Review Article

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Dietary calcium intake - a critical reappraisal

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The clinical implications of calcium deficiency include rickets, poor bone mass accrual as well as abnormal foetal programming during pregnancy, poor peak bone mass due to poor accrual in childhood and adolescence, postmenopausal osteoporosis and osteoporosis of the elderly. Serum calcium is maintained within a narrow normal range, chiefly by resorption from the skeleton and alteration of urinary calcium loss and absorption from gut. Absorption is dependent on vitamin D sufficiency, presence of calcium binders in diet (such as phosphate, oxalate and phytate), age group and physiological state. A 2004 WHO expert panel has examined available data on calcium balance studies as well as calcium deficiency states and recommended daily calcium intake in the adult to be 1000 mg per day, with adjustments suggested for other age groups and physiological states. Daily calcium intake in India, both the reality and the recommendations, are far lower than the Western data. A reappraisal of dietary calcium recommendations may be necessary for India.

Key words Calcium - diet - osteoporosis - rickets

Introduction

Calcium is an important mineral component of our diet. It is chiefly available to us in milk and milk products, certain seafood, legumes and some vegetables. Over the last 3 to 4 decades, the clinical implications of calcium deficiency are being better recognized, the economic burden of osteoporosis is increasing, and deficiency of vitamin D (important for calcium absorption) is being documented in tropical countries also. For all these reasons, a reappraisal of dietary calcium recommendations may be relevant.

Distribution of calicum in the human body

Ninety nine per cent of calcium in the human body is distributed in the skeleton. The 1 per cent, which is extraskeletal, is present in every cell in the body, and in the extracellular fluid (ECF). Ionized calcium concentration in the ECF is 4.8 mg/dl (1.2 mmol/l) and total calcium is approximately double. Serum calcium is maintained within a narrow normal range, chiefly by resorption from the skeleton and alteration of urinary calcium loss and absorption from gut. The secretion of parathormone affects these changes when ECF calcium is sensed to be low by the calcium receptor in the parathyroid gland[1].

Absorption of calcium occurs in the proximal small intestine, both through an active intracellular vitamin D dependent pathway (especially when intake is low) and through a non vitamin D dependent paracellular pathway (especially when calcium intake is high)[2]. Only

about 35 per cent of dietary intake is absorbed at an intake of about 400 mg per day. This percentage falls as intake rises further. Absorption is dependent on vitamin D sufficiency, presence of calcium binders in diet (such as phosphate, oxalate and phytate), age group and physiological state. The relatively high calcium to phosphorus ratio in breast milk (2.2) compared to cow milk (0.7) makes the former more favourable in terms of calcium absorption. The presence of phytate in legumes and wheat husk (and therefore *chapattis*) has been implicated in contributing to rickets in Indians living in the temperate climates of UK where sunshine (and therefore vitamin D) is inadequate[3]. The relatively poor bioavailability of calcium is also uniformly found with all salts used for calcium supplementation.

Loss of calcium from the body occurs through urine, faeces, as well as insensible loss. In adults, the minimum urinary loss is upto about 140 mg/day. This value rises with increased sodium intake and increased animal protein intake. Each gram of increased protein intake increases urinary calcium excretion by 1 mg per day. The mechanism is thought to be the high phosphate (and perhaps sulphate) content of protein, which complex calcium in the renal tubule and enhance its excretion[4-6]. Similarly, each gram of increased sodium intake increases urinary calcium excretion by 15 mg per day. Here the mechanism is through direct competition between the two ions for tubular reabsorption[7,8]. These two conditions which alter urinary calcium loss and calcium balance might be of relevance to calculation of calcium requirements in those populations whose daily intake of animal protein and salt may be less than that in Western diets. Hitherto, all the calcium balance studies in the literature have been performed on the background of Western diets only.

Insensible loss from skin, hair and nails accounts for 40 to 80 mg calcium loss per day. These amounts are unrelated to calcium intake[9,10].

Clinical implications of dietary calcium deficiency

A discussion of the details of the clinical implications of calcium deficiency (listed below) is beyond the scope of this review. The readers may refer to a number of useful references[11-16].

1. Metabolic bone disease of prematurity
2. Calcium deficiency rickets in childhood
3. Inadequate bone mass accrual in childhood and adolescence
4. Inadequate foetal bone mass accrual/other metabolic effects and programming
5. Possible secondary vitamin D deficiency
6. Osteoporosis - postmenopausal and senile

Calculation of calcium requirement in adults

This calculation has been done using the regression line, which has been drawn by several authors (who have performed calcium balance studies in the first half of the 20th century), between calcium intake and calcium excretion (urinary and foecal)[17-21]. The intake at which the calcium excretion is zero (intake and absorption are equal) would be regarded as the requirement. Though considerable differences exist between results thus obtained from different researchers, a WHO expert panel has concluded that this value is 520 mg per day for adults living in a western environment and consuming a western diet[22]. Accounting for insensible loss increases this value to 840 mg. Therefore, recommendations would be set at 1000 mg per day.

Such balance studies do not exist for the special groups described below. For them, the WHO expert panel has calculated the sum of available data on skeletal accretion and urinary and other losses, and estimated the dietary intake required to provide that amount of absorption. Their recommendations are as follows:

Special considerations for calcium requirement in different age groups, physiological states and cultures

1. Foetus and newborn: Calcium accretion into the skeleton is about 100 mg per day. The placenta provides calcium to the foetus by active transport, against a maternal gradient. Thus, the preterm baby, who no longer has the benefit of this protected source of calcium, is at risk for metabolic bone disease both due to calcium as well as phosphorus deficiency, unless provided special supplements. Urinary loss in infants is about 10 mg per day as is insensible loss. Thus infants need to absorb about 120 mg per day. Infants absorb calcium more efficiently than adults, and calcium absorption from human milk is better than from cow milk[23,24]. About 240 mg of calcium from human milk and 300 mg from cow milk is expected to provide 120 mg of absorbed calcium. The recommended intake from breast milk has therefore been suggested as 300 mg, and from cow milk as 400 mg.

2. *Children*: Skeletal accretion increases from 120 mg per day at 2 yr to 400 mg per day at 9 yr. Urinary, foecal and insensible losses amount to about 100 mg per day. The resulting total of 220 mg per day in the younger ages would be provided by an intake of about 400 mg per day, and recommendations may be set at 600 mg per day. This would gradually increase in the age groups of older children.

3. *Adolescent*: Skeletal accretion is 300 to 400 mg per day, urinary loss about 100 mg and insensible loss about 40 mg per day[25]. This target of at least 440 mg of absorbed calcium requires an intake of 1040 mg per day (the slope of the relationship between absorption and intake is flat at higher absorption levels, necessitating greater changes in intake to bring about the same increment in absorbed calcium), and recommendations would be set at 1300 mg per day.

4. *Pregnancy*: Foetal accrual is about 240 mg per day. Maternal urinary and insensible loss is about 180 mg. The target of absorbed calcium of 420 mg is expected to be provided by intake of 940 mg (calcium absorption is especially enhanced during pregnancy, via higher calcitriol level), leading to a recommendation of 1200 mg per day[26].

5. *Lactation*: Calcium loss in breast milk is of the order of 280 mg per day. Thus, absorption required is about 440 mg, which would be provided by about 1040 mg of intake, leading to a recommendation of 1300 mg per day[22]. Conversely, a number of investigators have reported the lack of correlation between lactational bone loss and supplementation of dietary calcium[27-31]. However, enhanced recommendations for calcium intake during lactation have been retained by governmental agencies.

6. *Menopause*: The extra urinary calcium loss during the postmenopausal period is 30 mg per day. As calcium absorption in this age group is lower than young adulthood, the amount of extra dietary intake needed to offset this loss is as high as 260 mg. This would increase the recommended intake from 1000 mg for younger adults to 1300 mg per day[32-34].

7. *Elderly*: The evidence that elderly men also have poor calcium absorption is less convincing than the data for postmenopausal women. Nevertheless, men over the age of 65 yr have been recommended 1300 mg per day by the WHO expert panel[22].

8. *Ethnic variations in diet*: Due to the influence of animal protein intake and dietary or urinary sodium on urinary calcium loss, as mentioned above, it is plausible that Indians, whose animal protein intake may be considerably lower than that of a typical western diet, may require a lower calcium intake. Similarly, urinary sodium in hot tropical environments may be low, leading to lower urinary calcium loss[35]. Conversely, the high phytate concentration present in commonly consumed Indian foods such as *chapattis* and legumes might be expected to increase the calcium requirement. Calcium balance studies in subjects living in such conditions are not yet available[36].

Table depicts the current recommendations by the official bodies of various countries.

Calcium intake in recently published Indian literature

Balasubramaniam *et al*[38] documented calcium deficiency rickets among toddlers attending an urban hospital in Lucknow. The mean daily calcium intake in this group of children belonging primarily to low and lower middle socio-economic group was 282 ± 114 mg. Mean serum 25 hydroxy vitamin D (25OHD) was normal, 20.0 ± 15.6 ng/ml, and rickets healed without any vitamin D supplementation in all children treated with calcium replenishment alone. In contrast to these toddlers, adolescent girls living in the same city, belonging to a similar socio-economic group, presenting with rickets/osteomalacia, were documented to suffer from severe vitamin D deficiency (mean 25 OHD 4.9 ± 2.7 ng/ml), with 20 out of 21 girls having values < 10 ng/ml[39]. Vitamin D deficiency was thought to be contributed to by skin pigment, clothing, poor outdoor activity, and possibly their poor calcium intake (265 ± 199 mg/day). The reason for poor calcium intake was economic deprivation and the prohibitive cost of milk, in some; in others it was due to food fads.

Unselected pregnant women attending a medical college hospital in northern India were documented to have a moderately good calcium intake of 842 ± 459 mg/day, mainly due to supplements advised during antenatal care[40]. In contrast, rural, poor socio-economic group pregnant women, studied in their home setting in Barabanki District, Uttar Pradesh, were documented to have a lower intake of 211 ± 158 mg/day (unpublished personal data).

Reports from other regions include 556 healthy school children (adolescents 10 -18 yr of age) from New Delhi, who were documented to have an intake of 314 ± 194 mg / day among low socio-economic group children and 713 ± 241 mg/day among high socio-

Table. Current recommendations of various countries for calcium intake (mg per day)

	ICMR[36]	USA, Canada[21]	UK[21]	Australia[21]	WHO, 2004[21]	WHO (low protein intake)[21]
0 - 6 months:	500	210	525			
Breast milk				300	300	300
Cow milk				500	400	400
7 – 12 months		270			400	450
1 - 3 yr		500	350		500	500
4 - 6 yr	400	800	450	530 - 800	600	550
7 - 9 yr		800	500		700	700
10 - 18 yr	600				1300	1000
Boys		1300	1000	1000 - 1200		
Girls		1300	800	800 - 1000		
Premenopausal women and men < 65 yr	400	1000	700	800	1000	750
Menopausal women and men > 65 yr		1200	700	Women 1000 Men 800	1300	800
Pregnancy (last trimester)	1000	1000 -1300	700	1100	1200	800
Lactation	1000	1000- 1300	1250	1200	1000	750

Superscript numerals denote reference numbers

economic group children[41]. Rural and urban women from Tirupathi had an intake of 264 ± 1.9 (mean ± SEM) and 356 ± 5.0 mg/day, respectively[42].

Conclusion

Calcium balance studies in subjects of different physiological states residing in different geographical regions of the world are required. Pending such results becoming available, recommendations for India, particularly for adolescent boys and girls, postmenopausal women and the elderly, may perhaps be revised upwards to bring them in the range of the recent WHO recommendations.

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