



## A study on the effect of diabetes and obesity on some lipids and some biochemical parameters of women in AL-Khoums city

\*Mona Alfakheri<sup>1</sup>, Seeq Altamtam<sup>2</sup>

<sup>1</sup>Faculty of health Science, Al-mergeb University, Libya

<sup>2</sup> Faculty of Education, Al-Jufra University, Libya.

### Keywords:

Obesity  
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lipids profile  
Calcium  
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Vitamin D

### ABSTRACT

Obesity and type 2 diabetes mellitus (T2DM) in women are increasing in prevalence owing to decreases in physical activity levels and a shift to diets that include addictive and/or high-calorie foods. These changes are associated with the adoption of modern lifestyles and the presence of an obesogenic environment, which have resulted in alterations to metabolism, adaptive immunity and endocrine regulation. This study clarifies the problem of the large prevalence of Type 2 Diabetes Mellitus (T2DM) with obesity on women in the city of AL-Khoums city and its impact on many chemical parameters. Many studies have confirmed the impact of diabetes and obesity on women, and thus the possibility of side effects increases if the patient neglects important advice from the doctor or neglects to take periodic treatment. It is difficult to limit the spread of the disease, but it is our duty, along with the scientific seminars and advice provided by the Diabetes Center in AL-Khuoms city, to delay the disease, and to give women all the important information about the dangers. of obesity on public health and the exacerbation of the risk with (T2DM). This study concluded that women with diabetes with obesity showed a significant effect on some lipids such as cholesterol and triglycerides, in addition to its effect on calcium, ferritin and vitamin D, and therefore other complications on body functions are certain.

دراسة تأثير السكر والسمنة على بعض الدهون وبعض المقاييس البيوكيميائية لدى النساء في مدينة الخمس.

\*منى الفاخري<sup>1</sup> وسيق التمام<sup>2</sup>

<sup>1</sup>كلية العلوم الصحية، جامعة المرقب، ليبيا

<sup>2</sup>كلية التربية، جامعة الجفرة، ليبيا.

### الكلمات المفتاحية:

السمنة  
مرض السكري  
ملف الدهون  
الكالسيوم  
الفيريتين  
فيتامين د

### المخلص

يتزايد انتشار السمنة ومرض السكري من النوع 2 (T2DM) لدى النساء بسبب الانخفاض في مستويات النشاط البدني والتحول إلى النظم الغذائية التي تشمل الأطعمة التي تسبب الإدمان و/أو الأطعمة ذات السعرات الحرارية العالية. ترتبط هذه التغييرات بتبني أنماط الحياة الحديثة ووجود بيئة مسببة للسمنة، مما أدى إلى تغييرات في التمثيل الغذائي والمناعة التكيفية وتنظيم الغدد الصماء. توضح هذه الدراسة مشكلة الانتشار الكبير لمرض السكري من النوع 2 (T2DM) مع السمنة على النساء في مدينة الخمس وتأثيرها على العديد من المعايير الكيميائية. أكدت العديد من الدراسات تأثير مرض السكري والسمنة على النساء، وبالتالي تزداد احتمالية حدوث آثار جانبية إذا أهمل المريض نصيحة الطبيب المهمة أو أهمل في تناول العلاج الدوري. من الصعب الحد من انتشار المرض ولكن من واجبنا إلى جانب الندوات العلمية والنصائح التي يقدمها مركز السكري في مدينة الخمس تأخير المرض وإعطاء المرأة كافة المعلومات المهمة عن المرض. الأخطار. من السمنة على الصحة العامة وتفاقم المخاطر مع (T2DM). خلصت هذه الدراسة إلى أن النساء المصابات بداء السكري المصابات بالسمنة أظهرن تأثيراً معنوياً على بعض الدهون مثل الكوليسترول والدهون الثلاثية، بالإضافة إلى تأثيره على الكالسيوم والفيريتين وفيتامين د، وبالتالي هناك مضاعفات أخرى على وظائف الجسم مؤكدة.

\*Corresponding author:

E-mail address: [Mmalfakheri@elmergib.edu.ly](mailto:Mmalfakheri@elmergib.edu.ly), ( S.Altamtam) [Seeq87ali@gmail.com](mailto:Seeq87ali@gmail.com)

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## Introduction

Type 2 diabetes (T2DM) is a chronic metabolic disorder with an alarming prevalence around the world. As a result of this aggravation, it is rapidly turning into an epidemic in some countries of the world, and the number of infected people is expected to increase rapidly in the next decade due to the increasing aging of the population, which already increases the responsibility on health care providers. Especially in developing countries (Abdulfatai *et al.*, 2012).

People with type 2 diabetes are more susceptible to various forms of short- and long-term complications, which often lead to their early death. This trend appears to increase morbidity and mortality rates in patients with type 2 diabetes due to the prevalence of this type of disease, its malignant and progressive appearance and delayed early recognition, especially in developing countries that are poor in medical and health resources such as Africa (Azevedo & Alla, 2008).

The past 50 years have witnessed an increasingly aging population with increasing prevalence and complications of type 2 diabetes (T2DM); Now, approximately half of individuals with diabetes are elderly (aged  $\geq 65$  years). Older adults with T2DM present particularly difficult medical and practical challenges. For example, the marked heterogeneity of this patient population, the potential presence of multiple comorbidities, increased susceptibility to hypoglycemia, increased care dependency and the impact of worsening health frailty all make diabetes management particularly difficult in this age group (Srikanth *et al.*, 2021).

Body mass index has a strong relationship with insulin resistance and diabetes. People who suffer from obesity have an increased amount of non-esterified fatty acids, glycerol, hormones, cytokines, inflammatory markers, and other substances that are involved in the development and worsening of insulin resistance. The pathogenesis of the development of diabetes is based on the fact that the beta islet cells in the pancreas are weak, which unfortunately causes a pathological lack of control of blood glucose. (Abdullah *et al.*, 2014), however, the most important risk factors in this era, when frequency of obesity is rapidly increasing worldwide, might be insulin resistance and type 2 diabetes (Park, 2006).

Glucose intolerance in women with DM, as a consequence of diminished insulin action, is associated with reduced lipoprotein lipase (LPL) activity and overproduction of TG-rich very low-density lipoproteins. The hallmarks of diabetic dyslipidemia mainly include hypertriglyceridemia, elevated low-density lipoprotein-cholesterol (LDL-C) and decreased high-density lipoprotein-cholesterol (HDL-C). Dyslipidemia can exacerbate insulin resistance in DM, leading to a worse clinical outcome (Jarvie *et al.*, 2010).

The World Health Organization (WHO) has unfortunately declared obesity to be the epidemic of the 21st century. In particular, many studies have shown that obesity increases the risk of vitamin D deficiency. Moreover, other studies showed that vitamin D deficiency was associated with a higher risk of type 2 diabetes, cardiovascular disease, hypertension, and obesity (Zahra *et al.*, 2018).

Vitamin D plays an important role in calcium metabolism, maintenance of the skeleton, control of cell proliferation and differentiation, and immunity (Kim *et al.*, 2013). Recently, it has been shown that vit D deficiency has a strong relationship with increased risk of type 2 diabetes, cardiovascular disease (CVD) as well as CVD risk factors such as hypertension and obesity (Forsythe *et al.*, 2012). Obese women are at a high risk of micronutrient deficiency, including calcium and vitamin D. They have low levels of calcitriol, which, by reducing the secretion of PTH, leads to the disturbance of calcium absorption from the intestines. The decreased concentration of calcitriol in the blood probably is due to the abundance of adipose tissue in which vitamin D can accumulate; vitamin D's release into the bloodstream then occurs when fat tissue is reduced during weight loss (Pannu, 2016).

## MATERIALS AND METHODS

### Experimental design:

This study was designed to examine some characteristics of the biochemical changes of obese women with diabetes during the period from May 21, 2022 to August 21, 2022 at the Diabetes Control Center and Treatment Center in Al Khoums city.

### Blood sampling:

The blood samples were transferred to the collection tube, and left for 10-15 minutes at room temperature. After about a quarter of an hour. About 3 ml of blood samples were collected from the vein in less than 2 minutes. The serum samples were separated by centrifugation at 4000 rpm for 5 minutes, and collected in new test tubes and stored at  $-20^{\circ}\text{C}$  until assayed.

### Biochemical parameters:

Biochemical parameters were assayed such as cholesterol (CHOL), HDL cholesterol, LDL cholesterol, triglycerides (TRI), Aspartate amino Transaminase (AST), Alanine amino Transaminase, Vitamin D (Vit D), Calcium (Ca), Ferritin (Fer).

### Statistical Analysis of Data:

Socio-demographic, clinical, and laboratory data were obtained from patients. Statistical analysis was carried out using (SPSS). XLSTAT program was used for descriptive statistics, graphing data and comparative statistics. The results were analyzed using one-way analysis of variance (ANOVA) followed by Fisher (LSD) test to compare groups with each other and Dennett two-sided test for comparisons with the control group.

## RESULTS AND DISCUSSION

In this study, which was conducted on 70 women with diabetes and obesity group (group2) and compared with 70 healthy women (group1) in the period from 21 May to 21 August, 2022 at the Diabetes Control Center and Treatment Center in Al Khoums city, the results showed that there were significant differences in the majority of the studied parameters, which were as follows:

**Table (1) lipid profile indicators (cholesterol, HDL.LDL triglycerides) for women with diabetes and obesity and healthy women.**

Parameters	GROUP 1 (Control group) Means $\pm$ S.E.M	GROUP 2 (Patient group) Means $\pm$ S.E.M	P value
Cholesterol (mg/dl)	137.5 $\pm$ 4.0	188.8 $\pm$ 5.6	0.000
High density lipoprotein (HDL) (mg/dl)	45.51 $\pm$ 1.2	42.3 $\pm$ 1.2	0.066
Low density lipoprotein (LDL) (mg/dl)	75.2 $\pm$ 2.5	96.8 $\pm$ 6.4	0.002
Triglycerides (mg/dl)	104.8 $\pm$ 3.3	185.4 $\pm$ 6.1	0.000

Values are mean  $\pm$  S.E.M. The values with different heights within each row are very different (analysis of variance,  $P < 0.05$ ).

**Table (2) Calcium, Ferritin and Vitamin D for women with diabetes and obesity and healthy women.**

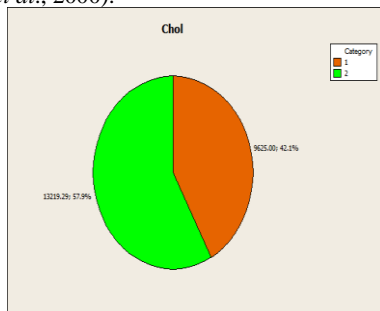
Parameters	GROUP 1 (Control group) Means $\pm$ S.E.M	GROUP 2(Patient group) Means $\pm$ S.E.M	P value
Ca (mg/dl)	24.2 $\pm$ 12	12.8 $\pm$ 2.1	0.000
Ferritin ( )	96.2 $\pm$ 5.1	31.0 $\pm$ 2.3	0.000
Vit. D (ng/dl)	10.60 $\pm$ 0.60	46.8 $\pm$ 1.3	0.000

Values are mean  $\pm$  S.E.M. The values with different heights within each row are very different (analysis of variance,  $P < 0.05$ ).

### 1. The effect of diabetes and obesity on cholesterol

Table (1) and figure (1) summarize the cholesterol level for group 2 Compared with group 1 for five months. Cholesterol level was significantly higher in group 2 than group 1. It was  $137.5 \pm 4.0$ ,  $188.8 \pm 5.6$  in group 1 and group 2, respectively. A comparable finding has been found in a study by (Kang *et al.*, 2014), they found that individually the mean serum total cholesterol, triglyceride, and LDL levels were significantly higher and the average blood HDL level was lower among the obese group compared to the non-obesity group. This is supported by a study by Kang *et al.*, 2014 participants, which showed that women with obesity had higher levels of triglycerides in the blood and lower average HDL levels compared to women with a normal BMI and normal body fat percentage. In another study in a Caucasian population by Romero *et al.*, 2010 reported that the proportional relationship between increased body fat percentage in women with an increased risk of dyslipidemia and associated cardiovascular mortality. According to previous studies, the univariate association between blood glucose and cholesterol synthesis in

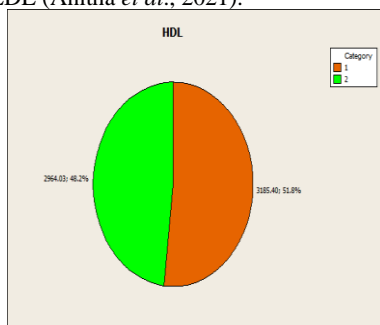
the present study could suggest that lowering of blood glucose levels would diminish cholesterol synthesis and increase cholesterol absorption; all of these changes could actually be seen after effective weight reduction in diabetic individuals (Simonen *et al.*, 2000).



**Figure (1):** Describes the statistical difference in cholesterol for females with diabetes and obesity

**2. The effect of diabetes and obesity on HDL**

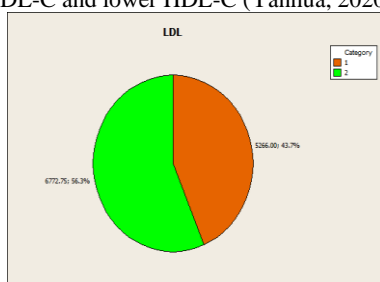
Table (1) and figure (2) summarize the HDL level for group 2 compared with group 1 for five months, no significant differences were found in group 2. It was  $45.51 \pm 1.2$ ,  $42.3 \pm 1.2$  in group 1 and group 2, respectively. HDL is the most abundant lipoprotein in human tissue and provides protection to cell membranes from oxidative stress (Sorani *et al.*, 2012). The change in HDL level in our study is consistent with study by (Tri, 2021) who obtained that there is a significant relationship between HbA1c levels and triglyceride levels and there was no significant relationship between HbA1c levels and LDL and HDL levels. This is also consistent with a study on diabetic patient's and obesity with high triglycerides, HDL and LDL, and treating this high with nutritional supplements, where it was found that patients had fluctuations in the level of triglycerides, HDL and LDL (Anitha *et al.*, 2021).



**Figure (2):** Describes the statistical difference in HDL for females with diabetes and obesity

**3. The effect of diabetes and obesity on LDL**

Table (1) and figure (3) summarizes the LDL level for group 2 compared with group 1 for five months. LDL was significantly higher in group 2 than group 1. It was  $75.2 \pm 2.5$ ,  $96.8 \pm 6.4$  in group 1 and group 2, respectively. Common causes of raised LDL, triglycerides and Low levels of density HDL are obesity and high alcohol intake. Impaired glycemic control has been linked to raised triglycerides in type 2 diabetes (T2D) (Nordestgaard, 2016). Our study on LDL is consistent with a study on Chinese subjects with type2 diabetes and obesity have proved to be more associated with metabolic risk factors of higher in LDL-C and lower HDL-C (Yanhua, 2020).

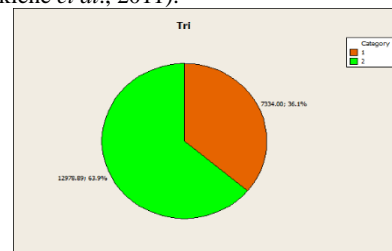


**Figure (3):** Describes the statistical difference in LDL for

females with diabetes and obesity

**4. The effect of diabetes and obesity on triglycerides**

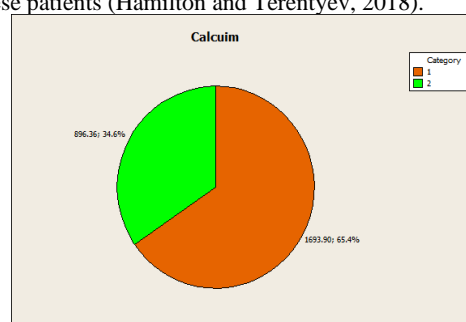
Table (1) and figure (4) summarize the triglycerides level for group 2 compared with group 1 for five months. Triglycerides were significantly higher in group 2 than group 1. It was  $104.8 \pm 3.3$ ,  $185.4 \pm 6.1$  in group 1 and group 2, respectively. This is also consistent with a study conducted by (Anitha *et al.*, 2021) on women with diabetes and obesity who suffer from high triglycerides and lipids, and the rise increased with pregnancy. A relationship between lipid metabolism and insulin resistance is well established. Insulin resistance such as that found in the present study is accompanied by raised circulating FAs (as a consequence of adipose tissue insulin resistance), which inhibit glucose uptake into skeletal muscle (Weigert *et al.*, 2005). Furthermore, lipid 'spill-over' from adipocytes is more frequent in obesity, with adipocytes exhibiting higher rates of spontaneous lipolysis, resulting in increased delivery of fatty acids and triglyceride production in non-adipose tissues (Laurencikiene *et al.*, 2011).



**Figure (4):** Describes the statistical difference in triglycerides for females with diabetes and obesity.

**5. The effect of diabetes on calcium**

Table (2) and figure (5) summarize the calcium rate for women with diabetes and obesity (group 2) compared with healthy women (group 1) for five months. Calcium rate was significantly lower in group 2 than group 1. It was  $24.2 \pm 12$ ,  $12.8 \pm 2.1$  in group 1 and group 2, respectively. Obesity was a risk factor for deficient calcium intake is of interest given the high prevalence of overweight and obesity among youth with (T2DM) (Liu *et al.*, 2010), This decrease in the rate of calcium with diabetes corresponds to a study that conducted by Wei *et al.*, 2021 where a decrease in calcium was recorded in patients with diabetes in agreement with the increase in their weight. Studies show that poor glycemic control and various complications of diabetes in obese offspring have a negative impact on bone mineral density. Abnormal metabolism of energy, vitamin D, electrolytes, and other organ functions of diabetes and its acute and chronic complications can lead to osteoporosis as a result of low calcium. Some antidiabetic medications may also lead to different levels of osteoporosis (Chunling *et al.*, 2021). Diabetes with obesity also paves the way for changes in the intracellular sodium and calcium balance. Specifically, diastolic intracellular calcium levels increase secondary to changes in the expression and function of the sarcoplasmic reticulum (SR) Ca<sup>2+</sup>-ATPase (SERCA) and consequently impaired Ca<sup>2+</sup> uptake in S. (Gallego *et al.*, 2021). This results in delayed depolarization and thus an increased likelihood of arrhythmias. considered central to these calcium-dependent pro-arrhythmic effects, dysregulation of cytosolic calcium and mitochondrial dysfunction have also been observed in obese patients (Hamilton and Terentyev, 2018).

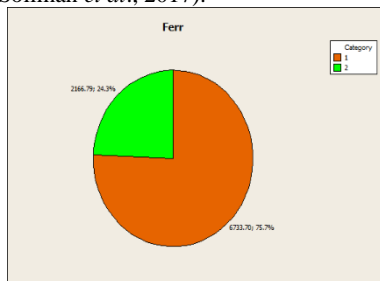


**Figure (5):** Describes the statistical difference in LDL for

females with diabetes and obesity

### 6. The effect of diabetes on ferritin:

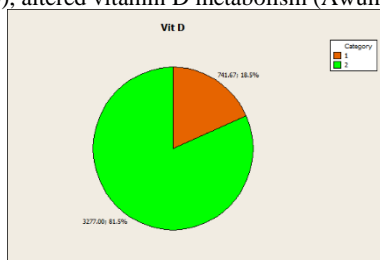
Table (2) and figure (6) summarize the ferritin rate for group 2 compared with group 1 for five months. The ferritin rate was significantly lower in group 2 than group 1. It was  $96.2 \pm 5.1$ ,  $31.0 \pm 2.3$  in group 1 and group 2, respectively. Obesity and type 2 diabetes mellitus (T2DM) are increasing in prevalence owing to decreases in physical activity levels and a shift to diets that include addictive and/or high-calorie foods. These changes are associated with the adoption of modern lifestyles and the presence of an obesogenic environment, which have resulted in alterations to metabolism, adaptive immunity and endocrine regulation. The size and quality of adipose tissue depots in obesity, including the adipose tissue immune compartment, are critical determinants of overall health (Sara *et al.*, 2022). Unfortunately, we observed a significant decrease in iron tissue depots; this is consistent with the study (Andrés *et al.*, 2021) which indicates a lack of iron stores in women with diabetes. They conclude that tissue iron depots correlate with insulin sensitivity. Iron deficiency, especially iron deficiency anemia, leads to changes in glucose and lipid metabolism. Hyperglycemia has been frequently observed in animal models of iron deficiency, a finding associated with altered hepatic insulin promoting enhanced lipogenesis and impaired lipid oxidation (Soliman *et al.*, 2017).



**Figure (6):** Describes the statistical difference in ferritin for females with diabetes and obesity

### 7. The effect of diabetes on vitamin D:

Table (2) and figure (7) summarize the vitamin D level for women with diabetes and obesity (group 2) comparing with healthy women (group 1) for five months. Compared to group 1, the vitamin D level was significantly higher in group 2 than group 1. It was  $10.60 \pm 0.60$ ,  $46.8 \pm 1.3$  in group 1 and group 2, respectively. Fluctuations in vitamin D may have a role in the pathogenesis of both forms of diabetes, and a better understanding of the mechanisms involved could lead to the development of preventive strategies (Mathieu *et al.*, 2005). Results of randomized clinical trials remain scarce and inconclusive to determine the relationship between vitamin D, obesity, and T2DM. Some studies have shown that vitamin D prevents fat accumulation, increases insulin synthesis, preserves pancreatic islet cells, reduces insulin resistance, and controls T2DM. To date, there is insufficient scientific evidence to support the use of vitamin D as a means of preventing and/or treating obesity and type 2 diabetes. (Flávia and Josefina, 2014). Our study is consistent with some studies suggesting an increase in vitamin D, which is likely due to race-related differences in vitamin D uptake by adipose tissue in obese subjects (Wortsman *et al.*, 2000), altered vitamin D metabolism (Awumey, 1998).



**Figure (7):** Describes the statistical difference in Vit D for females with diabetes and obesity

Conclusion: This study concluded that obesity in women with T2DM has a high significant effect on lipids and vitamin D

levels and low significant effect on calcium and ferritin levels.

### REFERENCES

- [1]- Abdulfatai B., Olusegun A., and Lateefat B. Type 2 Diabetes Mellitus: A Review of Current Trends, Oman Med J. 2012 Jul; 27(4): 269–273.doi: 10.5001/omj.2012.68 PMID: PMC3464757 PMID: 23071876
- [2]- Abdullah. S, Mohammed. A & Muhammad. Z. Mechanism linking diabetes mellitus and obesity, Diabetes Metab Syndr Obes. 2014; 7: 587–591.
- [3]- Andrés E Ortiz-Flores, María Ángeles Martínez-García, Lía Nattero-Chávez, Francisco Álvarez-Blasco, Elena Fernández-Durán, Alejandra Quintero-Tobar, Héctor F Escobar-Morreale, Manuel Luque-Ramírez. Iron Overload in Functional Hyperandrogenism: In a Randomized Trial, Bloodletting Does Not Improve Metabolic Outcomes. The Journal of Clinical Endocrinology & Metabolism, Volume 106, Issue 4, April 2021, Pages e1559–e1573, <https://doi.org/10.1210/clinem/dgaa978>
- [4]- Anitha Chandrasekaran, Varalakshmi Lalithya Pratti, Vinita Satyavrat, Shivani Aacharya, Amey Mane, Suyog Mehta, Ravindra Machhindra Kale, Gayathri Nagamuthu, Sasikala Selvaraj, Gayathri Rajagopal, and Sudha Vasudevan. Effect of a High-Protein High-Fibre Nutritional Supplement on Lipid Profile in Overweight/Obese Adults with Type 2 Diabetes Mellitus: A 24-Week Randomized Controlled Trial. Volume 2021 | Article ID 6634225 | <https://doi.org/10.1155/2021/6634225>.
- [5]- Awumey EM, Mitra DA, Hollis BW, Kumar R, Bell NH. Vitamin D metabolism is altered in Asian Indians in the southern United States: a clinical research centre study. J Clin Endocrinol Metab 1998; 83: 169–173.
- [6]- Azevedo M, Alla S. Diabetes in sub-saharan Africa: kenya, mali, mozambique, Nigeria, South Africa and zambia. Int J Diabetes Dev Ctries 2008. Oct;28(4):101-108 10.4103/0973-3930.45268.
- [7]- Chunling Li MM, Shufang Wang MM, Mengru Du MM, Yihan Wei MM, Sheng Jiang MD. Clinical Characteristics and Controllable Risk Factors of Osteoporosis in Elderly Men with Diabetes Mellitus. First published: 05 April 2021 <https://doi.org/10.1111/os.12957>.
- [8]- Flávia G. C, Josefina. B. Vitamin D: Link between Osteoporosis, Obesity, and Diabetes, Int. J. Mol. Sci. 2014, 15(4), 6569–6591.
- [9]- Forsythe. L, Livingstone., Barnes .M, Horigan. G, McSorley. E, Bonham .M, Effect of adiposity on Vitamin D status and the 25-hydroxycholecalciferol response to supplementation in healthy young and older irish adults. Br J Nutr. 2012; 107:126–34.
- [10]- Gallego. M., Zayas-Arrabal. J., Alquiza. A., Apellaniz.B., Casis. O. Electrical features of the diabetic myocardium. arrhythmic and cardiovascular safety considerations in diabetes Front Pharmacol, 12 (2021), p. 687256.
- [11]- Hamilton.S, Terentyev.D. Proarrhythmic remodeling of calcium homeostasis in cardiac disease: implications for diabetes and obesity. Front Physiol, 9 (2018), p. 1517
- [12]- Jarvie E, Hauguel-de-Mouzon S, Nelson SM., Lipotoxicity in obese pregnancy and its potential role in adverse pregnancy outcome and obesity in the offspring. Clin Sci (Lond) 2010; 119: 123–129.
- [13]- Kang S, Kyung C, Park JS, Kim S, Lee SP, et al. (2014) Subclinical vascular inflammation in subjects with normal weight obesity and its association with body fat: an 18 F-FDG-PET/CT study. Cardiovasc Diabetol 13: 70. pmid:24708764.
- [14]- Kim M, Na W, Sohn C. Correlation between Vitamin D and cardiovascular disease predictors in overweight and obese koreans. J Clin Biochem Nutr. 2013;52:167–71.
- [15]- Laurencikiene J, Skurk T, Kulyté A, Hedén P, Åström G, Sjölin E, et al. Regulation of lipolysis in small and large fat cells of the same subject. J Clin Endocrinol Metab. 2011;96:E2045–E2049.
- [16]- Liu LL, Lawrence JM, Davis C, Liese AD, Pettitt DJ, Pihoker C, et al. Prevalence of Overweight and Obesity in Youth With Diabetes in USA: The Search for Diabetes in Youth Study. Pediatr Diabetes (2010) 11(1):4–11. doi: 10.1111/j.1399-5448.2009.00519.x
- [17]- Mathieu.C C. Gysemans, C, Giulietti .A and Bouillon . R. Vitamin D and diabetes. Diabetologia volume 48, pages1247–1257 (2005)

- [18]- Nordestgaard BG. Triglyceride-rich lipoproteins and atherosclerotic cardiovascular disease. *Circ Res.* 2016;118:547–63.
- [19]- Park. S, Goodpaster. B, Strotmeyer .E . Decreased muscle strength and quality in older adults with type 2 diabetes: the health, aging, and body composition study. *Diabetes* 2006; 55: 1813– 1818.
- [20]- Pannu .P, Calton. E, Soares. M. Calcium and Vitamin D in Obesity and Related Chronic Disease. Vol 77. 1st edn. Elsevier Inc;2016.
- [21]- Romero-Corral A, Somers VK, Sierra-Johnson J, Korenfeld Y, Boarin S, et al. (2010) Normal weight obesity: a risk factor for cardiometabolic dysregulation and cardiovascular mortality. *Eur Heart J* 31: 737–746. pmid:19933515.
- [22]- Sara SantaCruz-Calvo, Leena Bharath, Gabriella Pugh, Lucia SantaCruz-Calvo, Raji Rajesh Lenin, Jenny Lutshumba, Rui Liu, Adam D. Bachstetter, Beibei Zhu & Barbara S. Nikolajczyk . Adaptive immune cells shape obesity-associated type 2 diabetes mellitus and less prominent comorbidities. *Nature Reviews Endocrinology* volume 18, pages23–42 (2022)Cite this article.
- [23]- Simonen P, Gylling H, Howard AN, Miettinen TA: Introducing a new component of the metabolic syndrome: low cholesterol absorption. *Am J Clin Nutr* 72:82–88,2000.
- [24]- Soliman AT, De Sanctis V, Yassin M, Soliman N . Iron deficiency anemia and glucose metabolism. *Acta Biomed.* 2017.,88(1):112-118.
- [25]- Soran, H., Hama, S., Yadav, R. & Durrington, P. N. HDL functionality. *Curr Opin Lipidol.* 23(4), 353–366 (2012).
- [26]- Srikanth. B, Ioannis. K, James. E & Clifford J. Type 2 diabetes mellitus in older adults: clinical considerations and management, *Nature Reviews Endocrinology* volume 17, pages534–548 (2021).
- [27]- Wei Wei, Wenbo Jiang, Wenbo Gu, Huanyu Wu, Haiyang Jiang, Guili Li, Qingrao Song, Jiabin Huang, Xuanyang Wang, Lulu Wang, Changhao Sun, Tianshu Han, and Ying Li . The joint effect of energy reduction with calcium supplementation on the risk factors of type 2 diabetes in the overweight population: a two-year randomized controlled trial. Published online 2021 Feb 11. Doi : 10.18632/aging.202485.
- [28]- Weigert, Cora, et al., "Interleukin-6 acts as insulin sensitizer on glycogen synthesis in human skeletal muscle cells by phosphorylation of Ser473 of Akt." *American journal of Physiology-Endocrinology and metabolism* 289.2 (2005)
- [29]- Wortsman J, Matsuoka LY, Chen TC, Lu Z, Holick MF. Decreased bioavailability of vitamin D in obesity. *Am J Clin Nutr* 2000; 72: 690– 693
- [30]- Yanhua Zhu ,Qiongyan Lin ,Yao Zhang, Hongrong Deng, Xiling Hu, Xubin Yang & Bin Yao . Mid-upper arm circumference as a simple tool for identifying central obesity and insulin resistance in type 2 diabetes Published: May 21, 2020. <https://doi.org/10.1371/journal.pone.0231308>
- [31]- Zahra. S, Marzieh . K, Parastoo .T, Akbar .H & Mohammad. H. Effect of Vitamin D Supplementation on Weight Loss, Glycemic Indices, and Lipid Profile in Obese and Overweight Women: A Clinical Trial Study. *International Journal of Preventive Medicine*; Published online 2018 Jul 20. doi: 10.4103/ijpvm.IJPVM\_329\_15.