METABOLISM CLINICAL AND EXPERIMENTAL 62 (2013) 1811–1818

Available online at www.sciencedirect.com

Metabolism

www.metabolismjournal.com

Physical activity is associated with bone geometry of premenarcheal girls in a dose-dependent manner

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ARTICLE INFO

Article history:
Received 7 February 2013
Accepted 13 August 2013

Keywords:
Exercise
Bone development
Peripheral quantitative computerized tomography
Pre-adolescence

ABSTRACT

Objective. To determine the relationship between habitual physical activity (PA) level and peripheral qualitative computed tomography-determined quantitative tibia characteristics of premenarcheal girls.

Methods. Premenarcheal girls matched for age (10–13 years), bone age and maturity level were assigned into: a) low PA group (LPA, n = 25), b) moderate PA group (MPA, n = 17), and c) high PA group (HPA, n = 18). Participants' daily dietary intake, tibia's geometry and serum levels of calcium and vitamin D were assessed.

Results. Premenarcheal girls demonstrating HPA exhibited greater pericortical thickness, cross-sectional area (CSA) and bone mineral content (BMC) ($p < .001$) in cortical bone, greater BMC, volumetric bone density (vBMD) and polar stress strength index (SSIp) in trabecular bone ($p < 0.001$–0.05) and greater total BMC ($p < .05$) and vBMD ($p < .01$) when compared to their physically inactive or moderately active counterparts. MPA exhibited greater values of cortical BMC ($p < .01$) and SSIp ($p < .05$) than LPA. Partial correlation analysis (adjusted for BMI) revealed modest associations between PA score and bone geometry parameters ($r = 0.36$–0.49, $p < .05$) at 38% of tibia length.

Conclusions. Habitual PA affects geometry of both cortical and trabecular areas of a long bone of premenarcheal girls in a dose-dependent manner. Specifically, PA increases both the density and size of cortical bone but only the density of trabecular bone during preadolescence. Given the importance of peak bone mass for future fracture risk, high levels of PA during childhood could be a major target for public health interventions aimed at optimising bone health in prepubertal children when the greatest bone gains occur.

Abbreviations: PA, Physical activity; MET, Metabolic Equivalent of Task; BMC, Bone mineral content; BMD, Bone mineral density; DXA, Dual energy X-ray absorptiometry; pQCT, Peripheral quantitative computed tomography; vBMD, Volumetric bone mineral density; LPA, Low PA; MPA, Moderate PA; HPA, High PA; BMI, Body mass index; CSA, Cross-sectional area; SSIp, Stress strength index in torsion; MCSA, Muscle cross-sectional area; ANOVA, Analysis of variance; 25(OH)D, Hydroxyvitamin D.

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0026-0495/$ – see front matter
http://dx.doi.org/10.1016/j.metabol.2013.08.006

1. Introduction

Physical activity (PA) has been proven a significant predictor and determinant of bone density and strength in early adolescent girls [1]. The effect of PA on the osteogenic process depends on activity characteristics (intensity, content, duration), individual factors such as nutritional and hormonal status [2] and age at which PA participation commenced [3] since the skeleton is more adaptable to PA before growth completion [4]. According to the American College of Sports Medicine, osteogenic response during periods of somatic growth is optimized when children participate in physical activities characterized by frequent loading of high strain magnitude [5]. Although there is a consensus that bone mineral accrual in peripubertal children is improved by weight-bearing exercise [5,6], the characteristics of an optimal exercise programme remain unclear. Daily physical education including both indoor and outdoor PA (i.e. ball-game activities, running, jumping) in girls aged 7–9 years enhanced bone mineral content (BMC), bone mineral density (BMD), and bone width [6].

A recent longitudinal study [7] demonstrated that long-term PA in childhood promotes bone health and prevents osteoporosis later in life since physically active children and adolescents (n = 154, ages 8–15 years at baseline) demonstrated a 8%–10% greater hip BMC in young adulthood (aged 23–30 years) when compared to their inactive counterparts, even after controlling for their adult physical activity levels. Boys appear to demonstrate a greater bone sensitivity to mechanical loading than girls and a stronger relationship between PA and BMC which has been partially attributed to their greater PA as compared to girls [8,9]. This fact represents an important public health issue given the well-established decline of PA in females during adolescence which is further exacerbated during adulthood [10].

Bone geometry assessments are considered important since even small alterations of bone configuration may have a pronounced effect on its resiliency [11]. Given the limitations of dual-energy x-ray absorptiometry (DXA) in providing information on bone size and geometry and in separating cortical from trabecular bone components that respond differently to exercise [12,13], peripheral quantitative computed tomography (pQCT) has several advantages since it is capable of distinguishing between trabecular and cortical bone as well as providing geometric information regarding the peripheral skeleton adaptations thereby enabling researchers to better evaluate the PA- and training-induced skeletal adaptations [14].

Broader cross-sectional studies using pQCT to evaluate the influence of lifestyle factors such as PA on bone acquisition and strength in premenarcheal girls are extremely limited. Recent evidence suggest that pQCT-determined bone area, density, and architecture of postmenarcheal girls were not related to the type of PA (impact vs. non-impact activities, i.e. running vs. cycling or swimming) [15]. To our knowledge, no prior studies have tested the effect of three different levels of habitual PA (high, moderate and low) on bone geometry of premenarcheal girls using pQCT. A previous study that employed pQCT technology reported that the volumetric BMD (vBMD) and cortical thickness of the tibia shaft of 245 healthy pre- and early pubertal girls (10–13 years), were higher for high PA girls as compared to low-PA girls [16]. However, girls in that study were matched only for chronological age and not for bone age or any other marker of biological maturity level. Therefore, the present investigation aimed to evaluate the effect of habitual PA level (high, moderate, low) on pQCT-determined quantitative bone characteristics of premenarcheal girls matched for maturity level, chronological and bone age.

2. Methods

2.1. *Study population*

Participants were recruited from a volunteer database, by word of mouth and fliers sent to schools, playgrounds and other locations that children usually spend time in the local community over a 3-month period. Children's inclusion in the study was based upon the following criteria (parents/guardians completed a health history questionnaire while girls underwent a thorough physical examination and a structured interview): 1) were at the premenarcheal period, 2) were Caucasian females aged 10–13 years, 3) were clinically healthy, 4) were not receiving medication known to affect bone metabolism, 5) had no immobilising surgery or fracture in the previous 12 months, 6) were all of similar bone age (10–11.5 years), 7) all had a similar maturity level on Tanner scale, and 8) their serum estradiol levels were below 25 pg/ml [17]. Participants were assigned into three PA groups according to a 4-day physical activity questionnaire: a) low PA group (LPA, N = 25), b) moderate PA group (MPA, N = 17), and c) high PA group (HPA, N = 18). The parents/guardians of 96 girls were initially approached and 82 consented to participate in the study. Twenty two girls were excluded because they did not meet the inclusion criteria. The study was approved by the Ethics committee of KAT hospital (Athens, Greece) and was conducted in accordance with the Declaration of Helsinki. Informed written consent was obtained from the parents or legal guardians of each child and each child gave verbal consent to participate in the study. Participants' physical and dietary characteristics are shown in Table 1.

2.2. *Antrhropometric measurements and maturity assessment*

Participants' body weight was measured after an 8-h fast while they were wearing underclothes on an electronic scale (Soehnle 7840; Soehnle, Nassau, Germany) calibrated to the nearest 0.1 kg. Barefoot standing height was measured to the nearest 0.1 cm by using a wall-mounted stadiometer (SECA 220; Seca, Hanover, MD). Body height and weight were measured in duplicate 1 week apart [coefficients of variation (CVs), 0.99 and 0.97, respectively]. Body mass index (BMI) was calculated as weight (in kilograms) per standing height (meters) squared. Tibial lengths (from the lateral knee joint space to the lateral malleolus tip) were measured in duplicate using an anthropometer and the average result