Research Article / Araştırma Makalesi

Triglyceride Glucose Index: As A Glycemic Control Indicator

Glisemik Kontrol Belirteci Olarak Trigliserid Glukoz İndeksi

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Abstract

Background: Type-2 Diabetes Mellitus (T2DM) continues to be the most common endocrine disease today. Easily accessible, accurate and reproducible markers are needed in addition to the accepted markers to evaluate insulin resistance (IR) and glycemic control. Therefore, our study aimed to evaluate the use of triglyceride glucose index (TyGI) as an indicator for insulin resistance and glycemic control.
Materials and Methods: Triglyceride(TG), HbA1c, fasting blood glucose (FBG), and total insulin (TI) values of 953 samples, studied simultaneously in our Faculty of Medicine Hospital Laboratory between March 2023 and August 2023, were retrospectively evaluated. The patients were divided into two groups as good and/or poor glycemic control regarding their HbA1c, and the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) values. Receiver Operating Characteristic (ROC) analysis was performed to assess the ability of TyGI to discriminate between good and/or poor glycemic control for each of HOMA-IR and HbA1c. Statistical significance level was accepted as $p<0.05$. Multivariate logistic regression analysis was performed as well.
Results: A total of 953 patients; with the mean age of 40,83±16,78 participated in the study. According to gender, all parameters except age (p: 0,613) showed significant differences ($p<0.001$). There were significant differences for FBG, HbA1c, HOMA-IR, TI, TG and TyGI parameters according to cut-off values in all two study groups ($p<0.001$). TG showed high positive correlation with TyGI (r: 0.796, $p<0.001$) and moderate positive correlation with FBG (r: 0.616, $p<0.001$) for both study groups, but low positive correlation with the others. TyGI, had a high selectivity and specificity for HOMA-IR with ≥8,76 cut-off value (AUC:0,72, Se:65%, Sp:70% ($p<0.001$: 95% CI:0,69-0,75)). In ROC analysis, TyGI had the highest AUC value for HbA1c, and the lowest for HOMA-IR group. The risk of poor glycemic control for HOMA-IR in men is 2.247 times higher than in women. As age increases by one unit, the risk of poor glycemic control for HOMA-IR increases by 1.045 times.
Conclusions: TyGI was significantly raised in incident T2DM patients with poor glycemic control. TyGI can act as s simple and useful markers that have the strong predictive capability to identify insuline resistance and anticipate the development of incident T2DM.

Keywords: Diabetes Mellitus, Insulin Resistance, Glycemic Control, Triglyceride, Glucose

Öz

Amaç: Tip-2 Diyabetes Mellitus (T2DM) günümüzde en yaygın endokrin hastalık olmaya devam etmektedir. İnsülin direncini (İD) ve glisemik kontrolü değerlendirmek için kabul görmüş belirteçlere ek olarak kolay erişilebilir, doğru ve tekrarlanabilir belirteçlere ihtiyaç duyulmaktadır. Bu nedenle çalışmamızda insülin direnci ve glisemik kontrol için bir gösterge olarak trigliserid glikoz indeksinin (TyGI) kullanımını değerlendirmeyi amaçladık.
Materyal ve Metod: Mart 2023 ile Ağustos 2023 tarihleri arasında Tıp Fakültesi Hastanesi Laboratuvarımızda eş zamanlı olarak incelenen 953 örneğin trigliserid (TG), HbA1c, açlık kan şekeri (AKŞ) ve toplam insülin (Tİ) değerleri geriye dönük olarak incelendi. Hastalar; HbA1c ve homeostasis model değerlendirmesiyle tahmin edilen insülin direnci (HOMA-İD) değerleri açısından iyi glisemik kontrol ve/veya kötü glisemik kontrol olmak üzere iki gruba ayrıldı. TyGI'nin, HOMA-İD ve HbA1c'nin her biri için iyi ve/veya kötü glisemik kontrol arasında ayrım yapabilme yeteneğini değerlendirmek amacıyla Duyarlılık ve Özgüllük Analizi (DÖA) yapıldı. İstatistiksel anlamlılık düzeyi $p<0,05$ olarak kabul edildi. Ayrıca çok değişkenli lojistik regresyon analizi yapıldı.
Bulgular: Çalışmaya yaş ortalaması 40,83±16,78 olan toplam 953 hasta katıldı. Cinsiyete göre yaş (p: 0,613) hariç tüm parametreler anlamlı farklılıklar gösterdi ($p<0,005$). Her iki çalışma grubunda da kesme değerlerine göre AKŞ, HbA1c, HOMA-İD, Tİ, TG ve TyGI parametreleri için anlamlı farklılıklar vardı ($p<0,001$). TG, her iki çalışma grubu için de TyGI ile yüksek pozitif korelasyon (r: 0,796, $p<0,001$) ve AKŞ ile orta derecede pozitif korelasyon (r: 0,616, $p<0,001$) gösterdi ancak diğerleri ile düşük pozitif korelasyon gösterdi. TyGI, ≥8,76 kesim değeri (Eğri Altı Alan (EAA):0,72, Duyarlılık:%65, Seçicilik:%70 ($p<0.001$: %95 GA:0,69-0,75)) ile HOMA-İD için yüksek seçiciliğe ve duyarlılığa sahipti. TyGI; HbA1c için en yüksek EAA'ya ve HOMA-İD grubu için ise en düşük EAA'ya sahipti. Erkeklerde HOMA-İD için kötü glisemik kontrol riski kadınlara göre 2.247 kat daha fazladır. Yaş bir birim arttıkça, HOMA-İD için kötü glisemik kontrol riski 1.045 kat artmaktadır.
Sonuç: TyGI, kötü glisemik kontrole sahip yeni T2DM hastalarında önemli ölçüde yükselmiştir. TyGI, insülin direncini belirlemek ve yeni T2DM gelişimini önceden tespit etmek için güçlü öngörücü yeteneğe sahip basit ve kullanışlı bir belirteç olarak işlev görebilir.

Anahtar Kelimeler: Diabetes Mellitus, İnsülin Direnci, Glisemik Kontrol, Trigliserit, Glikoz

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Introduction

Type-2 Diabetes Mellitus (T2DM), characterized by chronic hyperglycemia, can cause damage to different organ systems and lead to life-threatening health complications. (1). Obesity, a poor diet, and a sedentary lifestyle are major risk factors for T2DM (2, 3). According to various regional and nationwide studies, the total prevalence of DM in Türkiye is between 12.7% and 14.7% (4-7). T2DM diagnosis and treatment are costly and can be a significant burden to people. (8).

Good glycemic control is very important in the management of diabetes, as it reduces the risk of complications. Insulin resistance (IR) is characterized by decreased insulin sensitivity of peripheral tissues. IR, which plays an important role in the pathogenesis of metabolic syndrome and diabetes, can occur 10 to 20 years before the definitive diagnosis of T2DM (9). Glycated hemoglobin A1c (HbA1c), reflects average blood glucose in patients over approximately 3 months. Keeping HbA1c below 7% of target value has been shown to reduce vascular complications of diabetes (10, 11). In patients with T2DM, the risk of cardiovascular disease (CVD) increases by 18% for every 1% increase in absolute HbA1c value.(12). Diabetic dyslipidemia is another risk factor for CVD in diabetic patients. It is characterized by a decrease in high-density lipoprotein cholesterol (HDL-C), an increase in triglycerides (TG), and postprandial lipemia. Apart from these, the more atherogenic small, dense LDL is converted from low-density lipoprotein cholesterol (LDL-C) (13).

Multivariate scores developed to identify those at high risk of diabetes among healthy individuals are based on a combination of risk factors (metabolic syndrome, first-degree relative with diabetes, history of gestational diabetes, etc.), but they generally have poor predictive value (14). In order to accurately predict future diabetes, early circulatory biomarkers such as high-sensitivity C-reactive protein, interleukin-6, or tumor necrosis factor-alpha can be used (15). However, they are also inefficient for screening and are inconvenient and costly to use in daily laboratory practice.

In order to evaluate insulin sensitivity, the medical profession has therefore looked for substitute, indirect biomarkers. Strong predictive ability, high specificity, and sensitivity make Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) and Fasting Insulin (FI) popular surrogate markers for IR assessment. However, although being more practical than the hyperinsulinemic–euglycemic clamp technique, they are still difficult to use in day-to-day situations (16, 17). Since insulin is not measured in every hospital, and due to transportation problems of blood samples from small family medicine offices to the hospital laboratories or HOMA-IR measurement handicaps, the quest for easier biomarkers to incorporate into a routine test is ongoing. Because measurement of triglyceride, and glucose levels is common and reasonably priced, TyGI can be calculated more frequently in clinical practice (18).

For all these reasons, new markers are needed to identify people at high risk of developing diabetes. Early and effective diabetes identification can prevent early morbidity and increase patient well-being. Large epidemiological studies demand noninvasive and cost-effective diagnostics to identify and prevent T2DM. Triglyceride-glucose index (TyGI) is a new marker associated with insulin resistance and helps to identify those at high risk of chronic complications in people with T2DM who are still asymptomatic. The TyGI was proposed by Guerrero-Romero et al.(19) as a surrogate marker of insulin resistance measured by the hyperinsulinemic–euglycemic clamp test (20, 21). The TyGI is an accurate biomarker of insulin resistance and can be used to predict diabetes risk. It is simple to collect and quantify in clinical settings or large-scale epidemiological research. Several studies have identified a significant correlation between the TyGI and the risk of developing T2DM in China (22, 23), Singapore (24), Europe (25, 26), Korea (21, 27), Thailand (28), and Iran (29, 30).

Data indicating the significance of TyGI in incident T2DM is still lacking in Türkiye. Hence, the present study was designed to investigate the association of TyG index with HbA1c and insulin resistance in T2DM.

Materials and Methods

After taking approval of the ethical committee, this cross-sectional restrospective study was conducted inthe Tokat Gaziosmanpasa University Medical Faculty Hospital. All 953 participants aged between 18-75 years old, had blood tests for fasting blood glucose (FBG), The homeostatic model assessment for insülin resistance (HOMA-IR), HbA1c, Total Insulin (TI), and TG levels between March-August 2023 were included in the study. Their TyGIs were calculated. We excluded participants age under 18 years, having chronic thyroid disease, liver diseases, chronic kidney disease, hematological disorders or malignancies, systemic inflammatory or infectious diseases, history of metabolic or bariatric surgery and use of anti-inflammatory or steroid therapy.

Participants were grouped on the basis of HOMA-IR and HbA1c values and evaluated according to their cut-off values as 2.7 and 5.7 respectively. After evaluating the qualitative variables, we looked at the distributions of the quantitative variables. The relationship between the significant variables and TyGI was evaluated for each HOMA-IR and HbA1c group. We defined the cut-off values and ROC curves of TyGI for each study group. Then, we performed logistic regression analysis of the selected variables based on our study groups.

All the information of the patients were collected retrospectively from our hospital data system (ENLIL HBYS Co. Turkiye). Cobas c501 (Roche Diagnostics, GmbH, Manheim, Germany) instrument was used to estimate HbA1c, FBG, TG, levels. Serum TI estimation was performed on Cobas e411 (Roche Diagnostics, GmbH, Manheim, Germany). HOMA-IR was derived by the formula “Fasting Insulin(FI): (µU/L) × FBG (mg/dL) / 405 (31). The Following formula was used to calculate TyGI: [Serum TG(mg/dL) × FBG(mg/dL) / 2] (19).

Descriptive analyzes were conducted to provide information about the general characteristics of the study groups. Data for

continuous variables are presented as mean±standard deviation; Data regarding categorical variables are given as n (%). When comparing the means of quantitative variables between groups, the Significance of the Difference Between Two Means test is used. ROC analysis was used to determine performance measures in predicting TyGI, HOMAIR and HbA1c variables. P values were considered statistically significant when calculated to be less than 0.05. Ready-made statistical software was used in the calculations (SPSS 22.0 Chicago, IL, USA).

Results

A total of 953 patients; with the mean age of 40,83±16,78 participated in the study (Table 1 and 2). According to gender, all parameters, except age (p: 0,613) and TI (p: 0.005), showed significant differences (p<0.005) (Table2).

In Table 3, except age, all other variables showed significant differences according to the HOMA-IR cut-off value of 2.7 (p<0.001). In Receiver Operating Characteristic (ROC) analysis, TyGI, had the high sensitivity and selectivity for HOMA-IR with ≥8,76 cut-off value (AUC:0,72, Se:65%, Sp:70% (p<0.001: 95% CI:0,69-0,75)) (Table 4). In both study groups, TyGI showed high positive correlations with TG (r: 0,796, p<0.001), moderate positive correlations with FBG (r: 0,616, p<0.001) and low positive correlations with others in pairwise correlations (Table 5).

Table 1. Distribution of qualitative variables

		n	%
HOMA-IR group	<2,7	379	39,8%
	≥2,7	574	60,2%
HbA1c (%) group	<5,7	568	59,6%
	≥5.7	385	40,4%

Table 2. Distribution of quantitative variables by gender

Variables	Gender			P
	Total	Female *(n=652)*	Male *(n=301)*	
Age (Year)	40,83±16,78	41,02±15,74	40,43±18,86	0,613
HbA1c (%)	5,96±1,49	5,83±1,37	6,24±1,69	<0,001
TyGI	8,87±0,67	8,77±0,62	9,07±0,72	<0,001
FBG (mg/dL)	97,4[90-112]	96[89-108,05]	101[92-122,5]	<0,001*
HOMA-IR	3,2[2,08-5,22]	3,12[2,07-4,95]	3,49[2,14-6,62]	0,010*
TI (mIU/mL)	12,63[8,14-19,36]	12,57[8,13-18,73]	13,28[8,14-20,98]	0,298*
TG (mg/dL)	127[93,3-179]	121,75[86-166]	142,5[107-207]	<0,001*

*Data are shown as mean±Standard deviation or median[Quartile 1-Quartile 3].Independent Samples t test was used. *:Mann Whitney U test was used. FBG: Fasting Blood Glucose, TI: Total Insulin, TyGI: Triglyceride glucose index.*

ROC analysis curves, for TyGI regarding HOMA-IR, and HbA1c groups were shown in Figure 1 and 2, respectively. In multivariate logistic regression analysis, the risk of having poor glycemic control for HOMA-IR in men is significantly 2.247 times higher than in women (p=0.022). Each unit increase in age and FBG significantly increases the risk of poor glycemic control by 1.056 and 1.045 fold for HOMA-IR, respectively (p=0.001) (Table 6).

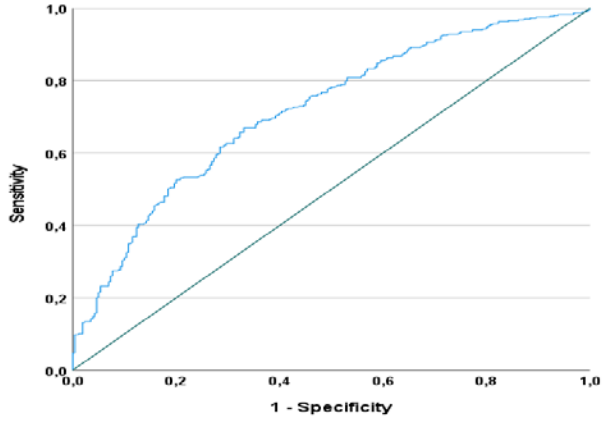

Figure 1. ROC analysis of TyGI for HOMA-IR (≥8,76 cut-off value (AUC:0,72, Se:65%, Sp:70% (p<0.001: 95% CI:0,69-0,75))

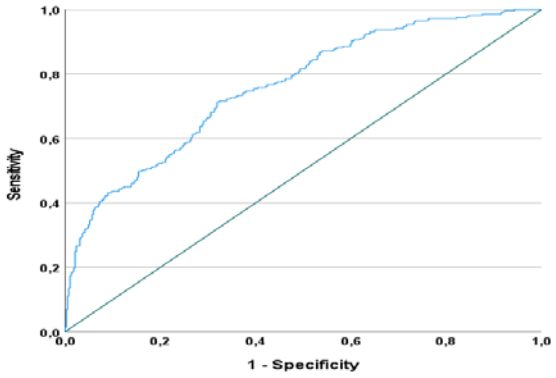

Figure 2. ROC analysis of TyGI for HbA1c (≥8,98 cut-off value (AUC:0,85, Se:84%, Sp:70% (p<0.001: 95% CI:0,82-0,87))

In Table 7, except age, all other variables showed significant differences according to the HbA1c cut-off value of 5.7 (p<0.001). In ROC analysis, TyGI, had the high sensitivity and selectivity for HbA1c with ≥8,98 cut-off value (AUC:0,85, Se:84%, Sp:70% (p<0.001: 95% CI:0,82-0,87)) (Tables 8). Every unit increase in age and FBG significantly increases the risk of poor glycemic control by 1.063 and 1.110 fold for HbA1c, respectively (p<0.001) (Table 9).

Table 3. Distribution of quantitative variables according to HOMA-IR groups

Variables	Total	HOMA-IR group		P
		<2,7	≥2,7	
	Mean±SD	Mean±SD	Mean±SD	
Age (Year)	40,83±16,78	40,16±17,01	41,84±16,4	0,130
HbA1c (%)	5,96±1,49	5,69±1,3	6,14±1,58	<0,001
TyGI	8,87±0,67	8,57±0,53	9,06±0,68	<0,001
FBG (mg/dL)	97,4[90-112]	92[87-99,4]	102[93-122]	<0,001*
TI (mIU/mL)	12,63[8,14-19,36]	7,78[5,32-9,36]	17,7[13,79-25,12]	<0,001*
TG (mg/dL)	127[93,3-179]	109[77-141,95]	145,1[107-204]	<0,001*

*Data are shown as mean±Standard deviation or median[Quartile 1-Quartile 3].Independent Samples t test was used. *:Mann Whitney U test was used. FBG: Fasting Blood Glucose, TI: Total Insulin, TyGI: Triglyceride glucose index.*

Tablo 4. ROC analysis results for HOMA-IR

Variable	Cut-off	AUC (95% CI)	Se	Sp	PPV	NPV	p
TyGI	≥8,76	0,72 (0,69-0,75)	0,65	0,70	0,76	0,57	<0,001

AUC: Area Under Curve, PPV:Positive predictive value, NPV: Negative predictive value, Se: Sensitiviy, Sp: Specifity

Table 5. Pairwise correlation between variables with TyGI for HOMA-IR

		Total	HOMA-IR <2.7	HOMA-IR ≥2.7
		TyGI	TyGI	TyGI
Age (Year)	r	0,331*	0,431*	0,365*
	p	<0,001	<0,001	<0,001
HbA1c (%)	r	0,582*	0,492*	0,599*
	p	<0,001	<0,001	<0,001
FBG(mg/dL)	r	0,616*	0,500*	0,626*
	p	<0,001	<0,001	<0,001
HOMA-IR	r	0,353*	0,162*	0,313*
	p	<0,001	0,009	<0,001
TI (mIU/mL)	r	0,232*	-0,070	0,128*
	p	<0,001	0,264	0,009
TG (mg/dL)	r	0,796*	0,850*	0,770*
	p	<0,001	<0,001	<0,001

Pearson correlation coefficient was used.

Table 6. Logistic regression analysis of selected variables by HOMA-IR group

Model	Univarite				Multivariate			
	p	Odds Ratio	95% C.I.for Odds Ratio		p	Odds Ratio	95% C.I.for Odds Ratio	
			Lower	Upper			Lower	Upper
Gender (F/M)	0.026	1.382	1.040	1.835	0.022	2.247	1.051	4.504
Age (Year)	0.130	1.007	.986	1.002	0.001	1.056	1.033	1.081
HbA1c	<0.001	1.293	1.154	1.449	0.213	0.660	0.343	1.269
FBG (mg/dL)	<0.001	1.016	1.010	1.021	0.007	1.045	1.012	1.079
TG (mg/dL)	<0.001	1.009	1.006	1.012	0.884	1.002	0.979	1.025
TyGI	<0.001	3.916	2.869	5.347	0.374	2.320	.363	14.823

Reference category: Women for Gender

Table 7. Distribution of quantitative variables according to HbA1c group

Variables	Total	HbA1c group		p
		<5.7	≥5.7	
Age (Year)	40,83±16,78	34,72±14,82	49,84±15,4	<0,001
HbA1c (%)	5,96±1,49	5,22±0,27	7,05±1,84	<0,001
TyGI	8,87±0,67	8,61±0,53	9,22±0,68	<0,001
FBG (mg/dL)	97,4[90-112]	95[88,9-104]	189[149-263]	<0,001*
HOMA-IR	3,2[2,08-5,22]	3,11[2,02-4,86]	4,38[2,88-8,92]	<0,001*
TI (mIU/mL)	12,63[8,14-19,36]	13,03[8,44-19,93]	10,66[5,72-17,3]	<0,001*

TG (mg/dL)	127[93,3-179]	123,1[92-172,1]	148[117-228]	<0,001*

*Data are shown as mean±Standard deviation or median[Quartile 1-Quartile 3].Independent Samples t test was used. *:Mann Whitney U test was used. FBG: Fasting Blood Glucose, TI: Total Insulin, TyGI: Triglyceride glucose index.*

Tablo 8. ROC analysis results for HbA1c

Variable	Cut-off	AUC (95% CI)	Se	Sp	PPV	NPV	p
TyGI	≥8,98	0,85 (0,82-0,87)	0,84	0,7	0,32	0,96	<0,001

AUC: Area Under Curve, PPV:Positive predictive value, NPV: Negative predictive value, Se: Sensitiviy, Sp: Specifity

Table 9. Logistic regression analysis of selected variables according to HbA1c group

	Univarite				Multivariate			
	p	Odds Ratio	95% C.I.for Odds Ratio		p	Odds Ratio	95% C.I.for Odds Ratio	
			Lower	Upper			Lower	Upper
Gender	0.004	1.503	1.140	1.982	0.864	0.930	0.408	2.120
Age (Year)	<0.001	1.067	1.056	1.078	<0.001	1.063	1.033	1.094
FBG(mg/dL)	<0.001	1.094	1.078	1.109	<0.001	1.110	1.059	1.164
HOMA-IR	<0.001	1.125	1.084	1.167	0.133	0.664	0.389	1.134
TI (mIU/mL)	0.002	1.012	1.005	1.020	0.149	1.111	0.963	1.283
TG (mg/dL)	<0.001	1.005	1.003	1.007	0.739	1.003	0.984	1.023
TyGI	0.001	6.004	4.292	8.399	0.074	4.414	0.865	22.530

Reference category: Women for Gender

Discussion

In our study, high levels of TyGI were found in patients with uncontrolled T2DM. Furthermore, TyGI also revealed a significant correlation with high TG, HbA1c, FBG, and HOMA-IR levels suggesting that TyGI can be used independently as a significant variable to determine the increased risk of developing incident T2DM. In ROC analysis, TyGI, had a high sensitivity and selectivity for HOMA-IR and HbA1c groups with cut-off values of ≥8,76, and ≥8,98 respectively. Increase in age and FBG showed significantly high poor glycemic control risk in terms of both HOMA-IR and HbA1c.

IR and β-cell disfunction are main characteristics of T2DM (3). Fat cells and adipose tissue, which produce a number of cytokines and hormones take a central role in metabolism of glucose and lipids (32). During fasting, fat cells hydrolyze TGs and release them as free fatty acids (FFAs) and glycerol, which are taken up and oxidized by skeletal muscle and liver while during feeding, they synthesize and store TGs (33). Muscle, liver, fat, pancreatic β-cells, and other tissues contribute to hyperglycemia and hyperlipidemia when IR is present (34). Glucokinase activity and glucose-stimulated insulin secretion in islets are reduced by TGs during hypertriglyceridemia (35). Hyperglycemia causes the islet cells, which already have a weaker antioxidant capacity themselves, to be exposed to continuous oxidative stress (36). Therefore, β-cell failure may be due to glucose toxicity and lipotoxicity (34). Newly published studies have suggested that TyGI is associated with IR and can be used as a reliable and useful surrogate indicator to define IR (15). Many studies have reported the association between TyGI and the occurrence of diabetes in patients (22, 30). This association persisted regardless of obesity status. The predictive value of TyGI was comparable to metabolic health.

However, few studies have evaluated the risk of diabetes based on the TyGI and its selectivity potential. In accordance with our study, Babic et al. (9) observed that TyGI increased in patients with high HbA1c levels and TyGI was significantly independently associated with HbA1c. In the same study, the positive relation between TyGI and uncontrolled glucose

levels proposed that TyGI could be used as an independently significant indicator in predicting the development and progression of insulin resistance. Another contribution of their study is that TyGI may also be a good surrogate indicator of glycemic control in addition to HbA1c. Both are routinely measured in clinical laboratories, are inexpensive, and reflect different cardiometabolic abnormalities, which are the main reasons for their use. The fact that they are not available in most primary care settings in low-income countries and are relatively expensive makes HbA1c weaker. Therefore, an alternative index that is inexpensive and routinely available may potentially be used by primary care physicians in the follow-up of T2DM patients and in the screening of prediabetic patients.

TyGI was shown to be significantly increased in patients with poor glycemic control and significantly associated with HbA1c in the study of Hameed et al. (37). Additionally, they showed that TyGI had the largest AUC in identifying diabetics with poor glycemic control. In our, in aacordance with this study, TyGI had alarge AUC for identifying poor glycemic control on the basis of HbA1c.

Lee et al. (38) have shown that a single TyGI determined at any given time can be a predictor of the risk of developing diabetes, that changes in TyGI levels over time affect the risk of developing diabetes, and that changes in metabolic health status, particularly in nonobese individuals, may be an independent risk factor for future diabetes. Our study showed a single time point measurement not changes in the TyGI levels, so we can only talk about risk of developing diabetes.

Liu et al.(39) and Zhang et al.(22) showed a significant association between TyGI and T2DM in normal-weight Chinese

patients, which was evident for women of all age groups and elderly men. Additionally, women tend to have higher hepatocellular lipids compared to men, both in the fasting state and after glucose and lipid loading.. Visceral fat tissue increases significantly for both sexes as people age, which may increase the risk of T2DM (40). Our stduy found significant positive aasociations between TyGI and a IR indicators like HbA1c, HOMA-IR, and TI. This association was also present for age of all men and women, but contrary to former studies, men tend to have higher T2DM deevolping risk than women.

Guerrero-Romero et al. (19) was the first to propose TyGI instead of HOMA-IR. TyGI showed high sensitivity (96.5%) and specificity (85.0%) for the diagnosis of insulin resistance in Mexican people compared to the hyperinsulinemic-euglycemic state. TyG showed moderate correlation with HOMA-IR. In the study of Simental-Mendía et al. (41) which included 748 apparently healthy participants, the sensitivity and specificity of TyGI in determining IR were 84.0% and 45.0%, respectively. The association between TyGI and incident T2DM has been reported in several studies (24, 28). In consistence with these studies, TyGI had 70% selectivity and 65% sensitivity for IR and it was a functional indicator of IR in our study.

Janghorbani et al. (42) reported that in the Iranian population, they found an increased risk of incident T2DM above 8.43 in men and 8.19 in women for TyGI. This risk may be up to five times greater in individuals in the top quartile of TyGI compared to those in the bottom quartile in both men and women. In our study, we determined an elevated risk for T2DM over 8.76 of TyGI for HOMA-IR. The risk of T2DM in men is 2.247 times higher than in women. The risk also increases by age for 1.045 times.

In a study conducted in a Brazilian population, and the TyGI appeared to outperform HOMA-IR in clinical practice (20). A 4-year retrospective longitudinal study in Koreans found that a high TyGI at baseline was associated with the development of T2DM, independent of obesity status (21). Therefore, the TyGI may be clinically important in preventing incident T2DM.

Strengths of the study include a large community-based sample size across a wide age range, high participation rates, standardized high-quality clinical and laboratory procedures, and adjustment for numerous potential confounding factors.

Its limitations are that the study was a retrospective cross-sectional study and its relationship with incident T2DM complications was not evaluated.

In conclusion, we think that TyGI is a valuable marker that reflects the degree of insulin resistance and can be easily calculated from routine laboratory data and predicts future diabetes risk in both obese and non-obese men and women. Therefore, our data should be validated in other populations for this marker to find more application in practice.

Ethical Approval: *Ethical approval of the study was obtained with the decision of Tokat Gaziosmanpasa University Medical Faculty Clinical Researches Ethics Committee dated 26.10.2023 and numbedred 23-KAEK-251.*

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Concept: M.K.
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Analysis and interpretation: M.K., O.D.
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