RELATIONSHIP BETWEEN PHYSICAL ACTIVITY, DIETARY INTAKE AND BONE PARAMETERS IN 10–12 YEARS OLD HUNGARIAN BOYS AND GIRLS

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SUMMARY

Objectives: Physical activity (PA) and adequate macro- and micronutrient intake have favourable influence on the bone status. The aim of this study was to analyse the relationships among PA, anthropometric data, dietary intake and ultrasound bone characteristics in children.

Methods: 10–12 years old Hungarian children (N = 123, 59 girls, 64 boys) provided physical activity, diet, anthropometric and bone data. PA was measured with accelerometer (Actigraph GT3X+). Diet was evaluated with three-day, 24-hour food recall. Calcaneal quantitative ultrasound (QUS) bone parameters were registered with Sonost3000 bone densitometer.

Results: Nutrition and anthropometry did not differ by gender. The values of broadband ultrasound attenuation (BUA) were significantly higher in boys. Girls spent significantly more time being sedentary, boys had greater light, moderate, vigorous, and moderate to vigorous physical activity (MVPA) levels. The children accumulated more than twice the suggested amount of public health guidelines for MVPA. QUS parameters correlated significantly with vigorous physical activity in boys, and with age, height, weight, fat percentage, and body mass index (BMI) for both genders. There was no significant relationship between nutrition and QUS; however, inadequate vitamin K intake correlated with less favourable bone parameters. Multiple linear regression analysis confirmed the importance of vigorous PA – speed of sound (SOS): $\beta = 0.358$, $p = 0.006$; BUA: $\beta = 0.340$, $p = 0.007$; bone quality index (BQI): $\beta = 0.377$, $p = 0.002$; vitamin K intake – SOS: $\beta = 0.256$, $p = 0.025$; BUA: $\beta = 0.235$, $p = 0.033$; BQI: $\beta = 0.295$, $p = 0.007$; BMI − SOS: $\beta = 0.207$, $p = 0.064$; BUA: $\beta = 0.455$, $p < 0.001$; BQI: $\beta = 0.284$, $p = 0.008$; and age – SOS: $\beta = 0.450$, $p < 0.001$; BUA: $\beta = 0.318$, $p = 0.004$; BQI: $\beta = 0.444$, $p < 0.001$).

Conclusions: Changes in the characteristics of ultrasound bone parameters among 10–12 years old children mainly depended on the amount of intense PA, adequate vitamin K intake and anthropometric variables related to age.

Key words: bone parameters, physical activity, dietary intake, children

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INTRODUCTION

The hypoactive lifestyle is widely diffused in developed countries and is one of the main risk factors of civilisation-based diseases as osteoporosis (1). Habitual physical activity and nutrition are two main environmental effects which can be determinants of bone health. Sedentary behaviour combined with unfavourable dietary habits (3, 4) are determinative as well as risk factors of several diseases and the bone degeneration processes (2–4). The beneficial effects of exercise on skeletal health is evident (5–7). Bone parameters are also associated with age, several anthropometric variables and body fat percentage (8, 9). Some previous studies have focused on the relationship between calcium and vitamin D intake and bone properties, and the effect of calcium supplementation on bone health during the prepubertal years (2, 9). Vitamin K may play an important role in bone health (10). Some studies suggest that a diet high in vitamin K is associated with a lower risk of hip fractures in aging men and women, but no consistent effects were reported in other studies in which the addition of vitamin K was assessed, and there is not enough evidence to recommend the routine use of vitamin K supplements for the prevention of osteoporosis (11). There are few studies that have investigated the effect of vitamin K on bone parameters in children (12, 13). Furthermore, no results have been published about the relationship between body structure, objective PA levels, combined absolute dietary intake and quantitative ultrasound bone parameters.

The aim of the present study was to report on lifestyle factors as PA, nutrition, and to analyse the relationships between ultrasound bone characteristics and the objective level of habitual PA, anthropometry, and macro- and micronutrient (vitamin D, vitamin K, calcium) intake in a school-based sample of Hungarian 10–12 years old children. Based on these aspects we focused on gender differences. Little is known about the combined effects of these factors on bone health assessed by quantitative ultrasound.

Our research questions were: What is the relation between calcaneus bone parameters with anthropometric variables, daily physical activity and dietary intake in 10–12 years old children? Are there gender differences in the effect of habitual physical activity and nutrition on bone parameters?

MATERIALS AND METHODS

Participants

Ten to twelve years old Hungarian children were randomly selected as a subsample from the cohort study of 737 children in a cross-sectional survey in 2013–2015. Total of 140 children took part in all procedures. We excluded children with invalid calcaneal quantitative ultrasound (QUS) measurement (n = 2), invalid accelerometer data (n = 5), inappropriate food recall data (n = 7), and no report on participation in a sport activity (n = 3). The complete data on variables used in the final analyses were available for 123 children (59 girls, 64 boys). All girls were premenarcheal. The children came from twelve primary public schools in various regions, including the capital, cities, small towns and villages (ten schools from urban, two schools from rural areas). For further analysis we divided the children into two subgroups by their adequate or definitely inadequate vitamin D (less than 2.5 µg per day), vitamin K (less than 40 µg per day), and calcium (less than 1,000 mg per day) consumption (14).

Procedures

Anthropometric measurements were taken according to the suggestions of the International Biological Programme. The instruments were calibrated prior to use, all measurements were taken on the subjects' right side. Anthropometric variables were measured using the protocol of the International Society for the Advancement of Kinanthropometry (ISAK) (15).

Body height (BH) was measured with a stadiometer (model 214, Seca-Bodymorph, Birmingham, UK) to the nearest 0.1 cm, body weight (BW) was recorded on a portable scale (model 707, Seca Corporation, Columbia, Maryland) to the nearest 0.1 kg. Skinfolds (biceps, triceps, subscapular, suprailiac, medial calf) were measured with the use of a caliper (Harpenden-CE0120, West Sussex, UK) to the nearest 0.2 mm.

Nutritional status was calculated with BMI (kg/m^2). Body fat percentage (fat%) estimation was determined with the modified procedure of Parizkova (16):

Fat% = 28.894 x log [2(biceps+triceps+subscapular+suprailiac+calf skinfolds)] − 41.18.

Calcaneal quantitative ultrasound parameters were registered with a SONOST3000 (Seoul, Korea) bone densitometer. Variables measured by QUS, are:

Speed of sound (SOS, m/s), which reflects elasticity and microarchitecture, was shown to predict fractures independent of bone mineral density (BMD), suggesting that it measures some aspects of bone strength and the material quality.

Broadband ultrasound attenuation (BUA, dB/MHz) reveals the mineral content of bone showing the best correlation to BMD, and it can also be a microstructural indicator of bone. The value of BUA depends on bone mass and the remaining intactness of trabecula-net.

Bone quality index (BQI = αSOS + βBUA, αβ: temperature corrections) predicts fracture risk, which makes it suitable for clinical use.

Habitual PA levels were monitored with triaxial accelerometer (ActiGraph GT3X+, Pensacola, FL, USA). The subjects wore the sensors for five consecutive days, 24 hours per day, avoided wearing it in water. One of the five days was always a weekend day. We measured daily activity from 6 a.m. to 8 p.m. in five epoch intervals. Activity levels could be divided into five zones: sedentary (Sed), less than 149 counts/minute (CPM); light physical activity (LPA), 150–499 CPM; moderate (MPA), 500–3,999 CPM; vigorous (VPA), 4,000–7,599 CPM; very vigorous activity (VVPA), greater than 7,600 CPM. These cut-off points are based on the metabolic equivalent (MET) formula METs = 2.757 + (0.0015*CPM) – (0.08957*age) – (0.000038*CPM*age) with assumed MET thresholds of 3, 6 and 9 METs (17). The amount of time in different activity zones are given in minutes. MVPA means moderate to vigorous physical activity. From the five days of data we evaluated the one-day average of PA. The level of habitual PA was also measured with the use of self-reported questionnaires (sport activity hours per week). More than half of the students were taking part in sport activities apart from their physical education (PE) lessons in school.

Diet was evaluated with a three-day, 24-hour food recall, adopted as recommended by the Dietary Reference Intakes using NutriComp® software. The children, with help of their parents, recorded and weighed all consumed food and drinks (to nearest 1 g/1 ml) over three days (two non-consecutive weekdays and one weekend day) wearing an accelerometer during this time.

To minimise mistakes of the data recording process, the participants were given detailed written explanations, and students received a verbal briefing by a trained nutritional consultant prior to testing. The data were recorded and analyzed by trained dietician. Total energy intake (kcal), carbohydrate (g), protein (g), lipid (g), Ω3 and Ω6 fatty acid (g), vitamin D (µg), vitamin K (µg), and calcium (mg) intakes were examined.

Statistical Analysis

Data were analysed with Statistica 11 software (StatSoft Inc., Tulsa, OK 74104, USA). Variables were checked for normality by Kolmogorov-Smirnov test. Values of skinfolds and micronutrients were log transformed in order to achieve normality. Differences between genders and subgroups were tested with Student t-tests for independent samples. We compared BH, BW, BMI between genders using z-scores of CDC growth charts (18) and calculated the z-score deviation of BH, BW, BMI from age and gender-specific CDC reference value (zBH, zBW, zBMI). We analysed the relationships of bone and anthropometric variables, PA, macro- and micronutrient intake using Pearson's correlation. We conducted multiple regression analyses to establish associations of bone parameters (as dependent variables) with age, zBMI, gender, sedentary time, VPA, calcium, vitamin D, and vitamin K intake as independent variables. The level of effective random error was set at 5% in all significance tests ($p < 0.05$).

RESULTS

The basic statistics of anthropometric and bone parameters are shown in Table 1 (mean ± SD).

There were no significant differences between genders in age, BH, BW, BMI, and fat%. We also compared height, weight and BMI between genders using CDC growth charts (18). There were no significant differences in the z-scores of BH (boys: 0.70 vs.

girls: 0.67; p = 0.819), BW (boys: 0.34 vs. girls: 0.34; p = 0.985), and BMI (boys: 0.03 vs. girls: 0.16; p = 0.469). Hungarian children were taller (p < 0.001 in both genders) but not heavier than the CDC references (boys: p = 0.187; girls: p = 0.212), and BMI were also similar (boys: p = 0.998; girls: p = 0.824). Only BUA differed significantly between genders (boys: 74.67 ± 12.44 vs. girls: 69.67 ± 10.26 dB/MHz; p = 0.018).

The daily activities at different intensity levels are shown in Figure 1. Girls spent significantly more time being sedentary, boys had significantly greater light, moderate, vigorous and MVPA intensity levels. On average, children accumulated 147.37 ± 44.13 minutes of MVPA daily (boys: 159.23 ± 36.90; girls: 133.44 ± 44.28; p = 0.002). Out of these amounts the VPA was 19.43 ± 10.19 minutes per day in the total sample (boys: 22.13 ± 12.13 vs. girls: 16.27 ± 8.24; p = 0.002). They spent 572.86 ± 99.80 minutes per day in the sedentary zone (boys: 553.69 ± 90.37 vs. girls: 595.36 ± 106.40; p = 0.026). Children spent 72.5 ± 7.8% of monitored time in the sedentary, 8.2 ± 2.5% in the LPA, 0.5 ± 0.5% in the very vigorous, and 18.7 ± 5.5% in the MVPA zone.

More than half of the students were taking part in sport activities apart from their PE lessons in school. The time spent doing sport activities (minutes per day), based on the questionnaire, did not differ between genders (boys: 35.56 ± 23.70; girls: 30.33 ± 19.47; p = 0.339).

We present some macro- and micronutrients which are important in bone development in Table 2. On average, these children take sufficient or greater than sufficient amount of energy, protein, carbohydrate, lipid, Ω3 and Ω6 fatty acids, and vitamin K. The calcium and vitamin D intakes are slightly lower than the recommendations. Genders did not differ in dietary intake.

The correlation pattern of PA, anthropometric and bone parameters are shown in Table 3. Each bone parameter correlated significantly with VPA in the total sample and in boys, but there was no significant correlation in girls. Age, zBH, zBW significantly correlated with bone variables in both genders; fat%, zBMI correlated with BUA in girls.

Dietary components did not correlate with bone parameters. We divided the children into two subgroups on the basis of their consumption of certain nutrients which may play a significant role in bone health. Children who took less than the recommended amount of the relevant nutrients were in the first group, and those who consumed adequate amounts of these nutrients were in the other group. More than half of the children did not have an adequate intake of calcium, two fifths of them did not have adequate vitamin D intake, and inadequate vitamin K intake was found in

Table 1. *Basic statistics of anthropometric and ultrasound bone parameters – Mean ± SD (N = 123)*

	Boys (n = 64)	Girls (n = 59)	p-value
Age (years)	11.12 ± 0.68	10.96 ± 0.75	0.216
Height (cm)	149.45 ± 7.05	148.90 ± 7.53	0.676
z-score of height	0.70 ± 0.81	0.67 ± 0.83	0.819
Weight (kg)	40.19 ± 7.92	41.45 ± 8.78	0.408
z-score of weight	0.34 ± 0.88	0.34 ± 0.89	0.985
Body mass index (kg/m^2)	17.91 ± 2.74	18.53 ± 2.78	0.212
z-score of body mass index	0.03 ± 1.09	0.16 ± 0.94	0.469
Fat (%)	19.10 ± 5.84	21.12 ± 5.42	0.052
SOS (m/s)	1492.74 ± 12.81	1490.08 ± 11.53	0.236
BUA (dB/MHz)	74.67 ± 12.44	69.67 ± 10.26	0.018*
BQI	61.52 ± 14.39	56.91 ± 11.44	0.056

SD – standard deviation; z-score – z-score of height, weight, body mass index using CDC growth charts (52); SOS − speed of sound (m/s); BUA – broadband ultrasound attenuation (dB/MHz); BQI − bone quality index (BQI = αSOS+βBUA, αβ − temperature corrections); *p < 0.05 − significant differences between genders

Table 2. *Basic statistics of dietary intake in study sample – Mean ± SD (N = 123)*

	Boys (n = 64)	Girls (n = 59)	Total (N = 123)	p-value
Energy (kcal)	2458.48 ± 683.42	2406.94 ± 635.08	2434.43 ± 661.81	0.716
Protein (g)	92.98 ± 24.79	86.88 ± 18.76	90.13 ± 22.39	0.201
Carbohydrate (g)	319.2 ± 97.3	315.31 ± 84.09	317.38 ± 91.38	0.842
Lipid (g)	87.96 ± 27.70	86.48 ± 23.34	87.27 ± 28.02	0.805
Ω3 fatty acid (g)	0.95 ± 0.61	0.88 ± 0.50	0.92 ± 0.57	0.544
Ω6 fatty acid (g)	19.08 ± 9.58	16.97 ± 8.61	18.10 ± 9.20	0.283
Vitamin D (µg)	2.40 ± 1.53	2.27 ± 1.08	2.34 ± 1.34	0.652
Vitamin K (µg)	99.40 ± 88.66	82.7 ± 45.9	91.31 ± 72.46	0.263
Calcium (mg)	893.36 ± 382.74	839.00 ± 321.60	867.99 ± 356.56	0.476

SD − standard deviation

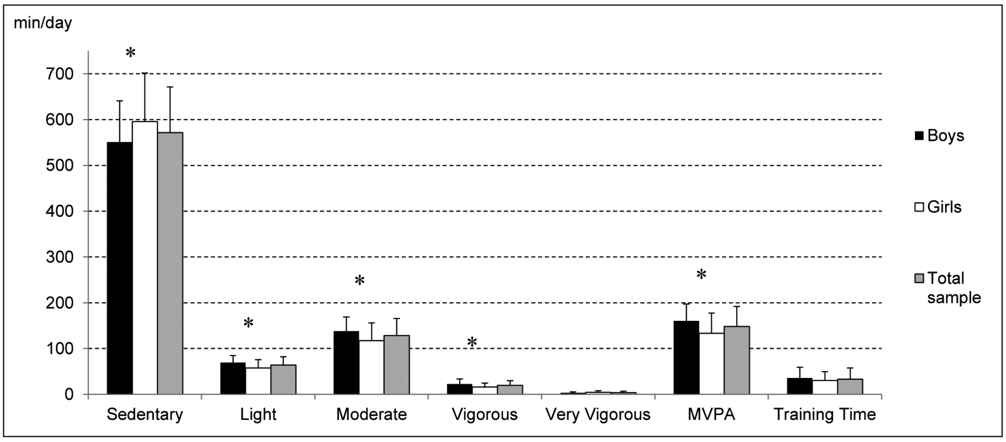

Fig. 1. *Pattern of daily physical activity (minutes per day) in 10–12 years old schoolchildren.*

MVPA – moderate and vigorous physical activity; *significant differences between genders $p < 0.05$

14% of them (12% of boys, 16% of girls). QUS parameters did not differ in the subgroups in vitamin D and calcium consumption.

Inadequate vitamin K intake was associated with a lower SOS value (1,492.43 ± 12.21 vs. 1,484.07 ± 10.85 m/s; $p = 0.028$) (Figure 2).

A multiple linear regression model was created for the bone parameters with the anthropometric and nutritional variables and the level of PA to determine which could predict the measured bone characteristics (Table 4). Independent parameters (gender, age, zBMI, calcium and vitamin D, K intake, sedentary and vigor-

Table 3. *Correlation pattern of physical activity, anthropometric variables and bone parameters (N = 123)*

Pearson's correlation coefficient	Total sample (N = 123)			Boys (n = 64)			Girls (n = 59)		
	SOS	BUA	BQI	SOS	BUA	BQI	SOS	BUA	BQI
Sedentary	−0.02	−0.02	−0.04	−0.05	−0.07	−0.08	0.06	0.12	0.09
Light physical activity	0.10	0.14	0.15	0.16	0.10	0.17	−0.03	0.09	0.02
Moderate physical activity	0.05	0.08	0.12	0.09	0.15	0.12	−0.10	−0.02	−0.06
Vigorous physical activity	0.23*	0.25*	0.29**	0.46***	0.33**	0.47***	−0.10	0.00	−0.08
Very vigorous physical activity	−0.09	−0.03	−0.06	0.21	0.14	0.23	−0.17	−0.10	−0.16
MVPA	0.09	0.12	0.15	0.23	0.15	0.25	−0.12	−0.01	−0.07
Age	0.37***	0.25**	0.37***	0.43***	0.16	0.38**	0.30*	0.32*	0.36**
zHeight	0.43***	0.48***	0.50***	0.57***	0.55***	0.59***	0.28*	0.41**	0.39**
zWeight	0.22*	0.41***	0.31**	0.24	0.39**	0.29*	0.21	0.51***	0.37**
Fat%	−0.11	0.15	−0.05	−0.13	0.08	−0.11	−0.08	0.32*	0.08
zBMI	0.04	0.25**	0.11	0.03	0.15	0.01	0.10	0.43**	0.25

MVPA − moderate to vigorous physical activity (min/day); zBMI – z score of body mass index (kg/m^2); SOS − speed of sound (m/s); BUA − broadband ultrasound attenuation (dB/MHz); BQI – bone quality index; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

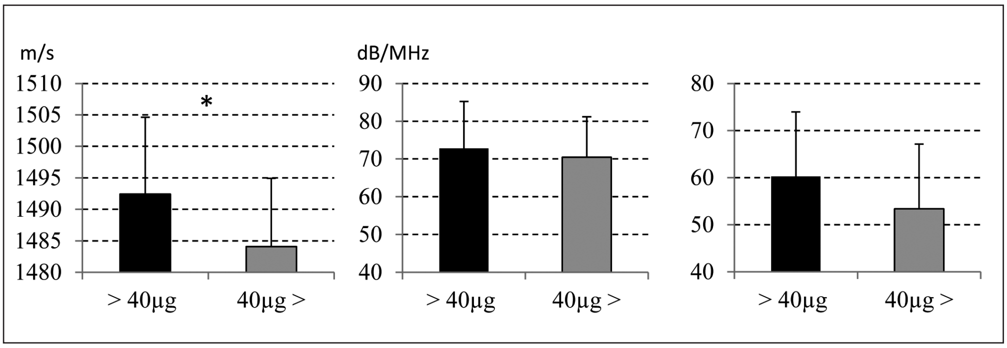

Fig. 2. *Ultrasound bone parameters (SOS, BUA, BQI) of adequate (40 μg and more), and inadequate (less than 40 μg) vitamin K intake in total sample.*

SOS − speed of sound (m/s); BUA − broadband ultrasound attenuation (dB/MHz); BQI − bone quality index; *significant differences between subgroups $p < 0.05$

Table 4. Results from multiple linear regression models of ultrasound bone parameters

Dependent variable	SOS $R^2 = 0.412$; $p < 0.001$ SEoE = 10.328			BUA $R^2 = 0.450$; $p < 0.001$ SEoE 9.533			BQI $R^2 = 0.477$; $p < 0.001$ SEoE 11.147		
	β	squared part cor	p-value	β	squared part cor	p-value	β	squared part cor	p-value
Intercept	1,381.97		<0.001	−22.876		0.311	−68.146		0.011
Gender	−0.092	0.011	0.413	−0.170	0.041	0.120	−0.130	0.025	0.228
Age (yrs)	0.450	0.226	<0.001	0.318	0.134	0.004	0.444	0.242	<0.001
zBMI (kg/m^2)	0.207	0.058	0.064	0.455	0.239	< 0.001	0.284	0.115	0.008
Calcium (mg)	0.081	0.007	0.515	0.095	0.011	0.431	0.067	0.005	0.571
Vitamin D (μg)	−0.097	0.012	0.403	−0.068	0.006	0.542	−0.034	0.002	0.750
Vitamin K (μg)	0.256	0.083	0.025	0.235	0.076	0.033	0.295	0.120	0.007
Sed (min/day)	0.076	0.007	0.519	0.021	0.000	0.854	0.031	0.001	0.780
VPA (min/day)	0.358	0.128	0.006	0.340	0.120	0.007	0.377	0.150	0.002

SOS – speed of sound (m/s); BUA – broadband ultrasound attenuation (dB/MHz); BQI – bone quality index; zBMI – z score of body mass index; Sed – sedentary; VPA – vigorous physical activity; SeoE – standard error of estimate; β – standardized regression coefficient

ous PA were selected based on the results of correlation analyses, and biological considerations. Multiple regression analysis also confirmed the importance of VPA (SOS: $\beta=0.358$, $p=0.006$; BUA: $\beta=0.340$, $p=0.007$; BQI: $\beta=0.377$, $p=0.002$) and age (SOS: $\beta=0.450$, $p<0.001$; BUA: $\beta=0.318$, $p=0.004$; BQI: $\beta=0.444$, $p<0.001$) on the values of ultrasound bone parameters.

Vitamin K intake was related to the values of QUS (SOS: $\beta=0.256$, $p=0.025$; BUA: $\beta=0.235$, $p=0.033$; BQI: $\beta=0.295$, $p=0.007$), and the associations with ultrasound bone parameters were no longer statistically significant after adjusting for age and gender. zBMI was associated with QUS (SOS: $\beta=0.207$, $p=0.064$; BUA: $\beta=0.455$, $p<0.001$; BQI: $\beta = 0.284$, $p=0.008$).

DISCUSSION

Physical Activity and QUS

In our study the Hungarian children accumulated double amounts of MVPA than in the international recommendations (3). Despite the wide range of time the children spent engaging in MVPA per day (3–278 min), only four of them were not sufficiently active. The relatively high PA level may have been influenced by the daily PE lessons in schools (5*45 minutes per week); these lessons were part of a programme which was gradually introduced from 2012 in all Hungarian schools. In addition, more than half of the children participated in organised sport activities in school or sport clubs.

Regular physical activity is identified as an important factor in bone health. However, MVPA did not correlate significantly with QUS in our sample. Previous studies support our results that VPA (with gender differencies) seems to be more strongly related to bone parameters than other intensity levels of PA (5, 19, 20). We also found gender differences (21, 22): there was a significant correlation between the amount of VPA and ultrasound bone characteristics in boys, but not in girls. Nevertheless, others found that higher levels of VPA were inversely correlated with better bone mineral content in prepubertal boys (20), and the results of a study including 2–10 years old children did not indicate any gender difference (23).

Moreover, physical activity has been shown to be one of the most important external key factors associated with bone parameters in boys, and our data suggest that more intensive PA may be more important than total activity and may be a good predictor of bone health.

Anthropometry and QUS

Anthropometric variables related to growth and bone parameters correlated positively in both genders. Age and BMI were good predictors of BUA and BQI values in our linear regression model. These results are consistent with some studies (8, 9). A previous study reported that overweight prepubertal boys had better DEXA bone parameters than that of boys with normal nutritional status (24). In our study body fat percentage did not correlate significantly to QUS in boys but did in 10–12 years old girls: a positive correlation was found between fat percentage and BUA, despite the fact that the fat% did not significantly differ between the genders in this sample. This result is contrary to the findings of other studies in which fat percentage correlated negatively with bone parameters in girls (9). Nonetheless, the small number of overweight subjects in our cohort limited the conclusions. Interactions of body fat content, other size-related variables and bone are controversial and the effect of excess weight on bone mass gain during growth are poorly understood and require further investigation (25).

Nutrition, Physical Activity and QUS

Previous studies have confirmed the relationship between nutrition, PA and bone characteristics (2, 14, 26, 27). In our study nutritional parameters did not differ by gender, and contrary to the above-mentioned studies, macro- and micronutrient intake did not correlate with bone variables. Although a significant proportion of our sample did not consume sufficient amount of calcium and vitamin D, intakes of these micronutrients were only slightly lower than the recommendations, which may partly explain why there was no correlation between calcium, vitamin D intake and bone parameters.

In respect of vitamin K intake and bone health, especially in children, there are only few previous studies with ambiguous results. In a study by van Summeren et al. better vitamin K status was associated with a more pronounced increase in bone mineral mass in healthy peripubertal children. Using invasive methods (DEXA and blood test) it was found that children with a high vitamin K status had markedly greater bone properties; however, this association was independent of physical activity, age, gender and BMI (13). In contrast, others found that vitamin K status was not consistently related to BMC (12).

In our study vitamin K intake did not correlate significantly with QUS values. However, we found that inadequate vitamin K intake is related to a lower value in SOS. Furthermore, in contrast to calcium and vitamin D intake, vitamin K intake was a good predictor of ultrasound bone parameters by our multiple linear regression model. Our findings draw attention to the fact that the adequate amounts of vitamin K is required for healthy bone development in childhood. It should be considered in children's school meals.

Limitations and Strength of the Study

The observations of this study are limited due to its cross-sectional nature, medium sample size and self-reported diet (three-day, 24-hour food recall) through questionnaire, which may be prone to over- or underestimation. A further limitation of the study is that at present, no reference ultrasound data are available to allow comparisons between our study groups and large age- and sex-matched cohorts. However, the groups in our study were quite comparable in terms of anthropomorphic data. Another limitation was that our findings are derived from 10–12 years old children, and Tanner stage was not assessed by the authors, so our results may not be accurate for all populations, suggesting the need for further investigation. Furthermore, a question may arise as to whether radiation-free calcaneal ultrasound is representative of total body bone status. Some previous studies have confirmed a high correlation with the data by DEXA. QUS parameters provide information about bone architecture, which also contributes to bone strength, and non-invasive QUS is highly recommended for the investigation of bone properties in children. One of the strengths of the present study is that it was the first complex investigation to combine evaluated diet, objective measurements of habitual PA, and anthropometric and bone characteristics of narrow age range in both genders which can provide opportunity to make more effective interventions in order to prevent bone degenerative processes.

CONCLUSIONS

Multiple regression analysis confirmed the importance of VPA, vitamin K intake, zBMI and age showing that these parameters significantly predicted ultrasound bone characteristics.

In conclusion, our findings provide an indication for effective interventions in school, as increasing intensive physical activity in PE lessons, and guaranteed adequate micronutrients intake including vitamin K in children's school meals during growth and development, which lead to favourable bone characteristics in children.

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Conflict of Interests

None declared

Adherence to Ethical Standards

The study was conducted in accordance with the Declaration of Helsinki for Human Research. The children participated exclusively as volunteers. For each participant, written consent was given by one of their parents and collected before the investigation. All participants and their parents received written information about the goal of the survey and the procedures. Data management was conducted anonymously. The protocol was approved by the Hungarian University of Physical Educations' Institutional Review Board.

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