IHJPAS. 36(2)2023

Ibn Al-Haitham Journal for Pure and Applied Sciences
Journal homepage:jih.uobaghdad.edu.iq

A Comparative Biochemical Study Between Patient's Obese and Healthy

Asmaa Salman Jasim
Department of Chemistry,College of Science for Women, University of Baghdad, Baghdad Iraq.
asmaa.Salman1205a@csw.uobaghdad.edu.iq

Perry Habib Saifullah
Department of Chemistry,College of Science for Women, University of Baghdad, Baghdad Iraq.
Perryhs_chem@csw.uobaghdad.edu.iq

Article history: Received 25 September 2022, Accepted 31 October 2022, Published in April 2023.

doi.org/10.30526/36.2.3036

Abstract

Objectives: Obesity rates have increased globally with increase in the incidence of comorbidities especially type 2 diabetes mellitus. A cross-sectional study was conducted on healthy obese adults to estimate: (i) comparisons of anthropometric indicators, lipid profile, and glycemic profile in obese compared with non-obese, and (ii) the association of anthropometrics and lipid profile with glycemic profile in obese adults. **Methods**: The study includes 120 individual with aged ranged (25 – 55) years were enrolled in this study. They were divided into two groups: group one (G1) consist of 90 patients with a body mass index (BMI) of more than 25 kg/m^2. Group two (G2) of 30 healthy adults as a control group with (BMI) of less than 25 kg/m^2.waist circumference (WC), hip circumference (HC), and waist/hip ratio (WHR) as anthropometric indicators, and fasting serum lipid profile, glycated hemoglobin (HbA1c), and Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) as biochemical variables were assessed. Statistical significance (α) was set at ($p<0.05$).**Results:** Based on independent samples T-test analysis acted as a significant comparison between non-obese and obese groups, anthropometrics and biochemical variables exhibited highly significant higher in obese compared with non-obese. Also, a positive significant correlation was found between WC and WHR with both of HOMA-IR and HbA1c. Finally, a positive significant association of HOMA-IR with triglycerides (TG), total cholesterol (TC), very low-density lipoprotein cholesterol (VLDL-C), low-density lipoprotein cholesterol (LDL-C) except for high-density lipoprotein cholesterol (HDL-C), no significance was found as well as HbA1c showed only positive significant association with LDL-C. **In conclusion**, the present study demonstrated that WC was the strongest indicator for increasing HOMA-IR than WHR. Also, this study revealed that abnormalities in lipid profile in obese participants have shown strong positive association with HOMA-IR, particularly LDL-C.

Keywords: obesity, visceral fat, lipid profile, insulin resistance, type 2 diabetes mellitus.

1. Introduction

Obesity rates have increased globally with an increased in the incidence of comorbidities; particularly type 2 diabetes mellitus (T2DM). Adiposity in the abdomen, particularly visceral adipose tissue (VAT), is thought to be a risk factor for the release of proinflammatory mediators and is linked to an increase in dyslipidemia, T2DM and cardiovascular disease (CVD) [1].

The characteristic dyslipidemia of obesity is associated with elevated (TG), (TC), (VLDL-C) and free fatty acids (FFA), decreased HDL-C with HDL dysfunction and normal or slightly elevated LDL-C with elevated small dense LDL [2]**.** Atherogenic dyslipidemia refers to the physiologically related combination of lipid abnormalities, such as hypertriglyceridemia and low HDL. In numerous studies conducted in different countries, this pattern of dyslipidemia has demonstrated a high association with T2DM and CVD [3-5].

With this background on the importance of abnormalities in lipid profile, central obesity and glycemic indices as a risk factors for T2DM disease in obese people, this current study was conducted on 120 adults with various BMIs to investigate whether (i) lipid profile(TC, TG, HDL-C, VLDL-C, and LDL-C) as well as abdominal obesity indicators (WC and WHR) could predict the BMI, and (ii) any association between glycemic profile, including (HOMA-IR) and (Hb1Ac) with BMI, WC, WHR as well as lipid profile.

2. Subjects and methods

2.1 Subjects

A cross-sectional design was performed in the current study. During the period of September 2021 to January 2022, all volunteers were recruited from Nu'man Teaching Hospital, Bagdad, Iraq after obtaining their consent to participate in the research using written informed consent as an Ethical consideration. More than ten were refused participation in this study, and three individuals were excluded from the study on the basis of their HbA1c test results that were higher than (6.5%). After excluding any pathology that could alter the results of the study, including, Rheumatoid arthritis, type 2 diabetes mellitus, thyroid diseases, cancer, pregnant women, and hypertension, 120 subjects were finally included in this analysis. The participants aged 25-55 years' old were divided into non-obese group with BMI less than 25 kg/m^2 and obese group with BMI more than 24.9 kg/m^2, matching the ages between them.

2.2 Methods

Demographic and anthropometric information were taken through the interview, including gender, age, the history of current diseases, height, weight, BMI, WC, HC, and WHR. BMI was estimated from dividing weight in kilograms by the square of height in square metres. Blood sample were obtained after an overnight fasting to evaluate fasting blood sugar (FBS), fasting insulin (INS), and lipid profile. Insulin levels were assessed with an enzyme-linked immunosorbent assay (ELISA). HbA1c levels were estimated with a sandwich immunodetection method. (TC), (TG), (HDL-C), and FBS were assessed by enzymatic oxidation method. (VLDL-C) and (LDL-C) were calculated using friedewald equation [6]. (HOMA-IR) was estimated according to the following formula [(Fasting INS × FBS) mg/dl / 405] [7].

2.3 Statistical analysis

All analysis and graphs were conducted using the IBM SPSS software V.22. The data were expressed as Mean±SD for numerical values. To examine differences in characteristics between non-obese and obese groups, we performed Independent samples T- test. Correlations between study variables were conducted using Pearson correlation. All of the analyzes were donated ($p<0.05$) as significantly significant.

3. Results

Comparison of anthropometric measurement and body composition analysis parameters between the two groups showed that (120) adults were included: 90 obese (25 males, 65 females) and 30 non-obese with (8 males, 22 females). Their characteristics are detailed in **Table 1**. Obese participants showed significantly higher than non-obese participants for WC, WHR, HOMA-IR, HbA1c, and lipid profile except for HDL-C that non-obese participants exhibited significantly higher levels than obese participants.

The results of Pearson correlation analysis between anthropometrics and lipid profile with glycemic profile. Positive associations of WC and WHR with HOMA-IR and HbA1c were found, as shown in **Table 2**. The most surprising aspect of the data is that a positive significant correlation ($P<0.05$) was showed between HOMA-IR with TG, TC, VLDL-C, and LDL-C except for HDL-C, no significance was found. No significant correlation ($P>0.05$) was found between HbA1c and TG, TC, HDL, and VLDL except LDL where a positive significant correlation was showed. Their association results are detailed in **Table 2.**

Table 1. Comparison of demographic, anthropometric, and biochemical variables

between non-obese and obese participants						
		Non-0bese	Obese			
		(Mean±SD)	(Mean±SD)	p-value		
Demographic variables						
n(120)		30	90			
male		8(26.7%)	25(27.8%)			
female		22(73.3%)	65(72.2%)			
Anthropometric variables						
BMI (kg/m^2)		22.9±1.78	32.49±4.33	p<0.001		
WC (cm)		78.93±8.23	102.89±13.21	p<0.001		
WHR		0.78±0.045	0.96±0.085	p<0.001		
Biochemical variables						
HOMA-IR		0.33±0.09	0.86 ±0.17	p<0.001		
HbA1c (%)		4.93±0.35	5.29±0.38	p<0.001		
TG (mg/dl)		102.54±15.8	150.93±18.07	p<0.001		
TC (mg/dl)		115.46±14.8	187.9± 23.43	p<0.001		
HDL (mg/dl)		56.6±12.8	40.06±12.26	p<0.001		
VLDL (mg/dl)		20.51±3.2	30.19±3.6	p<0.001		
LDL (mg/dl)		46.31±12.98	101.8±19.09	p<0.001		
Donates statistical significance (p<0.05).						

4. Discussion

As mentioned in Casadei and Kiel review, anthropometrics are important as diagnostic criteria for obesity, which significantly increases the risk for conditions such as cardiovascular disease, hypertension, diabetes mellitus, and many others [8]. BMI is a simple and widespread indicator for the diagnosis of obesity. The present study was designed to determine the relationship between obesity (higher than 25 kg/m^2) and metabolic syndrome, especially insulin resistance, and broadly supports the work of other studies in this area linking obesity with insulin resistance [9], [10].

Table 2. Pearson correlations between anthropometric variables and lipid profile with glycemic profile.

Variables		**BMI**	**WC**	**WHR**	**TG**	**TC**	**HDL**	**VLDL**	**LDL**
HOMA-IR	*r*	0.811	0.649	0.447	0.351	0.319	-0.11	0.355	0.535
	P-value	0.000*	0.000*	0.000*	0.001*	0.002*	0.301	0.001*	0.000*
HbA1c %	*r*	0.318	0.335	0.362	0.142	0.085	-0.183	0.126	0.364
	P-value	0.002*	0.001*	0.000*	0.183	0.425	0.084	0.236	0.000*
*Donates statistical significance ($p < 0.05$).									

In addition to previous explanations of BMI, WC and WHR are more accurate anthropometric measures to describe body fat distribution especially subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT) accumulation [11]. The results of present study indicate that the central obesity measures (WC and WHR) exhibited higher values in obese group than in non-obese group as well as association of WC and WHR with BMI that agrees with Jabłonowska-Lietz et al. and Nadeem et al. studies [12], [13]. As shown in **Figure 1.**

Another important finding in this study is that there is a significant and progressive increase of HOMA-IR and Hb1Ac according to BMI as shown in **Figure 1**, In accordance with previous studies [14-16]. Fernstrom et al. study explained increasing of HOMA-IR levels in obese people from their study. They observed that individuals who consumed more sugar and carbohydrates than is advised had higher HOMA-IR levels. Additionally, they showed that young individuals' healthy insulin resistance (HOMA-IR) and reduce the risk of developing diabetes were correlated with the recommended diet of seafood, fruits, and vegetables [17].

Abnormalities in the lipid profile have been found to be a significant complication that predisposes to a variety of diseases, including cardiovascular disease, diabetes, and obesity. In the current study, as shown in **Figure 1**, the finding is consistent with the work of other studies in this area linking lipid profile with BMI [18-22]. It also seems possible that the impacts of obesity on lipid metabolism are depending on the distribution of adipose tissues. Increased VAT and upper trunk SAT are associated with higher TG and lower HDL-C levels [23], as well as a pro-inflammatory feature of obesity that also alters lipid metabolism by activating resistin that lead to increased generation and secretion of VLDL through activating lipolysis in adipocytes, de novo fatty acid and triglycerides synthesis [24]. However, Moussavi *et al*. study showed no significant difference for TC, TG, LDL, and HDL between overweight/obese subjects and normal weight subjects [25]. Furthermore, the researchers from the Moor et al. study concluded that, despite the fact that dyslipidemia affects half of the sample's obese Cameroonian adults, it is unaffected by BMI [26]. This differs from the findings presented here.

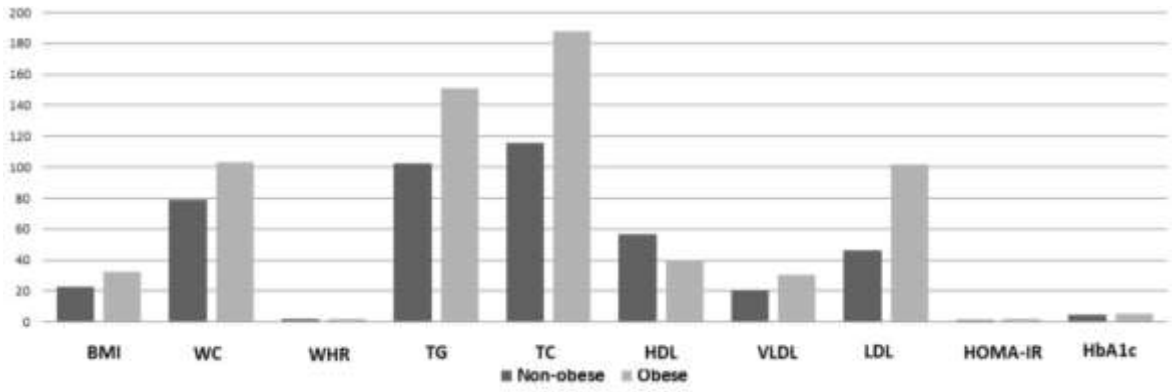

Figure1. Comparisons of demographic, anthropometric, and biochemical variables between non-obese and obese participants.

The current study results in **Table 2** showed a highly significant positive correlation ($P<0.01$) of HOMA-IR and HbA1c with WC and WHR. Several studies reported similar results of the present study [27-29]. Excess carbohydrate consumption increases triglyceride synthesis in the liver and adipose tissues, and elevated triglyceride levels increase central fat (representative of visceral fat), which is responsible for the release of various adipokines (such as resistin, visfatin, and tumor necrosis factor-alpha (TNF-α)) that are associated positively with insulin resistance and negatively with insulin sensitivity. These explanations are in concordance with the results of the other studies, which also showed WC as the best predictor of insulin resistance [30], [31].

Dyslipidemia is recognized as an independent risk factor for type 2 diabetes mellitus (T2DM) development [32]. According to the Chen et al. study, those with hyperlipidemia are more than three times more likely to develop T2DM than individuals with healthy lipids [33]. However, the role of dyslipidemia in the progression from normal glucose tolerance to diabetes remains unknown.

The results of the correlational analysis were presented in **Table 2** and showed a significant association of lipid abnormalities with HOMA-IR particularly (TG, TC, VLDL, and LDL) and HbA1c with LDL, in partial accordance with Lin et al. study showed that all lipid indices were correlated with HOMA-IR and HbA1c [34].

The most striking result to emerge from the data is that LDL, in accordance with previous studies have demonstrated that LDL levels were positively correlated with glycemic profile [35], [36].

Another interesting finding is that a positive association of TG and TC with HOMA-IR, similar to what has been previously reported in other studies [37], [38]. They also reported a significant correlation with HDL, in contrast to our findings of no association between HDL levels and HOMA-IR. A possible explanation for these findings is impaired insulin signaling, which leads to the increased hepatic secretion of VLDL as well as late clearance of TG-rich lipoproteins, owing to increased substrate levels of TG synthesis [39]. Furthermore, insulin resistance reduces lipoprotein lipase activity, resulting in delayed clearance of TG-rich lipoproteins, resulting in small dense LDL-C and lower HDL-C levels [40]. Another reason for this may be that the accumulation

of visceral fat in obesity generates an increase in free fatty acids, which induces adipocyte inflammation and consequently reduced insulin sensitivity, thus changing lipid metabolism [41].

5. Conclusion

In this paper, we showed that obesity, defined by BMI, WC, and WHR contributing HOMA-IR elevation as well as WC was the strongest indicator for increasing HOMA-IR than WHR. Also, our findings demonstrated that abnormalities in lipid profile in obese participants have shown strong positive association with HOMA-IR, particularly LDL. However, this analysis had several limitations. First, no inferences could be derived from the current study's cross-sectional approach. Second, additional potential factors impacting lipid variables, such as dietary features, were not included in this study. Third, the current study employed a small sample size. As a result, future studies that take dietary features into account, as well as additional prospective designs, are required to validate our findings and extend the sample size.

References

1. Stefan, N. Causes, consequences, and treatment of metabolically unhealthy fat distribution. *The lancet Diabetes & endocrinology*. **2020**, *8(7),* 616-627.
2. Klop, B.; Elte, J.W.; Castro, C.M. Dyslipidemia in obesity: mechanisms and potential targets. *Nutrients*. **2013**, *5(4),*1218-40.
3. Irfan, S.R.; Safdar, A.M.; Habib, S.H.; Begum, A.; Rahman, A.; Mohibullah, A.K. Assessment of Glycaemic Status, BMI and Dyslipidemia in a Group of Official Population of Bangladesh. *Bangladesh Critical Care Journal*. **2017**, *5(1),* 42-7.
4. Wang, S.; Ji, X.; Zhang, Z.; Xue, F. Relationship between lipid profiles and glycemic control among patients with type 2 diabetes in Qingdao, China. *International Journal of Environmental Research and Public Health*. **2020**, 17(15), 5317.
5. Hami, A.M. Association between HbA1c and Serum Lipid Profile among a sample of Iraqi Patients with Type2 Diabetes Mellitus. *Journal of the Faculty of Medicine*. **2021**, 63(3).
6. Friedewald, W.T.; Levy, R.I.; Fredrickson, D.S. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clinical chemistry*.**1972**, 18(6), 499-502.
7. Esteghamati, A.; Ashraf, H.; Esteghamati, A.R.; Meysamie, A.; Khalilzadeh, O.; Nakhjavani, M.; Abbasi, M. Optimal threshold of homeostasis model assessment for insulin resistance in an Iranian population: the implication of metabolic syndrome to detect insulin resistance. *Diabetes research and clinical practice*.**2003**, *84(3*), 279-287.
8. Casadei,K.; Kiel, J.; Freidl, M. Triceps tendon injuries. *Current sports medicine reports*. **2020**, *19(9),* 367-72.
9. Kojta, I.; Chacińska, M.; Błachnio, Z. A. Obesity, bioactive lipids, and adipose tissue inflammation in insulin resistance. *Nutrients*. **2020**, *12(5),*1305.
10. Sripetchwandee, J.; Chattipakorn, N.; Chattipakorn, S.C. Links between obesity-induced brain insulin resistance, brain mitochondrial dysfunction, and dementia. *Frontiers in endocrinology*. **2018**,*9,496*.
11. Ross, R.;Neeland, I.J.; Yamashita, S.; Shai, I.; Seidell, J.; Magni, P.; Santos, R.D.; Arsenault, B.; Cuevas, A.; Hu, F.B.; Griffin, B.A. Waist circumference as a vital sign in clinical practice: a Consensus Statement from the IAS and ICCR Working Group on Visceral Obesity. *Nature Reviews Endocrinology*.**2020**, *16(3),* 177-189.

12. Jabłonowska-Lietz, B.; Wrzosek, M.; Włodarczyk, M.; Nowicka, G.New indexes of body fat distribution, visceral adiposity index, body adiposity index, waist-to-height ratio, and metabolic disturbances in the obese. *Kardiologia Polska (Polish Heart Journal).***2017**, *75(11),* 1185-1191.
13. Nadeem, M.I.; Bakar, Y.I.A.; Akram, S.; Baig, A.A. Correlation of anthropometric indices with lipid profile indices among Malay obese and non-obese subjects in Malaysia. *Nutrition & Food Science.* **2020**, *51(2),* 278-288.
14. Park, J.; Lee, H. Obesity as associated factors for Insulin, Fasting blood sugar, and Hemoglobin A1c in Korean adults. *Journal of Digital Convergence*. **2019**, *17(10),* 349-357.
15. Martinez, K.E.; Tucker, L.A.; Bailey, B.W.; LeCheminant, J.D. Expanded normal weight obesity and insulin resistance in US adults of the National Health and Nutrition Examination Survey. *Journal of diabetes research.* 2017, vol. **2017**, 8 pages.
16. Boye, K.S.; Lage, M.J.; Shinde, S.; Thieu, V.; Bae, J.P. Trends in HbA1c and body mass index among individuals with type 2 diabetes: evidence from a US database 2012–2019. *Diabetes Therapy.* **2021**, *12(7),* 2077-2087.
17. Fernström, M.; Fernberg, U.; Hurtig-Wennlöf, A. Insulin resistance (HOMA-IR) and body fat (%) are associated to low intake of fruit and vegetables in Swedish, young adults: the cross-sectional lifestyle, biomarkers and atherosclerosis study. *BMC nutrition*. **2019**, *5(1),* 1-9.
18. Archana, A.V.; Ahmad, N.; Gupta, A. Study of body mass index (BMI) and serum lipid profile of patients at a tertiary hospital: A cross sectional study. *Int J Res Med Sci*. **2018**, *6(6),* 2060-2.
19. Eslami, O.; Shahraki, M.; Shahraki, T. Obesity indices in relation to lipid abnormalities among medical university students in Zahedan, south-east of Iran. *International Journal of Preventive Medicine.* **2019**, *10(15).*
20. Amini, S.; Shirali, S.; Jafarirad, S.; Ehsani, H.; Mohseni, H.; Bargard, M.S. Are lipid profile, body mass index, waist circumference, and blood pressure of depressed elderly patients different from healthy subjects*?. International Journal of Preventive Medicine*. 2019, *10,*185.
21. Manawat, R.; Shweta, V.K.S. Association of anthropometric variables with dyslipidemia in obesity. *National Journal of Physiology, Pharmacy and Pharmacology*. **2020**, *10(09),* 716-721.
22. Kiriyama, H.; Kaneko, H.; Itoh, H.; Kamon, T.; Mizuno, Y.; Fujiu, K.; Morita, H.; Yamamichi, N.; Komuro, I. Association between changes in body weight and lipid profile in the general population: a community-based cohort study. *European Heart Journal-Quality of Care and Clinical Outcomes*. **2021**, 7(1), 109-110.
23. Feingold, K. R. Obesity and dyslipidemia. *Endotext* [*Internet*]. 2020.
24. Rashid, S.; Kastelein, J.J. PCSK9 and resistin at the crossroads of the atherogenic dyslipidemia. *Expert review of cardiovascular therapy*. **2013**, *11(11),* 1567-77.
25. Moussavi Javardi, M.S.; Madani, Z.; Movahedi, A.; Karandish, M.; Abbasi, B. The correlation between dietary fat quality indices and lipid profile with Atherogenic index of plasma in obese and non-obese volunteers: A cross-sectional descriptive-analytic case-control study. *Lipids in Health and Disease*. **2020**, *19(1),* 1-9.
26. Moor, V.J.A.; Essama, D.B.; Agoons, B.B.; Bayem, J.C.; Marie, N.G.; Jingi, A.M.; Nkeck, J.R.; Nonga, B.N. Lipid Profile Abnormalities Observed in Obese Cameroonian Adults do not Depend on Their BMI or Abdominal Circumference. *Archives of Clinical and Biomedical Research.* **2022**, 6(1), 30-40.

27. Abraham, S.; Rubino, D.; Sinaii, N.; Ramsey, S.; Nieman, L.K. Cortisol, obesity, and the metabolic syndrome: A cross-sectional study of obese subjects and review of the literature. *Obesity*. **2013**, *21(1),* E105-E117.
28. Jabłonowska-Lietz, B.; Wrzosek, M.; Włodarczyk, M.; Nowicka, G. New indexes of body fat distribution, visceral adiposity index, body adiposity index, waist-to-height ratio, and metabolic disturbances in the obese. *Kardiologia Polska (Polish Heart Journal).* **2017**, 75(11), 1185-1191.
29. Syafiq, W.M.; Dwipayana, I.M.P.; Saraswati, M.R.; Gotera, W. Correlation between waist circumference and glycated haemoglobin (HbA1c) among type 2 diabetes mellitus patients in Diabetic Polyclinic Sanglah General Hospital. *Neurologico Spinale Medico Chirurgico*. **2020**, *3(2),* 66-70.
30. Wasir, J.S.; Misra, A.; Vikram, N.K.; Pandey, R.M.; Gupta, R. Comparison of definitions of the metabolic syndrome in adult Asian Indians. *JAPI***.** **2008**, *56*, 158-64.
31. Misra, A.; Khurana, L. The metabolic syndrome in South Asians: epidemiology, determinants, and prevention. *Metabolic syndrome and related disorders*. **2009**, *7(6),* 497-514.
32. Deng, J.; Wu, G.; Yang, C.; Li, Y.; Jing, Q.; Han, Y. Rosuvastatin attenuates contrast-induced nephropathy through modulation of nitric oxide, inflammatory responses, oxidative stress and apoptosis in diabetic male rats. *Journal of Translational Medicine*. **2015**, 13(1), 1-9.
33. Chen, L.; Xu, W.M.; Zhang, D. Association of abdominal obesity, insulin resistance, and oxidative stress in adipose tissue in women with polycystic ovary syndrome. *Fertility and Sterility*. **2014**, 102(4), 1167-1174.
34. Lin, D.; Qi, Y.; Huang, C.; Wu, M.; Wang, C.; Li, F.; Yang, C.; Yan, L.; Ren, M.; Sun, K. Associations of lipid parameters with insulin resistance and diabetes: a population-based study. *Clinical Nutrition.* **2018**, *37(4),* 1423-1429.
35. Balgi, V.; Harshavardan, L.; Sahna, E.; Thomas, S.K. Pattern of lipid profile abnormality in subjects with prediabetes. *TC*. **2017**, *11(98).*
36. Al Amri, T.; Bahijri, S.; Al-Raddadi, R.; Ajabnoor, G.; Al Ahmadi, J.; Jambi, H.; Borai, A.; Tuomilehto, J. The association between Prediabetes and dyslipidemia among attendants of primary care health centers in Jeddah, Saudi Arabia. Diabetes, Metabolic Syndrome and Obesity: *Targets and Therapy*. **2019**, *12*, 2735.
37. Xiang, S.K.; Hua, F.; Tang, Y.; Jiang, X.H.; Zhuang, Q.; Qian, F.J. Relationship between serum lipoprotein ratios and insulin resistance in polycystic ovary syndrome. International *journal of endocrinology.* **2012**, vol.2012, 4 pages.
38. Zheng, S.; Xu, H.; Zhou, H.; Ren, X.; Han, T.; Chen, Y.; Qiu, H.; Wu, P.; Zheng, J.; Wang, L.; Liu, W. Associations of lipid profiles with insulin resistance and β cell function in adults with normal glucose tolerance and different categories of impaired glucose regulation. *PLoS One*. **2017**, 12(2), e0172221.
39. Alzahrani, S.H.; Baig, M.; Aashi, M.M.; Al-Shaibi, F.K.; Alqarni, D.A.; Bakhamees, W.H. Association between glycated hemoglobin (HbA1c) and the lipid profile in patients with type 2 diabetes mellitus at a tertiary care hospital: a retrospective study. Diabetes, metabolic syndrome and obesity: *targets and therapy.* **2019**,*12*,1639.
40. Asato, Y.; Katsuren, K.; Ohshiro, T.; Kikawa, K.; Shimabukuro, T.; Ohta, T. Relationship between lipid abnormalities and insulin resistance in Japanese school children. Arteriosclerosis, *thrombosis, and vascular biology*. **2006**, *26(12),* 2781-6.

41. Rogero, M.M.; Calder, P.C. Obesity, inflammation, toll-like receptor 4 and fatty acids. *Nutrients*. **2018**, *10(4),* 432.