Determinants of peak bone mass in Chinese and Caucasian populations

SC Ho, PC Leung

As lifestyle and environmental factors may affect the formation of peak bone mass by as much as 20%, it is important to delineate the most effective factors and time of life, to help target health education and intervention measures. This paper aims to present available data on factors influencing the formation of peak bone mass in Chinese women. The discussion is written from the perspective of scientific evidence obtained from studies in Caucasian populations.

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Introduction

Osteoporosis is a disease which substantially increases fracture risks, especially among older women. Two of the important predictors of osteoporotic fractures in later life are the peak bone mass (PBM) attained during young adulthood and the rate and amount of bone loss which occurs with age.[1,2] Peak bone mass is the maximum amount of bone an individual acquires before bone loss begins. Subjects with high PBM are at a lower risk of reaching the fracture threshold in later life.[2] Small changes in PBM can produce quite large changes in subsequent fracture risks. It has been reported that a 5% difference in bone mass may mean a 40% difference in fracture risk and an increase by one standard deviation in bone mass may reduce the fracture risk by almost 100%.[3,4]

The age at which PBM is attained is controversial. It has been reported that the attainment of PBM occurs during adolescence.[5] A longitudinal study found a 7% increase in spine bone mass between the ages of 20 and 30 years.[6] The cross-sectional data from our study of 293 healthy women aged 20 to 40 years of age showed that skeletal consolidation continues from the age of 20 onwards until the early 30s. The PBM values are 1.03 g/cm^2 (SD = 0.12) for the spine and 0.86 g/cm^2 for the neck of femur (SD = 0.11). If a bone mineral density (BMD) value of below two standard deviations poses increased fracture risks, the corresponding values are 0.79 and 0.64 respectively. A general decline in bone mass of approximately 1% annually has been observed after the attainment of PBM. Comparable findings of an age-related decline in BMD at similar sites have been found in a study of Hong Kong Chinese women.[7] The Hong Kong data are based on cross-sectional studies and the results of an ongoing prospective study will help confirm the age of PBM. Such determination is important in terms of periods of life to help target health education as well as intervention measures in influencing the acquisition of PBM before it is attained.

The Chinese University of Hong Kong, Shatin, Hong Kong:
Department of Community and Family Medicine, Lek Yuen Health Centre
SC Ho, MPH, PhD
Department of Orthopaedics and Traumatology, Prince of Wales Hospital
PC Leung, MB, BS, FRACS
Correspondence to: Dr SC Ho

Factors influencing the attainment of peak bone mass

Genetic and racial factors have an effect, with wide geographical and population differences in bone mass, bone loss and fracture incidences having been observed. Caucasians have a higher bone mass than do Asians, and Blacks have a higher bone mass than Caucasians.[8,9] However, hip fracture incidences are higher among Caucasians than they are in Black, Asian and Hispanic populations.[10,11] American-Japanese experience higher hip fracture rates than do native Japanese, but have lower rates when compared with Caucasians.[12] The mean BMD of Hong Kong women has been found to be significantly lower compared with American women of similar ages, however, a comparative study between the United States and Hong Kong has shown a lower hip fracture incidence in the Hong Kong population.[7,10] This apparent contradiction could be due to different methods of bone mass measurements and data collection. However, variations in the environment, lifestyle, behaviour, and genetic factors may well contribute to this. Little is really known about the factors that contribute to geographic variations in bone mass and bone loss, and the time of life when such differences become apparent.

It is known that heredity plays a major role and may account for as much as 80% of the variation in bone mass found in the population. Maternal bone mass is strongly associated with bone mass in premenopausal women.[9] However, positive environmental factors may enhance the attainment of maximum PBM. Thus the understanding and promotion of such factors are urgent issues for both researchers and health care providers.

Higher body weight may explain the higher bone densities seen in American Black as opposed to American Caucasian women.[13] An increased body weight could be due to increased adipose tissue or muscle mass or both. High body weight also increases the weight-bearing stress on bone.[14,15] The positive association between adipose tissue and BMD could partly be due to the increased production of oestrogen and the promotion of bone mineralisation. Body size has been found to be related to BMD in postmenopausal women.[16-18] Data in younger women around the period of PBM formation are more limited. Body weight has been shown to be a strong predictor of BMD in healthy young women aged 20 to 39 years.[19] Studies in Hong Kong Chinese have shown that both lean body mass and body fatness in addition to body weight are significantly associated with BMD in women aged 31 to 40 years.[7] However, lean body mass has been found to be better correlated with spine BMD than other body measurements in young women aged 20 to 30 years. Hence, maintenance of body weight may help preserve bone mass in mid-life and older age.[20] It is possible that other factors such as physical activity could play a more important role in bone mineralisation during the period of bone consolidation.

Nutritional factors also play a role; studies in Caucasian populations have observed a positive role for calcium (Ca) in bone mass formation during infancy and the critical period of PBM formation.[20-22,4] Asians have a habitually low dietary intake of dairy products. A study of 161 healthy Japanese college students also found an association between BMD with their current intake of Ca.[23] Mean dietary Ca intake in the Hong Kong population is in the range of 350 to 450 mg daily.[8,24] Such an intake level is much lower than that found in Western populations, but is similar to the intake among elderly Japanese women living in Hawaii.[25] Calcium density also seems to be lower in Hong Kong Chinese women when compared with American populations.[24,26] Approximately 75% of dietary calcium in Dutch and American populations comes from milk and dairy products.[27,28] In Hong Kong Chinese populations, approximately one-fifth of total dietary Ca comes from dairy foods, while 50% are derived from vegetable sources—mainly leafy green vegetables and soybean products.[29]

Our study has indicated an optimising effect of high Ca intake on bone mass by 4% to 7% in women in their third decade of life, and high Ca density by up to 8% in women aged 31 to 40 years.[29] The difference in BMD between the high- and low-Ca intake groups was around 0.4 standard deviation. Similar results have been reported elsewhere.[4,30,31] Such optimising effects on bone mass are perhaps close to the maximum that can be achieved by nutrition alone, and may translate into a reduction of fracture risk by 40%.[2] Calcium balance studies have indicated that a negative balance occurs when daily intake is below 600 mg.[32] A recommended dietary allowance of 800 mg daily has been suggested as adequate for young adults.[33] Our data are in agreement with a threshold value of dietary Ca intake between 500 to 800 mg daily, suggested by other researchers.[22,34] A double-blind, placebo-controlled, randomised trial found that subjects with habitually low Ca intakes would benefit most from a high-Ca diet or Ca supplement. Our intervention study is assessing the effects of dairy supplements on bone mass development in young Chinese women before and around the age of PBM attainment. The study aims to increase daily calcium intake to 800 to 1000 mg. The results will be of particular interest in confirming the beneficial effect of Ca on PBM attainment in the Hong Kong population.

Lactose intolerance has a high prevalence in Chinese populations.[29] However, studies have reported that Ca absorption is not particularly affected in subjects with lactose intolerance.[35-37] Approximately 18% of our study population claimed to have lactose intolerance-related symptoms, however, there was little difference in the mean BMD and total Ca intake between the subjects with and without such symptoms. Symptoms of lactose intolerance may not be an important factor in influencing BMD in our population.

Other nutritional factors apart from Ca intake could be important in influencing bone mass. A number of studies have investigated the association of other nutritional factors such as protein, phosphorus and iron, with bone mass or fracture. Lower fracture rates have been observed in a population with high Ca, protein and phosphorus intakes.[38] Another study noted that high phosphorus intakes had a beneficial effect on bone in women.[39] Iron intake is also a significant predictor of proximal femur and forearm bone mineral content in premenopausal Caucasian women.[40] Although very high protein intake seems to be related to calciuria and decreased Ca balance, our study in Chinese women has shown a weak association of higher bone mass with higher protein intake.[41,29] This positive association could be due to the comparatively low level of protein intake in our study population—approximately 60 g daily. A positive effect for high phosphorus and iron intake on BMD in young women aged 21 to 30 years has also been found.[29]

Although others have found an inverse association between caffeine intake and bone mineral content in Japanese women, we failed to find any association between the two, probably because the caffeine intake in our study population was much lower—less than half that of the Japanese-American women studied.

Physical activity

Immobilisation and hypoactivity are associated with bone mineral loss. Active individuals have greater bone mass than inactive ones and sedentary subjects can increase their bone mass by being more active.[42] Athletes generally have higher bone mass than do non-athletes, the exception being women with exercise-induced amenorrhoea. Our data on college females aged 17 to 21 years also showed the athletes to have a significantly higher BMD compared with the non-athletes.[43]

Cross-sectional and longitudinal studies generally demonstrate a positive effect for weight-bearing exercise and bone mass maintenance in older populations.[44] A positive interactive effect between physical activity and Ca intake on bone mineral density has also been noted in young subjects.[45,27] However, the long term effect of exercise on the increase and maintenance of bone mass and prevention of fractures has been unclear. Most conclusions about the relationship between bone mass and physical activity are based on cross-sectional and observational studies.[27] A recent prospective study showed that regular exercise is a powerful determinant of PBM in the femoral neck in both young men and women.[46] Data from randomised clinical trials on the effect of exercise on bone mass in children and young adults are lacking. More studies are required before specific exercise programmes can be recommended.

Other lifestyle factors and implications

Smoking and excess alcohol consumption have been shown to be associated with low bone mass.[47] A recent study involving young adult men and women highlighted the deleterious effect of smoking in males.[46] It has also been suggested that smoking has an antioestrogenic effect, although the mechanism is unclear.[48] The prevalence of smoking among women has been low in Hong Kong. However, more adolescent females are smoking, and this will have long term adverse effects on their bone mass and fracture risks.

Although PBM is largely genetically determined, optimal environmental factors, such as an adequate Ca intake and physical activity in the early adult decades may increase PBM formation by 10% to 20%.[9] Our present research results have shown a beneficial effect of dietary Ca on PBM formation and a possible reduction of fracture risk by as much as 40%. Hong Kong Chinese, particularly older adults, do not consume dairy products. Three-quarters of our study population aged 21 to 30 years, and 85% of those aged 31 to 40 years, had Ca intakes below 600 mg daily. Although vegetables are not as rich a Ca source as is milk, the absorption fractions from vegetables (except for spinach) are quite similar.[49] Increased consumption of foods including dark leafy green vegetables, small fish with bones, seeds, nuts, and soybean products would help improve the total dietary Ca intake in the local population. The US National Institutes of Health Consensus Panel has recommended a Ca intake of 1000 mg daily for women aged 25 to 50 years and 1200 to 1500 mg for adolescents and those aged 11 to 24 years.[50] Considering the smaller body size and possibly better efficiency in Ca absorption, an intake of around 800 to 1000 mg daily could be recommended for young adults in the Hong Kong population (Lee WT, et al, unpublished data).

No specific exercise regimen can be recommended at this stage, but the maintenance of moderate activity for better bone mass attainment before the age of PBM and for general health and fitness from middle age onwards is recommended. All women, commencing with young girls, should be educated on lifestyle and dietary measures that can help decrease their fracture risks. Further research is needed in longitudinal studies of bone gain in young women and on methods of improving bone health. The differentiation of the most important factors is essential so that intervention measures can be planned to augment bone mass in young women.

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