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Physical activity from adolescence to young adulthood and bone mineral density in young adults from the 1982 Pelotas (Brazil) Birth Cohort

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ABSTRACT

Objective. To evaluate a prospective association between physical activity (PA) and bone mineral density (BMD) in young adults.

Method. Total body (TB), lumbar spine (LS) and femoral neck (FN) BMD were measured in participants from the 1982 Pelotas Birth Cohort by dual-energy X-ray absorptiometry at 30 y. PA was evaluated at 15, 18 (males) and 23 y.

Results. 3454 young adults were scanned (DXA) at least at one anatomical site. In males, PA at 15 y was associated with LS density ($\beta = 0.061$ g/cm^2; 95% confidence interval (CI): 0.015; 0.108). A positive dose–response effect was found for the association between PA at 18 y and BMD. Males in the two highest quartiles of PA at 23 y had significantly greater BMD at all anatomical sites than males in the lowest quartile. We observed greater BMD at 30 y in boys who were active at least in one of the assessments (18 or 23 y) compared to inactive boys at both ages. Females in the highest quartile of PA at 23 y showed greater FN density at 30 y ($\beta = 0.020$; 95%CI: 0.001; 0.039).

Conclusions. A physically active pattern is important to BMD across the first three decades of life. Potential beneficial effects of PA were not entirely lost with advancing age in male young adults.

Introduction

Bone health is critically important to the overall health and quality of life throughout the human's lifespan. Bones play a major role as a “storehouse” for minerals that are vital to the functioning of many other life-sustaining systems in the body. Unhealthy bones lead to an increase in fracture risk caused by low bone mass and deterioration of bone structure mainly characterized as osteoporosis (U.S. Department of Health and Human Services, 2004). This reduction in bone mass is an important health problem with social and financial impacts on society since each year about 2 million individuals suffer an osteoporotic-related fracture worldwide (WHO Scientific Group on the Prevention and Management of Osteoporosis, 2000).

The development of the skeleton can be influenced by early life factors (birth weight, maternal nutrition, etc.) (Cooper et al., 2009; Jones, 2011; Martinez-Mesa et al., 2013) and bone mass is determined by the factors that influence the gain, maintenance or bone loss across the lifespan, including modifiable and lifestyle factors, such as physical activity (Heaney et al., 2000). Although the benefits of physical activity to bone health are shown in the literature, there is controversy if the role of physical activity on bone mass has important benefits not only during growth, where the peak of accrual BMD was not reached, but also during adulthood, though in the maintenance phase of bone mass (Bielemann et al., 2013). In addition, evidences of the effect of physical activity during early ages on bone density in youth and later ages are scarce, mainly in middle or low-income countries where ethnicities and physical activity patterns are distinct from high-income countries (Bielemann et al., 2013).

Benefits of physical activity during adolescence and adulthood on bone mass are more consistent in males (Baxter-Jones et al., 2008; Delvaux et al., 2001; Kemper et al., 2000; Neville et al., 2002; Valimaki et al., 1994; Van Langendonck et al., 2003; Welten et al., 1994) whereas absence of association is found in some studies with females especially with a prospective effect of physical activity during adulthood (Barnekow-Bergkvist et al., 2006; Kemper et al., 2000; Neville et al., 2002; Uusi-Rasi et al., 2002).

This study was aimed at assessing the effect of physical activity during adolescence and young adulthood on bone mineral density in subjects belonging to the 1982 Pelotas (Brazil) Birth Cohort Study.

Methods

The study was carried out in Pelotas, a medium-sized city in southern Brazil that currently has 330,000 inhabitants. In 1982, all maternity hospitals in the city were visited daily and the 5914 liveborns whose families lived in the

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urban area of the city were examined and their mothers interviewed. These subjects have been followed-up many times.

In 1997, all households in a 27% systematic sample of the 259 census tracts in the urban area of the city were visited in search of individuals born in 1982. All existing households in these 70 census tracts were visited to locate the participants and 1076 adolescents were located. From July to September 2000, we followed the male subjects during the compulsory enlistment Army medical examination and 2250 of the 3037 males of the cohort were interviewed (follow-up rate: 79%, 143 known deaths). Between October 2004 and August 2005, the entire cohort was sought and 4297 cohort members were interviewed (follow-up rate 77%). From June 2012 to February 2013 another follow-up was carried out with the entire cohort and subjects were invited to visit the Epidemiologic Research Center. All procedures were approved by the Ethics Committee in Research of the Faculty of Medicine at Federal University of Pelotas and a written informed consent was obtained from all subjects.

Physical activity was measured at 15, 18 and 23 years of age. In 1997, the subjects were asked about their frequency in dance, sports and games, besides school or work-related activities. The options included: every day; at least once a week; at least once per month; and never. Subjects were considered as active if they responded “at least once a week”. In 2000, boys were asked about frequency and duration spent in exercises in a usual week (e.g. gym, sports club, household, school, and commuting to work). In the 2004–5 follow-up, the long form of the International Physical Activity Questionnaire (IPAQ) was administered (Craig et al., 2003). In this study we analyzed the weekly time spent in physical activity only during leisure-time. The time spent in vigorous-intensity physical activity was multiplied by two (Craig et al., 2003).

Time spent in physical activity at 18 and 23 years was divided into quartiles. We also estimated the variation in physical activity recommendation (150 min/week) from 18 to 23 years. Subjects were classified into one of the following categories: inactive at both ages; active only at the youngest age; active only at the oldest age; and active at both ages.

Bone mineral density (g/cm^2) in the 30 year follow-up was measured in total body, lumbar spine (L1–L4) and right femoral neck using the method of dual-energy X-ray absorptiometry (Lunar Prodigy Advance — GE®, Germany). DXA scans were not done in pregnant women and subjects weighing more than 120 kg or taller than 1.92 m. Subjects with metal plates or screws, implants and metal items were excluded from examination. Subjects that could not fit in the DXA scan area were submitted to half-body scans of their right side to estimate total body BMD.

At 30 years, height was measured to the nearest 1 mm with barefooted subjects using a wooden stadiometer. With respect to potential confounders, birth weight measured with pediatric scales (Filizola) soon after birth, monthly family income, household assets index at 2 years, maternal smoking during pregnancy and breastfeeding duration were collected in the perinatal or during the follow-ups in childhood. Calcium intake (mg/day) and phosphorus intake (mg/day) were measured in 2004–5 by a food-frequency questionnaire based on a list of food included in another instrument created by Sichieri and Everhart (1998). Current smoke was asked in 2000 and 2004–5 visits. Age at menarche was asked in 1997 (subsample) and in 2004–5, as well as the use of oral contraceptives. Skin color was evaluated by self-report in 2004–5. Data on lean mass (g) was obtained from total body DXA scans at 30 years.

The analyses were stratified by sex since potential effect modification was considered when the p-value for the interaction term was 0.2. Analysis of variance or Kruskal–Wallis test, depending on the heterogeneity of variance, was used to compare the mean time spent in physical activity at 18 and 23 years according to tertiles of BMD. Crude and adjusted analyses were performed using linear regressions. Covariates were included in the analyses according to the model presented in Fig. 1. The significance level was set at 5%. The analyses were performed with Stata 12 software (StataCorp, College Station, TX, USA).

Results

In the 2012–13 visit we interviewed 3701 subjects (follow-up rate: 68.1% — considering 325 known deaths), and 3454 young adults were scanned with DXA. In this study 3338, 3433 and 3450 participants met the inclusion criteria for total body, lumbar spine and femoral neck BMD, respectively. Table 1 shows the distribution of potential confounders as well as means and standard deviations of BMD at 30 years and physical activity evaluation at 15, 18 and 23 years. BMD at all anatomical sites was lower in females than in males. Almost 90% of males performed physical activity at least once a week at 15 years, whereas for females this proportion was 60%. Around 30% of males and 65% of females did not practice any leisure-time physical activity at 23 years.

The description of min/week spent in physical activity at 18 and 23 years in males according to BMD at 30 years is shown in Fig. 2. Differences on mean values of physical activity were observed between

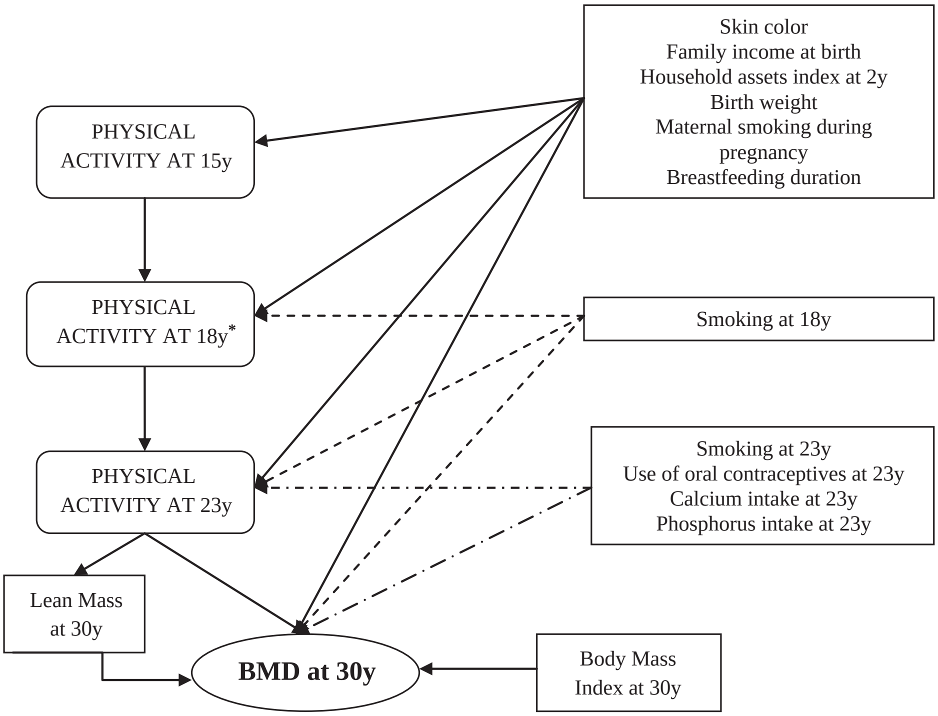

Fig. 1. Flow chart illustrating the three physical activity assessments and covariates used in the linear regression models between bone mineral density (BMD) and physical activity at different ages. *Information only available for males.

the tertiles of BMD for all anatomical sites. Time spent in physical activity at ages 18 and 23 by males who were in the highest tertile of BMD at 30 years was always higher than that for those in the lowest tertile of BMD at all anatomical sites. Time spent in physical activities at 23 years was higher in males who were in the second tertile of total body BMD compared to males in the first tertile ($p < 0.001$). Time spent in physical activities at 23 years by males in the highest tertile of femoral neck BMD was also higher than time spent in physical activities by males in the second tertile ($p = 0.021$).

BMD at all anatomic sites was higher among males and the p-values to test the interaction between physical activity effect at 15 and 23 years of age and sex ranged from <0.001 to 0.113. The crude analysis for men (Table 2) showed that physical activity in all ages was positively associated with BMD at all anatomical sites ($p < 0.05$). After adjusting for potential confounders, those males who practiced physical activity at least once a week at 15 years had on average an increase of 0.061 g/cm^2 (95%CI: 0.015; 0.108) in lumbar spine BMD at 30 years compared to those who practiced less than once a week. A dose–response effect was observed between physical activity at 18 years and BMD at 30 years, since BMD at all anatomical sites increased according to physical activity improvements ($p < 0.001$). However, at 23 years regression coefficients for males in the third and fourth quartiles were very similar. Including lean mass in the analyses (data not shown), physical activity at 15 years was positively associated with total body and lumbar spine BMD at 30 years and the coefficient was greater. When physical activity at 18 and 23 years was analyzed, the associations remained, although the coefficients were lower than in model 2.

Table 3 shows that, for females, physical activity at 15 years was not associated with BMD at 30 years in any anatomical site and physical activity at 23 years was positively associated with total body BMD at 30 years only in the crude analysis. We observed the opposite for femoral neck BMD. After controlling for confounders, the magnitude of the regression coefficient increased and the confidence interval for those women in the highest quartile of physical activity at 23 years did not include the null value [regression coefficient 0.020 (95%CI: 0.001; 0.039)] but this association was not linear. After adjustment for lean mass (data not shown), physical activity was not statistically associated with BMD.

About 50% of males engaged in physical activity at least once a week at 15 years and reached the recommendation of 150 min/week of physical activity at 18 years. And, about one of every three males reached this recommendation at 18 and 23 years. However, only 13% of females practiced physical activity at least once a week at 15 years and spent at least 150 min/week at 23 years (data not shown). Fig. 3 shows that those subjects who were physically active at 18 and 23 years showed the lower BMD at all anatomical sites, whereas those subjects who were active at both moments presented the highest BMD.

Discussion

We analyzed data from a population-based cohort study with young adults from southern Brazil investigating medium-to long-term potential effects of physical activity on BMD at different anatomical sites. Physical activity at different ages was more influential in men's bone content. Boys who engaged in physical activities at least once a week had greater lumbar spine BMD at 30 years. Furthermore, physical activity at 18 and 23 was positively associated with BMD at 30 years in all anatomical

Table 1
Past and current characteristics of males and females belonging to the 1982 Pelotas Birth Cohort.

Sample characteristics	Males			Females		
	n	Mean (SD)	Prevalence	n	Mean (SD)	Prevalence
Family income at birth (minimal wages)						
≤1	666		22.0	622		21.7
1.1–3	1463		48.4	1325		46.3
3.1–6	544		18.0	547		19.1
6.1–10	184		6.1	198		6.9
>10	167		5.5	168		5.9
Birth weight (g)	3035	3245.2 (573.5)		2873	3126. 6 (548.5)	
Breastfeeding duration (months)						
<1.0	636		23.3	535		20.6
1.0–2.9	709		25.9	696		26.8
3.0–5.9	611		22.3	601		23.1
6.0–8.9	261		9.5	236		9.1
9.0–11.9	114		4.2	95		3.7
≥12.0	404		14.8	434		16.7
Maternal smoking during pregnancy						
Non-smoker	1946		64.1	1864		64.8
1–14 cigarettes/day	807		26.6	787		27.4
≥15 cigarettes/day	284		9.4	225		7.8
Skin color (2004–5 follow-up)						
White	1658		74.9	1580		75.9
Non-white	555		25.1	503		24.1
Physical activity at 15 y						
≥once/week	493		87.9	310		60.2
<once/week	68		12.1	205		39.8
Physical activity at 18 y (quartiles)						
1st (0–60 min)	617	15.8 (25.6)	27.6	–	–	–
2nd (61–180 min)	642	138.6 (34.5)	28.7	–	–	–
3rd (181–360 min)	509	294.3 (54.2)	22.7	–	–	–
4th (>360 min)	469	854.6 (669.3)	21.0	–	–	–
Physical activity at 23 y (quartiles)						
1st (0 min)	637	0 (0.0)	28.8	1345	0 (0.0)	64.6
2nd (10–60 min)	190	51.3 (14.3)	8.6	178	44.4 (15.4)	8.6
3rd (61–270 min)	583	169.5 (57.2)	26.3	292	154.9 (54.4)	14.0
4th (>270 min)	803	784.5 (545.2)	36.3	267	677.1 (499.8)	12.8
Total body BMD (g/cm^2)	1604	1.27 (0.10)		1734	1.17 (0.08)	
Lumbar spine BMD (g/cm^2)	1687	1.24 (0.15)		1746	1.21 (0.13)	
Femoral neck BMD (g/cm^2)	1689	1.11 (0.15)		1761	1.01 (0.12)	

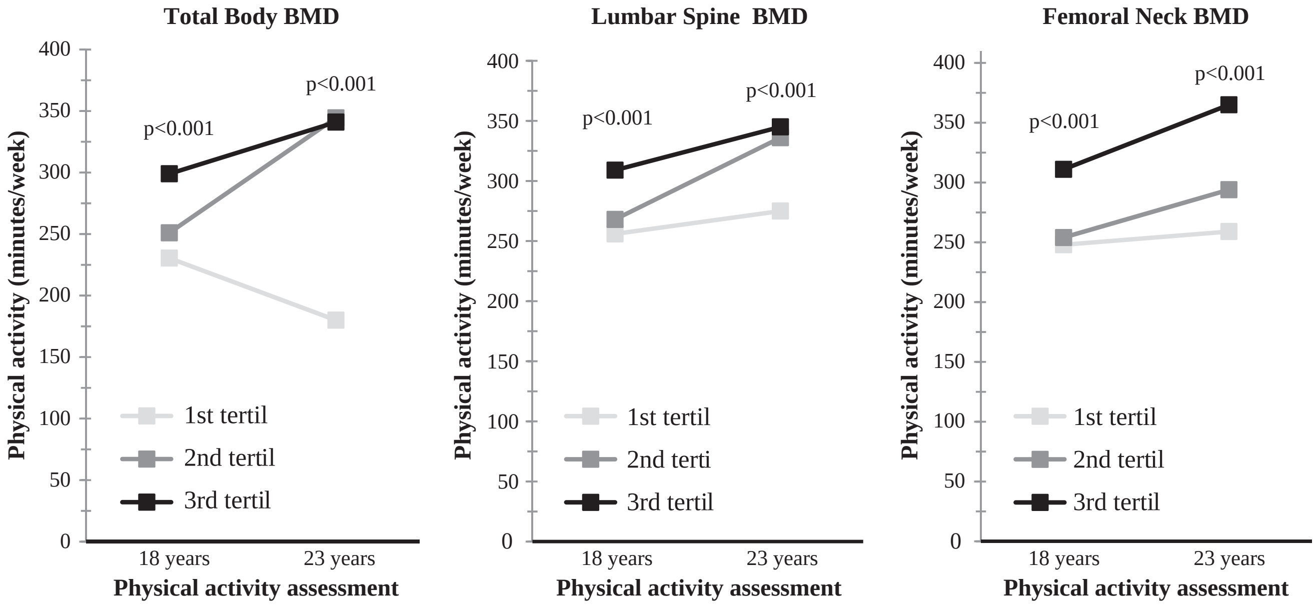

Fig. 2. Minutes per week of physical activity at 18 and 23 years in males from the 1982 Pelotas Birth Cohort according bone mineral density (g/cm^2) in tertiles.

sites. Coefficients of effect of physical activity at 23 years on BMD were similar for the third and fourth quartiles, suggesting that, after a certain level of physical activity, the positive effects on bone mass are reduced. Females in the highest quartile of physical activity at 23 years showed a higher femoral neck BMD at 30 years. Males who were active at least at 18 or 23 years had greater BMD at 30 years at all anatomical sites compared to inactive peers at both ages. It is suggested as a cumulative effect since higher coefficients were found in active males in both ages.

There is no consensus in the literature regarding the age at which the general population achieves peak bone density. There is some debate

Table 2
Crude and adjusted associations between physical activity at 15, 18 and 23 years and bone mineral density (g/cm^2) in males from the 1982 Pelotas Birth Cohort.

Model	Physical activity measurement	Bone mineral density (g/cm^2)					
		Total body		Lumbar Spine (L1–L4)		Femoral neck	
		n	p β coefficient (95%CI)	*n*	p β coefficient (95%CI)	*n*	p β coefficient (95%CI)
1	Physical activity at 15 y	351	$p = 0.033$	373	$p = 0.004$	374	$p = 0.026$
	≥once/week		0.035 (0.002; 0.066)		0.067 (0.022; 0.112)		0.059 (0.007; 0.111)
	<once/week		Ref.		Ref.		Ref.
	Physical activity at 18 y (min/week — quartiles)	1459	$p < 0.001$	1533	$p < 0.001$	1535	$p < 0.001$
	1st		Ref.		Ref.		Ref.
	2nd		0.021 (0.008; 0.034)		0.022 (0.002; 0.042)		0.028 (0.007; 0.049)
	3rd		0.037 (0.023; 0.051)		0.043 (0.022; 0.063)		0.047 (0.026; 0.069)
	4th		0.046 (0.031; 0.060)		0.062 (0.041; 0.084)		0.065 (0.043; 0.088)
	Physical activity at 23 y (min/week — quartiles)	1477	$p < 0.001$	1551	$p < 0.001$	1553	$p < 0.001$
	1st		Ref.		Ref.		Ref.
	2nd		0.011 (−0.007; 0.029)		0.024 (−0.004; 0.051)		0.033 (0.004; 0.062)
	3rd		0.040 (0.027; 0.053)		0.048 (0.028; 0.068)		0.058 (0.038; 0.079)
	4th		0.043 (0.031; 0.055)		0.053 (0.035; 0.071)		0.061 (0.042; 0.081)
2	Physical activity at 15 y	302	$p = 0.073$	320	$p = 0.010$	321	$p = 0.148$
	≥once/week		0.028 (−0.003; 0.058)		0.061 (0.015; 0.108)		0.038 (−0.014; 0.090)
	<once/week		Ref.		Ref.		Ref.
	Physical activity at 18 y (min/week — quartiles)	1251	$p < 0.001$	1315	$p < 0.001$	1317	$p < 0.001$
	1st		Ref.		Ref.		Ref.
	2nd		0.025 (0.012; 0.038)		0.031 (0.010; 0.052)		0.031 (0.010; 0.052)
	3rd		0.034 (0.020; 0.048)		0.042 (0.020; 0.064)		0.040 (0.018; 0.063)
	4th		0.041 (0.027; 0.055)		0.062 (0.039; 0.084)		0.055 (0.032; 0.078)
	Physical activity at 23 y (min/week — quartiles)	1259	$p < 0.001$	1323	$p < 0.001$	1325	$p < 0.001$
	1st		Ref.		Ref.		Ref.
	2nd		0.012 (−0.006; 0.029)		0.034 (0.004; 0.062)		0.038 (0.009; 0.067)
	3rd		0.031 (0.019; 0.044)		0.047 (0.026; 0.067)		0.047 (0.026; 0.068)
	4th		0.035 (0.023; 0.047)		0.051 (0.031; 0.071)		0.054 (0.035; 0.074)

Model 1: Crude.
Model 2: Adjustment for body mass index, skin color, family income at birth, household assets index, birth weight, maternal smoking during pregnancy, breastfeeding duration + other covariates according to analysis model (physical activity at 18 y: all variables previously described + smoking at 18 y – physical activity at 23 y: all variables previously described + calcium intake, phosphorus intake and smoking at 23 y).
Coefficients were obtained by linear regression.

Table 3
Crude and adjusted associations between physical activity at 15 and 23 years-old and bone mineral density (g/cm^2) in females from the 1982 Pelotas Birth Cohort.

Model	Physical activity measurement	Bone mineral density (g/cm^2)					
		Total body		Lumbar Spine (L1–L4)		Femoral neck	
		n	p β coefficient (95%CI)	*n*	p β coefficient (95%CI)	*n*	p β coefficient (95%CI)
1	Physical activity at 15 y	379	p = 0.461	378	p = 0.184	382	p = 0.725
	≥once/week		0.006 (−0.011; 0.024)		0.019 (−0.009; 0.046)		0.005 (−0.022; 0.031)
	<once/week		Ref.		Ref.		Ref.
	Physical activity at 23 y (min/week — quartiles)	1574	p = 0.014	1584	p = 0.265	1599	p = 0.811
	1st		Ref.		Ref.		Ref.
	2nd		0.001 (−0.013; 0.016)		0.000 (−0.024; 0.024)		−0.019 (−0.042; 0.003)
	3rd		−0.008 (−0.019; 0.004)		−0.009 (−0.027; 0.010)		−0.014 (−0.032; 0.004)
	4th		0.017 (0.005; 0.028)		0.016 (−0.004; 0.036)		0.014 (−0.005; 0.033)
2	Physical activity at 15 y	334	p = 0.761	333	p = 0.196	336	p = 0.934
	≥once/week		0.002 (−0.013; 0.018)		0.019 (−0.010; 0.048)		−0.001 (−0.027; 0.025)
	<once/week		Ref.		Ref.		Ref.
	Physical activity at 23 y (min/week — quartiles)	1387	p = 0.066	1397	p = 0.711	1408	p = 0.021
	1st		Ref.		Ref.		Ref.
	2nd		0.002 (−0.010; 0.015)		0.000 (−0.024; 0.024)		−0.018 (−0.040; 0.004)
	3rd		−0.008 (−0.018; 0.003)		−0.009 (−0.028; 0.010)		−0.009 (−0.026; 0.008)
	4th		0.011 (−0.001; 0.022)		0.006 (−0.015; 0.026)		0.020 (0.001; 0.039)

Model 1: Crude.
Model 2: Adjustment for body mass index, skin color, family income at birth, household assets index, birth weight, maternal smoking in the pregnancy, breastfeeding duration, age at menarche + other covariates according analysis model (physical activity at 23 y: all variables previously described + calcium intake, phosphorus intake, use of oral contraceptives and smoking at 23 y).
Coefficients were obtained by linear regression.

whether adults achieve peak bone mass by their early twenties (Haapasalo et al., 1996; Teegarden et al., 1995) or close to the 30 years (Recker et al., 1992). Thus, it is possible that the effects observed in this study could be due to an increase in BMD caused by physical activity more than the role in the prevention of mineral losses.

Our findings showed that association between previous physical activity and BMD at 30 years is mainly observed in men. It has been suggested that boys' bones are more sensitive to loading than girls' bones during adolescence (Kriemler et al., 2008) and the same was found in animals (Wallace et al., 2007). In addition, the failure to observe a relationship between physical activity and BMD among women could also be due to the physical activities that girls typically engage, which may not result in high loads or be intense enough to increase their bone density. Females from this cohort spent, on average, 80 min/week of vigorous-intensity physical activity less than males at 23 years (data not shown).

However, the variation in physical activity from 15 to 23 years showed greater lumbar spine and femoral neck BMD at 30 years in females who were active at both ages. These results show that women could benefit from physical activity if they were engaged in physical activity across the entire lifespan. This could reflect sports activities in the past, which are more osteogenic, since high participation in sports activity during adolescence is related to physical activity practice in the adulthood (Kjonniksen et al., 2009).

It is difficult to identify the impact of these associations on later fracture risk. However, fracture risk increases 1.5 to 3 times or more for each standard deviation (SD) decrease in BMD (Kanis et al., 1994). Inactive males in both 18 and 23 years had a BMD of 0.27 SD below average for all males and a BMD of 0.47 SD below average for active males in both 18 and 23 years, indicating a possible greater fracture risk in inactive males in the persistence of this condition.

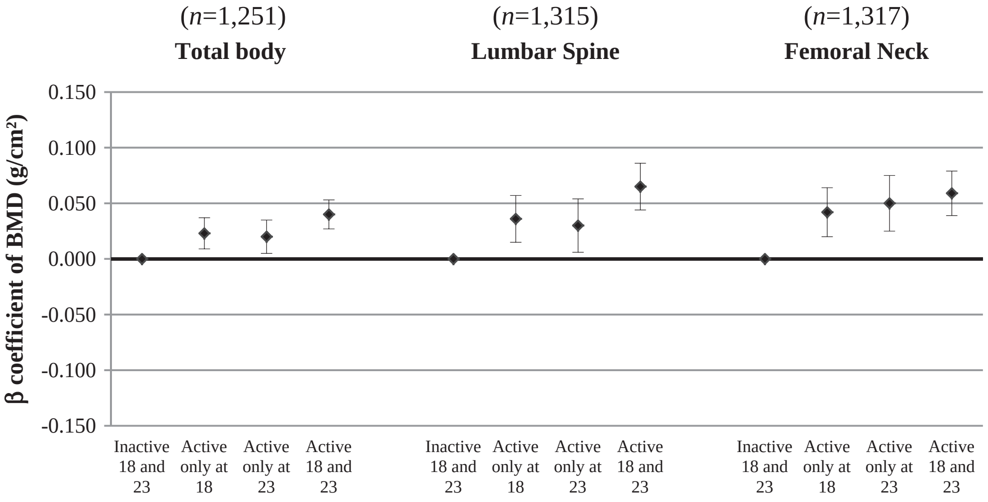

Fig. 3. Bone mineral density (g/cm^2) according to variation in physical activity measurements from 18 to 23 years in males belonging to the 1982 Pelotas Birth Cohort. Adjusted for current body mass index, family income at birth, household assets index at 2 y, skin color, maternal smoking during pregnancy, birth weight, breastfeeding duration, smoking at 18 y, smoking at 23 y, calcium intake at 23 y and phosphorus intake at 23 y.

There is some evidence that physical activity during the childhood is important to improvements in bone mass (Janz et al., 2008; Ondrak and Morgan, 2007), though studies with evaluation of physical activity during this age in association with later BMD were not found. Previous cohort studies reported that physical activity during adolescence and adulthood is positively associated with BMD in young adult males (Baxter-Jones et al., 2008; Delvaux et al., 2001; Kemper et al., 2000; Neville et al., 2002; Valimaki et al., 1994; Van Langendonck et al., 2003; Welten et al., 1994). However, there seems to be no consensus for the association between physical activity at these ages and BMD in women since some studies reported positive associations while others reported absence of association, mainly if considered the physical activity on adulthood (Barnekow-Bergkvist et al., 2006; Baxter-Jones et al., 2008; Cooper et al., 1995; Neville et al., 2002; Petit et al., 2004; Wang et al., 2003; Welten et al., 1994).

The mechanisms involving physical activity and bone health are explained by the capacity that bone tissue has to adapt its structure and function in response to mechanical forces and metabolic demands (Maimoun and Sultan, 2011). This mechanism starts when osteocytes detect mechanical strain and transduce the applied strain to osteoblasts and osteoclasts (Turner and Pavalko, 1998). Thus, the main response caused by physical activity on bones occurs when mechanical forces are generated from ground impacts and skeletal muscle contractions (Guadalupe-Grau et al., 2009).

In general, our results showed that effects of physical activity on BMD at 30 years were partially attenuated by lean mass, indicating its mediating effect. Lean mass stimulates osteogenesis via muscle forces on bones (Liu-Ambrose et al., 2006; Tudor-Locke and McColl, 2000) which impose the largest voluntary bone loads/strains and strongly influence bone mass (Frost, 2000). The lack of association between physical activity at 23 years and femoral neck BMD at 30 years after adjustment for lean mass in females suggests that the whole effect of physical activity was mediated by lean mass. However, in males it seems that other mechanisms are involved in this relationship.

The fact that coefficients of association in males were higher in BMD at femoral neck and lumbar spine sites could be explained because bone adaptation is greater in loaded regions (Guadalupe-Grau et al., 2009). Total body site includes no weight bearing anatomical sites, such as the arm, and the most part of physical activities practiced are weight bearing (walking, running, etc.) whereas activities such as handball and weight lifting that promote actions for other parts of the body are less common (Welten et al., 1994).

From these results it seems that there is no critical period for the effect of physical activity on bone mass, since our findings, at least for men, were positive for all ages of physical activity measurements, but a cumulative effect seems to be present. Although more attention is given to the growth period, the exercise benefits in BMD may be decreased in long-term periods, indicating that residual factors caused by physical activity such as structural changes, muscle strength and balance could be more important to prevent fractures in later life (Karlsson, 2007).

This study has several limitations and strengths. The comparison of the effects at different anatomical sites is an important strength, as well as confounders collected in different follow-ups. Moreover, adjusted coefficients were not much different from the crude coefficients, indicating a lower possibility of residual confounding.

Limitations are the lack of information for females at 18 years and the different instruments used to assess physical activity. The question used to estimate physical activity at 15 years is not appropriate. This question and questionnaire used at 18 years were not validated. However, we believe that important associations were found with data at 15 years. In addition, coefficients found using physical activity measurement at 18 years were in line with coefficients showed for physical activity measurement using the IPAQ at 23 years. Differences in the instruments are important because we cannot compare the coefficients observed at the different ages and also the analyses with variation in physical activity should be interpreted with caution. The use of an inappropriate instrument to detect the food intake of specific nutrients can influence the statistical adjustment and, though weight-bearing activities are more likely during the leisure-time, only to include these activities may be another limitation.

Conclusion

Physical activity in adolescence and young adulthood was positively associated with BMD at all anatomical sites in males, but not in females. The maintenance of physical activity was positive for BMD in males. Lean mass could be considered an important mediator. It seems that the effect of physical activity at adolescence is not entirely lost up to young adulthood. Physical activity should be encouraged to promote bone mass during adolescence and young adulthood. Physical activity may be a major determinant of BMD, helping to prevent osteoporosis, osteoporosis-related fractures and consequently the high costs due to hospitalizations later in life.

Conflict of interest statement

The authors declare that there are no conflicts of interests.

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