BMC Cardiovascular Disorders

RESEARCH

Open Access

Comparison of TyG and modified TyG indices in predicting coronary slow flow phenomenon

Jing Nan[1], Shuai Meng[1], Ruofei Jia[1], Wei Chen[1], Xingsheng Yang[1], Hongyu Hu[1], Lijun Han[1,2*] and Zening Jin[1]

Abstract

Background The coronary slow flow phenomenon (CSFP) represents a common condition in patients with ischemia and non-obstructive coronary artery disease (INOCA). The triglyceride-glucose index (TyG) and relative modified indices have been established to be associated with CSFP. However, comparison of the clinical value of TyG and its modified indices in predicting CSFP has not been evaluated.

Materials and methods INOCA patients were retrospectively enrolled. According to the corrected TIMI counts, the patients were divided into the CSFP group and the non-CSFP group. A total of 4,627 patients were enrolled in our study. Among them, 69 patients were divided into the CSFP group, while 586 patients were divided into the non-CSFP group. Demographic, clinical risk factors, and laboratory results, including TyG and its modified indices, were compared between the two groups. The prognostic value of TyG and its modified indices in CSFP was compared using the area under the curve (AUC).

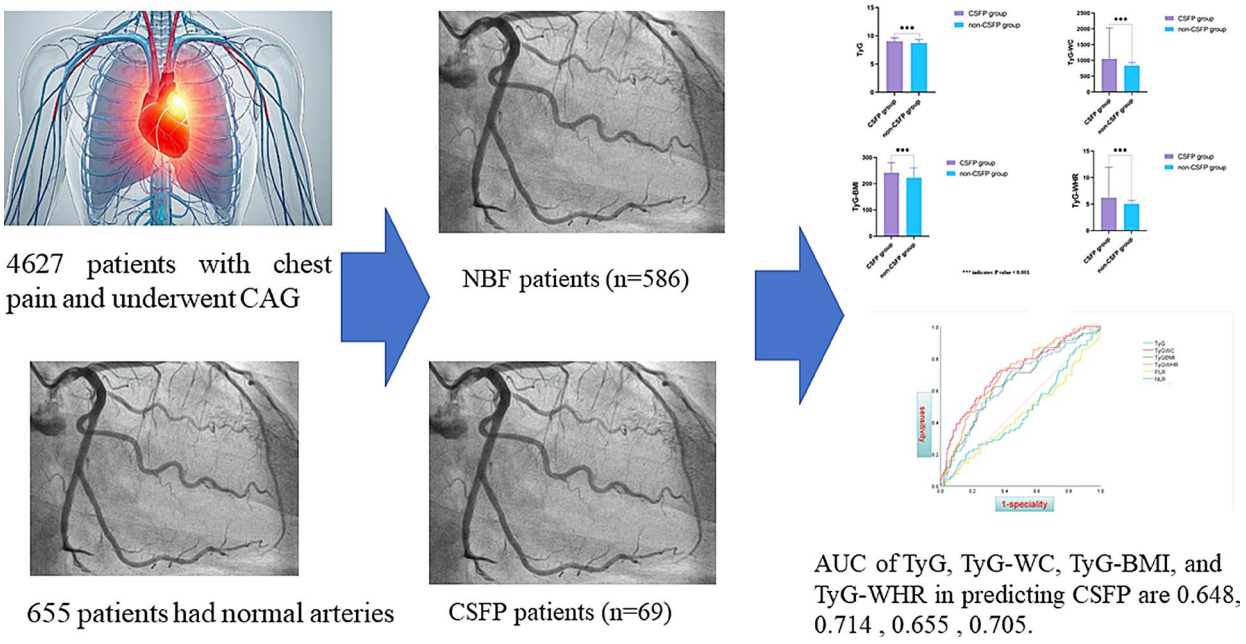
Results Most of the demographic and clinical risk factors between CSFP patients and non-CSFP patients were comparable. For patients with CSFP, the patients were more likely to have chronic kidney disease (CKD) (39.13% vs. 20.31%, $p < 0.001$) and less likely to have anti-diabetic therapy (14.49% vs. 27.13%, $p = 0.023$). The patients with CSFP also had higher body weight index (BMI) ($p < 0.001$), higher levels of uric acid (UA), triglyceride (TG) ($p = 0.017$), total cholesterol (TC) ($p = 0.016$) and low-density lipoprotein cholesterol (LDL-C) ($p = 0.006$), homocysteine ($p < 0.001$) and uric acid ($p < 0.002$). Both TyG and its modified indices, including TyG-WC, TyG-BMI were demonstrated to be independently associated with CSFP in multi-variable logistic analysis after adjusting other co-variables.Further receiver operating characteristic (ROC) curve demonstrated that TyG-WC showed the best performance in predicting CSFP compared with other indices. Subgroup analysis revealed that the predictive value of TyG-WC in CSFP was consistent in different subgroups except that the predictive value was better in male patients compared with female patients,

Conclusions Our investigation reveals that TyG, TyG-WC and TyG-BMI were independent risk factors for CSFP. TyG-WC showed a better predictive performance than other indices in predicting CSFP.

*Correspondence:
Lijun Han
h13522916899@163.com

Full list of author information is available at the end of the article

Graphical Abstract



Keywords Coronary slow flow phenomenal, Ischemia with no obstructive coronary artery, Triglyceride glucose ratio, Triglyceride glucose ratio- waist circumference

Introduction

Chest pain is a frequent reason for emergency visits, with cardiac causes including acute coronary syndrome (ACS) and non-cardiac etiologies. The diagnose of chest pain usually requires complex and sometimes invasive diagnostic methods for a conclusive diagnosis [1–4]. Coronary angiography (CAG) is pivotal for diagnosing ACS, but some patients exhibit chest pain without obstructive coronary arteries, classified as ischemia with no obstructive coronary arteries (INOCA) [5, 6]. Among INOCA patients, CSFP is a potential etiology, though its pathogenesis remains unclear [7, 8].

The detailed mechanism of CSFP are still unclear, however, inflammation and insulin resistance are closely related to the development of CSFP [7, 9–10]. The triglyceride-glucose ratio (TyG), initially proposed as a surrogate marker of insulin resistance, is now considered a novel inflammation parameter, and its clinical value has been extensively investigated in various cardiovascular disorders [11–13]. Recently, its clinical value in predicting CSFP has also been noted in some studies [14–17]. Moreover, the modified TyG indices, which combine TyG with other parameters such as body mass index, waist circumference, and waist-to-height ratio, have exhibited favorable predictive value in diseases including CSFP [18–21].

The clinical value of TyG and its indices in CSFP have been discussed before, however, which parameter has the best predictive value is still unclear. Our study, so far as we know, is the first study aiming to compare the clinical value of these indices in CSFP.

Methods

Study population

This retrospective study was performed at Beijing Tiantan Hospital, Capital Medical University. The detailed study information has been discussed in our previous study [22]. In conclusion, patients with chest pain and underwent CAG in our department from January 1st, 2022 to August 31st, 2023 were retrospectively enrolled. Patients with normal coronary arteries which confirmed by CAG were diagnosed with INOCA. Patients who were younger than 18 years old, patients with stenotic coronary arteries, patients with symptomatic heart failure, patients with severe hepatic or renal diseases, patients with aortic dissection or pulmonary embolism, patients with cardiomyopathy were excluded.

Data collection

The baseline demographic data and laboratory results were analyzed. Clinical information including demographic information (age, gender smoking history) and previous medical history (hypertension, diabetes

mellitus, dyslipidemia, coronary artery disease, cerebrovascular disease) were collected. The prior medication use as well as body weight, height, and waist circumference, were also collected. The calculation of the TyG index and its modified indices was illustrated in previous studies [14–21].

CSFP was diagnosed on the CAG results evaluated by professional cardiologists. The corrected TIMI frame count (CTFC) was used to evaluate the coronary blood flow and patients with CTFC more than 27 in at least one coronary artery were considered as CSFP [23].

Statistical analysis

Variables were shown as numbers and frequencies (percentages) or mean ± standard deviation or median (first quartile, third quartile), as appropriate. Categorical variables were compared with the chi-square test, continuous variables were compared with independent sample t-test or Mann-Whitney test. Multi-variable logistic analysis was employed to assess the associations between TyG and its modified indices and CSFP. Three models were used to adjust the confounding co-variables. In Model 1, no other co-variables were adjusted. In Model 2, gender, smoking, age, body mass index (BMI), chronic kidney disease, and anti-diabetic treatment were adjusted. In Model 3, gender, age, smoking, BMI, aspartate aminotransferase (AST), total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), apolipoprotein A1 (ApoA1), apolipoprotein B (ApoB), uric acid (UA), B-type natriuretic peptide (BNP), estimated glomerular filtration rate (eGFR), homocysteine (HCY), chronic kidney disease, and antidiabetic treatment were adjusted. To explore the dose-response relationship between TyG and its modified indices and the development of CSFP, logistic regression models incorporating restricted cubic splines (RCSs) for smooth curve fitting were also performed. The receiver operating characteristic (ROC) curve was applied to evaluate the predictive value of different indices. The comparison of the ROCs was used by net reclassification index (NRI) and integrated discrimination improvement (IDI). Data processing and analysis were performed using R version 4.3.0 (2023-06-21), along with Storm Statistical Platform (www.medsta.cn/software).

Results

A total of 4,627 patients underwent CAG, of whom 655 were identified as INOCA. These patients were subsequently divided into two groups: the CSFP group ($n = 69$) and the non-CSFP group ($n = 586$). The study flowchart is presented in Fig. 1.

The demographic data, prior medical history, and medication use history were compared between the CSFP group and the non-CSFP group, with the results summarized in Table 1. Overall, most parameters were comparable between the two cohorts. However, significant differences were observed in certain aspects. Patients in the CSFP group exhibited a significantly higher body mass index (BMI) compared to those in the non-CSFP group [26.56(25.35,28.72) vs. 25.56 (23.11,27.68),kg/m^2, $p < 0.001$]. Additionally, the prevalence of CKD was significantly higher in the CSFP group than in the non-CSFP group (39.13% vs. 20.31%, $p < 0.001$).

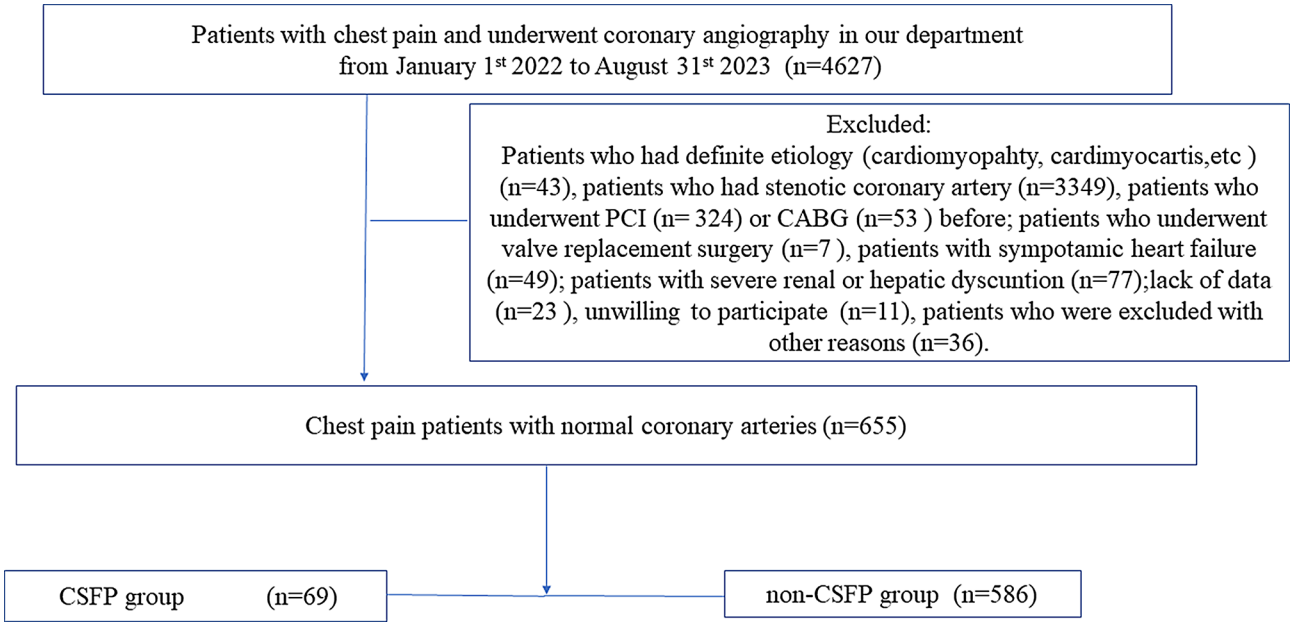


Fig. 1 Study flow chart

Table 1 The comparison results of demographic data, prior medical history, and medication use history between the CSFP group and the non-CSFP group

Variables	Non-CSFP group (*n* = 586)	CSFP group (*n* = 69)	Statistic	*P*
Age, years, M (Q_1, Q_3)	64.00 (57.00, 70.75)	64.00 (57.00, 69.00)	Z=-0.77	0.439
BMI, kg/m^2,M (Q_1, Q_3)	25.56 (23.11, 27.68)	26.56 (25.35, 28.72)	Z=-3.32	**< 0.001**
Gender, n(%)			χ^2=0.93	0.335
Female	204 (34.81)	20 (28.99)		
Male	382 (65.19)	49 (71.01)		
Hypertension, n(%)			χ^2=0.37	0.544
No	191 (32.59)	20 (28.99)		
Yes	395 (67.41)	49 (71.01)		
Diabetes melittus, n(%)			χ^2=2.68	0.102
No	348 (59.39)	48 (69.57)		
Yes	238 (40.61)	21 (30.43)		
Dyslipidemia, n(%)			χ^2=0.66	0.415
No	184 (31.40)	25 (36.23)		
Yes	402 (68.60)	44 (63.77)		
Previous stroke, n(%)			χ^2=1.22	0.269
No	482 (82.25)	53 (76.81)		
Yes	104 (17.75)	16 (23.19)		
Previous CAD, n(%)			χ^2=2.10	0.147
No	497 (84.81)	63 (91.30)		
Yes	89 (15.19)	6 (8.70)		
Chronic kidney disease, n(%)			χ^2=12.63	**< 0.001**
No	467 (79.69)	42 (60.87)		
Yes	119 (20.31)	27 (39.13)		
Current smoker, n(%)			χ^2=0.04	0.845
No	341 (58.19)	41 (59.42)		
Yes	245 (41.81)	28 (40.58)		
Anti-platelet therapy, n(%)			-	0.495
No	237 (40.27)	24 (34.78)		
Yes	349 (59.56)	45 (65.22)		
Nitrogen, n(%)			χ^2=0.04	0.850
No	372 (63.48)	43 (62.32)		
Yes	214 (36.52)	26 (37.68)		
RASSi, n(%)			χ^2=0.49	0.482
No	348 (59.39)	44 (63.77)		
Yes	238 (40.61)	25 (36.23)		
Beta blocker, n(%)			χ^2=0.00	0.952
No	278 (47.44)	33 (47.83)		
Yes	308 (52.56)	36 (52.17)		
CCB, n(%)			χ^2=0.77	0.380
No	396 (67.58)	43 (62.32)		
Yes	190 (32.42)	26 (37.68)		
Anti-diabetic therapy, n(%)			χ^2=5.15	**0.023**
No	427 (72.87)	59 (85.51)		
Yes	159 (27.13)	10 (14.49)		

Abbreviation CSFP: coronary slow flow phenomenal; BMI: body mass index; CAD: coronary artery disease; RASSi: angiotensin-converting enzyme inhibitor; CCB: calcium channel blocker

The baseline laboratory parameters were compared between the CSFP group and the non-CSFP group, with the results detailed in Table 2. In summary, patients in the CSFP group exhibited significantly higher levels of AST [21.10(17.30,25.80) vs. 19.00(16.30,24.00) U/L, $p = 0.026$], UA [384.90(308.90,443.70) vs. 337.20(283.18,402.45) mmol/L, $p = 0.002$], HCY[14.13(11.21,20.86) vs. 12.28 (9.98,15.75) mmol/L, $p < 0.001$], and BNP [241.70 (166.90,329.60) vs. 42.45 (20.18,97.87) pg/ml, $p < 0.001$]. Additionally, the levels of TC, TG, and LDL-C were also higher in the CSFP group compared to the non-CSFP group.

Table 2 The comparison results of baseline laboratory parameters between the CSFP group and the non-CSFP group

Variables	Non-CSFP group ($n=586$)	CSFP group ($n=69$)	Statistic	*P*
WBC, 10^9/L, M (Q_1, Q_3)	6.55 (5.40, 7.68)	6.20 (4.95, 7.54)	Z=-1.71	0.088
RBC, 10^{12}/L, M (Q_1, Q_3)	4.46 (4.11, 4.76)	4.50 (4.17, 4.70)	Z=-0.13	0.896
PLT, 10^9/L, M (Q_1, Q_3)	219.00 (184.00, 256.00)	208.00 (160.00, 249.00)	Z=-1.96	0.050
ALT, U/L, M (Q_1, Q_3)	19.40 (14.30, 27.70)	22.10 (15.10, 31.60)	Z=-1.43	0.153
AST, U/L, M (Q_1, Q_3)	19.00 (16.30, 24.00)	21.10 (17.30, 25.80)	Z=-2.22	**0.026**
Albumin, g/L, M (Q_1, Q_3)	39.60 (37.90, 41.30)	39.40 (37.50, 41.40)	Z=-0.78	0.438
Fasting glucose, mmol/L, M (Q_1, Q_3)	5.47 (4.87, 6.48)	5.18 (4.77, 5.83)	Z=-1.33	0.182
eGFR, ml/min, M (Q_1, Q_3)	100.96 (87.75, 110.32)	99.33 (91.83, 108.06)	Z=-0.24	0.812
UA, mmol/L, M (Q_1, Q_3)	337.20 (283.18, 402.45)	384.90 (308.90, 443.70)	Z=-3.12	**0.002**
TG, mmol/L, M (Q_1, Q_3)	1.39 (1.01, 2.07)	1.66 (1.12, 2.45)	Z=-2.38	**0.017**
TC, mmol/L, M (Q_1, Q_3)	3.63 (3.12, 4.39)	3.86 (3.32, 4.63)	Z=-2.41	**0.016**
HDL-C, mmol/L, M (Q_1, Q_3)	1.13 (0.98, 1.31)	1.16 (1.01, 1.33)	Z=-0.63	0.526
LDL-C, mmol/L, M (Q_1, Q_3)	1.94 (1.52, 2.60)	2.18 (1.80, 2.99)	Z=-2.74	**0.006**
ApoA1, mmol/L, M (Q_1, Q_3)	1.29 (1.16, 1.46)	1.31 (1.15, 1.44)	Z=-0.03	0.976
ApoB1, mmol/L, M (Q_1, Q_3)	0.70 (0.58, 0.86)	0.76 (0.66, 0.95)	Z=-2.42	**0.016**
HCY, mmol/L, M (Q_1, Q_3)	12.28 (9.98, 15.75)	14.13 (11.21, 20.86)	Z=-3.45	**<0.001**
HbA1C, %, M (Q_1, Q_3)	6.20 (5.80, 7.00)	6.10 (5.80, 6.60)	Z=-1.28	0.200
BNP, pg/ml, M (Q_1, Q_3)	42.45 (20.18, 97.87)	241.70 (166.90, 329.60)	Z=-10.86	**<0.001**
TyG, M (Q_1, Q_3)	8.73 ± 0.63	9.03 ± 0.61	t=-3.84	**<0.001**
TyG-WC, M (Q_1, Q_3)	834.09 (770.57, 903.21)	918.96 (832.54, 997.66)	Z = -5.83	**<0.001**
TyG-BMI, M (Q_1, Q_3)	222.17 ± 38.36	241.56 ± 38.69	t=-3.97	**<0.001**
TyG-WHR, M (Q_1, Q_3)	5.0(4.6, 5.4)	5.5 (5.1, 5.8)	Z = -5.59	**<0.001**

Abbreviation: CSFP: coronary slow flow phenomenal; ALT: alanine aminotransferase; AST: aspartate transaminase; eGFR: estimated glomerular filtration rate; UA: uric acid; TC: total cholesterol; TG: triglyceride; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; Apo: apolipoprotein; HCY: homocysteine; HbA1C: Glycosylated Hemoglobin, Type A1C; BNP: B-type natriuretic peptide; TyG: triglyceride-glucose ratio; TyG-WC: triglyceride-glucose ratio-waist circumference; TyG-BMI: triglyceride-glucose ratio- body weight index; TyG-WHR: riglyceride-glucose ratio-weight height ratio

Furthermore, the comparison of TyG and its modified indices between the CSFP and non-CSFP patients is also presented in Table 2.Compared with the non-CSFP group, the CSFP group demonstrated significantly higher levels of TyG (9.03 ± 0.61 vs. 8.73 ± 0.63, $p<0.001$), TyG-WC [918.96 (832.54,997.66) vs. 834.09 (770.57,903.21), $p<0.001$], TyG-BMI (241.56 ± 38.69 vs.222.17 ± 38.36, $p<0.001$),and TyG-WHR [5.5(5.1,5.8) vs.5.0(4.6,5.4), $p<0.001$].

To assess the potential nonlinear correlation between the indices and CSFP, we carried out Restricted Cubic Splines (RCS) fitting within the Logistic regression models. The findings suggested that some relationships are significantly non-linear while others may be closer to a linear relationship without statistic significance, as depicted in Fig. 2.

Subsequently, we proceeded with a multi-variable logistic regression analysis to appraise the association between these parameters and CSFP. The detailed results of the logistic regression analysis are presented in Table 3. Before we perform the multi-variable logistic analysis, the potential collinearity of the enrolled variables were tested and the results showed that there were moderate collinearity relationship between TG and TyG, TyG-WC, TyG-BMI and TyG-WHR. In conclusion, after adjusting for other confounding variables, TyG, TyG-WC, TyG-BMI except TyG-WHR emerged as independent risk factors for CSFP.

The predictive value of TyG and its modified parameters in CSFP were compared using the ROC curve. In summary, both TyG and its modified parameters have good predictive value in CSFP. The area under the curve (AUC) of TyG, TyG-WC, TyG-BMI, and TyG-WHR in predicting CSFP are 0.648 (0.580–0.717), 0.714 (0.647–0.781), 0.655 (0.586–0.723), 0.705 (0.644–0.767), respectively (Fig. 3). We also compared the predictive value between TyG-WC and other parameters in CSFP and TyG-WC has better performance when compared with TyG and other modified parameters using net reclassification improvement and integrated discrimination improvement (Table 4).

We further evaluated the predictive value of TyG-WC in different subgroups. The detailed results of TyG-WC in CSFP among different subgroups were shown in Table 5. The results demonstrated that TyG-WC was significantly associated with CSFP in patients with different age, BMI and smoking history. However, for male patients, the predictive value of TyG-WC in CSFP was not statistically significant.

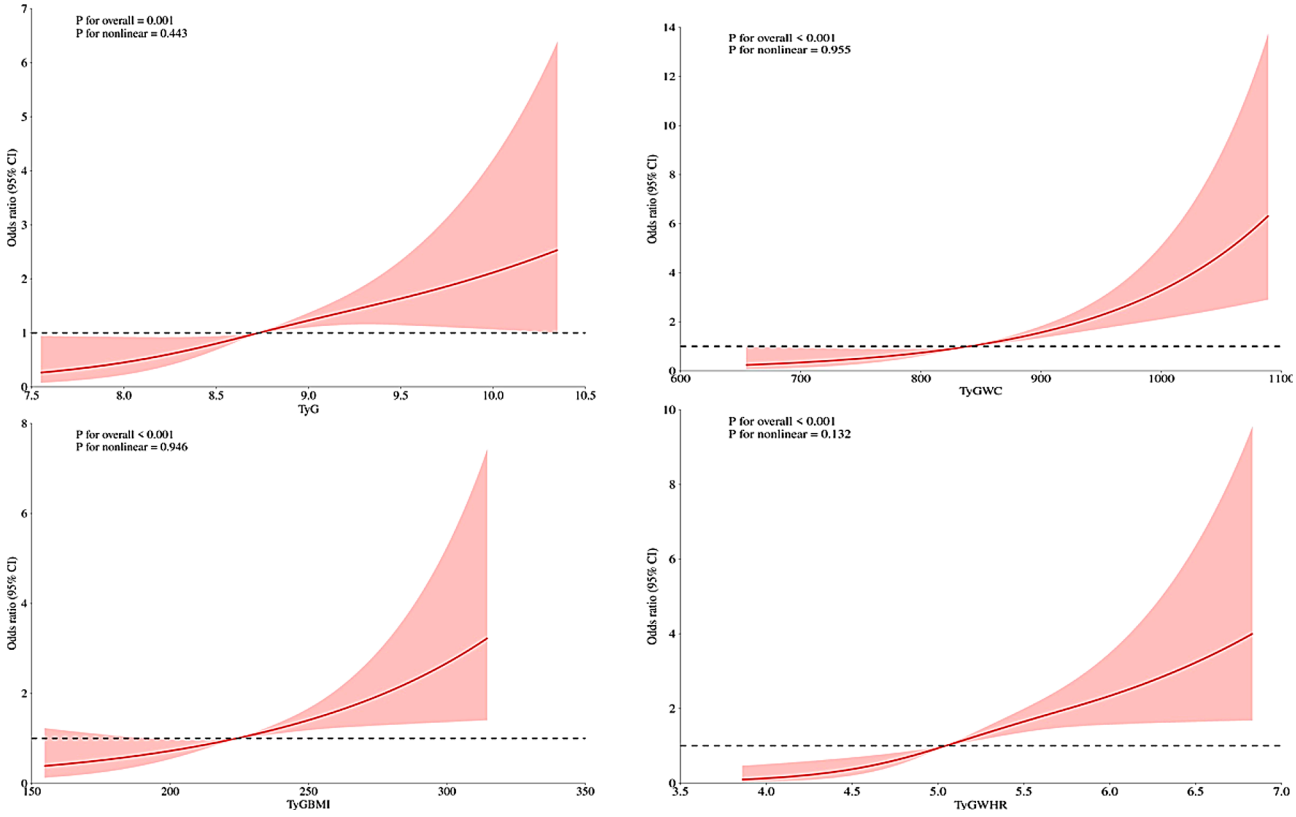


Fig. 2 Restricted cubic splines for TyG and its modified indices with CSFP

Table 3 Logistic regression analysis of TyG and its modified indices with CSFP

Variables	Model 1		Model 2		Model 3	
	OR(95%CI)	*P*	OR(95%CI)	*P*	OR(95%CI)	*P*
TyG	2.09 (1.42 ~ 3.07)	< 0.001	2.46 (1.36 ~ 3.95)	0.005	2.76 (1.43 ~ 4.84)	0.002
TyG-WC	2.51 (1.41 ~ 3.81)	< 0.001	2.77 (1.42 ~ 4.02)	< 0.001	2.91 (1.59 ~ 5.02)	< 0.001
TyG-BMI	1.01 (1.01 ~ 1.01)	< 0.001	0.87 (0.79 ~ 0.96)	0.008	0.85 (0.75 ~ 0.96)	0.007
TyG-WHR	2.77 (1.91 ~ 4.03)	< 0.001	1.31 (0.28 ~ 6.17)	0.736	1.39 (0.25 ~ 7.71)	0.703

Abbreviation CSFP: coronary slow flow phenomenal; TyG: triglyceride-glucose ratio; TyG-WC: triglyceride-glucose ratio-waist circumference; TyG-BMI: triglyceride-glucose ratio-body weight index; TyG-WHR: triglyceride-glucose ratio-weight height ratio; OR: Odds Ratio, CI: Confidence Interval

Model 1: we did not adjust other covariates

Model 2: we adjusted gender, smoking, age, BMI, chronic kidney disease, and antidiabetic therapy

Model 3: we adjusted gender, age, smoking, BMI, AST, TC, TG, LDL-C, HDL-C, ApoA1, ApoB, UA, BNP, eGFR, HCY, chronic kidney disease, antidiabetic therapy

Discussion

In this retrospective study, we investigated the clinical value of TyG and its modified indices in predicting CSFP.As one of the largest studies in this area, we identified two key findings. First, we demonstrated that TyG, TyG-WC, and TyG-BMI are all independent risk factors for CSFP in patients with INOCA. Second, our analysis revealed that TyG-WC exhibited superior predictive performance in identifying CSFP compared to other TyG-related indices.

TyG has recently emerged as a novel biomarker for a wide range of diseases [24]. It has been extensively reported that TyG is associated with both cardiovascular and non-cardiovascular conditions [25–28]. However, the correlation between TyG and CSFP has been underexplored. In a retrospective study by Kaplangoray et al.,118 CSFP patients and 105 non-CSFP patients were analyzed, and multivariate analysis revealed that TyG was an independent predictor of CSFP, with an AUC of 0.868 [14]. Similarly, studies by Bilen et al.and Yuksel et al.also demonstrated that the TyG index is an independent predictor of CSFP [15, 16]. Another study involving 1,100 participants further confirmed TyG as an independent risk factor for CSFP [17].These findings are consistent with our results.

The clinical value of TyG-modified indices has also been evaluated in numerous studies. For instance, Cheng Y and colleagues examined the relationship between

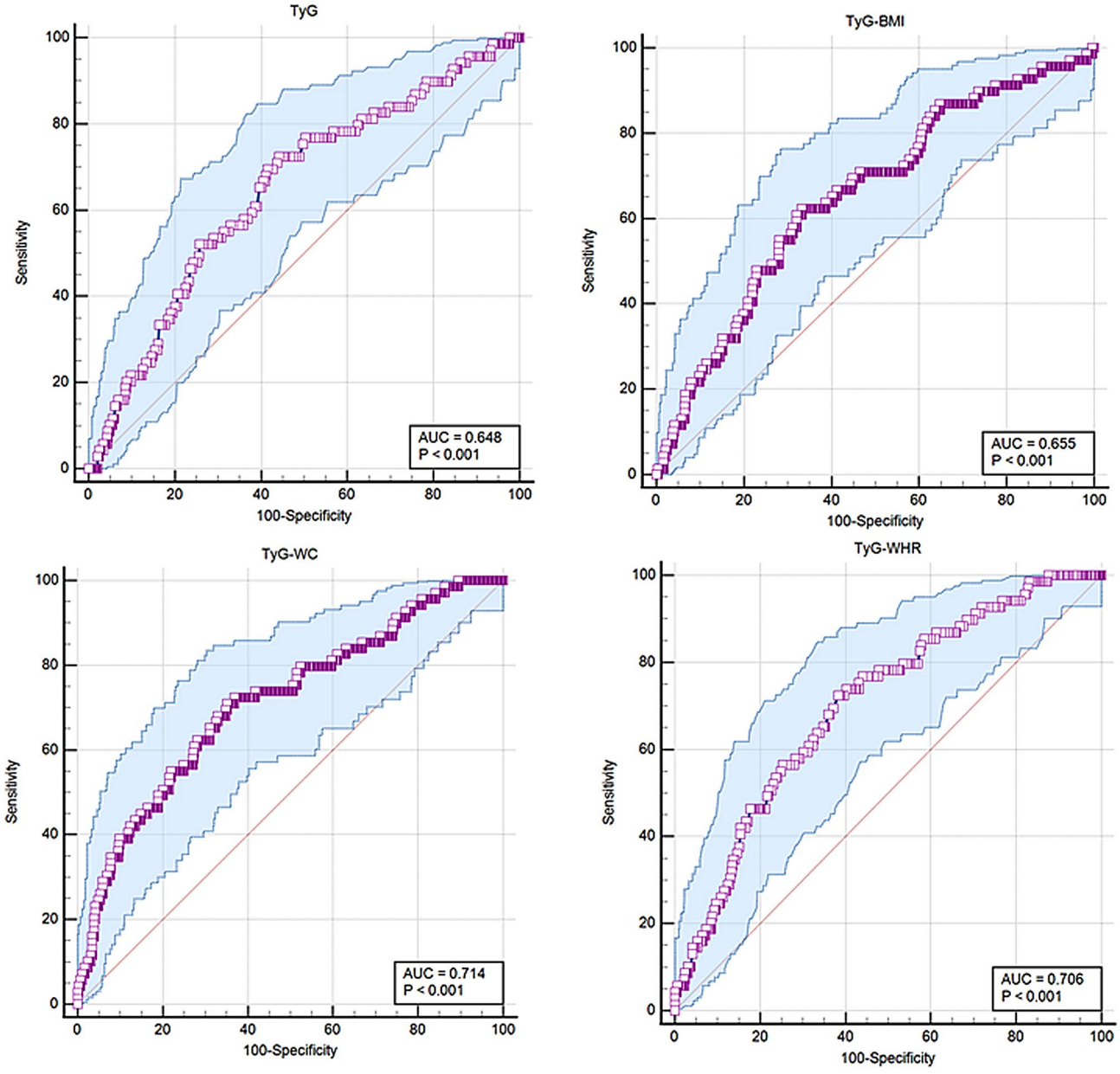


Fig. 3 The ROC curve of TyG and its modified indices in predicting CSFP

Table 4 The comparison results of net reclassification improvement and integrated discrimination improvement between TyG-WC and other indices in CSFP

	NRI: OR(95% CI)	*P*	IDI: OR(95% CI)	*P*
TyG-WC vs. TyG	0.4391 [0.2074–0.6708]	<0.001	0.0651 [0.0298–0.1003]	<0.001
TyG-WC vs. TyG-BMI	0.3368 [0.096–0.5776]	0.002	0.0609 [0.0218–0.1001]	0.006
TyG-WC vs. TyG-WHR	0.2166 [−0.0266–0.4597]	<0.001	0.0206 [0.0088–0.0324]	<0.001

Abbreviation: CSFP: coronary slow flow phenomenal; TyG: triglyceride-glucose ratio; TyG-WC: triglyceride-glucose ratio-waist circumference; TyG-BMI: triglyceride-glucose ratio-body weight index; TyG-WHR: triglyceride-glucose ratio-weight height ratio; OR: Odds Ratio, CI: Confidence Interval

Table 5 Results of subgroup analysis of TyG-WC in CSFP

Variables	*n* (%)	OR (95%CI)	*P*	*P* for interaction
All patients	655 (100.00)	2.09 (1.42 ~ 3.07)	**< 0.001**	
Gender				0.029
Female	224 (34.20)	0.98 (0.44 ~ 2.17)	0.955	
Male	431 (65.80)	2.67 (1.70 ~ 4.21)	**< 0.001**	
Diabetes				0.618
No	396 (60.46)	2.35 (1.46 ~ 3.78)	**< 0.001**	
Yes	259 (39.54)	1.90 (0.95 ~ 3.78)	0.068	
CKD				0.081
No	509 (77.71)	2.71 (1.67 ~ 4.37)	**< 0.001**	
Yes	146 (22.29)	1.26 (0.62 ~ 2.57)	0.523	
Current smoker				0.986
No	382 (58.32)	2.10 (1.23 ~ 3.59)	**0.006**	
Yes	273 (41.68)	2.12 (1.20 ~ 3.74)	**0.010**	
Age (years)				0.300
<65	334 (50.99)	1.76 (1.03 ~ 2.98)	**0.037**	
≥65	321 (49.01)	2.66 (1.48 ~ 4.79)	**0.001**	
BMI (Kg/m^2)				0.563
<24	208 (31.76)	2.54 (0.94 ~ 6.85)	0.066	
≥24	447 (68.24)	1.84 (1.20 ~ 2.83)	**0.005**	

Abbreviation CSFP: coronary slow flow phenomenal; CKD: chronic kidney disease; BMI: body weight index; OR: Odds Ratio, CI: Confidence Interval

TyG-BMI and cardiovascular outcomes in patients undergoing percutaneous coronary intervention. After adjusting for other variables, TyG-BMI was found to be correlated with the incidence of adverse clinical events [29]. In a retrospective study by Li ZP et al., 1625 INOCA patients were analyzed, and the TyG-BMI index was identified as an independent predictor of CSFP [19]. Xue Y et al.discovered that TyG-WC was positively associated with liver stiffness and exhibited the strongest diagnostic capacity among related indices [26]. Additionally, Xuan W found that TyG-WHtR was independently associated with the risk of developing diabetes [30].

The comparative analysis of TyG and its modified indices has also been explored in previous studies. Miao H and colleagues compared the capabilities of TyG and its modified parameters in identifying patients with hypertension and high cardiovascular risk. After adjusting for other confounding factors, both TyG and the modified parameters demonstrated favorable predictive values. Among these, TyG-WC exhibited the highest diagnostic effectiveness for hypertension [31]. However, in another study by Yang C et al., TyG and its modified indices were evaluated, and the results indicated that TyG-WHR showed the best performance in predicting newly onset hypertension in the general population [32]. Similarly, Li X et al.assessed the predictive value of TyG and its modified indices in newly onset diabetes, and the findings revealed that TyG-WHR outperformed other parameters in this context [33].

The pathogenesis of CSFP is multifaceted and complex. Endothelial dysfunction, inflammation, oxidative stress, and insulin resistance have all been implicated as key factors associated with CSFP [7, 8, 34]. Previous studies have demonstrated that endothelium-dependent flow-mediated dilatation function is compromised in patients with CSFP. Additionally, cellular factors that influence endothelial vasoconstriction or vasodilation are often imbalanced, as shown in various studies [35–37].

Inflammation is another potential mechanism underlying CSFP. Elevated levels of high-sensitivity C-reactive protein and other inflammatory biomarkers have been observed in patients with CSFP in prior research [38, 39]. Oxidative stress is also considered a possible mechanism, as evidenced by higher levels of malondialdehyde and superoxide dismutase in CSFP patients, indicating that oxidative stress may impair endothelial function [40, 41].

These mechanisms are likely interconnected and may collectively contribute to the development of CSFP. Our findings are consistent with these previously established mechanisms, suggesting that the associations we observed may be mediated through these pathways.

In our study, the TyG-WC exhibited an AUC value of 0.714,indicating only a modest discrimination ability. However, it is still worthy since some well-known risk scores, including the Framingham risk score, also demonstrate modest discrimination ability [42, 43]. Given its simplicity and non-invasive nature, TyG-WC may still prove useful as a screening tool for identifying CSFP patients prior to undergoing CAG.

The underlying mechanism for the superiority of TyG-WC over other TyG indices in predicting CSFP remains unclear. TyG is a well-accepted biomarker for insulin

resistance, while waist circumference (WC) is a well-established indicator of visceral adiposity. Both TyG and WC are potentially associated with atherosclerosis and inflammation, which are key mechanisms underlying CSFP [7, 34]. The combination of TyG and WC may therefore provide a more prominent association with CSFP compared to other TyG indices.

In conclusion, to the best of our knowledge, this is the first study to compare the predictive values of TyG and its modified indices in predicting CSFP. Our findings indicate that TyG-WC exhibits relatively superior discriminative ability in predicting CSFP compared to other indices.

Our study has several limitations. First, as a single-center retrospective study, our preliminary findings require further validation through multi-center studies. An external validation cohort with a larger and more diverse group of participants is necessary to confirm our results. Second, the prognostic value of TyG and its modified indices regarding the long-term clinical outcomes of CSFP patients remains to be explored in future studies. Third, our study only included patients with chest pain, which could introduce potential selection bias. Finally, the measurement of waist circumference and BMI relied on the accuracy of the measurement process and may have been subject to observer variability.These factors could also represent potential limitations in our study.

Acknowledgements
None to declare.

Author contributions
J. N collected the data, and wrote the paper S. M, RF. J, HY. H, XS. Y collected the data and analyzed the TIMI flow counts. ZN. J revised the data and wrote the paper. LJ. H collected the data and supervised the writing. All of the authors reviewed the manuscript.

Funding
None.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This research was carried out in line with the Helsinki Declaration. Written informed consents were retrieved from patients and/or their authorized relatives, and the ethical clearance was obtained from Beijing Tiantan Hospital, affiliated with Capital Medical University (KY-23-037). Due to the nature of our study, we did not registered this study so the clinical trial number was not applicable.

Consent for publication
All of the authors agree to publish this study.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Cardiology and Macrovascular Disease, Beijing Tiantan Hospital, Capital Medical University, Beijing, China
[2]No.119 South Fourth Ring West Road, Fengtai District, Beijing 100070, P. R. China

Received: 21 February 2025 / Accepted: 22 April 2025
Published online: 30 April 2025

References

1. Gulati M, Levy PD, Mukherjee D, et al. 2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR guideline for the evaluation and diagnosis of chest pain: executive summary: A report of the American college of cardiology/american heart association joint committee on clinical practice guidelines. Circulation. 2021;144(22):e368–454.
2. Kontos MC, de Lemos JA, Deitelzweig SB, et al. 2022 ACC expert consensus decision pathway on the evaluation and disposition of acute chest pain in the emergency department: A report of the American college of cardiology solution set oversight committee. J Am Coll Cardiol. 2022;80(20):1925–60.
3. Asadi Anar M, Ansari A, Erabi G, et al. Prognostic value of fragmented QRS in acute pulmonary embolism: a cross-sectional-analytic study of the Iranian population. Am J Cardiovasc Dis. 2023;13(1):21–8.
4. Sajjadi S, Mohebbi A, Ehsani A et al. Identifying abdominal aortic aneurysm size and presence using natural Language processing of radiology reports: a systematic review and meta-analysis. Abdom Radiol.2025. https://doi.org/10.1007/s00261-025-04810-5
5. Maurovich-Horvat P, Bosserdt M, Kofoed KF, et al. CT or invasive coronary angiography in stable chest pain. N Engl J Med. 2022;386(17):1591–602.
6. Mehta PK, Huang J, Levit RD, et al. Ischemia and no obstructive coronary arteries (INOCA): A narrative review. Atherosclerosis. 2022;363:8–21.
7. Chalikias G, Tziakas D. Slow coronary flow: pathophysiology, clinical implications, and therapeutic management. Angiology. 2021;72(9):808–18.
8. Alvarez C, Siu H. Coronary Slow-Flow phenomenon as an underrecognized and treatable source of chest pain: case series and literature review. J Investig Med High Impact Case Rep. 2018;6:2324709618789194.
9. Roshanravan N, Shabestari AN, Alamdari NM, et al. A novel inflammatory signaling pathway in patients with slow coronary flow: NF-κB/IL-1β/nitric oxide. Cytokine. 2021;143:155511.
10. Dai XT, Kong TZ, Zhang XJ, et al. Relationship between increased systemic immune-inflammation index and coronary slow flow phenomenon. BMC Cardiovasc Disord. 2022;22(1):362.
11. Zhang B, Peng A, Li S, et al. Association of triglyceride-glucose index and neutrophil-to-lymphocyte ratio with coronary artery disease. BMC Cardiovasc Disord. 2023;23(1):534.
12. Xie E, Ye Z, Wu Y, et al. Association between the triglyceride-glucose index and severity of coronary artery disease. Cardiovasc Diabetol. 2022;21(1):168.
13. Zhang W, Liu L, Yin G, et al. Triglyceride-glucose index is associated with myocardial ischemia and poor prognosis in patients with ischemia and no obstructive coronary artery disease. Cardiovasc Diabetol. 2024;23(1):187.
14. Kaplangoray M, Toprak K, Başanalan F, et al. Investigation of the relationship between Triglycerides-Glucose index and coronary slow flow: A retrospective Case-Control study. Arq Bras Cardiol. 2023;120(6):e20220679.
15. Bilen MN, Barman HA, Dogan O, et al. The triglyceride-glucose index as a predictive marker for coronary slow flow phenomenon. Eur Rev Med Pharmacol Sci. 2024;28(8):3016–23.
16. Yuksel Y, Yildiz C. Evaluation of triglyceride-glucose index in coronary slow flow patients. Kardiologiia. 2023;63(5):62–7.
17. Buber I, Nar R, Kaya D, et al. Assessment of triglyceride/glucose index with respect to coronary slow flow. Bratisl Lek Listy. 2022;123(8):585–8.
18. Ahn SH, Lee HS, Lee JH. Triglyceride-glucose-waist circumference index predicts the incidence of cardiovascular disease in Korean populations: competing risk analysis of an 18-year prospective study. Eur J Med Res. 2024;29(1):214.
19. Li ZP, Chen J, Xin Q, et al. Triglyceride glucose-body mass index as a novel predictor of slow coronary flow phenomenon in patients with ischemia and nonobstructive coronary arteries (INOCA). BMC Cardiovasc Disord. 2024;24(1):60.
20. Dou J, Guo C, Wang Y, et al. Association between triglyceride glucose-body mass and one-year all-cause mortality of patients with heart failure: a retrospective study utilizing the MIMIC-IV database. Cardiovasc Diabetol. 2023;22(1):309.

21. Zhuang Y, Wang Y, Sun P, et al. Association between triglyceride glucose-waist to height ratio and coronary heart disease: a population-based study. Lipids Health Dis. 2024;23(1):162.
22. Han L, Li M, Xie W, et al. Association between orthostatic hypotension with coronary slow flow in patients with chest pain: A single center experience. Clin Cardiol. 2024;47(11):e70050.
23. Ipek G, Kamber T, Yilmaz H, et al. Long-Term change in flow rates in patients with coronary slow flow. Cardiology. 2023;148(6):500–5.
24. Ramdas Nayak VK, Satheesh P, Shenoy MT, et al. Triglyceride glucose (TyG) index: A surrogate biomarker of insulin resistance. J Pak Med Assoc. 2022;72(5):986–8.
25. Yin JL, Yang J, Song XJ, et al. Triglyceride-glucose index and health outcomes: an umbrella review of systematic reviews with meta-analyses of observational studies. Cardiovasc Diabetol. 2024;23(1):177.
26. Xue Y, Xu J, Li M, et al. Potential screening indicators for early diagnosis of NAFLD/MAFLD and liver fibrosis: triglyceride glucose index-related parameters. Front Endocrinol (Lausanne). 2022;13:951689.
27. Shi YY, Zheng R, Cai JJ, et al. The association between triglyceride glucose index and depression: data from NHANES 2005–2018. BMC Psychiatry. 2021;21(1):267.
28. Zhang J, Yin B, Xi Y, et al. Triglyceride-glucose index is a risk factor for breast cancer in China: a cross-sectional study. Lipids Health Dis. 2024;23(1):29.
29. Cheng Y, Fang Z, Zhang X, et al. Association between triglyceride glucose-body mass index and cardiovascular outcomes in patients undergoing percutaneous coronary intervention: a retrospective study. Cardiovasc Diabetol. 2023;22(1):75.
30. Xuan W, Liu D, Zhong J, et al. Impacts of triglyceride Glucose-Waist to height ratio on diabetes incidence: A secondary analysis of A Population-Based longitudinal data. Front Endocrinol (Lausanne). 2022;13:949831.
31. Miao H, Zhou Z, Yang S, et al. The association of triglyceride-glucose index and related parameters with hypertension and cardiovascular risk: a cross-sectional study. Hypertens Res. 2024;47(4):877–86.
32. Yang C, Song Y, Wang X, et al. Association of hypertension with the triglyceride-glucose index and its associated indices in the Chinese population: A 6-year prospective cohort study. J Clin Hypertens (Greenwich). 2024;26(1):53–62.
33. Li X, Sun M, Yang Y, et al. Predictive effect of triglyceride Glucose-Related parameters, obesity indices, and lipid ratios for diabetes in a Chinese population: A prospective cohort study. Front Endocrinol (Lausanne). 2022;13:862919.
34. Zhu Q, Wang S, Huang X, et al. Understanding the pathogenesis of coronary slow flow: recent advances. Trends Cardiovasc Med. 2024;34(3):137–44.
35. Niu H, Wei Z, Zhang Y, et al. Atorvastatin improves coronary flow and endothelial function in patients with coronary slow flow. Exp Ther Med. 2018;15(1):904–8.
36. Zhao C, Zong Z, Zhu Q, et al. The LncRNA MALAT1 participates in regulating coronary slow flow endothelial dysfunction through the miR-181b-5p-MEF2A-ET-1 axis. Vascul Pharmacol. 2021;138:106841.
37. Camsarl A, Pekdemir H, Cicek D, et al. Endothelin-1 and nitric oxide concentrations and their response to exercise in patients with slow coronary flow. Circ J. 2003;67(12):1022–8.
38. Li JJ, Qin XW, Li ZC, et al. Increased plasma C-reactive protein and interleukin-6 concentrations in patients with slow coronary flow. Clin Chim Acta. 2007;385(1–2):43–7.
39. Turhan H, Saydam GS, Erbay AR, et al. Increased plasma soluble adhesion molecules; ICAM-1, VCAM-1, and E-selectin levels in patients with slow coronary flow. Int J Cardiol. 2006;108(2):224–30.
40. Tanriverdi H, Evrengul H, Enli Y, et al. Effect of homocysteine-induced oxidative stress on endothelial function in coronary slow-flow. Cardiology. 2007;107(4):313–20.
41. Enli Y, Turk M, Akbay R, et al. Oxidative stress parameters in patients with slow coronary flow. Adv Ther. 2008;25(1):37–44.
42. D'Agostino RB, Sr, Vasan RS, Pencina MJ, et al. General cardiovascular risk profile for use in primary care: the Framingham heart study. Circulation. 2008;117(6):743–53.
43. Okumura K, Tomita H, Nakai M, et al. A novel risk stratification system for ischemic stroke in Japanese patients with Non-Valvular atrial fibrillation. Circ J. 2021;85(8):1254–62.

Publisher's note