·Original Article in English·

Significance of bone mineral content and bone mineral density in assessing the bone intensity in children and adolescents

Hong ZHANG, Peng-Fei SHAN, Er-Yuan LIAO, Xian-Ping WU, Xing-Zhi CAO

Institute of Endocrinology and Metabolism, Second Xiangya Hospital, Central South University, Changsha 410011, *China*

Abstract: Objective This study aims to investigate the influences of body weight on bone mineral content (BMC) and bone mineral density (BMD) of lumbar spines and proximal femur in healthy children and adolescents aged 6 - 15 years and to compare the differences between BMC and BMD. **Methods** The BMC and BMD of anteroposterior and supine lateral lumbar spines and proximal femur in 547 healthy children and adolescents from Changsha region were measured by DXA QDR-4500A fan beam bone densitometry. **Results** The body weight, body mass index (BMI), BMC and BMD of lumbar spines and proximal femur increased with age in both male and female children and adolescent ($P < 0.05$ or 0.01). The body weight was more correlated with BMC than with BMD. The BMC adjusted by weight of lumbar spines and proximal femur increased, while the BMD adjusted by weight of them decreased with age. **Conclusions** It is suggested that BMC is more coincident with the property of bone intensity in terms of mechanics so BMC is a better marker than BMD for the assessment of bone intensity in children and adolescents aged 6 - 15 years.

[**Chin J Contemp Pediatr, 2004, 6(3): 176 - 179**]

Key words: Bone mineral content; Bone mineral density; Children and adolescents

评价儿童青少年骨体重负荷的意义及指标选择

张红，单鹏飞，廖二元，伍贤平，曹行之 中南大学湘雅二医院代谢内分泌所，湖南 长沙 410011

[摘　要] 目的 探讨儿童青少年骨体重负荷对腰椎和髋部骨矿含量(BMC)、骨密度(BMD)的影响，并比较两指标的优次。**方法** 应用 DXA QDR - 4500A 型扇形束骨密度仪测量长沙地区 547 例 6~15 岁儿童青少年腰椎前后位，仰卧侧位及髋部股骨近端的骨量。**结果** 不论男女，儿童青少年体重、体块指数(BMI)、腰椎及髋部 BMC 和 BMD 随年龄增加而增加($P < 0.05$或0.01)；体重与 BMC 的相关性较体重与 BMD 的相关性更密切；髋部及腰椎各部位体重标准化 BMC 随年龄增加而增大，而髋部和腰椎各部位体重标准化 BMD 随年龄增加反而减小。**结论** 6~15 岁儿童青少年腰椎及髋部 BMC 指标判断骨强度优于 BMD，尤以髋部及腰椎侧位 BMC 为佳。

[**中国当代儿科杂志，2004，6(3)：176 - 179**]

[关　键　词] 骨矿含量；骨密度；儿童青少年

[中图分类号] R179　**[文献标识码]** A　**[文章编号]** 1008 - 8830(2004)03 - 0176 - 04

Up until now bone mineral density (BMD) has been used for the diagnosis of bone quantity loss and osteoporosis but it has recently been discovered, both domestically and abroad, that body weight has a pivotal influence on the total bone quantity[1,2]. Based on the load of body weight on different bones, the bigger ones were selected (i.e. anteroposterior lumbar spines (L_{1-4}), supine lateral lumbar spines ($latL_{2-4}$) and left proximal femur) to investigate the influences of body weight on bone mineral content

[Received] August 19th, 2003; [Revised] November 23rd, 2003

[Foundation Item] The 10th 5-year national medicine science & technology key program (2001BA702B03).

[Biography] Hong ZHANG (1966 -), Female, Doctor, Associate Professor, Specializing in the prevention and treatment of osteoporosis and diabetes mellitus.

[Correspondence Author] Er-Yuan LIAO, 86 Renmin Middle Road, Institute of Endocrinology and Metabolism, Second Xiangya Hospital, Central South University, Changsha 410011, China (Email: 13873137337@vip.sina.com).

(BMC) and BMD[2]. In this article 547 children and adolescents were tested in order to judge if either BMC or BMD of lumbar and proximal femur could be used as an index of the bone intensity.

Subjects and methods

Subjects

This research was conducted in Changsha, Hunan Province from May, 2001 to April, 2003. Five hundred and forty-seven healthy children and adolescents aged 6 – 15 years, among them 250 male and 297 female, were randomly selected to measure body weight and height as well as bone quantity. All factors including diseases and drugs that could affect bone metabolism were excluded according to Kelly's criterion[3].

Methods

Physical examination

The height was measured with shoes off, keeping the error within 0.5 cm. Body weight was measured permitting only a single layer of clothes with a precision of 0.5 kg. Then the body mass index (BMI) was calculated as following: BMI (kg/m^2) = body weight (kg)/height square (m^2).

Bone quantity

Both the BMC and BMD are referred to as bone quantity for convenience. The projected area and the BMC of lumbar and proximal femur were measured at the same time by QDR-4500A fan beam DXA bone densitiometry (equipped with automatic C arm, Hologic company, USA). The BMD was calculated by the densitiometry itself with its own software, i. e. BMD= BMC/area(g/cm^2).

The veracity of this instrument could be indicated by its coefficient of variation (CV) which could be expressed as the average ± standard deviation ($\bar{x} \pm s$). When the BMD for the above region were measured in 23 normal or abnormal testees at different time, the $\bar{x} \pm s$ was 0.92% ± 0.42% (0.44% – 1.92%) with 95% confidence interval (CI) from 0.64% to 1.20%. While the BMD for an artificial lumbar model was measured up to 4 years, its $\bar{x} \pm s$ was 0.33% – 0.40%[4].

Statistical analysis

All data were checked and inputted into a PC and SPSS 10.0 software was employed to conduct statistical calculation. All testees were grouped based on their age and each group was in 2 year intervals[5]. The data for all groups were expressed as $\bar{x} \pm s$.

Results

Changes of body weight, BMI, BMC and BMD of the lumbar spine and proximal femur with age

The body weight, BMI, BMC and BMD of L_{1-4}, latL_{2-4} and proximal femur of male and female children and adolescents in different groups by age are listed in Table 1. As shown in the table, the body weight of each group increased with age ($P < 0.05$ or 0.01, except for the male 10-year-old above group), while the BMC and BMD of L_{1-4}, latL_{2-4} and proximal femur gained with body weight ($P <$ 0.05 or 0.01). Compared with the 6-year-old above group, the body weight, BMI, BMC of L_{1-4}, latL_{2-4} and proximal femur, BMD of L_{1-4}, latL_{2-4} and proximal femur of the group of between 14 to 15 years old, increased by 129%, 20%, 199%, 236%, 237%, 60%, 58% and 41% respectively in males and 137%, 33%, 191%, 209%, 175%, 84%, 55% and 42% respectively in females.

The correlation between body weight, BMI and bone quantity

1) Body weight and BMI were obviously positively correlated with the BMC and BMD of all bone tested ($P < 0.01$); 2) Body weight was more correlated with BMC and BMD ($r = 0.528 - 0.888$, $P < 0.01$) than BMI ($r = 0.479 - 0.634$, $P <$ 0.01); 3) Body weight was more correlated with BMC ($r = 0.551 - 0.888$, $P < 0.01$) than with BMD ($r =$ $0.528 - 0.797$, $P < 0.01$); 4) Body weight had the highest correlation with the BMC of proximal femur ($r = 0.888$, $P < 0.01$), second higher with that of latL_{2-4} ($r = 0.864$, $P < 0.01$) and last with that of L_{1-4}($r = 0.859$, $P < 0.01$). See Table 2.

Bone quantity adjusted by body weight (simply adjusted bone quantity)

Adjusted bone quantity = bone quantity/body weight. Adjusted BMC and BMD of L_{1-4}, latL_{2-4} and proximal femur of male and female children and adolescents in different groups by age are listed in Table 3. It was shown that both male and female adjusted BMC of L_{1-4}, $latL_{2-4}$ and proximal femur (together with body weight) gained with age, while the adjusted BMD of L_{1-4}, $latL_{2-4}$ and proximal femur decreased with age (though body weight increased).

Table 1 Age-related body weight (kg), body mass index (kg/m^2), BMC (g), and BMD (g/cm^2) of the lumbar spine and proximal femur ($\bar{x} \pm s$)

Sex	Age (year)	n	Body weight (kg)	BMI	L_{1-4} BMC	L_{1-4} BMD	$LatL_{2-4}$ BMC	$LatL_{2-4}$ BMD	Proximal femur BMC	Proximal femur BMD
Male	6−	30	23.8±5.0	16.4±2.1	15.37±3.21	0.508±0.058	6.00±1.53	0.466±0.069	9.38±2.67	0.603±0.075
	8−	42	30.5±7.3[a]	17.6±2.9	19.45±3.86[a]	0.554±0.064[a]	7.82±1.43[a]	0.508±0.060[a]	12.35±2.80[a]	0.643±0.070
	10−	50	34.1±7.1	17.5±2.6	22.61±3.94	0.578±0.070	9.95±1.86[b]	0.561±0.070[b]	15.49±2.59[b]	0.682±0.076
	12−	66	46.7±11.8[b]	19.1±3.1[b]	34.33±10.48[b]	0.695±0.119[b]	15.16±5.10[b]	0.659±0.112[b]	24.80±7.31[b]	0.785±0.127[b]
	14−15	62	54.4±10.6[b]	19.8±3.1[b]	45.94±10.73[b]	0.815±0.116[b]	20.18±4.56[b]	0.735±0.088[b]	31.66±6.97[b]	0.851±0.131[b]
Female	6−	41	21.7±4.4	15.3±2.2	15.86±3.10	0.534±0.065	5.93±1.27	0.460±0.070	9.02±1.83	0.573±0.065
	8−	38	26.2±5.0[a]	15.6±2.0	19.16±3.54[a]	0.576±0.065[a]	7.12±1.54[a]	0.492±0.066[a]	11.43±2.24[b]	0.610±0.066
	10−	46	35.3±6.3[b]	17.3±2.2[b]	27.29±6.38[b]	0.678±0.085[b]	11.07±2.80[b]	0.608±0.075[b]	16.79±3.49[b]	0.700±0.080[b]
	12−	69	44.9±6.9[b]	18.9±2.4[b]	38.17±7.42[b]	0.791±0.102[b]	15.16±3.04[b]	0.664±0.070[b]	21.69±3.67[b]	0.751±0.102[b]
	14−15	103	51.4±7.6[b]	20.4±3.0[b]	46.10±7.21[b]	0.883±0.088[b]	18.33±3.00[b]	0.712±0.070[b]	24.79±3.93[b]	0.813±0.095[b]

Note: The comparison is performed between the two neighbouring age groups with the same sex. a represents $P<0.05$, and b represents $P<0.01$

Table 2 Correlation of body weight and BMI with BMC and BMD of lumber spines and proximal femur

	L_{1-4} BMC	L_{1-4} BMD	$LatL_{2-4}$ BMC	$LatL_{2-4}$ BMD	Proximal femur BMC	Proximal femur BMD
Body weight	0.859	0.797	0.864	0.788	0.888	0.782
BMI	0.593	0.596	0.571	0.545	0.620	0.634

Note: The number of the table refers to the coefficient of correlation, all $P<0.01$

Table 3 Age-related body weight adjusted BMC (g/kg) and BMD ($g/cm^2/kg$) of the lumber spine and proximal femur ($\bar{x} \pm s$)

Sex	Age (year)	n	L_{1-4} BMC	L_{1-4} BMD	$LatL_{2-4}$ BMC	$LatL_{2-4}$ BMD	Proximal femur BMC	Proximal femur BMD
Male	6−	30	0.650±0.070	0.0218±0.0027	0.254±0.048	0.0201±0.0033	0.393±0.068	0.0260±0.0040
	8−	42	0.650±0.090	0.0188±0.0030	0.264±0.048	0.0174±0.0039	0.412±0.069	0.0220±0.0044
	10−	50	0.676±0.117	0.0175±0.0032	0.296±0.050	0.0169±0.0031	0.463±0.077	0.0207±0.0039
	12−	66	0.733±0.136	0.0153±0.0025	0.322±0.063	0.0145±0.0024	0.532±0.086	0.0173±0.0032
	14−15	62	0.853±0.170	0.0153±0.0025	0.375±0.072	0.0139±0.0023	0.584±0.090	0.0159±0.0024
Female	6−	41	0.741±0.125	0.0253±0.0044	0.277±0.053	0.0216±0.0043	0.421±0.064	0.0274±0.0053
	8−	38	0.760±0.109	0.0231±0.0031	0.282±0.053	0.0197±0.0032	0.453±0.070	0.0245±0.0039
	10−	46	0.774±0.116	0.0195±0.0025	0.314±0.057	0.0176±0.0026	0.479±0.072	0.0201±0.0032
	12−	69	0.852±0.120	0.0178±0.0023	0.339±0.054	0.0150±0.0021	0.485±0.060	0.0169±0.0021
	14−15	103	0.908±0.152	0.0174±0.0024	0.362±0.069	0.0141±0.0022	0.486±0.069	0.0161±0.0021

Discussion

Body weight is the main source of bone load and this determines the mechanical strength of the bone. As a good example, the anti-fracture ability of the thighbone is in proportion with body weight according to some researchers. But as for children and adolescents aged 6 - 15 years, no domestic research has demonstrated whether BMC or BMD is better. Nielsen[6] has proposed that BMC and BMD should be adjusted by body weight when they are applied for diagnosis or as risk indexes of fracture, but he doesn't provide any detailed proof. Greenspan[7] believes bone quantity can stand for 60% - 80% of bone intensity and is in proportion with body weight. Other investigators have observed that the body weight, total bone quantity as well as thigh bone quantity of the rat are obviously positively correlated with the pressure resistant property of centrums[8]. Based on data of 117 young people from 20 to 40 years old, Yang et al[9] found that adjusted BMC was better than adjusted BMD for the assessment of mechanical strength of the bone. Here in this report, it was also found that the body weight, BMI, BMC and BMD of lumbar and proximal femur increased with age in children and adolescents both male and female. Considering that both body weight and bone quantity increase with age, this study compared the degree of correlation between body weight and BMC and BMD of all bone tested. Results included: 1) Body weight was more correlated with BMC and BMD of all bone tested than BMI; 2) Body weight was more correlated with BMC than with BMD of all bone tested, and among them BMC of the proximal femur was the first correlated and that of $latL_{2-4}$ the second. Since body weight is highly correlated with BMC, BMC and BMD must be adjusted by body weight to avoid the influence of body weight variation. When adjusted by body weight, BMC of the proximal femur and $latL_{2-4}$ enhanced with body weight, according with the mechanical property of the bone, i. e. high mechanical strength of the bone as well as high BMC always goes with heavy body weight. On the contrary adjusted BMD of the proximal femur and $latL_{2-4}$ decreased when body weight gained, going against the forenamed principle about the mechanical strength of the bone. As a conclusion, BMC especial body weight adjusted BMC of the proximal femur and $latL_{2-4}$ is a better index than BMD for the assessment of mechanical strength of the bone in children and adolescents aged 6 - 15.

[References]

[1] Korpelainen R, Korpelainen J, Heikkinen J, Vaananen K, Keinanen-Kiukaanniemi S. Lifestyle factors are associated with osteoporosis in lean women but not in normal and overweight women: a population-based cohort study of 1 222 women [J]. Osteoporos Int, 2003, 14(1): 34 - 43.

[2] Ma J-F, Wang W-Z, Chen L, An Z, Jiang J-J, Yang D-Z. Effects of body weight and height on bone quality of the lumber spine and proximal femur in young and prime people from Chengdu region [J]. Chin J Osteoporos (in Chinese), 2002, 8(2): 118 - 120.

[3] Kelly TL. Bone mineral density reference databases for American men and women [J]. J Bone Miner Res, 1990, 5 (Suppl 2): S249.

[4] Liao EY, Wu XP, Deng XG, Huang G, Zhu XP, Long ZF, et al. Age-related bone mineral density, accumulated hone (bone) loss rate and prevalence of osteoporosis at multiple sketetal sites in Chinese women [J]. Osteoporos Int, 2002, 13(8): 669 - 676.

[5] Li J-B, Li H-Q, Wang S-Y, Hu Y. Relationship between bone mineral content and serum bone-gla-protein and alkaline phosphatase levels in puberty [J]. Chin J Contemp Pediatr (in Chinese), 2002, 4(1): 11 - 14.

[6] Nielsen SP. The fallacy of BMD: a critical review of the diagnostic use of dual X-ray absorptiometry [J]. Clin Rheumatol, 2000, 19(3): 174 - 183.

[7] Greenspan SL, Maitland LA, Myers ER, Krasnow MB, Kido TH. Femoral bone loss progresses with age: a longitudinal study in women over age 65 [J]. J Bone Miner Res, 1994, 9(12): 1959 - 1965.

[8] Wu X-P, Liao E-Y, Lu Z-Y, Song X-C, Huang G, Deng X-G. Correlation between bone mass and bone biomechanics in rats [J]. Chin J Osteoporos (in Chinese), 1999, 5(03): 1 - 4.

[9] Yang D-Z, Zhang Q, Yang H, Qi L-P. Bone mineral content is a better criterion in evaluation of bone strength for diagnosis of osteoporosis [J]. Chin J Osteoporos (in Chinese), 2002, 8(1): 10 - 12.

(Edited by Yuan-Dong DUAN)