Review Article

The role of nutrition on optimizing peak bone mass

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The growth years provide an important window of opportunity for building peak bone mass. More than one-fourth of adult bone mass is acquired between the ages of 12 to 14 years in girls and 13 to 15 years in boys. Although genetics determine 60-80% of peak bone mass, lifestyle choices including diet and physical activity are also predictors of bone accrual during growth. Calcium and vitamin D are two nutrients that are most likely to be deficient. Dietary calcium predicts 10-15% of skeletal calcium retention during adolescence with race and sexual maturity in the models. Boys retain more calcium than girls and black girls retain more calcium than whites girls. The role of Vitamin D status on peak bone mass is not well understood. Results of randomized, controlled trials are mixed and the effects of vitamin D supplementation on calcium absorption in children has not been studied. Dietary salt increases urinary calcium excretion. Exercise can enhance the effect of dietary calcium through enhanced bone geometry.

Key Words: peak bone mass, nutrition, calcium, Vitamin D, salt

INTRODUCTION

Annual costs associated with osteoporosis are estimated at $30 billion annually.[1] Building the highest possible peak bone mass within one's genetic potential is a main strategy for reducing the risk of osteoporosis later in life.[2] Bone mineral density is a strong predictor of fracture as is advancing age.[3] Almost half of adult bone mass is acquired during adolescence with one-fourth occurring in a narrow span of about two years. An important longitudinal study from pre-puberty through the pubertal growth spurt in white children found that average skeletal calcium retention at the peak rate of accretion was 325 mg/d for girls and 409 mg/d for boys.[4] This is a tremendous period of growth and is thought to be the main period in life to influence lifelong bone health. Figure 1 shows the life course of bone mass and factors influencing it.

Heritability plays the dominant role in determination of peak bone mass. Tracking of total body bone mineral density from age 10 to 18 y is obvious by looking at individual plots in the longitudinal study of Matkovic et al.[5] But lifestyle behaviors also influence bone mass including physical activity and diet.[2] Several nutrients and dietary components have been studied extensively that are associated with an important role in development of peak bone mass. These include calcium and dairy products, vitamin D, salt and protein.

Calcium and Dairy

Dietary calcium is associated with increased calcium retention in adolescents up to 1300 mg/d above which the increase is not statistically significant.[6] Calcium intake explained 12.3% and race explained 13.7% of the variation in skeletal retention in pubertal girls.[7] It is difficult to distinguish between the relationship of calcium vs. dairy product intake to bone health because typically dairy products contribute the majority of calcium in the diets of most children. When dairy product consumption is low, so is calcium intake. Retrospective studies generally show that low consumption of milk during childhood and adolescence is associated with higher risk of fracture later in life.[8] A randomized, controlled trial in adolescent girls showed that a milk intervention increased serum IGF-1 which was presumed related to the greater bone gain in the intervention group.[9] Chevally et al.[10] observed an interesting interaction between calcium intake and age of menarche and the influence of bone. Girls aged 8 y were randomized to receive calcium fortified foods for one year and were subsequently followed until peak bone mass had accrued. The girls who received the intervention reached onset of menarche at an earlier age. This extra period of exposure to estrogen led to greater bone gains in the calcium intervention group, even though the intervention lasted only 1 year of the 8 years of follow up.

Dairy products and calcium supplements have rarely been directly compared so it is difficult to know if the other constituents in milk contribute to peak bone mass. It would likely depend on the quality of the rest of the diet because dairy products provide many important nutrients that promote growth beyond calcium including magnesium, phosphorus, potassium, protein, and several vitamins. In one study of 10-12 year old girls comparing cheese, a calcium carbonate supplement, and a vitamin D supplement on bone mass accrual, the girls who received cheese had greater gain in tibial cortical thickness.[12]

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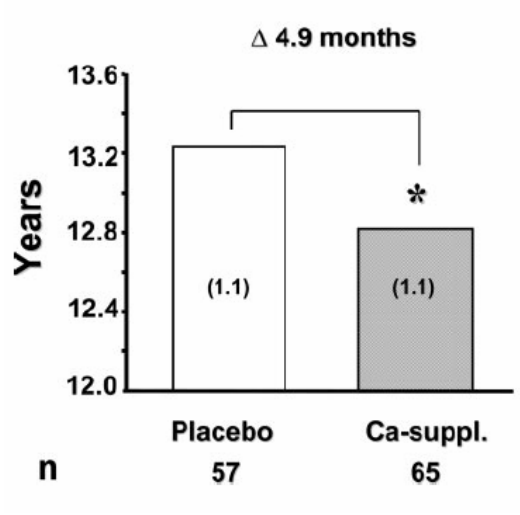

Figure 1. Bone mass throughout the lifespan

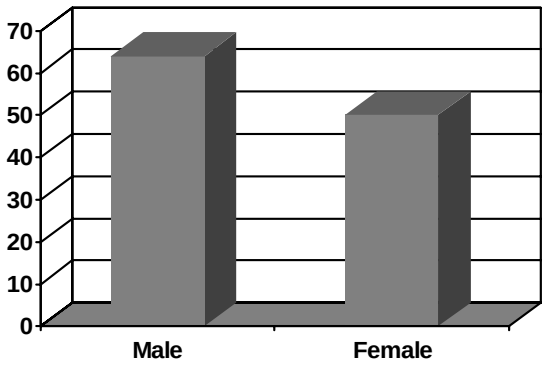

Figure 2. % Adolescents in 20 countries meeting country specific calcium recommendations (adapted from reference 12)

Calcium deficiency is rather universal. Looker evaluated calcium intake in 20 countries relative to calcium recommendations for their country and found a considerable gap for adolescents (Figure 2).[12]

One explanation for low milk consumption is the common incidence of lactose intolerance. Although milk in divided doses with meals is well tolerated by black adolescents with lactose maldigestion,[13] bad experiences with high doses reduces motivation for liberal dairy consumption. Calcium from nondairy sources are rarely used to close the gap in individuals who do not drink milk.[14] Milk avoiders have increased risk of prepubertal bone fractures compared to their milk drinking counterparts.[15]

Vitamin D

Adequate vitamin D status is thought necessary for active calcium absorption through vitamin D dependent-calcium transport proteins. Although the vitamin D status indicator, serum 25-hydroxyvitamin D, has been positively correlated with calcium absorption in adults,[16] they have not been related in children.[17] Randomized, controlled trials of vitamin D intervention in children have shown mixed results on bone parameters. One study showed a positive effect on bone mineral content gain of spine and femur in 225 11-year old girls of modest doses of vitamin D (400 IU) for 1 year.[18] Another study showed much higher doses were required, i.e. the equivalent of 2000 IU/d, to see a positive effect over the same time and then only at one skeletal site, i.e. total hip BMC and area.[19] Others have shown no benefit to growing bones of low dose vitamin D supplementation.[11] Obtaining recommended levels of vitamin D are difficult with the current food supply if exposure to UVB radiation is limited.

Salt

Dietary salt is in abundance in most Western diets. Salt has a hypercalciuric effect and reduces net calcium retention. The magnitude of the impact is greater in white than black adolescent girls, partly because black youth excrete less sodium, and consequently, less calcium than white youth.[20]

Diet Patterns

Overall diet patterns are likely as important or more important to growing bone than adequacy of individual nutrients. The whole diet needs to be considered to determine if energy needs for growth are being met. The whole diet determines nutrient adequacy across all the essential nutrients. It also determines the presence of dietary constituents that can enhance or inhibit nutrient absorption, influence their excretion, or influence bone turnover. The whole diet determines the acid-base balance which is thought to influence excretion of calcium and other minerals. Dietary protein has also been of concern because of its effect on hypercalciuria. However, more recently, it has been shown that overall calcium balance is not affected due to protein-induced hypercalciuria. In children, protein intake has been positively associated with bone gain.[21] A simple summary of some of these processes is given in Figure 3.

In summary, adolescence is an important period to build optimal peak bone mass to protect against fracture later in life. Diets rich in dairy products, protein, and fruits and vegetables and low in salt are considered bone healthy diets. Adequate physical activity before and during puberty is also important. Exercise and dietary calcium can interact to enhance bone strength through improved bone geometry.[22]

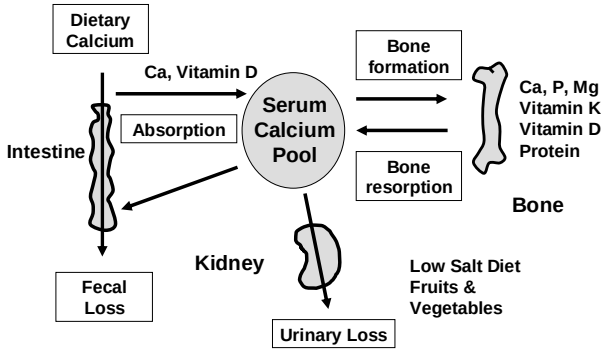

Figure 3. Summary of Diet Effects on Calcium Retention

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Connie M Weaver, no conflicts of interest, except an indicated in the "**ACKNOWLEDGEMENT**".

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