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Original article

Bone Mineral Density in Postmenarchal Adolescent Girls in the United States: Associated Biopsychosocial Variables and Bone Turnover Markers

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Abstract

Purpose: During adolescence, bone formation prevails over resorption, resulting in accumulation of 40% of peak bone mass throughout this time period. Although multiple studies have explored bone mass accrual during the early stages of puberty, less is known about factors that may influence bone accrual during later years of adolescence. In the present cross-sectional study we examined relationships among bone mineral density (BMD) and demographic factors, behavioral variables, and bone metabolism markers in postmenarchal adolescent girls.

Methods: The population was comprised of 389 healthy postmenarchal adolescent girls aged 11–18 years, who were recruited into a prospective study of the effect of depot medroxyprogesterone acetate (DMPA) on bone health in adolescents. At the baseline visit, investigators collected demographic, reproductive health, and lifestyle data, and performed a complete physical examination. Body mass index (BMI) was calculated. Before study initiation, BMD at the lumbar spine, total hip, and femoral neck was measured by dual-energy X-ray absorptiometry (DXA), and markers of bone metabolism (serum bone-specific alkaline phosphatase [BAP], serum osteocalcin, and urinary N-telopeptide [uNTX]) were measured. The baseline data from this study were analyzed to evaluate possible correlates of BMD in postmenarchal adolescent girls. Potential associations between BMD values and other parameters were assessed by analysis of variance and Pearson's correlation coefficient.

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Results: Participants enrolled in the study had a mean (± SD) chronological age of 14.9 ±1.7 years (range 11–18), mean gynecologic age of 39.9 ±23.0 months (range 1–120) postmenarche, and mean BMI of 23.5 ±4.6 kg/m^2 (range 16.0–42.2). Racial/ethnic distribution was 46% African American, 35% Caucasian, and 19% other races; 9% had previously been pregnant. Positive correlations were observed between lumbar spine BMD and chronological age (r = .301, $p < .0001$), gynecologic age (r = .349, $p < .0001$), and BMI (r = .371, $p < .0001$). Total hip and femoral neck BMD values were significantly higher ($p < .05$ and $p < .05$, respectively) in African American participants compared with non-African American participants. Previous history of pregnancy was significantly associated with a lower BMD at the lumbar spine ($p < .0001$) and the total hip ($p < .01$) when compared with the BMD of adolescents who had never been pregnant. Cigarette smoking and alcohol use were not associated with significant differences in BMD. Negative correlations were observed between gynecologic age and the levels of BAP (r = −.564, $p < .0001$), osteocalcin (r = −.349, $p < .0001$), and uNTX (r = −.281, $p < .0001$), and between lumbar spine BMD and BAP (r = −.363, $p < .0001$), osteocalcin (r = −.129, $p < .05$), and uNTX (r = −.202, $p < .001$) levels.

Conclusions: Our data demonstrate that chronological age, gynecologic age, race/ethnicity, BMI, and previous history of pregnancy are markedly associated with BMD in postmenarchal adolescent girls. Bone accretion in the postmenarchal years continues in the face of a slowdown in bone turnover during this time period.

Keywords: Adolescent; Female; Bone density; Bone markers

The amount of skeletal mass acquired during adolescence is one of the most important factors in determining the risk of osteoporosis and fractures later in life [1]. In healthy females, about 40% of peak bone mass is accumulated during the adolescent years [2]. On average, young women attain 92% of their total body bone mineral content (BMC) by age 18 years, and 99% by age 26 [3]. However, the attainment of peak bone mass in young women is site specific; peak bone mass appears to be attained in the femoral neck by age 16 [4], whereas in the lumbar spine, bone mass continues to increase throughout the third decade of life [5].

The accretion of bone mass in adolescents involves the interaction of multiple calcitrophic hormones such as growth hormone (GH), insulin-like growth factor-1 (IGF-1), and estrogen [6]. In addition to genetic and ethnic/racial factors that affect this process, environmental factors such as dietary habits and physical activity may influence the accretion of bone mass during adolescence [6].

Imaging techniques such as the dual energy X-ray absorptiometry (DXA) have been employed to assess BMC and bone mineral density (BMD) in children and adolescents [2]. In addition, biochemical markers of bone turnover have been used in evaluating bone formation and bone resorption. Sensitive indicators for bone formation include serum-bone-specific alkaline phosphatase (BAP) and osteocalcin. Urinary N-telopeptide (uNTX), the amino telopeptide cross-linking domain of type I collagen, and urinary pyridinoline and deoxypyridinoline, the nondeductible cross-links between the telopeptide regions of the collagen molecules, are good indicators of bone resorption [7].

Although longitudinal growth is most rapid during early pubertal stages in girls, bone mineral accrual is greatest around the time of menarche [8]. Peak velocity of bone mass accumulation has been reported about .7 years after the peak in longitudinal growth velocity [9]. Menarche is a milestone for both longitudinal growth and bone mass accretion in adolescent girls. Although there is a decrease in the rate of longitudinal growth immediately after menarche, intensive bone accrual continues for several years after this physiological milestone [4].

Although multiple studies have explored the bone mass accrual during the early stages of puberty, less is known about factors that may influence bone accrual during later years of adolescence. In the present study, we examined relationships among BMD and demographic factors, behavioral variables, and bone metabolism markers in a large population of postmenarchal adolescent girls.

Methods

Participants and procedures

The study population was comprised of a convenience sample of 389 healthy postmenarchal adolescent girls aged 11–18 years from 10 large metropolitan areas in the United States. The girls were recruited to participate in a prospective study examining the effect of depot medroxyprogesterone acetate (DMPA) on BMD in adolescents. Potential participants were excluded if they had histories of conditions that might affect bone health such as eating disorders, hypothyroidism or hyperthyroidism, hyperparathyroidism, malignancies, Cushing's disease, renal or hepatic diseases, congenital bone diseases, chronic hypertension, type 1 or type 2 diabetes, or any other condition that may lead to immobilization. Also, potential participants who were taking bone-modifying agents such as glucocorticoids or anticonvulsants, and those who had used DMPA within the previous 6 months, were excluded from enrollment. Participants with a history of pregnancy were eligible for enroll-