THE EFFECT OF NUTRITION ON THE DEVELOPMENT OF ENDEMIC OSTEOMALACIA IN PATIENTS WITH SKELETAL FLUOROSIS

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SUMMARY: The aim of the study was to study the relationship between nutrition and endemic osteomalacia, resulting in bone deformation with hump back, spinal curvature and "O" legs, in persons living in high drinking water fluoride areas with skeletal fluorosis. A dietary survey was made of 30-50 families from each of three villages in high fluoride areas of China, and in 273 persons in whom skeletal fluorosis was diagnosed clinically, clinical and radiological assessments were made for the presence of endemic osteomalacia with bone deformation together with measurement of the serum calcium and total protein. A higher incidence of osteomalacia was found in persons with a lower intake of energy, protein, calcium and Vitamin C, particularly multiparous women. Poor nutrition was seen to be an important cause of endemic osteomalacia in high fluoride areas and that prevention would be aided by a better diet.

Key words: Calcium; China; Diet; Endemic osteomalacia; Epidemiology; Fluoride; Nutrition; Protein; Skeletal fluorosis; Vitamin C.

Introduction

Although a relationship between nutrition and endemic osteomalacia is recognized, few epidemiological studies have been made.[1,2] In an animal study, monkeys given a diet with low calcium and high fluoride for 60 months developed osteomalacia, while control groups with low calcium or high fluoride developed osteoporosis and osteosclerosis respectively.[3] In the USA, it has been suggested that no clinically significant, adverse, physiological or functional effects, with the exception of dental fluorosis, are to be anticipated in persons whose water supply contains up to 8 parts per million (ppm) of fluoride, while, in India, skeletal fluorosis has been described with 3-4 ppm of fluoride in the drinking water.[4] In China, skeletal fluorosis is widespread with variations in incidence being related to differences in the diet and economic conditions. In the present study the relationship between nutrition and endemic osteomalacia was examined in three villages with high drinking water fluoride levels but different diets.

Materials and Methods

Thirty to fifty families from each of three high fluoride areas were randomly selected for study. In two villages - Beichengzi, drinking water fluoride 5.9 ppm, in the eastern mountain part of Lainyuan county, and Dongjingji, drinking water fluoride 4.5 ppm, in the western basin of Yangyuan county, - the people were very poor and worked mainly in agriculture without secondary occupations. Their main crops were maize and millet with little access to fruit or meat. Dongjiao, drinking water fluoride 5.2 ppm, in the eastern suburb of Tianjin city was used as a control

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village. There the residents had a higher standard of living with wider employment opportunities and better nutrition. The food intake for each family under study was weighed for three days and the sex, age and ability to work for each family member recorded. The average intakes of energy and nutrients for each person were calculated and compared to the Recommended Daily Allowance (RDA) for China.[5] An assessment for the presence of skeletal fluorosis was made according to the Standard for the Prevention and Treatment of Endemic Fluorosis of China[5] and when found, pelvic, forearm and leg X-ray examinations were made and the serum calcium and total protein measured. The Chi-square Test and Fisher's Exact Test were used for testing for statistical significance.

Results

In the poorer villages of Beichengzi and Dongjingji, there was less Vitamin C in the diet and the intakes of energy, protein and calcium were significantly less than the RDA, while in Dongjiao they were significantly higher as shown in Tables 1 and 2.

Vitamin A intake, expressed as Retinol equivalents, was less than the RDA in all three villages but especially so in Beichengzi and Dongjingji.

The incidence of endemic bone deformation, diagnosed clinically, was higher in Beichengzi and Dongjingji than in Dongjiao, where no cases of hump back or spinal curvature occurred, as shown in Table 3.

Twenty two (29%) of the cases of bone deformation were male and 54 (71%) female giving a male:female ratio of 1:2.5.

The serum calcium and total protein levels were significantly lower in Beichengzi and Dongjingji compared to Dongjiao as shown in Table 4.

X-rays showed that osteosclerosis was significantly less prevalent in persons with skeletal fluorosis in Beichengzi and Dongjingji than in Dongjiao as shown in Table 5. Radiological evidence of osteomalacia was not found in Dongjiao but was present in the poorer villages of Beichengzi and Dongjingji, this difference being significant with a one sided test. Twenty four of the 28 persons with radiological evidence of osteomalacia were women (85.7%).

Discussion

Using energy, protein and calcium as indicators, the villages of Beichengzi and Dongjingji had significantly lower levels of nutritional intake than Dongjiao and a higher incidence of skeletal fluorosis. Protein contains amino acids and is required for growth, replacement of body tissues and the synthesis of hormones, enzymes, haemoglobin, antibodies and phagocytes. As well as being a basic component of bone, it promotes the absorption of calcium.[6] The intake of animal protein in the form of meat and eggs was less in Beichengzi and Dongjingji at 2.7 g and 30 g a day, compared to Dongjiao with 79.7 g a day. Because animal proteins usually have a higher concentration of essential amino acids that most vegetable proteins, the people living in Beichengzi and Dongjingji had poorer nutritional levels and together with a deficiency in energy and protein was a deficiency in calcium. Calcium is needed throughout life with 99% of the 1300 g in the human body being in bone. At least 1000 mg a day is recommended to build bones and teeth. The intakes of calcium in Beichengzi and Dongjingji at 327 mg (54.5% of RDA) and 241 mg (40.1% of RDA) were significantly lower than in Dongjiao at 762 mg (127.0% of RDA).

Vitamin C is required for the formation of collagen, the protein fibres that bind cells together and form the body's connective tissue. Vitamin C is necessary for the step in collagen synthesis that gives collagen its rigid and stable structure and thus gives strength to the bones, cartilage, teeth, gums, muscles, vascular tissues and skin.[7] The intakes of Vitamin C were significantly lower in Beichengzi and Dongjingji at 43 mg (71.1% of RDA) and 63 mg (105% of RDA) than in Dongjiao at 164 mg (273% of RDA).

Persons in Beichengzi and Dongjingji with skeletal fluorosis and poor nutrition had a higher incidence of osteomalacia than residents of Dongjiao, as well as lower calcium and total protein levels in the serum and less osteosclerosis.

TABLE 1. Daily food intake per person for residents of the three villages

Food	Beichengzi		Dongjingji		Dongjiao	
	Intake (in g)	% of total intake	Intake (in g)	% of total intake	Intake (in g)	% of total intake
cereals	495.0	68.2	509.4	51.3	582.3	45.7
starchy tubers	23.6	3.3	76.7	7.7	118.0	9.3
legumes	4.4	0.6	1.5	0.2	2.6	0.2
legume products	1.2	0.2	21.2	2.1	11.2	0.9
meat and eggs	2.7	0.3	30.3	3.0	79.7	6.3
vegetables	177.2	24.4	335.3	33.7	439.8	34.5
oils	1.4	0.2	0.5	0.1	16.6	1.3
other	20.6	2.8	18.8	1.9	23.9	1.9
Total	726.1	100.0	993.7	100.0	1274.1	100.0

TABLE 2. Daily nutrient intake per person for residents of the three villages

	RDA	Beichengzi		Dongjingji		Dongjiao	
		Intake	% of RDA	Intake	% of RDA	Intake	% of RDA
Energy	2600 kcal	1839*	70.7	2005*	77.1	2741**	105.7
Protein	75 g	51*	68.0	65*	86.7	85**	113.3
Fat		23		21		53	
Carbohydrates		270		389		483	
Calcium	600 mg	327*	54.5	241*	40.1	762**	127.0
Iron	12 mg	22	183.3	12	100.0	25	208.0
Retinol equivalents	1000 iu	219	21.9	214	24.4	315	31.5
Vitamin B1	1.3 mg	2.1	161.5	1.9	146.2	2.5	192.3
Vitamin B2	1.3 mg	0.7	53.8	0.5	38.5	1.0	76.9
Vitamin C	60 mg	43.0***	71.7	63.0***	105.0	164.0***	273.0

* Significantly lower than the RDA (National Standard of China), Chi-square test, $p<0.05$

** Significantly higher than the RDA, Chi-square test, $p< 0.05$

*** Significantly lower in Beichengzi and Dongjingji compared to Dongjiao, χ^2 test, $p<0.05$

TABLE 3. Endemic bone deformation in the villages

Fluoride in drinking water	Beichengzi 5.9 ppm		Dongjingji 4.5 ppm		Dongjiao 5.2 ppm		Total	
	No	%	No	%	No	%	No	%
Cases of hump back	13§	24.1	20§	10.5	0	0	33	12.1
Cases of spinal curvature	2	3.7	7	3.7	0	0	9	3.3
Cases of "O"-legs	4	7.4	28	14.6	2	7.1	34	12.4
Total with bone deformation	19*	35.2	55**	28.8	2	7.1	76	27.8
Total without bone deformation	35	64.8	136	71.2	26	92.9	197	72.2
Total with skeletal fluorosis	54	100	191	100	28	100	273	100

§ comparing Beichengzi and Dongjingji together with Dongjiao, Fisher's Exact Test, 2 sided p = 0.0069

* comparing Beichengzi with Dongjiao, Fisher's Exact Test , 2 sided p = 0.0069

** comparing Dongjingji with Dongjiao, Fisher's Exact Test, 2 sided p = 0.0117

* and ** comparing Beichengzi and Dongjingji together with Dongjiao, Fisher's Exact Test, 2 sided p = 0.0074

TABLE 4. Serum calcium and total protein levels in persons with skeletal fluorosis

	Beichengzi	Dongjingji	Dongjiao
Serum calcium < 6 mg/dL	16.7%*	11.4%*	2.0%
Serum total protein < 3.1 g/dL	15.3%*	68.4%*	0.7%

* comparing Beichengzi and Dongjingji with Dongjiao, Chi-square test, p < 0.005

TABLE 5. The presence of osteosclerosis and osteomalacia, determined radiologically, in persons with skeletal fluorosis in the villages

	Beichengzi n = 54		Dongjingji n = 191		Dongjiao n = 28	
	No	%	No	%	No	%
Osteosclerosis present	23*	42.6%	104**	54.5%	22	78.6%*
Osteomalacia present	4§	7.4%	24§	12.6%	0	0%

* comparing Beichengzi with Dongjiao, Fisher's Exact Test, 2 sided p = 0.0023

** comparing Dongjingji with Dongjiao, Fisher's Exact Test, 2 sided p = 0.0230

* and ** comparing Beichengzi and Dongjingji together with Dongjiao, Fisher's Exact Test, 2 sided p = 0.0085

§ comparing Beichengzi and Dongjingji together with Dongjiao, Fisher's Exact Test, 2 sided p = 0.0915, 1 sided p = 0.0407

Of those with radiological evidence of osteomalacia, 85.7% were women, who were particularly at risk when multiparous. The extra energy and protein requirements for pregnancy were not met by the diet available for women in Beichengzi and Dongjingji. In contrast in Dongjiao, with better nutrition, no cases of hump back or spinal curvature were found and the skeletal fluorosis had symptoms and signs of lesser severity.

The results are consistent with the primary factors, in the aetiology of osteomalacia in a high fluoride environment, being an insufficient intake of energy, protein, calcium and Vitamin C. It is seen to be essential that, during pregnancy and lactation, mothers have a good supply of dietary calcium to cover their needs and those of the growing baby. With a high fluoride intake, calcium fluoride is formed in the intestine and excreted in the faeces thus increasing the likelihood of a low blood calcium if there is an insufficient dietary intake. In turn, this may lead to parathyroid stimulation with a secondary hyperparathyroidism, bone matrix absorption, osteoporosis, and osteomalacia. With the pressure from the body weight, pregnancy and labour, deformation may occur with curvature of the lumbar spine, hump back, scoliosis and "O" legs. An adequate intake of Vitamin D, a healthy diet with a wide variety of foods and regular exercise can assist with calcium absorption.[7]

Thus poor nutrition is seen to be an important cause of endemic osteomalacia in a high fluoride environment, and increasing dietary energy, calcium, protein and Vitamin C may help in prevention, especially in pregnant and nursing women, and children.

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