Physical Activity, Bone Mass and Bone Structure in Pre-pubertal Children

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Abstract

Physical activity (PA) has been described as one of the best strategies to optimize skeletal development during growth. In this study, at baseline 81 boys and 53 girls aged 7–9 years were included in a curriculum-based exercise intervention program comprising 40 minutes of PA per school day. Age and gender-matched 57 boys and 50 girls, assigned to the general Swedish school curriculum of 60 minutes PA per week, served as controls. Both boys and girls in the intervention group had significantly higher accrual of bone mineral content and larger gain in bone size in the lumbar vertebrae. No exercise-induced bone mineral accrual or structural changes were observed at the femoral neck. The PA measured by accelerometers was high so that all children reached the international recommended level of 60 minutes of moderate to vigorous PA per day. Children who participated in the exercise intervention groups were reported to experience more of the highest intensities of physical activities. This study has identified that a school-based exercise intervention program in pre-pubertal children enhances the skeletal benefits at the lumbar spine but not bone mineral accrual or structural changes at the femoral neck.

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Introduction

Low bone mineral density (BMD) is a risk factor for fragility fractures and much of the fracture preventive effort today is devoted to preventing low BMD. The peak bone mass (PBM) is also to be considered as an important determinant of bone strength and fracture prevention in old age because around 50% of bone mass at the age of 70 years is estimated to be predicted by PBM (1, 2). Theoretical analyses estimate that a 10% increase in PBM could delay the development of osteoporosis by 13 years (3). Physical activity (PA) has been described as one of the lifestyle factors that could optimize gain in bone mass and bone strength during growth. During childhood and adolescence, both high-intensity and moderate-intensity PA increases PBM and bone structure (4, 5). The pre- and early peri-pubertal period, a period with fast skeletal growth, is usually considered as the best opportunity to enhance skeletal strength by exercise (6).

The specific effects of PA on bone health have been investigated in numerous cross-sectional studies, prospective observational studies, prospective controlled intervention and prospective randomized controlled trials (RCT). Reports suggest that resistance and high-impact exercise is the type of training that confers the most obvious benefits during these ages (7). However, most of the studies have included volunteers and used specifically designed high-impact PA programs, such as jumping down from a height, and organized sports activities (8-11). One problem with such monotonic programs is the high dropout frequency (12). Exercise interventions have also evaluated whether school-based physical education (PE) classes that use a variety of physical activities, jumping activities or circuit training, influence bone mass and the femoral neck (FN) structure using hip structural analysis (HSA) (13-15).

The current knowledge in this thesis is whether moderately intense exercise intervention programs could improve bone mass and bone structure (16). PA could possibly be used as a prevention strategy against low bone mass and low bone structure because studies have shown that exercise-induced skeletal benefits during growth and young adulthood persist into adulthood, assisting in fracture reduction (17).

Based on the consistency of literature, PA during growth has been described as one of the best strategies to optimize skeletal development during growth. However, most exercise intervention studies in children have involved the use of volunteers and specifically designed high impact exercise programs. Therefore, this study aimed to evaluate whether a general school-curriculum-based, moderately intense exercise intervention program and the mode of transportation to school could influence bone mass and bone structure in a group of pre pubertal children.

Study design and Methodology

The study subjects were recruited from first two years' evaluations of the Paediatric Osteoporosis Prevention (POP) cohort. The POP Study, in Sweden, is a prospective controlled exercise intervention study in school children that annually assesses musculoskeletal development in school children. Four neighboring schools that were government-funded and located in the same socioeconomic background were invited to the study. One school was invited to participate as the intervention school and the other three schools served as control schools. In the intervention school, the normal mean Swedish curriculum of 60 minutes per week was increased to 40 minutes per day (200 minutes per week). Children from the control schools were also assigned to similar activities as performed in the intervention school, but limited to the mean duration of PE classes in Swedish school, one or two sessions per week or mean 60 minutes per week. The physical educational curriculum in Swedish schools includes PE classes with a variety of activities, such as ball games, running, jumping and climbing. The intervention was deliberately designed not to be a specific osteogenic exercise program. The physical educational classes were conducted under supervision by the ordinary class teacher, typical of PE classes in Swedish schools. The studies were approved by the Ethics Committee of Lund University and the Radiographic Committee at Malmo University Hospital, Malmo, Sweden. Also, the studies were conducted according to the Helsinki Declaration and informed written consent was obtained from parents or guardians of participants prior to the commencement of the study.

Anthropometric measurements

Body weight was measured with an electric scale to the nearest 0.1 kg and body height by a wall-tapered height meter to the nearest 0.5 cm. The children were measured in light clothes in sock soles. BMI; kg/m^2 was calculated as weight in kilograms divided by height in meters squared. The TB fat mass and TB lean mass was measured by a DXA TB scan (DXA, DPX-L version 1.3z, Lunar®, Madison, WI).

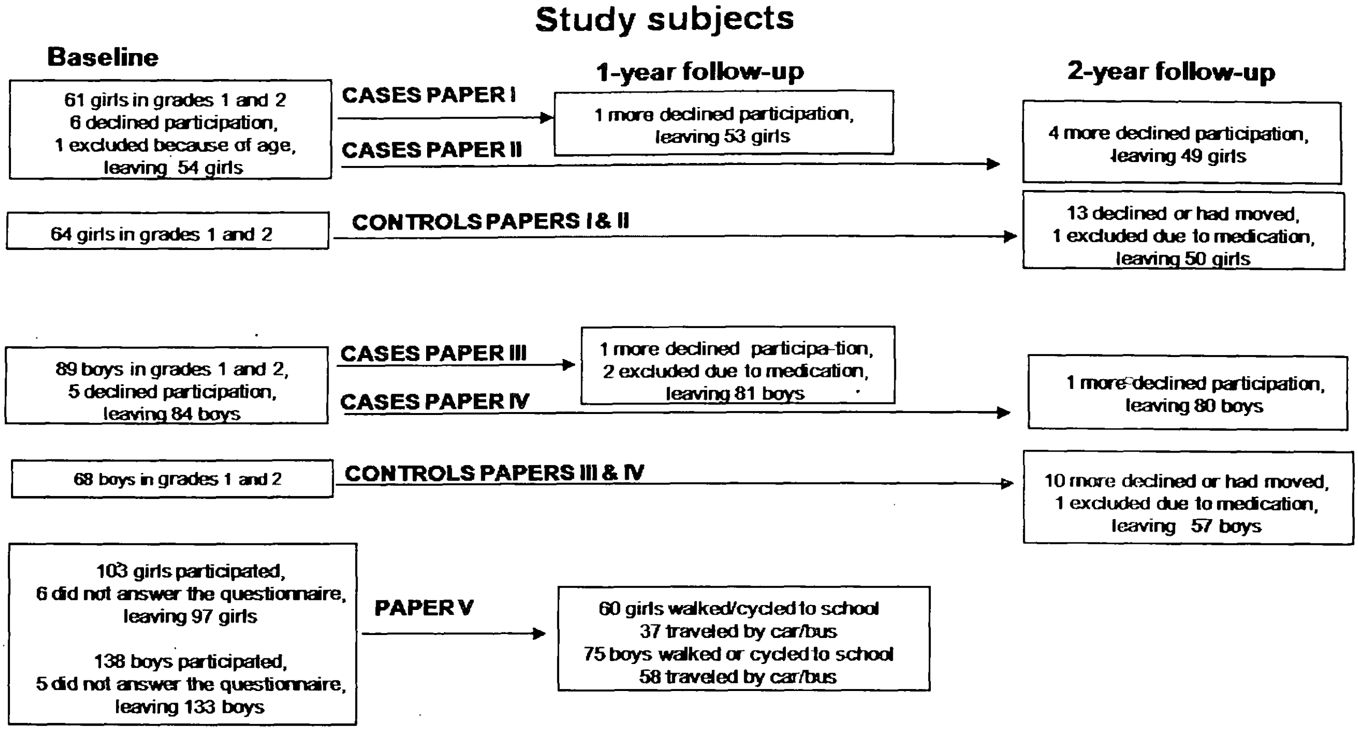
Dual energy X-ray absorptiometry (DXA)

DXA (DXA, DPX-L version 1.3z, Lunar®, Madison, WI) was used to assess development in the children. During the measurements the children were dressed in light clothes and no shoes. *Paediatric software was used in children below 35 kg in weight. Bone mineral content* (BMC) and areal bone mineral density (aBMD) were evaluated for the total body (TB), the LS (L2–L4 vertebrae), third lumbar vertebra (L3) and FN. The width of the L3 was estimated from the LS scans and the width of the FN was estimated from the hip scans. DXA is the most commonly available bone densitometry technique and considered the gold standard in the measurement of BMC and BMD. BMC is expressed in grams. BMD (g/cm^2) is calculated by dividing the total amount of bone mineral by the projected bone area. The high precision, the non invasive short scan time and the low radiation dose which is less than the daily dose of radiation from the natural background radiation are the advantages of the DXA technique (18). However, DXA measurements do not estimate the material composition or the structure of the bone, which is a disadvantage because it is well known that bone material composition, bone geometry and bone micro-architecture are also important for bone strength. One field that has gained interest during the last few years is the DXA based hip geometry, specific software-- the hip structural analysis (HSA), where the three-dimensional structure of the hip is estimated from the two-dimensional hip DXA scan (19). **Cross-sectional moment of inertia** (CSMI, cm^4) is derived from the integral of the bone mass profile across the minimum bone cross-section together with its center of mass. CSMI estimates the ability of FN to withstand bending forces and is calculated using the mass of the absorptive curve (20).

Hip structural analysis (HSA)

Hip structure has been evaluated by the DXA-derived HSA software provided by Lunar Instruments Corporation (Madison, WI). All standard image files of the proximal femur were analyzed by one technician, using the HSA software. Using this software the X-ray absorption data of the proximal femur is extracted from the output image data file and the BMC, aBMD and its distribution within the FN calculated. First the operator has to manually define the center of the femoral head and place the FN axis as accurately as possible along the FN. Thereafter, the region of interest in the FN is placed in the proximal part of the FN, and finally the femoral shaft axis is defined centrally along the shaft.

flow of study subjects through the study



software will then iteratively assess all cross-sections in the femoral neck region of interest (FN ROI) and identify the plane with the least CSMI. The CSMI estimated by DXA has been found to be highly correlated with the CSMI measured directly on adult cadaver specimens ($r^2 = 0.96$) (20). Automatic identification of the weakest cross-section of the FN is a fundamental feature of the HSA software, and this cross-sectional level is then used for subsequent calculation of Z and CSA. The Z is computed as CSMI divided by half the width of the FN. The endosteal diameter was estimated using the algorithm described by Thomas J. Beck (21). Mean cortical thickness was calculated as the difference between the periosteal and the endosteal diameter divided by two.

Objective assessment of physical activity

Subjective level of PA and lifestyle factors were assessed using an interviewer administered questionnaire. Because of the difficulties in subjectively assessing the level of PA in children, accelerometers have been increasingly used for objective measurements of PA in children (22). Objective assessment of PA by accelerometers provide valid and reliable measures of intensity, frequency, duration and total amount of PA

Technology Incorporated, Fort Walton Beach, FL, USA) accelerometer, model 7164. The accelerometer measurements were performed for four consecutive days at the two-year follow-up evaluation. Accelerometer data are averaged over a period called an epoch. A recording epoch of ten seconds was selected for this study. SAS-based software (SAS Institute Inc, Cary, NC, USA) was used to analyze all accelerometer data. This software automatically deletes missing data, defined as continuous sequences of 60 consecutive epochs (i.e. 10 minutes) or more with zero counts. In order to minimize inter-instrumental variation, all accelerometers were calibrated against a standardized vertical movement. Mean activity was considered to be the total accelerometer counts per valid minute of monitoring (mean counts/min; cpm). Age- and body-mass-specific cut-off points exist for accelerometer counts representing activity of varying intensities, and these cut-off points made it possible to roughly estimate the number of minutes the child was engaged in activity above a specific intensity threshold. Time spent performing above three Metabolic Equivalents (METs) was considered to reflect moderate-to-vigorous physical activity (MVPA), and time spent above six METs was considered to reflect vigorous physical activity (VPA). Cut-off points used for all children were >167 counts/epoch for MVPA and >583 counts/epoch for VPA (25). As both animal and human studies suggest that a mechanical load inserted with a high load, a fast load and for the skeletal an unusual load confers the highest anabolic skeletal response (7, 26). we also wanted to compare the duration of the most intense activities between the groups. For this reason we also report the duration of activities >1000 counts/10-second epoch or >6000 counts per minutes per day and > 1667 counts/10-second epoch or >10,000 counts per minute per day (27, 28).

Results

At baseline, the two groups did not differ with regard to lifestyle factors, age, anthropometrics or bone parameters. When compared the annual changes, both boys and girls in the intervention group had significantly higher accrual of BMC and larger gain in bone size in the lumbar vertebrae. No between-group differences were observed for annual changes in the FN bone mineral accrual or hip structural changes measured. The positive effects in the lumbar spine were less in absolute values in the boys than in the girls (Table1-3).

Total duration of PA estimated by questionnaire was higher in the intervention group than in the control group. In contrast, at follow-up, there was no difference in the total amount of daily activity measured by accelerometers, while the intervention group was presented with a higher proportion of the most intense activities, above 10,000 cpm (counts per minute). No differences were reported in activity level when comparing children who walked or cycled to school with those who went by car or bus. The PA measured by accelerometers was high such that all children reached the international recommended level of 60 minutes of moderate to vigorous PA per day (Table 4-5).

Discussion

This study evaluates a prospective controlled school-based PE intervention program in pre-pubertal children aged 7 to 9 years at baseline. The study reports that the intervention was not associated with improved accrual of bone mineral or beneficial structural changes at FN during the first two years when the inferences were drawn based on measurements with the DXA-derived HSA analyses (27-29). In contrast, the exercise intervention was associated with a significant positive influence in the accrual of bone mineral in L2-L4 and gain in bone size in the L3 in both girls and boys during the one- and two-year period. (27, 30-32). The positive effects in LS in the boys were less in both absolute and relative values when compared with the changes in the girls. Why there was an exercise-induced effect in LS but not in FN and why the benefits were more obvious in girls is not clear. The proportion of trabecular bone varies from being about 25% in the distal radius and femoral neck to 66–75% in the vertebral body (33).The larger proportion of trabecular bone in a lumbar vertebral body than in FN could partly explain the discrepancy, as skeletal response to mechanical load is more often seen in trabecular than cortical regions due to the larger surface-to-volume ratio in trabecular bone.

The children were on a high level of habitual PA as observed by the accelerometer data, that all children, both girls and boys, reached the international recommended level of PA per day (34). Thus, if the children were already physically active, the amount of additional school-based training contributed proportionately less to the total amount of PA than in cohorts with sedentary children (35). The extra amount of exercise gained by the intervention could be enough to lead to benefits in a predominantly trabecular region, such as LS, but not in FN.

Differences between boys and girls in the level of PA could also explain the more obvious effects in the girls. As the boys generally had a higher level of activity than the girls, the intervention in the girls contributed proportionally more to the total amount of PA than in the boys (27, 31). Girls with the same chronological age as boys are generally closer to puberty than boys and the changes in bone mineral accrual and bone size in the lumbar spine is more obvious in girls than the boys (36). Because of the earlier onset of puberty, girls reach peak BMC velocity roughly 1.5 years earlier than boys (6). Thus, the observation that LS bone mass increases initially more in girls than in boys of the same chronological age is consistent with the literature (36, 37).

The HSA is another technique trying to assess hip geometry, but exercise intervention studies have so far reported conflicting results. Some studies have reported that everyday PA during growth predicts hip structure (38, 39), while other trials have opposed this view (40).

The discrepancies in the conclusions when comparing the trials could be based on differences in the study designs. The maturational level and gender of the children was different in the cited trials, and it is known that exercise-induced skeletal benefits are easiest to reach in the early pubertal period. Because of the study

Table 1 Annual changes boys 1 year follow-up

	Cases (N=81)	Controls (N=57)	P-value
Height (cm)	5.6 ± 1.1	5.7 ± 0.6	0.45
Weight (kg)	3.2 ± 1.8	3.3 ± 1.2	0.75
Lean mass (kg)	2.2 ± 0.6	2.1 ± 0.4	0.38
Fat mass (kg)	1.3 ± 1.5	1.0 ± 0.9	0.14
Lumbar spine	**Cases (N=76)**	**Controls (N=51)**	
L3 BMC (g)	0.87 ± 0.55	0.58 ± 0.26	**0.0007**
L3 BMD (g/cm^2)	0.041 ± 0.036	0.027 ± 0.015	**0.01**
L3 vBMD (g/cm^3)	0.003 ± 0.017	0.002 ± 0.007	0.82
L3 width (cm)	0.14 ± 0.14	0.07 ± 0.07	**0.0010**
L2L4 BMC (g)	2.46 ± 1.20	1.94 ± 0.51	**0.004**
L2L4 BMD (g/cm^2)	0.041 ± 0.024	0.028 ± 0.011	**0.0005**
Femoral neck	**Cases (N=74)**	**Controls (N=48)**	
width (cm)	0.10 ± 0.16	0.09 ± 0.08	0.80
CSMI (cm^4)	0.081 ± 0.119	0.082 ± 0.046	0.95
BMD (g/cm^2)	0.036 ± 0.07	0.037 ± 0.03	0.92
BMC (g)	0.211 ± 0.42	0.292 ± 0.19	0.21
CSA (cm^2)	0.098 ± 0.13	0.093 ± 0.06	0.81
Section modulus (cm^3)	0.051 ± 0.07	0.051 ± 0.03	0.99
Endosteal diameter (cm)	0.09 ± 0.16	0.08 ± 0.08	0.83

Values are mean ± SD

Table 2 **Annual changes boys at 2 year follow-up**

	Cases (N=80)	Controls (N=57)	P-value
Height (cm)	5.6 ± 0.7	5.7 ± 0.6	0.19
Weight (kg)	3.4 ± 1.6	3.3 ± 1.2	0.57
Lean mass (kg)	2.2 ± 0.5	2.1 ± 0.4	0.92
Fat mass (kg)	1.3 ± 1.4	1.0 ± 0.9	0.10
Lumbar spine	**Cases (N=76)**	**Controls (N=51)**	
L3 BMC (g)	0.72 ± 0.30	0.58 ± 0.26	**0.009**
L3 BMD (g/cm^2)	0.031 ± 0.02	0.027 ± 0.02	0.30
L3 vBMD (g/cm^3)	0.001 ± 0.010	0.002 ± 0.007	0.46
L3 width (cm)	0.11 ± 0.06	0.07 ± 0.07	**0.0015**
L2L4 BMC (g)	2.06 ± 0.76	1.94 ± 0.51	0.30
L2L4 BMD (g/cm^2)	0.030 ± 0.015	0.028 ± 0.011	0.37
Femoral neck	**Cases (N=73)**	**Controls (N=48)**	
Neck width (cm)	0.108 ±0.084	0.098± 0.060	0.49
CSMI (cm^4)	0.078 ± 0.067	0.082 ± 0.046	0.70
BMD (g/cm^2)	0.025 ± 0.038	0.037 ± 0.032	0.06
BMC (g)	0.231 ± 0.213	0.281 ± 0.205	0.20
CSA (cm^2)	0.080 ± 0.079	0.093 ± 0.060	0.31
>6000 counts/min (min/day)	0.044 ±0.040	0.50 ± 0.027	0.39
>10000 counts/min (min/day)	0.103 ± 0.81	0.090 ± 0.057	0.35

Values are mean ± SD

Table 3 Annual changes girls at 1 year follow-up

	Cases (N=53)	Controls (N=50)	P-value
Weight (kg)	3.5 ±2.2	3.2 ± 1.3	0.42
Height (cm)	6 ± 1.2	5.7 ± 0.96	0.19
Lean mass (kg)	2.2 ± 0.75	1.9 ± 0.56	**0.01**
Fat mass (kg)	1.9 ± 1.5	1 ± 0.86	**<0.001**
Lumbar spine	**Cases (N=50)**	**Controls (N=48)**	
L3 BMC (g)	0.91 ± 0.61	0.54 ± 0.24	**<0.001**
L3 BMD (g/cm^2)	0.047 ± 0.035	0.024 ± 0.014	**<0.001**
L3 vBMD (g/cm^3)	0.004 ± 0.015	0.001 ± 0.007	0.22
L3 width (cm)	0.16 ± 0.10	0.09 ± 0.05	**<0.001**
L2L4 BMC (g)	2.35 ± 1.13	1.77 ± 0.55	**0.0019**
L2L4 BMD (g/cm^2)	0.042 ±0.026	0.026 ± 0.01	**<0.001**
Femoral neck	**Cases (N=42)**	**Controls (N=43)**	
width (cm)	0.086 ± 0.247	0.067 ± 0.113	0.64
CSMI cm^4)	0.069 ± 0.167	0.074 ± 0.067	0.86
CSA (cm^2)	0.084 ± 0.180	0.091 ± 0.078	0.82
Section modulus (cm^3)	0.044 ± 0.088	0.049 ± 0.042	0.73
Endostealdiameter	0.078 ± 0.240	0.057 ± 0.114	0.59
Mean Cortical thickness	0.004 ± 0.008	0.005 ± 0.005	0.44

Values are mean ± SD

Table 4 Physical activity in boys evaluated by accelerometers

At 2 year follow-up in boys	Intervention (N=72)	Controls (N=55)
Recording time (hrs/day)	12 (1)	13(1)
Mean activity (counts/min)	770 (267)	728 (211)
>3METs (min/day)	211(55)	209 (45)
>6 METS (min/day)	44 (21)	48 (19)
>6000 counts/min (min/day)	16 (10)	15 (9)
>10000counts/min (min/day)	4 (3), p=0.01	2 (3)

Values are mean ± SD

Table 5 Physical activity in girls evaluated by accelerometers

At 2-year follow-up	Intervention (N=41)	Controls (N=40)
Recording time (hrs/day)	12 (1)	12 (1)
Mean activity (counts/min)	644 (184)	590 (115)
>3 METS (min/day)	194 (45)	185 (35)
>6 METS (min/day)	34 (15)	35 (12)
>6000 counts/min (min/day)	13 (8)	11(6)
>10000 counts/min (min/day)	3(3), p<0.001	1(1)

Values are mean ±SD

design, this study cannot rule out that a more intense training program or a program spanning a longer period could lead to structural and bone mineral benefits also in FN. *For* example, soccer training for three years in pre-pubertal boys has been associated with obvious bone mass benefits also in FN (35). To report that high-intensity osteogenic programs in volunteers are associated with skeletal benefits does not increase our knowledge. Instead this study was designed to evaluate whether a general school-based PE intervention program on a population-based level, also including children with little or no interest in sports, could be used as a preventive strategy against low bone strength. Furthermore, we wanted to evaluate an intervention at a level so that all children could participate.

One cross-sectional publication has reported that a higher level of daily PA is associated with beneficial structural changes in the hip evaluated by the HSA software in pre-pubertal children at a mean age of 5.2 years (38). Two observational studies with 6 and 7 years of follow-up in children and adolescents support the view that higher level of PA is associated with the higher CSA and Z of the FN compared to less active peers (39, 41). One randomized school-based jumping intervention program, including three sessions of ten minutes per week over seven months, reported that there were no beneficial effects found in the gain in hip structure in 43 pre-pubertal girls in the training group in comparison with 25 matched girls in the control group. In contrast, in 43 early pubertal girls in the same study, the gain in FN BMD was 2.6% and gain in Z 4.0% larger, with a p value < 0.05, in intervention girls in comparison to the gain in 63 early pubertal girls without this intervention program (13). Another randomized prospective controlled trial evaluating a school-based exercise intervention program followed during 20 months, with the intervention consisting of circuit training given for 12 minutes, three times a week in pre-pubertal boys, reported that the 31 boys in the intervention group had increased FN BMC 4.3% more (p <0.01) and Z 7.5% more (p <0.05), than the 33 boys in the control group (42). The differences in gender, follow-up period and maturational status may influence the conclusions in these two papers.

DXA-derived BMD is a measure that estimates the amount of bone mineral in a three-dimensional bone structure but projected on a two-dimensional area of the bone. Because the third dimension of the bone, the depth, cannot be estimated by DXA, BMD is also often called areal BMD (aBMD; g/cm^2), which includes the total amount of bone mineral within the scanned area (43). This is one problem when trying to estimate the accrual of bone mineral in a skeleton that changes in size, as in growing children (43). The large individual variation in changes in bone size and body composition (fat mass and lean body mass) that occur during growth can also obscure results when prospectively following growing children (44). The total amount of soft tissue, the distribution of fat mass and the ratio between the fat and the lean mass are also important when estimating the actual BMD level. It is known that differences in fat in the bone marrow or the soft tissue above, below or around the bones may affect the DXA bone variables (45, 46). Thus, the changes in lean tissue and fat content during the study period could also influence the estimated level of BMC. The finding of higher fat mass in control group in the present study contradicts other studies in pre-pubertal boys that report participation in sport to be associated with reduced fat mass and improved gain in lean mass (46).

DXA scanners were designed to measure bone density, not the structure of a bone, so poor spatial resolution complicates the detection of bone dimensions (19). Inconsistent positioning of the limb, especially in anteversion of the hip or inaccurate placement of the ROI, may also result in a measurement error (47). This especially accounts for prospective studies when individual changes are followed by repeated scans in the same individual. The DXA-derived HSA is a two-dimensional technique that is transferred to a three-dimensional assessment of the bone. For example, CSMI measured in a single plane of a DXA-projected area does not represent the bending strength of whole bone because it measures CSMI in one direction only (19). Even a smaller error in this estimate will lead to a greater error as CSMI is proportional to the fourth power of the radius of the femoral neck (16). The two-dimensional estimation of the periosteal dimension also gives rise to problems, as the skeleton can respond to mechanical load by expansion in different directions (9) and may be not captured by the HSA analyses. The calculated CSMI value, derived from a single slice in one plane, may then not reflect the true CSMI. The bending strength of FN would therefore be inaccurately estimated. The cortical thickness and the endosteal diameter are estimated after making assumptions of a homogenous porosity in the cortical shell, a homogenous cross-sectional shape that assumes FN to be cylindrical, not elliptical (21).

In spite of these limitations, HSA should be regarded as one method to focus interest not only on the amount of bone mineral but also FN structure when trying to better understand the skeletal response during mechanical load and PA. The discrepancy when comparing the literature highlights the requirement of further prospective investigations in children and adolescences, with the use of objectively measured intervention programs and three-dimensional imaging techniques such as CT and MRI when evaluating the hip structural changes.

Walking and cycling to school could be an important regular source of PA in growing children. Cross-sectional studies support this view when reporting that walking and cycling to school are associated with a higher level of PA compared to traveling by vehicle (48, 49). However, this prospective study (**50**) reported that a physically active mode of transport to school was not, as evaluated by accelerometers, associated with higher overall levels of PA than transportation by car or bus. Also, there were no differences in the accrual of bone mineral or gain in bone size when the two transportation groups were compared. The discrepancy could be due to fact that the children in the POP cohort were on a general high level of PA so that the additional PA provided by active school transportation was of no biological significance. Another possible explanation is that the children lowered their leisure time PA if they practiced active school transportation supporting a previous report which infers the total amount of PA in children to be constant (51). That is, if children increase one activity they decrease another. Accelerometer data supported that there actually was no different level of PA between the two transportation groups (50). Furthermore, the distance from home to school was in general short in the POP cohort, 0.5 to 1.7 kilometers. In other words, active school transportation could be of importance in cohorts with a low habitual level of PA or a longer distance to school. Whether or not active school transportation provides skeletal benefits, as advocated over the years, as well as other health-related benefits must also be evaluated in further follow-up studies within this cohort.

The intervention program in the POP cohort, as estimated by the questionnaire, was associated with a higher duration of exercise per week. In contrast, the accelerometer data could not verify this (27, 28). As previously shown, the children in the POP study were all on a relatively high level of PA, irrespective of being in the intervention group or not and irrespective of having active or passive school transportation (27, 28, 50). In fact, all children reached the international recommended level of 60 minutes of MVPA per day set by the United Kingdom Expert Consensus Group (34). The present study supports that the accelerometer-measured total level of PA was no different between the intervention and control group, while the most intense activity, above 10,000 counts per minute, was higher in the intervention group could possibly be influenced by an intervention program (27, 28). The finding is of considerable interest as high-intensity activities with few daily repetitions are more important than a long duration of exercise if the purpose is to reach skeletal benefits (7, 26, 52).

Conclusions

A prospective, controlled, moderate exercise intervention program in the general school curriculum for pre-pubertal children aged 7 to 9 years at baseline suggests that the increaseed duration of PE classes has a positive influence on BMC accrual and bone size in the lumbar vertebrae. However, the program does not influence the bone mineral accrual or structural changes at the FN during the first two years. Also, the positive effects in the LS are less in absolute values in the boys than in the girls during the first two years of follow-up. The actual self-reported significant differences in the total duration of PA between the intervention and control group were not found when the two groups were compared with the accelerometers for total level of PA. Children in the exercise intervention groups, however, both girls and boys, were reported with more of the highest intensities (> 10,000 counts per minute) of PA as detected by accelerometers. Regardless of the mode of school transportation, all girls and boys reached above the international recommended level of PA per day. The relatively low amount of additional PA contributed by active school transportation seems not to influence bone health.

Perspectives

Further studies are required to determine whether an exercise program exceeding two years and in children closer to puberty could be beneficial also for the FN structure. In addition, trials with a longer follow-up period should be performed so as to evaluate whether the benefits measured at LS are transitory or additive with each year over the entire growth, thus rendering benefits in PBM and bone size of biological significance. More advanced techniques such as pQCT and MRI should be applied for the assessment of bone structure in order to add more knowledge within this field.

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