Progress of Research on Some Trace Element Nutrition in China

X. S. Chen

Institute of Nutrition and Food Hygiene,
Chinese Academy of Preventive Medicine, Beijing, China

During last two decades, the research work on trace element nutrition made rapid progress in China. Due to the differences among the national geographic environment, the living condition and dietary habits of the population, the important relationship between the status of trace element nutrition and the health of people has been demonstrated. This paper is going to discribe some recent advance in studies on Zinc deficiency, iron deficiency anemia and iodine deficiency goiter of people in our country. In 1982, we organized a national wide nutrition survey and collected 2774 hair samples of preschool children from 21 provinces and cities. The average Zn level was 103 ppm. Fourty point nine percent of Zn level in hair was over 110 ppm and 23.1% of them below 70 ppm. According to the data suggested by Chen X. C. *et al.*, Zn concentration below 110 ppm in hair is considered as inadequate Zn nutritional status. Zn concentration of 70 ppm in hair may accepted as the harder line of Zn deficiency. So 23.1% of the preschool children may be at risk of Zn deficiency. (Table 1)

Zn level in hair of 644 children aged between 1–6 year in city and countryside of Beijing were measured. Twenty five point six percent of them is below 70 ppm, a little bit higher than the average of that in the whole country. (Table 2)

In another study, Prof. Chen X. C. in our Institute reported Zn concentration in plasma and hair of 703 children from three groups. The first group which contained 187 preschool healthy children were brought into the Child Health Clinic in Beijing for routine physical examination but didn't present any clinical sings of disease. The Zn average level in hair is 100.4 ± 40.3 ppm in this group, 38.0% of them is over 110 ppm, 23% below 70 ppm. The 303 children of group 2 from 11 nurseries and kindergartens in Beijing without any clinical signs of disease had an average hair Zn content of 92.3 ± 41.2 ppm, 34.2% below 70 ppm. (Table 3)

The above data showed that one fourth of preschool children in China may be at risk of Zn nutritional deficiency. They consumed ordinary diet and were without any clinical signs. Zinc bioavailability in Chinese diet pattern might be suboptimal. Because 90% of the calories was from plant origin.

The third group had 213 children. They were brought into outpatient clinics in Beijing because of pica, anorexia or poor growth. Seventy-five presented with growth retardation, 47 with pica, and 91 with major complaint of anorexia. The mean values of plasma and hair Zinc of the third group is significantly lower than that of the well-nourished children. The children who were in this group

received a Zinc supplementation of Zinc sulfate, 3–5 mg per kg per day. After three to six monthes, not only their hair and plasma Zinc level were significantly increased, but also their growth improved, their pica or anorexia cured.(Table 4) Recently Zn and Vit. C fortified soft drink was given to 50 cases with pica and anorexia. Therapeutic effect was significant. The clinical signs were disappeared in 26 children and improved in 20 cases. The therapeutic effect of this soft drink is better than that of 0.4% Zinc sulfatae syrup. There are too many kind of Zn fortified food such as Zn fortified candy, Zn fortified biscuit and Zn fortified table salt appeared in the market. Due to the interaction of trace element, we don't think this abused trace element fortification is reasonable. So there are still a lot of research work need to be done for Zinc nutrition in China, including Zn evaluation, Zn bioavailability, and so on.

Iron deficiency and iron deficiency anemia are common nutritional problems in China. The amount of iron available from the diet varies considerably. The incidence rate of iron deficiency anemia in various reports was also varied. The reason may be that the evaluating criteria adopted by authors are quite different and that the influential factors of iron deficiency anemia are very complicated.

In 1980, a survey of 7499 children under 7 years of age in 8 provinces and cities was made. Fourty percent of the children had hemoglobin level less than 11 g/dl. Wang Wenguang *et al.* also reported the prevalence of anemia in 1481 children under 7-year-old in 16 kindergartens and nurseries in urban areas and 1757 preschool children in remote mountain areas. The average prevalence of anemia, defined as hemoglobin level below 11 g/dl was 8.3% in the entire urban group, 16.5% in those under three years of age, and 35.9% in 7 to 12-month-old infants. This means that the incidence rate of children among 7-month to 1-year-old is much high. For the rural group, the figures were 24.2%, 35.1% and 48.8% respectively (Table 5). So the incidence rate of anemia in children in rural areas is higher than that in the city. A soft drink powder fortified with ferrous sulfate and ascorbic acid was given to the children. The result was satisfactory (Table 6).

In Wang's survey of 3000 children under 7 years of age in 4 provinces including Heilongjiang, Yunnan, Beijing and Xinjiang, 32.6%, 32.7%, 33.7% and 34% of the children were found to have level of hemoglobin less than 11 g/dl respectively. (Table 7)

Some data indicated that the platelet monoamine oxidase activity (MAO) in children with iron deficiency anemia was lower than that of the healthy children. But the urinary excretion of vanillyl mandelic acid (VMA) in children with iron deficiency anemia was higher than that of the healthy children. The MAO activity and the urinary excretion of VMA returned to the normal levels within one month after the iron therapy. Therefore our scientists considered that iron deficiency in children and infants might lead to the behavioral alteration (Table 8).

Studies in our Institute also indicated that iron deficiency anemia occurs with greater frequency in pregnant women. A progressive drop in the hemoglobin, hematocrit, serum iron and transferritin saturation values in pregnant women was reported.

The incidence of iron deficiency anemia in these pregnant women were 34.3% in the second

Table 1. Average Zn concentration of preschool children in China

Location	No. of subjects	Average Zn concentration μg/g	>110 μg/g		<70 μg/g	
			No.	%	No.	%
21 provinces and cities	2774	103.42	1137	41.6	640	23.4
Beijing	187	100.4	71	37.5	43	23.0

From Yin T. A. *et al.*

Table 2. Distribution of hair zinc content of 644 preschool children

Hair Zinc (ppm)	Boys		Girls		Boys and Girls	
	No.	%	No.	%	No.	%
70	82	21.4	83	31.9	165	25.6
70.1–110.6	114	29.7	84	32.3	198	30.8
110.7	188	48.9	93	35.8	281	43.6
Total	384	100.0	260	100.0	644	100.0

From Chen X. C. *et al.*

Table 3. The distribution of hair Zinc content in the examined preschool children

Group	Average μg/g	>110 μg/g %	<70 μg/g %
I	100.4 ± 40.3	38.0	23.0
II	92.3 ± 41.2	34.7	34.2

Table 4. Hair and plasma zinc values on different group of children before and after zinc treatment

Group	age (year)	Before treatment		After treatment	
		Plasma Zn	Hair Zn	Plasma Zn	Hair Zn
		μg/dl	μg/g	μg/dl	μg/g
Well nourished	6.0 ± 2.8	99.8 ± 15.7 (n = 30)	152.9 ± 32.0 (n = 94)		
Pica	3.0 ± 2.2	90.4 ± 38.1 (n = 47)	78.1 ± 25.7^{+} (n = 47)	109.1 ± 32.4^{+} (n = 47)	134.1 ± 59.4^{+} (n = 47)
Anorexia	4.6 ± 2.5	79.3 ± 24.0* (n = 69)	81.2 ± 26.9^{+} (n = 91)	108.2 ± 32.5^{+} (n = 69)	131.5 ± 32.7^{+} (n = 69)
Poor growth	4.9 ± 2.5	83.2 ± 26.3* (n = 25)	82.3 ± 29.4^{+} (n = 75)	101.0 ± 30.9^{+} (n = 25)	119 ± 35.0^{+} (n = 59)

Adopted from Chen X. C. 1983; * $P < 0.05$ + $P < 0.001$

Table 5. Prevalence of anemia by age

Age	Kindergarten and Nurseries			Living at Home (Urban)			Living at Home (Rural)		
	No.	Cases	%	No.	Cases	%	No.	Cases	%
7 mo	21	2	9.5	211	22	10.4	91	29	31.8
1yr	67	24	35.9	207	40	19.3	129	63	48.8
2yr	234	68	29.1	358	87	24.3	405	149	36.8
3yr	418	28	6.1	136	14	10.2	252	67	26.6
Total	740	122	16.5	912	163	17.8	877	308	35.1
4yr	230	1	0.4				201	53	26.4
7yr	511	8	1.6				679	65	9.6
Total	1481	131	8.3				1757	426	24.2

Table 6. Therapeutic effects of iron fortified soft drink powder given to children under 3 years old at home for 3 months

Groups	No. of Children	Iron Supplement	Before Treatment		After Treatment	
			Hb (g/dl)	Hct (%)	Hb (g/dl)	Hct (%)
Hb < 11g/dl	11	9.1	10.0 ± 0.6	32 ± 4.1	15.1 ± 1.5	45 ± 4.7
Hb 11–12g/dl	17	8.6	11.3 ± 0.3	34 ± 2.9	15.0 ± 2.3	45 ± 4.9
Hb > 12g/dl	73	6.5	12.1 ± 2.5	38 ± 3.7	15.0 ± 2.3	44 ± 5.5

Table 7. Incidence rate of anemia in preschool children of different nationality and different areas %

Place / Age (Years)	Heilong Jiang		Xin Jiang		Yun Nan		Beijing
	Han	Chao	Han	Uygur	Han	Bai	Han
< 1	65.2	46.3	48.9	42.6		62.2	
1	46.8	39.0	27.3	39.3		41.4	
2	28.8	23.0	11.4	33.6		24.4	
3 – 6	16.4	22.3	9.0	27.5		20.7	
Average	32.6	29.5	17.3	34.0		32.7	33.7

trimster and 36.4% in the third trimester. There was also a significant decrease in serum ferritin accompanied by a rise of FEP (Table 9, 10; Figure 1, 2, 3).

Table 8. Platelet MAO and urine VMA in children with iron deficiency anemia

	Before Treatment		After Treatment	
	Cases	X ± SD	Cases	X ± SD
Hb (g/dl)	16	9.56 ± 0.30	6	11.08 ± 0.52
SI (ug/dl)	13	40.86 ± 5.07		
MAO (I.U./37°, 3h/mg)	16	9.99 ± 1.74	6	23.82 ± 3.95
VMA (I.U./24 hour urine)	9	7.17 ± 1.32	6	4.21 ± 0.44

Table 9. Iron deficiency anemia in pregnant women

	Middle stage of pregnancy	Late stage of pregnancy
No. of subjects	99	89
Cases	34	32
Incidence rate %	34.3	36.0

Table 10. Hematologic parameters of pregnant women in comparison with nonpregnant women

	Pregnant women	Nonpregnant women
	n = 99	n = 68
Hb (g/dl)	11.40 ± 1.17+	13.46 ± 1.28
RBC ($10^4/mm^3$)	369.0 ± 32.6	429.3 ± 35.0
EP (ng/dl)	47.9 ± 1.63	38.4 ± 1.40
PF (ng/dl)	10.5 ± 3.80	46.2 ± 2.03

An iron and ascorbic acid fortified glucose was given to 33 pregnant women with anemia. At the end of one month, the hematological criteria were improved significantly (Table 11, 12). So the conclusion is that the anemia of the pregnant women was not due to haemodilution, but rather than to iron deficiency. The observation in late pregnancy showed that, without iron supplementation, normal maternal iron stores are almost exhausted as evaluated by FEP, PI, TIBC, DUIBC, TS and SF (Table 13).

According to the Chinese dietary pattern, the major energy intake comes from plant resources. Therefore the bioavailability of iron is probably quite low. The improvement of dietary regimen or iron supplementation during the pregnancy should be put foward to improve the iron

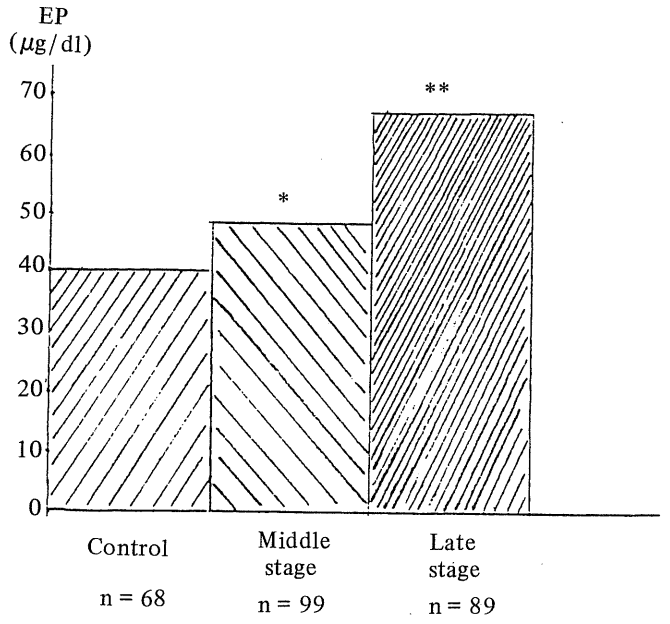

Fig. 1. EP of pregnant women in different stages of pregnancy in comparison with nonpregnant women; P*<0.001, **P<0.005.

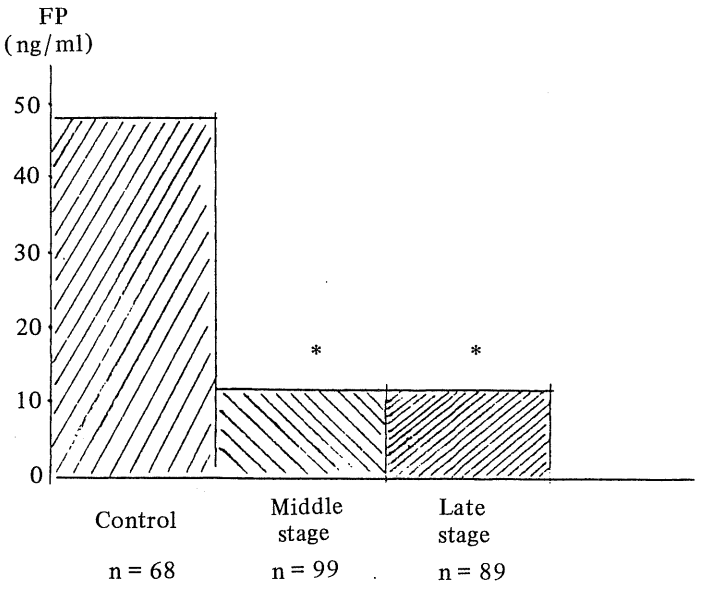

Fig. 2. PF of pregnant women in different stages of pregnancy in comparison with nonpregnant women; *P<0.001.

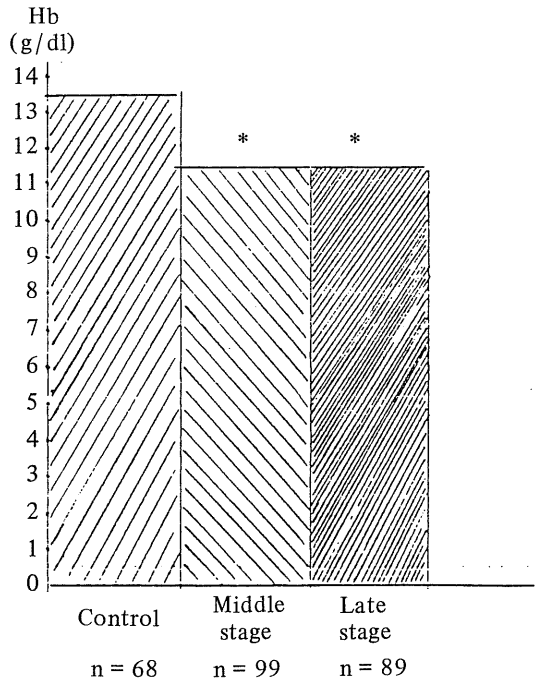

Fig. 3. Hb of pregnant women in different stages of pregnancy in comparison with nonpregnant women; *P<0.001.

Table 11. Therapeutic effects of 33 anemia cases of pregnant women

Items	Before Treatment	After Treatment	P
Hb (g/dl)	10.3 ± 0.57	11.7 ± 1.4	< 0.001
RBC (10^4/mm^3)	380 ± 44	394 ± 50	= 0.054
Hct %	31.6 ± 2.8	33.4 ± 3.6	< 0.002

Table 12. Therapeutic effects of iron soft drink powder on children under 3 years in nurseries

Length of Treatment (months)	Number of Children	Before Treatment			After Treatment		
		Hb (g/dl)	RBC (10^4/mm^3)	Hct (%)	Hb (g/dl)	RBC (10^4/mm^3)	Hct (%)
1	16	10.4±1.3		34±3.4	13.1±1.8		38±3.0
2	23	10.6±1.2	401±46.5	33±6.8	14.3±1.8	470±40.9	41±5.1

Table 13. The results of FEP and PI in healthy and pregnant women (X ± SD)

Items	Healthy women (20 cases)	Pregnant women (13 cases)
FEP (μg%)	53.28 ± 12.37	91.80 ± 48.24*
PI (μg%)	93.50 ± 9.40	73.90 ± 16.40
TIBC (μg%)	330.49 ± 20.00	444.6 ± 44.6
UIBC (μg%)	236.99 ± 22.14	371.5 ± 42.0
TS (%)	28.39 ± 3.40	16.6 ± 3.3

status of pregnant women. Our strategies for the eradication of iron deficiency include:

1. Promotion of breast feeding.
2. Iron supplementation.
3. Food fortification: Food fortified with iron and other related nutrients.
4. Education and professional training: To disseminate the nutritional knowledge to people so they know how to choose food rich in iron.

Goiter is an endemic disease widely spreaded in the mountain areas of China affecting 1464 counties with a total of 250 million people. The incidence rate of goiter is about 10% in severely endemic areas. Using iodized table salt to control goiter in 512 counties, occuping 35% of total affected population proved to be very successful. A grand total 10 million people was cured from goiter with the treatment of iodized salt and iodized oil and more than 100 million people in endemic areas were protected from goiter with iodine supplementation. In some areas, goiter incidences were reduced from 4 million cases to only half a million after 10 years implementation of goiter prevention program.

The iodine concentration in the table salt used for prevention is 1/50000 to 1/20000. Zeng Guo Yan reported a fortification study with 1/50000 iodine used in two production brigade. The urinary iodine excretion of children with endemic cretinism increased from 13.6 μg/g creatinine to 157.6 μg/g creatinine, after a treatment of iodine fortified table salt for 1 year. The result of thyroid function test in these children were also found much improved. Zhang Bao Tian carried out an experiment to explore the iodine concentration suitable for population in endemic areas. They used three different iodine level. The results showed that 1/20000 and 1/40000 iodine are suitable for decreasing the incidence of goiter, increasing the urinary iodine excretion and improving the function of thyroid. The treatment group with 1/80000 iodine fortified table salt is not effective. So they suggested that a 1/40000 iodine level in table salt is good enough for prevention of goiter, while 1/20000 may be too expensive since the size of population in China is too large. (Table 14)

In the beginning of the seventies, we noticed a prevalence of goiter in coast areas of our country. In 1978, Yu Zhu Heng carried out a number of epidemiological survey. The data showed that high iodine intake can cause goiter too. The incidence rate of goiter in population resided in coast area was 3–7%. He found a high correlation between incidence of goiter and urinary iodine

excretion. When the total urine iodine was below 50 μg/l and the iodine concentration of water was below 5 μg/l, the less excretion was associated with a higher incidence of goiter. The incidence of goiter was the lowest when the iodine concentration of water was 5–40 μg/l and the urinary iodine excretion is 50–400 μg/g creatine. The incidence of goiter increased gradually when the urine iodine excretion is more than 400 μg/g creatinine, the iodine concentration of water is more than 40 μg/l. The intelligence quotient of children in goiter endemic area was much lower than that in nonendemic areas.

Iodine supplementation such as iodine fortified table salt was very successful to prevent the goiter and cretinism in endemic areas of China. But further research and practical works for eliminating the harm of iodine deficiency will still be needed.

Other trace elements including Mn, Mo, Cu, Zn in food and some trace elements such as Cr, Mn, Cu, Mg in human blood, milk and hair were also analyzed. The results indicated a big geographical variations. (Table 15).

Table 14. A comparison of the preventive results between the different iodine concentration in table salt

Group	Incidence rate of goiter	Physiological enlargement of thyroid	Urinary iodine excretion	^{131}I absorbance by thyroid
	%	%	μg/g creatine	%
1/20,000	0.18	11.08	175	25.14
1/40,000	0.17	9.99	150	25.90
1/80,000		18.73	81	41.5
Control in endemic areas	1.75	35.47	47	68.16

Table 15. Trace element content in Chinese food (μg/g dry matter, X ± S.D.)

	Zn	Mn	Cu	Fe	Mo
Rice	19.5 ± 3.6	30.4 ± 8.8	2.4 ± 0.4	9.5 ± 1.5	0.66 ± 0.41
Wheat	29.8 ± 7.3	40.9 ± 1.0	5.5 ± 0.6	50.4 ± 7.1	0.60 ± 0.18
Corn	18.6 ± 2.8	6.3 ± 0.2	1.9 ± 0.2	25.4 ± 7.8	0.49 ± 0.03
Soy bean	35.1	22.9	13.0	65.2	6.59
Potato	14.1	5.0	7.4	18.4	0.50

REFERENCES

1. Chen, X. C. *et al.* (1985): Low levels of zinc in hair and blood, pica, anorexia and poor growth in Chinese preschool children. Am. J. Clin. Nutr., 42, 694.
2. Wang, W. O. *et al.* (1986): Hematologic response to iron and ascorbic acid administration in preschool children with anemia. Nutrition Research, 6, 241.

3. Wang, W. G. *et al.* (1983): Studies on iron deficiency anemia of preschool children. Acta Nutrimenta sinica, 5, 73.
4. Wang H. *et al.*: Investigation of the relationship of the iron nutritional status between maternal and infants. Acta Nutrimenta Sinica (In press).
5. Wang, W. O. *et al.* (1984): Studies on iron deficiency anemia of pregnant women in Beijing. Acta Nutrimenta Sinica, 6, 135.
6. Chen, Z. Z. *et al.* (1984): Iron deficiency in late pregnancy (with results of observation on free erythrocyte prophyrin transferrin saturation and marrow iron in 16 cases). National Medical J. of China, 64, 108.
7. Lio, O. K. *et al.* (1983): Determination of the platelet monoamine oxidase activity and the urinary excretion of vornillyl mandelic acid in children with iron deficiency anemia. Chinese I. of Pediatric, 21, 262.
8. Yu Zhiheng *et al.* (1984): The relation of iodine with the goiter prevalence in human subjects. Acta Nutrimenta Sinica, 6, 3, 255.
9. Chen, Zupei *et al* (1986): Discussion about the control of the iron deficiency disease. Chinese Journal of Endemiology, 5, 3, 225.
10. Liu Zitai *et al.* (1987): The prevention and recent development in the research of the iodine deficiency disease. Chinese Journal of Endemiology, 6, (1), 51.
11. Researching group of endemic thyroidism and cretin, Gui yang Medical College (1984): Observation of the preventive effects on the endemic cretin by using iodate. Chinese Journal of Endemiology, 3, (4), 243.