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Original Article

Vitamin D and Nutritional Status of Children Evaluated via Bioelectric Impedance Analysis

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Abstract

Objective: Nutritional disorders affect growth in children. The present study aimed to assess the nutritional status and vitamin D levels in children by use of different nutritional assessment parameters via bioelectric impedance analysis. **Methods:** Two hundred and seventy-nine patients who applied to our general paediatrics outpatient clinic with various complaints, such as poor nutrition, obesity, weakness, fatigue, pain in the legs and a lack of adequate sunshine, were included in the study. Anthropometric measurements, body composition analysis data gathered with an In-Body 230 device, and bioelectric impedance analysis (BIA) data were assessed for all patients. The patients were grouped according to BMI SDS as lean, normal weight, overweight or obese. The subjects' 25(OH)D vitamin levels were obtained from laboratory recordings. ***Results:*** Of the patients, 44.1% (n=123) were female. The mean age was 10.0±3.6 (2-17) years. Of the patients, 18.6% (n=52) were lean, 47.3% (n=132) were normal weighted, 14.7% (n=41) were overweight, and 19.4% (n=54) were obese. The mean 25(OH)D levels of the lean, normal weighted, overweight and obese patients were 22.9±13.5 ng/mL, 25.8±11.8 ng/mL, 20.7±7.7 ng/mL and 17.9±9.7 ng/mL respectively. Levels of 25(OH)D were lower in the obese group than in the other groups, but this difference was not significant. The prevalence of obesity is increased in boys during adolescence, while 25(OH)D levels are decreased among girls. ***Conclusions:*** The evaluation of nutritional status and body fat composition via BIA may be a helpful and reliable method of preventing and treating childhood obesity and malnutrition.

Key words Bioelectric impedance analysis; Body composition analysis; Malnutrition; Vitamin D

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Introduction

Growth reflects a child's general health and nutritional status. Adequate nutrition in children is possible with the intake of the necessary calories, protein, vitamins, minerals and trace elements required to survive and to provide adequate growth.[1] Malnutrition refers to both inadequate nutrition and overnutrition. Both have become serious health problems worldwide. Nutritional deficiency has been defined as an alteration in the normal body composition that can be prevented or treated with nutritional replacement.[2,3] In recent years, bioelectrical impedence analysis (BIA) has been used with gradually increasing frequency because of easy application, noninvasiveness, high reproducibility and fast results in determining nutritional status, along with physical nutritional anthropometric evaluation.[4] Recent studies have shown that BIA-derived body composition measurements are helpful in the evaluation of nutritional status and growth (to determine basic measures and follow-up for the progression of changes in nutritional status). Vitamin D, which has a key role in the maintenance of normal bone mineral balance, plays significant roles in many parts of the body. Studies have shown a correlation between low serum 25(OH)D vitamin levels and obesity, diabetes mellitus and metabolic syndrome. This is thought to be related with the expression of vitamin D receptor in adipose tissue, the solubility of vitamin D in fat and the deposition of vitamin D in adipose tissue.[5,6]

This study was conducted to determine the nutritional states of patients who presented to the Division of General Pediatrics between 2015 and 2016 and the correlation between their nutritional states and 25(OH)D vitamin levels.

Methods

Two hundred seventy-nine patients aged between 2 and 17 years who presented to the Istanbul Faculty of Medicine, Department of Pediatrics, Division of General Pediatrics between January 2015 and September 2016 were included in this study. After approval was obtained from the local ethics committee of the Istanbul Faculty of Medicine (ethics committee file number: 2016/831), the body compositions and nutritional states of the patients were evaluated using the bioelectrical impedence method. The demographic properties of all subjects were recorded by asking face-to-face questions. Body weights were measured using an In-Body 230 bioeletricial impedence analyser (100 g sensitivity). Heights were measured using a stadiometer (1 mm sensitivity) with shoes and clothes off. Body mass index (BMI) values were calculated with a bioelectrical impedence analysis device. Standard deviation scores (SDS, z score) for body weight, height and BMI were calculated based on the normal age- and gender-appropriate values using the following formula.[7]

SDS (z score) = (Current height – Mean height) / Standard deviation (SD)

The subjects' body weight (kg), body muscle mass (kg), body fat mass (kg) and %, body water mass (kg), body protein mass (kg), body mineral mass (kg), body mass index (kg/m^2) and basal metabolism rate (kcal) values were analysed using an In-Body 230 bioelectrical impedence analysis device. The subjects' lean body weight values were calculated by adding the body mineral, protein and water ratios. In our study, the subjects' 25(OH)D vitamin levels were obtained from laboratory recordings.

SPSS (Statistical Package for Social Sciences) Version 24.0 was used for the statistical analysis of the data obtained in the study. In the analyses in which groups and descriptive statistical methods (mean, standard deviation, median, minimum and maximum) were compared, a Student's t-test was used for the mean values between two groups, and a chi-square test was used for the categorical variables. A one-way Anova test was used in comparisons of three or more groups that showed a normal distribution. Pearson's correlation test (coefficient: r), which is a parametric test, was used to investigate correlations between the data. A p-value of <0.05 was considered statistically significant.

Results

A total of 279 subjects who presented to the Department of General Pediatrics between 2015 and 2016 were included in the study. One hundred and twenty-three (44.1%) of these subjects were female, and 156 (55.9%) were male. The mean age was 10.0±3.69 (2-17) years (Table 1). In our study, 25(OH)D vitamin levels were measured in a total of 106 patients, 62 (58.5%) of whom were male and 44 (41.5) of whom were female (mean age 9.89±3.75 years). No statistically significant differences were found between the genders in terms of height, body weight or BMI SDS (Table 1). According to the BMI SDS levels, 18.6% (n=52) of all subjects were lean, 47.3% (n=132) were normal, 14.7% (n=41) were overweight and 19.4% (n=54) were obese. No statistically significant difference was found between the genders in terms of BMI measurement.

Table 1 Height, weight and body mass index (BMI) distributions of the subjects by gender

Gender	Age* (years)	Height† (cm) SDS	Weight† (kg) SDS	BMI† (kg/m^2) SDS
Female (n=123)	10.8±3.82	141±19.7 -0.09±1.63	43.1±22.8 0.09±1.63	20.1±7.04 0.17±2.1
Male (n=156)	9.33±3.45	134.9±21.2 0.01±1.38	35.8±19.5 -0.05±1.82	18.3±5.41 -0.06±1.84
Total (n=279)	10.0±3.69	137.6±20.8 0.05±1.48	39.0±21.3 0.04±1.98	19.1±6.24 0.04±1.96

* p<0.05; †p>0.05

When the BIA data were compared by gender, statistically significant differences were found in terms of body water mass, the amount of protein, muscle mass, mineral mass, lean body weight and body fat mass. The lean body mass obtained via BIA was found to be 72.5±12.4% in the girls and 77.6±12.1% in the boys (Table 2). No statistically significant difference was found when basal metabolism rates were compared by gender.

No statistically significant difference was found between the BMI SDS subgroups in terms of age distribution. When the BIA data were compared between the BMI SDS subgroups, statistically significant differences were found in terms of body water, minerals, protein, lean body weight, muscle mass, body fat mass or basal metabolism rate (Table 3). Also, 29.2% of subjects (n=31) whose 25(OH)D vitamin levels were examined were lean, 47.2% (n=50) were normal, 7.5% (n=8) were overweight and 16% (n=17) were obese.

Among the BMI SDS groups, no statistically significant differences were found between the age distributions of the subjects whose 25(OH)D vitamin levels were examined. Statistically significant differences were found in terms of body water mass, the amount of body protein, body muscle mass, lean body weight and body fat mass. No statistically significant differences were found in terms of the basal metabolism rate and serum 25(OH)D vitamin levels between the BMI SDS subgroups (Table 4).

When the relationships between 25(OH)D vitamin levels and anthropometric values were examined, a negative correlation was found between 25(OH)D vitamin levels and body fat mass (p:0.021, r:-0.223). A statistically significant positive correlation was found between 25(OH)D vitamin levels and body water, protein and lean body weight (p:0.23, r:0.014, p:0.020, r:0.227, p:0.013, r:0.241). No correlation was found between the 25(OH)D vitamin levels and the basal metabolism rate or mineral or muscle mass. A negative correlation was found between the height SDS

Table 2 Analysis of the bioelectrical impedance analysis (BIA) data by gender

BIA data	Female (n=123)	Male (n=156)	Total	p
Body water mass (%)	55.3±9.51	53.2±9.22	57.0±9.44	0.001*
Amount of body protein (%)	14.7±2.41	14.1±2.45	12.2±2.28	0.000*
Mineral (%)	5.18±0.86	5. 2±0.85	5.30±0.85	0.008*
Body fat mass (%)	24.4±12.3	27.4±12.4	22.0±11.6	0.000*
Body muscle mass (%)	37.6±6.00	36.4±5.81	38.6±5.97	0.001*
Lean body weight (%)	75.3±12.5	72.5±12.4	77.6±12.1	0.001*
Basal metabolism rate (kcal)	971.1±257.4	999.2±238.0	947.8±269.8	0.097

*p<0.05 (significant difference)

Table 3 Analysis of the bioelectrical impedance analysis (BIA) data by body mass index (BMI) for all subjects

	BMI				p
	<-2 SDS (lean) n=52 (18.6%)	1 to -2 SDS (normal) n= 132 (47.3%)	1 to 2 SDS (overweight) n=41(14.7%)	>2 SDS (obese) n=54 (19.4%)	
Age (years)	10.4±4.42	9.42±3.61	10.9±2.95	10.9±3.44	0.058
Height (SDS)	-0.77±1.51	-0.21±1.43	0.92±0.91	0.82±1.25	0.000*
Weight (SDS)	-2.47±0.81	-0.48±1.17	1.37±0.80	2.73±0.66	0.000*
BIA data					
Body water mass (%)	63.6±8.70	58.9±5.33	49.8±5.44	42.7±4.76	0.000*
Amount of body protein (%)	17.1±1.05	15.6±1.48	13.3±1.55	11.4±1.34	0.000*
Mineral (%)	1.56±0.64	1.72±0.78	2.13±0.73	2.51±0.86	0.000*
Body fat mass (%)	11.9±4.85	19.8±7.06	32.3±7.56	41.9±6.46	0.000*
Body muscle mass (%)	41.8±5.42	39.5±4.85	35.1±4.03	30.9±3.57	0.000*
Lean body weight (%)	86.8±9.09	80.1±7.14	67.9±7.38	58.1±6.48	0.000*
Basal metabolism rate (kcal)	863±206.8	915±240.6	1027.5±219.5	1165.6±257.4	0.001*

*p<0.05 (significant difference)

value and several of the BIA data, including the amount of body water, the amount of body protein, mineral weight and lean body weight, in the study group (p:0.008, r:-0.257; p:0.003, r:-0.289; p:0.000, r:-0.21; and p:0.004, r:-0.279, respectively). On the other hand, a positive correlation was found between height and body fat mass and basal metabolism rate (p:0.001, r:0.306 and p:0.003, r:0.284, respectively) (Table 5).

Discussion

Nutritional disorders affect growth in children and are among the first and most significant indicators of a disruption in the general health state. Rapid advancements in science and technology have led to a decrease in health problems related with inadequate nutrition. On the other hand, problems related with overnutrition and excess energy have increased.[8] Malnutrition, which refers to both inadequate and excessive nutrition, has become a significant health problem worldwide. There are regional differences across Europe, obesity rates reaching up to 23% and 29% have been found in the 7-11 age group and 12-18 age group, respectively. The frequency of obesity is usually higher in girls than in boys.[9,10] Studies conducted in our country show that the frequency of obesity in childhood has reached 6.5% and the frequency of being overweight has reached 14.3%. In our study, the frequency of obesity in the 2-17 year age group was found to be 19.4% (10.1% in boys and 9.3% in girls) and the frequency of being overweight was found to be 14.7% (7.5% in boys and 7.2% in girls).[11,12] In conclusion, the frequency of obesity in our study was found to be higher than in other studies conducted in our country but lower than in studies conducted in Europe. The frequency of being overweight was found to be similar to the results of other studies conducted in our country.

Although body composition is being analysed extensively in adults, body composition analysis is a method that is still being developed, especially for use in children, and may be helpful in obtaining information regarding the health and nutritional states of patients.[13] The main components of body composition are fat mass (FM), total body water (TBW) and fat free mass (FFM). Our information related with body composition in children is limited due to the large differences between children and adults. These differences cause additional difficulties in determining body composition in children. It has been shown that lean body weight and water and bone mineral content change during growth.[13] Similarly, body water mass, mineral mass and lean body weight decreased and body muscle mass, fat mass and the basal metabolism rate increased as the age increased within the 2-17-year age group in our study.

In children, the impact of gender is minimal until the

Table 4 The bioelectrical impedance analysis (BIA) data by body mass index (BMI) for subjects whose serum 25(OH)D vitamin levels were examined

	BMI				
	<-2 SDS (lean) n=31 (29.2%)	**1 to -2 SDS (normal) n= 50 (47.2%)**	**1 to 2 SDS (overweight) n=8 (7.5%)**	**>2 SDS (obese) n=17 (16.1%)**	**p**
Age (years)	10.6±4.15	9.00±3.48	11.2±4.24	10.5±3.61	0.317
Height (SDS)	-1.15±1.49	-0.55±1.50	0.73±1.21	0.55±0.92	0.000*
Weight (SDS)	-2.44±0.82	-0.71±1.25	1.30±1.03	2.63±0.72	0.000*
25(OH)D vitamin (ng/ml)	22.9±13.5	25.8±11.8	20.7±7.76	17.9 ±6.69	0.106
BIA data					
Body water mass (%)	62.8±10.86	59.1±5.93	49.9±7.60	42.3±5.60	0.000*
Amount of body protein (%)	17.0±1.10	15.7±1.67	13.3±2.03	11.3±2.04	0.000*
Mineral (%)	6.10±0.41	5.48±0.57	4.88±0.74	3.86±0.54	0.000*
Body fat mass (%)	12.0±4.98	19.5±7.98	31.8±10.3	42.5±7.60	0.000*
Body muscle mass (%)	41.7±5.98	38.8±5.62	35.0±4.99	30.4±3.99	0.000*
Lean body weight (%)	85.9±11.1	80.4±7.97	68.2±10.3	57.4±7.65	0.000*
Basal metabolism rate (kcal)	866.6±206.8	863.7±206.8	1062.6±283.5	1147.1±288.8	0.059

*p<0.05 (significant difference)

age of 10 years, but this impact increases after the age of 10 years.[14] At this time, changes in body composition occur in girls and boys due to increases in sex hormones. Body composition and the segmental distribution of fat and muscle mass begin to vary by gender as age increases.[15] In our study, it was found that body water decreased as the age increased, and more body water was seen in boys than in girls. In 2009, Kaya and Özçelik evaluated 335 adolescent girls aged between 14 and 18 years and 409 adolescent boys aged between 14 and 18 years and found the body fat percentage obtained via BIA to be 23.6±0.3 in the girls years and 21.2±9.9 in the boys.[16] In our study, the body fat percentage obtained via BIA was found to be 29.3±12.8% in the girls and 23.0±12.9% in the boys. In our study, these values were found to be slightly higher.

The basal metabolism rate is affected by many factors, including age, gender, amount of muscle tissue, lean body mass, growth and hormones. In our study, no significant difference was found between genders in terms of the basal metabolism rate. However, it was found that the basal metabolism rate increased as age increased in both female and male subjects. These results show that the basal metabolism rate increases as adolescence approaches.

As the fat mass in the body increases, the amounts of body water and muscle mass decrease. Similarly, it was found that body fat mass, the basal metabolism rate and the mineral rate were increased and the amount of body protein, water, muscle and lean body weight were decreased in obese subjects in our study. In a study conducted in Australia to investigate body compositions in obese children via DEXA and BIA, the body fat percentage obtained via BIA was found to be 41.4±8.3%.[17] In our study, the average body fat percentage in obese subjects was found to be similar (41.9±6.46%).

Adequate nutrition is very important for the development of the bone structure and its ability to endure mechanical stress. Vitamin D levels may be low in lean subjects because of eating habits that lead to inadequate nutrition. Therefore, the correction of malnutrition and the administration of vitamin D is necessary in excessively lean subjects. In a study conducted in Uganda with 158 subjects aged between 6 and 24 months, 117 of whom had malnutrition and 41 of whom had normal weight, serum vitamin D levels were found to range between 32.5 mmol/l and 32.2 mmol/l (below 20 ng/ml) in subjects who had malnutrition.[18] In our study, 25(OH)D vitamin levels were measured in a total of 106 (%38) patients with various medical conditions which may affect the nutritional or vitamin D status. For this reason, the results make it difficult to generalise to other children in the population. Vitamin D levels were found to be low in 40% of the subjects who had normal body weight, excluding subjects who had low body weight.

In our study, 29.2% of subjects whose vitamin D levels were measured were lean, and 16.1% were obese. The frequency of obesity was higher in the male subjects in our study than in the females (12.3% of the male subjects and 3.8% of the female subjects). Although vitamin D levels were investigated at a higher rate in the lean subjects, these levels were found to be higher in these subjects as compared to the obese subjects (the mean vitamin D level was found to be 22.9±13.5 ng/ml in the lean subjects and 17.9±9.69 ng/ml in the obese subjects). This result shows that vitamin D is deposited in the adipose tissue, as stated in other studies. In the study conducted by Wortsman et al, it was reported that there was no significant difference between obese and non-obese subjects in terms of vitamin D synthesis in the skin.[19] In a study conducted by Reinehr et al, 133 obese and 23 non-obese children were examined in terms of

Table 5 Correlation of the bioelectrical impedance analysis data with 25(OH)D vitamin levels and anthropometric measures in subjects whose serum 25(OH)D vitamin levels were examined (Pearson's correlation test)

	Bioelectrical impedance analysis													
	Amount of body water (%)		**Amount of body protein (%)**		**Mineral (%)**		**Body fat mass (%)**		**Body muscle mass (%)**		**Lean body weight (%)**		**Basal metabolic rate (kcal)**	
	p	**r**	**p**	**r**	**p**	**r**	**p**	**r**	**p**	**r**	**p**	**r**	**p**	**r**
25(OH)D vitamin	0.014*	0.237	0.020*	0.227	0.064	0.180	0.021*	-0.223	0.116	0.153	0.013*	0.241	0.1680	-0.086
Height (SDS)	0.008*	-0.257	0.003	-0.289	0.000	-0.333	0.001*	0.306	0.285	-0.105	0.004	- 0.279	0.003	0.284
Weight (SDS)	0.000*	-0.648	0.000	-0.741	0.000	-0.802	0.000*	0.773	0.000	-0.493	0.000	-0.702	0.000	0.461
BMI (SDS)	0.098	-0.686	0.000	-0.792	0.000	-0.842	0.000*	0.825	0.000	-0.583	0.000	-0.745	0.000	0.404

*p<0.05 (significant difference)

vitamin D levels, and vitamin D levels were found to be lower in the obese children than the non-obese children.[20] Similar results were found in our study. In a retrospective study conducted by Smotkin-Tangorra et al with 217 obese children, vitamin D deficiency was found in 55.2% of these children.[21] In our study, vitamin D levels were found to be below 20 ng/mL in ten (58.8%) of 17 subjects**.** It was found that the amount of body minerals also increased as the amount of body fat increased in the 279 subjects included in the study. In 106 subjects whose vitamin D levels were investigates, the amount of minerals was observed to decrease as the amount of body fat increased. However, no significant correlation was found between vitamin D and the amount of minerals in the correlation analysis.

The American Association of Clinical Endocrinologists considers a vitamin D level of 30 ng/mL or above to be adequate.[22] We used the vitamin D classification of the American Association of Clinical Endocrinologists and considered a vitamin D level of 20 ng/mL or below to be deficient, a vitamin D level of 21-29 ng/mL to be insufficient and a vitamin D level of 30 ng/mL or above to be normal.[22] In a study conducted by Absoud et al with 1,102 children and adolescents aged between 4 and 18 years in Great Britain, vitamin D deficiency (<20 ng/mL) was found in 35% of the participants.[23] Similarly, the vitamin D level was found to be below 20 ng/mL in 48.1% of the subjects and between 21 and 29 ng/mL in 28.5% of the subjects in our study. Vitamin D deficiency or insufficiency were found in 76.4% of the subjects.

Adolescent girls have a lower intake of vitamin D via foods and lower serum 25(OH)D levels as compared to boys.[24] The subjects in the adolescent group who particpated in our study were not receiving vitamin D. Severe and prolonged vitamin D deficiency in adolescence may be asymptomatic and go unnoticed, in contrast to vitamin D deficiency in children. In a study conducted by Rockell et al with 1,585 children aged between 5 and 14 years in New Zeland, vitamin D levels were found to be below 15 ng/ml in 31% of the participants and lower in the girls as compared to the boys.[25] One meta-analysis emphasized that being an adolescent was a risk factor for vitamin D deficiency and that vitamin D deficiency was more frequent in girls than boys.[24] In our study, serum 25(OH)D vitamin levels were found to be lower in adolescent girls as compared to boys in the same age group.

Our study is one of the few studies to examine the relationship between nutritional status, as determined via BIA, and 25(OH)D vitamin levels. As observed in this study, 25(OH)D deficiency is common in children. The improvement of vitamin D levels across all age groups is important because vitamin D plays a significant role in the lifecycle of the human body.

It is important to highlight that we cannot generalise our results, principally due to the small sample size. Therefore BIA data may not be sufficient to represent children's nutritional status. When the results obtained in our study were evaluated, certain limitations were observed. These limitations include a lack of consideration of the nutritional information regarding the subjects, the low number of the subjects, the inability to fully evaluate clothing style, which is one of the factors that affects vitamin D level; and the failure to use questionnaires regarding eating frequency.

In conclusion, vitamin D deficiency is commonly observed in adolescents according to the results obtained in our study. Female adolescents and obese individuals are at risk in terms of vitamin D deficiency. Therefore, the regulation of nutrition and vitamin D supplementation are necessary in obese individuals. The body composition in children with malnutrition might make them susceptible to nutricional disorders; therefore, a health-oriented nutrition education is necessary in order to modify dietary habits. In addition, the evaluation of nutritional status and body fat composition via BIA may be a helpful and reliable method of preventing and treating childhood obesity.

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Declaration of Interest

The authors declare that there is no conflict of interest.

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