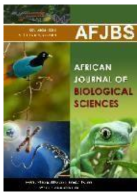
https://doi.org/ 10.33472/AFJBS.6.5.2024. 4722-4730

AFJBS

African Journal of Biological Sciences



The Impact of an Increased Body Mass Index on The Absorption of Some Vitamins

Amera Kamal Mohammed[1], Thanaa Abdulmahdi Mokif[2] ,Karar.N.J.Musafer [3]*,Sarwan W.Bradosty[4]

[1] Pharmacology & toxicology Dept., College of pharmacy, University of Kirkuk, 36001Kirkuk -Iraq.ORCID ID: 0000-0002-8984-6824, dr.amera.k@uokirkuk.edu.iq.

[2]Babylon Technical Institute, Al-Furat Al-Awsat Technical University, 51015, Babylon, Iraq. ORCID ID: 0000-0002-9661-8280, inb.thn@atu.edu.iq.

[3*]Dentistry Department., Al-Zahrawi University College, 56001 Kerbala, Iraq.ORCID ID: orcid.org/0000-0002-3713-7444, karar.shahir@hotmail.com

[4]Medical Laboratory Science Department,College of Science,Cihan university-Erbil,IraqORCID ID : 0000-0002-4659-4081 , sarwan.hamad@cihanuniversity.edu.iq

*Corresponding Author: Karar.N.J.Musaferkarar.shahir@hotmail.com

Article History
Volume 6, Issue 5, 2024
Received: 11 May 2024
Accepted: 17 May 2024
doi: *10.33472/AFJBS.6.5.2024. 4722-4730*

Abstract

Background: The chemical substances that are necessary for an organism to perform certain biological processes are named vitamins, which are crucial for metabolism. And deficiencies are more common in obese people with deficits in A, C, D, and E. Objective: This study aimed to evaluate serum concentrations of vitamin C, D (25-hydroxyvitamin D), A, and vitamin E and their association with increased body adiposity BMI in comparison to healthy subjects. Methods: 87 subjects, were divided into 2 groups: 46 obese individuals (BMI 30-39.9 kg/m^2) and 41 control individuals without any multivitamin supplements (BMI 18.5-24.9 kg/m^2). The study subjects underwent examination at the Ibn al-Nafis specialized laboratory (September 2019 to February 2020)., BMI was determined, and by Using the Competitive-ELISA Assay Kit, the levels of vitamins A, C, D (25-hydroxyvitamin D), and E were measured. Colorimetric Approach; Elabscience Model. SPSS 15 was used for the statistical analyses, and P-values of lessthan 0.05 were considered statistically significant. Results: Obese individuals' BMI and WCwere considerably higher ($P < 0.05$) than those in healthy categories. while having significantly lower ($P \leq 0.05$) levels of vitamin E and vitamin D. While the results of the study showed that obesity groups in every age group had statistically significant differences among females and males($P<0.05$) and vitamin D and vitamin C when compared with healthy males and females, nonetheless, there were no notable variations in the categories of obese people of both sexes compared to healthy individuals. Furthermore, there is a significant association between vitamin C and BMI in obese individuals, but there was a notable negative association between those individuals and vitamin A, conclusion: Vitamins A, E, and D absorption issues may be correlated with obesity (higher BMI).

Keywords: vitamin C, D, A, E, Body mass index, obese.

Introduction

Vitamin plays a central role in metabolism and is an organic molecule that the body needs in small quantities to perform the important biological functions of the body. Humans and other species require micronutrients, especially vitamins, in varying amounts of less than 100 milligrams per day for human nutrition during their lives to coordinate several physiological functions and maintain good health. [1]. Water-soluble and fat-soluble vitamins are the two types of vitamins. Humans have thirteen vitamins: four fat-soluble (A, D, E, and K) and nine water-soluble (B, C, D, E, and K) (eight B and C vitamins). Water-soluble vitamins are quickly dissolved in water and excreted from the body, to the point that urinary output is a good indicator of vitamin intake [2]. Since they are more difficult to store, it is necessary to consume them more consistently [3]. Fat-soluble vitamins are processed by the intestinal tract with the aid of lipids (fats). Vitamin A and D can build up in the body, resulting in dangerous hypervitaminosis. Malabsorption of fat-soluble vitamins is particularly important for cystic fibrosis and the development of cardiovascular diseases (CVD) [4,5]. According to new research, some micronutrient deficiencies can play a role in fat deposition, chronic inflammation, and metabolic disorders like T2DM [6, 50]. Low iron, zinc, vitamin A, vitamin E, and vitamin C concentrations were more common in obese children and adolescents than in children and adolescents of average weight [7, 8]. A lack of these micronutrients can raise the risk of obesity or raise the body mass index.For instance, it has been demonstrated that vitamins A, C, and E decrease or block leptin expression in both human and animal models [9, 10]. In much research, metabolic syndrome has been associated with vitamin D insufficiency when examining the correlation between vitamin D levels and dyslipidemia in obese children [11]. In studies, a higher BMI has been linked to lower vitamin D levels [12]. Obesity is a big public health concern around the world. Approximately 1.9 billion adults worldwide who are overweight or obese account for [13]. This study aimed to see if there was a connection between micronutrient status and obesity.

Materials and Method

In the current paper 87 participants were divided into 2 groups: G1 (41) healthy and G2 (46) obese (increased body mass index). G2 contain 20 males and 26 females, while G1 contains 15 males and 26 females. Participants did not take any multivitamin supplements, have no chronic diseases, have no history of thyroid disease, or have any drugs that might interfere with the results obtained. They lived in Babylon Governorate, Iraq, with information from all patients and control groups including age, sex, weight (kg), and height (meter). In the study samples, people who take vitamin supplements or practice sports were excluded. During the study period, they were examined in the laboratories of the Ibn al-Nafis specialized laboratory (September 2020 to February 2021). The mean age was (27.95±0.70). The body mass index (BMI) was (29.05±0.77) kg/m^2 (mean ± S.E.) and the age was (mean ± S.E.) years. The formula used to determine the BMI was BMI = weight (kg)/height $(m)^2$, and the waist circumference was measured when the person was standing at the width-wise narrowest point of the body, which is typically immediately above the belly button in both genders (about 102 cm for men and 88 cm for women). 5 ml of venous blood were collected from each Participant; then blood was separated from the residual serum by centrifugation at 3000 rpm for 15 minutes. Using the Competitive-ELISA Assay Kit, Model: Elabscience. The ELISA kit uses the Co Vitamin C, D (25-hydroxyvitamin D), A, and E were evaluated by colourimetric means.

Results

Table 1 reveals significant differences in WC, BMI, Vitamin D, and E for obese Participants (34,44±0,86 vs. 22,90±0,23), (115,56±1,37 vs. 85,37±0,95), and (1,34±1,05 vs. 17,24±0,86) in healthy Participants (12,35±1,05 vs. 180,34), respectively. No statistically significant differences were observed in age, vitamin C, or vitamin A compared to healthy Participants.

Table 1: Comparison of age, BMI, WC, vitamins C, D, A and E according to the study groups.

Parameters	Control group N= 41 Mean ±SE	Obese group N= 46 Mean ±SE	P-value of group
Age (years)	29.73 ± 1.03	26.31±0.92	**0.71**
BMI(Kg/M^2)	22.90±0.23	34.44±0.86	**0.001***
WC (cm)	85.37±0.95	115.56±1.37	**0.01***
viamin C (µg/mL)	10.53±0.57	9.61±0.47	**0.53**
25(OH) viamin D (ng/ml)	19.58±1.34	16.25±0.83	**0.02***
viamin A (µg/mL	4.74±0.27	5.34±0.33	**0.23**
viamin E (µg/mL)	17.24±0.86	12.35±1.05	**0.03***

.

BMI: Body Mass Index, WC: Waist Circumference, 25(OH) Vit D:25-hydroxy vitamin D. ***P value is significant ≤ 0 .05 level, SE: St andard Error.**

Although the results of the study showed that the obesity groups in every age group, there are statistically significant disparities between females and males at a substantial level (P <0.05, Vitamin D and C when compared with healthy males and females where the male rates (24.63 ±1.24vs 26.20±1.90),(18.45±1.48 vs 21.30±2.95) and (11.02±0.65 vs 10.69±0.67) as for the female(27.73 ±1.30 vs 30.87±1.16),(14.38± 0.75 vs19.03 ± 1.51) and (8.41± 0.60 vs 10.48 ±0.72) respectively, In contrast, as indicated by Table (2), there were no appreciable differences between the obese groups of both sexes and the healthy population.

Table (2): Comparison of age, BMI, WC, vitamins C , D, A , E according to the sex of the study groups.

Parameters	Control group N= 41		Obese group N= 46		P-value of sex
	Male N= 15 Mean ±SE	Female N= 26 Mean ±SE	Male N= 22 Mean ±SE	Female N= 26 Mean ±SE	
Age (years)	26.20±1.90	30.87±1.16	24.63±1.24	27.73±1.30	**0.002***
BMI(Kg/M^2)	22.61±0.45	23.01±0.27	33.79±1.34	34.99±1.12	**0.49**
WC (cm)	87.59±1.44	83.50±1.18	113.50±2.37	116.22±1.64	**0.13**
viamin C (µg/mL)	10.69±0.67	10.48±0.72	11.02±0.65	8.41 ±0.60	**0.05***
25(OH) viamin D (ng/ml)	21.30±2.95	19.03±1.51	18.45±1.48	14.38±0.75	**0.05***
viamin A (µg/mL)	5.70±0.77	5.22±0.36	5.04±0.41	4.49±0.35	**0.42**
viamin E (µg/mL)	16.80±1.54	17.38±1.04	13.81±1.63	11.12 ±1.33	**0.88**

BMI: Body Mass Index, WC: Waist Circumference, 25(OH) Vit D:25-hydroxy vitamin D
***P value is significant ≤ 0 .05 level, SE: standard Error**

The association analysis in Table (3) showed a significant positive relationship between BMI and vitamin C in the obese community. Furthermore, the results demonstrated a substantial inverse relationship between the groups of obese individuals and vitamin A, whereas the findings found that there was no significant correlation between the BMI and the obese levels of vitamin D 25(OH) and E.

Table (3): The coefficient of correlation between BMI and the concentrations of C, D, A and E vitamins in the Obese group

Parameters	BMI (Kg/M^2)	
	R	P-value
viamin C (µg/mL)	0.29	**0.05***
25(OH) vit D (ng/ml)	0.17	0.23
viamin A (µg/mL	-0.31	**0.03***
viamin E (µg/mL)	0.05	0.72

Correlation coefficient (r). * Correlation is significant ≤ 0.05 level.

Discussion

Overweight and obesity are disorders characterized by a disproportionate excess body weight, essentially due to the accumulation of fat, and many international health institutions believe that the current century is a pandemic. Obesity is related to some chronic, non-communicable disorders, including metabolic syndrome, type 2 diabetes, cardiovascular disease, and cancer [14]. Also with a significant positive relationship between BMI and vitamin C and decreased vitamin D and E levels among those obese. But no association was found between BMI and vitamin D or E levels. Additionally, studies also showed inverse relationship between various types of obesity and vitamin A. According to the data. Garcia et al. (2013), show that obesity was associated with a lower concentration of vitamin C and vitamin E, the study findings in line with Garcia et al. (2013). Vitamin C and E had a negative correlation with BMI, while Vitamin A had a positive correlation with BMI [15].
Prior research have demonstrated that compared to typical adult weights, obese people had 5–12% minor micronutrient intakes and a greater risk of dietary insufficiency [16]. Obesity backgrounds extra body weight and lowers the concentration of vitamin D3 obtained by food in blood serum, which is dispersed [38]. This reduced the vitamin D3 quantity generated through the skin [39]. Individuals who have a lot of fat tissue also have a lot of vitamin D3 built up in them. Vitamin E deficiency is also linked to abdominal obesity [40,41]. in obese children the Morinobu et al. were reported the inverse association between α-tocopherol concentrations and blood lipids levels [42]. According the study by Neuhouser et al. were described the serum α-tocopherol concentrations in obese adolescents were on average 10% lesser than in adolescents with normal body weight. Patients who are Obese appear to have higher risks of vitamin C deficiency [43]. Ascorbic acid, an antioxidant reduces the severity of oxidative stress , may be leads to the development of insulin resistance, which is often detected in obese patients. The Vitamin C blocks the destructive effect of free radicals, improves endothelial function, and decreases insulin resistance. Johnston found an inverse connotation between vitamin C plasma concentration and body mass index . According to many studies, patients obese have low serum carotenoid concentrations and an increased risk of vitamin A deficiency. According to Neuhouser et al. investigation, vitamin C deficiency was present in Obese subjects [44-49], Probably the reason behind this is the increased expenditure of vitamin A resulting from oxidative stress and inflammatory processes in patients with impaired carbohydrate metabolism. This is most likely because individuals with poor glucose metabolism spend more vitamin A as a result of oxidative damage and inflammatory processes. Several studies have also indicated that micronutrient deficiencies are common among school-aged children in Mexico; vitamin C deficiency affects about 30% of the population [17–19]. Other research has shown that rural women are more likely to be deficient in micronutrients and that zinc and vitamin C levels are linked to obesity, adiposity, and leptin levels. [20] A vitamin D deficiency is linked to obesity, hypertension, diabetes, hyperglycemia, and dyslipidemia, all of which are cardiovascular risk factors. Vitamin D has a lipid profile even in non-obese children, and low vitamin D levels may lead to dyslipidemia or obesity [21].

The findings are in line with those of Reddy et al. (2017), who discovered that vitamin D deficiency or insufficiency is widespread among obese and overweight adolescents [22]. Our findings contradicted those of Oommen and Al-Zahrani in 2015, who found no substantial connection between obesity and vitamin D deficiency, implying that vitamin D deficiency does not play a significant role in obesity in Saudi women over 40 years of age [23].On the other hand, some studies found that both groups had similar average serum vitamin D levels, the metabolic syndrome group had slightly lower vitamin D levels than obese individuals. In both diabetic and non-diabetic subject's vitamin D deficiency has been linked to higher BMI [24, 25]. whereas vitamin C concentration is correlated with the increase in body and abdominal fat. Vitamin C levels were shown to be inversely related to BMI, body fat, and waist circumference in adult populations, indicating that they were inversely related to overweight and obesity. [20,26]. ascorbic acid plays many roles in reducing weight. by modulating lipolysis of adipocytes [27, 28]. also, findings from controlled animal model studies supported the connection between low vitamin C levels and the spread of lifestyle-related diseases. [29]. Although research shows that chronically feeding obese rats a vitamin A-rich diet reduces obesity and its complications by controlling different pathway genes in the liver, retroperitoneal white adipose tissue, and brown adipose tissue, [30]. However, many genetic SNP disorders may lead to obesity and even T2DM [51]. However obese individuals have lower vitamin A levels and vitamin A intakes than people of normal weight [31]. Vitamin E has been shown to possess anti-oxidant, anti-inflammatory, anti-obesity, anti-hyperglycemic, anti-hypertensive, and anti-hypercholesterolemic properties. For MetS and its constituent parts to evolve, vitamin E pathways are important. [32], Vitamin E intake is crucial for mitigating the negative consequences of a high-fat diet. [33] Vitamin E has an important role in the control and metabolism of lipids because it is channelled into pathways correlated to lipoproteins and cholesterol in humans. [34]. Patients with metabolic syndrome had substantially reduced plasma levels of vitamins A, C, E, and D than healthy subjects. When these vitamins are reduced, they can contribute to the pathophysiology of metabolic illnesses. [34,35,36,37].

Conclusion

It's yet unknown how well particular vitamins are absorbed by fat individuals. There may be a connection between an excess of body weight and excessive energy value and a vitamin A, E, or D insufficiency.

References

1- Godswill ,A. C., Somtochukwu, I. V. , Ikechukwu O. A.and Kate, E. C. Health Benefits of Micronutrients (Vitamins and Minerals) and their Associated Deficiency Diseases: A Systematic Review. International Journal of Food Sciences 2520-4637 (online) Vol. 3, Issue 1, No. 1, pp 1 - 32, 2020.

2- Fukuwatari T, Shibata K . Urinary water-soluble vitamins and their metabolite contents as nutritional markers for evaluating vitamin intakes in young Japanese women. Journal of Nutritional Science and Vitaminology2008;54 (3): 223–9.

3- Asif M. A review on adverse effects of overdose vitamins on human health." Persian Journal of Medical Sciences (PJMS).6102 : 3.4 .

4- Maqbool A, Stallings VA. Update on fat-soluble vitamins in cystic fibrosis Current Opinion in Pulmonary Medicine 2008; 14 (6): 574–81.

5- Mitu ,O., Cirneala, I. A., Lupsan ,A.I., Iurciuc ,M. , Mitu, I. , Dimitriu ,D. C. , Costache, A. D., Petris A. O., and Costache ,I. I. The E_ect of Vitamin Supplementation on Subclinical Atherosclerosis in Patients without Manifest Cardiovascular Diseases: Never-ending Hope or Underestimated Effect . Molecules 2020, 25, 1717; doi:10.3390/molecules25071717.

6- Garcia OP, Ronquillo D, Caamano Mdel C, Camacho M, Long KZ, Rosado JL, Zinc, vitamin A, and vitamin C status are associated with leptin concentrations and obesity in Mexican women: Results from a cross-sectional study. *Nutr. Metab. (Lond.)* 2012;*9*, 59.

7- Aeberli I, Hurrell RF, Zimmermann MB. Overweight children have higher circulating hepcidin concentrations and lower iron status but have dietary iron intakes and bioavailability comparable with normal weight children. Int. J. Obes. (Lond.) 2009; 33, 1111–1117.

8- De Souza Valente da Silva, L, Valeria da Veiga G, Ramalho RA. Association of serum concentrations of retinol and carotenoids with overweight in children and adolescents. *Nutrition* 2007; *23*, 392–397.

9- Mohammed A K and Hassan A J. Assess the relationship between insulin fasting levels and healthy obesity in adults in the province of Babylon, Iraq." Iraqi National Journal of Chemistry. 2015,15,4: 318-328.

10- Mohamed AK, and Hassan A J. Assess the relationship between leptin levels with classes of obesity in adult of Babylon, Iraq. Mesopotamia Environmental Journal Special Issue C. 2017: 130-135.

11- Turer CB, Lin H, Flores G. Prevalence of vitamin D deficiency among overweight and obese US children. Pediatrics **2013**; 131, e152–e161. [CrossRef] [PubMed]

12- WHO. Facts Sheet NÊ311, Obesity and overweight. World Health Organization (WHO) ; 2015 [cited 2016 March].

13- Mohammed A K, Mokif, Th A, Hadwan, M H. The effect of Morbid Obesity on the Liver Function Enzymes.Research Journal of Pharmacy and Technology. 2019; 12, 5: 2241-2244.

14- García O P, Ronquillo D, Caamaño M C, Martínez G, Camacho M, López V, Rosado J L. Zinc, Iron and Vitamins A, C and E Are Associated with Obesity, Inflammation, Lipid Profile and Insulin Resistance in Mexican School-Aged Children.Nutrients 2013; 5, 5012-5030.

15- Agarwal SC, Reider J R, Brooks V L. Fulgoni 3rd, Comparison of prevalence of inadequate nutrient intake based on body weight status of adults in the United States: an analysis of NHANES 2001–2008, J. Am. Coll. Nutr 2015 34 ,126–134..
16- Rivera-Domarco J, Shama-Levy T, Villalpando-Hernandez S,González-de Cossío T, Hernández-Prado B, Sepúlveda J. Encuesta Nacional de Nutrición 1999. (National Nutrition Survey 1999); Instituto Nacional de Salud Publica: Cuernavaca, Mexico, 2001.
17- Olaiz-Fernandez G, Rivera-Dommarco J, Shamah-Levy T, Rojas R, Villalpando-Hernández S, Hernández-Ávila M , Sepúlveda-Amor J. Encuesta Nacional de Salud y Nutrición; Instituto Nacional de Salud Publica: Cuernavaca, Mexico, 2006.
18- Shamah-Levy T, Villalpando S, Jauregui A, Rivera JA. Overview of the nutritional status of selected micronutrients in Mexican children in 2006. *Salud Publica Mex* **2012**; *54*, 146–151
19- Garcia OP, Ronquillo D; Caamano Mdel C; Camacho M, Long KZ, Rosado JL. Zinc, vitamin A, and vitamin C status are associated with leptin concentrations and obesity in Mexican women: Results from a cross-sectional study. *Nutr. Metab. (Lond.)* **2012**; *9*, 59
20- Kim MR , Jeong SJRelationship between Vitamin D Level and Lipid Profile in Non- Obese Children. *Metabolites* 2019; 9,125. doi:10.3390/metabo9070125.
21- - Reddy TP , Reddy K , Reddy M S , Manjunath G A .Levels of vitamin D among overweight and obese adolescents: an observational study. Int J Contemp Pediatr 2017;4(6):1934-1939.
22- Oommen A , Al-Zahrani IH. Association of obesity with vitamin D deficiency and theclinical implications. Int J Res Med Sci 2015 ;3: 3262-5.
23- Mirhoseini M , Daemi H , Masoom Babaiee M , Asadi-Samani M , Mirhoseini L, Sedehi M. The relationship between vitamin D deficiency and metabolic syndrome in obese individuals. J Renal Inj Prev 2018;7(4):275-279. DOI: 10.15171/jrip.2018.61.
24- - Rafiq S , Jeppesen PB . Body Mass Index, Vitamin D, and Type 2 Diabetes: A Systematic Review and Meta-Analysis. Nutrients 2018; 10, 1182; doi:10.3390/nu10091182
25- Johnston CS, Beezhold BL, Mostow B, Swan PD. Plasma vitamin C is inversely related to body mass index and waist circumference but not to plasma adiponectin in nonsmoking adults. *J. Nutr* **2007**; *137*, 1757–1762.
26- Hasegawa N, Niimi N, Odani F. Vitamin C is one of the lipolytic substances in greentea. *Phytother. Res* **2002**; *16*, S91–S92.
27- - Garcia-Diaz DF, Campion J, Milagro FI, Paternain L, Solomon A, Martinez JA . Ascorbic acid oral treatment modifies lipolytic response and behavioural activity but not glucocorticoid metabolism in cafeteria diet-fed rats. *Acta Physiol. (Oxf.)* **2009**; *195*, 449–457.
28- Ipsen DH , Pernille Tveden-Nyborg P, Lykkesfeldt J . Does Vitamin C Deficiency Promote Fatty Liver Disease Development?Nutrients2014; 6, 5473-5499.
29- Jeyakumar S M , Vajreswari A .Vitamin A as a key regulator of obesity & its associated disorders: Evidences from an obese rat. model. Indian J Med Res 2015,141:275-284.

30- Olga P. G .Micronutrients, immunology and inflammation Effect of vitamin A deficiency on the immune response in obesity Proceedings of the Nutrition Society 2012; 71, 290–297.

31- Wong SK, Chin K-Y, Suhaimi FH, Ahmad F , Ima-Nirwana S. Vitamin E As a Potential Interventional Treatment for Metabolic Syndrome: Evidence from Animal and Human Studies. Front. Pharmacol.2017; 8:444.

32- Al-Kushi GA, El Sawy AN, Hijazi MM, Header AE, Hataba AA (2016) Therapeutic Effect of Vitamin E on Testicular Tissue Damage Caused by Obesity. J Obes Weight Loss Ther 2016; 6(5): 320. doi:10.4172/2165-7904.1000320

33- Galmés S, Serra F, Palou A .Vitamin E Metabolic Effects and Genetic Variants: A Challenge for Precision Nutrition in Obesity and Associated Disturbances . Nutrients 2018; 10, 1919; doi:10.3390/ nu10121919

34- Godala M, Materek-Kusmierkiewicz I, Moczulski D, Rutkowski M, Szatko F, Gaszynska E, and Kowalski J. Metabolic Syndrome Increases the Risk of Plasma Vitamin A, C, E and D Deficiency. Endocrinol Metab Syndr 2016; 5: 254.

35- Blaner, W.S. Vitamin A Signaling and Homeostasis in Obesity, Diabetes, and Metabolic Disorders. Pharmacol. Ther. 2019, 197, 153–178.

36-Jaff D, - Effect of green tea on obesity and serum lipid profiles in both normo- and hyper-cholesterolemic rabbits. international Journal of Research in Pharmaceutical Sciences,2019:10 1035-1041, DOI:10.26452/ijrps.v10i2.378,

37- Al-Obaidi W M L , Study of Many Biochemical and Oxidative Stress Variables in Patients with Atherosclerosis in Kirkuk City, Journal for Research in Applied Sciences and Biotechnology: 2022, 1(3):197-203 .DOI:10.55544/jrasb.1.3.26.

38- Al-Suhaimi EA, Al-Jafary MA. Endocrine roles of vitamin K-dependent- osteocalcin in the relation between bone metabolism and metabolic disorders. Rev Endocr Metab Disord. 2020 Mar;21(1):117-125. doi: 10.1007/s11154-019-09517-9. PMID: 31761961.

39- Karonova T, Andreeva A, Nikitina I, Belyaeva O, Mokhova E, Galkina O, et al. Prevalence of Vitamin D deficiency in the North-West region of Russia: A cross-sectional study. J Steroid Biochem Mol Biol. 2016;164:230–4.

40- Thakur, V., & Jain, A. (2020). COVID 2019-suicides: A global psychological pandemic. Brain, behavior, and immunity, 88, 952.

41- Hendarto, A., Alhadar, A. K., & Sjarif, D. R. (2019). The effect of vitamin E supplementation on lipid profiles and adiponectin levels in obese adolescents: a randomized controlled trial. Acta Med Indones, 51(2), 110-116.

42- Morinobu, T., Murata, T., Takaya, R., & Tamai, H. (2002). Nutritional status of beta-carotene, alpha-tocopherol and retinol in obese children. International journal for vitamin and nutrition research, 72(3), 119-123.

43- Lewis C. C., Mettert K. D., Dorsey C. N., Martinez R. G., Weiner B. J., Nolen E., Powell B. J. (2018). An updated protocol for a systematic review of implementationrelated measures. Systematic Reviews, 7(1), Article 66. https://doi.org/10.1186/s13643-018-0728-3.

44- Wallström, P., Wirfält, E., Lahmann, P. H., Gullberg, B., Janzon, L., & Berglund, G. (2001). Serum concentrations of β-carotene and α-tocopherol are associated with diet, smoking, and general and central adiposity. The American journal of clinical nutrition, 73(4), 777-785.

45- Galan, P., Viteri, F. E., Bertrais, S., Czernichow, S., Faure, H., Arnaud, J., & Hercberg, S. (2005). Serum concentrations of β-carotene, vitamins C and E, zinc and selenium are influenced by sex, age, diet, smoking status, alcohol consumption and corpulence in a general French adult population. European journal of clinical nutrition, 59(10), 1181-1190.

46- Switzer, K. C., Nagy, M. S., & Mullins, M. E. (2005). The influence of training reputation, managerial support, and self-efficacy on pre-training motivation and perceived training transfer. Applied HRM Research, 10(1), 21-34.

47- Bonet, M. L., Ribot, J., Galmés, S., Serra, F., & Palou, A. (2020). Carotenoids and carotenoid conversion products in adipose tissue biology and obesity: Pre-clinical and human studies. Biochimica et Biophysica Acta (BBA)-Molecular and Cell Biology of Lipids, 1865(11), 158676.

48- Góes É, Cordeiro A, Bento C, Ramalho A. Vitamin A Deficiency and Its Association with Visceral Adiposity in Women. Biomedicines. 2023 Mar 22;11(3):991. doi: 10.3390/biomedicines11030991. PMID: 36979970; PMCID: PMC10046475.

49- Shen, Y., Liu, K., Luo, X. et al. The low prevalence rate of vitamin E deficiency in urban adults of Wuhan from central China: findings from a single-center, cross-sectional study. Eur J Med Res 28, 141 (2023). https://doi.org/10.1186/s40001-023-01103-9.

50- Musafer KNJ, Huyop fahrul Z, Ewadh MJ, Supriyanto E, Rava M. A Systematic Mapping Study on the Risk Factors Leading to Type II Diabetes Mellitus. Karbala Int J Mod Sci. 2020;6(3):275–83.

51- Musafer KNJ, Rava M, Chobok AS, Shamsuddin S, Al-Mousawi MRR, Hayup F. A meta-analysis and review on genetic mapping of type 2 diabetes mellitus in Iraq. Egypt J Med Hum Genet. 2023;24(1):66.