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The Effectiveness of a Curricular-Based Exercise Intervention on Bone Health and Body Composition in Swedish Boys and Girls in an Elementary School Setting

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Abstract

Objective: To investigate whether curricular-based physical activity intervention was associated with cortical and trabecular bone microstructure, and fitness parameters among elementary school children.

Methods: This was a case-controlled quasi-experimental study to which 79 children were recruited (19 girls and 21 boys attending the intervention school, and 23 girls and 16 boys attending the control school). The curricular-based intervention consisted of two extra weekly classes of 30-45 minutes each, besides the ordinary physical education classes. The assessments included cortical and trabecular bone microstructure and body composition using high-resolution peripheral quantitative computed tomography (HR-pQCT) and dual-energy X-ray absorptiometry (DXA), respectively. Anthropometrics, Tanner and menarchal stages were evaluated on the same occasions. Self-administered questionnaires were used to assess exercise habits and foreign background. Analyses split by gender were done using unpaired t-test and linear regression, adjusted for age, height, weight and pubertal stage.

Results: Girls in the intervention school had significantly higher total volumetric BMD (+15.1%; p<0.01), cortical thickness (+18.7%; p=0.01) and trabecular bone volume fraction (+11.5%; p=0.01), as compared with girls in the control school. The results remained unchanged in linear regression models adjusted for age, height, weight, and Tanner stage. No convincing effects on bone health were found for the boys. There were no significant differences for DXA bone variables when comparing intervention boys and girls with controls.

Conclusion: A curricular-based exercise intervention program providing opportunities for elementary school children to be physically active during the school day appear to be associated with bone health among girls, but not boys.

Keywords: Physical activity; Intervention; Bone health; Body composition; Children; Peak bone mass; HR-pQCT

Introduction

Accumulating evidence indicates that physical activity during childhood and adolescence can bring substantial health benefits important for both the current and future health [1,2]. Learning to move is a necessary skill underlying physical activity and it has been suggested that the development of motor skills is a significant determinant of sustained physical activity levels throughout the lifespan [3]. Mounting evidence however, suggest that there is a substantial decline in physical activity levels from childhood to adolescence [4]. Previous research suggests that the decline is much more marked in girls than boys [4]. These negative secular trends may affect later involvement in physically active lifestyles. A sedentary lifestyle not only increase the risk for weight gain and obesity and constitute a major risk for numerous diseases, but may also speed the aging process. The presence of obesity in adolescence is also shown to

be a risk factor for obesity in adulthood [5]. A sedentary lifestyle is also believed to have numerous repercussions on bone metabolism during adolescence and may therefore be a substantial determinant of bone mass accumulation and bone fragility [6]. On the other hand, a previous study indicates that engagement in sport activities during growth confers positive effects on bone geometry even though sport activity is ceased [7]. Given the large shift toward lower levels of physical activity in children, increasing youth activity levels is a priority, and the school environment should be considered an important arena for promoting physical activity.

Although bone mass is mainly genetically determined [8], the foundation for skeletal health is established early in life and approximately 90% of adult bone mass is acquired during childhood and adolescence [9]. Adolescence is a period of rapid skeletal development essential for the attainment of peak bone mass (PBM), the greatest amount of bone mass achieved during life at a given skeletal site [10]. Because the foundation for skeletal health is established so early in life, osteoporosis prevention should begin by optimizing bone mineral development throughout childhood and

adolescence. Optimizing PBM through regular weight-bearing physical activity is suggested as a potential strategy to reduce the risk of development of bone fragility later in life [10].

The school environment provides an important arena for creating good life habits, initiating changes, and preventing bad health by promoting physical activity [11]. Although there is growing evidence for the benefits of physical activity on various health outcomes including bone parameters [12-14], there has been a worldwide tendency to reduce school-based physical education in favor of academic subjects [15]. The beneficial effects of exercise and the disadvantages of a sedentary lifestyle, support the notion that cutbacks in physical education lessons might be counterproductive. In Sweden, the time allocated for physical education has been drastically reduced by changes in the school curriculum. There is a concern that physical education takes valuable time away from academic work. However, allocating more time for physical education does not seem to compromise academic results [16,17]. In order to develop public health strategies to prevent the decline in physical activity over the life course more research addressing the benefits of school-based physical activity is needed.

A political reform implemented in Sweden in 2004 made collaborations between sports clubs and schools possible. A curriculum-based intervention program resulting from that political reform was shown to positively correlate with children's academic performance and psychological health, particularly for girls [16,18]. The aim of the present study was to investigate whether the curriculum-based physical activity intervention enabled by a governmental investment is associated with children's (1) trabecular and cortical bone structure and (2) body composition. We hypothesized that children in the intervention school would benefit from the intervention in terms of both bone structure and body composition, as compared with controls.

Material and Methods

Study sample and setting

This case-controlled quasi-experimental study, previously described in detail [16], included children from elementary schools in Mölndal, Sweden. In 2003, the Swedish government made an agreement with The Swedish Sports Confederation to engage more children in organized sports. In 2004, the "School-in-Motion" program was integrated into the curriculum of selected elementary schools. Another elementary school in the same region served as a control group in the analyses. The socio-economic characteristics in both the intervention and control schools were similar to those in Mölndal [16]. In both schools, the standard physical education curriculum of 2 weekly classes was unchanged during the intervention period. All parents and students were informed about the intervention, and written consent was obtained from the parents before data collection. The study was approved by the Regional Ethical Review Board in Gothenburg (Ref number: 752-09) and the study is conducted in accordance with relevant ethical guidelines.

Procedure

In the first semester of 2004, additional curriculum-based physical activity was introduced at the study school in collaboration with the local sports club. The amount of physical activity was nearly doubled for all students from preschool class to grade 6. Besides the ordinary classes, two extra weekly classes of 30-45 minutes each were mandatory for all children. The extra classes consisted of "play and motion" activities designed to be engaging, enjoyable, health-promoting, and noncompetitive and consisting of different sports and games with or without use of equipment. To assess the effect of the intervention on body composition and bone parameters students in grades 5 and 6 underwent dual-energy X-ray absorptiometry (DXA) and high-resolution peripheral quantitative computed tomography (HR-pQCT).

Measures and covariates

Each participant was asked a series of questions about curriculum based physical activity, previous and current physical activity out of school using a detailed questionnaire whose reliability has been tested [19]. The questionnaire also recorded average time per week spent in sport activities, level of perceived exertion in the sport activity as well as the duration of previous and present physical activity. To assess foreign cultural background we used a self-administered questionnaire. A foreign cultural background was defined as being foreign born or native-born with two foreign-born parents. The intake of milk and other dairy products and food supplement of all participants was also specified. Pubertal stage (or Tanner stage) was measured with a sex-specific self-administered scale, ranging from I (prepubertal) to V (fully mature), as described by Tanner [20]. Participants reported their pubertal stage by comparing their own physical development to the 5 stages by the use of photographs depicting the different Tanner stages. This method has previously been shown to be reliable in adolescents [21]. In addition, the female participants provided information about their menarcheal status.

Bone microarchitectural measurement

Trabecular architecture, as regards trabecular thickness, number and separation, and volumetric bone density were measured in the left tibia metaphysis using a high-resolution peripheral quantitative computed tomography (HR-pQCT) device (XtremeCT; Scanco Medical AG, Brüttisellen, Switzerland). Scan time was 3 minutes. The participant's lower leg was immobilized during the scan using anatomically formed carbon fiber shells, especially designed for the lower extremity (Scanco Medical). Measurements were carried out according to a standardized protocol previously described [22]. In short, the tibial length was measured between the medial malleolus and the medial condyle. A reference line was manually placed at the center of the end plate of the distal tibia. One hundred ten parallel computed tomography slices, with a nominal isotropic resolution (voxel size) of 82 μm, were obtained at 8% of the tibial bone length, delivering a 3D representation of an approximately 9-mm section of the tibia in the proximal direction. The entire volume of interest was automatically separated into a cortical and a trabecular region. From this separation and by previously described methods to process the data [23], we obtained total bone area (Tt.Ar; square millimeters), total volumetric bone mineral density (Tt.vBMD; milligrams per cubic centimeter), cortical volumetric bone mineral density (Ct.vBMD; milligrams per cubic centimeter), cortical thickness (Ct.Th; millimeters), trabecular bone volume fraction (BV/TV; percent), trabecular number (Tb.N; millimeters-1), trabecular thickness (Tb.Th; millimeters) and trabecular separation (Tb.Sp; millimeters). The in vivo precision error of density (total, trabecular, and cortical) measurements, performed on 33 older women at our facility, expressed as the coefficient of variation, ranged from 0.2% to 0.5%. The

reproducibility of geometrical and structural parameters ranged from 0.2% to 3.6%. The quality of the measurements were assessed by a five-grade scale, recommended by the manufacturer (Scanco Medical), in which 1 had the highest quality, 2-3 acceptable quality (included in the analyses), and grade 4-5 unacceptable quality (excluded from the analyses), due to motion artifacts. One measurement (one girl in the control group) was considered to have unacceptable quality (grade 5), leaving 22 girls in the control group. The same device, software, and operator were used throughout the whole study.

Dual-energy X-ray absorptiometry (DXA)

Areal bone mineral density (aBMD) (g/cm^2) was measured in whole body using the Lunar Prodigy DXA (GE Lunar Corp., Madison, WI). The full body measurement also provides information on fat and lean mass, expressed in grams or as a percentage of body weight. Scan time was 4.5 minutes.

Data analyses and analytical approach

Variables are reported as frequency and percentage or mean ± SD. Data were checked for outliers and for normality with histograms and tests of skewness and kurtosis for normality. Based on the results showing that the data adapted well to a normal distribution both for boys and girls, group differences in anthropometric variables, HR-pQCT, and DXA variables were assessed with the unpaired t test (two-sided). Given that puberty has a fundamental role for bone development and that the onset of puberty differ between boys and girls [24], the analyses were split by gender. Mann–Whitney U-test was used when comparing categorical variables from questionnaires and Fisher's Exact Test or unpaired t test was used for binary and continuous data. In order to adjust for covariates, linear regression analyses were conducted and the results presented as linear regression coefficients. Based on previous findings that children's assessment of

their pubic hair distribution is superior to their assessment of breast and genital development [25], Tanner pubic hair development was used as covariates in the linear regression analyses. Because the changes from one Tanner stage to the next may not be linear, we recoded the five Tanner stages into dummy variables. The sample size of the study was calculated to 19 in each group (38 girls and 38 boys) to be able to detect a 10% difference in tibia total volumetric bone mineral density, assuming a standard deviation of the difference between groups of 30 mg/cm^3 and with an alpha level of 0.05 and a statistical power of 80%. Analyses were performed with the Statistical Package for the Social Sciences (SPSS 16.0; IBM, Armonk, NY). All tests were two-sided; $p < 0.05$ was considered statistically significant.

Results

Descriptive characteristics, anthropometries, puberty, curricular physical activity, and exercise habits outside school

In total, 79 students in grades 5 and 6 were recruited for the study among whom 40 (19 girls and 21 boys) attended the intervention school and 39 (23 girls and 16 boys) attended the control school. The characteristics of the study cohort for boys and girls, as well as anthropometries and pubertal stage are presented in Table 1. In the between-group analysis there was no significant differences among girls or boys with respect to age, height, weight, BMI, or pubertal stage as measured by Tanner or reported menarche. In the intervention school three children (7.5%) did report having a foreign cultural background as compared with six children (15.4%) in the control group (p=0.7). No statistically significant differences were detected when comparing children in the intervention school with children in the control group. Therefore, the analyses were stratified by sex.

Variable	Girls			Boys		
	Intervention Group (n=19)	Controls (n=23)	P	Intervention Group (n=21)	Controls (n=16)	P
Age (years)	12.13 ± 0.60	12.16 ± 0.57	0.85	12.01 ± 0.53	12.22 ± 0.63	0.28
Height (cm)	152.6 ± 10.04	156.9 ± 6.80	0.11	152.7 ± 7.81	154.7 ± 6.51	0.42
Weight (kg)	46.42 ± 11.68	46.81 ± 10.19	0.91	41.99 ± 8.03	46.73 ± 7.02	0.07
BMI (kg/m2)	19.63 ± 2.83	18.89 ± 3.12	0.43	17.93 ± .71	19.51 ± 2.53	0.08
Tanner stage*			0.08			0.32
1	3 (15.8)	2 (8.7)		2 (9.5)	2 (12.5)	
2	9 (47.4)	6 (26.1)		11 (52.4)	5 (31.3)	
3	5 (26.3)	10 (43.5)		8 (38.1)	7 (43.8)	
4	2 (10.5)	4 (17.4)		0 (0.0)	2 (12.5)	
5	0 (0.0)	1 (4.3)		0 (0.0)	0 (0.0)	
Tanner stage**			0.46			0.99
1	7 (36.8)	7 (30.4)		6 (28.6)	6 (37.5)	
2	6 (31.6)	6 (26.1)		13 (61.9)	6 (37.5)	

3	4 (21.1)	6 (26.1)		0 (0.0)	4 (25.0)	
4	2 (10.5)	4 (17.4)		2 (9.5)	0 (0.0)	
5	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
Had reached menarche	5 (26.3)	6 (27.3)	1			
Dairy intake						
Drinks milk	18 (94.7)	17 (73.0)	0.11	20 (95.2)	14 (87.5)	0.57
Milk intake/day (dl)	3.6 ± 1.8	4.6 ± 2.4	0.68	5.3 ± 2.4	5.5 ± 3.1	0.88
Eats cheese	18 (47.4)	20 (52.6)	0.61	20 (95.2)	13 (81.3)	0.3
Cheese intake/day (slices)	1.9 ± 1.1	1.8 ± 1.6	0.66	2.2 ± 1.5	3.0 ± 3.2	0.77
Drinks yogurt or sour milk	17 (89.5)	17 (73.9)	0.26	19 (90.5)	15 (93.8)	1
Yogurt or sour milk intake/day (dl)	2.0 ± 1.2	2.4 ± 1.5	0.51	2.1 ± 1.2	2.1 ± 1.2	0.99

Values are presented as number (n) and percentage (%) for categorical variables. Continuous variables are presented as mean ± standard deviation. BMI, Body Mass Index. *Female breast and male genetalia, **Pubic hair distribution. Comparisons between the intervention group and controls for boys and girls separately for anthropometric variables and dairy intake were made with Fisher's Exact Test (binary data) or unpaired t test (two-sided). Comparisons between the intervention group and controls for boys and girls separately for Tanner stages were made with Mann–Whitney U-test. p-values<0.05 was considered significant.

Table 1: Cohort characteristics for the intervention group and controls stratified by sex.

Current and previous physical activity pattern was investigated and as expected, the intervention for both girls and boys increased the amount of curriculum-based physical activity (p<0.01 and p<0.01, respectively) (Table 2). There were no significant between-group differences among girls or boys with respect to current or previous exercise habits outside school, apart from the number of years, practicing a previous sport activity. More specifically, the number of years of participation in a previous organized sport activity (>1 year previously) was significantly higher among girls in the control school than among girls in the intervention school (p<0.01) (Table 2).

	Girls			Boys		
Variable	**Intervention Group (n=19)**	**Controls (n=23)**	**P**	**Intervention Group (n=21)**	**Controls (n=16)**	**P**
Curriculum-based physical activity			**<0.01**			**<0.01**
1 time/wk	0 (0.0)	1 (4.3)		0 (0.0)	1 (6.3)	
2 times/wk	4 (21.1)	21 (91.3)		2 (9.5)	13 (81.3)	
>3 times/wk	15 (78.9)	1 (4.3)		19 (90.5)	2 (12.5)	
Participated in organized sports activity the past 12 months, n (%)	17 (89.5)	21 (91.3)	0.62	21 (100.0)	15 (93.8)	1
Total amount of time of training/wk (hours)	3.8 ± 2.0	4.3 ± 2.7	0.61	5.2 ± 2.6	5.8 ± 1.9	0.46
Number of years participating in organized sport activity*	4.6 ± 2.6	4.6 ± 1.8	0.93	5.0 ± 2.3	5.6 ± 2.1	0.39
Participated in organized sports activity > one year ago, n (%)	9 (47.5)	14 (60.9)	0.54	9 (42.9)	7 (43.8)	1
Years of practicing the previous sports activity	1.9 ± 1.1	3.9 ± 1.8	**<0.01**	1.8 ± 1.1	2.1 ± 1.4	0.7

Results for categorical variables are presented as number (n) and percentage (%). Continuous variables are presented as mean ± standard deviation. Comparisons between the intervention group and controls for boys and girls separately for curriculum-based physical activity and leisure time physical activity were made with unpaired t test (two-sided) or Fisher's Exact Test (binary data). p-values<0.05 were considered significant and are presented in bold numbers. *) Ball game, dance, riding, hockey, gymnastics, martial arts, swimming, orientation, track and field, and figure skating.

Table 2: Time in physical education and leisure time physical activity outside school, stratified by sex.

Bone microarchitectural measurements

The analyses of between-group differences with respect to the HR-pQCT variables showed that girls in the intervention school had significantly higher total volumetric BMD (+15.1%; p<0.01), cortical thickness (+18.7%; p=0.01) and trabecular bone volume fraction (+11.5%; p=0.01), as compared with girls in the control school (Table 3). For the boys, the comparison between intervention and controls showed that the intervention boys had 11.9% (p=0.05) higher trabecular separation as well as -10.3% (p=0.04) lower total bone area (Table 3).

Linear regression analyses, using school affiliation as independent variable and bone microstructure as well as body composition as dependent variables, were used to adjust for potential confounders. When adjusting the linear regressions for age, height, weight, and tanner stage the intervention for girls was associated with a larger total bone area (Tt.Ar: ß=11.35, 95% CI: 1.46-21.25; p=0.03) and higher total volumetric bone mineral density (Tt.vBMD: ß=36.83, 95% CI: 16.31-57.35; p<0.01). The intervention was also associated with thicker cortical bone (Ct.Th: ß=0.16, 95% CI: 0.04-0.28; p<0.01) among girls.

For trabecular bone traits, the intervention was associated with higher trabecular bone volume fraction (BV/TV: ß=1.62, 95% CI: 0.49-2.76; p<0.01) but could not be explained by any of the other trabecular bone traits (Table 4). For the boys, the intervention was associated with lower total volumetric bone mineral density (Tt.vBMD: ß=-25.30, 95% CI: -46.97--3.63; p=0.02) but no other bone traits after adjustment for confounders (Table 4).

Dual-energy X-ray absorptiometry (DXA)

The analyses of group differences for DXA variables showed that boys in the intervention group had significantly lower whole-body fat mass (-22.7%; p=0.04) and fat mass at the leg (-28.6%; p=0.01) as compared with boys in the control school (Table 3). In addition, boys in the intervention group had lower abdominal fat mass, although this association did not reach statistical significance (-27.0%; p=0.17). In linear regression models adjusted for age, height, weight, and Tanner stage only the association for fat mass at the leg remained significant (Table 4). There were no significant differences for DXA variables when comparing intervention girls with controls (Table 3).

Variable	Girls			Boys		
	Intervention Group (n=19)	Controls (n=22)	p	Intervention Group (n=21)	Controls (n=16)	p
HR-pQCT						
Tt.Ar (mm^2)	95.65 ± 20.91	84.31 ± 19.06	0.07	87.18 ± 13.06	97.18 ± 15.61	**0.041**
Tt.vBMD (mg/cm^3)	295.1 ± 38.9	256.4 ± 27.3	**<0.01**	263.4 ± 24.6	283.4 ± 37.3	0.057
Ct.vBMD (mg/cm^3)	777.0 ± 41.4	754.7 ± 37.9	0.08	731.4 ± 32.4	751.2 ± 25.6	0.052
Ct.Th (mm)	1.08 ± 0.22	0.91 ± 0.20	**0.01**	0.91 ± 0.13	1.02 ± 0.19	0.059
BV/TV (%)	14.97 ± 1.91	13.43 ± 1.42	**0.01**	14.62 ± 2.13	15.61 ± 1.85	0.148
Tb.N (mm^{-1})	1.86 ± 0.26	1.77 ± 0.21	0.21	1.84 ±0.27	2.00 ± 0.17	0.056
Tb.Th (mm)	0.08 ± 0.01	0.08 ± 0.01	0.22	0.08 ± 0.01	0.08 ± 0.01	0.645
Tb.Sp (mm)	0.47 ± 0.78	0.50 ± 0.06	0.18	0.47 ± 0.07	0.42 ± 0.04	**0.048**
DXA						
BMD (g/cm^2)	0.99 ± 0.09	0.97 ± 0.07	0.57	0.98 ± 0.06	1.01 ± 0.06	0.16
BMC (g)	1715 ± 484	1751 ± 335	0.79	1626 ± 263	1763 ± 241	0.11
Whole-body lean mass (g)	31848 ± 6267	32151 ± 4353	0.85	32142 ± 4619	32956 ± 3848	0.57
Whole-body fat (%)	28.64 ± 5.15	28.0 ± 8.7	0.77	20.67 ± 8.18	26.73 ± 9.00	**0.04**
Abdominal fat (g)	935.2 ± 471.98	886.8 ± 616.3	0.78	583.6 ± 493.5	799.4 ± 413.3	0.17
Fat mass leg (g)	2778 ± 1012	2790 ± 1087	0.97	1829 ± 789	2562 ± 932	**0.01**

Results are presented as mean ± standard deviation. Comparisons between the intervention group and controls for boys and girls separately were made with unpaired t test (two-sided). HR-pQCT: High-Resolution Peripheral Quantitative Computed Tomography; Tt.Ar: Total Bone Area; Tt.vBMD: Total Volumetric Bone Mineral Density; Ct.vBMD: cortical Volumetric Bone Mineral Density; Ct.Th: Cortical Thickness; BV/TV: Trabecular Bone Volume Fraction; Tb.N: Trabecular Number; Tb.Th: Trabecular Thickness; Tb.Sp: Trabecular Separation; DXA: Dual-Energy X-Ray Absorptiometry; BMD: Bone Mineral Density; BMC: Bone Mineral Content.

p-values<0.05 were considered significant and are presented in bold numbers.

Table 3: HR-pQCT and DXA measures in the intervention group versus controls, stratified by sex.

Variable	Girls (n=42)			Boys (n=37)		
	β	95% CI	p	β	95% CI	P
HR-pQCT						
Tt.Ar (mm^2)	11.35	1.46-21.25	**0.03**	-7.07	-135.4-108.7	0.15
Tt.vBMD (mg/cm^3)	36.83	16.31-57.35	**<0.01**	-25.3	-46.97--3.63	**0.02**
Ct.vBMD (mg/cm^3)	20.71	-3.85-45.26	0.10	-19.74	-40.64-1.17	0.06
Ct.Th (mm)	0.16	0.04-0.28	**0.01**	-0.1	-0.22-0.02	0.09
BV/TV (%)	1.62	0.49-2.76	**<0.01**	-1.29	-2.75-0.18	0.08
Tb.N (mm^{-1})	0.04	-0.11-0.20	0.56	-0.1	-0.27-0.06	0.22
Tb.Th (mm)	0.01	0.00-0.01	0.06	0	-0.01-0.00	0.46
Tb.Sp (mm)	-0.02	-0.06-0.03	0.51	0.04	-0.01-0.08	0.10
DXA						
BMD (g/cm^2)	0.02	-0.01-0.05	0.17	-0.02	-0.05-0.02	0.40
BMC (g)	21.7	-71.09-114.49	0.60	-27.69	-117.9-62.6	0.54
Whole-body lean mass	1036	-222-2294	0.10	1037	-109-2183	0.07
Whole-body fat (%)	-1.31	-4.26-1.64	0.37	-2.2	-4.80-0.38	0.09
Abdominal fat (g)	-80.44	-205.23-44.34	0.20	21.44	-93.70-136.6	0.71
Fat mass leg (g)	-109.72	-358-140	0.38	-263.9	-490--38	**0.02**

Linear regression models were adjusted for age, height, weight, and Tanner stage. Presented in the table are the linear regression coefficient (β) dependent on unit with corresponding 95% confidence interval (CI) and p-value.

HR-pQCT: High-Resolution Peripheral Quantitative Computed Tomography; Tt.Ar: Total Bone Area; Tt.vBMD: Total Volumetric Bone Mineral Density; Ct.vBMD, Cortical Volumetric BMD; Ct.Th: Cortical Thickness; BV/TV, Trabecular Bone Volume Fraction; Tb.N: Trabecular Number; Tb.Th: Trabecular Thickness; Tb.Sp: Trabecular Separation; DXA, Dual-Energy X-Ray absorptiometry; BMC, bone mineral content; BMD, bone mineral density. p-values<0.05 were considered significant and are presented in bold numbers.

Table 4: Adjusted linear regressions, stratified by sex, for the association between school affiliation and DXA as well as HR-pQCT-derived variables.

Discussion

The "School-in-Motion" intervention program that was mandatory for all children beginning in the pre-school class was significantly associated with higher total volumetric BMD, cortical thickness, and trabecular bone volume fraction among girls 5 to 6 years later. These findings were also valid after adjustment for potential confounders, such as puberty and body size. Although the intervention did not show any positive associations for bone parameters in boys, they did however, show gains in body composition with lower whole body fat as well as a non-significant reduction in abdominal fat in comparison to controls.

This is the first study to investigate potential associations in improved bone microstructure and body composition using a Swedish governmental investment that sought to increase physical activity levels among school-aged children through cooperation between schools and sports clubs. The novel aspects of this study included the non-competitive and joyful character of the physical activity intervention implemented through a cooperation with local sports clubs, that made it possible to engage all children, not only those who were fond of exercise. As argued in a previous similar study [26],

children with a low physical activity level and lack of interest in exercise in general, may perhaps benefit the most from interventions as the present one, since the increase in the physical activity level were most likely greater in these children, as compared with more physically active children. In contrast to the majority of previous intervention studies lasting less than three months [27], the curricular-based intervention in the present study is a long-term intervention, that was mandatory for all children from preschool class.

Previous prospective studies have demonstrated that physical activity implemented within the school curriculum has positive effects on bone health in prepubertal girls [28-31,14]. The intervention schools had 1.5–29% greater bone mineral accrual (at lumbar spine and femoral neck) as compared with girls in the control groups [28-31]. Also, a recent systematic review conclude that exercise interventions during childhood led to 0.6% to 1.7% greater annual increase in BMD (total body, femoral neck, and spine), as measures by DXA, with effects predominantly among children who were prepubertal [32]. Interventions have been somewhat more inconclusive regarding boys, potentially explained by their in general higher level of activity compared to girls. Despite the length of the physical

intervention in the present study there were no group differences in terms of DXA bone variables. As previously suggested, effect of physical activity on DXA-derived bone variables might demand more osteogenic activities (e.g., jumping) [26] than incorporated in this long-term intervention. However, physical activity within the school curriculum was associated with reduced fat mass in boys but not girls. These results are in line with a previous meta-analysis concluding that evidence for the effectiveness of school-based physical activity interventions on fitness and adiposity remain inconclusive [33].

The two dimensional measurement captured with DXA is a very good clinical tool. However, with no ability to separate trabecular from cortical bone it misses potential structural differences. Prior studies have shown that physical activity among young individuals has a beneficial effect on bone geometry and microstructure [34,35]. These studies have investigated the effect of physical activity by the use of two well-validated methods; either questionnaire [35] or by wearing accelerometer for seven days [34]. The studies were however not able to investigate the effect over long time. Long-term effects on bone geometry were elucidated in a intervention study, where two weekly sessions of specialized-led PE over 4 years of primary school resulted in greater increases in mid-shaft tibial cortical area in girls and cortical thickness in boys compared to children undertaking usual practice PE [14]. Within the present study, the associations of long-term curriculum-based physical activity on bone geometry and microstructure was investigated. The study results indicate beneficial associations of curriculum-based physical activity on bone geometry for girls but not boys. The discrepancy in long-term results for cortical bone measurements in boys may be due to measuring at two different sites at the tibia with large differencies in the amount of cortical bone present.

Prior findings within the same cohort indicate that the girls seem to benefit from the intervention more than boys with respect to academic achievement and psychological health [18]. These findings may be a result of the intervention boys being more active in general, as compared with the girls. An already high degree of physical activity and participation in sports most likely diminish the observed differences of the physical activity intervention. As mentioned in the previous study by Hasselstrom et al. [26], this reasoning is supported by previous findings [36,37]. The relative change in the physical activity level would thus be lower among boys, as compared with girls as a result of an curriculum-based intervention [26]. The higher degree of physical activity within boys participating in the intervention group was also reflected by a large difference in body weight. Although not significant, the difference in body weight between intervention boys and controls is noteworthy (41.99 ± 8.03 *vs.* 46.73 ± 7.02; p=0.07), since body weight and BMI are well-described determinants of bone mass [38,39]. The observed higher weight, mainly driven by more fat, leading to an increased skeletal loading among boys in the control group may have been a major contributor to their development in bone dimension and density and could be the reason for eliminated differences of the intervention in boys.

An important strength of the current study is its controlled design, which increases the validity of the association between physical activity level and bone health parameters. Our results should however be considered in light of several methodological limitations. As in most previous studies, one limitation pertains to the quasi-experimental design of the study as well as the small sample size. Due to a limited sample size and the risk of over fitting the regression models, the number of confounders used were limited, but still might over exceed the number of confounders usually recommended [40]. Although associations were established between performed intervention and bone traits, the used study design did not enable us to look at causality. Certain study designs are much less vulnerable to selection bias than others. A randomized design would have significantly reduced the risks of systematic differences between intervention subjects and controls, other than whether they participated in the program. However, in our study, it was simply not possible to allocate the children to one school or the other. Nor was it possible to randomize within the intervention school, as children had participated in the intervention program since their pre-school class i.e., several years prior to inclusion in the present study. Measuring changes over time would have allowed more powerful hypothesis testing. However, since the physical activity intervention was scheduled and mandatory for all children beginning in the pre-school class, we had a unique opportunity to investigate the association between a long-term curriculum-based intervention program and bone health. Therefore, we chose a controlled quasi-experimental design, taking into account socio-economic characteristics in the selection of the control group. In defining the amount of physical activity or exercise, an important component is the total dose of activity and the intensity at which it is performed [41]. Our study, is therefore limited by the lack of objective measurement of intervention intensity. Further longitudinal controlled studies with a randomized design are warranted to confirm and clarify the promise of physical activity to improve children's bone health and potentially decrease the number of fractures in young and old age.

Conclusion

Our results show that providing opportunities and motivation for young people to be physically active during the school day may be beneficial for girls in terms of future bone health. Co-operation between schools and local sports clubs might be a successful approach. However, further studies in similar school environments are needed to validate or findings.

Author Contributions

Made substantial contributions to conception and design, acquisition of data, or analyses and interpretation of data: LBK and DS. Participated in drafting the manuscript or revising it critically for important intellectual content: LBK and DS. Approved the final version of the submitted manuscript: LBK and DS. The following authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: LBK and DS.

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