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Association between triglyceride glucose-body mass index and hypertension in Chinese adults: A cross-sectional study

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Abstract

The triglyceride glucose-body mass index (TyG-BMI) has been considered an alternative marker of insulin resistance (IR). This cross-sectional study was designed to mainly investigate the association between TyG-BMI, triglyceride glucose combined with body mass index, and hypertension in Chinese adults. The relationship between TyG-BMI and hypertension was examined by multivariate logistic regression and restricted cubic spline model. Multiple logistic regression models were also performed to examine the associations between the individual components of TyG-BMI (BMI, TyG index, TG and FBG) and hypertension. The incremental ability of TyG-BMI versus its individual components for hypertension discrimination was evaluated by C-statistic and net reclassification index. Subgroup analysis was performed to examine potential interactions. A total of 92,545 participants (38.9% men, mean age 53.7 years) were included for final analysis. Logistic regression models showed TyG-BMI and its individual components were all significantly associated with the odds of hypertension (p for trend < .001). The restricted cubic spline regression manifested a linear association between TyG-BMI and hypertension (p for non-linear = .062). The addition of TyG-BMI, in comparison with each individual component, exhibited the maximum incremental value for the discrimination of hypertension on the basis of base model (C-statistic: 0.679, 95% CI: 0.675-0.683 for base model vs. 0.695, 95% CI: 0.691-0.699 for base model + TyG-BMI; net reclassification index: 0.226, 95% CI: 0.215-0.234). TyG-BMI was significantly associated with the odds of hypertension and can be a better discriminator of hypertension.

KEYWORDS
hypertension, insulin resistance, triglyceride glucose-body mass index (TyG-BMI)

Danying Deng and Chaolei Chen contributed equally for this work.

1 | INTRODUCTION

Hypertension represents the primary cause of cardiovascular disease (CVD) and premature mortality throughout the world.[1] Despite the widespread use of antihypertensive drugs, the prevalence of hypertension continues to increase. It was expected an estimated 60% increase in adults with hypertension in 2025 compared to 2000, reaching 1.56 billion, especially in economically developing countries.[2] In China, the prevalence of hypertension was approximately 27.9% among adults and 60% among the elderly population in 2012—2015, while the awareness, treatment, and control of hypertension were low.[3,4]

Insulin resistance (IR) is generally recognized as decreased insulin sensitivity, resulting in reduced cellular glucose uptake and utilization.[5] As part of metabolic syndrome, IR affects insulin-regulated pathways and contributes significantly to the progression of numerous cardiovascular risk factors.[6,7] Body mass index (BMI) and insulin levels have been widely reported to be associated with hypertension, and BMI affects blood pressure through multiple mechanisms including IR.[8,9] The triglyceride glucose (TyG) index has been proven to be a surrogate marker of IR.[10,11] Since the strong correlation between obesity and IR was well established, the integration of TyG index and obesity parameters theoretically has an advantage of reflecting IR.[12,13] In addition, previous studies have demonstrated that both lipotoxicity and glucotoxicity are contributors to the development of IR.[14,15] Recently, the triglyceride glucose-body mass index (TyG-BMI), the logarithmic product of fasting blood glucose (FBG) and fasting triglyceride (TG) multiplied by BMI, has been suggested as an alternative indicator of IR.[16] Unlike traditional methods of assessing IR, such as the hyperinsulinemic-euglycemic clamp (HEC) and homeostasis model assessment of IR (HOMA-IR), TyG-BMI does not require measuring insulin but only FBG, TG and BMI (the three most frequently used clinical indicators), which is not only more stable for the IR evaluation but also relatively inexpensive.[10,12]

Several studies have explored the association of TyG-BMI with hypertension.[12,17–20] However, the results were inconclusive due to limited sample size or lack of representative population. Moreover, few studies have specialized in the only one indicator TyG-BMI, rather than a mixture with other indicators. Therefore, we aimed to investigate the association between TyG-BMI and hypertension among Chinese adults.

2 | METHODS

2.1 | Participants

The China-PEACE MPP (Patient-centered Evaluative Assessment of Cardiac Events Million Persons Project) was a government-funded public health project and a large-scale screening initiative to detect population at high risk of CVD all over China.[21] The China-PEACE MPP design and methods have previously been described.[21–23] We analyzed data from participants of the Early Screening and Comprehensive Intervention Program for High Risk Population of CVD between

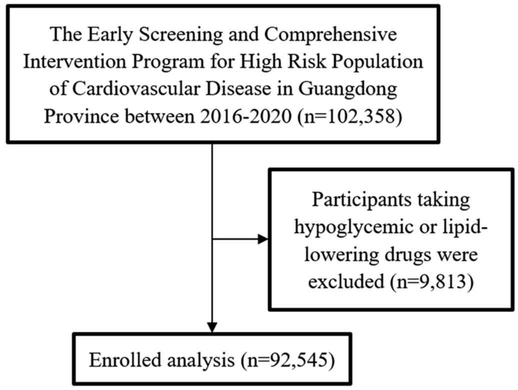

FIGURE 1 The research flow chart of study participants.

January 1, 2016 and December 31, 2020 in Guangdong province, China. This program was a vital branch of the China-PEACE MPP. Participants who were aged 35–75 years old and dwelled locally more than 6 months before screening met the inclusion criteria. Totally, 102,358 subjects were enrolled. Considering the calculation of TyG-BMI needs FBG and TG, subjects who had taken hypoglycemic agents or lipid-lowering drugs during the past two weeks that may affect FBG or TG were excluded. Finally, 92,545 participants were included for analysis (Figure 1). The current research was approved by the Institutional Ethics Review Committee of Guangdong Provincial People's Hospital. We have obtained signed informed consent from each participant.

2.2 | Data collection and definitions

Standardized questionnaires were administered by well-trained staff to gather socio-demographic information, lifestyle behaviors, medication in the past 2 weeks and personal history of disease. Socio-demographic information included age, gender, nationality, education level, marital status, current job, household income and medical insurance. Lifestyle behaviors included smoking status and alcohol drinking status. Medication included use of antidiabetic, lipid-lowering, antiplatelet and antihypertensive agents. Personal history of disease included self-reported diabetes, cancer, and CVD. Physical measurements were performed to exam height, weight, waist circumference (WC), systolic blood pressure (SBP), as well as diastolic blood pressure (DBP). Sitting in a comfortable position, the right upper arm was measured twice for blood pressure using the HEM-7430 electronic monitor (Omron, Kyoto, Japan). Height and weight were measured without shoes and hats, accurate to 0.1 cm and 0.1 kg, respectively. Fingertip blood samples were collected from all subjects on an empty stomach to determine FBG, TG, total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C). Diabetes was defined as FBG $\geq$ 7 mmol/L, current taking hypoglycemic agents or self-report of physician diagnosis. Dyslipidemia was defined as TC $\geq$ 6.2 mmol/L, LDL-C $\geq$ 4.1 mmol/L, or self-reported receiving hypolipidemic medication. Hypertension was defined as SBP/DBP $\geq$ 140/90 mmHg or taking antihypertensive drugs.[24]

2.3 | TyG-BMI calculation

BMI was calculated as weight in kilograms divided by height in meters squared. TyG index was calculated by the formula Ln [FBG (mg/dl) × fasting TG (mg/dl)/2].[11] TyG-BMI was calculated as BMI multiplied by TyG index.[16]

2.4 | Statistical analysis

Baseline characteristics of analyzed population were grouped by quartiles of TyG-BMI (Q1, Q2, Q3, Q4) and the presence or absence of hypertension. Continuous variables were presented as medians (inter quartile range) due to their non-normal distribution, which was examined by the Kolmogorov-Smirnov test. Categorical variables were reported as number (percentage) and compared using the Wilcoxon Mann-Whitney test, Kruskal-Wallis *H*-test, or chi-square tests as appropriate. Three sets of multivariate logistic regression models were constructed to estimate odds ratio (OR) with 95% confident interval of hypertension for TyG-BMI versus its individual components (BMI, TyG index, TG and FBG). In Model 1, no adjustment was made. In Model 2, only age and gender were adjusted. Model 3 was additionally adjusted for marriage, farmer, annual household income, smoking, drinking, having medical insurance, diabetes, dyslipidemia, history of CVD, WC, TC, LDL-C, and HDL-C. Next, a restricted cubic spine was applied to assess the correlation between TyG-BMI and hypertension. Moreover, C-statistic and net reclassification index were determined to evaluate the incremental value of TyG-BMI versus its individual components for the discrimination of hypertension. Finally, we conducted subgroup analysis and calculated the *p*-value for interactions, including gender (male or female), age (<65 or ≥65 years), and diabetes (no or yes). Receiver operating characteristics (ROC) curve analysis was also employed to assess the specificity and sensitivity of TyG-BMI in identifying hypertension, compared with each individual component. $p < .05$ was considered statistically significant.

3 | RESULTS

3.1 | Baseline characteristics

In the current study, a total of 92,545 participants (men: 38.9% and median age: 53.7 years) were included. Baseline participant characteristics by quartiles of TyG-BMI and hypertension status were listed in Tables 1 and 2, respectively. We observed all baseline characteristics variables differed significantly in groups except the variable of having medical insurance ($p < .05$). Participants with hypertension were older, having higher levels of WC, BMI, TC, TG, FBG, TyG-BMI, more likely to be farmers, smokers, alcohol drinkers, and more likely to have diabetes, dyslipidemia and CVD when compared with subjects without hypertension (Table 2).

3.2 | Odds ratios of TyG-BMI for hypertension

Covariables including age, gender, marriage, farmer, annual household income, smoking, drinking, having medical insurance, diabetes, dyslipidemia, history of CVD, WC, TC, LDL-C, and HDL-C were controlled in Model 3. When treating TyG-BMI as a continuous (per SD increment) variable, odds ratio in the multiple logistic regression model was 1.51 (1.48, 1.54). When treating TyG-BMI as a categorical variable, the multivariate ORs for hypertension were 1.44 (1.38, 1.51) for Q2, 1.89 (1.80, 1.98) for Q3, and 2.76 (2.61, 2.91) for Q4 (p for trend < .001), compared with Q1 of TyG-BMI (Table 3). Multiple logistic regression models were also performed to examine the associations between each individual component of TyG-BMI and hypertension. As seen in Table 3, BMI, TyG index, TG and FBG were all significantly associated with hypertension and P for trend of each individual component was < .001. TyG-BMI was linearly related to hypertension in the multivariate-adjusted restricted cubic spine model (p for non-linear = .062) (Figure 2).

3.3 | Subgroup analysis

As stratified by age, gender and diabetes, we performed subgroup analysis shown by forest plots to explore the association between TyG-BMI and hypertension (Figure 3). No interaction was observed between the three subgroups and the odds of hypertension.

3.4 | Incremental value of TyG-BMI for the discrimination of hypertension

In comparison with its individual components, the addition of TyG-BMI exhibited the maximum incremental value for the discrimination of hypertension on the basis of base model, in terms of increased C-statistic (0.679, 95% CI: 0.675-0.683 for base model vs. 0.695, 95% CI: 0.691-0.699 for base model + TyG-BMI), and net reclassification index (0.226, 95% CI: 0.215-0.234). Base model for hypertension includes age, gender, marriage, farmer, annual household income, smoking, drinking, having medical insurance, diabetes, dyslipidemia, history of CVD, WC, TC, LDL-C, HDL-C (Table 4).

3.5 | ROC curve analysis for hypertension

The results of ROC analysis of TyG-BMI and its individual components for identifying hypertension were summarized in Supplementary Table S1 and Supplementary Figure S1. TyG-BMI had a maximum area under the curve (AUC) for detection of hypertension (0.645, 95% CI: 0.642-0.649). FBG presented an optimal cut-off value of 0.359 and the highest specificity of 0.619. BMI had the highest sensitivity of 0.627.

TABLE 1 Baseline characteristics of study participants according to quartiles of triglyceride glucose-body mass index.

	Q1	Q2	Q3	Q4	*p*-Value
Number	23137	23134	23138	23136	
Age, years	52.5 (44.3-62.4)	53.6 (45.9-62.5)	54.2 (47.0-62.6)	54.2 (47.0-62.3)	<.001
SBP, mmHg	120.5 (110.0-133.0)	125.5 (114.5-137.5)	129.0 (118.0-142.0)	134.0 (123.0-147.5)	<.001
DBP, mmHg	74.0 (68.0-81.5)	77.0 (70.5-84.5)	79.5 (72.5-87.0)	82.5 (75.5-90.5)	<.001
BMI, kg/m^2	20.4 (19.3-21.4)	22.9 (22.1-23.8)	24.8 (23.9-25.8)	27.6 (26.3-29.3)	<.001
WC, cm	74.0 (70.0-78.0)	80.1 (76.0-85.0)	85.0 (81.0-90.0)	92.0 (87.0-97.0)	<.001
TC, mg/dl	179.0 (151.9-209.9)	185.2 (157.7-215.3)	188.7 (160.1-220.0)	193.3 (163.9-226.5)	<.001
TG, mg/dl	84.2 (68.2-106.3)	106.3 (83.3-137.3)	132.0 (100.1-177.2)	179.9 (131.1-254.3)	<.001
LDL-C, mg/dl	99.0 (75.8-117.5)	105.5 (82.0-126.8)	105.6 (82.7-130.7)	105.6 (82.7-129.5)	<.001
HDL-C, mg/dl	64.2 (53.4-77.3)	56.8 (47.2-68.8)	52.2 (43.3-63.4)	48.3 (39.8-58.8)	<.001
FBG, mg/dl	93.6 (84.6-102.6)	97.2 (88.2-106.2)	100.8 (91.8-111.6)	106.2 (95.4-120.6)	<.001
TyG index	8.3 (8.1-8.5)	8.5 (8.3-8.8)	8.8 (8.5-9.1)	9.2 (8.8-9.6)	<.001
TyG-BMI	171.0 (160.6-178.5)	196.6 (191.0-201.9)	219.0 (213.1-225.4)	251.5 (240.9-268.0)	<.001
Gender, *n*%					<.001
Male	7695 (33.3)	8437 (36.5)	9587 (41.4)	10312 (44.6)	
Female	15442 (66.7)	14697 (63.5)	13551 (58.6)	12824 (55.4)	
Education level, *n*%					<.001
Less than high school	15749 (68.1)	15937 (68.9)	16365 (70.7)	16920 (73.1)	
High school or above	7388 (31.9)	7197 (31.1)	6773 (29.3)	6216 (26.9)	
Marital status, *n*%					.015
Married	20849 (90.1)	21002 (90.8)	21028 (90.9)	21006 (90.8)	
Other	2288 (9.9)	2132 (9.2)	2110 (9.1)	2130 (9.2)	
Annual household income, *n*%					<.001
<50,000 yuan	12987 (56.1)	12734 (55.0)	12593 (54.4)	12260 (53.0)	
>50,000 yuan	10150 (43.9)	10400 (45.0)	10545 (45.6)	10876 (47.0)	
Farmer, *n*%					<.001
No	19981 (86.4)	20397 (88.2)	20494 (88.6)	20644 (89.2)	
Yes	3156 (13.6)	2737 (11.8)	2644 (11.4)	2492 (10.8)	
Having medical insurance, *n*%					.042
No	1556 (6.7)	1637 (7.1)	1559 (6.7)	1483 (6.4)	
Yes	21581 (93.3)	21497 (92.9)	21579 (93.3)	21653 (93.6)	
Smoking, *n*%					<.001
No	19393 (83.8)	19573 (84.6)	19171 (82.9)	18620 (80.5)	
Yes	3744 (16.2)	3561 (15.4)	3967 (17.1)	4516 (19.5)	
Alcohol drinking, *n*%					<.001
No	22079 (95.4)	22073 (95.4)	21856 (94.5)	21657 (93.6)	
Yes	1058 (4.6)	1061 (4.6)	1282 (5.5)	1479 (6.4)	
Diabetes, *n*%					<.001
No	22436 (97.0)	21767 (94.1)	20818 (90.0)	18491 (79.9)	
Yes	701 (3.0)	1367 (5.9)	2320 (10.0)	4645 (20.1)	

(Continues)

TABLE 1 (Continued)

	Q1	Q2	Q3	Q4	*p*-Value
Dyslipidemia, *n*%					<.001
No	20456 (88.4)	19855 (85.8)	19350 (83.6)	18675 (80.7)	
Yes	2681 (11.6)	3279 (14.2)	3788 (16.4)	4461 (19.3)	
History of CVD, *n*%					<.001
No	22968 (99.3)	22923 (99.1)	22893 (98.9)	22859 (98.8)	
Yes	169 (0.7)	211 (0.9)	245 (1.1)	277 (1.2)	
Hypertension, *n*%					<.001
No	17974 (77.7)	15764 (68.1)	13567 (58.6)	10843 (46.9)	
Yes	5163 (22.3)	7370 (31.9)	9571 (41.4)	12293 (53.1)	

Note: Data are presented as medians (inter quartile range) or number (%).
Abbreviations: BMI, body mass index; CVD, cardiovascular disease.; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol;Q, quartiles; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride; TyG, triglyceride glucose; TyG-BMI, triglyceride glucose-body mass index; WC, waist circumference.

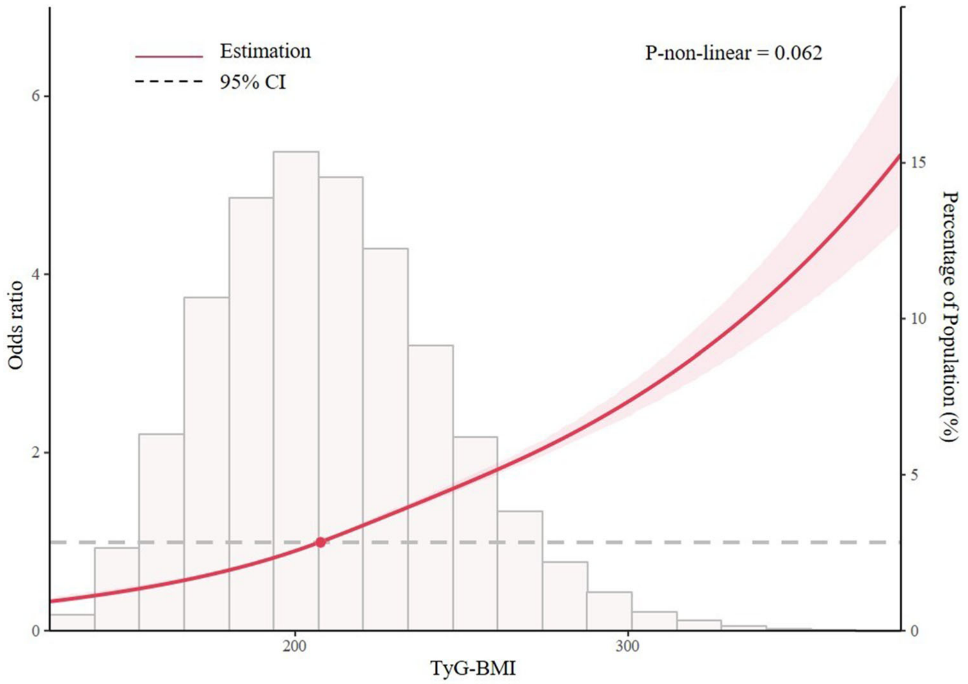

FIGURE 2 Multivariate-adjusted restricted cubic spine model of the association between triglyceride glucose-body mass index and hypertension.

4 | DISCUSSION

We have examined the association between TyG-BMI and hypertension among Chinese adults aged from 35 to 75 years old. We found TyG-BMI was positively associated with hypertension and its individual components BMI, TyG index, TG and FBG were all significantly associated with the odds of hypertension. In the incremental value for the discrimination of hypertension, TyG-BMI was superior to each individual component.

The current study mainly revealed that TyG-BMI was positively related to hypertension, which was similar to previous studies. A cross-sectional study, including a total of 105,070 Chinese lean individuals without hypertension, showed that TyG-BMI was an effective assessment indicator positively correlated with prehypertension.[12] Bala and colleagues found that TyG-BMI was independently connected to the presence of hypertension, but no superiority could be demonstrated over BMI alone.[18] In another cross-sectional study with 117,056 subjects, Cheng and colleagues pointed out that TyG-BMI was positively

TABLE 2 Baseline characteristics between study participants with and without hypertension.

	Overall	Non-hypertension	Hypertension	*p*-Value
Number	92545	59096	33449	
Age, years	53.7 (46.1-62.4)	50.8 (44.0-59.7)	59.1 (51.0-65.6)	<.001
SBP, mmHg	127.0 (116.0-140.5)	120.0 (111.0-128.0)	146.0 (138.0-158.0)	<.001
DBP, mmHg	78.5 (71.0-86.0)	74.5 (68.5-80.0)	88.5 (81.0-94.5)	<.001
BMI, kg/m^2	23.8 (21.8-26.0)	23.3 (21.3-25.4)	24.7 (22.7-27.0)	<.001
WC, cm	83.0 (76.7-89.2)	81.0 (75.0-87.1)	86.0 (80.0-92.0)	<.001
TC, mg/dl	186.7 (158.1-218.0)	184.4 (156.6-215.3)	190.6 (161.2-222.3)	<.001
TG, mg/dl	117.8 (86.8-168.3)	110.8 (82.4-156.8)	131.1 (95.7-188.7)	<.001
LDL-C, mg/dl	105.5 (80.8-126.4)	104.0 (79.6-124.5)	105.6 (82.7-129.9)	<.001
HDL-C, mg/dl	55.3 (44.8-67.7)	56.1 (45.6-68.8)	53.4 (43.7-65.3)	<.001
FBG, mg/dl	99.0 (88.9-109.8)	97.2 (88.2-108.0)	102.6 (91.8-115.2)	<.001
TyG index	8.7 (8.3-9.1)	8.6 (8.3-9.0)	8.8 (8.5-9.2)	<.001
TyG-BMI	207.5 (185.2-232.5)	200.9 (180.0-224.6)	219.5 (196.6-244.2)	<.001
Gender, *n*%				<.001
Male	36031 (38.9)	21609 (36.6)	14422 (43.1)	
Female	56514 (61.1)	37487 (63.4)	19027 (56.9)	
Education level, *n*%				<.001
Less than high school	64971 (70.2)	39374 (66.6)	25597 (76.5)	
High school or above	27574 (29.8)	19722 (33.4)	7852 (23.5)	
Marital status, *n*%				<.001
Married	83885 (90.6)	5172 (8.8)	3488 (10.4)	
Other	8660 (9.4)	53924 (91.2)	29961 (89.6)	
Annual household income, *n*%				<.001
<50,000 yuan	50574 (54.6)	31407 (53.1)	19167 (57.3)	
>50,000 yuan	41971 (45.4)	27689 (46.9)	14282 (42.7)	
Farmer, *n*%				<.001
No	81516 (88.1)	52863 (89.5)	28653 (85.7)	
Yes	11029 (11.9)	6233 (10.5)	4796 (14.3)	
Having medical insurance, *n*%				.071
No	6235 (6.7)	4048 (6.8)	2187 (6.5)	
Yes	86310 (93.3)	55048 (93.2)	31262 (93.5)	
Smoking, *n*%				<.001
No	76757 (82.9)	49300 (83.4)	27457 (82.1)	
Yes	15788 (17.1)	9796 (16.6)	5992 (17.9)	
Alcohol drinking, *n*%				<.001
No	87665 (94.7)	56393 (95.4)	31272 (93.5)	
Yes	4880 (5.3)	2703 (4.6)	2177 (6.5)	
Diabetes, *n*%				<.001
No	83512 (90.2)	54830 (92.8)	28682 (85.7)	
Yes	9033 (9.8)	4266 (7.2)	4767 (14.3)	
Dyslipidemia, *n*%				<.001
No	78336 (84.6)	50755 (85.9)	27581 (82.5)	
Yes	14209 (15.4)	8341 (14.1)	5868 (17.5)	

(Continues)

TABLE 2 (Continued)

	Overall	Non-hypertension	Hypertension	*p*-Value
History of CVD, *n*%				<.001
No	91643 (99.0)	58728 (99.4)	32915 (98.4)	
Yes	902 (1.0)	368 (0.6)	534 (1.6)	

Note: Data are presented as medians (inter quartile range) or number (%).
Abbreviations: BMI, body mass index; CVD, cardiovascular disease.; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol;Q, quartiles; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride; TyG, triglyceride glucose; TyG-BMI, triglyceride glucose-body mass index; WC, waist circumference.

TABLE 3 The associations between TyG-BMI versus its individual components and hypertension by multivariate logistic regression analysis.

	Case/total	Model 1	Model 2	Model 3
TyG-BMI				
Per SD increment		1.68 (1.66, 1.71)	1.72 (1.69, 1.74)	1.51 (1.48, 1.54)
Quartiles				
Q1	5015/23137	1.0	1.0	1.0
Q2	7162/23134	1.62 (1.55, 1.69)	1.65 (1.58, 1.72)	1.44 (1.38, 1.51)
Q3	9267/23138	2.41 (2.32, 2.51)	2.48 (2.37, 2.58)	1.89 (1.80, 1.98)
Q4	12005/23136	3.90 (3.74, 4.06)	4.09 (3.92, 4.26)	2.76 (2.61, 2.91)
p for trend		<.001	<.001	<.001
BMI				
Per SD increment		1.57 (1.55, 1.59)	1.61 (1.59, 1.64)	1.40 (1.37, 1.42)
Quartiles				
Q1	5494/23160	1.0	1.0	1.0
Q2	7243/23120	1.47 (1.41, 1.53)	1.52 (1.46, 1.58)	1.29 (1.23, 1.34)
Q3	9135/23138	2.10 (2.02, 2.18)	2.19 (2.10, 2.28)	1.60 (1.52, 1.68)
Q4	11577/23127	3.22 (3.10, 3.35)	3.46 (3.32, 3.60)	2.26 (2.15, 2.38)
p for trend		<.001	<.001	<.001
TyG index				
Per SD increment		1.47 (1.45, 1.49)	1.45 (1.43, 1.47)	1.28 (1.25, 1.30)
Quartiles				
Q1	5787/23159	1.0	1.0	1.0
Q2	7504/23164	1.44 (1.38, 1.50)	1.41 (1.35, 1.47)	1.25 (1.20, 1.30)
Q3	9087/23108	1.95 (1.87, 2.02)	1.87 (1.80, 1.95)	1.48 (1.42, 1.55)
Q4	11071/23114	2.76 (2.65, 2.87)	2.67 (2.57, 2.78)	1.79 (1.70, 1.88)
p for trend		<.001	<.001	<.001
TG				
Per SD increment		1.32 (1.30, 1.34)	1.32 (1.30, 1.33)	1.16 (1.14, 1.18)
Quartiles				
Q1	6294/23694	1.0	1.0	1.0
Q2	7638/22910	1.38 (1.33, 1.44)	1.35 (1.30, 1.41)	1.20 (1.15, 1.25)
Q3	8917/22817	1.77 (1.71, 1.84)	1.72 (1.65, 1.79)	1.37 (1.31, 1.43)
Q4	10600/23124	2.34 (2.25, 2.43)	2.29 (2.20, 2.38)	1.58 (1.50, 1.66)
p for trend		<.001	<.001	<.001

(Continues)

TABLE 3 (Continued)

	Case/total	Model 1	Model 2	Model 3
FBG				
Per SD increment		1.31 (1.29, 1.33)	1.29 (1.28, 1.31)	1.14 (1.12, 1.16)
Quartiles				
Q1	6610/23149	1.0	1.0	1.0
Q2	7886/24671	1.18 (1.13, 1.22)	1.18 (1.13, 1.22)	1.14 (1.09, 1.18)
Q3	8157/21941	1.48 (1.42, 1.54)	1.47 (1.42, 1.53)	1.35 (1.29, 1.41)
Q4	10796/22784	2.25 (2.17, 2.34)	2.19 (2.10, 2.27)	1.65 (1.58, 1.73)
p for trend		<.001	<.001	<.001

Note: Data are represented as odds ratio (95% confident interval).
Model 1 adjust for none.
Model 2 adjust for age and gender.
Model 3 adjust for age, gender, marriage, farmer, annual household income, smoking, drinking, having medical insurance, diabetes, dyslipidemia, history of cardiovascular disease, waist circumference, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol.
Abbreviations: BMI, body mass index; FBG, fasting blood glucose; SD, standard deviation; TG, triglyceride; TyG, triglyceride glucose; TyG-BMI, triglyceride glucose-body mass index; Q, quartiles.

TABLE 4 Incremental value of triglyceride glucose-body mass index versus its individual components for the discrimination of hypertension.

	C-statistic (95% CI)	Net reclassification index (95% CI)
Base model	0.679 (0.675-0.683)	/
+ BMI	0.692 (0.688-0.696)	0.190 (0.173-0.198)
+ TyG index	0.685 (0.681-0.689)	0.174 (0.167-0.178)
+ TG	0.682 (0.678-0.686)	0.111 (0.095-0.118)
+ FBG	0.682 (0.678-0.686)	0.108 (0.102-0.123)
+ TyG-BMI	0.695 (0.691-0.699)	0.226 (0.215-0.234)

Note: Base model: age, gender, marriage, farmer, annual household income, smoking, drinking, having medical insurance, diabetes, dyslipidemia, history of cardiovascular disease, waist circumference, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol.
Abbreviations: BMI, body mass index; CI, confidence interval; FBG, fasting blood glucose; TG, triglyceride; TyG, triglyceride glucose; TyG-BMI, triglyceride glucose-body mass index.

linked to the prevalence of hypertension (*p* for trend < .001), which was parallel to our findings.[19] Yuan and colleagues held that TyG-BMI and TyG-waist circumference (WC) had better abilities in the prediction of hypertension compared with HOMA-IR based on an ongoing open cohort study, however, TyG-WC presented the highest AUC value (0.618, 95% CI: 0.597-0.639) for identifying hypertension.[20] The results of above studies consistently presented a strong association of TyG-BMI with hypertension but the predictive value of TyG-BMI for hypertension remains to be further explored. As an IR surrogate, TyG-BMI was linked to hypertension possibly through IR-related hyperinsulinemia, which may influence the activity of sympathetic nervous system or enhance activation of the renin-angiotensin-aldosterone system.[25,26] To date, only a few studies reported the relationship between TyG-BMI and hypertension. In our study, we put the focus on Chinese population aged 35–75 and investigated the association of TyG-BMI with hypertension, compared with its individual components.

Our study indicated that BMI, TyG index, TG and FBG were all independently associated with hypertension, but the discriminative power of them was inferior to TyG-BMI. Findings from Zhu and colleagues demonstrated that discriminative ability of TyG index for hypertension was superior to lipid and glycemic parameters such as TG and PBG (2 h post-load blood glucose) in the Chinese elderly population.[27] Linderman and colleagues pointed out that the association between BMI and blood pressure was positive, indicating that increased BMI was associated with the prevalence of hypertension across nearly children, adolescence or adults.[28] In addition, Cheng and colleagues found that the predictive value of TyG-BMI for the prevalence of hypertension was higher than that of TyG index, which was consistent to our study.[19] However, Bala and colleagues found no superiority of TyG-BMI over the use of BMI as predictor of hypertension.[18] IR and obesity both may lead to hypertension through a serious of pathophysiological mechanisms. Nevertheless, not all individuals with obesity or excessive weight will develop hypertension. Furthermore, different from previous studies, our study population was Chinese population aged 35–75 and therefore may lead to differences in results. TyG-BMI combined the effects of TyG index and BMI, which may account for its better discriminative performance for hypertension.

Several speculations are being made regarding the mechanisms linking TyG-BMI and hypertension. First, elevated TyG-BMI represents some degree of glucose intolerance, an atherogenic lipoprotein phenotype characterized by low HDL-C and high TG levels, smaller and more intensive LDL particles, and endothelial dysfunction.[29] Second, hypertension can cause increased TyG-BMI by altering insulin and glucose delivery to skeletal muscle cells, leading to impaired glucose uptake.[30] Third, the common pathogenesis of IR and hypertension may be sympathetic nervous system activation, which contributes to vasoconstriction and, possibly, changes in vascular structure.[9,30]

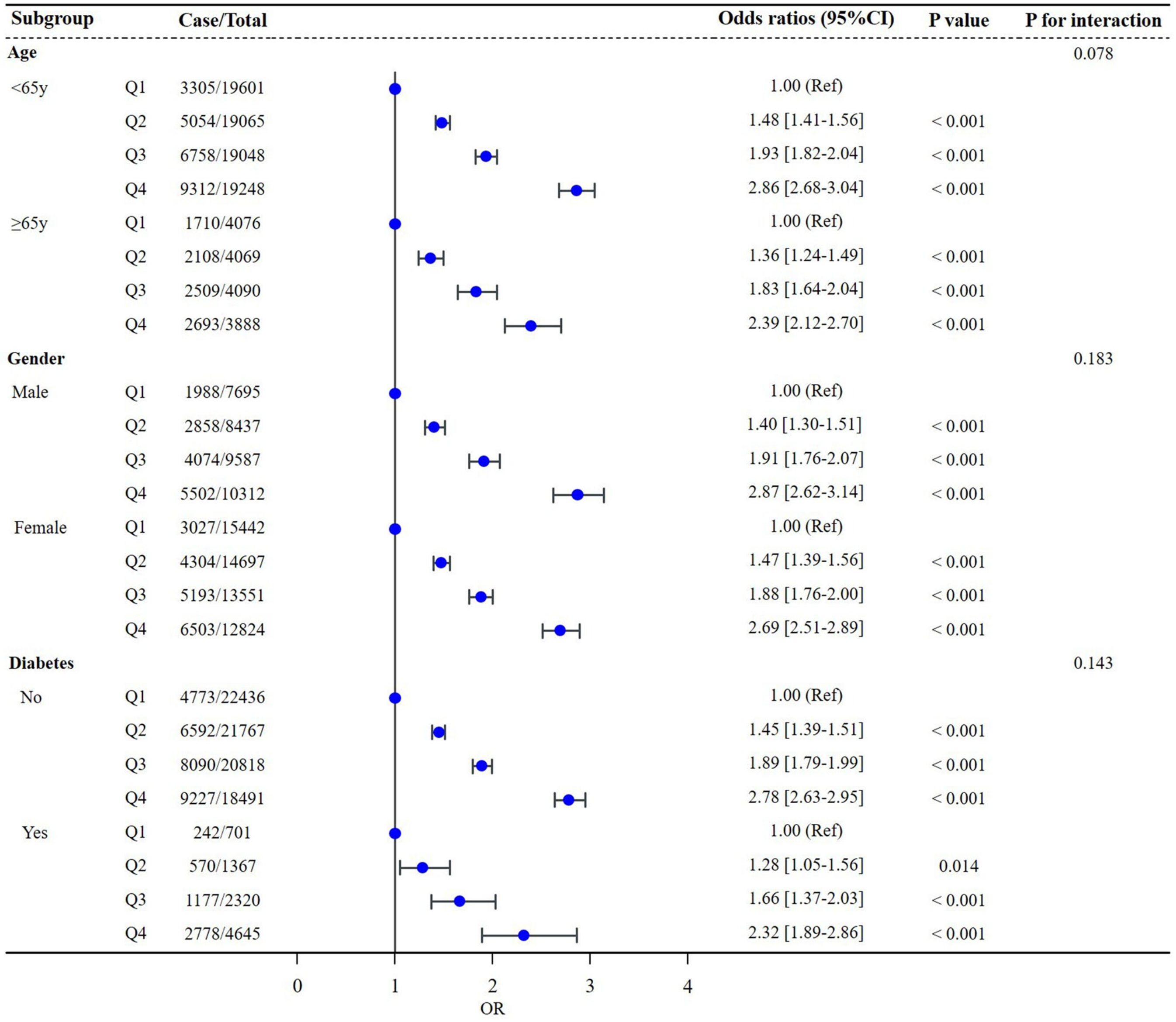

FIGURE 3 Forest plots of subgroups analysis.

Some limitations with regard to this study should be noted. First, this study did not use HEC, the gold standard for assessing IR, and consequently could not evaluate true insulin levels.[12] Second, the current study did not suggest causality due to its cross-sectional nature, which requires a well-designed prospective cohort study to elucidate. Finally, the findings applied mainly to Chinese adults and may not be directly extrapolated to people in other populations.

In conclusion, TyG-BMI was linearly associated with hypertension in Chinese adults and superior to its individual components BMI, TyG index, TG and FBG in discriminative ability for hypertension. Therefore, we indicated that TyG-BMI could be a better and more efficient index for the screening of hypertension.

AUTHOR CONTRIBUTIONS

Danying Deng participated in the design of this study and drafted the manuscript. Chaolei Chen performed statistical analysis and data interpretation. Jiabin Wang collected the data. Chaolei Chen and Songyuan Luo helped to draft the manuscript. Yingqing Feng conceived of the study and participated in its design. All authors reviewed and approved this manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The original contributions are presented in the article/supplementary material, further inquiries can be directed to the corresponding authors.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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