Yonsei Medical Journal
Vol. 34, No. 1, 1993

Peak Bone Mass and Affecting Factors in Korean Women

**Sung-Kil Lim, Nam Ho Lee, Jong Ho Lee[1], Mi Sook Choi
Yoon-Sok Chung, Kwang Jin Ahn, Hyun Chul Lee and Kap Bum Huh**

Maximizing peak bone mass is advocated as a way to prevent osteoporosis. To evaluate the peak bone mass and the affecting factors in Korean women, we analyzed bone stiffness in 116 middle school students, 118 high school students and 115 female college students by using the Achilles densitometer (Lunar Corporation). Peak bone stiffness of Korean women was relatively lower than that of white women (94% of white women) and a rapid rise of bone stiffness was observed in those subjects 3~4 years after menarche. In adolescent females without menstruation, the bone stiffness was lower than that of adolescent girls with menstruation. The factors affecting the peak bone mass was similar to the risk factors of post menopausal osteoporosis: menstruation status, calcium intake and physical activity. The amount of calcium intake in Korean girls at the critical age (3~4 years after menarche) was lower than the RDA (requirement of daily allowance) at this age. To improve any program aimed at maximizing peak bone mass, further intensive study will be required to evaluate some other common factors affecting peak bone mass in Korean.

Key Word: Peak bone mass

Previous studies have focused on the administration of calcium supplements and hormonal replacements to post menopausal women for the prevention of osteoporosis (Heany *et al.* 1991; Lindsay *et al.* 1978; Kiel *et al.* 1987). Recently many researchers have recognized that peak bone mass is more important, and that initial bone mass is a better predictor of post menopausal fractures (Dhuper 1990; Seeman *et al.* 1988; Tylàvsky *et al.* 1989). The rapid accumulation of bony tissue in the lumbar spine and femoral neck of female individuals is quite distinct in Caucasian women, since most of the total gain in BMD/BMC recorded in girls between the age of 9~18 is accumulated within a 4-year period from 11~15 years of age (Bonjour *et al.* 1991; Gilsanz *et al.* 1988).

Many factors affect the development of peak bone mass, including genetics, sex, diet, exercise, and hormones (Pock *et al.* 1987; Buchanan *et al.* 1980). Many populations in developing countries have shorter stature, smaller skeletons, and also lower calcium intakes than those in Western countries. Delayed development of peak bone mass has also been observed in west African adolescents whose calcium intake was relatively low during adolescence (Lo *et al.* 1990).

Bone mineral density of Koreans is lower than that of Caucasians (Yong *et al.* 1988). The amount of calcium intake is also lower than that of Caucasians, and their major source of calcium intake from food is more from non-animal source than from dairy products (Ministry Health and Social Affair 1989).

We evaluated the critical period for rapid accumulation of bone mass in Korean women and the major determinants of peak bone density to maximize the peak bone mass and minimize

Received December 22, 1992
Accepted January 19, 1993
Department of Internal Medicine, College of Medicine Yonsei University and [1]Department of Food and Nutrition, College of Human Ecology, Yonsei University, Seoul, Korea
Address reprint requests to Dr. S-K Lim, Department of Internal Medicine, Yonsei University, College of Medicine, C.P.O. Box 8044, Seoul, Korea, 120-752

the impact of post menopausal and age-related bone loss. Bone mass was assessed in 12~21 year old healthy Korean subjects by using an Achilles bone densitometer at the level of Os Calcis.

MATERIALS AND METHODS

Normal female subjects were recruited from middle and high school and colleges in Seoul. Those subjects with a previous history of bone disease, illness, drug use or delayed puberty which could affect bone mass were excluded. All subjects were seen by the same investigator. Height and weight were measured, and the body mass index (BMI) was derived from the formula: $BMI=kg/m^2$. Bone stiffness was assessed by an Achilles densitometer from Lunar Radiation, Madison, Wisconsin, USA, as previously described (Langton *et al.* 1990). BUA and bone stiffness were analyzed. The precision, accuracy and reproducibility of this machine have been previously reported (Heany *et al.* 1989). Appropriate dietary calcium was estimated by questionnaire as described previously (Fox *et al.* 1990). Basal energy expenditure and total physical activity were measured by the 24 hr recall method (Christian *et al.* 1991). The results were analyzed by simple correlation.

RESULTS

The relationship between bone stiffness and age is depicted in Fig. 1. Bone stiffness was increased rapidly during the ages of 12 to 13. After then, the increments of increasing bone stiffness became slower until the age of 16 and reached the plateau phase after 16 years. The rapid increment was also observed during the first 6 months period after menarche after which it became slower until 3 years after menarche (data not shown). BUA also showed similar findings (Fig. 2). Bone stiffness at 21 years of age was only 94% of bone stiffness in 20~40 year old Caucasian women (Fig. 1). Bone stiffness of postmenacheal girls was always much higher than that of premenacheal girls at the same age. Height and body weight have a positive correlation with bone stiffness in premenacheal girls (Fig. 3). However the correlation with height was not observed in postmenacheal girls. Total daily energy expenditure and calorie intake have a positive correlation with bone stiffness in postmenacheal girls (Fig. 4). Total calcium intake and animal calcium intake also have a positive correlation with bone stiffness (Fig. 5). The amount of calcium intake at age 12, 13, 14 and 15 was 461 mg, 719 mg, 768 mg and 867 mg respectively (Fig. 6).

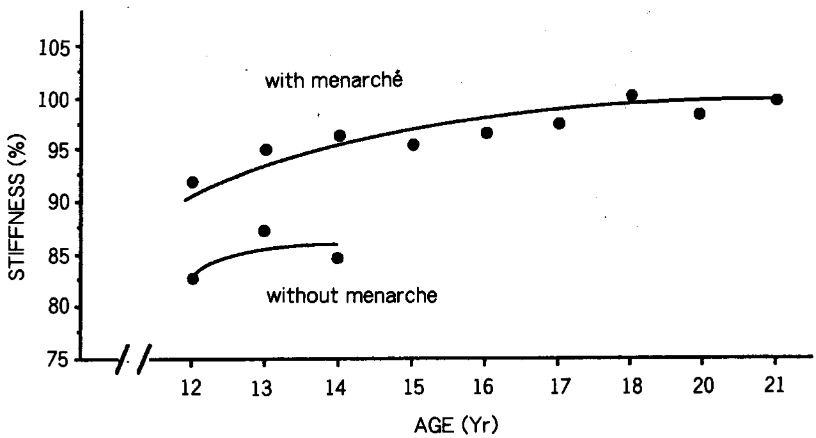

***Fig. 1.** Age-related increments of bone stiffness in adolescent females.*

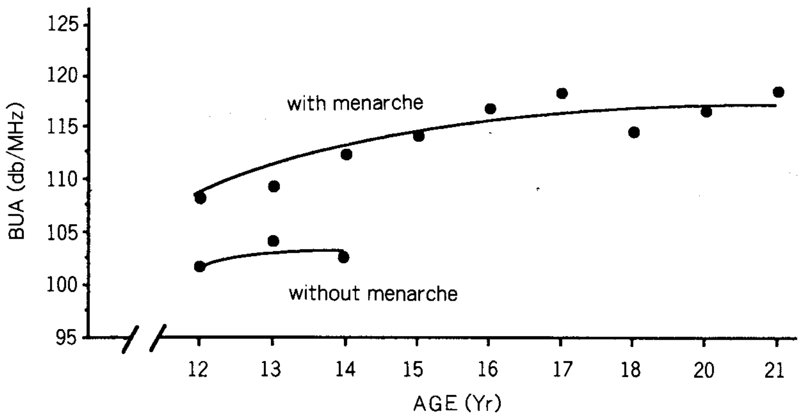

Fig. 2. *Age-related increments of BUA in adolescent females.*

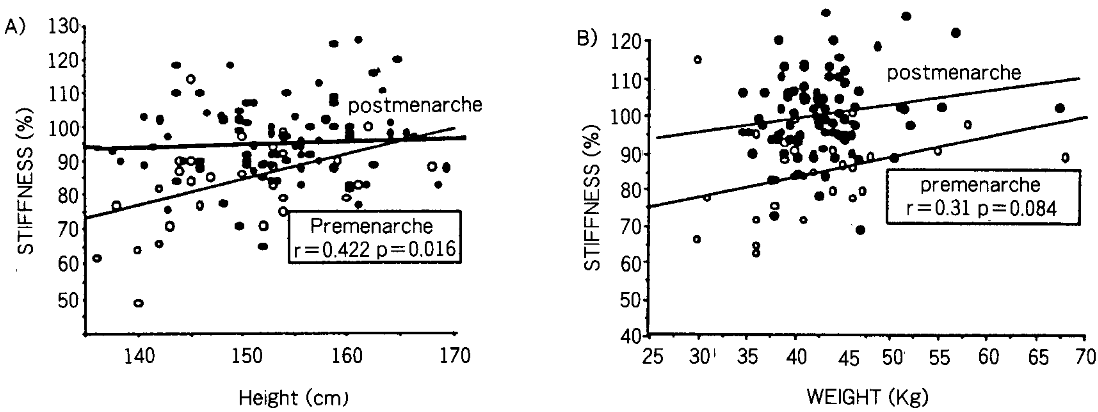

Fig. 3. *Relationship between bone stiffness and body status in adolescent females (●—postmenarche, ○—premenarche).*

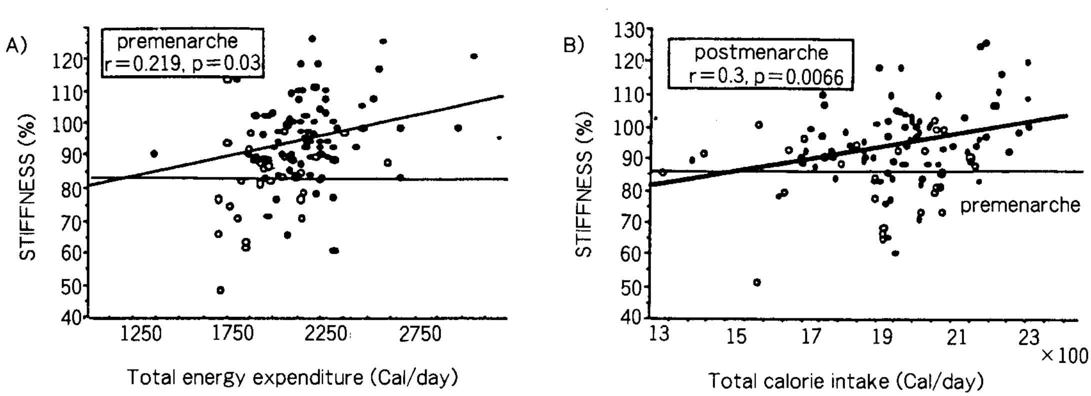

Fig. 4. *Relationship between bone stiffness and total calori intake or total energy expenditure in adolescent females (●—postmenarche, ○—premenarche).*

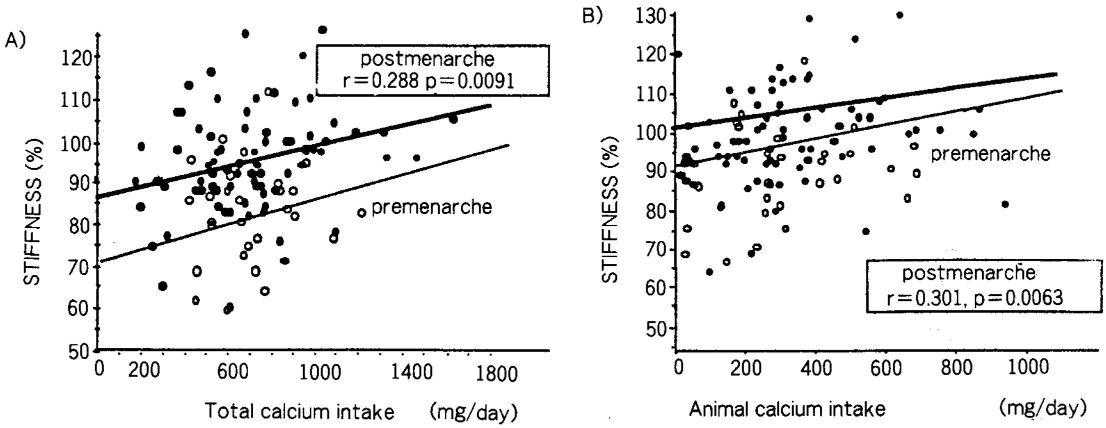

Fig. 5. *Relationship between bone stiffness and calcium intake in adolescent females (●—postmenarche, ○—premenarche).*

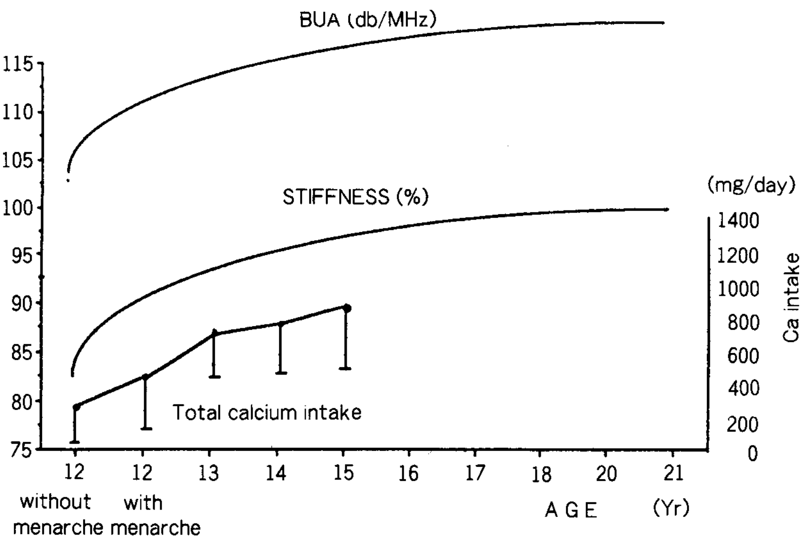

Fig. 6. *Bone stiffness, BUA and total calcium intake according to the age in adolescent females with regular menstruation.*

This value was lower than the U.S. Recommended Daily Allowance (RDA) 1,200 mg.

DISCUSSION

The generally accepted notion has been that in both males and females bone mass continued to accumulate substantially at all skeletal sites until the fourth decade (Stevenson *et al.* 1982). However, many recent studies failed to reveal any significant difference between a group of 14-to 19-year old adolescent females and a cohort of young adults, aged 25~35 year (Riggs *et al.* 1990). Previous reports have indicated that the rate of bone mass formation increases continuously until 15 or 16 years of age (Bonjour *et al.* 1991). However, our data showed three different phases: a very sharp increase of bone stiffness at 12 and 13 year of age, a slow increase of bone stiffness until 16 years, and a plateau phase after 16 or 17 years. The discrepancy might be caused by the different site of examination. This might be the first paper to evaluate the formation of peak bone in Os Calcis by using the Achilles. The measured bone mineral densities by antero-posteriol projection of the spine always include a lot of cortical bone, including the spinous process. However Os Calcis is mainly composed of trabecular bone, and tradbecular bone is much more sensitive to the change of serum estradiol than is cortical bone. Even though Os Calcis is not an important fracture site related to osteoporosis, our data might reflect the true maturation phase of trabecular bone in women.

Bone stiffness was much different between girls who had reached menarche and girls who had not reached menarche at any age. This suggested that sex hormones are very important for the formation of peak bone mass. The increasing rate of slope was stiff at 12 and 13 year of age, and bone mass accumulation had only a positive correlation with height in pre menacheal girls, while the mean ages of menarche in our subjects were 13.6±0.8 years old. Thus our data confirmed again that bone mass accumulation in girls is less directly dependent upon factors that determine the timing of the pubertal stage occurrence than upon those that control the age-dependent statural growth (Bonjour *et al.* 1991).

Physical activity and total calorie intake affected bone mass in our study as in others (Johnson *et al.* 1992). We also have confirmed that more physically fit and stronger girls have greater bone stiffness (Bonjour *et al.* 1991). The amount of calcium intake, total or animal calcium intake, has a good positive correlation with bone stiffness. However total calcium intake in 12~15 year old girl was less than the Recommended Daily Allowance (RDA) for this age: 1,200 mg/day (Christian *et al.* 1991). Low calcium intake delayed the formation of peak bone mass in Zambian girls (Lo *et al.* 1990). However, we don't know whether the limited amount of calcium intake in our subjects can delay peak bone mass because we don't have any reference values in Os Calcis.

From this study we found that the peak bone mass in Korean women seemed to be slightly lower than that of Caucasians, and the rate of bone accumulation in Os Calcis was different from that of the spine and femoral neck. Encouraging more calcium intake and exercise with early detection of delayed puberty might be very important for prevention of osteoporosis at a later age. However more studies are required to find more common environmental factors affecting peak bone mass in Koreans.

REFERENCES

Bonjour J-P, Theintz G, Buchs B, Slosman D, Rizzoli R: Critical years and stages of puberty for spinal and femoral bone mass accumulation during adolescence. *J Clin Endocrinol Metab 73: 555-563, 1991*

Buchanan JR, Myers C, Lloyd T, Leuenberger P, Demers LM: Determinants of peak trabecular bone density in women: The role of androgens, estrogen, and exercise. *J Bone Mineral Res 3: 673-680, 1980*

Christian JL, Greger JL: *Nutrition for living.* Benjamin/Cummings Publ Co Inc, CA., *1991, 111-139*

Dhuper S, Warren MP, Brooks-G J, Fox R: Effects of hormonal status on bone density in adolescent girls. *J Clin Endocrinol Metab 71: 1083, 1990*

Fox TE, Loughridge JM, Shepherd R: A calcium questionale-validation using weighed intake. *Nutr Res 10: 603-613, 1990*

Gilsanz V, Gibbens DT, Carlson M, Boechat MI, Cann CE, Schulz EE: Peak trabecular vertebral density: a comparison of adolescent and adult females. *Calcif Tissue Int 43: 260-2, 1988*

Heany RP: Effect of calcium on skeletal development, bone loss, and risk of fractures. *Am J Med Suppl 5B, 23S-28S, 1991*

Heany RP, Avioli LV, Chestnut CH, Lappe J, Recker RR, Brandburger GH: Osteoporotic bone fragility. *JAMA 261: 2986-2990, 1989*

Johnos CC, Miller JZ, Slemenda CW, Reister TK, Hui S, Christian JC: Calcium supplementation and increase in bone mineral density in children. *N Engl J Med 327: 82-86, 1992*

Kiel DP, Felson DT, Anderson JJ, Wilson PWF, Moskovitz MA: Hip fracture and the use of estrogens in post menopausal women: the Frammingham study. *N Engl J Med 317: 1169-74, 1987*

Langton CM Ali AV, Riggs CM Evans GP: A contact method for the assessment of ultrasonic velocity and broad band attenuation in cortical and cancellous bone. *Clin. Phys physiol Meas, 3: 243-249, 1990*

Lindsay R, Hart DM, Maclean A, Clark AC, Kraszewski A, Garwood J: Bone response to termination of estrogen treatment. *Lancet 1: 1325-1327, 1978*

Lo CW, Jarjou LMA, Poppitt S, Cole TJ, Neer A: *Delayed development of bone mass in West African adolescents.* In Claus Christiansen and Kirsten Overgaard eds. Osteoporosis 1990, Handelstrykkeriet Aalborg ApS, Aalborg, Denmark, *1990, 73-77*

Ministry Health and Social Affair. *National Nutritional Suvey Report. 1989, 151-167*

Pock NA, Eisman JA, Hopper JL, Yeates MG, Sambrook PN, Eberi S: Genetic determinants of bone mass in adults. *J Clin Invest 80: 706-710, 1987*

Riggs BL, Melton IV LJ: Involutional osteoporosis. *N Eng J Med 314: 1676-1679, 1990*

Seeman E, Hopper JL, Bach LA, Cooper ME, Parkinson E, Mckay J, Jernms G: Reduced bone mass in daughters of women with osteoporosis. *N Engl J Med 320: 554-1988*

Stevenson JC, Whitechead MI: Post menopausal osteoporosis. *Br Med J 282: 585-588, 1982*

Tylavsky FA, Bortz AD, Hancock PL, Anderson JJ: Familial resemblance of radial bone mass between premononpausal mothers and their college-age daughters. *Calcif Tissue Int 45: 265, 1989*

Yong SJ, Lim S-K, Huh KP, Park BM, Kim NH: Bone mineral density in Korean. *The Korean Journal of Internal Medicine 31: 13-18, 1988*