The Dose-Response Relationship of Tea-Induced Osteofluorosis and Brick Tea Fluoride Intake

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Abstract:

Goal: Determine the dose-response relationship between tea-induced osteofluorosis and brick tea intake.

Method: In two representative tea-induced fluorosis areas in the north and south of China, namely Aba County of Sichuan province and Chen Banner of Inner Mongolia Autonomous Region, osteofluorosis suffers were diagnosed by means of x-ray and a regression analysis was conducted to investigate sufferers fluoride intake from brick tea.

Result: In Aba County, level 1, 2, and 3 osteofluorosis sufferers have an average daily intake of fluoride from drinking brick tea of 6.26, 9.92, and 12.80 mg, respectively. In Chen banner, level 1 and level 2 osteofluorosis sufferers have a daily intake of fluoride from drinking brick tea of 6.26 and 10.23 mg, respectively; no level 3 sufferers were found. A linear relationship exists between disease severity and annual brick tea consumption ($F = 330.23$, $p < 0.01$), with a correlation coefficient of 0.77.

Conclusion: A dose-response relationship exists between the severity of osteofluorosis and the intake of fluoride from tea drinking.

Keywords: Osteofluorosis; brick tea; dose-response relationship

Tea-induced fluoride poisoning is a disease which results from people drinking large quantities of brick tea which is high in fluoride content. In China, the disease occurs in areas with ethnic minorities that have the habit of drinking brick tea. A distinctive characteristic of the disease is the fact that dental fluorosis in children is relatively light, while osteofluorosis in adults is comparatively severe. In the first half of 1999, the Disease Control Department of the Ministry of Health asked the Chinese Endemic Disease Prevention and Treatment Centre to organize experts in the field to carry out a survey of the current situation relevant to tea-induced fluoride poisoning. The present study presents a portion of this investigation.

1. Subjects and Methods

1.1 Area Selection

After soliciting the opinions of Chinese experts in endemic fluoride poisoning, we selected two representative endemic regions, one in the north, one in the south, where brick tea is ingested in great quantities and the resulting fluorosis is severe. The southern area is Aba country of Sichuan Province, and the north is Chenbaerhu (Chen) Banner in Inner Mongolia Autonomous Region. From each region, a pastoral area with the most severe poisoning was selected.

1.2 Subject Selection

The residents of Aba Country are of the Tibetian nationality, and the residents of Chen Banner are of the Mongolian nationality. According to previous studies, osteofluorosis detection rates are higher for those over the age of 40,[3] therefore the subjects of our investigation were all over the age of 40. They were born in the area, had lived there on a permanent basis, and all had the habit of drinking brick tea.

1.3 Osteofluorosis Examination

A single form was created, and the presence of the following conditions were surveyed: arthralgia, lumbago, acroanesthesia, tetany, ankylosis, flexural limbs, elbow flexion difficultly, difficulty touching opposite auricle, restriction of arm abduction, difficulty squatting, dorsal column sclerosis, kyphosis, and paralysis. Subjects with 3 of the above characteristic conditions were also x-rayed,

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Table 1: The consumption rate of brick tea and ingestion of milk or butter tea by severity of fluorosis symptoms						
Disease Severity	Aba County			Chen Banner		
	n	Annual average consumption of brick tea(kg)	Daily ingestion of milk or butter tea (ml)	n	Annual average consumption of brick tea (kg)	Daily ingestion of milk or butter tea (ml)
normal	2	2.00 ± 0	1600.00 ± 565.69	22	2.59 ± 0.80	1909.09 ± 942.09
Level 1	13	4.15 ± 1.07	3030.77 ± 1364.66	35	4.09 ± 1.20	2822.86 ± 1410.48
Level 2	42	6.58 ± 1.35	3728.57 ± 1709.41	18	6.32 ± 2.69	3436.11 ± 1623.16
Level 3	22	8.49 ± 2.40	3336.36 ± 1714.62	-	-	
Note: No level 3 fluorosis was diagnosed in Chen Banner						

primarily a right lateral x-ray of the forearm, but for those with a positive result on the first x-ray, a posterior anterior x-ray of the pelvis and a right lateral x-ray of the thigh including a frontal view of the knee joint were added.

1.4 X-Ray Diagnosis Standard

Classification was carried out according to the national standards for x-ray diagnosis of osteofluorosis[4].

1.5 Survey of Tea Fluoride Intake

Interviews were used to retrospectively determine the average consumption rate of brick tea over the most recent 3 years and the daily per capita ingestion of milk or butter tea by subjects; the former was further converted into a daily per capita consumption rate. From each investigated area, 4 samples of brick tea were collected and measured for fluoride content using the ion selective electrode method[5], and from this the daily per capita fluoride intake rate from tea drinking was calculated.

1.5 Statistical Analysis

SPSS was used to carry out the statistical analysis. Results are expressed as mean ± standard deviation; comparison between group indices was conducted using the non-parametric Mann-Whitney U test.

2. Results

2.1 Consumption Rate of Brick Tea

The average consumption rate of brick tea and the average ingestion rate of milk or butter tea among residents of Aba Country and Chen Banner generally increases with the severity of fluorosis symptoms; the increase in the average consumption rate of brick tea is particularly clear (table 1).

2.2 Brick Tea Intake

The concentration of fluoride in brick (butter or milk) tea may vary, but in the same area, given that there is only a single manufacturer of brick tea, the fluoride content of brick tea is roughly similar. The results of this study's analysis of brick tea samples are as follows: the fluoride content of brick tea in Aba country is 550.4 ± 152.5 mg/kg; the fluoride content of brick tea in Chen Banner is 590.9 ± 123.4 mg/kg. Using this result, further analysis indicates that in both areas the severity of fluorosis symptoms tends to increase with the average intake of fluoride from brick tea (Table 2).

Table 2: The intake of fluoride from brick tea by severity of fluorosis symptoms				
Disease Severity	Aba County		Chen Banner	
	n	Avg. daily intake (mg)[1]	n	Avg. daily intake (mg)
normal	2	3.02 ± 0	22	4.19 ± 1.30
Level 1	13	6.26 ± 1.61	35	6.62 ± 1.94
Level 2	42	9.92 ± 2.04	18	10.23 ± 4.35
Level 3	22	12.80 ± 3.77	-	-
[1]Average daily intake of fluoride from brick tea (mg)				

2.3 Statistical Significance

Since the ingestion of tea by the fluorosis sufferers from each of the two regions is roughly the same, we overcome the relative paucity of subjects in each area by combining the corresponding data of the two areas (Table 3). A comparison of the brick tea consumption of normal residents with level 1 sufferers, level 1 sufferers with level 2 sufferers, and level 2 sufferers with level 3 sufferers all yield statistically significant results at the $p < 0.01$ level. As for brick tea fluoride intake, comparison of normal with level 1 sufferers and level 1 sufferers with level 2 sufferers are both significant at the $p < 0.01$ level.

Table 3: Comparison of brick tea consumption with ingestion of brick tea by severity of fluorosis symptoms

Disease Severity	n	Annual avg. consumption of brick tea(kg)	Average Daily ingestion of brick tea (mg)
normal	24	2.54 ± 0.78	1883.33 ± 912.08
Level 1	48	4.11 ± 1.15**	2879.17 ± 1386.86**
Level 2	60	6.50 ± 1.84**	3640.83 ± 1675.71**
Level 3	22	8.49 ± 2.51**	3736.36 ± 1715.63

** $p < 0.01$

2.4 Regression Analysis

A linear regression analysis of the relationship between fluorosis severity and annual brick tea consumption yields $F = 330.25$, $p < 0.01$, indicating that there is a direct linear relationship between the two variables; the regression equation is $y = -0.26 + 0.3x$, and the correlation coefficient is 0.77. A linear regression analysis of the relationship between fluorosis severity and daily ingestion of brick tea yields $F = 47.32$, $p < 0.01$, also indicating that there is a linear relationship between these two variables; the regression equation is $y = 0.42 + 2.52 \times 10\text{-}4x$, and the correlation coefficient is 0.41. The correlation coefficient for brick tea consumption and severity is higher than that for tea ingestion, indicating that annual brick tea consumption more accurately reflects the severity of the disease.

3. Discussion

Similar studies have also previously carried out research on the ingestion of fluoride of people living in areas subject to tea-induced fluoride poisoning. Many have investigated areas where ethnic Tibetans live, discovering that residents ingest over 10 mg of fluoride per person per day from tsampa and butter tea[3,6]. The focus of these studies is to investigate the relationship between severity of osteofluorosis in sufferers and the amount of brick tea consumed. To date, there are no studies of these sort outside of China. The two major reasons for this are: first, there are few areas with endemic tea-induced fluoride poisoning outside of China, and those that exist are of relatively low severity, mostly consisting of cases of child dental fluorosis; adult osteofluorosis is rare. The second is the need to overcome statistical distortions due to confounding factors; age is a particular problem, since the severity of osteofluorosis increases with age. The present study selected subjects over the age of 40 with the goal of basically eliminating age as an influence on the severity of osteofluorosis.

The study shows that, whether in the southern endemic area of Aba County or the northern endemic area of Chen Banner, the severity of osteofluorosis always increases with the consumption of annual consumption of brick tea; the correlation coefficient is 0.77. There is also a similar relationship between the daily ingestion of brick tea drinks and osteofluorosis severity, with a correlation coefficient of 0.41. The predictive power of the two variables differ in that the difference between the milk and butter tea ingestion rate for the level 3 sufferers, who are all over the age of 45, is not statistically significant as compared to the ingestion rate for the level 2 suffers. This result suggests that brick tea ingestion rate is not as reliable an indicator as overall brick tea consumption, due to differences in the concentration of the brewed tea. Thus we believe that although there are a number of factors which affect the severity of osteofluorosis in sufferers, the consumption of dry brick tea is the most important; as more is consumed, severity will increase, and vice versa.

Our study discovered that even among healthy individuals, the ingestion rate of brick tea was near or over national safety standards (3.5 mg per person per day); this does not include the fluoride coming from other sources, or roughly 0.5 mg per day. In younger

populations within an endemic tea-drinking fluoride-poisoning area, there are still people who are "healthy" by clinical standards. However, in populations above the age of 60, practically everyone has some degree of osteofluorosis. It is clear that in areas of endemic fluoride poisoning it is very difficult to completely prevent the onset of osteofluorosis, and the best possible result in treating the disease is to prevent the prevalence of osteofluorosis symptoms of medium or higher severity. According to the data in our study, in order to achieve this goal the annual consumption of brick tea must not exceed 3 kg, and the daily intake of fluoride from brick tea must not exceed 5 mg.

Our data was collected using retrospective interviews; although relatively reliable, the brick tea consumption and brick tea drink ingestion data would be more reliable if collected directly; in particular there is the problem of memory bias. Therefore, this study only offers an initial understanding of the dose-response relationship between the severity of osteofluorosis and brick tea intake. If we wish to bring this understanding to a higher level of precision, we must conduct additional field studies in the future.

References

[1] Jiang Ge. The current state of tea-induced fluorosis and relevant research in China. *Chinese Journal of Control of Endemic Diseases*. 1988, 31(6):349-351

[2] Sun Dianjun, Zhao Xinhua, Yu Guangqian, et al. A research study on endemic tea-induced fluoride poisoning of ethnic Tibetans in Aba County, Sichuan Province [A]. In *Proceedings of International Conference on Fluoride and Arsenic Research in the Asia-Pacific Region* [C], Chinese Endemic Disease Association, 1999, 121.

[3] The Health and Disease Prevention Station of Sichuan Province, the Health and Disease Prevention Station of Aba Prefecture, the Health and Disease Prevention Station of Rangtang County. Tea-induced fluoride poisoning—A endemic disease study of Rangtang County in the Aba Tibetan Autonomous Prefecture of Sichuan Province [J]. Chinese Journal of Epidemiology. 1988, 5(2): 110—113.

[4] Ministry of Health of the People's Republic of China. *Health Industry Standards of the People's Republic of China: Diagnosis Standards for Osteofluorosis* [S]. Bejing: National Technical Supervisory Press, 1999.

[5] Ministry of Health of the People's Republic of China, Endemic Disease Prevention and Treatment Department. *Endemic Fluoride Poisoning Manual* [M]. Chinese Research Center for the Prevention and Treatment of Endemic Diseases, 1991, 80-90.

[6] Cao Jin, Zhao Yan, Liu Jianwei, et al. Study of the Total Intake of Fluoride in the Population of Tea-induced Fluoride Poisoning Suffers in Sichuan Province [J]. Chinese Journal of Epidemiology, 1995, 14(5): 278-279 YUBIN TAN. THE EFFECTS OF FLUORIDE ON THE METABOLISM AND EACH OF THE SYSTEM IN THE BODY, Chinese Journal of Control of Endemic Diseases, 1994; 9(4);230

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