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Bone mineral density in adolescents

Higher values in a rural area—a population-based study of 246 subjects in southern Sweden

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We performed, in a cross-sectional study, dual energy X-ray absorptiometry (DXA) among 15–16-year-old boys (n 58) and girls (n 44) living in an urban area and among boys (n 82) and girls (n 66) of the same age from a rural area. We measured bone mineral density (BMD) of the total body, the lumbar spine and the hip. In the rural population, we found significantly higher BMD levels in the lumbar spine (14% for the boys and 12% for the girls) and the total body (6.9% for the boys and 3.4% for the girls). We detected no significant differences in the hip BMD.

Adolescents in rural areas seem to develop a higher peak bone mass and thereby presumably have a lower risk of developing fragility fractures.

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Published studies differ somewhat regarding age at which peak bone mass occurs. Recker et al. (1992) reported an increase in BMD in women up to age 30 whereas others found little or no gain after age 15–16 (Bonjour et al. 1991, Theintz et al. 1992, Rico et al. 1993). The boys in these studies showed increased bone mass up to the age of 18–20. What happens during childhood with regard to peak bone mass is of importance concerning the risk of fractures (Hui et al. 1988, 1989, Cummings et al. 1990, Gärdsell et al. 1991a).

Previous studies on regional differences in southern Sweden have shown a higher incidence of hip and fragility fractures in an urban area than in a rural area, and also lower bone mass among the elderly (Gärdsell et al. 1991b, Jonsson et al. 1992). However, the difference between the populations seemed to disappear in middle-age. The explanation for this difference among the elderly may be differences in lifestyle and in the middle-aged the difference disappears (Jonsson et al. 1993).

We examined whether differences in bone mass exist between an urban and a rural adolescent population in southern Sweden.

Subjects and methods

140 boys and 110 girls from two regions in southern Sweden, 80 km apart, participated in this population-based study. The subjects, aged 15–16 (9th grade), were invited to take part in an investigation in which their bone mass, height and weight were measured, and lifestyle factors were evaluated by a questionnaire.

58 boys and 44 girls came from a suburb of the city of Malmö, the third largest city in Sweden. The group was selected because the demographic structure of this suburb is similar to that of the entire city of Malmö (pop. 245,000, 1595 inhabit/km^2; Hanson and Larsson 1991). They constituted the whole suburban population in this age group.

To match the number of urban subjects a rural control of 79 boys and 65 girls were also evaluated from Hässleholm County (pop. 50,000, 39 inhabit/km^2). They were recruited from two schools, one in the town of Hässleholm (pop 25,000) and one in the country-side. All students in the 9th grade of these schools were asked to participate.

The children and their parents signed a consent form prior to the tests. 85% of the children invited in the urban area and 91% in the rural area participated in the investigation.

Measurements in the urban group were performed as part of another project (Düppe 1997) from November 1992 to April 1993 and in the rural group during May 1995. No one was excluded because of disease. All participants were Caucasian.

With 80% power and 95% significance we would detect an age-adjusted difference of 0.06 units in femoral neck BMD for both boys and girls with this study design.

The study protocol was approved by the Ethics Committee of the University of Lund.

Bone mass measurements

BMD (areal density, g/cm^2) was assessed in the supine position by DXA, using the Lunar DPX-L bone densitometer (Lunar Corp. Madison, WI, USA), one densitometer in Malmö and one in Hässleholm. To calibrate the BMD scans against each other, the Hologic spine phantom and the Lunar spine phantom were used. The values measured with the Hologic phantom were 0.93% lower for BMD, comparing the rural (Hässleholm) with the urban (Malmö) DXA values. Corresponding figures using the Lunar phantom gave BMD values 0.38% lower for the urban DXA than for the rural. No correction of the measured values was done.

The measurements and the software analyses were made by the same technician. Quality control was performed daily with the Lunar spine phantom.

In all subjects, a total body scan and a separate scan of the left hip were done. With the total body software from the manufacturer, BMD values of the total body and lumbar spine vertebrae L1-L4 were calculated. Using the femur software, the hip BMD (Ward's triangle and femoral neck) were calculated.

Questionnaire

Physical activity levels were assessed with the questionnaire used in previous studies (Grimby et al. 1971, Hanson and Larsson 1991). Each participant was asked which of a series of statements corresponded best to their own level of activity. A score (min. 2, max. 8) was created, taking into account seasonal variations.

Dietary intakes of calcium were not assessed with a formal food-frequency questionnaire, but the intakes of milk and other dairy products were specified. The purpose was to identify those who avioded milk and other dairy products. Socioeconomic and medical histories were recorded.

Statistics

We used the Statistica® version 5.0, StatSoft Inc. The Student's t-test was used for comparing bone mineral measurements and anthropometric variables between the groups and the Mann-Whitney U-test was used to compare smoking and physical activity between the groups. Bone mineral data were adjusted for covariates in an ANOVA/MANOVA model. Correlation coefficients were calculated with Pearson's (bone mineral measurements versus anthropometric variables) or Spearman's correlation (bone mineral measurements versus physical activity).

Results

There was a difference in age between the groups because the measurements, as mentioned above, were not performed in the same month. There were no differences between the groups regarding height, weight, body mass index (BMI) or time of menarche (Table 1).

2 patients from the rural and 3 from the urban group did not drink milk because of allergy. All 5 were on adequate calcium substitution and their BMD values did not differ from the others.

When comparing boys and girls in the same group, rural boys had higher BMD values in the hip (femoral neck $p = 0.02$ and Ward's triangle $p = 0.02$) than the girls. The girls in the urban group had higher BMD values in the lumbar spine ($p = 0.01$) than the boys.

Boys

Adjusted for age, the total body BMD and lumbar spine BMD were higher in the rural group than in the urban group (Table 1). No difference in the hip BMD was observed after adjustment. Adjusting for BMI and physical activity, as well as age, did not affect the difference between the groups. Analyzing the two groups separately, we found a correlation between BMD of the hip (Ward's triangle) and age in the urban group ($r = 0.26$, $p = 0.05$), but no statistically significant correlation at any site with bone mineral data and age in the rural group ($r = 0.12$–0.20). At all sites we found a positive correlation with BMI, strongest for total body BMD ($r = 0.51$ in the rural and $r = 0.57$ in the urban group, $p < 0.001$ for both groups). Physical activity correlated with bone mineral data in all measured regions in the rural ($r = 0.31$–0.42, $p < 0.01$), but not in the urban group ($r = -0.02$–0.05).

In the urban group, 28% were smokers and in the rural group 15%. The level of self-reported physical activity was higher in the rural group (Table 2).

Girls

As among the boys, the total body BMD and the lumbar spine BMD were statistically significantly higher in the rural group than in the urban group. These differences were still significant when adjusted for age (Table 1). Adding adjustment for BMI, physical activity and time since menarche did not affect the difference between the groups. There was no significant correlation between age and BMD in either group ($r = -0.1$ in the urban and $r = 0.05$ in the

Table 1. Results of measurements in urban (U) and rural (R) populations

Variable	N U	N R	Mean (SD) U	Mean (SD) R	95% CI U	95% CI R	P-value [a]	Est. diff. [b]	P-value [c]
Boys									
Age (years)	58	79	15.6 (0.3)	16.0 (0.3)	15.5–15.7	15.9–16.0	<0.0001		
Height (cm)	58	79	174 (8.5)	175 (8.2)	171.4–175.9	172.8–176.5	0.5		
Weight (kg)	58	79	61 (9.0)	62 (9.1)	58.6–63.3	60.3–64.3	0.4		
BMI (kg/m²)	58	79	20.2 (2.2)	20.4 (2.2)	19.6–20.7	19.9–20.8	0.6		
BMD (g/cm²)									
Total body	58	79	1.087 (0.09)	1.162 (0.10)	1.063–1.11	1.139–1.184	<0.0001	0.052±0.019	0.007
Lumbar	58	79	1.102 (0.12)	1.258 (0.18)	1.070–1.133	1.217–1.296	<0.0001	0.125±0.032	0.0001
Femoral neck	57	79	1.055 (0.14)	1.107 (0.16)	1.020–1.091	1.072–1.143	0.05	0.022±0.030	0.5
Ward	57	79	1.050 (0.16)	1.103 (0.19)	1.008–1.092	1.060–1.147	0.09	0.020±0.036	0.6
Girls									
Menarche (years)	43	64	12.4 (1.1)	12.6 (1.1)	12.1–12.8	12.3–12.8	0.5		
Age (years)	44	65	15.5 (0.3)	15.8 (0.3)	15.4–15.6	15.8–15.9	<0.0001		
Height (cm)	44	65	167 (5.8)	166 (6.6)	165.7–169.2	164.3–167.6	0.2		
Weight (kg)	44	65	57 (7.5)	55 (8.2)	54.8–59.3	52.8–56.8	0.1		
BMI (kg/m²)	44	65	20.3 (2.2)	19.9 (2.6)	19.7–21.0	19.2–20.5	0.3		
BMD (g/cm²)									
Total body	44	65	1.110 (0.07)	1.148 (0.08)	1.088–1.132	1.128–1.169	0.01	0.039±0.018	0.03
Lumbar	44	65	1.162 (0.11)	1.298 (0.16)	1.127–1.196	1.258–1.337	<0.0001	0.141±0.031	<0.0001
Femoral neck	43	65	1.040 (0.13)	1.050 (0.13)	0.999–1.081	1.018–1.081	0.7	0.013±0.029	0.7
Ward	43	65	1.037 (0.18)	1.035 (0.15)	0.983–1.090	0.997–1.074	1.0	0.013±0.036	0.7

[a] P-value for t-test.
[b] Estimated difference adjusted for age ± confidence interval
[c] P-value adjusted for age

rural group for total body BMD). BMI correlated with BMD at all sites in the rural group, strongest with total body BMD ($r = 0.57$, $p < 0.001$), but in the urban group only with total body BMD ($r = 0.38$, $p = 0.01$). Physical activity correlated with the total body BMD ($r = 0.33$, $p = 0.008$) and the lumbar spine BMD ($r = 0.35$, $p = 0.008$) in the rural group, but no significant correlation was found in the urban group.

Girls in the rural area reported more physical activity (Table 2), but the frequency of smoking was similar, with 18% smoking in the urban and 11% in the rural group.

Table 2. Self-reported physical activity score, median (range)

	Urban	Rural	P-value (Mann-Whitney)
Boys	6 (2–8)	6 (2–8)	0.06
Girls	5 (2–8)	6 (3–8)	0.008

Max. score 8, min. score 2

Discussion

We found differences in bone mass in these two populations of adolescents, lower values occurring among the urban children. The age-adjusted difference in the lumbar spine BMD between the groups is 0.9 SD higher for girls and 0.7 SD higher for boys in the rural area. According to a meta-analysis by Marshall et al. (1996), this would mean 35% fewer hip fractures for girls and 28% for boys, in a population more than 50 years of age. Hui et al. (1985) found differences among children (and adults) comparing two Caucasian populations in the US, using single photon absorptiometry measurements of the radius. The authors concluded that part of the difference was due to environmental and/or genetic factors. However, the two populations were not homogeneous regarding ethnic origin. Gilsanz et al. (1991), using quantitative computed tomography, showed that there is a racial difference, with 22–24% higher vertebral BMD in black girls than in white girls. The difference was present only late in puberty. The populations in our study were almost entirely of Swedish origin and the ethnic difference, if any, between the two groups therefore can be assumed to be negligible.

We did not use Tanner's classification (1978), which is perhaps a weakness, but we made the assumption that the average onset of puberty was the same in both groups. The time of menarche was equal in both groups and the fact that adjustment for time since menarche did not affect the difference between the girls supports this assumption.

The finding that physical activity affects bone mass is well documented in adults (Nilsson and Westlin 1971, Jacobson et al. 1984, Block et al. 1989, Colletti et al. 1989, Karlsson et al. 1993, Välimäki et al. 1994, Casez et al. 1995), but few studies of children have been published. Fehily et al. (1992) found a positive correlation between sports activity during adolescence and BMD of the radius in subjects aged 20–23 years using the SPA technique. Slemenda et al. (1991, 1994) found a positive correlation in 5–14-year-old children between physical activity and BMD of the radius, measured by the SPA technique, and the hip measured by the dual photon absorptiometry technique, but not in the lumbar spine. In a study from New Zealand, Turner et al. (1992) found a positive correlation between physical activity and BMD of the femoral neck and of the trochanter, in an investigation of 138 16-year-old girls, using DXA.

Is was only in the rural group that we found any statistically significant correlation with physical activity and BMD but one contributing factor to the higher BMD levels in the rural group could be the higher level of self-reported physical activity. It seems unlikely that the two groups would change their physical behavior abruptly, so it can be assumed that this difference has been present for some years.

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