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Bone accrual at the forearm during adolescence: is prevention likely to work?

Raquel Lucas
(rlucas@med.up.pt)
Milton Severo,
Elisabete Ramos,
Henrique Barros

U.PORTO
FMUP FACULDADE DE MEDICINA UNIVERSIDADE DO PORTO

Department of Clinical Epidemiology, Predictive Medicine and Public Health
University of Porto Medical School, Porto, Portugal
Al. Prof. Hernâni Monteiro
4200-319 Porto, Portugal
http://epidemiologia.med.up.pt

ISPUP
INSTITUTO DE SAÚDE PÚBLICA DA UNIVERSIDADE DO PORTO

Institute of Public Health of the University of Porto,
Porto, Portugal
Rua das Taipas, 135-139
4050-600 Porto, Portugal
http:// www.ispup.up.pt

INTRODUCTION

Whether bone quality is essentially modifiable or tracks predictably up to adulthood is unclear. Identifying a biological timing during adolescence when changes in bone mineral density (BMD) are greater and most influenced by modifiable factors is important in suggesting effective timing for primary prevention strategies of fragility fractures.

OBJECTIVES

1. To estimate, across pubertal development stages, the associations between
   - early adolescence BMD and anthropometry
   - changes in anthropometric characteristics

   } and BMD in late adolescence (17 years old);

1.1. To identify a biological timing where interventions on modifiable factors are likely to have highest impact on future bone properties.

METHODS

We evaluated girls from a cohort of adolescents born in 1990, the Epidemiological Health Investigation of Teenagers in Porto, Portugal (EPITeen). In 2003/2004, all 51 schools that provided teaching to adolescents born in 1990 were approached and 46 participated: 2787 eligible adolescents were thereby identified. Among these 78% agreed to participate and provided information for at least part of the protocol. The follow-up evaluation was conducted in 2007/2008 (79% of the initial sample). Evaluations included self-administered questionnaires and physical examination at school, keeping the same protocol. Bone mineral density (BMD, g/cm^2) was measured at the non-dominant distal forearm by dual-energy X-ray absorptiometry using a Lunar® PIXI device. Pubertal development stage was defined using gynecologic age (GA) in years from menarche. Anthropometry included height, weight, and fat and fat-free mass (the latter two by bioelectrical impedance). BMD at 17 years old was the main outcome and associations were estimated using linear regression and 95% confidence intervals (95% CI).

2160 adolescents recruited for the EPITeen cohort → 1116 girls evaluated (2003/2004) → 934 girls with information on - BMD_{13} - $anthropometry_{13}$ → 754 girls re-evaluated (2007/2008) → 709 girls with information on - BMD_{13} and BMD_{17} - $anthropometry_{13}$ -$anthropometry_{17}$ - menarche age

RESULTS

Bone mineral density increased linearly with gynecologic age, independently of chronologic age (Figure). Girls with higher gynecologic age had increased mean BMD in early adolescence but this disparity narrowed throughout adolescence since mean annual BMD variation from 13 to 17 years old increased inversely with gynecologic age (Table 1). Pearson's correlation between baseline BMD and its increase varied from -0.12 in the youngest to -0.45 in the oldest GA. After adjustment for baseline BMD, weight, fat mass and height and standardization, the effect size of anthropometric variables and their changes in determining BMD in late adolescence was highest in the lowest gynecologic age group. In the oldest gynecologic age group, BMD at 17 years old was strongly determined by baseline BMD but not by anthropometric variables (Table 2).

Figure. Mean forearm BMD according to gynecological age (time from menarche), by age at baseline (13 or 14) and follow-up (16 or 17)

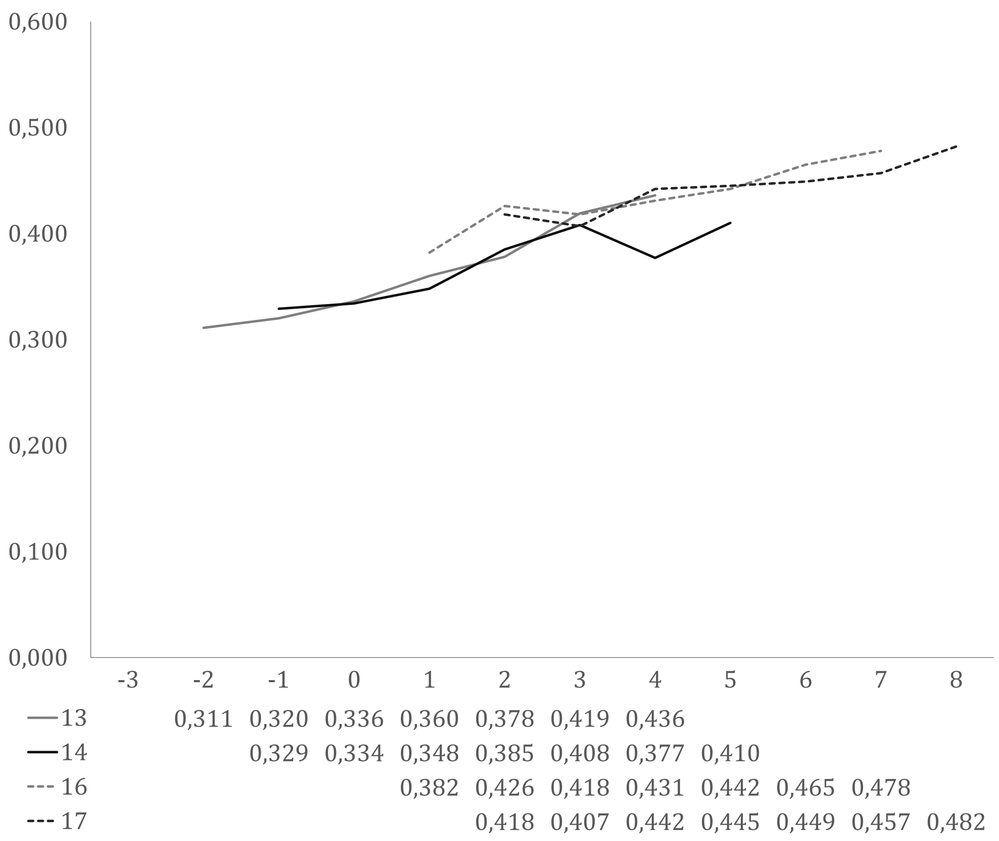

Table 1. Mean characteristics of adolescents at 13 and 17 years old, by classes of gynecologic age

	Gynecologic age (years)		
	≤0	1	≥2
n	268	224	217
Mean follow-up period (months)	39.8 (39.2; 40.5)	38.7 (38.0; 39.3)	39.4 (38.6; 40.1)
Mean baseline height (cm)	156.5 (155.6; 157.4)	159.2 (158.4; 160.0)	158.8 (157.9; 159.6)
Mean height change (cm/year)	1.4 (1.3; 1.5)	0.7 (0.7; 0.8)	0.5 (0.4; 0.6)
Mean baseline weight (kg)	48.6 (47.4; 49.7)	53.7 (52.4; 55.0)	55.2 (54.1; 56.4)
Mean weight change (kg/year)	2.1 (1.9; 2.2)	1.1 (0.9; 1.3)	1.0 (0.8; 1.2)
Mean baseline fat mass (kg)	11.8 (11.0; 12.5)	14.9 (14.0; 15.8)	16.3 (15.5; 17.0)
Mean baseline fat mass change (kg/year)	0.6 (0.4; 0.8)	-0.1 (-0.2; 0.1)	-0.2 (-0.4; -0.0)
Mean baseline BMD (g/cm^2)	0.329 (0.323; 0.334)	0.358 (0.351; 0.365)	0.392 (0.385; 0.399)
Mean BMD change (g/cm^2-year)	0.029 (0.028; 0.030)	0.024 (0.022; 0.026)	0.018 (0.016; 0.019)
Mean follow-up BMD (g/cm^2)	0.422 (0.416; 0.429)	0.433 (0.426; 0.439)	0.448 (0.442; 0.455)

Table 2. Estimated associations between BMD (mg/cm^2) in late adolescence and baseline anthropometry and anthropometric changes, according to gynecologic age (years)

Gynecologic age (years)	Regression coefficients	Weight (per kg or kg/year)		Fat mass (per kg or kg/year)		Height (per cm or cm/year)	
		Baseline	Change	Baseline	Change	Baseline	Change
≤0	Crude	2.02 (1.04; 2.28)	-3.90 (-8.41; 0.62)	2.47 (1.46; 3.48)	-2.10 (-6.97; 2.78)	1.41 (0.54; 2.28)	-18.59 (-25.07; -12.12)
	Adjusted*	3.47 (1.57; 5.36)	7.08 (1.58; 12.57)	-4.67 (-7.24; -2.10)	-3.48 (-9.04; 2.08)	-0.89 (-1.76; -0.02)	-5.36 (-11.09; 0.37)
	Adjusted* and standardised	32.59 (14.78; 50.41)	10.01 (2.24; 17.78)	-28.48 (-44.13; -12.82)	-4.58 (-11.89; 2.73)	-6.45 (-12.75; -0.16)	-5.03 (-10.40; 0.34)
1	Crude	1.66 (1.04; 2.28)	1.31 (-2.90; 5.53)	2.10 (1.18; 3.02)	0.14 (-5.02; 5.30)	0.47 (-0.62; 1.56)	-15.53 (-28.28; -2.79)
	Adjusted*	2.42 (0.32; 4.52)	9.51 (1.45; 17.58)	-3.12 (-6.05; -0.19)	-6.12 (-16.52; 4.28)	-0.55 (-1.58; 0.48)	3.76 (-6.78; 14.31)
	Adjusted* and standardised	23.71 (3.12; 44.30)	14.62 (2.22; 27.02)	-21.02 (-40.75; -1.30)	-7.69 (-20.76; 5.38)	-3.25 (-9.36; 2.87)	1.89 (-3.40; 7.19)
≥2	Crude	2.24 (1.53; 2.95)	-0.25 (-4.60; 4.09)	3.14 (2.10; 4.18)	-1.88 (-7.07; 3.32)	0.05 (-1.03; 1.13)	-18.97 (-33.40; -4.54)
	Adjusted*	1.44 (-0.51; 3.38)	5.66 (-2.87; 14.19)	-0.90 (-3.54; 1.74)	0.34 (-10.18; 10.85)	-0.68 (-1.59; 0.23)	4.82 (-6.45; 16.08)
	Adjusted* and standardised	12.40 (-4.39; 29.19)	8.65 (-4.39; 21.70)	-5.32 (-20.97; 10.33)	0.43 (-13.00; 13.86)	-4.20 (-9.81; 1.41)	2.18 (-2.92; 7.29)

* Adjusted to baseline BMD, weight, fat mass and height.

CONCLUSIONS

We confirmed gynecologic age as a better indicator of biological bone development than chronologic age and this needs to be considered when defining reference curves. Tracking was overestimated if calculated irrespectively of gynecologic age.
The associations between bone quality in late adolescence and trends in anthropometric parameters were stronger up to one year after menarche – this may be the biological timing when interventions have the highest impact.

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