Al-Azhar University Journal
for Virus Research and Studies

Triglyceride Glucose Index as A Promising Biomarker for Glycemic Control in Type 2 Diabetic Patients

Samar Kamalelden Mohamed Mohamed[1], Fatma Kamel Hammad[1], Mervat El Shahat Khalifa El Wakeel[2] and Shaymaa Abdel Hafeez Mohammed[1]

[1]Department of Endocrinology and Metabolism, Faculty of Medicine for Girls, Al-Azhar University, Cairo, Egypt

[2]Department of Clinical Pathology, Faculty of Medicine for Girls, Al-Azhar University, Cairo, Egypt

***E-mail: doctor_smr5@yahoo.com**

Abstract

Diabetes Mellitus (DM) is increasing at an alarming rate throughout the world, the assessment of glycemic control is of prime importance because of its key role in the management of type 2 DM. Diabetics with poor glycemic control have adverse effects on the life expectancy; however, laboratory determinations of plasma HbA1c are not yet widely available in addition to its high cost. Recently, the TyG index, a product from the fasting levels of triglycerides and glucose, presented promising results as a surrogate marker for the assessment of insulin resistance. Is to evaluate the potential of using TyG index and TyG derived indices (TyG-WC, TyG-BMI) to assess glycemic control and its correlation with HbA1c in patients with type 2 DM. This cross-sectional study was conducted on 50 type 2 diabetic patients recruited from Endocrinology and Metabolism department of Al-Zahraa University Hospital. They were divided into two groups according to HbA1c level Group 1: included 11 controlled type 2 diabetic patients with HbA1c less than 6.5% Group 2: included 39 uncontrolled type 2 diabetic patients with HbA1c more than 6.5%. Detailed history, clinical examination and anthropometric measurements were assessed for all selected patients. Fasting plasma glucose, glycosylated hemoglobin (HbA1c), total cholesterol, triglycerides, low density lipoprotein (LDL-C), high density lipoprotein HDL-C, and fasting insulin) were measured then insulin resistance index (IR) was calculated as follow: HOMA-IR =(FBI (uIU/ml) x FBG (mg/dl))/405 .TyG indices were calculated according to the following formula: triglyceride glucose index (TyG) is calculated as TyG index = ln (fasting TG [mg/dL] x fasting glucose [mg/dL]/2). Triglyceride waist circumference (TyG-WC) calculated asTyG-WC= TyG x waist circumference. Triglyceride BMI (TyG-BMI) calculated asTyG-BMI = TyG xBMI. The mean triglyceride glucose index in the uncontrolled cases was statistically significantly higher as compared to the cases with controlled diabetes, Significant positive correlation was found between triglyceride glucose index and fasting blood glucose, postprandial blood glucose, HbA1c, triglyceride and HOMA-IR. Triglyceride glucose index revealed the highest accuracy for detection of uncontrolled diabetic cases.

Keywords: Diabetes mellitus, Insulin resistance, Triglyceride glucose index

1. Introduction

Diabetes Mellitus (DM) is increasing at an alarming rate throughout the world, the assessment of glycemic control is of prime importance because of its key role in the management of type 2 DM. Diabetics with poor glycemic control have adverse effects on the life expectancy and quality of life [1].

Glycated hemoglobin (HbA1c) has been considered as a good indicator of overall glycemic control and possible risk for long term complications. It is validated; however, laboratory determinations of plasma HbA1c are yet not widely available and standardized in all services in addition to its high cost [2].

Triglyceride glucose index (TyG) index, a product from the fasting levels of triglycerides and glucose, presented promising results as a surrogate marker for the assessment of insulin resistance (IR) [3] with a good correlation with gold standard hyperglycemic clamp according to a study in Brazilian [4] and Mexican [5].

So, measuring serum TG level as part of TyG index or alone can be a useful and cost-effective marker and represent the glycemic and cardiovascular status of an individual simultaneously**.** The aim of the present study was to evaluate the potential using of TyG index and TyG derived indices (TyG-WC, TyG-BMI) to assess glycemic control and its correlation with HbA1c in patients with type 2 DM.

2. Patients and Methods

This study is a cross-sectional study including 50 type 2 diabetic patients. The study was conducted at Al–Zahraa University Hospital (Al-Azhar University), Cairo, Egypt.

The diabetic patients were divided into 2 groups according to HbA1c level: Controlled group: Included 11 type 2 diabetic patients with HbA1c less than 6.5%. Uncontrolled group: Included 39 type 2 diabetic patients with HbA1c more than 6.5%.

This cross-sectional study was done during a period of 6 months starting from February 2021 till July 2021. The study was approved by the Review Board of Al-Azhar Faculty of Medicine for Girls ethical committee. Study design was explained, and verbal informed consent was obtained from participants prior to enrollment in this study. The current study included 50 type 2 diabetic patients on oral antidiabetic medications; they were selected according to the following (inclusion and exclusion) criteria.

2.1 Inclusion criteria

Patient with age range (32 to 61) year who had previously established diagnosis of T2DM according to the American Diabetes Association [6]. The patients were diagnosed based on plasma glucose criteria, either the fasting blood glucose ≥ 126 mg/dl or 2 hour post prandial blood glucose ≥ 200 mg/dl during a 75-g oral glucose tolerance test, or HbA1C ≥ 6.5 %.

2.2 Exclusion criteria

Type 1 diabetes mellitus, Type 2 DM on insulin therapy, Gestational diabetes, Female patient on hormonal replacement therapy, Thyroid disorders, Smokers, extremely obese patients, Patients on lipid lowering therapy, Patients with chronic liver diseases or chronic renal diseases, Patients with infection or history of recent infection and Patients with malignancy.

2.3 Subjects of this study were submitted to the following laboratory investigations included:

- Fasting plasma glucose [mg/dl] by spectrophotometric technique.
- 2-hour postprandial blood glucose.
- Glycosylated hemoglobin (HbA1c).
- Lipid profile including serum total cholesterol [mg/dl], (TG) [mg/dl], high density lipoprotein cholesterol HDL-C [mg/dl]. Low-density lipoprotein cholesterol (LDL-C) was calculated by using Friedwald formula: (Total cholesterol) – (HDL-C) - ([TG]/5) [7].
- Fasting serum insulin [µIU/ml] by ELISA.
- Assessment of insulin resistance (IR) index by using Homeostatic Model Assessment of insulin resistance **(HOMA-IR)** equation.
- HOMA- IR = Fasting Insulin (µU/ml) x fasting glucose (mg/dl) /405 [8] .
- TyG indices were calculated according to the following formula [9] as TyG index = ln (fasting TG [mg/dL] x fasting glucose [mg/dL]/2). Triglyceride waist circumference (TyG-WC) calculated as TyG-WC= TyG x waist circumference. Triglyceride BMI (TyG-BMI) calculated as TyG-BMI = TyG xBMI.
- BMI was calculated according to the following equation BMI = kg/m^2.

2.4 Statistical analysis of the data

Data were fed to the computer and analyzed using IBM SPSS software package version 22.0. Qualitative data were described using number and percent. Quantitative data were described using median (minimum and maximum) for non-parametric data and mean, standard deviation for parametric data after testing normality using Kolmogrov-Smirnov test. Significance of the obtained results was judged at the (0.05) level. Significance test results are quoted as two-tailed probabilities. For all the above-mentioned tests, the level of significance was tested, expressed as the probability of (p-value) and the results were explained as following: Non-significant if the p value is > 0.05, Significant if the p value is ≤ 0.05 and highly significant if the p value < 0.01.

3. Results

Table (1): Demographic data and characteristics of the studied patients.

		Total no. = 50
Age (years)	Mean ± SD	47.12 ± 7.41
	Range	32 – 61
Sex	Female	25 (50.0%)
	Male	25 (50.0%)
Duration of diabetes (years)	Median (IQR)	4 (2 – 6)
	Range	1 – 20
Body weight (Kg)	Mean ± SD	85.98 ± 15.22
	Range	53 – 115
Height (cm)	Mean ± SD	164.52 ± 9.47
	Range	145 – 185
BMI (kg/m2)	Mean ± SD	31.57± 4.48
	Range	22 – 42
Waist circumference (cm)	Mean ± SD	110.90 ± 16.01
	Range	50 – 140

Table (2): Blood glucose level and degree of diabetes control among the studied patients.

		Total no. = 50
Fasting blood glucose (mg/dl)	Mean ± SD	193.12 ± 79.95
	Range	95 – 434
Postprandial blood glucose (mg/dl)	Mean ± SD	238.42 ± 86.30
	Range	120 – 450
HbA1C (%)	Mean ± SD	8.21 ± 1.78
	Range	5.71 – 12.73
Degree of diabetes control	Controlled	11 (22%)
	Uncontrolled	39 (78%)

Table (3): Comparison between controlled and non-controlled diabetic patients as regard HbA1c, fasting blood glucose and post prandial blood glucose level.

	Controlled	**Ucontrolled**	**Test value**	**P-value**	**Sig.**
	No. = 11	**No. = 39**			
HbA1C (%)	6.05 ± 0.24	8.82 ± 1.52	-5.985•	<0.001	HS
Fasting blood glucose (mg/dl)	134 (107 – 153)	191 (153 – 246)	-3.233≠	<0.001	HS
Postprandial blood glucose (mg/dl)	160.91 ± 41.87	260.28 ± 83.15	-3.809•	<0.001	HS

P-value > 0.05: Non-significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant •: Independent t-test; ≠: Mann-Whitney test.

Table (4): Comparison of lipid profile between controlled and non-controlled studied diabetic patients.

	Controlled	**uncontrolled**	**Test value**	**P-value**	**Sig.**
	No. = 11	**No. = 39**			
Total cholesterol (mg/dl)	160.64 ± 46.57	156.05 ± 34.58	0.359•	0.721	NS
Triglyceride (mg/dl)	166.55 ± 41.53	164.74 ± 46.35	0.116•	0.908	NS
HDL (mg/dl)	35 ± 4.69	35.44 ± 3.28	- 0.353•	0.726	NS
LDL (mg/dl)	92.33 ± 39.42	87.66 ± 32.09	0.405•	0.682	NS

Table (5): Comparison between controlled and non-controlled studied diabetic patients as regard serum fasting insulin and HOMA IR.

	Controlled	**Uncontrolled**	**Test value**	**P-value**	**Sig.**
	No. = 11	**No. = 39**			
Serum fasting insulin (mlU/ml)	9.77 (4.5 – 13.35)	10.5 (4.71 – 16.58)	-0.925 ≠	0.355	NS
HOMA-IR	2.85 (1.67 – 3.73)	4.71 (3 – 7.19)	-2.248≠	0.025	S

Table (6): Comparison between controlled and non-controlled studied diabetic patients as regard triglyceride glucose index, triglyceride waist circumference and triglyceride BMI.

	Controlled	**Uncontrolled**	**Test value**	**P-value**	**Sig.**
	No. = 11	**No. = 39**			
Triglyceride glucose index	9.23 ± 0.31	9.61 ± 0.41	-2.838•	0.007	HS
Triglyceride waist circumference	1090.94 ± 91.75	1051.15 ± 165.30	0.762•	0.450	NS
Triglyceride BMI	290.12± 39.75	303.44± 42.92	-0.923 •	0.361	NS

P-value > 0.05: Non-significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant, •: Independent t-test

Table (7): Correlation between triglyceride glucose index and the other studied parameters.

	Triglyceride glucose index	
	r	P-value
Triglyceride waist circumference	0.192	0.181
Triglyceride BMI	0.114	0.429
Age	0.017	0.906
Duration of diabetes (years)	0.227	0.112
Body weight Kg	-0.066	0.651
Height (cm)	0.022	0.878
BMI	-0.187	0.194
Waist circumference (cm)	-0.175	0.223
Fasting blood glucose (mg/dl)	0.677**	0.000
Postprandial blood glucose (mg/dl)	0.540**	0.000
HbA1C	0.420**	0.002
Total cholesterol (mg/dl)	-0.051	0.725
Triglyceride (mg/dl)	0.238	0.096
HDL (mg/dl)	-0.145	0.314
LDL (mg/dl)	-0.125	0.386
Serum fasting insulin (mlU/ml)	0.012	0.937
HOMA IR	0.229	0.110

P-value > 0.05: Non-significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant.

4. Discussion

Diabetes mellitus (DM) is one of the most common metabolic disorders that is increasing at an alarming rate all over the world. The latest estimates of diabetes mellitus showed a prevalence rate of 11.1% with diabetes in 2019, expected to rise to 13% by 2045 [10].

During the past three decades, HbA1c has been used as a biomarker for evaluating glycemic control in type 1 and type 2 diabetes [11].

An index composed of triglyceride and glucose, termed "triglyceride-glucose index" or simply "TyG index" has been suggested to help as surrogate marker for insulin resistance [12].

TyG index has been reported to precede and significantly predict diabetes and cardiovascular events in adults, older adults and hypertensive patients [13].

So, TyG index was suggested as a diagnostic marker for early identification of diabetic complications, therefore, this study was conducted to evaluate the potential using of TyG index and TyG derived indices (TyG-WC, TyG-BMI) to assess glycemic control and its correlation with HbA1c in patients with type 2 DM.

In our study, the age ranges from 32 to 61 years mean age (47.12 ± 7.41) was similar results were shown by Megahed and Farg [14], they reported that mean age 49.76 ± 9.19 years. Moreover, this result was in agreement with Mufunda et al., [15] who found that the mean age of their studied sample was 48 years. This could be explained as this age group (middle age) has the highest percentage of work and stress.

In the current study, 50% of cases were females and the other 50% were males, there is variable sex distribution of type 2 diabetic patients in the different studies. Mostafa [16] also revealed that more than three quarters of the studied sample were females.

In this study, the duration of DM for the included cases ranged from 1 to 20 years with 50% of the cases in the range between 2 and 6 years. In the current study there was no statistically significant difference between controlled and uncontrolled diabetic patients regarding age. The lack of statistically significant age difference in the present study is of value to nullify the effect of age on the studied parameters. This is in agreement with Souliotis et al., [17] who reported no difference between poor and good glycemic control as regard the age. Our results disagreed with Othman et al.,[18] who found that poor glycemic control is more common among patients

older than 50 years old, and with duration of diabetes more than 7 years. The reason for the difference between our study and other studies may be the variation in clinical characteristics of the participants. Some studies have proposed that the longer duration of diabetes is the greater the risk of development of complications associated with type 2 diabetes [19]. In our study, there was no statistically significant difference between controlled and uncontrolled diabetes cases regarding the duration of DM. In accordance with our results Souliotis et al.,[17] showed that there was none statistically significant difference as regard duration of treatment and glycemic control between controlled and uncontrolled patients. On the opposite side, the duration of DM has been reported as a predictor of poor glycemic control in previous study [20] Hyperlipidemia is associated with insulin resistance, and it is common in patients with type 2 diabetes mellitus. Insulin resistance and associated hyperinsulinemia are associated with hypertriglyceridemia, increased low-density lipoprotein (LDL), and low serum high-density lipoprotein (HDL) cholesterol concentrations [21] . In the current study, there was no statistically significant difference between controlled and uncontrolled diabetic cases regarding the lipid profile. This agreed to study done by Awadalla et al., [22] they reported that there was no significant difference in TG, TC, LDL, and HDL between the glycemic control group and the uncontrolled group. Our results disagree with Rabbani [23] who reported that there was significant difference of the level of total cholesterol, triglycerides and LDL-cholesterol levels between controlled and uncontrolled diabetic patients. Our study agreed with Hameed who showed that the HOMA-IR in the uncontrolled DM patients were statistically significantly higher as compared with the controlled group [24].

The predicating ability of TyG index has been studied in different metabolic states. Guerrero-Romero et al. [5] proposed that TyG index could be a marker of IR with an excellent correlation with the gold standard euglycemic-hyper insulinemic clamp test. In addition, another study suggested that TYG index can predict the risk of future DM [25].

In the current study, the mean triglyceride glucose index in the uncontrolled cases was 9.61± 0.41 which was statistically significantly higher as compared with the cases with controlled diabetes (9.23 ± 0.31) (p=0.007).

Few studies have shown that TyG-related markers are positively associated with cardio metabolic disease, including coronary artery calcification (CAC) [9]. And in longitudinal study done by Yun et al., [26] using a large health-screening cohort, they observed that individuals with high TyG-related indices are more likely to experience coronary artery calcification (CAC) progression. Among these indices, TyG-WC showed the strongest association with CAC progression, a marker that predicts coronary artery disease and patient prognosis. According to ROC analysis, TyG-WC was the most reliable predictor of CAC progression among the parameters they evaluated. This positive association between TyG-WC and CAC progression signifies the adverse cardiovascular outcomes in individuals with a high TyG-WC. In the current study, there was no statistically significant difference in the TyG-BMI between the uncontrolled DM patients (303.44±42.92) and controlled DM patients (290.12± 39.75) (p=0.361). This disagreed with Hameed who showed that the mean TyG-BMI in the uncontrolled DM patients were statistically significantly higher (291.93± 57) as compared with the controlled diabetic group (276±48) (p=0.043) [24] In our study, there was statistically significant positive correlation found between triglyceride glucose index and fasting blood glucose, postprandial blood glucose, HbA1c, triglyceride and HOMA-IR in all patients. Also, there was statistically significant positive correlation between triglyceride waist circumference

triglyceride BMI and in one side and triglyceride BMI, body weight, BMI, waist circumference and triglyceride on other side.This came in accordance with Hameed who showed that TyG Index, TyG-BMI, TyG-WC correlate significantly with HbA1c and HOMA-IR in addition TyG index showed significant correlation with HDL-C, LDL-C, VLDL-C [24]. Also agree with Parhofer [27] who showed that TyG derived indices showed a significant correlation with HbA1c, IR and a good AUC, but, the TyG index showed the best performance. In the current study, the best cutoff point of TyG index to identify the uncontrolled T2 DM was >9.2 with 79.49 % sensitivity and 63.64% specificity. The AUC was 0.766 with statistically significant predictive ability (p=0.002). This agreed with Hameed who reported that TyG index was the most efficient surrogate marker for identification of diabetes control, showed that TyG index had the largest AUC for detection of diabetic control. (AUC for TYG index:0.839) [24] also agree with Timalsina et al., [28] who reported that TyG value ≥ 9.12 was noted to be optimal cutoff for predicting poor glycemic control, with 86.1% sensitivity and 61.5% specificity. Other proposed cut-of values from research conducted in Spain were similar (men: 8.43, women: 8.19), and the pooled AUC was 0.750 (0.707–0.810) [29]. However, to establish more valid cut-off values, further studies, including correlation studies between the TyG index and the gold standard methods for insulin resistance, are needed. The TyG index has the advantage of being applicable in clinical practice since both triglyceride and glucose levels are routinely measured and the cost of these measurements is low. Several studies have reported the predictive ability of the TyG index in both patients with metabolic disorders and the general population [30].

There are some reported limitations in this study; first the study is cross sectional, second, we included only type 2 diabetic patients, we may extend the study in the future to include healthy individuals.

Finally, this study included relatively small sample size from one center only that could limit the power of the obtained results.

5. Conclusion

The current data suggests that poor glycemic control risk might be screened using indices derived from FBG, TG, and anthropometric parameters indicative of adiposity and insulin resistance among elderly individuals with T2DM. Among them, triglyceride glucose index revealed the highest accuracy for detection of uncontrolled diabetic cases. The best cutoff point of triglyceride glucose index to identify uncontrolled diabetic cases was >9.2 with 79.49 sensitivity and 63.64 specificity. The AUC was 0.766.

Funding Sources: There was no support for this study from any governmental, private, or non-profit organization.

Conflicts of interest: no competing interests.

References

1. Keating, S. T., Plutzky, J. and El-Osta, A. (2016): Epigenetic changes in diabetes and cardiovascular risk. Circulation research, 118(11), 1706-1722.

2. Saha, S., & Schwarz, P. E. (2017). Impact of glycated hemoglobin (HbA1c) on identifying insulin resistance among apparently healthy individuals. *Journal of Public Health*, *25*(5), 505-512.

3. Er, L. K., Wu, S., Chou, H. H., Hsu, L. A., Teng, M. S., Sun, Y. C., & Ko, Y. L. (2016). Triglyceride glucose-body mass index is a simple and clinically useful surrogate marker for insulin resistance in nondiabetic individuals. *PLoS One*, *11*(3), e0149731.

4. Vasques, A. C. J., Novaes, F. S., de Oliveira, M. d. S., Souza, J. R. M., Yamanaka, A., Pareja, J. C., Tambascia, M. A., Saad, M. J. A. and Geloneze, B. (2011): TyG index performs better than HOMA in a Brazilian population: a hyperglycemic clamp validated study. Diabetes research and clinical practice, 93(3), e98-e100.

5. Guerrero-Romero, F., Simental-Mendía, L. E., González-Ortiz, M., Martínez-Abundis, E., Ramos-Zavala, M. G., Hernández-González, S. O., Jacques-Camarena, O. and Rodríguez-Morán, M. (2010): The product of triglycerides and glucose, a simple measure of insulin sensitivity. Comparison with the euglycemic-hyperinsulinemic clamp. The Journal of Clinical Endocrinology & Metabolism, 95(7), 3347-3351.

6. *ADA* (2019): Classification and diagnosis of diabetes American diabetic association: standards of medical care in diabetes—2019 Diabetes care, 45(Supplement 1), S17-S39.

7. Friedewald, W. T., Levy, R. I. and Fredrickson, D. S. (1972): Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clinical chemistry, 18(6), 499-502.

8. Matthews, D., Hosker, J., Rudenski, A., Naylor, B., Treacher, D. and Turner, R. (1985): Homeostasis model assessment: insulin resistance and β-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia, 28(7), 412-419.

9. Zhang, S., Du, T., Zhang, J., Lu, H., Lin, X., Xie, J., Yang, Y. and Yu, X. (2017): The triglyceride and glucose index (TyG) is an effective biomarker to identify nonalcoholic fatty liver disease. Lipids in health and disease, 16(1), 1-8.

10. Alam, S., Hasan, M., Neaz, S., Hussain, N., Hossain, M. and Rahman, T. (2021): Diabetes Mellitus: Insights from Epidemiology, Biochemistry, Risk Factors, Diagnosis, Complications and Comprehensive Management. Diabetology, 2(2), 36-50.

11. Holmer, H. K., Ogden, L. A., Burda, B. U. and Norris, S. L. (2013): Quality of clinical practice guidelines for glycemic control in type 2 diabetes mellitus. PloS one, 8(4), e58625.

12. Khan, S. H., Sobia, F., Niazi, N. K., Manzoor, S. M., Fazal, N. and Ahmad, F. (2018): Metabolic clustering of risk factors: evaluation of Triglyceride-glucose index (TyG index) for evaluation of insulin resistance. Diabetology & metabolic syndrome, 10(1), 1-8.

13. Park, B., Lee, H. S. and Lee, Y.J. (2021): Triglyceride glucose (TyG) index as a predictor of incident type 2 diabetes among nonobese adults: a 12-year longitudinal study of the Korean Genome

and Epidemiology Study cohort. Translational Research, 228, 42-51.

14. Megahed, F. I. A. L., & Farg, H. K. (2020). Most Effiecnt Factors Affecting Glycemic Control of Type II Diabetic Patients Attending Suez Canal University Hospitals in Egypt Applying Stepwise Regression.

15. Mufunda, E., Ernersson, Å. and Hjelm, K. (2018): Limited knowledge of diabetes in patients attending an outpatient diabetes clinic at a referral hospital in Zimbabwe: a cross-sectional study. Pan African Medical Journal, 29(1), 1-13.

16. Mostafa, O. A. S. A. (2013): Effect of lifestyle modification on control of type 2 diabetes mellitus; A prototype for primary health care settings: An intervention study performed in the outpatient clinic of the national institute of diabetes and endocrinology in Cairo.

17. Souliotis, K., Koutsovasilis, A., Vatheia, G., Golna, C., Nikolaidi, S., Hatziagelaki, E., Kotsa, K., Koufakis, T., Melidonis, A. and Papazafiropoulou, A. (2020): Profile and factors associated with glycaemic control of patients with type 2 diabetes in Greece: results from the diabetes registry. BMC Endocrine Disorders, 20(1), 16.

18. Othman, F., Afiffy, N., Melegy, A. and Mostafa, O. (2016): Factors affecting poor glycemic control among diabetic patients in outpatient clinic at Kar Al-Aini Hospital. Med J Cairo Univ, 84(2), 191-197.

19. Yeap BB, McCaul KA, Flicker L et al. (2015): Diabetes, myocardial infarction and stroke are distinct and duration-dependent predictors of subsequent cardiovascular events and all-cause mortality in older men. J Clin Endocrinol Metab; 100:1038–1047.

20. Cheng, L. J., Wang, W., Lim, S. T. and Wu, V. X. (2019): Factors associated with glycaemic control in patients with diabetes mellitus: a systematic literature review. Journal of clinical nursing, 28(9-10), 1433-1450.

21. Tangvarasittichai, S. (2015): Oxidative stress, insulin resistance, dyslipidemia and type 2 diabetes mellitus. World Journal of Diabetes, 6(3), 456.

22. Awadalla H., Noor S.K., Elmadhoun W.M., Bushara S.O., Almobarak A.O., Sulaiman A.A., Ahmed M.H. (2018): Comparison of serum lipid profile in type 2 diabetes with and without adequate diabetes control in Sudanese population in north of Sudan. Diabetes Metab. Syndr. 2018; 12:961–964.

23. Rabbani N, Chittari MV, Bodmer CW, Zehnder D, Ceriello A, Thornalley PJ. (2010): Increased glycation and oxidative damage to apolipoprotein B100 of LDL cholesterol in patients with type 2 diabetes and effect of metformin. Diabetes.; 59:1038–1045.

24. Hameed, E. K. (2019): TyG index a promising biomarker for glycemic control in type 2 diabetes mellitus. Diabetes Metab Syndr, 13(1), 560-563.

25. Lee, S.H., Kwon, H.S., Park, Y.M., Ha, H.S., Jeong, S. H., Yang, H. K., Lee, J.H., Yim, H.W., Kang, M.I., Lee, W.C. (2014): Predicting the development of diabetes using the product of triglycerides and glucose: the Chungju Metabolic Disease Cohort (CMC) study. PloS one, 9(2), e90430.

26. Yun Kyung Cho, Jiwoo Lee, Hwi Seung Kim, Eun Hee Kim, Min Jung Lee, Dong Hyun Yang, Joon-Won Kang, Chang Hee Jung, Joong-Yeol Park, Hong-Kyu Kim , Woo Je Lee (2021). Triglyceride Glucose-Waist Circumference Predicts Coronary Calcium Progression Compared with Other Indices of Insulin Resistance: A Longitudinal Observational Study. J Clin Med. 2021 Jan; 10(1): 92

27. Parhofer, K. G. (2015): Interaction between glucose and lipid metabolism: more than diabetic dyslipidemia. Diabetes & metabolism journal, 39(5), 353.

28. Timalsina, S., Mahato, S., & Nepal, S. (2021). Utility of Triglyceride-Glucose index in predicting glycemic control in type 2 diabetes mellitus. *Birat Journal of Health Sciences*, *6*(2), 1444-1448.

29. Navarro-González, D., Sánchez-Íñigo, L., Pastrana-Delgado, J., Fernández-Montero, A. and Martinez, J. A. (2016): Triglyceride–glucose index (TyG index) in comparison with fasting plasma glucose improved diabetes prediction in patients with normal fasting glucose: The Vascular-Metabolic CUN cohort. Preventive medicine, 86, 99-105.

30. Zheng, R. and Mao, Y. (2017): Triglyceride and glucose (TyG) index as a predictor of incident hypertension: a 9-year longitudinal population-based study. Lipids in health and disease, 16(1), 1-7.