Review Article

Calcium requirements for Asian children and adolescents

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Calcium is important for bone health. Over the last 15 years, reference calcium intakes in Western countries have been revised upwards for maximizing bone mass at skeletal maturity and for prevention of osteoporotic fractures. Some of these reference figures have also been adopted for use in Asian countries. However, the scientific data based on for revising reference calcium intakes in the West was largely based on Caucasians. Limited human studies relating to calcium requirements and bone mineralization have been conducted in Asians in Asia. In children and adolescents, a trial has confirmed no effects of calcium supplementation on bone gains in adolescent girls after 7 years. A meta-analysis has also revealed that calcium supplementation has little beneficial effects on bone gain. Given that genetic factors, hormonal status, body size, bone structure, diets, physical activity, vitamin D status and adaptation could modify calcium retention and bone integrity, these factors need to be considered collectively to promote bone health in Asian populations. Furthermore, studies to identify indigenous foods rich in calcium and high in bioavailability are needed to widen sources of dietary calcium. Ethnic differences in calcium retention, hormonal status, bone structure, bone mineral accretion and peak bone mass are evident among Asians, Caucasians and Blacks in USA. Hence, reference calcium intakes for Asians are likely to be unique and different from those of Caucasians. More research has to be conducted in Asian populations in order to develop appropriate reference calcium intakes for the region.

Key Words: Calcium, calcium requirements, dietary reference intake, bone mass, children, adolescents

INTRODUCTION

Adequate calcium intake is important for bone health throughout the lifespan and for the prevention of osteoporotic fractures in later years. Over the last 15 years reference calcium intakes have been revised upward for maximizing bone mass at skeletal maturity and for prevention of osteoporotic fractures in Western industrialized countries.[1-3] Some of these figures have also been adopted for use in Asian countries.[4-5] One has to be cautious that the scientific data based on which to devise these reference calcium intakes were largely based on Caucasian populations by taking into consideration their genetic make-ups, life-styles and cultural factors. There are limited human studies investigating calcium metabolism and requirements based on Asian populations. Direct adoption of these figures from Western populations may not truly reflect the actual calcium needs in Asian people.[3,6]

Bone mineral mass accrual is a life-long process spanning from infancy through to early adulthood until peak bone mass is achieved by the second decade of life.[3] Consolidation of bone mass has been found to occur in late adolescence and early adulthood after cessation of bone growth.[7] Pubertal development during adolescence is a critical period of time in life to accrue bone mass. Because over 50% adult bone mass is accumulated in this 3-4 years period starting from the onset of puberty.[8]

Calcium supplementation trials

Which is the best interventional strategy to maximize peak bone mass is largely unknown and hypothetical. In the literature, there has been no intervention study long enough to test the effect of nutritional factors to maximize peak bone mass. Calcium is the nutrient that has been studied widely. Over the past 20 years more than 19 short-term (<3 years) randomized calcium supplementation studies using calcium pills or dairy foods in children and adolescents[9] including those conducted in USA[10-11] and China.[12-14] Results showed that there were small increases in total, regional BMC and BMD across these studies regardless the amount of calcium or basal level of calcium intake. Several follow-up studies conducted after cessation of calcium supplementation showed that the benefits of bone mineral gained from these short term (1-3 y) calcium supplementation trials did not persist[15-18] which can be largely explained by the phenomenon of bone remodeling transient.[19]

A recent longer term controlled calcium supplementation

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trial (7 years) in females spanning from aged 8-11y to early adulthood [7] demonstrated that the effect of calcium supplementation significantly improved bone mass in the first 4 years only, i.e. during pubertal growth spurt. However, girls in the control group at post pubertal period were able to catch-up bone mineral accretion when pubertal growth spurt was over. Thereby, there was no significant difference in bone mass between the study and control group at the end of the 7th year. Hence, the overall 7-y calcium supplementation had minimal effect on bone gain during adolescence.

Meta-analysis on calcium supplementation trials

Furthermore, a meta-analysis [9] was conducted to evaluate the efficacy of calcium supplementation trials using calcium or diary products on BMD accretion in children, and to see whether the effect of calcium supplementation persists after termination of supplementation. Results showed that there was no beneficial effect of supplementation on femoral neck or lumbar spinal BMD. There was only a small effect on total body BMC and upper limb BMD. Only the beneficial effect in the upper limb persisted after supplementation terminated, which is ~1.7% greater increase in the study group compared with the controls. Baseline calcium intake, sex, ethnicity, physical activity or pubertal staging did not confine the outcomes. It was concluded that there was only a small effect of calcium supplementation on the upper limb; however, the small increase in bone mass is unlikely to result in modifying fracture risks significantly during childhood, adolescence as well as later in life. The findings do not support the use of calcium supplementation in healthy children as a public health intervention as concluded by the authors.

Evidence gathered so far points to the fact that the use of calcium supplements or dairy foods to increase bone gains in childhood and adolescence was largely ineffective or the impact was minimal on long-term basis. It has been argued that the current Adequate Intake of calcium (1300 mg/d) for adolescents in USA assumed that this figure is the highest value above which no further calcium intake would give rise to any increase in calcium absorption or body calcium retention[3]. Whether this is an desirable level of calcium intake and whether this value will lead to maximal calcium retention is not known.[20] When revisiting the results of the 7-y calcium supplementation study [7] in which catch-up phenomenon of bone mass occurs in late adolescence and early adulthood has led to the notion that advocating calcium intakes of 1300 mg/d to adolescence may not be a necessary public health approach, which is a far reaching level beyond habitual intakes of adolescents in USA and has not been achieved by more than 80% US adolescent girls.[20-21]

Ethnic differences in calcium needs

Ethnic differences in bone mass and its accretion rate are evident among Asian, Black, Caucasian and Hispanic adolescents in USA.[8, 22-23] These could be attributable to genetic differences,[8,24] body size,[25] duration of pubertal growth,[8, 22, 25] development of bone structure and geometry during growth,[26] nutrition,[27-29] physical activity[25,30] and other lifestyle factors.[31] There are also ethnic differences in fractional calcium absorption. Chinese children and adolescents have been found to have higher fractional calcium absorption with either normal[32-33] or suboptimal [34] vitamin D status when compared with those of Caucasian counterparts.[35-36] Black children were also found to have higher calcium absorption and calcium retention than the Caucasians.[36-37]

Furthermore, matured Asian adults have lower average body weight and bone mass than Caucasians of the same age. Less mechanical loading and hence lower absolute bone mass is required to accumulate throughout early years to achieve the matured adult bone mass in Asians.[6] As a result, the amount of daily skeletal calcium accretion for growing Asian children and adolescents could be less than that of the Caucasian counterparts.[6,12] Furthermore, height of children[38] and women[39] has been found positively correlated with calcium absorption which supports the notion that the amount of calcium required in childhood and adolescence also depends on the genetically pre-determined final height. In fact, recent population studies in Mainland Chinese men and women have also demonstrated that the ages to achieve peak bone mass at various skeletal sites varied from early 20 to mid-30 years of age, which are different from those of Caucasians.[40-42] And that the level of peak bone mass achieved in the Chinese is also lower than that of Caucasians.[40,42] These studies provide some evidence on the ethnic differences in calcium metabolism and bone mineral acquisition in skeletal development.

Calcium intakes of Asian children and adolescents

Calcium intakes of children and adolescents in Asia are relatively low[43-47] in comparison to the Western counterparts. This could be partly attributable to the non-milk based diets, poor dietary habits in some individuals, inadequate information and knowledge on calcium rich foods and their bioavailability. Foods such as, calcium fortified soy milk,[48] kale and broccoli[49] have been identified as good sources of calcium in *in vivo* studies. Indigenous Asian foods that are rich in calcium such as tofu, tempeh, sea weeds, nuts and seeds dishes and green leafy vegetables etc. have yet to be identified and tested for calcium bioavailability in human studies. This information will certainly increase the choices of calcium rich foods in the Asian diets. Since 2005, an Asian regional cooperative project (RAS60/41) comprising more than 10 Asian countries, co-ordinated by the authors and funded by the International Atomic Energy Agency (IAEA), has been conducted to utilize food-based approaches and interventional strategies to promote bone mass and prevent osteoporosis in Asia. Asian foods high in calcium will be identified, some foods will be put to calcium bioavailability tests using stable isotopes and followed by human supplementation studies. Results of which will be useful to identify foods high in calcium bioavailability in Asia. Identification of functional foods or prebiotics that enhances calcium absorption will also be helpful to optimize body calcium retention. Inulin, a non-digestible oligosaccharides is an example that has been shown to enhance calcium absorption and bone mass in children.[50]

DISCUSSIONS AND CONCLUSION

Evidence has shown that dietary calcium or calcium

supplements is not a magic bullet to maximize bone mass in children and adolescents. And that the 'Adequate Intake' of calcium for adolescents (1300 mg/d) has been commented as too high in USA,[20] which is definitely difficult to achieve without supplementation for children and adolescents living in Asia.

A holistic approach with emphasis on the overall balanced diets comprising the 5 food groups, active lifestyles with sufficient weight-bearing exercises, healthy body weight, adequate vitamin D status, and avoidance of unhealthy lifestyles such as smoking, alcoholism is of paramount importance to optimize bone growth and mineralization, and to achieve peak bone mass. However, calcium intakes cannot be too low to allow sufficient calcium retention and bone mineralization in children and adolescents. Calcium intake below 600 mg/d has been found unlikely to lead to optimal calcium absorption and bone mineral accretion and even catch-up mineralization at post-pubertal period in Caucasian adolescents accustomed to dairy intake.[3,20] Nevertheless, the definition of adequate calcium intake among Asian children and adolescents has yet to be defined in future scientific studies. Human studies based on children and adolescents living in Asia is necessary to take into account factors like genetics, hormonal status, calcium balance and adaptation, body size, lifestyles and cultural food habits in order to establish appropriate reference calcium intakes for Asian children and adolescents.

In addition, hypovitaminosis D is widespread in children and adolescents around the world including Asia.[51] The combined beneficial effect of calcium and vitamin D on bone gain in children and adolescents has been observed in Chinese adolescents.[4] There is a need to evaluate the synergistic effects of calcium and vitamin D on body calcium retention and bone mineral acquisition in Asian children and adolescents. The current high level of reference calcium intake could be compromised if vitamin D status of population groups could be improved. Furthermore, in Asia there is a lack of testing of indigenous foods and functional foods, other than dairy products, which are potentially high in calcium and calcium bioavailability, this scientific information is very important to help devise a list of foods or diets rich in calcium and high in bioavailability for consumers to choose for the benefits of bone health.

To end this review, we would like to recall the remarks from Professor V. Ramalingaswami in his plenary speech addressing New Global Perspective on Overcoming Malnutrition at the 15th International Congress of Nutrition (Adelaide, Australia in 1993):[52]

> *"In nutrition, one sees a repetition of history in time and space. It would seem a wise policy to go back to some of the nutritionally sound and wholesome principles and practices in indigenous and traditional systems before they are lost in the avalanche of modernity."*

AUTHOR DISCLOSURES

WTK Lee and J Jiang had no conflicts of interest.

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