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The Relationship between Body Compositions and Serum Vitamin D Levels in Obese Adolescents

Muhammed Abdullah Varol[1*], Prof. Dr. Yasemin Altuner Torun[2], Çiğdem Karakükçü[3], Durmuş Doğan[4]

[1]Pediatrician, Department of Pediatrics, Private Medigün Hospital Soma, Manisa, Türkiye
[2]Division of Pediatric Hematology Oncology, Department of Pediatrics, Istinye University School of Medicine, İstanbul Türkiye
[3]Department of Biochemistry, Erciyes University School of Medicine, Kayseri, Turkey
[4]Department of Pediatrics, Çanakkale Onsekiz Mart University Faculty of Medicine, Çanakkale, Turkey

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***Corresponding author:** Muhammed Abdullah Varol
Pediatrician, Department of Pediatrics, Private Medigün Hospital Soma, Manisa, Türkiye

Abstract **Original Research Article**

Purpose**:* Obesity and vitamin D deficiency is a significant public health problem with increasing frequency in childhood. Although numerous studies explored the correlation between obesity and vitamin D, the study is aimed to investigate such relationship in consideration of few/no studies on vitamin D and body compositions in obese people. ***Methods**:* A total of 62 adolescents aged 12 to 18 were included in the study, comprising 33 obese adolescents and 29 with normal weight. Blood samples were analyzed for 25-hydroxyvitamin D (25(OH)D), calcium (Ca), phosphorus (P), magnesium (Mg), alkaline phosphatase (ALP), parathyroid hormone (PTH), insulin, C-reactive protein (CRP), total cholesterol, LDL cholesterol (LDL), triglycerides (TG), and HDL cholesterol (HDL). Body fluid status and composition were assessed using bioimpedance spectroscopy (BIS) for both the obese and control groups. ***Results: Total body water (TBW), extracellular water (ECW), intracellular water (ICW), ECW/ICW (E/I) ratio, lean tissue index (LTI), adipose tissue index (FTI), lean tissue mass (LTM), adipose tissue mass (ATM), body cell mass (BCM) values were significantly higher in the obese group in comparison with the control group ($p < 0.05$). There was no significant difference in 25(OH)D levels in the obese and control groups ($p > 0.05$). The distribution of 25(OH)D values below and above 20 did not differ significantly in the obese and control groups ($p > 0.05$). Cholesterol, insulin and HOMA-IR values were detected significantly higher in the obese group than in the control group ($p < 0.05$). HDL and Ca values were significantly lower in the obese group than in the control group ($p < 0.05$). A significant positive correlation was discovered between BMI value and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values ($p < 0.05$). A significant positive correlation was discovered between HOMA IR value and TBW, ECW, ICW, E/I, FTI, FAT, ATM values ($p< 0.05$). No significant correlation was encountered between 25(OH)D value and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values ($p >0.05$). A significant negative correlation was discovered between HDL value and ECW, LTI, BCM values ($p <0.05$). A positive correlation was found between serum total cholesterol, LDL cholesterol and triglyceride levels and LTI ($p<0.05$). ***Conclusion:*** Although it is known that vitamin D is generally low in obese people due to the storage of which in adipose tissue, there was no significant difference between 25(OH)D levels in the obese and non-obese groups in our study. As the BMI value increased, significant increases were observed in TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM parameters. In this study, we did not find any significant relationship between 25(OH)D and body composition. In such case, more studies are needed to argue that changes in body water and fat distribution have no effect on serum 25(OH)D levels or that 25(OH)D does not affect body water and fat distribution.

Keywords: Adolescent, obesity, 25(OH) vitamin D, body composition.

1. INTRODUCTION AND PURPOSE

Obesity, an important health problem due to its increasing frequency all over the world, exhibits increase in childhood with the decrease in physical activity and the change in eating habits [1]. The most common type of obesity in children is simple (exogenous) obesity; that is, there is no underlying endocrine or syndromic problem [2]. The most important reason why obesity, observed with increasing frequency, is perceived as a critical health problem in children is that it leads to hyperinsulinemia and insulin resistance, which in turn results in "metabolic syndrome in which hypertension, imbalance in blood fat levels, atherosclerosis, coronary heart disease, and type 2 diabetes form sub-clinical reflections [3,4]. In recent years, it has been suggested that vitamin D prevents the formation of the foresaid

diseases caused by obesity and insulin resistance, while its deficiency facilitates the emergence of these diseases [5].

Obese people have a high risk of vitamin D deficiency [6]. Recent studies set forth that vitamin D deficiency in obese people is directly proportional to BMI [7,8]. It is further stated that 25(OH)D levels in overweight and obese individuals are lower than in normal weight individuals [9,10].

Obesity-related vitamin D deficiency is pertinent to the decrease in the availability of vitamin D with skin and dietary properties as a result of accumulation in body fat compartments. Since vitamin D is stored in fat, there is an inverse relationship between obesity and 25(OH)D. Compared to normal weight adolescents, the need for vitamin D is higher in obese people. Obesity does not affect the skin's vitamin D synthesis capacity, on the contrary, it leads to more accumulation in the subcutaneous adipose tissue, reducing its availability [7]. With bioimpedance, body composition is measured indirectly using two bioelectrical parameters (resistance and reactance). It is simply based on the principle of detecting body water and composition by giving electric current to the human body at very low levels and at different frequencies [11].

The BIA method, which is used in the evaluation of the body composition of obese individuals, is frequently used in the evaluation of body compositions in terms of being safe as well as being cost-effective and giving effective results. Adipose tissue and distribution areas are different in obese girls than in boys, and it has been reported that muscle mass in boys is significantly higher than in girls [12,13].

There are studies on obesity in children and adolescents, vitamin D and measurement of body composition by bioimpedance method. However, to the best of our knowledge, there is no study examining the relationship between body composition and serum vitamin D level in obese adolescents using the BIA method. For this reason, our study aimed to evaluate the relationship between body composition and serum vitamin D levels in obese adolescents.

2. PATIENTS AND METHODS

This study was commenced with the approval of the Faculty of Medicine Ethics Committee (05.06.2015–2015/275: decision no: 40). Informed verbal and written consent was obtained from the legal parents of the children included in the study. A total of 27 boys and 35 girls who met the criteria were included in the study.

Inclusion Criteria:

- Being between the ages of 12 and 18.
- Tanner stage + 2 and above for girls.
- For obese patients, BMI should be above the 95th percentile and there should be no additional diseases.
- Not having a chronic disease and having a normal physical examination for the control group.

Criteria for dismissal from the study:

- The occurrence of systemic inflammatory diseases during the course of study.

Working Method

The subjects included in the study were evaluated in terms of the following parameters in the summer period (June-July-August 2015).

62 people in total participated in the study. The demographic characteristics of the people participating in the study were recorded and their height, weight, body mass index, systolic and diastolic blood pressures were measured. Blood samples of the study participants were taken from the forearm vein early in the morning following an 8-hour fasting period.

Ca, P, Mg, PTH, ALP, 25-Hydroxyvitamin D, FBS, lipid panel and insulin levels were studied in serum samples taken from the subjects.

Bioimpedance measurement: (BCM-Fresenius Medical Care D GmbH) BCM - Body Composition Monitor was used to measure the patient's fluid status and body composition through BIS method. For the measurement, a total of 4 electrodes, two electrodes on both hands and two feet, were attached to the wrists and the back of the hands and feet in the supine position, 1 cm proximal to the wrists and metacarpo phalangeal and metatarsophagonal joints, and the measurements were completed in 1-4 minutes after having entered the age, weight and height data for each patient.

Parameters considered in bioimpedance measurement:

ATM : Adipose Tissue Mass
BCM : Body Cell Mass
E/I : ECW/ICW
ECW : Extracellular Water
FAT : Fat mass
FTI: Fat Tissue Index (FTI = Fat/height2) (The adipose tissue index was calculated by dividing the ATM in kilograms by the square of the height in meters.)
ICW : Intracellular Water
LTI: Lean Tissue Index (LTI = LTM/height2) (The lean tissue index was calculated by dividing the lean tissue mass (LTM) in kilograms by the square of the height in meters.)
LTM : Lean Tissue Mass
TBW : Total Body Water

Statistical Method

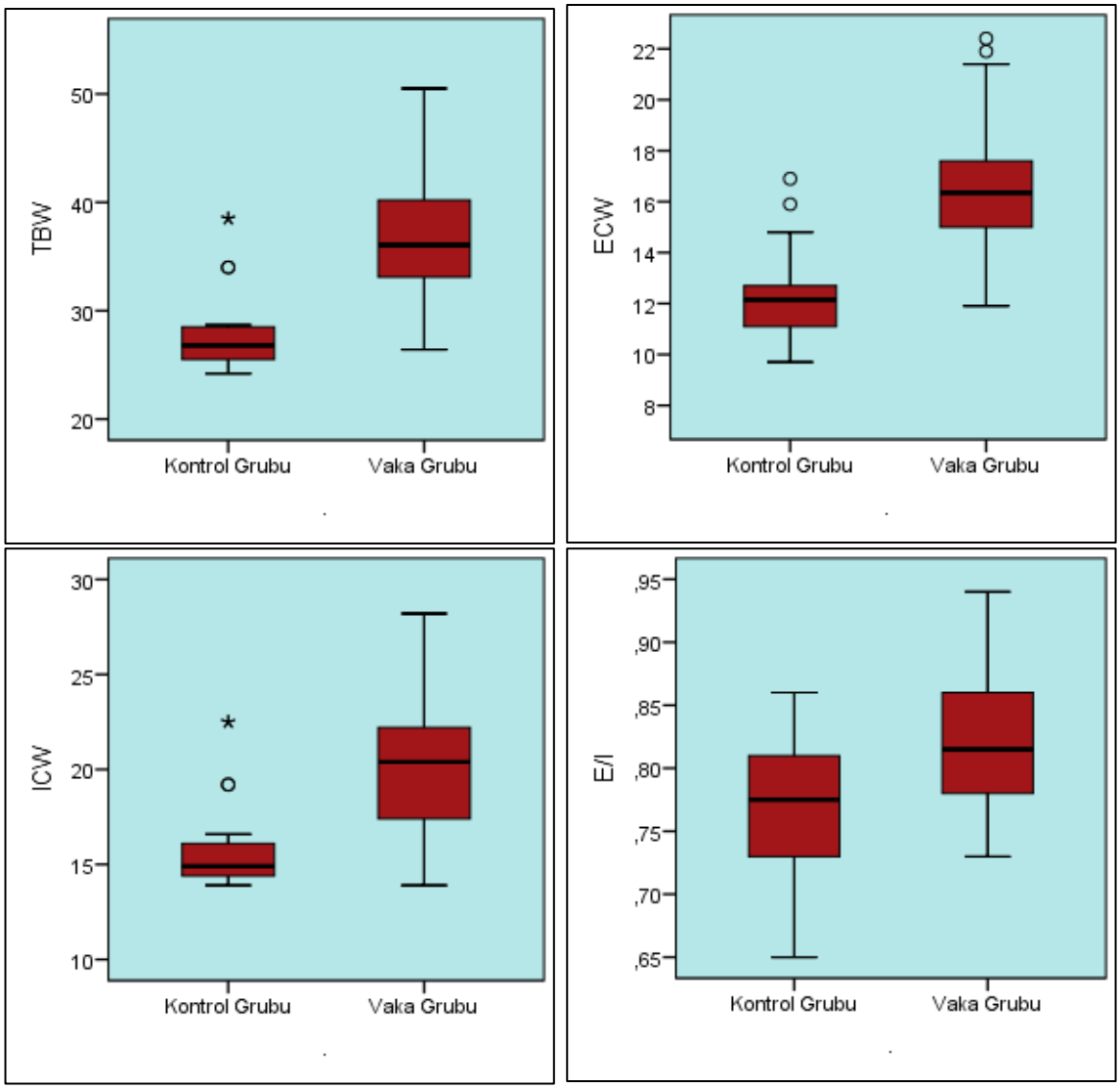
In the descriptive statistics of the data, mean, standard deviation, median lowest, highest, frequency and ratio values were employed. The distribution of variables was measured by the Kolmogorov-Smirnov test, Mann-Whitney U test and independent sample t-test were used in the analysis of quantitative data. Chi-square test was used to analyze qualitative data. Spearman correlation analysis was used in correlation analysis. SPSS 22.0 program was employed in the analysis.

3. RESULTS

TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values turned out significantly higher in the case group than in the control group ($p < 0.05$) (Table 1) (Figure 1).

Table 1: Body composition measurements of the groups

	Mean ± sd	Med	(Min-Max)	Mean ± sd	Med	(Min-Max)	p
TBW		26,3	24,2 - 3 3-,5		36,1	26,4 - 50,5	***<0,0001***
ECW		12,2	9,7 - 16,9		16,4	11,9 - 22,4	***<0,0001***
ICW		14,9	13,9 - 22,5		20,4	13,9 - 23,2	***<0,0001***
E/I		0,8	0,7 - 0,9		0,S	0,7 - 6,3	***0,002***
LTI	12,5 ±1,2			14,1 ± 1,7			***<0,0001***
FTI	8,2 ± 2,5			13,2 ± 4,3			***<0,0001***
LTM		31,8	23,3 - 50,3		39,4	25,S - 53,5	***0,001***
FAT		16,3	9,3 - 21,7		36,5	21,2 - 53,6	***<0,0001***
ATM		22,0	13,3 - 29,6		49,7	23,3 - 72,9	***<0,0001***
BCM		17,4	14,9 - 23,6		22,0	13,S - 30,2	***0.001[m]***



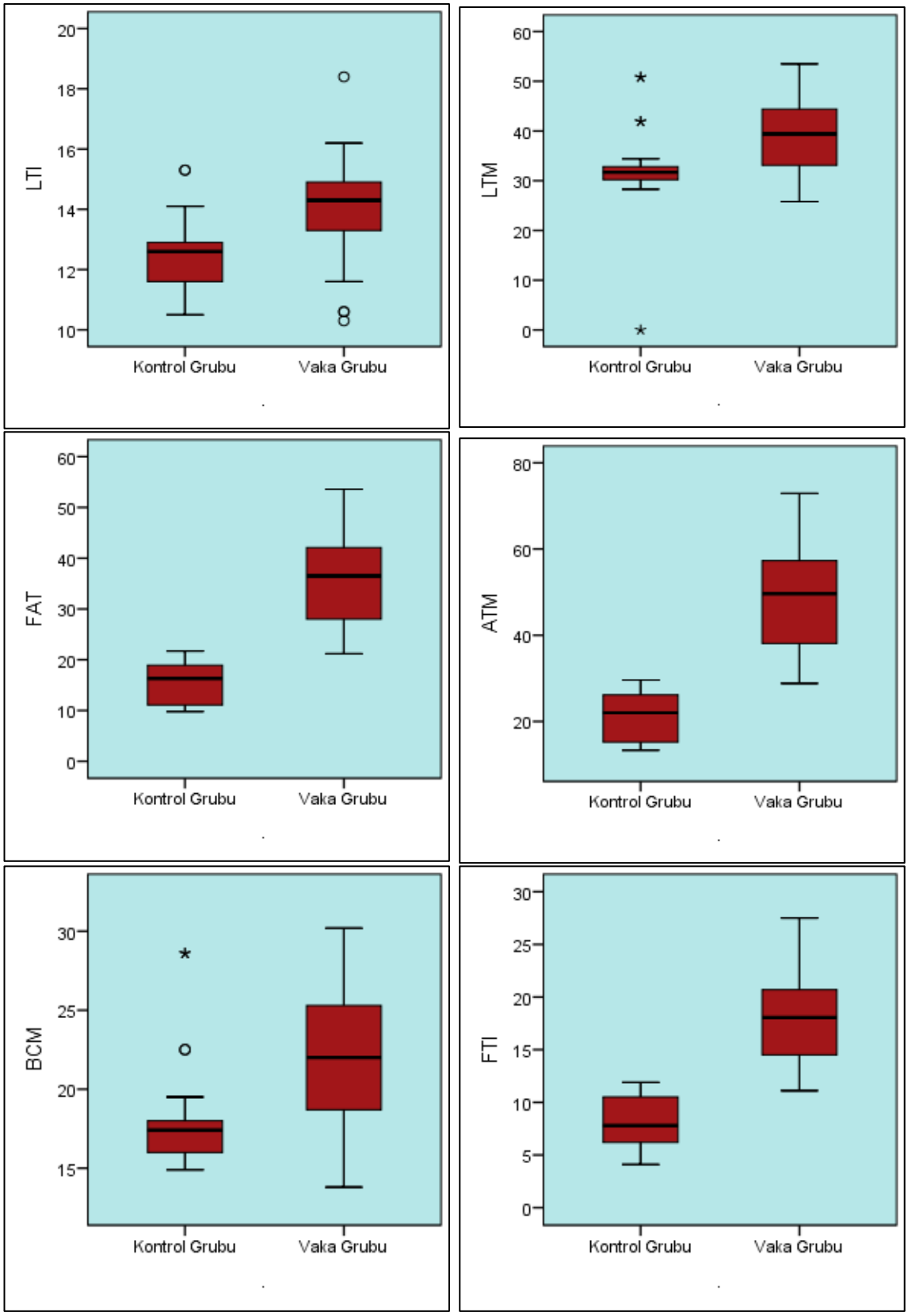


Figure 1: Body composition graphs of the groups

LDL, TG, P, MG, ALP, PTH, CRP, 25(OH)D values did not differ significantly in the control and obese groups ($p > 0.05$). The distribution of 25(OH)D above 20 in the obese and control groups did not differ significantly either ($p>0.05$) (Table 2).

Cholesterol and insulin values were significantly higher in the obese group than in the control group ($p < 0.05$).

HDL and Ca values were significantly lower in the obese group than in the control group ($p < 0.05$).

HOMA-IR value was significantly higher in the obese group than in the control group (Table 2).

Table 2: Biochemical measurements of groups

		Control Group				Subject group			
		Mean ± sd	**Med**	**(Min-Max)**		**Mean ± sd**	**Med**	**(Min-Max)**	**P**
ALP		161,2 ± 84,4				164,4 ± 76,0			0,882
LDL		70,5 ± 19,5				83,6 ± 23,5			0,051
TG		78,0 ± 33,0				105,3 ± 55,5			0,869
CA		9,8 ± 0,4				9,6 ± 0,3			***0,003***
P		3,7 ± 0,5				3,6 ± 0,6			0,808
25-OH-D		17,1 ± 6,0				17,7 ± 9,5			0,773
HDL			47	36	- 72		46	26 - 73	<***0,001***
Glucose			96	87	- 118		92	76 - 115	***0,005***
Cholesterol			130	95	- 190		152	93 - 222	<***0,001***
MG			2,1	1=7	- 3,0		2,1	1,8 - 2,4	0,382
PTH			34,9	14,5	- 88,2		34,0	16,6 - 84,7	0,607
CRP			3,2	3,2	- 14,8		3,2	3,2 - 14,3	0,122
INSULIN			7,7	2,6	- 24,7		11,9	1,5 - 73,3	***0,007***
HOMA-IR			1,8	0,6	- 6,3		2,7	0,3 - 17,4	***0,022***
25(0H)D	≤30 30 >	26 92,9% 1 3.6%				28 82,4% 3 8,8%			0.615 x^2

		Control group	**Subject group**	
		n *%*	n *%*	P
25-OH-D	<20 20>	20 71.4% 7 25.0%	21 61.8% 10 29.4%	0.59 Tx^2

A significant positive correlation was revealed between BMI value and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values ($p < 0.05$) (Table 3).

Table 3: The relationship between BMI and body compositions

		TBW	ECW	ICW	E/I	LTI
BMI	r	0.665	0.721	0.567	0.492	0.392
	p	***0.000***	***0.000***	***0.000***	***0.000***	***0.002***
		FTI	LTM	FAT	ATM	BCM
BMI	r	0.969	0.282	0.946	0.945	0.297
	p	***0.000***	***0.026***	***0.000***	***0.000***	***0.019***
Spearman Korelasyon						

A significant positive correlation was evident between HOMA IR value and TBW, ECW, ICW, E/I, FTI, FAT, ATM values ($p< 0.05$) (Table 4)

Table 4: **Relationship between HOMA-IR and body compositions**

		TBW	ECW	ICW	E/I	LTI
HOMa-IR	r	0.346	0.388	0.324	0.281	0.244
	p	***0.010***	***0.003***	***0.016***	***0.040***	0.073
		FTI	LTM	FAT	ATM	BCM
HOMa-IR	r	0.285	0.192	0.346	0.345	0.223
	p	***0.035***	0.161	***0.010***	***0.010***	0.102

Spearman Correlation

There was no significant correlation between serum 25(OH)D levels and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values (p >0.05) (Table 5,6).

Table 5: The relationship between 25(OH)D level and body composition in obese patients

	25 - OH-D	
Obese Group	r	p
TBW	-0,18	0,33
ECW	-0,2	0,29
ICW	-0,12	0,52
E-I	-0,26	0,17
LTI	-0,02	0,9
FTI	-0,26	0,2
LTM	0,15	0,45
ATM	-0,11	0,57
BCM	-0,01	0,98

Table 6: The relationship between 25(OH)D level and body compositions in the control group

	25 - OH-D	
Control Group	r	p
TBW	0,03	0,89
ECW	0,12	0,54
ICW	-0,07	0,72
E-I	-0,01	0,94
LTI	-0,08	0,68
FTI	-0,14	0,45
LTM	-0,05	0,78
ATM	-0,22	0,24
BCM	-0,02	0,91

A significant positive correlation was discovered between cholesterol levels and TBW, ECW, ICW, LTI, FTI, LTM, ATM, BCM values (p < 0.05). There was no significant correlation between cholesterol value and E/I value (p >0.05) (Table 7).

There was a significant positive correlation between LDL value and LTI value (p < 0.05). There was no significant correlation between LDL value and TBW, ECW, ICW, E/I, FTI, LTM, ATM, BCM values (p >0.05) (Table 7).

A significant positive correlation was revealed between TBW, ECW, ICW, LTI, FTI, LTM, ATM, BCM values and TG values (p < 0.05). There was no significant correlation between TG value and E/I value (p >0.05) (Table 7).

A significant negative correlation was found between HDL value and ECW, LTI, BCM values (p < 0.05). There was no significant correlation between HDL value and TBW, ICW, E/I, FTI, LTM, FAT, ATM values (p >0.05) (Table 7).

There was no significant correlation between LDL level and TBW, ECW, ICW, LTI, LTM, BCM values (p >0.05) (Table 7).

Table 7: The relationship between lipid profile and body compositions

		TBW	ECW	ICW	E/I	LTI
Cholesterol	r	0.334	0.351	0.381	-0.019	0.397
	P	***0.020***	***0.015***	***0.008***	0.901	***0.005***
LDL	r	0.230	0.254	0.275	-0.083	0.330
	P	0.116	0.081	0.059	0.581	***0.022***
TG	r	0.422	0.362	0.413	-0.076	0.411
	P	***0.003***	***0.012***	***0.004***	0.611	***0.004***
HDL	r	-0.224	-0.123	-0.204	0.257	-0.352
	P	0.130	0.410	0.16S	0.085	***0.015***
		FTI	LTM	FAT	ATM	BCM
Cholesterol	r	0.395	0.310	0.409	0.407	0.327
	P	***0.006***	***0.032***	***0.004***	***0.004***	***0.023***
LDL	r	0.278	0.245	0.274	0.272	0.255
	P	0.056	0.093	0.059	0.061	0.081
TG	r	0.320	0.389	0.342	0.334	0.428
	P	***0.027***	***0.006***	***0.017***	***0.020***	***0.002***
HDL	r	-0.007	-0.306	0.012	0.020	-0.344
	P	0.961	***0.036***	0.935	0.895	***0.018***

There was no significant correlation between ALP level and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values ($p > 0.05$) (Table 8).

There was a significant negative correlation between Ca level and E/I, FTI, ATM values ($p < 0.05$) (Table 8).

There was no significant correlation between p level and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values ($p > 0.05$) (Table 8).

There was no significant correlation between MG level and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values ($p > 0.05$) (Table 8).

There was no significant correlation between PTH level and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values ($p > 0.05$) (Table 8).

Table 8: Relationship between Ca, P, Mg, ALP, PTH and body compositions

		TBW	ECW	ICW	E/I	LTI
ALP	r	0.094	0.092	0.093	-0.037	0.159
	p	0.488	0.495	0.491	0.789	0.238
CA	r	-0.207	-0.244	-0.120	-0.352	-0.141
	p	0.126	0.069	0.377	***0.008***	0.300
P	r	0.027	-0.006	0.030	-0.037	0.131
	p	0.846	0.966	0.831	0.793	0.344
MG	r	0.056	0.001	0.066	-0.100	0.056
	p	0.685	0.993	0.634	0.474	0.688
PTH	r	-0.063	-0.050	-0.110	0.053	-0.051
	p	0.658	0.725	0.439	0.713	0.722
		FTI	LTM	FAT	ATM	BCM
ALP	r	-0.127	0.133	-0.080	-0.070	0.130
	p	0.346	0.325	0.553	0.603	0.337
CA	r	-0.390	-0.016	-0.335	-0.337	-0.023
	p	***0.003***	0.909	***0.012***	***0.011***	0.866
P	r	-0.037	0.046	-0.032	-0.033	0.069
	p	0.791	0.743	0.816	0.812	0.620
MG	r	-0.089	0.093	-0.077	-0.069	0.054
	p	0.521	0.505	0.581	0.622	0.697
PTH	r	-0.134	-0.095	-0.130	-0.128	-0.080
	p	0.345	0.504	0.359	0.364	0.573

Spearman Correlation

4. DISCUSSION

In this study, BIA method was employed to evaluate the body composition of obese children. In the group of obese patients, TBW (Total body water), ECW (Extracellular water), ICW (Intracellular water), E/I: ECW/ICW, LTI (Lean tissue index), FTI (Adipose tissue index), LTM (Lean tissue mass), and ATM (Adipose tissue mass), BCM (Body cell mass) values were observed to be significantly higher than the control group.

In the body of the literature, there are limited publications on the measurement of body composition by bioimpedance method in obese adolescents. In our obese group, body fat percentages were discovered to be higher than in the normal weight control group, as we expected. Furthermore, LTM, which shows muscle mass, being higher than the control group suggests that muscle mass may have increased in order to carry increased body weight in obese patients. There are publications in the body of the literature demonstrating that both adipose and non-adipose tissue compartments, especially skeletal muscle mass, increase as BMI increases [14]. We are of the opinion that TBW increases on account of high number of BCM in obese people. Moreover, the increase in the E/I ratio in obese people has shown that ECW increases more than ICW in obese patients.

In our study, a significant positive correlation was detected between BMI value and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values. In other words, as the body-mass index increases, total fluid volume, lean tissue and adipose tissue mass increase. In a study by Luke *et al.*, a strong correlation was found between BMI and adipose tissue mass [15]. In our study, as BMI increased, ATM and FTI increased more than TBW, LTM and LTI. In other words, BMI was increased by adipose tissue rather than total body water and muscle mass.

Our study revealed that 25(OH)D and PTH values did not differ significantly in the control and obese groups. However, vitamin D deficiency was common in both groups. Ca values were significantly lower in the obese group than in the control group, even though they were at normal serum values. In our study, vitamin D was not lower in obese patients than in the control group, although calcium was low. In obese patients, it may be dilutional due to excess extracellular fluid.

Excessive vitamin D deficiency in both groups is suggestive of the fact that vitamin D deficiency is a result of its prevalence in Turkey. Although Turkey has a sun-rich geography, vitamin D deficiency continues to be an important problem affecting pregnant women, infants and adolescent children [16].

The relationship between childhood obesity and vitamin D status is well defined [17]. In some studies on this subject, it is stated that vitamin D deficiency is common among obese children. In a retrospective study conducted by Smotkin-Tangorra *et al.*, [18] on 217 obese children, vitamin D deficiency turned out in 55.2% of these children. In the same study, BMI was found to be higher in the vitamin D deficiency group than in those without it, while 25(OH)D levels were found to be negatively correlated with BMI. Total body fat is closely correlated with 25(OH)D, which indicates the status of vitamin D, and accumulation in adipose tissue has been demonstrated to be the cause of vitamin D deficiency in obese people [19]. Body fat percentage is inversely related to serum 25(OH)D levels, and high body fat percentage may play a key role in explaining both insulin resistance and low vitamin D levels [20]. In the study conducted by Wortsman *et al.*, [21], it is suggested that there is no significant difference between obese and non-obese people in terms of vitamin D production in the skin, and that the vitamin D made in the skin is stored in the subcutaneous adipose tissue to a large extent as the cause of vitamin D deficiency in obese people, and in addition, the intake from food sources decreases. Moreover, in many studies, it is revealed that vitamin D levels in obese people are lower in comparison with the healthy people [21, 22], and in some of these studies, it is also demonstrated that there is an inverse relationship between BMI and 25(OH)D levels [22]. In addition, there are publications reporting high PTH levels with low serum 25(OH)D levels in obese patients [21]. In their study, Parikh *et al.*, [23] discovered 25(OH)D and 1,25(OH)2D levels to be low and PTH levels to be high in obese patients regardless of age, gender, and race.

In our study, although an increase in PTH levels was expected in patients with vitamin D deficiency, there was no difference between obese and non-obese cases in terms of PTH values when the general average was scrutinized.

As known, an increase in PTH level is expected in case of a deficiency of 25(OH)D level [24]. In our study, although vitamin D levels were low in both the obese and control groups, PTH levels were found to be normal. This suggests that calcium metabolism is balanced in all cases, and that calcium balance can be maintained even at these low levels.

In our study, although BMI in obese patients was significantly higher than in healthy subjects, serum PTH levels were similar to those of healthy controls, and there was no significant increase in PTH levels in the obese group.

This study fails to set forth that the increase in BMI in obese cases is related to PTH. Based on all these data, it is not possible to argue that increased PTH causes obesity or obesity causes PTH increase. However, it does not seem possible to completely reject such views due to the limited number of cases in our study.

No nutritional record was taken for daily calcium intake of the cases in our study. However, the measurement of PTH levels provides us with information about vitamin D intake or insufficiency, as well as indirectly about calcium intake. Nevertheless, significantly lower serum calcium level in obese cases than in the healthy group may help us comment that the calcium intake of these cases is not sufficient.

The results obtained in this study, which included a limited number of cases, suggest the hypothesis of low vitamin D levels in obese patients and storage in adipose tissue stated in the body of the literature. However, we can argue that the detection of similar PTH and vitamin D levels in the control group, and the similar vitamin D results in cases with normal and excess fat mass do not comply with the argument that serum levels are low because vitamin D is stored in adipose tissue. However, the prevalence of vitamin D deficiency in our entire study group may lead us to reach conclusions that contradict the body of the literature. Contrary to what is stated, PTH (25), which is a hormone that increases fat production, was detected at similar levels in obese cases to healthy cases, suggesting that obese cases were similar to the healthy group in terms of vitamin D intake.

It is known that obesity that develops in childhood leads to insulin resistance in the future [26]. The advanced effects of insulin resistance and obesity are progressive cardiovascular disease, high blood pressure, and type 2 DM [27]. In our study, we employed HOMA-IR as a criterion to describe insulin resistance. We relied on HOMA-IR ≥2.5 as an indicator of insulin resistance. In our study, the mean HOMA-IR was found to be high (2.7) in obese cases, while the mean HOMA-IR remained to be 1.8 in the control group. Insulin and HOMA-IR values turn out to be significantly higher in the obese group than in the control group. In addition, TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values, which demonstrated a significant increase in the obese group, also exhibited a positive correlation with HOMA-IR.

Our study revealed no significant correlation between 25(OH)D level and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values. In a study conducted by Pludowski *et al.*, in primary hypertensive children and adolescents, lean body mass is positively correlated with vitamin D levels, and body fat mass is negatively correlated [28]. Moreover, in a study conducted in the Korean population, a negative correlation was revealed between serum 25(OH)D level and total body fat amount [30]. However, no such relationship was discovered in our study.

In our study, a significant negative correlation exists between HDL value and ECW, LTI, BCM values. There was no significant correlation between HDL value and TBW, ICW, E/I, FTI, LTM, FAT, ATM values.

In a study conducted by Pietrobelli *et al.*, no significant relationship was evident between HDL and adipose tissue components, as is the case in our study. However, a significant correlation was prevalent between higher BCM, muscle mass and lean tissue mass and lower serum HDL concentration. They expounded the process where as muscle mass increases, HDL concentration decreases with attribution to the lipoprotein lipase enzyme in the muscle increasing HDL catabolism [31].

This study demonstrates a positive correlation between cholesterol, LDL cholesterol and triglyceride levels and LTI, and a negative correlation between HDL cholesterol and LTI. In the body of the literature, LTI is set out to be an independent determinant of leptin/adiponectin ratio (L/A), which has been defined as a new marker for atherosclerosis. A low LTI level is indicative of protein malnutrition. As the LTI falls, the L/A ratio decreases. As obesity increases, the L/A ratio increases. High L/A ratio is associated with cardiovascular complications [32,33]. Therefore, it is suggested that high LTI values may be associated with cardiovascular complications.

Vitamin D deficiency in adolescents appears to be a common public health problem. Although it is known that vitamin D is generally low in obese people owing to the fact that it is stored in adipose tissue, there was no significant difference between 25(OH)D levels in the obese and non-obese groups in our study. As the BMI value increased, significant increases were observed in the measured bioimpedance parameters. In this study, we fail to find a significant relationship between 25(OH)D and body composition. As such, more studies are needed to conclude that changes in body water and fat distribution have no effect on serum 25(OH)D level, or that 25(OH)D does not affect body water and fat distribution.

5. CONCLUSIONS

1. TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values were found to be significantly higher in the obese group than in the control group.
2. A significant positive correlation was revealed between BMI and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values.
3. Serum 25-OH-D levels did not differ significantly in the control and obese groups. The distribution of 25(OH)D values above and below 20 and 30 ng/mL did not differ significantly in the obese and control groups. However, vitamin D deficiency was evident in both groups. Ca value was significantly lower in the obese group than in the control group.
4. While the mean HOMA-IR was discovered to be high in obese cases, the mean HOMA-IR was within normal limits in the control group. Serum insulin level and HOMA-IR value were

significantly higher in the obese group than in the control group. In addition, a significant positive correlation was revealed between HOMA IR value and TBW, ECW, ICW, E/I, FTI, FAT, ATM values.

5. No significant correlation was revealed between serum 25(OH)D levels and TBW, ECW, ICW, E/I, LTI, FTI, LTM, ATM, BCM values.
6. A significant negative correlation was discovered between HDL value and ECW, LTI, BCM values.
7. Positive correlation existed between serum cholesterol, LDL cholesterol and triglyceride levels and LTI while a negative correlation was evident between HDL cholesterol and LTI.

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