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DIETARY PATTERN AND ITS RELATIONSHIP BETWEEN BONE MINERAL DENSITY IN GIRLS AND BOYS WITH CYSTIC FIBROSIS – PRELIMINARY REPORT

SPOSÓB ŻYWIENIA I JEGO ZWIĄZEK Z GĘSTOŚCIĄ MINERALNĄ KOŚCI U DZIEWCZĄT I CHŁOPCÓW Z MUKOWISCYDOZĄ

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Abstract

Background: *Nutrition influence on cystic fibrosis (CF) patients survival is well documented and dietary therapy is one of basic elements of their treatment. Prolonged survival of CF patients might yet emerge comorbidities, which include bone mineral disease.*

The aim: *The assessment of the dietary pattern and its relationship between bone density in boys and girls with cystic fibrosis.*

Material and methods: *89 patients aged 10-18 years from 3 Polish CF Centres were included into the study. To obtain a knowledge about quality of diet, a 3-day food record was assessed and percent of recommended for CF patients intake of energy, protein, carbohydrates, fat, vitamin D3, calcium, phosphorus was counted. Bone mineral density (BMD) in lumbar spine (L1-L4) was measured and expressed as a Z-score. To assess nutritional status, anthropometric measurements was evaluated (body weight, height and BMI). Descriptive methods, Mann-Whitney test, T-Student test, Spearman correlation and one-way ANOVA were used for statistical analyses.*

Results: *The patients with cystic fibrosis did not meet specific for CF nutritional guidelines. A deficiency in recommended intake was observed in energy (88%), protein (82%), calcium (78%) and vitamin D3 (71%). The intake of phosphorus was higher than recommended (142%). A nutritional status was significantly reduced, as compared with the reference group ($p<0.001$). Boys characterized significantly lower body weight ($p=0.019$) and height ($p=0.036$) than girls as well as worse caloric ($p=0.023$) and carbohydrates intake ($p=0.005$). However, girls had reduced vitamin D3 content in their diet ($p<0.001$). The bone mineral density in the whole group was reduced and Z-score amounted to -0.95±1.17. Tendency to decreasing of BMD with age was observed. BMI showed important correlation with bone mineral density both in girls ($p<0.001$) and in boys ($p=0.020$).*

Conclusion: *CF patients do not follow specific for them dietary recommendations and essential differences were observed between girls and boys. Nutritional status (BMI) showed correlation with bone mineral density in CF patients. Therefore intensive nutritional therapy according to recommendations is needed.*

Key words: nutrition, calcium, vitamin D, adolescents, densitometry

Streszczenie

Wprowadzenie: *Wpływ żywienia na długość życia chorych z mukowiscydozą (ang. Cystic Fibrosis – CF) jest dobrze udokumentowany, a postępowanie dietetyczne jest jednym z podstawowych elementów*

leczenia pacjentów z CF. Systematyczne wydłużanie się wieku przeżycia chorych może powodować ujawienie się niedoborów żywieniowych prowadzących do chorób towarzyszących, jakimi są m.in. zaburzenia w gospodarce mineralnej kości.

Cel: *Celem pracy była ocena sposobu żywienia dziewcząt i chłopców z mukowiscydozą i jego związku z gęstością mineralną kości.*

Materiał i metody: *Do badania włączono 89 pacjentów w wieku 10-18 lat. W celu ustalenia jakości diety, oceniono sposób żywienia za pomocą zapisu 3-dniowych jadłospisów, obliczając procent realizacji zapotrzebowania zgodnie z rekomendacjami opracowanymi dla pacjentów z mukowiscydozą. Dotyczyło to pokrycia zapotrzebowania kalorycznego, białka, tłuszczu, węglowodanów, witaminy D3, wapnia i fosforu. Oceniono gęstość mineralną kości (Bone Mineral Density – BMD) w odcinku lędźwiowym (L1-L4). Wynik wyrażono, jako wartość standaryzowaną Z-score. W celu określenia stanu odżywienia dokonano pomiarów antropometrycznych (masa i wysokość ciała oraz BMI). Wykonano następujące obliczenia statystyczne: analizy opisowe, test Manna-Whitneya, test t-Studenta, korelację Spearmana, oraz jednoczynnikową analizę wariancji ANOVA.*

Wyniki: *Badani pacjenci nie spełniali opracowanych dla chorych na mukowiscydozę zaleceń żywieniowych. W diecie zaobserwowano niedobory energii (88% normy), białka (82%), wapnia (78%) oraz witaminy D3 (71%). Wykazano nadmierne spożycie fosforu (142%).*

Stan odżywienia (parametry antropometryczne) badanej grupy był obniżony i w sposób statystycznie istotny różnił się od grupy referencyjnej ($p<0,001$). Chłopcy charakteryzowali się znacznie niższą masą ciała ($p=0,019$) i wysokością ($p=0,036$) niż dziewczęta, a także niższą kalorycznością diety ($p=0,023$) oraz zawartością węglowodanów ($p=0,005$). Dietę dziewcząt cechowała mniejsza zawartość witaminy D3 w diecie ($p<0,001$) w porównaniu do chłopców. Średnia wartość gęstości mineralnej kości w całej grupie była obniżona i wynosiła -0,95±1,17. Zaobserwowano tendencję do obniżania się BMD wraz z wiekiem. Stan odżywienia wyrażony jako BMI wykazał statystycznie istotną korelację z gęstością mineralną kości, zarówno u dziewcząt ($p<0,001$), jak i u chłopców ($p=0,020$).

Wnioski: *Pacjenci z CF nie przestrzegali opracowanych dla nich zaleceń dietetycznych. Zaobserwowano istotne różnice między dziewczętami i chłopcami. Stan odżywienia (BMI), wykazał korelację z gęstością mineralną kości (BMD), co wymaga intensywnej terapii żywieniowej, zgodnie z opracowanymi rekomendacjami.*

Słowa kluczowe: żywienie, wapń, witamina D, młodzież, densytometria

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INTRODUCTION

Nutrition influence on CF patients survival is well documented. Dietary therapy is one of basic elements of cystic fibrosis treatment [1, 2]. The Polish Cystic Fibrosis Society [3] recommends high energy diet (120-150% of age mates' demand for energy), high fat (35-45% of energy), and high protein diet (15% of energy) in order to provide appropriate nutrition diet. In individual approach, patients may need 110-200% of energy in comparison with healthy population in respect of age and sex [4]. Cystic fibrosis patients have an elevated risk of osteoporosis. Osteoporosis and osteopenia contribute towards morbidity increase and life quality level decrease in CF patients. In this group of patients, fractures may result in pulmonary function deterioration, thoracic cavity normal physiotherapy disturbance and are a contraindication for lung transplantation. Proper bones mineralization depends on diet, regular physical activity, physical development, muscle mass gain as well as normal pubescence. Diet during bones mineralization prophylaxis should be based on calcium and vitamin D3 regular supplementation [5, 6].

AIM OF THE STUDY

The aim of the study was the assessment of the dietary pattern and its relationship between bone density in boys and girls with cystic fibrosis.

MATERIAL AND METHOD

Study group

The study comprised 89 CF patients aged 10-18 years. The sample consisted of 46 boys and 43 girls. The mean age of the children was 12.3±3.5 years. The patients were recruited from three Polish CF Centres: The Cystic Fibrosis Centre of the Institute of Mother and Child in Warsaw – 49 patients, The Department of Pediatric Gastroenterology and Hepatology of the Children's Memorial Health Institute in Warsaw – 15 patients, The Department of Gastroenterology Metabolic Disease of The University of Medical Sciences in Poznań – 25 patients.

The survey was carried out from 05.2007 until 05.2009 during ambulatory patients' scheduled visits in the above CF Centres.

All patients were in stable clinical condition. For the whole group mean FEV1% was 82.29±20.54 %, in girls 85.06±17.14 %; and in boys 79.70±23.17 %. Diagnosis of CF was confirmed by sweat chloride concentration and genetic analysis before the candidates were included in the study group. DNA was analyzed in order to determine the type of CFTR gene mutation. The studies were carried out on admission in the Medical Genetics Laboratory of the Institute of Mother and Child. CFTR genotype was F508del/F508del in 51 of the children, F508del/Mt in 22 of the children, and Mt/Mt in 16 of the children, where Mt represents any mutation other than F508del.

Candidates were included in the study on the basis of the following criteria:

- at least ten years of age;
- severe pancreatic insufficiency (stool concentration of elastase-1 less than 100 μg/g and pancreatic enzyme supplementation);
- compliance with vitamin supplementation.

Candidates were excluded on the basis of the following criteria:

- long-term treatment with systemic steroids;
- hepatic cirrhosis; and
- dependence on supplied oxygen.

For all of the children included in the study, dietary assessment, anthropometric measurements, bone mineral densitometry were performed. Signed informed consent was obtained from the parents of each child. The study was approved by the Bioethics Committee of the Institute of Mother and Child (No. KBET/29/2006).

Dietary assessment

Measuring dietary intake enables the assessment of nutritional adequacy and can provide information about nutrients, including energy, food, and eating habits.

Dietary assessment was carried out basing on 3-days diet records. For each patient, average nutritional value of diet was calculated: energy (kcal), proteins (g), fat (g), carbohydrates (g), calcium (mg), phosphorus (mg) and vitamin D3 (μg). Calculations were made with the use of DIETA 2 computer programme [7].

Elicited results of nutritional values estimated for each patient individually were compared with National Food and Nutrition Institute standards formulated in 2008 for healthy population [8]. Based on Polish Cystic Fibrosis Society recommendations [3], for every examined patient, 120% of energy requirement was calculated in compliance with age and sex and in comparison with healthy age mates [8]. In this estimation, 15% of energy originated from proteins, 35% from fat and 50% of energy came from carbohydrates [3]. Normal values were defined as 90-110% of standards [8].

Due to the lack of specific standards for CF patients, the proportions of calcium, phosphorus and vitamin D3 intake were contrasted with standards for healthy children of Polish population from 2008 [8].

Calcium and vitamin D3 content in diet was compared with standards of Adequate Intake – AI [8]. Demand for calcium in healthy boys and girls at the age 12-18 years amounts to 1300mg/24hrs whereas for vitamin D, it is 5 μg/24 hrs [8]. Phosphorus content in daily nutritional rations was compared with Estimated Average Reference – EAR [8] which for healthy children aged 10-18 years amounts to 1050 mg/24 hrs.

Anthropometric measurements

To assess nutritional status anthropometric measurements were conducted. Body height and body mass were recorded to one decimal place. Body mass index (BMI) was used as an indicator of relative weight, and was calculated by dividing the body mass in kilograms by the square of the body height in meters.

Bone mineral densitometry

Bone mineral density in the lumbar spine (L2 to L4) was measured using a Hologic Explorer dual-energy X-ray absorption densitometer and expressed in terms of the BMD Z-score. In accordance with Polish and European guidelines, bone mineral density was considered normal for Z-scores greater than -1, moderately low for scores between -1 and -2, and very low for scores less than -2 [3, 10].

Statistical methods

On the basis of collected research material, values of standard deviations (±SD), minimum and maximum values as well of 1q and 3q quartile of analyzed features were computed, separately for both sexes.

Anthropometric parameters were expressed in terms of standard deviation away from age-specific and sex-specific reference means for the population of Warsaw reported by Palczewska and Niedźwiedzka [9].

Differences between the children and the reference population were evaluated using Student's t-test for single samples.

For all continuous variables describing body built, diet, nutritional condition and bones mineral density, on the assessment of sex differences significance, t-Student test for independent variables of normal distribution was applied. In the case of abnormal distribution, non-parametric Mann-Whitney Z-test was adopted. To assess relationships between bone mineral density and nutritional variables Spearman correlation R were employed. The t-Student tests for independent variables were applied to test the effect of nutrition (expressed as a percentage of intakes of nutrition parameters) on bones mineral density. One-way analyses of variance ANOVA were applied to test dependence of BMD on age. BMD was dependent variable, and age independent variables with three groups: 1) 10-12 years; 2) 13-15 years; 3) 16-18 years. The age categories were used due to the use of National Food and Nutrition Institute standards [8] included in the assessment of diet of the CF patients, which are dependent on age and sex.

Differences were considered significant at $p<0.05$. All analyses were carried out using the STATISTICA 10.0 software package.

RESULTS

Table I. presents standardized anthropometric measurements and BMD Z-score in children and adolescents

Table I. Standardized anthropometric measurements and BMD Z-score in children and adolescents with cystic fibrosis and statistical significance in comparison with healthy reference population [9].

Tabela I. Średnie standaryzowane wartości masy ciała, wysokości ciała, BMI oraz BMD dzieci i młodzieży z mukowiscydozą oraz istotność różnic w porównaniu z układem odniesienia [9].

Parameter ***Zmienna***	**Mean ± SD**	**Min**	**Max**	**t***	**p**
Body weight *Masa ciała*	-0.77±0.90	-2.47	2.16	-8.12	<0.001
Body height *Wysokość ciała*	-0.74±1,34	-4.41	3.82	-5.24	<0.001
BMI	-0.57±0,74	-1.73	1.94	-7.26	<0.001
BMD	-0.93±1,07	-3.30	2.10	-8.19	<0.001

Values are expressed as mean Z-scores (S.D.) and range/*Wartości Z-score wyrażone jako średnie (SD).*
*Student t-test: mean Z-score = 0/*Test T-Studenta: średnia Z-score=0.*

Table II. Differences between cystic fibrosis girls and boys in anthropometric measurements and BMD Z-score.

Tabela II. Różnice w zmiennych antropometrycznych i BMD Z-score pomiędzy dziewczętami i chłopcami.

	Girls ***Dziewczęta (n=43)***	**Boys** ***Chłopcy (n=46)***	**t***	**p**
	± SD			
Body weight *Masa ciała*	-0.40±1.05	-1.06±1.51	2.37	0.019
Body height *Wysokość ciała*	-0.57±0.84	-0.97±0.91	2.13	0.036
BMI	-0.46±0.67	-0.67±0.80	1.30	0.197
BMD Z-score	-0.85±1.00	-1.00±1.14	0.69	0.492

*Student's t-test/*Test T-Studenta.*

with cystic fibrosis. Standardized body height, body mass and BMI were significantly lower in the whole group than in the reference population (Table I). Mean value of bones mineral density in the whole group was significantly decreased as compared with reference population and amounted to -0.93±1.07. Girls were significantly taller and had significantly higher body weight as compared to boys, whereas there were not any significant differences between boys and girls in BMI and BMD (Table II).

The caloric intake in comparison to CF recommendation was too small and amounted to 88.0±22.1% of norm, similarly to protein (81.7±23.3%), calcium (73.2±32.0%) and vitamin D3 (71.2±38.5%). In the examined group, phosphorus was the only diet component which was ingested excessively and it amounted to 143.0±41.6 % of daily intake (Table III).

Table III. presents comparison of energy, macronutrient and micronutrient intakes for boys and girls as far as covering diet particular elements. Significantly higher energy value of diet as well as carbohydrates content were observed in girls than in boys. Vitamin D intake was higher in boys.

Table IV. presents the results of t-tests applied to examine the relationship between diet and bones mineral density. No statistically significant relations were found between parameters of nutrition (energy, protein, calcium, phosphorus and vitamin D3 expressed as a percent of intake in comparison to standards, listed in methods section) and bones mineral density (BMD Z-score).

Table V. presents Spearman's correlation coefficients R between nutrition variables, and standardized values of BMI, and bone mineral density (BMD) in boys and girls, separately. Significant correlation was observed between calcium intake and bone mineral density in boys ($R=0.39$; $p<0.001$). Nutritional status expressed as standardized BMI showed significant relationship with BMD, both in girls ($R=0.56$; $p<0.001$) and boys ($R=0.34$; $p=0.02$).

Table VI. presents one-way Anova results of bone mineral density depending on the age of CF patients. The differences did not exceed the threshold of statistical significance, but we observed tendency to decrease BMD value with age.

Table III. Energy, macronutrient and micronutrient intakes of girls and boys with cystic fibrosis.
Tabela III. Spożycie energii, makroelementów i mikroelementów u dziewcząt i chłopców z mukowiscydozą.

		TOTAL (n=89)	GIRLS *DZIEWCZĘTA (n=43)*				BOYS *CHŁOPCY (n=46)*				Z*	p
		± SD	± SD	Median	1Quartile	3Quartile	± SD	Median	1Quartile	3Quartile		
Energy *Energia*	kcal	2697.1±656.4	2554.66±524.8	2513.7	2168.5	2900.3	2830.3±740.4	2763.5	2315.3	3299.5		
	120% of RDA	88.0±22.1	92.7±19.9	90.2	79.9	101.3	83.6±23.4	80.8	63.2	97.5	2.26	0.023
Protein *Białko*	g	93.9±25.9	87.8±22.9	87.4	72.0	103.3	99.8±27.4	94.3	83.6	118.6		
	15% of energy	81.7±23.3	84.7±22.0	82.8	66.5	97.7	78.9±24.4	76.9	61.8	90.7	1.49	0.136
Fat *Tłuszcz*	g	109.9±32.0	102.6±28.8	102.6	81.1	120.9	116.7±33.6	114.7	95.0	127.5		
	35% of energy	92.0±27.3	95.6±27.5	91.8	78.5	107.7	88.7±26.9	89.1	67.9	102.9	1.28	0.199
Carbohydrates *Węglowodany*	g	346.9±90.5	334.2±68.7	336.2	292.0	375.1	358.9±106.4	345.9	294.4	431.6		
	50% of energy	90.7±24.5	97.0±20.9	96.3	83.2	113.2	84.8±26.3	80.0	67.7	102.1	2.80	0.005
Calcium *Wapń*	mg	1013.4±411.9	951.8±366.1	915.0	704.3	1230.3	1070.9±446.9	1001.3	784.3	1321.7		
	% AI	78.3±32.0	73.2±28.2	70.4	54.2	84.6	83.0±34.9	77.0	60.3	104.1	-1.16	0.247
Phosphorus *Fosfor*	g	1488.2±417.9	1424.1±401.8	1358.7	1182.3	1639.0	1548.1±428.1	1436.3	1284.3	1803.7		
	%EAR	143.0±41.6	135.6±38.3	129.4	112.6	156.1	149.9±43.7	136.8	122.3	172.9	-1.68	0.093
Vitamin D *Witamina D*	µg	3.6±1.9	2.91±1.51	2.50	1.70	3.49	4.17±2.08	3.67	2.73	5.36		
	%AI	71.2±38.5	58.1±30.1	49.9	33.9	69.9	83.4±41.6	73.4	54.6	107.2	-3.49	0.0004

*Mann-Whitney test/test Manna-Whitneya, differences between girls and boys/*różnice pomiędzy dziewczętami i chłopcami*

Table IV. Relationship between bones mineral density (BMD Z-score) and nutrition parameters – results of t-tests.

Tabela IV. Zależność pomiędzy zmiennymi żywieniowymi a gęstością mineralną kości (BMD Z-score) – wyniki testu t.

Variables ***Zmienne***	**BMD Z-score values for two groups Mean±SD**			
	Norm of intake ***Norma zalecanego spożycia***	**Insufficiency* of intake** ***Niedobór zalecanego spożycia***	**t**	**P**
Energy *Energia*	-0.75±1.10	-1.09±1.04	1.50	0.137
Protein *Białko*	-0.88±1.30	-0.96±0.95	0.31	0.759
Fat *Tłuszcz*	-0.82±1.10	-1.06±1.04	1.04	0.299
Carbohydrates *Węglowodany*	-0.81±1.10	-1.07±1.04	1.13	0.263
Calcium *Wapń*	-0.74±1.29	-1.02±0.97	1.14	0.259
Phosphorus *Fosfor*	-0.81±1,08	-1.53±0.91	1.54	0.157
Vitamin D3 *Witamina D3*	-1.07±1.23	-0.89±1.03	-0.64	0.521

*Except from phosphorus, which was the only one component of diet with excessive intake/*Poza fosforem, który był jedynym składnikiem diety spożywanym w nadmiarze.*

Table V. Correlations between dietary variables, nutrition status and bone mineral density in cystic fibrosis girls and boys.

Tabela V. Korelacje pomiędzy zmiennymi żywieniowymi, stanem odżywienia a gęstością mineralną kości wśród dziewcząt i chłopców z mukowiscydozą.

Variables ***Zmienne***	**Bone mineral density** ***Gęstość mineralna kości BMD Z-score***			
	Girls ***Dziewczęta***		**Boys** ***Chłopcy***	
Percent of intake *Procent realizacji zalecanego spożycia*	R	p	R	P
Energy Energia	-0.06	0.717	0.23	0.130
Protein Białko	-0.08	0.624	0.16	0.299
Calcium Wapń	-0.11	0.473	0.39	<0.001
Phosphorus Fosfor	-0.25	0.111	0.29	0.053
Vitamin D3 Witamina D3	-0.08	0.609	0.06	0.702
BMI SDS	0.56	<0.001	0.34	0.020

Table VI. Bone mineral density in age groups of the children and adolescents with cystic fibrosis – results of one-way ANOVA.

Tabela VI. Wartości gęstości mineralnej kości w grupach wieku badanych dzieci i młodzieży z mukowiscydozą – wyniki jednoczynnnikowej ANOVA.

Age groups ***Grupy wiekowe***	**BMD Z-score values** ***Wartość BMD Z-score*** **Mean ± SD**	**F**	**p**
10-12 years/*lat*	-077±0.85	2.99	0.057
13-15 years/*lat*	-0.85±1.20		
16-18 years/*lat*	-1.49±1.25		

DISCUSSION

Cystic fibrosis is a genetically conditioned disease comprising many organs. Modern diagnostics, complex treatment and new therapies have contributed to prolonged survival time and CF is no longer only disease in children. Due to the extended life time, CF related bone mineral density disturbances might appear [11].

In CF, numerous risk factors of decreased bone mineral density could be present, hence the goal of the study was to assess how dietary patterns influence bone mineral density.

In our study, in accordance with CF diet recommendations, decreased proportion of energy intake was observed in patients' diet and it amounted to 88%. Also Sermet-Gaudelus et al. [12] observed non satisfactory energy value in diets. In Australian report [13], evaluating bone mineral density of CF patients and their healthy peers, higher energy intake was observed in comparison with control group. Similar results were obtained by Salamoni et al. [14] who examined group of patients with normal nourishment condition in comparison with healthy age mates. In this study [14] CF patients ingested 30% more protein in comparison with the control group in contrary to our patients, where protein intake was insufficient and it constituted 82% of recommended intake for CF. We did not observed statistically significant differences between sexes, however protein intake were higher in girls (85% of CF norm) than in boys (77% of CF norm). Salamoni et al. [14] noticed also increased intake of phosphorous, similarly to our study, where phosphorus intake amounted to 142% of norm. In turn, in Brazilian assessment [15], phosphorus intake in adolescents was normal in 91.9% of examined individuals.

Excessive phosphorus intake may lead to bone mass loss. In our study, despite the increased intake of phosphorus, statistically significant difference in the reduced bone mineral density was not observed (Table IV). Furthermore, due to lack of assessment dietary products structure, it is hard to precise which group of products contributed to phosphorus highest ingestion. However, the highest intake of fat (92%) and carbohydrates (91%) in comparison to other nutrients was observed, cereal products and processed food might take a big part in examined patients' diet. Also in the Polish healthy population, phosphorus intake was increased and amounted to 1208 mg/day. In boys and adult men was 1441 mg/day and remained higher than in girls and adult women (1008 mg/day) [16]. In our CF patients mean phosphorus content in the diet of girls and boys was comparably excessive and counted 1424 mg/day and 1548 mg/day, respectively.

Calcium is another constituent of the diet which is essential in forming bones - especially in childhood and adolescence. Due to long term dietary deficiency of this element, the organism releases it from osseous reservoirs which may result in the decrease of bone mineral density [17].

In our study, decreased calcium content in the diet was observed and amounted to 78% of adequate intake. In contrary, multicentre study, which was carried out in France, revealed that calcium intake in children and adolescents exceeded the amounts recommended for their healthy age mates [12]. Similar results were demonstrated in American [18] and Swiss [14] studies. Also in the surveys of three CF Canadian centres, average contents of calcium and vitamin D3 in diet were higher than those recommended for the age of 8-18 years, though, calcium supplements were included into the analysis. What is more, diet assessment was based on Food Frequency Questionnaire which makes its results encumbered with errors. Also Ujhelyi et al. [19] incorporated this method of analysis. In the group of 11 participants (average age – 8 years), calcium intake was insufficient and amounted to 1072±450 mg whereas in adolescents group it was considerably lower and amounted to 886±329 mg (16 participants, average age – 15 years).

However, studies carried out in healthy population in some European countries revealed that calcium average content in children's diet aged 4-10 years and 11-17 years did not exceed 1000 mg/24 hours. The lowest values were characteristic for Poland and Great Britain [20]. In Łódź centre, in healthy 9-13 year old children, calcium intake was lowered in 87% of examined persons and amounted to 66.2% of Adequate Intake in boys and 59.2% in girls [21]. In our own study, higher calcium insufficiencies concerned more often girls (73% of norm) than boys (83% of norm). Additionally, we found statistically significant positive correlation between calcium intake and BMD in boys. According to our practice and observations CF boys tends to consume more dairy products than girls. In general, the reason for calcium decreased amount in school children's diet may be limited milk and dairy products ingestion as well as of food enriched with this element. At present, school adolescents consume milk and dairy products once a day or even less [22]. It is not an optimal and recommended frequency and it does not provide proper amounts of mineral elements especially calcium.

Up to now, there have been no studies concerning appropriate dose of calcium supplementation in CF patients. According to recommendations, calcium should come from diet [10].

Vitamin D was another element of diet assessed in this study. In our group of patients, too small content of vitamin D3 in diets was observed as it constituted only 71% of Adequate Intake. Statistically smaller ($p<0.01$) content of vitamin D3 was observed in girls' diet (58%) than in boys' diet (83%).

Available literature does not include many papers assessing vitamin D3 intake. In American studies by Rovner et al. [18], vitamin D3 intake in CF patients aged 8-25 years was higher than in present study and amounted to 164% of norm. Similarly, in the study by Grey et al. [23], vitamin D3 exceeded recommended values. In turn, in Scandinavian survey [24] carried out on a large number of CF patients (406 persons) aged 0.53-65.9 years, vitamin D3 intake amounted to 4.6 μg. In our study, the average value was slightly lower and significantly different between girls and boys amounted to 2.9±1.5 μg/24 h and 4.2±2.1 μg/24 h ($p<0.001$), respectively.

The tendency to decreased intake of vitamin D3 in diet is also very characteristic for Polish children and adolescents [21, 25]. It may result from the fact that vitamin D3 mainly originates from sea fish and the consumption of which is very small in our country. Studies show that children with cystic fibrosis CF typically consume similar nutritional amounts as their healthy peers, despite recommendations to achieve a higher fat and calorie intake. Adolescents may be at even greater risk of poor dietary intake due to their increased energy requirements and tendency for increased non-adherence to medical regimens [26].

Our results analyzing influence of diet on bone mineral density did not provide any statistically significant correlation with the examined parameters (Table IV). However, patients with insufficiencies in their intake were characterized by lower BMD that those with proper diet. In the investigated group, greater number of dietary elements (energy, protein, calcium, phosphorus and vitamin D3) was assessed in respect of their influence on bone mineral density than in other literature reports. There are three papers assessing diet and BMD interdependence. In their reports, Serment-Gaudelus et al. [12] followed only the influence of diet energy value on bone mineral density whereas Buntain et al. [27] observed calcium intake and Haslam et al. [28] studied energy value as well as calcium and vitamin D3 content in a diet. In all these papers, no statistically significant correlation between diet and bone mineral density was found. Convergent data were elicited in our study, however, in sex considering correlation analysis, dependence between calcium intake and bone mineral density in boys was found ($r=0.39$; $p<0.001$).

According to our findings, boys with increasing diet content, increases BMD, whereas negative correlation in diet and BMD was found in girls (Table V). This could suggest a different metabolism between sex and would give implications for the future like increased risk of osteoporosis in girls with CF. Nevertheless further study is needed to inspect this findings.

Our analysis revealed that standardized BMI as a component of nutritional status, was a factor influencing bone mineral density for both, girls and boys. Poor somatic development was observed in our CF patients in comparison with reference population. Significantly lower values of standardized variables (body mass, body height and BMI) were observed. Available literature evaluating nourishment status [29] and bone mineral density revealed decreased somatic development in comparison with control group [18, 30, 31]. In children and adolescents group, significant relationship between BMD and BMI was found [32, 33]. However, decreased bones mineral density is observed in properly nourished patients [6, 34].

We also observed tendency to decreasing BMD with the patients age. Adolescence and young adulthood is an important and vulnerable period for patients with cystic CF. It is widely recognized that this is also a time of significant acceleration of morbidity and mortality in CF. Decline pulmonary function and BMI, which is also associated with adherence [35] could affect BMD of CF patients with age as well.

The limitations of our study include the fact that, three-day record may not fully register long term diet followed by CF patients. Long term study is needed to verify our findings.

The challenge to improve nutritional status is individualization of the treatment plan, tailored to the needs and conditions of the patient.

CONCLUSIONS

1. CF patients do not follow specific for them dietary recommendations and essential differences were observed between girls and boys.

2. Nutritional status (BMI) showed correlation with bone mineral density (BMD) in CF patients, this requires intensive nutritional therapy according to recommendation.

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