Factors affecting bone mineral density in young athletes of different disciplines: a cross--sectional study

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B Data Collection
C Statistical Analysis
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Anna Kopiczko

Department of Human Biology, Józef Piłsudski University of Physical Education in Warsaw, Warsaw, Poland

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Abstract

Background & Study Aim: Recent studies of bone mineral status have indicated that exercise increases and maintains bone mass and strength at various skeletal locations. In addition, it has been pointed out that intense exercise during growth and young adulthood may reduce the risk of fractures later in life. However, there is no clear consensus on the identification of the best exercise for the bones and a specific frequency of exercise. This study aimed was the knowledge about femoral neck (FN) and lumbar spine (L1-L4) bone mineral density (BMD) and bone mineral content (BMC) in adolescent athletes performing different disciplines.

Material & Methods: Data come from cross-sectional surveys with 156 boys from three physical activity (PA) groups: PA with a large osteogenic index (OI), (n = 54, speed-power athletes, throwing athletes, martial arts), PA with a low OI (n = 52, swimming, water polo, and diving) and inactive (n = 50). BMD and BMC were measured by densitometry. Body composition (fat mass – FM and fat free mass – FFM) was analysed using bioelectrical impedance methods. Eating habits were assessed using standardized dietary assessment questionnaires.

Results: The higher hip BMD was shown in boys from the PA with large OI. In the spine, boys in the group with a high proportion of exercise with large OI had the highest BMC. The strongest relationships with bone indicators were found for PA level, protein intake and dairy products. The main indicators significantly affecting BMD in the FN were: fat free mass (FFM), dairy products, calcium intake, protein intake and PA level (adj. R2 = 0.78). Significantly affecting BMD L1-L4 were: dairy products, protein intake, and PA level (adj.R2 = 0.63). In FN BMC the significantly affecting were: FFM, dairy products, protein intake and PA level (adj.R2 = 0.71). Similar results were obtained for total hip BMC, but in addition to the effect of dairy products. In BMC L1-L4 was significantly affected only PA level (adj.R2 = 0.31).

Conclusions: PA with a large OI proved to be a strong factor in determining the highest BMD in the hip and spine. This study also confirmed a significant effect on BMD by diet.

Keywords: bone health in adolescence • calcium intake • dairy products • martial arts • protein intake • somatic features • speed-power athletes • throwing athletes

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Author's address: Anna Kopiczko, Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education, Department of Human Biology, Section of Anthropology, 34 Marymoncka St., 00-968, Warsaw, Poland; e-mail: anna.kopiczko@awf.edu.pl

Bone mineral content – is widely used as the most important material for bone fragility, strength, and structure, covering trabecular bone that carries high potential accuracy of indicators of osteoporosis and fracture risk [15].

Bone mineral density – is the amount of bone mineral in bone tissue. The concept is of mass of mineral per volume of bone, relating to density in the physics sense, although clinically it is measured by proxy according to optical density per square centimetre of bone surface upon imaging [15].

Dual-energy X-ray Absorptiometry – is a type of X-ray examination that is used to assess bone mineral density and body fat. It is one of the basic research in the diagnosis of osteoporosis. Densitometry is a non-invasive and painless examination. It is made using a special X-ray machine that emits very little radiation [15].

Osteogenic index – the measure of effectiveness for exercise protocols, used to predict the osteogenic potential of exercise [2].

Peak bone mass – it's the maximum amount of whole-body BM content reached during the life of an individual. About a quarter of an individual's peak bone mass is acquired in an interval of 2 years surrounding the time the maximum height of the individual is reached, with 90% of peak bone mass reached by the age of 18 years [15].

INTRODUCTION

Recent studies of bone mineral status have indicated that exercise increases and maintains bone mass and strength at various skeletal locations. In addition, it has been pointed out that intense exercise during growth and young adulthood may reduce the risk of fractures later in life [1-3]. However, there is no clear consensus on the identification of the best exercise for the bones and a specific frequency of exercise [4].

It has been recognized that bones respond to stresses caused by these forces. Dynamic and high-value loads induce greater deformation in the bones and are indicated to be effective in appropriately loading the skeleton. The mechanisms underlying the osteogenic response to particular types of exercise have been studied for several decades. Findings have shown that exercise with prolonged bone loading improves bone mineral density (BMD), bone mineral content (BMC) and bone strength. However, it has not been pinpointed whether too much duration or too much load can cause the opposite effect. Researchers are still attempting to determine what dose and what type of exercise would be best for optimal mineralization and other bone indicators [5-7]. The mechanical loading of the skeleton may be a key factor to increase bone mineral accrual in children and adolescents [8].

In addition to physical activity, research indicates a significant impact of diet, its type, and the amount of nutrients consumed on bone health. Both to build peak bone mass (PBM) and to maintain the degree of mineralization in subsequent periods of osteogenesis, an adequate amount of protein, calcium, phosphorus, and vitamin D from the diet is necessary. Several studies have shown that insufficient calcium and/or vitamin D intake was detrimental to bone metabolism and bone health [9, 10]. Other studies highlight the varying effects of diets on bone health. Vegetarian diets continue to gain popularity also in youth and young adults. Many studies on the effects of such diets on bone health have appeared. Adult respondents from National Health and Nutrition Examination Survey (NHANES) surveys who self-identified as vegetarians exhibited significantly lower BMDs than non-vegetarians [11, 12]. Among children and adolescents, studies on the impact of the type of diet and eating behaviour on BMD in healthy populations are significantly less and need to be supplemented.

This study aimed was the knowledge about femoral neck (FN) and lumbar spine (L1-L4) bone mineral density (BMD) and bone mineral content (BMC) in adolescent athletes performing different disciplines.

MATERIAL AND METHODS

Participants and procedures

This cross-sectional study involved 156 youth boys (Caucasians of European origin) aged 17.5 ±1.1 years. The sample was drawn from the Sport Screening Study, which is an ongoing, cross-sectional bone health in sports population conducted by the Department of Human Biology, Józef Piłsudski University of Physical Education in Warsaw (Poland). In this project used a deliberate random model of group selection, as we have intentionally selected age range and gender – boys, and then the invitation for participation in the study was sent to randomly chosen sport schools from Warsaw city. Then, after verification with the parent and the boy of the inclusion and exclusion criteria, measurements were taken among qualified boys. A total of 135 training boys applied to participate. Excluded from the study were 29 boys. The analysis included the results of 106 boys training various sports disciplines.

Additionally, randomly selected results of physically inactive boys (n = 50) from the team's previous studies were used for comparison. The reasons for exclusion from the study are: exclusion criteria, boys who did not join the full study or have resigned out during the project.

This part of the project was carried out from January to April 2023 in the densitometry and kinanthropometry laboratory by a team of Anthropologists with the necessary qualifications and experience in research to perform the measurements on the entire study group.

The exclusion criteria included bone metabolic diseases, kidney disease, thyroid and parathyroid diseases, cancers, rheumatoid arthritis, and long-term steroid treatment. The study included boys who, according to their mother's interview, were assessed as healthy full-term new-borns (i.e., born between 38th and 42nd week of pregnancy).

The study was approved by the Bioethics Committee of the National Institute of Public Health, National Institute of Hygiene in Warsaw, Poland (protocol no. 1/2021) and conforms to the Declaration of Helsinki. Participants in the study and their parents were provided with information about the aims of the study and the study schedule. Written and informed parental consent was obtained for their child's participation, as well as participant assent obtained for this research project.

Methods of physical activity assessment

Data on physical activity, type of exercise performed, frequency of training, or sports activities were collected in a face-to-face interview. Participants were divided into three groups: two groups according to their physical activity and one physically inactive group. The first group included physical activities with a large osteogenic index (OI) and with weight-bearing activities (WBAs): speed-power athletes (sprint, high jump, long jump), throwing athletes (discus, shot put, javelin throw), and martial arts (taekwondo, karate kyokushin). Included in this group were boys engaged in these activities at least twice a week as part of a systematic sports activity in school and/or sports club. The second group included physical activities considered to be a low OI: swimming, water polo, and diving [2] where most of the training takes place in the water in axial stress relief of the skeletal system. Included in this group were boys practicing these activities as a form of training in swimming sections and in the water polo ball team. The length of training experience of the boys in activity groups (large OI and low OI) was between 3 and 6 years. The physically inactive group is boys who do not train in any sport and do not participate in extra sports activities.

Basic somatic characteristics and bone tissue indicators

Basic somatic characteristics such as body weight, body height, body fat mass (FM), and fat-free mass (FFM) were measured using kinanthropometry in accordance with the applicable methodology, to the standards proposed by the International Society for the Advancement of Kinanthropometry (ISAK) [13]. Body composition (FM and FFM) was analysed by means of the JAWON Medical X-scan PLUS 970 (Jawon Medical Co. Ltd., Seul, South Korea) analyser using bioelectrical impedance methods. Somatic measurements and body composition were taken in the morning. Body mass index (BMI) was also calculated in accordance with the methodology recommended by WHO [14]. Bone indicators such as BMD and BMC of nondominant hip and lumbar spine (L1-L4) were measured by the densitometry method (dual-energy X-ray absorptiometry, DXA). This project used a Norland XR-46 bone densitometer (Swissray-USA, Norland Medical Systems Madison, USA). This study used the various regions of interest (ROIs): the proximal femur (femoral neck, total hip) and lumbar spine (L1-L4). The precision error for the lumbar spine as a percentage coefficient of variance was less than 1% during the study period. DXA scans (total and sub regional) were obtained for all participants included in the present study and were performed by certified radiology technicians. According to the densitometric testing procedure and recommendations of the International Society for Clinical Densitometry [15] the scanner was calibrated daily. The calibration was performed against the standard calibration block supplied by the manufacturer to control for possible baseline drift.

Eating habits and diet evaluation method

Eating habits were assessed using standardized dietary assessment questionnaires in a face-to-face interview with the boys. The food frequency questionnaire (FFQ) was used to assess the frequency of dairy product consumption for the last three months preceding the survey. Food frequency questionnaires (FFQs) are usually self-administered, in this study after self-administered a follow-up interview was conducted with the respondent to verify the accuracy of the nutrition data. Besides the food list and the consumption frequency category section (non-quantitative FFQs), the FFQs was include the portion size of each food item (semi-quantitative FFQs) [16]. The interview included questions about the amount of dairy products consumed from the groups of milk, cheese, yogurt, fermented dairy products, and cottage cheese. To assess the intake of energy, calcium, phosphorus, vitamin D, and protein from the diet, the following was used the 24-hour recall method repeated two times. Questions included the amount and frequency of dairy product consumption per day. In this study, quantitative (g/person/day) and qualitative dietary data were collected for the last three months preceding the survey. Energy (kcal/day), calcium intake (mg/day), protein intake (g/person/day), vitamin D intake (µg/day), and phosphorus intake (mg/day) were calculated in a computer program for nutrition analysis (Diet 6.0, National Institute of Public Health – National Research Institute, Warsaw, Poland).

Statistical analysis

The research results were analysed with the use of Statistica software (ver. 13.3, StatSoft, USA). Means (M) and standard deviations (SD or ±) were calculated for all indicators and each of the three groups of boys. The normality of distribution was verified by the Shapiro-Wilk test and the assumption of equality of variances assessed with the Levene test of homogeneity of variance. The data analysis was based on the factor analysis of variance (ANOVA) and the Bonferroni (post hoc) test. The ANCOVA was applied in order to find relationships between bone indicators BMD, BMC and somatic indicators, diet and eating habits in boys, and level of PA (as qualitative predictor). The two-way analysis of variance ANOVA was also employed to provide an in-depth analysis of the observed relationships. The following levels of significance were used in the analyses: $p<0.05$; $p<0.01$; $p<0.001$ (p: p-value).

RESULTS

The basic characteristics of the three PA groups of boys

The groups differed significantly in 9 of 18 analysed indicators, especially bone indicators and diet. Inactivity boys had higher fat mass (FM) compared to the two PA groups and had higher body weight compared to PA with low OI. All values of bone indicators were highest in PA with large OI. PA with large OI had statistically significantly higher BMD of the femoral neck, total hip, and BMC of total hip and lumbar spine compared to inactive boys and PA with low OI. And also, PA with low OI had statistically significantly higher BMC femoral neck and total hip compared to inactive boys. Significant differences were noted between the three groups of boys in 3 variables of diet and eating habits. The significantly highest consumption of dairy products per day, calcium, and protein intake per day was reported in PA with large OI, significantly higher than the other two groups of boys (Table 1).

Table 1. Characteristics of the study population (M and SD).

Variable (indicator)	PA Inactive (n = 50)	PA with low OI (n = 52)	PA with large OI (n = 54)	F (p)
		Age and somatic features		
Age (years)	17.5 ±1.2	17.0 ±0.9	16.9 ±1.2	3.89 (0.091)
Body weight (kg)	**70.1 ±2.5#**	**62.6 ±5.3#**	65.9 ±4.3	8.66 (0.013)
Body height (cm)	169.0 ±5.3	170.2 ±6.6	169.8 ±5.9	2.44 (0.122)
BMI (kg/m^2)	23.7 ±2.4	20.1 ±3.0	22.6 ±1.6	2.98 (0.267)
FM (kg)	**21.3 ±3.9#***	**15.2 ±3.5#**	**16.7 ±1.5***	4.19 (0.033)
FFM (kg)	48.8 ±5.2	47.4 ±4.6	49.2 ±4.2	2.36 (0.216)

Variable (indicator)	PA Inactive (n = 50)	PA with low OI (n = 52)	PA with large OI (n = 54)	F (p)
		Bone		
BMD Femoral neck (g/cm²)	**0.875 ±0.117***	**0.881 ±0.104^**	**1.392 ±0.283*^**	11.08 (0.002)
BMC Femoral neck (g)	**5.124 ±1.528*#**	**6.022 ±1.060#**	**7.473 ±1.381***	8.66 (0.026)
BMD Total Hip (g/cm²)	**0.825 ±0.410***	**0.817 ±0.524^**	**1.388 ±0.368*^**	10.45 (0.003)
BMC Total Hip (g)	**24.21 ±7.29*#**	**26.54 ±8.02^#**	**31.17 ±9.07*^**	19.12 (<0.001)
BMD L1-L4 (g/cm²)	0.911 ±0.161	0.877 ±0.09	1.521 ±0.321	15.81 (<0.001)
BMC L1-L4 (g)	**84.22 ±7.26***	**89.47 ±9.19^**	**105.32 ±10.15*^**	9.45 (0.002)
		Diet and eating habits		
Dairy products (n/day)	**1.6 ±1.5***	**1.7 ±1.3^**	**3.4 ±1.6*^**	11.32 (0.002)
Energy (kcal/day)	2712 ±435.9	2333.4 ±612.9	2654.2 ±554.1	1.67 (0.301)
Calcium intake (mg/day)	**321.5 ±91.7***	**333.5 ±105.2^**	**441.8 ±113.0*^**	10.61 (<0.001)
Protein intake (g/person/day)	**52.6 ±14.9***	**53.0 ±10.2^**	**64.3 ±11.4*^**	21.51 (<0.001)
Vitamin D intake (µg/day)	2.6 ±0.9	1.9 ±0.9	2.9 ±0.7	1.87 (0.875)
Phosphorus intake (mg/day)	1110.4 ±151.1	1168.9 ±129.7	1147.1 ±107.5	2.15 (0.234)

Note: **BMI** body mass index; **FM** fat mass; **FFM** fat-free mass; **BMD** bone mineral density; **BMC** bone mineral content; * differences between Inactive vs. PA with large OI; # differences between Inactive vs. PA with low OI, ^differences between PA with large OI vs. PA with low OI

The results of analyses of the relationships PA, somatic, diet, eating habits indicators with BMD and BMC

Of all the variables analysed, the strongest relationships with bone indicators were consistently found for PA level, protein intake (g/person/day), and dairy products (n/day). Covariance analysis indicated that the main indicators significantly affecting BMD in the femoral neck were five variables: FFM (KG), dairy products (n/day), calcium intake (mg/day), protein intake (g/person/day) and PA level (adj. R^2 = 0.78). Similar results were obtained for total hip BMD but in addition to the effect of calcium intake (mg/day) (adj. R^2 = 0.61). The main indicators significantly affecting BMD L1-L4 were three variables: dairy products (n/day), protein intake (g/person/day), and PA level (adj. R^2 = 0.63). In turn, in BMC femoral neck the main indicators significantly affecting were four variables: FFM (kg), dairy products (n/day), protein intake (g/person/day), and PA level (adj. R^2 = 0.71). Similar results were obtained for total hip BMC, but in addition to the effect of dairy products (n/day), (adj. R^2 = 0.67). In turn, BMC L1-L4 the main parameter significantly affected was only PA level (adj. R2 = 0.31), (Table 2).

The analysis of the variance of indicators most strongly related to bone tissue

Both PA and protein intake were found to be highly significantly related to the BMD in this section of the skeleton (p< 0.0001), with the F-test values for PA being significantly higher and therefore the relationship being stronger (F = 21.03 vs.17.00) (Table 3A). Similar relationships and the same direction and strength of the relationship were shown for PA and total hip and lumbar spine BMD (Tables 3B, 3C).

DISCUSSION

The development of bone tissue in childhood and adolescence is important for bone health later in life and depends on many factors [17, 18]. This study analysed the relationship between exercise with different OI, body composition, diet and hip and lumbar BMD in healthy adolescent boys. In

Table 2. Relationships between BMD, BMC in hip and lumbar spine (L1-L4) and selected variable (results of ANCOVA analyses).

Variable (indicator)	BMD femoral neck	BMD total hip	BMD L1-L4
		F(p)	
BMI (kg/m^2)	0.711 (0.386)	0.437 (0.471)	0.640 (0.496)
FM (kg)	0.536 (0.412)	0.682 (0.556)	1.269 (0.193)
FFM (kg)	9.122 (0.001)	5.344 (0.022)	2.645 (0.103)
Dairy products (n/day)	11.144 (0.002)	8.691 (0.004)	6.911 (0.013)
Calcium intake (mg/day)	3.426 (0.053)	2.775 (0.093)	3.022 (0.059)
Protein intake (g/person/day)	15.191 (0.000)	11.054 (0.003)	9.635 (0.001)
Vitamin D intake (µg/day)	0.645 (0.512)	0.873 (0.802)	0.662 (0.433)
Phosphorus intake (mg/day)	0.954 (0.450)	0.845 (0.356)	0.516 (0.045)
PA (level)	26.321 (0.000)	15.421 (0.000)	13.621 (0.000)
		F(p) and Rˆ2 adj.	
	38.72 (0.000) 0.78	26.59 (0.000) 0.61	20.56 (0.000) 0.53
Variable (indicator)	**BMC femoral neck**	**BMC total hip**	**BMC L1-L4**
		F(p)	
BMI (kg/m^2)	0.614 (0.592)	0.391 (0.575)	1.023 (0.248)
FM (kg)	0.519 (0.443)	0.785 (0.377)	1.226 (0.215)
FFM (kg)	4.315 (0.033)	3.641 (0.050)	0.983 (0.664)
Dairy products (n/day)	3.644 (0.052)	1.156 (0.278)	1.668 (0.198)
Calcium intake (mg/day)	0.898 (0.334)	2.448 (0.088)	0.773 (0.472)
Protein intake (g/person/day)	13.61 (0.000)	16.136 (0.000)	2.691 (0.221)
Vitamin D intake (µg/day)	0.944 (0.361)	0.896 (0.412)	0.574 (0.071)
Phosphorus intake (mg/day)	0.065 (0.828)	1.120 (0.198)	2.616 (0.106)
PA (level)	6.702 (0.002)	26.22.(0.000)	10.031 (0.003)
		F(p) and Rˆ2 adj.	
	33.29 (0.000) 0.71	28.19 (0.000) 0.67	11.66 (0.000) 0.31

Note: **BMI** body mass index; **FFM** fat-free mass; **BMD** bone mineral density; **BMC** bone mineral content; **PA** physical activity; **F** Ronald A. Fisher's test; **p** p-value; level of statistical significance; **Rˆ2 adj.** the adjusted R-squared values of determination.

Table 3A. The strength of the relationships of the PA and protein intake (g/person/day) with **femoral neck BMD** (the results of the two-way analysis of variance, PA and protein intake as determining variables, BMD as the dependent variable).

Variables	Mean Square	F (p)
PA	6.0212	21.0331 (<0.001)
protein intake	4.0243	17.0022 (<0.001)
interaction	0.6012	4.0361 (0.0223)

Note: **F** Ronald A. Fisher's test; **p** p-value, level of statistical significance

Table 3B. The strength of the relationships of the PA and protein intake (g/person/day) with **total hip BMD** (the results of the two-way analysis of variance, PA and protein intake as determining variables, BMD as the dependent variable).

Variables	Mean Square	F (p)
PA	5.0254	20.1221 (<0.001)
protein intake	4.1223	16.9322 (<0.001)
interaction	0.5531	2.8211 (0.051)

Note: **F** Ronald A. Fisher's test; **p** p-value, level of statistical significance

Table 3C. The strength of the relationships of the PA and protein intake (g/person/day) with **lumbar spine BMD** (the results of the two-way analysis of variance, PA and protein intake as determining variables, BMD as the dependent variable).

Variables	Mean Square	F (p)
PA	4.0766	19.0541 (<0.001)
protein intake	3.6712	16.1112 (<0.001)
interaction	0.5211	2.5414 (0.051)

Note: **F** Ronald A. Fisher's test; **p** p-value, level of statistical significance

this study, BMD of the femoral neck and total hip, a limb important in running exercises, and technical exercises in team sports as well as individual sports and martial arts, was significantly affected by the level of physical activity and FFM and also diet indicators such as the number of dairy products per day and protein intake (g/person/day). The higher mineralization of the hip was shown in boys from the physically active group with large OI. In these studies, the lowest bone mineralization was recorded in the physically inactive group. BMD levels in the lumbar spine were significantly influenced by diet, especially dairy products and protein intake, in association with physical activity. In the spine, boys in the group with a high proportion of exercise with large OI had the highest bone mass.

Many studies have shown that children and adolescents attending sports activities had higher levels of physical fitness [19, 20], more health-promoting body composition [21, 22], better physical condition, and better bone mineralization [23] compared to inactive peers. Sports performance depends on an athlete's technique, motor performance and physical fitness and body dimensions, muscle performance [24]. The type of physical activity, participation in strength training, and resistance exercises with a high OI are important determinants of bone status [23]. Previous studies showed that the accrual of bone mass can be optimized by mechanical loading through exercise interventions [25, 26, 7, 27]. A bone adaptation most readily occurs with mechanotransduction of impact loading in exercise with large OI such as running or jumping [28, 29]. Good bone mineralization is important for the prevention of musculoskeletal overload and injury especially in physically active adolescent children.

The results of this cross-sectional study confirm that physical activity with a high proportion of osteogenic exercise results in greater bone mineralization at both the hip and lumbar spine. Boys who were physically active but played sports with low OI had poorer mineralization of the hip and spine. Previous studies have similarly shown, swimmers where the skeletal system is in relief had lower forearm BMD than athletes and even lower BMD than inactive boys [23].

Further research has shown that cycling and swimming were influenced by low total BMD and low lower limb BMD. In contrast, combat sports athletes, rugby players, soccer players, and runners had high total BMD and high lower limb BMD [30]. A few studies estimated the effect of weight-bearing activities (WBAs) on BMC and BMD during childhood and adolescence. One of the results showed that analysed training programs were capable of significantly increasing BMC and BMD during growth. However, as in our research, the effect of diet on BMD was also significant, because bone status was also dependent on differences in the amount of habitual calcium intake per day [7]. In this study, variables related to diet and eating habits were also significant for BMD levels. Consumption of dairy products and the level of protein and calcium intake from the diet were significant for BMD. One study showed positive and independent longitudinal and cross-sectional associations between the consumption of dairy products and PA with BMD in the total body and at the lumbar spine in young children. Consumption of dairy products by children was associated with higher lumbar-spine BMD and also PA assessed by accelerometry was positively related to total-body and lumbar-spine BMD in boys and lumbar-spine BMD in girls [31].

Vitamin D and dairy products may stimulate bone mineralization and linear growth in children. In this study dairy products was an important effect on BMD in boys, however, there was no significant relationship between BMD and vitamin D intake. The study from Sweden was to evaluate vitamin D status and the effects of vitamin D intervention on BMD and BMC in children with fair and dark skin during winter. In this study, no difference, in general, was found in BMD or BMC after vitamin D intervention [32]. Several nutritional factors have been associated with BMD [33].

Nutrients such as calcium, phosphate, vitamin D, and proteins, milk, and dairy products, dietary patterns have shown some relationship with bone status [34-36], however, research is inconclusive. Some studies indicate that children avoiding dairy products are at higher risk of fractures, as are adults or older people following a dairy-free diet. The intervention studies have shown the beneficial impact of dairy products on bone during growth and on bone turnover in adults. In observational studies, the consumption of dairy products, particularly fermented products that provide probiotics in addition to calcium, phosphorus, and protein, appears to be associated with a lower risk of hip fracture [37]. Rizzoli et al. [37] described that more than 60% of the variance of PBM is genetically determined and that the remainder may be amenable to interventions such as adequate dietary intake of calcium, protein, and vitamin D, as well as regular weight-bearing physical activity [38]. Van den Heuvel et al. [39] review addressed the most robust point estimate on the role of dairy products in bone mineralization or fracture risk. Plain dairy products or those fortified with calcium and/or vitamin D can improve total BMC in Caucasians and Chinese girls. In addition, in Caucasian and Chinese women, calcium from fortified dairy products may support the BMD increase [39]. Results for BMC were available, but no studies have investigated the potential of dairy products to reduce fracture risk in children. Most of these studies focus on adults and the effect of diet on the risk of osteoporosis and bone fractures [40].

Strengths and limitation

In this study, accurate research methodology was used. A high-quality densitometric apparatus and the extensive experience of the technician allowed for the collection of reliable data on bone indicators. The quality of these studies was enhanced by BMD analyses in two important skeletal areas, the hip, and the spine. The major strength of the study is a multi-factorial analysis. Several important factors were assessed rather than single variables. One of the study limitations is the relatively small yet sufficient size of the study group. It cannot provide a full representation of the population of Polish boys at this age.

CONCLUSIONS

In this study, the level of PA in three groups of boys proved to be an important determinant of BMD and BMC in the hip and lumbar spine. Physically active boys had significantly better bone mineralization compared to inactive boys. However, the most important factor determining the highest BMD indicators turned out to be the type of physical activity. Physical activities with a large osteogenic index (OI) and physical activity with weight-bearing activities (WBAs) proved to be a strong factor in determining the highest BMD in the hip and spine. This study also confirmed a significant effect on BMD levels, diet, and eating habits, especially the consumption of dairy products, as well as protein and calcium in the diet.

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