Journal of Food and Nutrition Research, 2020, Vol. 8, No. 4, 195-200
Available online at http://pubs.sciepub.com/jfnr/8/4/6
Published by Science and Education Publishing
DOI:10.12691/jfnr-8-4-6

Relationship between Anthropometric Measurements and Serum Vitamin D Levels in a Convenient Sample of Healthy Adults

Seham Abu Jadayil[1,*], Bassam Abu Jadayel[2], Hamed Takruri[3], Marwan Muwalla[1], Hiba Al-Sayyed[1]

[1]Department of Nutrition, Faculty of Pharmacy & Medical Sciences, University of Petra, Amman, Jordan
[2]Orthopedic Surgery Consultant/ Medical Doctor-Private Clinic, Amman, Jordan
[3]Department of Nutrition and Food Technology, Faculty of Agriculture, The University of Jordan, Amman, Jordan
*Corresponding author: sabujadayil@uop.edu.jo

Received April 17, 2020; Revised May 19, 2020; Accepted May 26, 2020

Abstract The deficiency of vitamin D has been linked to many factors such as; age, female gender, and obesity. An inverse relationship between serum vitamin D and the percentage of fat, body weight, and body mass index (BMI) has been found. So, this study aimed to examine the relationship between anthropometric measurements such as body weight, BMI, percentage of body fat, and physical activity and serum vitamin D levels in a convenient sample of healthy adults in Jordan. Serum vitamin D level was assessed in a convenient sample of 52 healthy Jordanian volunteers aged between 18 to 45 years were recruited. A questionnaire about their socio-demographic information was filled, anthropometric measurements were carried out. According to Pearson's correlation analysis, only percentage of body fat (inverse relationship; $r = -0.296$, $p = 0.039$) and height (positive relationship; $r = 0.514$, $p = 0.000$) were significantly associated with serum vitamin D levels in all participants ($p < 0.05$). Weekly physical activity hours and educational levels were positively and significantly associated with serum vitamin D levels in females only. Age and other anthropometric measurements had no significant relationships with the serum level of vitamin D in all participants or either in males or females. There was a significant relationship between occupational level and serum vitamin D levels ($p = 0.043$). In conclusion, there was no significant correlation between anthropometric measurements and serum vitamin D levels except for a significant inverse relationship with the percentage of body fat. Additionally, serum vitamin D level was marginal in females and sufficient in males enrolled in this study.

Keywords: *Vitamin D, serum level, anthropometric measurements, healthy volunteers, Jordan*

Cite This Article: Seham Abu Jadayil, Bassam Abu Jadayel, Hamed Takruri, Marwan Muwalla, and Hiba Al-Sayyed, "Relationship between Anthropometric Measurements and Serum Vitamin D Levels in a Convenient Sample of Healthy Adults." *Journal of Food and Nutrition Research*, vol. 8, no. 4 (2020): 195-200. doi: 10.12691/jfnr-8-4-6.

1. Introduction

Vitamin D is essential in the regulation of Ca and P homeostasis and for the maintenance of the health of bones, teeth, and muscles [1,2]. Vitamin D deficiency is currently recognized as a common public health problem [3], that causes growth retardation and rickets in children, and osteomalacia in adults [3,4]. Also, low vitamin D status is prevalent in many chronic diseases such as diabetes, some types of cancers, cardiovascular diseases, and autoimmune diseases [3,4].

Humans get vitamin D from exposure to sunlight and its natural sources in the diet; however, natural dietary sources of vitamin D are limited [1], and therefore dietary supplements are also used to cover its requirements [5]. An appreciable amount (50-90%) of vitamin D is synthesized in the skin primarily by the activation of 7-dehydrocholesterol after exposure to the sun; particularly UVB (290-320 nm) that converts 7-dehydrocholesterol to provitamin D3, which is then converted to the active form, vitamin D3, in the liver and the kidneys [3,5,6,7].

The best indicator of vitamin D status in the blood is 25-hydroxyvitamin D concentration [8,9]. In 2010, the Institute of Medicine (IOM)/ Food and Nutrition Board (FNB) established a new cut off points for serum vitamin D concentrations. Persons are at risk of vitamin D deficiency at serum 25(OH)D concentrations <30 nmol/L (<12 ng/ml). Serum 25(OH)D levels between 30 and 50 nmol/L (12-20 ng/ml) are inadequate for optimal bone and overall health in healthy individuals, while levels≥50 nmol/L (≥20 ng/ml) are considered adequate [9,10].

The prevalence of vitamin D deficiency has been increased in Jordan and globally (70-90%); due to insufficient sun exposure, limited dietary sources, and malabsorption [3,8,11].

Despite that Jordan is a sunny country in general, published data suggested widespread vitamin D deficiency in Jordan [12]. A nationwide study conducted by Batieha, *et. al.* (2009) showed that the prevalence of vitamin D deficiency was 37% in women [13]. Another study that was done by El-Khateeb *et al.* (2019) showed that the overall prevalence of low vitamin D levels (25 (OH) D <30 ng/ml) was 89.7%, with higher prevalence in males (92.4%) than in females (88.6%) [3].

The deficiency of vitamin D has been linked to many factors such as; skin pigmentation, use of sunscreen, age, female gender, and obesity [4,14]. An inverse relationship between serum vitamin D and the percentage of fat, body weight, and body mass index (BMI) has been found [15].

This study aimed to examine the relationship between anthropometric measurements such as body weight, BMI, percentage of body fat, and physical activity and serum vitamin D levels in a convenient sample of healthy adults in Jordan.

2. Subjects and Methods

2.1. Subjects

In this cross-sectional study, a total of 52 healthy Jordanian volunteers (26 females and 26 males) aged between 18 to 45 years were recruited conveniently, between August 5 and October 23, 2017. All the procedures were performed in an Orthopedic clinic under the supervision of the Orthopedic physician. All procedures performed in this study were under the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans and ethical standards of the University of Petra Research Committee ethical standards. The volunteers signed informed consent before their inclusion in the study and were given the full instructions about the study. Inclusion criteria included being healthy and had not ingested any medication known to affect vitamin D metabolism during the previous 3 months. Exclusion criteria included the presence of any chronic disease and the use of any medications known to affect vitamin D metabolism during the previous 3 months.

2.2. Socio-demographic Data

Every participant was asked to fill out a questionnaire about his/her socio-demographic, health and cultural status, under the supervision of a professionally trained investigator. The questionnaire contained many items, including age, that was calculated from the date of birth, the date of attendance at the clinic, sex, occupation, marital status, educational level, and physical activity information.

2.3. Anthropometric Measurements

The measurements were done in a standard way by the same operator in the same clinic. Height was measured to the nearest 0.5 cm using a calibrated stadiometer (Seca, Germany) with subjects in full standing position without shoes [16]. Weight was measured to the nearest 0.1 kg by using a calibrated electronic scale (Seca, Germany) with minimal clothing and without shoes [16]. Body mass index (BMI) was calculated by a standard formula (weight in kilogram/height in meters squared) [17]. Participants' BMI was then categorized into four groups as follows: underweight (<18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2) and obese (30 kg/m^2) [17].

Body fat mass and percentage of body fat were measured using body composition analyzer In Body® [16].

2.4. Blood Tests

Blood samples were obtained for each participant by Orthopedic Physician in the Orthopedic clinic to measure serum vitamin D. Venous blood samples were drawn with Vacutainer EDTA and gel tubes, then immediately centrifuged at 6000 rpm for 5 minutes, and separated using (HETTICH EBA 200). Serum samples were stored in a refrigerator until they were analyzed on the next day. The blood samples were sent sequentially to a certified Lab in Amman.

The quantitative determination of total 25-hydroxyvitamin D [25 (OH) vitamin D] levels (Access 2 Immunoassay Systems (BECKMAN COULTER)) with commercially available kits ("ACCESS 25-OH Vitamin D 2X50 DET" B24838).

2.5. Statistical Analysis

Independent-samples t-test was run to determine if there were differences in serum vitamin D levels, age, anthropometric measurements, and physical activity hours between males and females. Data are presented as mean ± standard deviation (SD). As serum vitamin D level was normally distributed, Pearson's Correlation was used to measure the correlation between each variable of anthropometric measurements, physical activity hours and vitamin D level. A one-way ANOVA with a post hoc test was conducted to determine if the ability of serum vitamin D level was different for groups with different occupations, for groups with different BMI levels, and between the different educational level groups, followed by the Bonferroni post-hoc test. A $p < 0.05$ was considered statistically significant. Missing data were removed using pair wise deletion. All statistical analysis was performed using IBM SPSS for Windows version 21 (SPSS Inc., Chicago, USA).

3. Results

3.1. Characteristics of the Participants

The characteristics of the participants are shown in Table 1. This study included 52 participants (26 males and 26 females). Most of the participants were single (52%), especially females (n=16). The percentage of participants had a Bachelor of Science Degree (39%), and most of the participants were employed in different jobs (92% of the males and 38% of the females).

3.2. Anthropometric Measurements, Physical Activity Hours and Serum Vitamin D Level in the Participants

Table 2 shows anthropometric measurements, physical activity hours and serum vitamin D levels in the participants. The age of the participants ranged between 19-45 years, with a mean of 28.98 ±7.18 years with no significant differences between males and females ($p > 0.05$). There was a significant difference in height, weight, BMI, and serum vitamin D level between males and females ($p < 0.05$); these values were higher in males. On the other hand, the percentage of body fat was significantly higher ($p < 0.05$) in females than in males. No significant difference between males and females in terms of fat mass and physical activity hours per week.

Pearson's correlation analysis was used to investigate the relationship between age, anthropometric measurements, weekly physical activity hours, and educational level with serum level of vitamin D in all participants according to sex (Table 3). Only height (positive relationship), and percentage of fat (inverse relationship) were significantly associated with serum vitamin D levels in all participants ($p < 0.05$).

On the other hand, weekly physical activity hours and educational levels were positively and significantly associated with serum vitamin D levels in females only. Age and other anthropometric measurements had no significant relationships with the serum level of vitamin D in all participants or either in males or females. Despite this, there was an inverse relationship between age, BMI and the serum vitamin D level.

Studying the relationship between educational level, occupation, and BMI categories with serum level of vitamin D in all participants revealed that only serum vitamin D level was significantly different for different occupational levels ($p < 0.05$), there were no statistically significant differences in serum vitamin D level between the different educational level groups, and the different BMI groups ($p > 0.05$) (Table 4).

Table 1. Characteristics of the Participants

Variables	All Participants		Male		Female	
	No	%	No	%	No	%
Subjects	52		26	50%	26	50%
Marital Status	52		26		26	
Single	27	52%	11	42%	16	61%
Married	24	46%	15	58%	9	35%
Divorced	1	2%	0	0%	1	4%
Educational Level	51		26		25	
< Secondary	9	18%	5	19%	4	16%
Secondary	15	29%	10	38%	5	20%
Diploma	5	10%	2	8%	3	12%
BSc	20	39%	8	31%	12	48%
> BSc	2	4%	1	4%	1	1%
Occupation	52		26		26	
Employee	34	66%	24	92%	10	38%
Unemployed	9	17%	0	0%	9	35%
Student	9	17%	2	8%	7	27%

Abbreviations: No: Number of participants; BSc: Bachelor of Science Degree.

Table 2. Anthropometric Measurements, Physical Activity Hours and Serum Vitamin D Levels in the Participants

Variables	No	Total Participants Mean ±SD	No	Male Mean ±SD	No	Female Mean ±SD	Sex Difference (p)
Age (years)	52	28.98 ±7.18	26	28.19 ±6.71	26	29.77 ±7.67	0.434
Height (cm)	51	167.27 ±8.83	25	173.34 ±6.66	26	161.43 ±6.41	< 0.001
Weight (Kg)	51	73.13 ±17.41	25	83.04 ±15.58	26	63.60 ±13.45	< 0.001
BMI (kg/m2)	51	25.87 ±4.75	25	27.49 ±4.10	26	24.31 ±4.89	0.015
Fat%	49	29.06 ±8.04	23	24.98 ±7.01	26	32.67 ±7.21	< 0.001
Fat Mass (g)	49	20.70 ±9.06	23	20.10 ±9.89	26	21.24 ±8.42	0.665
PA hours (Hours)/week	52	1.58 ±2.58	26	1.65 ±2.62	26	1.50 ±2.58	0.832
Vit D (ng/ml)	52	20.20 ±7.10	26	23.41 ±5.85	26	17.00 ±6.87	0.001

Results are expressed as mean ± standard deviation.
$P < 0.05$ considered statistically significant.
Abbreviations: No: number of participants; BMI: body mass index; PA hours: physical activity hours per week; Vit D: serum level of vitamin D.

Table 3. Pearson's Correlation of Socio Economic/Demographic Factors with Serum Vitamin D Levels

Variables	Total		Male		Female	
	r	p	r	p	R	p
Age (years)	-0.056	0.693	-0.221	0.277	0.154	0.453
Height (cm)	0.514**	0.000	0.306	0.137	0.350	0.079
Weight (Kg)	0.222	0.117	0.049	0.818	-0.105	0.610
BMI(kg/m2)	-0.006	0.968	-0.071	0.735	-0.252	0.215
Fat%	-0.296*	0.039	-0.122	0.579	-0.121	0.555
Fat Mass(g)	-0.121	0.406	-0.015	0.946	-0.176	0.391
PA hours (Hours)/week	0.183	0.193	-0.119	0.562	0.460*	0.018
Educational Level	0.264	0.062	0.314	0.118	0.472*	0.017

Abbreviations: BMI: body mass index; PA hours: physical activity hours per week.
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 4. Relationships between Socio Demographic Information of the Study Participants and Serum Vitamin D Levels

Variables	N	Mean ±SD Vit D ng/ml	p-value
Educational Level			0.535
< Secondary	9	18.33 ±7.75	
Secondary	15	18.81 ±5.53	
Diploma	5	19.20 ±8.85	
BSc	20	21.33 ±7.53	
>BSc	2	29.50 ±2.36	
Total	51	20.17 ±7.17	
Occupation			0.043
Employee	34	21.48 ±6.52	
unemployed	9	14.90 ±6.63	
Student	9	20.68 ±7.97	
Total	52	20.20 ±7.10	
BMI			0.165
Underweight	2	21.73 ±1.34	
Healthy(normal) weight	22	18.71 ±6.36	
Overweight	18	21.33 ±7.80	
Obese 1	6	23.08 ±4.48	
Obesity 2	3	12.48 ±4.62	
Total	51	19.90 ±6.82	

Results are expressed as mean ± standard deviation.
P<0.05 is considered statistically significant.
Abbreviations: BMI: body mass index; Vit D: serum level of vitamin D.

4. Discussion

Our study examined the relationship between demographic characteristics, anthropometric measurements such as age, body weight, BMI, body fat, and physical activity and serum vitamin D levels in a cross-sectional study of healthy adults from Jordan.

The mean of BMI was normal for females, whereas males were overweight (24.31 ± 4.89 and 27.49 ± 4.10, respectively) [17]. The mean percentage of fat was more than the acceptable range for both males and females (24.98 ± 7.01 and 32.67 ± 7.21, respectively) [16]. According to the IOM/FNB committee classification [9,10] of vitamin D deficiency; serum level of vitamin D was potentially at risk in females (17.00 ± 6.87), and sufficient in males (23.41 ± 5.85). This result is in agreement with other reports in Jordan; which indicated that females were more likely to have low vitamin D levels than males. Although Jordan is a sunny country almost in most days of the year, the highest rate among females might be explained by the probability that they were not receiving enough exposure to the sun because of their dressing style [3] or staying at home more than males, especially that 35% of females in this study were unemployed.

There were significant differences (p-value = 0.043; Table 4) in serum vitamin D levels according to the occupation (employee, unemployed, and students). The highest value of serum vitamin D concentration was in employee participants (21.48 ± 6.52), then in students (20.68 ±7.97), and the least in unemployed participants (14.90 ±6.63) (p = 0.043). This may be due to exposure of employee participants to the sun and outdoor physical activity. Also, Unemployed people in Jordan, especially females, spend less time outdoors and therefore they were less likely to be exposed to the sun [4].

We found a strong inverse correlation between the percentage of fat and serum vitamin D level. The correlation was significant ($p < 0.05$) in all participants, but was not significant neither among males nor among females. By increasing the percentage of fat, the serum level of vitamin D decreased. On the other hand, the inverse correlation between fat mass or BMI and serum vitamin D level was not significant, neither in all participants nor in each gender.

An inverse correlation between the percentage of body fat and serum vitamin D level was reported in the study of Mathieu, et al. (2018); the authors found that participants in the lowest serum 25(OH)D quartile (4.7-17.5 ng/ml) had a higher fat mass (9.3 kg/m2) compared with participants in the third (8.40 kg/m2; Q3 = 26.1-34.8 ng/ml) and highest (8.37 kg/m2; Q4 = 34.9-62.5 ng/ml) quartile ($P_{overall} = 0.03$) [18].

A variety of studies demonstrated that serum vitamin D level is inversely associated with BMI and body fat content [9]. This maybe because vitamin D is a fat-soluble vitamin and may be trapped by excess body fat [19]. Greater amounts of subcutaneous fat may sequester vitamin D and alter its release into the circulation [9]. Another possible explanation is that obese people are less likely to participate in outdoor activities, thus decreasing sun exposure and limiting the endogenous production of cholecalciferol into the skin [3].

Contrary to our expectations, we did not find an inverse association between body weight and serum vitamin D level, this may be due to the small sample size and that the study sample was a convenient one.

Unlike results of other studies, we did not find a significant inverse association between age and serum vitamin D level (r = -0.056, p = 0.434) in all participants, whereas a significant inverse relationship was found in a study conducted by El-Khateeb *et. al.* in Jordan in 2019 [3]. Changes in vitamin D metabolism can occur with aging; insufficiency of vitamin D possibly may be due to increased indoor time. Age-related reduction of epidermal levels of 7-dehydrocholesterol thus less skin synthesis of vitamin D and advancing age results in a reduction of vitamin D receptors in intestine and bone [9]. In our study, this inverse correlation was not significant which may be due to the low range of the age of participants (18-45) years, as well as the small sample size of the study.

Unexpectedly, there was a positive correlation between circulating 25OHD and height among the study participants. Whereas vitamin D is a key to skeletal development and its deficiency may result in short stature associated with rickets. The same results were found in other reports [20].

We found a positive significant correlation between weekly physical activity hours and serum vitamin D levels only in females (r = 0.460, p = 0.018). The relationship is inconsistent in the whole sample of participants and male participants. This may be due to a few physical activity hours weekly, and a small sample size.

Also, there was a positive correlation between educational level and serum vitamin D level, but this correlation was significant only in females (P-value = 0.017). As shown in Table 4, the relationship among educational level categories and serum vitamin D levels was not significant. It is true that the highest value of serum vitamin D was in the participants whose educational level of more than BSc (29.50 ng/ml ±2.36), but this correlation cannot be generalized because this relationship in the participants of category 2 only, and this is not representative.

The absence of a relationship between BMI categories and vitamin D serum levels in the present study is similar to that found by Qatatsheh et al. (2014) who assessed the prevalence of vitamin D deficiency among female university students and employees at the Hashemite University/ Jordan [12]. Our results may be attributed to the fact that most of the participants were in the normal and overweight BMI ranges and only a few cases were obese, although obese grade 1 and overweight participants had higher serum levels of vitamin D compared to those with normal BMI. This inconsistent relationship cannot be generalized to the wider population due to the small size of the sample used in the present study.

There are several limitations to this study. The first is that this was a descriptive, cross-sectional study with a relatively small number of participants, limiting the generalization of results to the general Jordan population. The small sample size may have limited our ability to find a strong association between 25(OH)D status and some measured variables.

5. Conclusions

In conclusion, there was no significant correlation between anthropometric measurements and serum vitamin D levels except for a significant inverse relationship with the percentage of body fat. Additionally, there was a relationship between occupation and serum level of vitamin D. Serum vitamin D level was marginal in females and sufficient in males. Further studies are needed in which the number of participants is large and the inclusion of increasing those with the obese BMI category.

Acknowledgments

We would like to express our deepest appreciation and gratitude to The Deanship of Research and Postgraduate Studies in Petra University for financial support, and Prof. Mohammad Jehad Tabbaa / Department of Animal Production/ University of Jordan for help in the statistical analysis.

Statement of Competing Interests

All authors declare no conflict of interest.

List of Abbreviations

BMI	Body Mass Index
UVB	Ultraviolet B-rays
IOM	Institute of Medicine
FNB	Food and Nutrition Board
25(OH)D	25-hydroxyvitamin D
WHO	World Health Organization
SD	Standard Deviation

References

[1] Petrenya, N., Lamberg-Allardt, C., Melhus, M., Broderstad, A.R. and Brustad, M. “Vitamin D status in a multi-ethnic population of northern Norway: the SAMINOR 2 Clinical Survey”, Public Health Nutrition, 1-15. December 2018.

[2] Mendes, M.M., Darling, A.L., Hart, K.H., Morse, S., Murphy, R.J. and Lanham-New, S.A. “Impact of high latitude, urban living and ethnicity on 25-hydroxyvitamin D status: a need for multidisciplinary action?’, Journal of Steroid Biochemistry and Molecular Biology, 1-26. December 2018.

[3] El-Khateeb, M., Khader, Y., Batieha, A., Jaddou, H., Hyassat, D., Khawaja, N., Abujbara, M. and Ajlouni, K. “Vitamin D deficiency and associated factors in Jordan”, SAGE Open Medicine, 7. 1-6. August 2019.

[4] Subinay, D., Mrina,l P. and Anshuman, D. “The Dependency of vitamin D status on anthropometric data”, Malays J Med Sci., 21(3). 54-61. May-Jun 2014.

[5] Holick, M.F. “Vitamin D deficiency”, N Engl J Med., 357. 266-81. July 2007.

[6] Alshiyab, D.M., Al-qarqaz, F.A., Heis, L.H., Muhaidat, J.M., Eddin, W.S. and Atwan, A.A. “Assessment of serum vitamin D levels in [atients with vitiligo in Jordan: a case-control study”, Dermatology Research and Practice, 2019. 1-5. October 2019.

[7] Garg, S., Dasguptam A., Maharana, S.P., Paul, B., Bandyopadhyay, L. and Bhattacharya, A. “Sun E\exposure and vitamin D in rural India: a cross-sectional study”, Indian Journal of Public Health, 62(3). 175-181. July-September 2018.

[8] Kennel, K.A., Drake, M.T. and Hurley, D.L. “Vitamin D deficiency in adults: when to test and how to treat”, Mayo Clin Proc., 85(8). 752-758. August 2010.

[9] Zempleni, J.W., Suttie, G.W., Gregory, J.F. and Stover, P.J. “Hand Book of Vitamins”. CRC Press. The Taylor & Francis Group. Boca Raton London New York, 2014, 51-88.

[10] Office of Dietary Supplements (ODS). “Vitamin D: fact sheet for health professionals”, National Institute of Health. March 2020. [Online]
[Online]. Available: https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/

[11] Abu-Samak, M.S., AbuRuzm M.E., Masa'Deh, R., Khuzai, R. and Jarrah, S. “Correlation of selected stress associated factors with vitamin D deficiency in Jordanian men and women”, International Journal of General Medicine, 12. 225-233. 2019.

[12] Qatatsheh, A., Tayyem, R., Al-Shami, I., Al-Holy, M.A. and Al-rethaia, A.S. "Vitamin D deficiency among Jordanian university students and employees", Nutrition & Food Science, 45(1). 68 - 82. February 2015.

[13] Batieha, A., Khader, Y., Jaddou, H., Hyassat, D., Batieha, Z., Khateeb, M., Belbisi, A. and Ajlouni, K. “Vitamin D status in Jordan: dress style and gender discrepancies”, Ann Nutr Metab., 58. 10-18. January 2011.

[14] Elizondo-Montemayor, L., Castillo, E.C., Rodríguez-López, C., Villarreal Calderón, J.R., Gómez-Carmona, M., Tenorio-Martínez, S., Nieblas, B. and García-Rivas, B. “Seasonal variation in vitamin D in association with age, inflammatory cytokines, anthropometric parameters, and lifestyle factors in older adults”, Mediators of Inflammation, 2017. 1-14. September 2017.

[15] Barrea, L., Muscogiuri, G., Annunziata, G., Laudisio, D., Alteriis, G., Tenore, G.C., Colao, A. and Savastano, S. “A New light on vitamin D in obesity: A novel association with Trimethylamine-N-oxide (TMAO)”, Nutrients, 11. 1-15. June 2019.

[16] LEE, R.D. and Nieman, D.C. “Nutritional Assessment”. McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, 2013, 166-220.

[17] WHO. “Global Strategy on Diet, Physical Activity and Health. Obesity and Overweight”. WHO Press, Geneva. 2020 [Online]
[Online]. Available: https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight

[18] Mathieu, S.V., Fischer, K., Dawson-Hughes, B., Freystaetter, G., Beuschlein, F., Schietzel, S., Egli, A. and Bischoff-Ferrari, H.A. “Association between 25-Hydroxyvitamin D status and components of body composition and glucose metabolism in older men and women”, Nutrients, 10. 1-12. November 2018.

[19] McVey, M.K., Geraghty, A.A., O’Brien, E.C., Kilbane, M.T., Crowley, R.K., Twomey, P.J., McKenna, M.J., McAuliffe, F.M., “An exploratory analysis of associations of diet, sun exposure, and body composition with 25OHD at five years of age”, Journal of Steroid Biochemistry and Molecular Biology, 1-19. December 2018.

[20] Kremer, R., Campbell, P.P., Reinhardt, T. and Gilsanz, V. “Vitamin D status and Its relationship to body fat, final height, and peak bone mass in young women”, J Clin Endocrinol Metab, 94(1). 67-73. January 2009.