The calcium absorption of Chinese children in relation to their intake

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Standard dietary calcium requirements for various age groups have mostly been estimated and derived from studies performed in Caucasian populations. This is the first calcium absorption study performed in Chinese children who may not drink milk regularly. A technique using double-labelled stable calcium isotope was employed to measure true fractional calcium absorption. Thirty four seven-year-old children with calcium intakes ranging from 172 to 1641 mg/d were studied. They were then randomised into two groups, one being given 300 mg elemental calcium daily for six months, the other being given placebo tablets daily for the same period. It was found that the mean true fractional calcium absorption was 63% and 55% in children whose daily calcium intake was below 500 mg and above 500 mg respectively. Both absorption rates were much higher than those reported in Caucasian children, and there was a physiological increase from 58% to 64% in true fractional calcium absorption as children grew from age seven to seven and a half. Calcium supplementation caused a significant fall in calcium absorption (61% to 56%). The change in calcium absorption during the six months of supplementation was significantly different to the control values, even after adjusting for other baseline variables. It was concluded that calcium absorption is affected by calcium intake and calculations of recommended daily calcium intakes should take this into account.

HKMJ 1995;1:58-62

Keywords: Calcium absorption; Chinese children; Calcium intake; Calcium supplementation

Introduction

One of the major differences between the traditional diet of Chinese and Caucasian populations is the rare consumption of cow's milk and dairy products by the former. This is reflected in the daily calcium intake which is three times higher in Caucasians. Westernisation in Hong Kong has led to an increase in milk consumption and calcium intake in children's diets. Whether it is really beneficial to encourage a much higher calcium intake in childhood depends on further scientific investigation. This has great implications should there be any radical shift in the traditional diet of the 1.2 billion people living in mainland China.

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For many generations, Chinese infants have been weaned from breast milk when approximately one year old. The main source of dietary calcium for children and adults has been green vegetables, soy bean products, cereals, seeds, nuts, shells, and bone. Children did not seem to suffer from this level of calcium intake. Hypocalcaemia in children occurs mainly as a result of endocrine or metabolic disorder rather than nutritional deficiency. Indeed, reports of clinical disorders due to dietary calcium deficiency in childhood are scarce.

Osteoporosis, a condition in the elderly considered to be partly related to low calcium intake was not found to be more common in Chinese, but the reverse—only one-third were affected compared with their American counterparts who had a much higher habitual calcium intake.[1,2] Whether or not Chinese have different absorption efficiency was studied in this paper. This is important because the recommended calcium requirement for a population is estimated according to the efficiency of absorption, which may differ among different ethnic groups, particularly with different levels of dietary calcium intake.

Previous studies investigating the dietary intake of Hong Kong Chinese children have demonstrated a wide range of calcium intakes as some children drink milk, while others do not.[3] Mainland Chinese children receive practically no milk after they are one year old.[4] Recruitment of children from the mainland enabled us to study children with different calcium intakes.

Most calcium absorption and metabolic studies are tedious, requiring the collection of faeces, hence, these are seldom performed in children. The newly developed technique of double-labelled stable calcium isotope (DLCI) enables the true fractional calcium absorption (TFCA) to be measured safely and accurately in children.

Subjects and methods

The subjects had previously participated in a much bigger study on calcium supplementation and bone mineral content.[5] In 1991, 22 Hong Kong seven-year-olds were chosen from the cohorts of a longitudinal study of growth and nutrition and 12 children of the same age and ethnic origin were chosen from a school in Jiangmen, Guangdong Province.[6] At the time of recruitment, their habitual daily nutrient intakes, including energy, calcium, protein, and phosphorus were assessed by the research dietitian. Body weight and height were measured in the standard ways. In Hong Kong, the children were weighed on a Seca electronic scale, accurate to 0.1 kg, wearing light clothing, and measured with a Harpenden stadiometer, accurate to 0.1 cm. In Jiangmen, the children were weighed on a Lichipai beam balance and measured with a kg stadiometer, with the same accuracy. Baseline TFCA was studied using DLCI. The children were randomised into two groups, with one receiving a daily calcium supplement of 700 mg calcium carbonate containing 300 mg elemental calcium for six months, while the other group received placebo sucrose tablets (having the same taste and smell). Both investigators and subjects were blinded to the type of tablets received by each child. Tablets were distributed by teachers in Jiangmen and by mothers in Hong Kong. After six months, TFCA was repeated in each subject (details of the method used are described in another paper).[7] Each child was asked to fast overnight. In the morning, 0.75 mg ^{42}Ca was injected intravenously followed by the oral ingestion of 8 mg ^{44}Ca contained in a 100 gm chocolate milk drink. A standard breakfast consisting of sponge cake and 250 ml fruit juice was given two hours later. A 500 ml urine sample was collected exactly 24 hours later to help determine the ratio of the two stable isotopes (Norwich Laboratory, UK).

The relationship between the initial TFCA and each individual's calcium intake was studied using Pearson T correlations. As 500 mg/d is frequently quoted as the required amount of dietary calcium, a cutoff daily calcium intake of 500 mg/d was used to divide subjects into groups A and B. The mean TFCA of the two groups was compared. Children were also grouped according to whether or not calcium supplementation was given for six months. Differences in TFCA values between the two groups were tested by non-parametric Mann Witney U test. The non-parametric Wilcoxon signed rank test was used to test intrapersonal changes in TFCA over the trial period. Multiple regression analysis was used to identify the relative contributions of initial calcium intake, treatment effect, and the effect of interaction between baseline calcium intake and treatment effect on the prediction of changes in TFCA over the trial period. The significance level was set at $P < 0.05$, 2-tailed. Statistical analysis was performed by SPSS/PC, Version 4.0, SPSS Inc., Chicago, Illinois, US. Ethical approval was obtained from the Faculty of Medicine, The Chinese University of Hong Kong and the AFRC Institute of Food Research, UK. Informed consent was obtained from the parents of all subjects.

Results

The calcium intake of Hong Kong children ranged between 185 to 1641 mg/d, including 14 children who consumed milk regularly and eight who did not. In contrast, the calcium intake of the 12 Jiangmen children had a narrower range of 172 to 552 mg/d. Dietary intakes of energy, phosphorus and protein in Hong Kong children were significantly higher than those in Jiangmen children due to the higher consumption of meat and sugary drinks in the former. Although the calcium intake of Hong Kong children was higher than that of Jiangmen children, calcium intake corrected for energy intake showed no difference. Neither were there any significant differences in weight or height (Table 1). There was no significant correlation between TFCA and calcium intake. Intakes of protein, carbohydrate, fat, phosphorus, body weight, and height did not show any significant correlation with TFCA either.

The nutrient intake of group B (calcium intake > 500 mg/d)—mostly Hong Kong children—was significantly higher than that of group A (calcium intake ≤ 500 mg/d). The mean (SD) TFCA of group A was 63.1% (10.7%), significantly higher than the 54.8% found in group B (7.3%) (Table 2).

Compliance in the supplementation group was

Table 1. Baseline nutrient intake, weight and height of the seven-year-old Chinese children

	Hong Kong n = 22 mean (SD)	Jiangmen, Guangdong n = 12 mean (SD)	p
Energy, KJ/d	7724 (1874)	4678 (1021)	<0.0001
Calcium, mg/d	693 (410)	381 (103)	<0.01
Ca/energy, mg/MJ	85.3 (34.2)	81.3 (14.3)	ns
Phosphorus, mg/d	1002 (327)	683 (180)	<0.01
Ca:P ratio	0.66 (0.22)	0.56 (0.12)	ns
Protein, g/d	77 (19)	58 (17)	<0.01
Weight, kg	20.9 (2.57)	21.3 (3.2)	ns
Height, cm	119.3 (3.6)	119.5 (4.1)	ns

ns not significant

Table 2. True fractional calcium absorption (TFCA), nutrient intake, weight, and height of the seven-year-old Chinese children with daily calcium intake ≤ 500 mg/d (group A) and > 500 mg/d (group B)

	Group A n = 19 mean (SD)	Group B n = 15 mean (SD)	p
TFCA, %	63.1 (10.7)	54.8 (7.3)	<0.05
Calcium, mg/d	363 (91)	862 (394)	<0.0001
Energy, KJ/d	5355 (1324)	8290 (1957)	<0.001
Ca/energy, mg/MJ	70.4 (20.1)	101.1 (28.9)	<0.01
Phosphorus, mg/d	716 (163)	1109 (340)	<0.001
Ca:P ratio	0.52 (0.13)	0.76 (0.17)	<0.001
Protein, g/d	61.6 (18.3)	81.6 (17.6)	<0.01
Weight, kg	19.8 (2.3)	21.5 (2.6)	ns
Height, cm	120 (3.5)	119 (3.8)	ns

ns not significant

assessed by counting the number of tablets left at the end of the trial. Compliance was very high—94.5%. There was no significant difference between the mean compliance of the study and control groups and there were no drop outs. The baseline mean calcium intakes of the supplement group were slightly higher, but this was not significant. Phosphorus and protein intakes were significantly higher in the study group. The average weight and height of the two groups were similar. There was no significant difference in the initial TFCAs of the study group and the control group (mean 60.6%, SD 11.4% and mean 58.2%, SD 9.0% respectively). After six months, the difference in TFCAs was significant, (mean 55.6%, SD 12.7% in the study group vs mean 64.3%, SD 10.7% in the control group) (Table 3). Thirteen of 17 controls showed an increase in TFCA after six months, while 14 of 17 showed a fall in TFCA in the study group. This change was significant ($p < 0.01$) and the difference remained even after adjusting for baseline dietary intakes of calcium, phosphorus and protein, weight and height ($p < 0.01$). Multiple regression analysis using variables of initial calcium intake, treatment effect, and the effect of their interaction for the prediction of the change in TFCA over the trial period showed that it was only the treatment effect that was influential ($p < 0.05$).

A dietary survey of the children after the six-month trial was not repeated because the nutrient intakes were estimated to be similar to those of the baseline, with

Table 3. True fractional calcium absorption (TFCA) before and after a six-month trial of calcium supplementation and the baseline nutrient intakes and body size in the two groups

	Study group n = 17 mean (SD)	Control group n = 17 mean (SD)	p
Baseline TFCA, %	60.6 (11.4)	58.2 (9.0)	ns
TFCA at six months, %	55.6 (12.7)	64.3 (10.7)	<0.05
Calcium, mg/d	672 (392)	494 (324)	ns
Energy KJ/d	7055 (2170)	6235 (2183)	ns
Ca/energy, mg/MJ	91.8 (30)	76.3 (26)	ns
Phosphorus, mg/d	980 (328)	798 (294)	<0.05
Ca:P ratio	0.661 (0.2)	0.586 (0.18)	ns
Protein, g/d	76.1 (17)	64.8 (22.3)	<0.05
Weight, kg	21.3 (2.9)	20.7 (2.6)	ns
Height, cm	119.6 (3.6)	119.3 (4.0)	ns

ns not significant

the exception of calcium. The mean calcium intake of the study group would of course be 300 mg more than the baseline amount, i.e. 972 mg/d.

Discussion

The FAO/WHO recommended daily dietary calcium intake for children is 500 mg/d.[8] This estimate was based on studies in Caucasian populations, assuming an absorption rate of 40%. Indeed, studies have shown Caucasian children and adolescents to have TFCA values of 30% to 36% and a daily calcium intake of approximately 1000 mg.[9,10] Our study demonstrated a much higher absorption rate among Chinese children—64% with a daily intake of 494 mg and 56% with a daily intake of 972 mg. Similar high absorption rates have also been reported in Sri Lanka and India—60% absorption with a calcium intake of 200 to 300 mg/d. A review of 99 metabolic balance studies in children aged two to eight years showed that the mean urinary calcium loss fell from 117 mg/d to 60 mg/d when mean calcium intakes declined from 1600 mg/d to 470 mg/d, also reflecting a higher absorption rate when daily intake is reduced.[11] Calcium absorption increases with age to cope with growth requirements. This could explain why children aged seven and a half had a higher TFCA than did the seven-year-olds. The six months of 300 mg daily calcium supplementation presumably altered the state of calcium equilibrium by downward regulation of the subject's calcium absorption mechanism. The regulation of TFCA occurred in children with different levels of habitual calcium intake in order to absorb a necessary amount of calcium for growth. Such regulation is obvious during puberty when bone mineral content rapidly increases despite an unchanged calcium intake (Leung SS, et al, unpublished data). The abscence of correlation between baseline TFCA and current calcium intake could be due to the small sample size and the non-linear relationship between the two. The sample size was limited by the high cost of the isotopes, but was adequate to demonstrate the difference in TFCA found between the high and low intake groups.

The long tradition of having a low calcium intake in the Chinese diet has possibly led to Chinese developing a higher calcium absorption rate. The requirement for calcium intake in Chinese could differ markedly from that of Caucasians. The recent increase in the prevalence of osteoporosis in Hong Kong is associated with a change in dietary practice such as a decreased consumption of calcium-rich Chinese food and a more sedentary lifestyle. There may be a lower limit of calcium intake below which the body suffers, even with adaptability. In addition, such adaptability may disappear after the menopause because of hormonal changes. These hypotheses can be tested by conducting further calcium absorption studies. Studies that are extended to include different age groups will help to establish calcium requirements in habitually non-milk drinking populations.

The technique of double-labelled isotopes measures

TFCA by giving one isotope orally and the other one intravenously, to correct for endogenous calcium secreted into the intestine. The technique is superior to traditional balance studies which fail to differentiate between endogenous calcium and dietary sources. Using double-labelled calcium isotopes only requires a sample of body fluids, e.g. urine and blood, and the ratio of the two isotopes in the body fluids. The test is also less time consuming. However, it is still very expensive, thus limiting the number of subjects who can be enrolled in such studies.

Acknowledgements

The authors would like to thank the Research Grant Council, Hong Kong, for sponsoring the project and Miss D Leung, Miss H Tsang, Dr SH Wong, Dr YC Xu, Dr WP Zeng, and Mr W Tung for their assistance, also Dr J Lau for assisting with the statistical analysis and SmithKline Beecham (Hong Kong) for supplying the calcium and placebo tablets.

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