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redakcja@pediatricendocrinology.pl
www.pediatricendocrinology.pl
www.pteidd.pl

Serum vitamin D level may be associated with body weight and body composition in male adolescents – a longitudinal study

Stężenie witaminy D w surowicy może mieć związek z masą i składem ciała u nastolatków płci męskiej – długotrwałe badanie

[1,2]Saeid Doaei, [3]Seyed Alireza Mosavi Jarrahi, [4]Saheb Abbas Torki, [5]Rouhollah Haghshenas, [5]Zahra Jamshidi, [6,7]Shahla Rezaei, [8]Alireza Moslem, [9]Fereshteh Ghorat, [10,11]Adeleh Khodabakhshi, [12]Maryam Gholamalizadeh

[1]Cancer Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2]Department of Health Education, Research Center of Healthand Environment, School of Health, Guilan University of Medical Sciences, Rasht, Iran
[3]Center for Cancer Epidemiology, West Asia Organization for Cancer Prevention, Sabzevar University of Medical Sciences, Iran
[4]Department of Nutrition, Faculty of Nutrition Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
[5]Department of Physical Education, Semnan University, Semnan, Iran
[6]Student Research Committee, Shiraz University of Medical Sciences, Shiraz, Iran
[7]Department of Clinical Nutrition, School of Health & Nutrition, Shiraz University of Medical Sciences, Shiraz, Iran
[8]Iranian Research Center on Healthy Aging, Sabzevar University of Medical Sciences, Sabzevar, Iran
[9]Non-Communicable Diseases Research Center, Sabzevar University of Medical Sciences, Sabzevar, Iran
[10]Department of Nutrition, School of Public Health, Kerman University of Medical Sciences, Kerman, Iran
[11]Physiology Research Center, Kerman University of Medical Sciences, Kerman, Iran
[12]Student Research Committee, Cancer Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Abstract

Introduction: The prevalence of both obesity and vitamin D deficiency has been dramatically increased worldwide.

Aim of the study: This study aimed to investigate the association between vitamin D serum level and anthropometric indices of overweight and obese male adolescents at baseline and after 18 weeks of a weight reduction intervention.

Methods: This study was carried out on 90 male students aged 12 to 16 years who were randomly selected from two schools in Tehran, Iran. The participants were assigned to two groups with high and low vitamin D level based on their serum vitamin D levels at baseline. Five ml blood samples were collected at the baseline and after the 18 weeks of a weight reduction intervention. Height, weight, body mass index (BMI), body fat percent and body muscle percent were measured using a bio impedance analysis (BIA) scale.

Results: Vitamin D level in non-obese adolescents was significantly higher than the obese participants (44.01 vs 37.67 ng/dl, $p < 0.04$). However, there was no significant correlation between changes of vitamin D level and anthropometric measurements after 18 weeks. Adjusting the effect of age did not alter the association. Further adjustments for physical activity, dietary intake of vitamin D, and fat and muscle percentage had no effect on the results.

Conclusion: The serum level of vitamin D was negatively associated with obesity, but not with short-term changes of anthropometric measurements in male adolescents.

Key words:
vitamin D, obesity, adolescents, body composition, BMI.

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Maryam Gholamalizadeh
Nutrition and Endocrine Research Center
Shahid Beheshti University of Medical Science
Jannat, 0021, Tehran, Iran
e-mail: gholamalizadeh@sbmu.ac.ir

Introduction

Obesity is one of the most serious health problems in both developing and developed countries [1]. Obesity and overweight has dramatically increased among children and adolescents over the past 3 decades [2]. The prevalence of obesity in Iranian adolescents is 11.9% [3]. The worldwide rise in the obesity rate of the school-aged children [4] is a risk factor for childhood obesity and is also associated with certain diseases including type 2 diabetes mellitus, heart diseases, hypertension, dyslipidemia, and other chronic conditions [4–6].

Vitamin D deficiency is an important public health problem and may be associated with obesity [5]. Some studies have reported that obesity might be related to deficiency of some micronutrients such as vitamin D [7–10]. Some studies found a link between vitamin D deficiency and obesity [7–10]. Vitamin D deficiency is apparently linked with unhealthy diet and the lack of sun exposure [8–10]. The sedentary lifestyle and less outdoor activity have important roles in both obesity risk and vitamin D deficiency [11]. Extra body adipose tissue may reduce the bioavailability of vitamin D as a result of trapping vitamin D in adipocytes [12, 13].

A reverse association was found between body mass index (BMI) and vitamin D level [14, 15] in some studies, while the others found no association between BMI and vitamin D [16, 17].

One study found that each unit increase on BMI lead to decrease vitamin D level as 1.15% [18]. It is possible that the interaction between vitamin D and anthropometric indices can be mutual and serum vitamin D may also have some effects on body fat percentage. Controversial results were reported on the effect of vitamin D supplementation on anthropometric indices [19, 20]. In some studies, vitamin D supplementation reduced body fat mass, but had no effect on weight and waist circumferences [21, 22]. A possible underlying mechanism is that vitamin D deficiency can cause secondary hyperparathyroidism leading to rising intracellular free calcium in adipocytes which can blunt lipolytic response to catecholamines and sharpen lipogenesis that contribute to fat accumulation in body [23]. Improvement of vitamin D status to the normal levels also can reverse the process of fat accumulation and may lead to fat reduction [24]. So, this study aimed to investigate the association between vitamin D and anthropometric indices in overweight and obese male adolescents after 18 weeks of a comprehensive lifestyle intervention.

Material and methods

Study population

This study was carried out as an ancillary study within a randomized, controlled, school-based trial on 100 overweight and obese 12 to 16 years male adolescents who were randomly selected from January to May 2016 from two male high schools of Tehran, Iran. All participants were resident in the same metropolitan area (urban area) (the latitude: 35.715298, and the longitude: 51.404343). Thus, they were expected to be similar regarding the level of sun exposure. Five ml blood samples were collected at the baseline and after 18 weeks of the study. The participants were divided in two groups of high and low vitamin D level based on their serum vitamin D levels at baseline.

The inclusion criteria were as follows: adolescents with overweight according to BMI chart of World Health Organization (WHO), 12 to 16 years old, not being suffered from weight-related disease, not using weight affecting drugs, anti-inflammatory drugs, and calcium/vitamin D supplements, and having the willingness to participate in the study. Ten students were excluded due to fear of blood sampling and the final analysis was performed on the remaining 90 subjects. Subjects were assigned to two groups: high serum vitamin D level ($\geq$ 40 ng/dl, $n = 41$) and low serum vitamin D level ($<$ 40 ng/dl, $n = 49$), based on data of a previous study suggested that maintenance of 25(OH)D level between 40 and 60 ng/ml is ideal, safe, and optimal for multiple health outcomes [25].

Anthropometric measurements

The height of students was measured with a wall-mounted stadiometer to the nearest 0.1 cm (Seca 711; Seca, Hamburg, Germany). A bio impedance analysis scale (BIA) (Omron BF511, Kyoto, Japan) was used to measure weight (nearest 0.1 kg), BMI, body fat percentage (BF), and skeletal muscle percentage (SM) after entering the subjects' age, gender, and height. This device is a digital, mobile, and non-invasive device that has eight electrodes that sends an extremely weak electrical current of 50 kHz and less than 500 πA through the body to determine the amount of muscle tissue. The validity of this device has been confirmed in previous studies [26]. All data were classified according to the z-score guidelines defined by WHO recommendations (for weight and BMI).

Serum vitamin D measurements

Blood samples (5 ml) were collected of all participants in the study at baseline and after 18 weeks. A direct competitive enzyme-linked immunosorbent assay (ELISA) method and vitamin D VIDAS Kit (Marcy-l'Étoile, bioMérieux, France) were used for measuring 25-hydroxy vitamin D level. The VIDAS 25-OH vitamin D total assay is considered suitable measuring D2 and D3 serum and serum level with high accuracy. Correlation between the results from VIDAS Kit with the reference methods of chromatography and volume spectrometry was $r = 0.93$ which is indicative of the efficiency of this method.

Dietary intake of vitamin D

Intakes of vitamin D were assessed by a validated 168-item semi-quantitative FFQ [27]. The FFQ consisted of 168 food items with standard portion sizes commonly consumed by Iranian people. Face-to-face interviews were administered by a trained dietitian. Dietary vitamin D intake (μg/day) was calculated by using the analyzed in Modified Nutritionist-4 software program which was modified for Iranian foods.

Physical activity assessment

For adjusting the effect of confounding factors, data on physical activity level were collected using physical activity tracker smart bands (Mi 2, Xiaomi, China) which was validated in a previous study [28].

Intervention

The intervention was implemented for 12 weeks in two levels. In the first level, the environmental and lifestyle changes were applied to the school level and all of the students in the intervention school were covered. The five dimensions of Ottawa Charter [29] were used for systemic implementation of the interventions in school level. Our intervention objects were:
- modify the health policy at the school level to influence weight and BMI,
- creating supportive environment to weight reduction,
- strengthen community action to achieve a healthy weight,
- developing personal skills to adopt a healthy lifestyle, and
- reorienting health services to prevent and treatment of obesity.

We had some strategies for every object and many operational activities for every strategy. In the second level, the personalized diet and physical activity intervention were implemented for each participant. In addition, parents were provided an educational session regarding healthy meals and creating a supportive environment at home for healthy diet and physical activity. The personalized diet was adopted with free snacks offered in school days by researchers. Furthermore, a high-intensity interval training was carried out for improving the physical activity at the schools. In this method, students warmed up for 10 min under supervision of an exercise physiologist and they were involved in high-intensity exercise for a minimum of 30 min. The details of intervention program have been explained elsewhere [30].

Statistical analysis

To ensure normality of data distribution, Kolmogorov-Smirnov test was applied. Binominal logistic regression was used to evaluate the association between vitamin D and obesity and the correlation of vitamin D with weight changes. Confounders such as age, food intake, and physical activity were adjusted in different regression models. Also, we applied generalized linear model (GLM) repeated measurements to evaluate the correlation between changes of serum vitamin D and anthropometric indices. SPSS version 21 was used for data analysis and p-value < 0.05 was considered as the significant level.

Ethics statement

Written consent forms were obtained before the study. The study was approved by the Ethics Committee of the National Nutrition and Food Technology Research Institute, Tehran, Iran (reference number: Ir.sbmu.nnftri.rec.1394.22).

Results

Eight percent of the participants had vitamin D deficiency (< 20 ng/ml), 13% had insufficient (20–30 ng/ml), and 79% of them had normal levels of this vitamin (> 30 ng/ml). The level of vitamin D in 46% of them was in the optimal area for health related outcomes (> 40 ng/ml, $n = 41$). Anthropometrics measurements and serum vitamin D levels of the two groups were summarized in Table I. The mean of serum vitamin D levels in

Table I. Characteristics of the study participants

	Overweight (48)	Obese (42)	*p*-value
	Mean (SD)	Mean (SD)	
Age (year)	13.92 (0.91)	13.95 (0.92)	0.86
25(OH) D (ng/ml)	44.012 (14.69)	37.6667 (14.02)	0.04
Height (cm)	167 (8.25)	168 (8.07)	0.62
Weight (kg)	65.1582 (12.79)	81.9690 (13.31)	0.001
BMI (kg/m^2)	23.2521 (1.62)	29.0381 (2.94)	0.001
BMI z-score	1.04 (0.44)	2.02 (0.38)	0.001
BF%	22.9876 (5.66)	30.8738 (5.02)	0.001
SM%	36.7874 (2.38)	33.8262 (2.09)	0.001
Vitamin D intake (µg/day)	7.4795 (1.34)	5.7150 (1.14)	0.245
Physical activity (min/day)	45 (15.36)	37 (12.67)	0.133

SM% – skeletal muscle percentage; BF% – body fat percentage; BMI – body mass index

Table II. Comparison of the participants with high and low levels of vitamin D

Parameter	Low vitamin D level (n = 49) at baseline	High vitamin D level (n = 41) at baseline	*P*-value	Low vitamin D level (n = 49) after intervention	High vitamin D level (n = 41) after intervention	*P*-value
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
Age (year)	13	13	0.69	14 (0.93)	14 (0.75)	0.73
25(OH)D (ng/ml)	27.9878	51.9816	0.000	19.67 (7.4)	41.31 (16.2)	0.001
Height (cm)	169	165	0.02	171 (8.25)	165 (16.44)	0.92
Weight (kg)	76.8683	69.7693	0.01	78.4 (13)	71.8 (14.7)	0.62
BMI (kg/m^2)	26.4976	25.4959	0.22	26.7 (3.8)	25.6 (3.8)	0.37
BMI z-score	1.64	1.42	0.14	1.61 (0.69)	1.51 (0.59)	0.52
BF%	26.9951	26.3940	0.68	27.6 (6.96)	25.15 (7.69)	0.35
SM%	35.3220	35.4754	0.79	35.6 (2.9)	36 (2.75)	0.85
Vitamin D intake (μg/day)	6.19 (0.53)	7.04 (1.6)	0.58	6.58 (0.69)	7.83 (1.9)	0.78
Physical activity (min/day)	44 (17)	39 (14)	0.42	41 (12)	37 (11)	0.69

SM% – skeletal muscle percentage; BF% – body fat percentage; BMI – body mass index

Table III. Repeated measures analyses for the anthropometric indices in high and low vitamin D groups after 4 months of the intervention

Parameter	Within F	*P*-value*	Between F	*P*-value*
Weight (kg)	0.01	0.9	3.3	0.07
Height (cm)	0.66	0.42	3.2	0.08
BMI (kg/m^2)	0.57	0.45	0.78	0.38
BMI z-score	3.9	0.06	0.007	0.93
Fat%	2.57	0.11	0.34	0.56
SM%	0.39	0.53	0.05	0.82

SM% – skeletal muscle percentage; BF% – body fat percentage; BMI – body mass index
*adjusted for age, dietary intake of vitamin D, changes in vitamin levels and physical activity

obese subjects were significantly lower than the overweight subjects (44.01 vs. 37.67 ng/dl, $p < 0.04$). In obese subjects, the mean of BF was significantly higher and SM was significantly lower than the non-obese subjects (all $p < 0.05$) (Table I). Subjects with high level vitamin D had lower weight ($p < 0.01$) than low level of vitamin D. No significant differences were found in age, BMI, BF, SM, physical activity and dietary intake between two groups (Table II).

In regards of investigation of the correlation between changes of vitamin D and anthropometric indices after 18 weeks in both groups and after adjustments for age, dietary intake of vitamin D and physical activity, no significant association was found (F within: 0.01 ($p = 0.9$), F between: 3.3 ($p = 0.07$) (Table III). Using logistic regression for evaluating the effect of serum D level (before and after the study) on weight changes, we found that serum vitamin level had no significant correlation with changes of body weight. The result remained meaningful after more adjustment on age (model 1), physical activity (model 2), dietary vitamin D intake (model 3), BF, and SM (model 4) (Table IV).

Discussion

The results identified that serum vitamin D level had an inverse association with BMI in male adolescents and obese students had lower vitamin D level compared with non-obese students. However, no significant association was found between changes of vitamin D levels with changes of anthropometric indices after 18 weeks.

In line with our study, Rodrigues *et al.* [31] have found the reverse association between vitamin D and weight in school-aged

Table IV. Effect of vitamin D serum level on the weight change of participant before and after study

	Vitamin D before		Vitamin D after	
	P-value	B (95% CI)	*P*-value	B (95% CI)
Model 1	0.713	0.987 (0.923–1.056)	0.89	1.004 (0.940–1.074)
Model 2	0.661	0.896 (0.920–1.054)	0.85	1.006 (0.920–1.054)
Model 3	0.398	0.960 (0.874–1.055)	0.926	1.004 (0.920–1.097)
Model 4	0.387	0.957 (0.868–1.057)	0.954	1.003 (0.919–1.096)

Model 1: Adjusted for AGE; model 2: Additional adjustments for physical activity; model 3: Further adjustment for dietary vitamin D intake; model 4: Further adjustment for fat and muscle percentage

children. The results can be caused by this fact that storing vitamin D in obese adipose tissue may have a negative effect on vitamin D bioavailability [12]. Moreover, some other studies have reported reverse correlation between vitamin D and BMI [32–36]. One study on 3528 male and female adolescents aged 12–19 with the aim of investigating vitamin D and cardiovascular risk factors, a significant reverse association was reported between vitamin D level and BMI [35].

However, some other studies found contradictory results. In a study on students (aged 14 to 17) 96% of subjects had vitamin D deficiency but no significant association was found between vitamin D and BMI [37]. More Studies on teenage girls in Malaysia and South Korea [39, 40] and one recent study in Bulgaria [38], have reported no relationship between BMI and vitamin D. In the other study on 11–19-year-old students, Cizmecioglu *et al.* did not find any association between weight and vitamin D status but they observed a negative correlation between vitamin D and BMI in overweight and obese individuals who suffered from vitamin D deficiency [41]. On the other hand, sex may influence on the level of vitamin D. Muscogiuri *et al.* found that 25OHD concentration was higher in males compared with females in all BMI groups. Males with vitamin D deficiency had lower fat mass compared with females [42].

The differences in the obtained results of the studies can be due to the difference in the characteristics of the studied populations, race, sex, and the season of the investigation [43, 44]. Nessvi *et al.* reported that Asians have the lowest level of vitamin D among the world. Also, vitamin D is in the lowest level in winter compared to the other seasons [45]. Levis *et al.* assessed vitamin D serum in men and women living in south Florida in late summer and winter. The result of seasonal variation identified a significant increase in vitamin D serum level during summer (14% in men and 13% in women) [46]. Turer *et al.* have investigated prevalence of vitamin D deficiency among 6–18 American children and found a higher prevalence of deficiency among the children with severe obesity (49% and 21% respectively). The lowest prevalence was reported between Caucasians. Also, it was more common in winter/spring than the summer and autumn [47].

No significant association was found between vitamin D serum levels with changes of anthropometric indices after 18 weeks. This may be due to reduced exposure to sunlight due to school exam season [48]. The interactions of obesity and serum level of vitamin D with genotype and gene expression is also frequently reported [49, 50]. The role of genetic profile in serum vitamin D level was reported by Brouwer-Brolsma *et al.* This study revealed carrier of minor allele of *CYP2R1*, *CYP24A1*, and *DHCR7* may have higher vitamin D level [51]. Exposure to sunlight, vitamin D intake, and the genotype can explain about 35% of the variations of vitamin D levels [51].

However, this study had some limitations. The level of exposure to sunlight and the participants' genotype were not exactly examined in our study. We did not assess sun exposure, but all participants were collected of same area that have similar life style and sun exposure. For reducing the bias of seasonal variations, we enrolled all the adolescents in the same season. Another limitation of this study was using BIA for the assessment of body composition which has lower accuracy compared with gold standard methods for anthropometric measurements such as dual X-ray absorptiometry [52].

Conclusions

Vitamin D serum levels had a reverse association with body weight in male adolescents. However, no significant association was observed between vitamin D serum levels and changes of anthropometric indices after 18 weeks. Future perspective studies with special focus on mediating factors can be helpful in identifying the association of vitamin D with anthropometric measurements.

References

1. Kelishadi R, Azizi-Soleiman F. Controlling childhood obesity: a systematic review on strategies and challenges. J Res Med Sci 2014; 19: 993–1008.
2. Brennan LK, Brownson RC, Orleans CT. Childhood obesity policy research and practice: evidence for policy and environmental strategies. Am J Prev Med 2014; 46: e1–e16. doi: 10.1016/j.amepre.2013.08.022
3. Bahreynian M, Kelishadi R, Qorbani M, et al. Weight disorders and anthropometric indices according to socioeconomic status of living place in Iranian children and adolescents: The CASPIAN-IV study. J Res Med Sci 2015; 20: 440–453. doi: 10.4103/1735-1995.163960.
4. Ezzeddin N, Eini-Zinab H, Ajami M, et al. WHO Ending Childhood Obesity and Iran-Ending Childhood Obesity Programs Based on Urban Health Equity Indicators: A Qualitative Content Analysis. Arch Iran Med 2019; 22: 646–652.
5. Sayyari AA, Abdollahi Z, Ziaodini H, et al. Methodology of the Comprehensive Program on Prevention and Control of Overweight and Obesity in Iranian Children and Adolescents: The IRAN-Ending Childhood Obesity (IRAN-ECHO) Program. Int J Prev Med 2017; 8: 107. doi: 10.4103/ijpvm.IJPVM_426_17
6. Vaisi-Raygani A, Mohammadi M, Jalali R, et al. The prevalence of obesity in older adults in Iran: a systematic review and meta-analysis. BMC Geriatr 2019; 19: 371. doi: 10.1186/s12877-019-1396-4
7. Thomas-Valdés S, Tostes MDGV, Anunciação PC, et al. Association between vitamin deficiency and metabolic disorders related to obesity. Crit Rev Food Sci Nutr 2017; 57: 3332–3343. doi: 10.1080/10408398.2015.1117413
8. Aliashrafi S, Arefhosseini SR, Lotfi-Dizaji L, Ebrahimi-Mameghani M. Effect of vitamin D supplementation in combination with weight loss diet on lipid profile and sirtuin 1 in obese subjects with vitamin D deficiency: a double blind randomized clinical trial. Health Promot Perspect 2019; 9: 263–269.
9. El-Khateeb M, Khader Y, Batieha A, et al. Vitamin D deficiency and associated factors in Jordan. SAGE Open Medicine 2019; 7: 2050312119876151.
10. Ross AC, Manson JE, Abrams SA, et al. The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine: what clinicians need to know. J Clin Endocrinol Metab 2011; 96: 53–58. doi: 10.1210/jc.2010-2704
11. Prasad P, Kochhar A. Interplay of vitamin D and metabolic syndrome: A review. Diabetes Metab Syndr 2016; 10: 105–112. doi: 10.1016/j.dsx.2015.02.014
12. Wortsman J, Matsuoka LY, Chen TC, et al. Decreased bioavailability of vitamin D in obesity. Am J Clin Nutr 2000; 72: 690–693. doi: 10.1093/ajcn/72.3.690
13. Barrea L, Savastano S, Di Somma C, et al. Low serum vitamin D-status, air pollution and obesity: A dangerous liaison. Rev Endocr Metab Disord 2017; 18: 207–214. doi: 10.1007/s11154-016-9388-6
14. Pilone V, Tramontano S, Cutolo C, et al. Clinical factors correlated with vitamin D deficiency in patients with obesity scheduled for bariatric surgery: A single center experience. Int J Vitam Nutr Res 2020; 90: 346–352. doi: 10.1024/0300-9831/a000662
15. Gao X, Wang H, Bidulescu A. Lifestyle interventions along with vitamin D supplements on reducing leptinemia in obese man. Int J Obes (Lond) 2020; 44: 1626–1627. doi: 10.1038/s41366-020-0599-2
16. Bell NH, Epstein S, Greene A, et al. Evidence for alteration of the vitamin D-endocrine system in obese subjects. J Clin Invest 1985; 76: 370–373. doi: 10.1172/JCI111971
17. Nesby-O'Dell S, Scanlon KS, Cogswell ME, et al. Hypovitaminosis D prevalence and determinants among African American and white women of reproductive age: third National Health and Nutrition Examination Survey, 1988-1994. Am J Clin Nutr 2002; 76: 187–192.
18. Vimaleswaran KS, Berry DJ, Lu C, et al. Causal relationship between obesity and vitamin D status: bi-directional Mendelian randomization analysis of multiple cohorts. PLoS Med 2013; 10: e1001383. doi: 10.1371/journal.pmed.1001383
19. Zittermann A, Ernst JB, Gummert JF, Börgermann J. Vitamin D supplementation, body weight and human serum 25-hydroxyvitamin D response: a systematic review. Eur J Nutr 2014; 53: 367–374. doi: 10.1007/s00394-013-0634-3
20. Subih HS, Zueter Z, Obeidat BM, et al. A high weekly dose of cholecalciferol and calcium supplement enhances weight loss and improves health biomarkers in obese women. Nutr Res 2018; 59: 53–64. doi: 10.1016/j.nutres.2018.07.011
21. Salehpour A, Hosseinpanah F, Shidfar F, et al. A 12-week double-blind randomized clinical trial of vitamin D_3 supplementation on body fat mass in healthy overweight and obese women. Nutr J 2012; 11: 78. doi: 10.1186/1475-2891-11-78
22. Haghshenas R, Jamshidi Z, Doaei S, Gholamalizadeh M. The Effect of a High-intensity Interval Training on Plasma Vitamin D Level in Obese Male Adolescents. Indian J Endocrinol Metab 2019; 23: 72–75. doi: 10.4103/ijem.IJEM_267_18.
23. Zemel MB, Shi H, Greer B, Dirienzo D, Zemel PC. Regulation of adiposity by dietary calcium. FASEB J 2000; 14: 1132–1138.
24. Juránková M, Bílý J, Hrazdíra E. Effects of high-intensity strength interval training program on body composition. J Hum Sport Exerci 2015; 10: 314–319.
25. Bischoff-Ferrari HA, Giovannucci E, Willett WC, et al. Estimation of optimal serum concentrations of 25-hydroxyvitamin D for multiple health outcomes. Am J Clin Nutr 2006; 84: 18–28. doi: 10.1093/ajcn/84.1.18
26. Pribyl MI, Smith JD, Grimes GR. Accuracy of the Omron HBF-500 body composition monitor in male and female college students. Int J Exerc Sci 2011; 4: 93–101.
27. Mirmiran P, Esfahani FH, Mehrabi Y, et al. Reliability and relative validity of an FFQ for nutrients in the Tehran lipid and glucose study. Public Health Nutr 2010; 13: 654–662. doi: 10.1017/S1368980009991698
28. Tam KM, Cheung SY. Validation of Electronic Activity Monitor Devices During Treadmill Walking. Telemed J E Health 2018; 24: 782–789. doi: 10.1089/tmj.2017.0263
29. Eriksson M, Lindström B. A salutogenic interpretation of the Ottawa Charter. Health Promot Int 2008; 23: 190–199. doi:10.1093/heapro/dan014
30. Kalantari N, Mohammadi NK, Rafieifar S, et al. Indicator for Success of Obesity Reduction Programs in Adolescents: Body Composition or Body Mass Index? Evaluating a School-based Health Promotion Project after 12 Weeks of Intervention. Int J Prev Med 2017; 8: 73. doi: 10.4103/ijpvm.IJPVM_306_16
31. Rodríguez-Rodríguez E, Navia-Lombán B, López-Sobaler AM, Ortega RM. Associations between abdominal fat and body mass

index on vitamin D status in a group of Spanish schoolchildren. Eur J Clin Nutr 2010; 64: 461–467. doi: 10.1038/ejcn.2010.26
32. Lagunova Z, Porojnicu AC, Lindberg F, et al. The dependency of vitamin D status on body mass index, gender, age and season. Anticancer Res 2009; 29: 3713–3720.
33. Mansour MM, Alhadidi KM. Vitamin D deficiency in children living in Jeddah, Saudi Arabia. Indian J Endocrinol Metab 2012; 16: 263–269. doi: 10.4103/2230-8210.93746
34. Reis JP, von Mühlen D, Miller ER 3rd, et al. Vitamin D status and cardiometabolic risk factors in the United States adolescent population. Pediatrics 2009; 124: e371–e379. doi: 10.1542/peds.2009-0213
35. Nimitphong H, Chanprasertyothin S, Jongjaroenprasert W, Ongphiphadhanakul B. The association between vitamin D status and circulating adiponectin independent of adiposity in subjects with abnormal glucose tolerance. Endocrine 2009; 36: 205–210. doi: 10.1007/s12020-009-9216-9.
36. Stokić E, Kupusinac A, Tomić-Naglić D, et al. Obesity and vitamin D deficiency: trends to promote a more proatherogenic cardiometabolic risk profile. Angiology 2015; 66: 237–243. doi: 10.1177/0003319714528569
37. Rafraf M, Hasanabad SK, Jafarabadi MA. Vitamin D status and its relationship with metabolic syndrome risk factors among adolescent girls in Boukan, Iran. Public Health Nutr 2014; 17: 803–809. doi: 10.1017/S1368980013003340
38. Galunska BT, Gerova DI, Galcheva SV, Iotova VM. Association between vitamin D status and obesity in Bulgarian pre-pubertal children: a pilot study. Int J Res Med Sci 2016; 4: 361–368.
39. Jang HB, Lee HJ, Park JY, Kang JH, Song J. Association between serum vitamin d and metabolic risk factors in korean schoolgirls. Osong Public Health Res Perspect 2013; 4: 179–186. doi: 10.1016/j.phrp.2013.06.004
40. Khor GL, Chee WS, Shariff ZM, et al. High prevalence of vitamin D insufficiency and its association with BMI-for-age among primary school children in Kuala Lumpur, Malaysia. BMC Public Health. 2011; 11: 95. doi:10.1186/1471-2458-11-95.
41. Çizmecioğlu FM, Etiler N, Görmüş U, Hamzaoğlu O, Hatun Ş. Hypovitaminosis D in obese and overweight schoolchildren. J Clin Res Pediatr Endocrinol 2008; 1: 89–96. doi: 10.4008/jcrpe.v1i2.43
42. Muscogiuri G, Barrea L, Somma CD, et al. Sex Differences of Vitamin D Status across BMI Classes: An Observational Prospective Cohort Study. Nutrients 2019; 11: 3034. doi:10.3390/nu11123034
43. Weishaar T, Rajan S, Keller B. Probability of Vitamin D Deficiency by Body Weight and Race/Ethnicity. J Am Board Fam Med 2016; 29: 226–232. doi: 10.3122/jabfm.2016.02.150251
44. Zhao X, Xiao J, Liao X, et al. Vitamin D Status among Young Children Aged 1-3 Years: A Cross-Sectional Study in Wuxi, China. PLoS One 2015; 10 (10): e0141595. doi: 10.1371/journal.pone.0141595
45. Nessvi S, Johansson L, Jopson J, et al. Association of 25-hydroxyvitamin D3)levels in adult New Zealanders with ethnicity, skin color and self-reported skin sensitivity to sun exposure. Photochem Photobiol 2011; 87: 1173–1178. doi: 10.1111/j.1751-1097.2011.00956.x
46. Levis S, Gomez A, Jimenez C, et al. Vitamin d deficiency and seasonal variation in an adult South Florida population. J Clin Endocrinol Metab 2005; 90: 1557–1562. doi: 10.1210/jc.2004-0746
47. Turer CB, Lin H, Flores G. Prevalence of vitamin D deficiency among overweight and obese US children. Pediatrics 2013; 131: e152–e161. doi: 10.1542/peds.2012-1711
48. Wacker M, Holick MF. Sunlight and Vitamin D: A global perspective for health. Dermatoendocrinol 2013; 5: 51–108. doi: 10.4161/derm.24494
49. Gholamalizadeh M, Doaei S, Akbari ME, et al. Influence of Fat Mass- and Obesity-Associated Genotype, Body Mass Index, and Dietary Intake on Effects of Iroquois-related Homeobox 3 Gene on Body Weight. Chin Med J (Engl) 2018; 131: 2112–2113. doi: 10.4103/0366-6999.239309
50. Kalantari N, Keshavarz Mohammadi N, Izadi P, et al. A haplotype of three SNPs in FTO had a strong association with body composition and BMI in Iranian male adolescents. PLoS One 2018; 13: e0195589. doi: 10.1371/journal.pone.0195589
51. Brouwer-Brolsma EM, Vaes AMM, van der Zwaluw NL, et al. Relative importance of summer sun exposure, vitamin D intake, and genes to vitamin D status in Dutch older adults: The B-PROOF study. J Steroid Biochem Mol Biol 2016; 164: 168–176. doi: 10.1016/j.jsbmb.2015.08.008
52. Achamrah N, Colange G, Delay J, et al. Comparison of body composition assessment by DXA and BIA according to the body mass index: A retrospective study on 3655 measures. PLoS One 2018; 13 (7): e0200465. doi: 10.1371/journal.pone.0200465