in Table 5. The morbidities of dental fluorosis of Tibetan and

Table 4. Correlation analysis between the total intake of fluorine and the source of fluorine

Fluorine source	Correlation coefficient (r)	Equation of rectilinear correlation	p-value
Brick tea	0.99	Y = 1.368x + 0.24	0.02
Zanba	0.96	Y = 3.311x + 1.75	0.03
Rice	-0.2620	Y = 10.86x + 8.25	0.74
Flour	-0.0371	Y = 0.357x + 1.8	0.91
Vegetables	-0.1912	Y = -6.17x + 7.94	0.81

Table 5. The morbidity rate and the dental fluorosis index in children

Sex	No. of children		No. with dental fluorosis		Morbidity rate (%)		Dental fluorosis index	
	Tibetan	Han	Tibetan	Han	Tibetan	Han	Tibetan	Han
Male	213	86	107	11	50.2	12.8	1.32	0.19
Female	162	75	85	7	52.4	9.3	1.34	0.15
Total	375	161	192	18	51.2	11.05	1.33	0.17

Table 6. Morbidity of dental fluorosis by classification

Sex	No. of children		Light grade (1-3)		Medium grade (4)		Severe grade (5-7)	
	Tibetan	Han	Tibetan	Han	Tibetan	Han	Tibetan	Han
Male	213	86	37.6	12.8	5.2	0	7.5	0
Female	162	75	41.8	9.3	4.9	0	5.6	0
Total	375	161	39.4	11.05	5.1	—	6.7	—

Han children were significantly different ($\chi^2 = 75.71$; $p < 0.01$). The morbidity rate of dental fluorosis in Tibetan children was higher than that of Han children; there was not a significant difference between the morbidity rate of males and females.

According to the classification method of Horowitz et al. (12), the dental fluorosis index of Tibetan children was 1.33. The control group (Han children) was negative.

Table 6 shows the classification of dental fluorosis according to the standard of Horowitz et al. (12). The primary pathologic change of dental fluorosis was chalk-like lesions (grading 1-3).

The concentrations of urinary fluorine of Tibetan and Han children were significantly different ($\chi^2 = 6.5$; $p < 0.01$). The concentration of urinary fluorine was considered to be an indicator of fluorine load. Watanabe et al. (16) showed that the fluorine excreted in urine in 24 hr was 18-35% of the intake of fluorine each day. The intake of fluorine of Tibetan children each day was 5.49 mg; thus, the accumulation of fluorine was 5.57 mg, which exceeded the maximum acceptable value by 1.07 mg.

Skeletal fluorosis. According to the Department of Endemic Disease Prevention,

Chinese Health Ministry (14), 685 Tibetan adults, over 16 years old, were investigated for signs of skeletal fluorosis. Of these, 216 adults had clinical signs of skeletal fluorosis; the detectable rate was 31.53%. Among them, 56 persons had grade 1 symptoms (≥ 3 kinds of clinical symptoms): the rate was 8.18%; 154 persons had grade II symptoms (clinical symptoms and signs of skeletal fluorosis): the rate was 22.48%; and 6 persons had grade III symptoms (signs of skeletal fluorosis plus humpback, paralysis, and disability): the rate was 0.88%. Symptoms included pain in joints (39.21%), lumbago (26.14%), numbness of the extremities (16.87%), tetany (4.10%), and hand-foot rigidity (3.80%). Of the 160 persons we analyzed who had signs of skeletal fluorosis, 100% had upper limb flexion, 69.38% had difficulty in touching their shoulder, 31.88% had difficulty touching their ear, 30% had difficulty raising their forearm straight, 56.75% had difficulty squatting, 5.63% had spine rigidity, and 3.75% had humpback and paralysis.

The age distribution of the detectable rate of skeletal fluorosis in Tibetan adults is presented in Table 7. The detectable rate of skeletal fluorosis increases with age, especially after age 30, and the detectable rate of skeletal fluorosis in Tibetan adults over 40 years of age was 50%. The rate of skeletal

fluorosis was much higher in males than in females ($\chi^2 = 9.65$; $p < 0.01$) (see Table 8). The major differences are seen in clinical grade II ($\chi^2 = 15.88$; $p < 0.01$). The reason for this large difference is unknown.

Of 108 persons with at least three signs of skeletal fluorosis in this investigation, X-ray examination was used to study 31 randomly selected cases (Table 9). Twenty-four persons were diagnosed with skeletal fluorosis by X ray, 77.42% of the X-ray group. Among them, 8 were in the initial stage, 9 were grade I, and 7 were grade II. Most of them had pathological changes that appeared on X-ray photos of the forearm. The major findings in these X-ray photos of the skeletal fluorosis patients include osteoporosis, radial collateral interosseous membrane ossificational hyperplasia, narrow joint space, cystic degeneration under the articular surface, and ulnar and radial collateral interosseous membrane ossificational hyperplasia (detectable rate of 87.5%); this last finding is the specific change caused by skeletal fluorosis.

Discussion

The economy and the transportation in Daofu County, Sichuan Province, are behind the times. The territory of this county is vast but the population density is small. There is no industrial pollution in this area so the respiratory intake of fluorine is consid-

ered to be low. The concentration of fluorine in drinking water is also low. However, the main foods of Tibetans in this area, zanba and brick tea with milk or butter, contain a large amount of fluorine. The concentrations of fluorine in the zanba and the tea were much higher than in other foods. The intakes of fluorine of Tibetan children and adults were 2–3 times higher than the RDA (15), but the intake of fluorine of Han inhabitants was lower than the RDA.

Tibetan children absorbed 5.17 mg fluorine by drinking the brick tea mixed with either milk or butter and by eating zanba. The intake of fluorine from tea and zanba together was 94.2% of the total intake of fluorine and exceeded the international RDA for the total intake of fluorine by children by 2.2-fold. The absorbed fluorine caused the tea-drinking fluorosis. The index of dental fluorosis of the Tibetan children in this area was 1.33, which was graded as medium fluorosis by the classification standard of Horowitz et al. (12).

When the total intake of fluorine exceeded the RDA by 2.2 times, the concentration of urinary fluorine of Tibetan children reached 1.84 mg/l, which resulted in an increase in dental fluorosis (see Table 10). The total fluorine intake of Han children was below the RDA; therefore, the morbidity rate of dental fluorosis was lower and the index of dental fluorosis was negligible.

Total fluorine intake of Daofu County Tibetan adults was 10.43 mg/person/day. Of this total fluorine, 94.4% comes from brick tea and zanba. The fluoride intake of these Tibetan adults was 4.1 times higher than the Han adults who did not drink brick tea, and their urinary fluoride concentration was 2.68 times higher than that of the Han adults. Among the Tibetans over 16 years of age, the detectable rate of skeletal fluorosis was 32.83%; 24.32% of examined people were determined to have skeletal fluorosis of grade II or III. Among people over 40 years old, the rate of skeletal fluorosis was over 50% (Table 7). According to the Chinese standard, this is a medium fluorosis area considering the grade of dental fluorosis

Table 7. Age distribution of the detectable rate of Tibetan adult skeletal fluorosis

Age (n)	No. with skeletal fluorosis		Grade ^a		
	No.	Rate (%)	I	II	III
16–19 (94)	3	3.19	2.13 (2)	1.06 (1)	—
20–29 (237)	13	5.49	4.22 (10)	1.27 (3)	—
30–39 (83)	30	36.14	14.46 (12)	21.69 (18)	—
40–49 (94)	48	51.06	12.77 (12)	38.30 (36)	—
50–59 (66)	57	81.36	19.70 (13)	66.67 (44)	—
60–69 (50)	37	74.00	10.00 (5)	62.00 (31)	2.00 (1)
70–79 (31)	26	83.87	3.23 (1)	64.52 (20)	16.13 (5)
>80 (3)	2	66.67	33.33 (1)	33.33 (1)	—

^aValues are percent and number (in parentheses) of the age group.

Table 8. Sex distribution of the detectable rate of skeletal fluorosis in Tibetan adults

Sex	No. with skeletal fluorosis		Grade ^a		
	No.	Rate (%)	I	II	III
Male (n = 264)	105	39.77	6.82 (18)	31.44 (83)	1.52 (4)
Female (n = 394)	111	28.17	9.64 (38)	18.02 (71)	0.51 (2)

^aValues are percent and number (in parentheses) of group.

Table 10. The total intake of fluorine and the responses of fluorosis

Population	Age (years)	Fluorine intake (ng/person/day)	Urinary fluorine (mg/l)	Morbidity rate of dental fluorosis (%)	Dental fluorosis index	Detectable rate of fluorosis (%)
	>15	10.43	1.96	—	—	32.83
Han	8–15	1.44	0.74	11.1	0.17	—
	>15	2.54	0.73	—	—	0

Table 9. Results of X-ray examination of 31 cases of skeletal fluorosis

Grade (n)	X-ray changes ^a		
	Periosteum change	Joint change	Trabecular bone change
Extremely mild (8)	50.0 (4)	62.5 (5)	87.5 (7)
Mild, grade I (9)	100.0 (9)	88.9 (8)	100.0 (9)
Medium, grade II (7)	100.0 (7)	100.0 (7)	100.0 (7)
Severe, grade III (0)	—	—	—

^aValues are percent and number (in parentheses) of group.

and skeletal fluorosis. Because of the low population density of the Tibetan living area and our limited funding, we could not X-ray every case of skeletal fluorosis that was diagnosed by the clinic. Among 160 persons with skeletal fluorosis, a random sample of 31 persons was given X rays. Twenty-four of these were diagnosed with skeletal fluorosis by X ray (rate = 77.42%).

Brick tea fluorosis can be considered to be a new type of fluorosis. Brick tea fluorosis occurs in a limited area, but until now, this problem has been ignored.

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