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ORIGINAL RESEARCH

The Impact of Triglyceride-Glucose Index on Carotid Atherosclerosis: A Prospective Cohort Study in Middle Aged and Elderly Low-Income in Rural Chinese

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Background: Atherosclerotic cardiovascular disease (ASCVD) is a major global health burden. The triglyceride-glucose (TyG) index, as a surrogate marker of insulin resistance, is associated with atherosclerosis, but its role in predicting carotid plaque and intima-media thickness (IMT) changes remains unclear. This study aimed to assess the relationship between the TyG index and carotid plaque incidence and IMT changes over a six-year period in a cohort of middle-aged and elderly individuals with low income and low education in rural China.

Methods: The study was conducted from 2014 to 2020 in 18 rural villages in Tianjin, China. A total of 2702 participants were included in the IMT analysis, and after excluding those with carotid plaques at baseline, 1595 participants were included in the plaque incidence analysis. Multivariate logistic regression was used to assess the relationship between the TyG index and outcomes. Subgroup analyses were based on significant indicators from the multivariate adjustment.

Results: During the six-year follow-up, 551 new cases of carotid plaque were identified, with an incidence rate of 34.5%. Univariate analysis showed a significant association between the TyG index and increased plaque incidence. However, after adjusting for multiple confounders, the TyG index emerged as an independent predictor only for IMT increase. Each 1-unit increase in TyG was associated with a 49% increased risk (RR: 1.49; 95% CI: 1.05–2.13; P = 0.026), with this association being particularly strong in males, individuals aged ≥60 years, and those without hypertension.

Conclusion: Results highlight the importance of incorporating the TyG index into cardiovascular risk assessments, especially for IMT changes in specific subpopulations. The study underscores the need for targeted prevention strategies in rural, low-education and low-income populations. Future research is needed to elucidate the potential interactions between the TyG index and other metabolic factors in ASCVD.

Keywords: triglyceride-glucose index, carotid plaque, intima-media thickness, cardiovascular risk factors, rural populations

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Introduction

Atherosclerotic cardiovascular disease (ASCVD) remains a leading cause of morbidity and mortality globally.[1] Over the past few decades, the global incidence of ASCVD, especially in developing regions, has been on the rise, increasing from 34.74 million cases in 1990 to 66.81 million cases in 2021. This surge has led to an approximate 46% increase in the burden of disability-adjusted life-years (DALYs), from 199 million to 292 million.[2–4] In China, with the intensification of population aging, carotid atherosclerosis and carotid plaque are gradually increasing. About 31% of Chinese people have CP, and the prevalence increases tenfold with age. Moreover, 70% of carotid atherosclerosis occurs in rural China, highlighting the necessity for early detection and prevention strategies targeting potential risk factors of atherosclerosis.[5–7]

The triglyceride-glucose (TyG) index, a cost-effective and reliable surrogate marker of insulin resistance, has been validated using the HIEC technique as well as in epidemiological and clinical studies.[8–10] Research into the relationship between the TyG index markers of subclinical atherosclerosis such as carotid intima-media thickness (IMT) and carotid plaque formation has garnered increasing attention.[11–13] A large-scale cohort study in China has pointed out that the TyG index is closely related to the clustering of cardiovascular risk factors (such as hypertension, hyperglycemia, hyperlipidemia, obesity, smoking, drinking, etc). and is associated with the high-risk determination of cardiovascular diseases in the screened population.[14,15] The TyG index has been shown to be associated with the prevalence of IMT and carotid plaque in various populations, suggesting its potential role as a predictor of ASCVD risk.[11,12,16–19] However, findings from prospective studies remain inconsistent. Some studies suggest a significant association between TyG index and the incidence of carotid plaque,[20] while others have failed to confirm this relationship.[21,22]

Several controversies and research gaps exist in this field. While the TyG index is widely regarded as a marker for insulin resistance and its role in atherosclerosis, the evidence on its independent predictive value for carotid plaque formation is conflicting.[20,22] Furthermore, the increment of TyG index is closely related to the progression of atherosclerosis,[23] but there is limited research on the relationship between TyG index and changes in IMT over time, especially in low-education and low-income populations.[12] Existing studies have often been cross-sectional and prospective study with short follow-up periods, limiting their ability to establish causality or to account for the influence of confounding factor. Additionally, the relationship between TyG index and the stability or other characteristics of carotid plaques remains underexplored rarely.

The aim of this study is to evaluate the association of TyG index with the incidence of carotid plaque and changes in IMT over a six-year period in a cohort of low-income, low-education, middle-aged, and elderly individuals in rural China.

Methods

Study Design and Population

This study was designed as a prospective cohort study conducted over a six-year period from 2014 to 2020 in rural areas of Tianjin, China. The target population includes individuals with low income, low education, middle-aged and older adults, and those with limited education. These groups have a higher incidence of atherosclerotic cardiovascular disease (ASCVD). With increasing age, the number of plaques and carotid intima-media thickness (IMT) also increase. In rural areas, where low income and low education are more prevalent, the disease burden is even more severe, making this population particularly worthy of further study.[6,7] Participants were recruited from 18 villages, and a total of 2869 individuals were initially enrolled. After excluding those with missing baseline data on triglycerides (TG), fasting blood glucose (FBG), or carotid ultrasound during follow-up, 2702 participants (1076 males and 1626 females) were included in the analysis of IMT changes. After excluding individuals with carotid plaques at baseline, 1595 participants were included in the analysis of carotid plaque incidence (Figure 1).

The study was approved by the ethics committee at Tianjin Medical University General Hospital to conform to the Declaration of Helsinki regarding use of human subjects (IRB2018-100-01), and written informed consent was obtained from each patient during recruitment.

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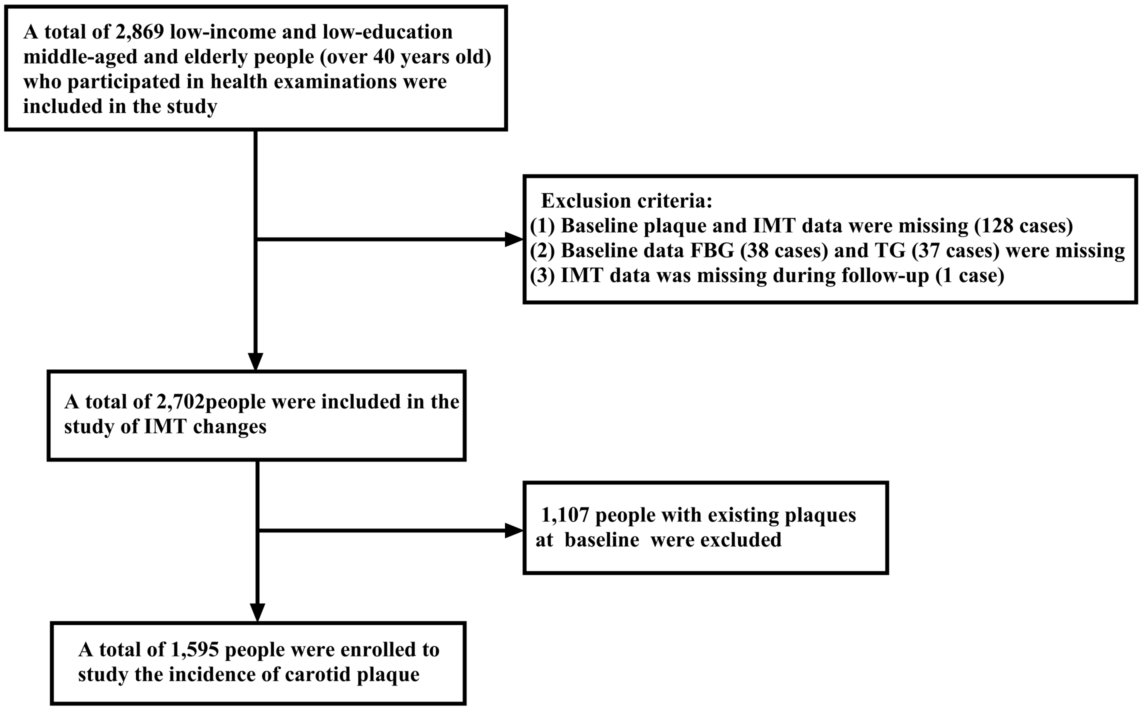

Figure 1 Flow chat of participants selection. Figure 1 showed that a total of 2869 low-income, low-education middle-aged, and elderly individuals were initially enrolled. After excluding those with missing baseline data on TG, FBG, or carotid ultrasound during follow-up, 2702 participants (1076 males and 1626 females) were included in the analysis of IMT changes.1595 participants were included in the analysis of carotid plaque incidence after excluding individuals with carotid plaques at baseline.

Data Collection and Measurements

Baseline data were collected in 2014 and included sociodemographic and clinical information. Name, gender, age, education, history of diabetes and hypertension were collected through face-to-face interviews conducted by trained researchers. Trained medical personnel collected physical measurements, including height, weight, and blood pressure, using standard instruments. Blood pressure was measured using a mercury sphygmomanometer, with the average of 2–3 measurements recorded for both systolic blood pressure (SBP) and diastolic blood pressure (DBP). All measurements were recorded by the same researcher to minimize systematic errors.

Laboratory tests were performed to measure FBG, TG, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). B-mode ultrasound was used to assess the intima-media thickness (IMT) and presence of plaques in the common carotid artery.

Definitions and Grouping

The 2014 report on the Multidimensional Poverty Index (MPI) indicated that the MPI for rural residents was 0.028, compared to 0.007 for urban residents, reflecting the greater multidimensional deprivation experienced by rural populations.[24] Based on this, we defined the low-income population as those with a per capita annual income below $1600 in 2014, and focused on those who were deprived in multiple dimensions, including education, health, and living standards, all of which were below the national average in China. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m²).[25] Smoking was defined as smoking at least one cigarette per day for more than a year, and drinking was defined as consuming at least 45 grams of alcohol per day over the past year. Hypertension was defined as SBP ≥140 mmHg and/or DBP ≥90 mmHg or the use of antihypertensive medication or self-reported history of hypertension.[26]

Diabetes was defined according to the criteria set by the American Diabetes Association, which includes an A1C ≥6.5%, FPG ≥126 mg/dL, or a 2-hour plasma glucose level ≥200 mg/dL during an oral glucose tolerance test, or use of diabetes medications, or a self-reported history of diabetes.[27]

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Hyperlipidemia is defined as hypercholesterolemia (total cholesterol ≥6.2 mmol/L), hypertriglyceridemia (triglyceride ≥2.3 mmol/L) and high- and low-density lipoprotein cholesterolemia (low density lipoprotein cholesterol ≥4.1 mmol/L).[28]

The TyG index was calculated using the formula: ln [TG (mg/dL) * FPG (mg/dL)/2].[29] Participants were divided into four groups based on the quartiles of their TyG index values. Carotid plaque was defined as a focal structure that encroaches into the arterial lumen by at least 0.5 mm or 50% of the surrounding IMT value, or by having a total thickness >1.5 mm.[30,31]

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were expressed as frequencies and percentages. The Student's *t*-test and chi-square test were used for univariate analysis. Logistic regression models were employed for multivariate analysis to assess the relationship between the TyG index and the incidence of carotid plaque and changes in IMT. The relationship was expressed as relative risk (RR) and its 95% confidence interval (95% CI).

Subgroup analyses were performed based on significant factors identified in the univariate analysis to further explore the relationship between the TyG index and the incidence of carotid plaque and changes in IMT. Statistical significance was set at a P-value < 0.05. All statistical analyses were conducted using SPSS (version 25.0) and GraphPad Prism (version 10.2.3).

Results

Figure 1 showed that a total of 2869 individuals were initially enrolled. After excluding those with missing baseline data on TG, FBG, or carotid ultrasound during follow-up, 2702 participants (1076 males and 1626 females) were included in the analysis of IMT changes. After excluding individuals with carotid plaques at baseline, 1595 participants were included in the analysis of carotid plaque incidence.

Baseline Characteristics

A total of 2702 participants were included in the IMT changes analysis, comprising 1076 males (39.8%) and 1626 females (60.2%). The average age of the study population was 59.60 ± 8.47 years. The mean BMI was 25.70 ± 3.60 kg/m², and the mean SBP and DBP were 146.07 ± 21.29 mmHg and 86.85 ± 11.22 mmHg, respectively. The TyG index ranged from 7.13 to 7.31, with an overall mean of 7.24 ± 0.63. Notably, 41.0% of participants had carotid plaques at baseline (Table 1).

Table 1 Demographic Characteristics of Baseline (2014)

Characteristics	Man	Woman	Total
Total, n (%)	1076 (39.8%)	1626 (60.2%)	2702 (100%)
Age, years old	60.96 (8.76)	58.71 (8.15)	59.60 (8.47)
Age group, n (%)			
Under 45 years old	16 (1.5%)	25 (1.5%)	41 (1.5%)
45–59 years old	456 (42.4%)	878 (54.0%)	1334 (49.4%)
60–74 years old	527 (49.0%)	666 (41.0%)	1193 (44.2%)
≥ 75 years old	77 (7.2%)	57 (3.5%)	134 (5.0%)
Years of education, years*	6.51 (2.83)	4.30 (3.64)	5.18 (3.51)
Education level, n (%)*	1073 (39.8%)	1624 (60.2%)	2697 (100%)
Illiterate	45 (4.2%)	460 (28.3%)	505 (18.7%)
Primary school education	519 (48.4%)	678 (41.7%)	1197 (44.4%)
Junior school education	413 (38.5%)	390 (24.0%)	803 (29.8%)
High school and above	96 (8.9%)	96 (5.9%)	192 (7.1%)

(*Continued*)

Table 1 (Continued).

Characteristics	Man	Woman	Total
BMI (kg/m²)*	25.26 (3.33)	25.99 (3.75)	25.70 (3.60)
BMI grouping, n (%)*	1074 (39.8%)	1624 (60.2%)	2698 (100%)
Under weight	16 (1.5%)	20 (1.2%)	36 (1.3%)
Normal	370 (34.5%)	461 (28.4%)	831 (30.8%)
Overweight	469 (43.7%)	724 (44.6%)	1193 (44.2%)
Obesity	219 (20.4%)	419 (25.8%)	638 (23.6%)
Smoking history, n (%)*	1075 (39.9%)	1619 (60.1%)	2694 (100%)
Never smoking	189 (17.6%)	1514 (93.5%)	1703 (63.2%)
Current smoking	511 (47.5%)	43 (2.7%)	554 (20.6%)
Ever smoking	375 (34.9%)	62 (3.8%)	437 (16.2%)
Drinking history, n (%)*	1076 (39.9%)	1623 (60.1%)	2699 (100%)
Never drinking	283 (26.3%)	1551 (95.6%)	1834 (68.0%)
Current drinking	578 (53.7%)	36 (2.2%)	614 (22.7%)
Ever drinking	215 (20.0%)	36 (2.2%)	251 (9.3%)
Total cholesterol TC, mmol/L	4.62 (0.99)	5.03 (1.10)	4.87 (1.08)
Triglyceride TG, mmol/L	1.59 (1.35)	1.86 (1.18)	1.76 (1.26)
HDL-C, mmol/L	1.39 (0.46)	1.49 (0.49)	1.45 (0.48)
LDL-C, mmol/L*	2.55 (0.81)	2.75 (0.93)	2.67 (0.89)
Hyperlipidemia, n (%)			
No	857 (79.6%)	1113 (68.5%)	1970 (72.9%)
Yes	219 (20.4%)	513 (31.5%)	732 (27.1%)
Diabetes, n (%)			
No	882 (82.0%)	1285 (77.8%)	2147 (79.5%)
Yes	194 (18.0%)	361 (22.2%)	555 (20.5%)
Blood glucose FBG, mmol/L	5.90 (1.39)	5.94 (1.60)	5.92 (1.52)
Hypertension, n (%)*			
No	210 (19.5%)	335 (20.6%)	545 (20.2%)
Yes	865 (80.5%)	1291 (79.4%)	2156 (79.8%)
Systolic blood pressure SBP, mmHg*	147.36 (20.53)	145.22 (21.74)	146.07 (21.29)
Diastolic pressure DBP, mmHg*	88.67 (11.08)	85.64 (11.15)	86.85 (11.22)
TyG index	7.13 (0.63)	7.31 (0.62)	7.24 (0.63)
TyG grouping			
Q1	346 (32.2%)	329 (20.2%)	675 (25.0%)
Q2	275 (25.6%)	401 (24.7%)	676 (25.0%)
Q3	253 (23.5%)	423 (26.0%)	676 (25.0%)
Q4	202 (18.8%)	473 (29.1%)	675 (25.0%)
Plaque 2014, n (%)			
Without	542 (50.4%)	1053 (64.8%)	1595 (59.0%)
Have	534 (49.6%)	573 (35.2%)	1107 (41.0%)
IMT average	0.58 (0.09)	0.56 (0.08)	0.57 (0.09)

Note: (1) The results of continuous variables are expressed as: mean (SD); (2) An *indicates that there are missing values, education years and education groups are missing in 5 cases, BMI and BMI groups are missing in 4 cases, smoking history is missing in 8 cases, drinking history is missing in 3 cases, SBP, DBP and hypertension are missing in 1 case and LDL is missing in 171 cases.

Incidence of Carotid Plaque

During the six-year follow-up period, 551 new cases of carotid plaque were identified among 1595 people, corresponding to an incidence rate of 34.5%. Univariate analysis revealed significant associations between the incidence of carotid plaque and several factors, including gender, age, years of education, smoking status, alcohol consumption, diabetes, hypertension, FBG, SBP, DBP, LDL-C, HDL-C, and the TyG index ($P < 0.05$; Supplemental Table 1).

After adjusting for confounding variables, age, hypertension, diabetes and LDL-C were identified as significant independent risk factors. Specifically, individuals aged 45–59, 60–74, and ≥75 years had a 4.02-fold, 5.36-fold, and 17.73-fold increased risk of developing carotid plaque, respectively, compared to those aged <45 years ($P < 0.05$). Similarly, the presence of hypertension and diabetes increased the risk of carotid plaque by 1.48-fold and 1.63-fold, respectively ($P < 0.05$). Each 1 mmol/L increase in LDL-C was associated with a 16% increase in plaque risk ($P = 0.026$), while a 1 mmol/L increase in HDL-C was associated with a 42% reduction in plaque risk ($P < 0.001$). Contrary to expectations, the TyG index was not found to be an independent predictor of carotid plaque after adjusting for multiple factors ($P > 0.05$; Table 2).

Subgroup analysis also failed to show a significant association between the TyG index and plaque incidence across different age, gender, hypertension, and diabetes subgroups (Figure 2).

Changes in Carotid Intima-Media Thickness (IMT)

At the end of the follow-up, IMT increased in 2479 participants (91.7%). Univariate analysis identified significant associations between IMT changes and gender, age, educational level, hypertension, and SBP ($P < 0.05$; Supplemental Table 2).

Multivariate logistic regression analysis further identified age, TyG index, and educational level as independent predictors of IMT increase. The TyG index was also found to be an independent risk factor for IMT increase, with each unit increase in TyG associated with a 49% increased risk (RR: 1.49; 95% CI: 1.05–2.13; $P = 0.026$). Notably, the second quartile of TyG (8.3921 ≤ TyG < 8.7676) was associated with a 54% increased risk of IMT increase compared to the first quartile (TyG < 8.3921) (RR: 1.54; 95% CI: 1.01–2.34; $P = 0.043$), while no significant associations were observed in the third and fourth quartiles ($P > 0.05$). The risk of IMT increase was 4.28-fold, 6.49-fold, and 10.75-fold higher in individuals aged 45–59, 60–74, and ≥75 years, respectively, compared to those aged <45 years ($P < 0.001$; Table 3).

Table 2 Multivariate Analysis of Influencing Factors of Plaque Incidence

Characteristics	Reference	RR (95% CI)	P value
TyG		1.00 (0.80–1.25)	0.999
Gender	Men		
Women		0.66 (0.43–1.01)	0.054
Age	Under 45 years old		
45–59 years old		4.02 (1.37–11.74)	0.011
60–74 years old		5.36 (1.81–15.89)	0.002
≥ 75 years old		17.73 (4.91–64.09)	<0.001
Degree of education	Illiterate		
Primary school education		1.02 (0.74–1.39)	0.926
Junior school education		0.86 (0.60–1.23)	0.408
High school and above		0.72 (0.43–1.21)	0.216
Hypertension	No		
Yes		1.48 (1.06–2.06)	0.023
Diabetes	No		
Yes		1.63 (1.14–2.33)	0.008
Smoking history	Never smoking		
Current smoking		1.18 (0.77–1.81)	0.460
Ever smoking		1.34 (0.88–2.06)	0.175
Drinking history	Never drinking		
Current drinking		0.97 (0.65–1.46)	0.886
Ever drinking		1.12 (0.68–1.83)	0.661
DBP, mmHg		0.99 (0.98–1.01)	0.297
SBP, mmHg		1.01 (0.92–1.02)	0.037
LDL-C, mmol/l		1.16 (1.02–1.33)	0.026
HDL-C, mmol/l		0.58 (0.43–0.79)	<0.001
FPG, mmol/l		1.03 (0.92–1.15)	0.604

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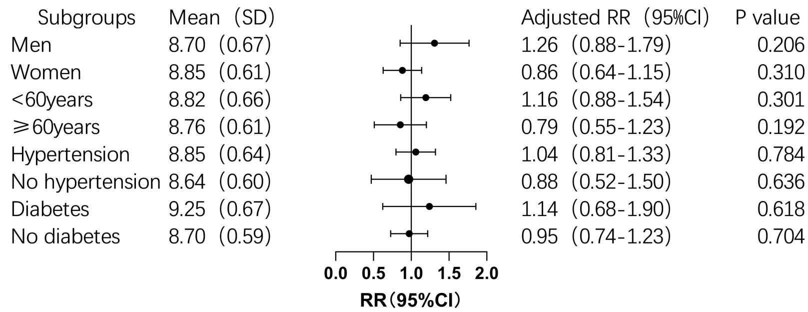

Figure 2 Association between the TyG index and incidence of carotid plaque in subgroups in logistic models. Figure 2 showed that there was not a significant association between the TyG index and plaque incidence across different age, gender, hypertension, and diabetes subgroups (P > 0.05).

Subgroup analysis revealed that the association between the TyG index and IMT increase was particularly pronounced in males, individuals aged ≥60 years, and those without hypertension (P < 0.05). In these subgroups, the TyG index was found to be a significant predictor of IMT increase, with the highest risk observed in males (RR: 1.88; 95% CI:

Table 3 Multivariate Analysis of Influencing IMT Increase

Characteristics	Reference	RR (95% CI)	P value
TyG index		1.49 (1.05–2.13)	0.026
TyG four groups	Q1		
Q2		1.54 (1.01–2.34)	0.043
Q3		1.14 (0.76–1.72)	0.524
Q4		1.67 (0.91–3.09)	1.00
Gender	Men		
Women		0.61 (0.35–1.06)	0.082
Age	Under 45 years old		
45–59 years old		4.28 (2.12–8.64)	<0.001
60–74 years old		6.49 (3.07–13.73)	<0.001
≥ 75 years old		10.75 (3.06–37.73)	<0.001
Degree of education	Illiterate		
Primary school education		0.82 (0.52–1.29)	0.392
Junior school education		0.50 (0.31–0.81)	0.005
High school and above		0.54 (0.29–1.01)	0.054
Hypertension	No		
Yes		1.37 (0.92–2.05)	0.119
Hyperlipemia	No		
Yes		0.93 (0.58–1.49)	0.760
Smoking history	Never smoking		
Current smoking		1.12 (0.63–1.97)	0.706
Ever smoking		1.22 (0.69–2.18)	0.492
Drinking history	Never drinking		
Current drinking		0.93 (0.54–1.59)	0.789
Ever drinking		0.60 (0.34–1.07)	0.083
BMI, kg/m²	< 18.5, underweight		
18.5 ≤ BMI<24, normal		1.71 (0.57–5.15)	0.340
24 ≤ BMI < 28, overweight		1.71 (0.57–5.17)	0.343
BMI ≥ 28, obesity		1.72 (0.55–5.36)	0.354
DBP, mmHg		1.00 (0.98–1.02)	0.753
SBP, mmHg		1.00 (0.99–1.01)	0.854
FPG, mmol/l		0.88 (0.80–0.97)	0.008
HDL-C, mmol/l		1.27 (0.87–1.85)	0.214
TC, mmol/l		0.95 (0.81–1.12)	0.550

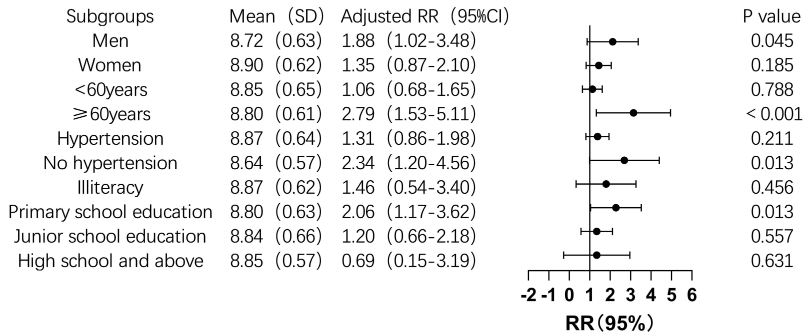

Figure 3 Association between the TyG index and changes in carotid intima-media thickness (IMT) in subgroups in logistic models. Figure 3 showed that the association between the TyG index and IMT increase was particularly pronounced in males, individuals aged ≥60 years, and those without hypertension (P < 0.05). In these subgroups, the TyG index was found to be a significant predictor of IMT increase, with the highest risk observed in males (RR: 1.88; 95% CI: 1.02–3.48; P = 0.045), no hypertension (RR:2.34;95% CI:1.20–4.56, P=0.013) and in individuals aged ≥60 years (RR: 2.79; 95% CI: 1.53–5.11; P < 0.001).

1.02–3.48; P = 0.045), no hypertension (RR: 2.34;95% CI: 1.20–4.56, P=0.013) and in individuals aged ≥60 years (RR: 2.79; 95% CI: 1.53–5.11; P < 0.001; Figure 3).

Discussion

The primary aim of this study was to evaluate the relationship between the TyG index and the incidence of carotid plaque and changes in IMT in a low-income, low-education, middle-aged, and elderly population in rural China. This large-sample, six-year prospective cohort study is well-suited to better evaluate the potential role of the TyG index as a predictor of atherosclerotic cardiovascular disease, with a particular focus on its ability to independently predict the formation of carotid plaques and the progression of IMT over a six-year period. The high prevalence of ASCVD and other comorbidities in this population significantly increases the disease burden, thereby highlighting the importance of exploring the predictive performance of the TyG index for disease outcomes.[6,14] While the TyG index was significantly associated with the incidence of carotid plaque in univariate analyses, it did not emerge as an independent predictor after adjusting for other risk factors in multivariate models. TyG index was found to be an independent predictor of IMT increase, particularly in certain subgroups. Individuals in the second quartile of the TyG index had a significantly higher risk of IMT progression compared to those in the first quartile, and this association was particularly strong among males, individuals aged 60 years and older, and those without hypertension. These findings suggest that the TyG index may play a more nuanced role in atherosclerotic processes, with its predictive value varying across different subpopulations.

The association between the TyG index and the occurrence of carotid plaque has been reported in several previous studies, suggesting that a higher TyG index is linked to an increased risk of plaque formation. These studies have generally supported the notion that the TyG index, as a surrogate marker of insulin resistance, plays a significant role in the development of atherosclerosis. For example, a cross-sectional study conducted among railway workers in Northwest China demonstrated a significant association between higher TyG index levels and the presence of carotid plaque.[17] Similarly, a population-based study in Southeastern China found that individuals with elevated TyG index had a higher prevalence of carotid plaque, especially in those at high risk for stroke.[18] Another study involving middle-aged and elderly populations in Hubei Province reported a strong correlation between TyG index and the presence of carotid plaque, particularly among males and individuals with normal blood pressure.[11] Additionally, a cohort study in a Japanese population observed that the TyG index was associated with carotid plaque formation when the index was below a certain threshold (9.06), but this relationship diminished at higher levels.[21] Lastly, a prospective cohort study conducted in China found that the TyG index could serve as a dose-response indicator of carotid plaque incidence, reinforcing its potential utility in cardiovascular risk prediction.[20] In comparison to these studies, our research did not find a significant independent relationship between the TyG index and the incidence of carotid plaque after adjusting for confounding factors such as age, hypertension, and diabetes. This discrepancy may be attributed to differences in study design, population characteristics, or the follow-up duration. Unlike previous studies that often relied on cross-sectional data or shorter follow-up periods, our study utilized a six-year prospective cohort design, allowing for a more rigorous assessment of the temporal relationship between TyG index and plaque formation. Furthermore, our study focused on a specific population of low-income, low-education, middle-aged, and elderly individuals in rural China, which may exhibit distinct metabolic and cardiovascular profiles compared to other cohorts. A large Chinese cohort study found that as the TyG index increases, the number of cardiovascular risk factors (such as hypertension, hyperglycemia, hyperlipidemia, obesity, and smoking) in individuals with cardiovascular diseases also rises.[14] In our study, diabetes, hypertension, and hyperlipidemia all had significant impacts on the incidence of carotid plaque. Therefore, one possible explanation for the lack of independent correlation of TyG is that the strong influence of these traditional cardiovascular risk factors may have masked the predictive value of the TyG index in this population. Additionally, the variability in plaque measurement methods and the specific carotid segments analyzed could also contribute to the differences observed between studies. It is also plausible that the role of the TyG index in plaque formation is more complex and may involve interactions with other metabolic and vascular factors that were not fully captured in our analysis.

The relationship between TyG index and carotid IMT has been explored in previous studies, but findings remain somewhat inconsistent. Some studies have shown a clear association between TyG index and IMT, supporting its role as a marker for early atherosclerosis, while others have not found a significant relationship or have focused on different populations, leading to some debate regarding its utility as a predictor. Miao et al[16] found that a higher TyG index was positively correlated with increased IMT in patients with ischemic stroke, suggesting that the TyG index could serve as a valuable biomarker for early detection of subclinical atherosclerosis in high-risk populations. Similarly, Jia et al[12] reported a U-shaped association between TyG index and IMT progression in both obese and non-obese adults, with the second quartile of TyG being associated with the lowest IMT, highlighting a potential threshold effect. A study by Li et al[11] in a middle-aged and elderly Chinese population also demonstrated that the TyG index was significantly associated with IMT, particularly in males and individuals without hypertension. Furthermore, TyG index was an independent risk factor for increased IMT in both hypertensive and normotensive individuals, reinforcing its predictive value for atherosclerosis progression.[13] In contrast to some of these studies, our research uniquely focused on a low-income, low-education, rural population and demonstrated that the TyG index was an independent predictor of IMT increase, especially in specific subgroups. Individuals in the second quartile of the TyG index had a significantly higher risk of IMT progression compared to those in the first quartile, which aligns with findings from Jia's earlier research indicating a non-linear relationship between TyG and IMT. Both Li et al and Yan et al have found that the association between the TyG index and ASCVD is particularly significant in elderly men, which may be attributed to differences in sex hormones. As men age, testosterone levels decline, and coupled with the more common habits of smoking and drinking among elderly men, the risk of cardiovascular disease increases.[11,32–34] It is worth noting that our study found that this association is not only particularly evident in men and individuals aged 60 and above but also significant in those without hypertension, indicating that the TyG index may be more predictive in these specific subgroups, a finding that has not been emphasized in previous studies. This is a novel finding that contributes to the existing literature by identifying population-specific risk factors that may amplify the predictive value of the TyG index. The stronger association of TyG index with IMT in males and older adults could be attributed to gender-related metabolic differences and the cumulative effects of aging on arterial health. In the case of non-hypertensive individuals, the TyG index may capture metabolic disturbances that are not influenced by blood pressure, but rather by insulin resistance and lipid metabolism, which are critical in the development of early atherosclerotic changes. This finding suggests that TyG index could be particularly useful in predicting subclinical atherosclerosis in populations that may otherwise be considered at lower cardiovascular risk, such as non-hypertensive adults.

This study has several limitations that should be acknowledged. First, the study population was drawn exclusively from low-income, low-education, middle-aged, and elderly individuals in rural China, which may limit the generalizability of the findings to other populations, particularly those in urban settings or with different socioeconomic backgrounds. This population-specific focus could affect the applicability of the results to broader groups and may introduce biases related to lifestyle and environmental factors unique to rural communities. Second, the measurement of carotid plaque was based on B-mode ultrasound, which, while widely used, may be subject to inter-observer variability and does not capture all aspects of plaque characteristics, such as stability, composition, or precise location within the carotid artery. This limitation could potentially affect the accuracy of the plaque incidence data and may explain the lack of significant association between the TyG index and plaque formation observed in this study. Additionally, the study did not account for the potential impact of medication use, particularly lipid-lowering and antihypertensive drugs, which could influence both the TyG index and the progression of atherosclerosis. The omission of this factor might have confounded the results, as individuals on such medications may have different cardiovascular risk profiles compared to those not on medication. To improve future studies, several measures could be implemented. Expanding the study population to include a more diverse demographic, both geographically and socioeconomically, would enhance the generalizability of the findings. Employing more advanced imaging techniques, such as magnetic resonance imaging (MRI) or three-dimensional ultrasound, could provide a more detailed assessment of plaque characteristics, leading to a better understanding of the relationship between TyG index and plaque formation. Additionally, collecting detailed data on medication use and other potential confounders would allow for more accurate adjustment in the analysis, reducing the potential for bias and improving the robustness of the findings.

Conclusion

This study provides valuable insights into the relationship between the TyG index and carotid atherosclerosis, specifically in a low-income, low-education middle-aged, and elderly population in rural China. The TyG index is a cost-effective and reliable measure of insulin resistance, providing support for risk prediction in low-income populations. Our findings suggest that while the TyG index is associated with changes in carotid IMT, it may not serve as an independent predictor of carotid plaque formation after adjusting for traditional cardiovascular risk factors. For patients, it is crucial to monitor and manage TyG index on reducing the stroke and CVD risk, particularly in high-risk populations. While the TyG index alone may not independently predict carotid plaque, it remains a useful tool in identifying individuals at risk for subclinical atherosclerosis. This can inform more targeted preventive strategies, particularly in rural low-education and low-income settings where resources for extensive cardiovascular evaluations may be limited. Moreover, by identifying specific risk factors such as the TyG index that are relevant to these communities, healthcare policies can be better tailored to address the unique challenges faced by these groups. This could lead to more effective prevention programs, ultimately reducing the incidence of stroke and other atherosclerosis-related conditions, thereby improving overall public health outcomes.

Data Sharing Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

References

1. Barquera S, Pedroza-Tobías A, Medina C, et al. Global overview of the epidemiology of atherosclerotic cardiovascular disease. *Arch Med Res*. 2015;46(5):328–338. doi:10.1016/j.arcmed.2015.06.006
2. Chen W, Li Z, Zhao Y, et al. Global and national burden of atherosclerosis from 1990 to 2019: trend analysis based on the global burden of disease study 2019. *Chin Med J*. 2023;136(20):2442–2450.
3. GBD 2021 Diseases and Injuries Collaborators. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet*. 2024;403(10440):2133–2161. doi:10.1016/S0140-6736(24)00757-8

4. Wang Y, Wang X, Wang C, Global ZJ. Regional, and national burden of cardiovascular disease, 1990-2021: results from the 2021 global burden of disease study. *Cureus*. 2024;16(11):e74333. doi:10.7759/cureus.74333
5. Fan J, Li X, Yu X, et al. Global burden, risk factor analysis, and prediction study of ischemic stroke, 1990-2030. *Neurology*. 2023;101(2):e137–e150. doi:10.1212/WNL.0000000000207387
6. Song P, Xia W, Zhu Y, et al. Prevalence of carotid atherosclerosis and carotid plaque in Chinese adults: a systematic review and meta-regression analysis. *Atherosclerosis*. 2018;276:67–73. doi:10.1016/j.atherosclerosis.2018.07.020
7. Clarke R, Du H, Kurmi O, et al. Burden of carotid artery atherosclerosis in Chinese adults: implications for future risk of cardiovascular diseases. *Eur J Prev Cardiol*. 2017;24(6):647–656. doi:10.1177/2047487317689973
8. Ormazabal V, Nair S, Elfeky O, et al. Association between insulin resistance and the development of cardiovascular disease. *Cardiovasc Diabetol*. 2018;17(1):122. doi:10.1186/s12933-018-0762-4
9. Khan SH, Sobia F, Niazi NK, et al. Metabolic clustering of risk factors: evaluation of Triglyceride-glucose index (TyG index) for evaluation of insulin resistance. *Diabetol Metab Syndr*. 2018;10:74. doi:10.1186/s13098-018-0376-8
10. Nevárez-Sida A, Guerrero-Romero F. The triglycerides and glucose index: a cost-effectiveness analysis compared with the homeostatic model assessment for insulin resistance. *Value Health Reg Issues*. 2023;37:49–52. doi:10.1016/j.vhri.2023.05.001
11. Li W, Chen D, Tao Y, et al. Association between triglyceride-glucose index and carotid atherosclerosis detected by ultrasonography. *Cardiovasc Diabetol*. 2022;21(1):137. doi:10.1186/s12933-022-01570-0
12. Jia X, Zhu Y, Qi Y, et al. Association between triglyceride glucose index and carotid intima-media thickness in obese and nonobese adults. *J Diabetes*. 2022;14(9):596–605. doi:10.1111/1753-0407.13312
13. Alizargar J, Bai CH. Comparison of carotid ultrasound indices and the triglyceride glucose index in hypertensive and normotensive community-dwelling individuals: a case control study for evaluating atherosclerosis. *Medicina*. 2018;54(5):71. doi:10.3390/medicina54050071
14. Zhang Y, Ren L, Ren M, et al. Correlation between the triglyceride-glucose index and high risk of cardiovascular disease: a cohort study of 102,061 subjects from Tianjin, China. *Risk Manag Healthc Policy*. 2021;14:2803–2810. doi:10.2147/RMHP.S316484
15. Gounden V, Devaraj S, Jialal I. The role of the triglyceride-glucose index as a biomarker of cardio-metabolic syndromes. *Lipids Health Dis*. 2024;23(1):416. doi:10.1186/s12944-024-02412-6
16. Miao M, Zhou G, Bao A, et al. Triglyceride-glucose index and common carotid artery intima-media thickness in patients with ischemic stroke. *Cardiovasc Diabetol*. 2022;21(1):43. doi:10.1186/s12933-022-01472-1
17. Pan J, Yang B, Wang Z, et al. Triglyceride-glucose index is related to carotid artery plaque in railway workers: a cross-sectional study. *Diabetes Metab Syndr Obes*. 2023;16:2561–2571. doi:10.2147/DMSO.S418358
18. Tang X, Zhang L, Li Y, et al. Relationship between triglyceride-glucose index and carotid plaques in a high-stroke-risk population in southeast China: a population-based cross-sectional survey. *Front Endocrinol*. 2022;13:1023867. doi:10.3389/fendo.2022.1023867
19. Li Z, He Y, Wang S, et al. Association between triglyceride glucose index and carotid artery plaque in different glucose metabolic states in patients with coronary heart disease: a RCSCD-TCM study in China. *Cardiovasc Diabetol*. 2022;21(1):38. doi:10.1186/s12933-022-01470-3
20. Zhang Y, Wu Z, Li X, et al. Association between the triglyceride-glucose index and carotid plaque incidence: a longitudinal study. *Cardiovasc Diabetol*. 2022;21(1):244. doi:10.1186/s12933-022-01683-6
21. Liu J, Ye M, Wang Y. Association between Triglyceride-Glucose Index and carotid plaque in Japanese population: a cross-sectional study. *BMJ Open*. 2023;13(6):e069663. doi:10.1136/bmjopen-2022-069663
22. Zhao S, Yu S, Chi C, et al. Association between macro- and microvascular damage and the triglyceride glucose index in community-dwelling elderly individuals: the Northern Shanghai Study. *Cardiovasc Diabetol*. 2019;18(1):95. doi:10.1186/s12933-019-0898-x
23. Rafati M, Rahimzadeh MR, Moladoust H. Evaluation of atherosclerosis severity based on carotid artery intima-media thickness changes: a new diagnostic criterion. *Ultrasound Med Biol*. 2019;45(11):2950–2957. doi:10.1016/j.ultrasmedbio.2019.07.412
24. Alkire S, Shen Y. Exploring multidimensional poverty in China: 2010 to 2014. In: *Research on Economic Inequality: Poverty, Inequality and Welfare*. Emerald Publishing Limited; 2017:161–228.
25. Chen K, Shen Z, Gu W, et al. Prevalence of obesity and associated complications in China: a cross-sectional, real-world study in 15.8 million adults. *Diabetes Obes Metab*. 2023;25(11):3390–3399. doi:10.1111/dom.15238
26. Mancia G, Kreutz R, Brunström M, et al. 2023 ESH guidelines for the management of arterial hypertension the task force for the management of arterial hypertension of the European society of hypertension: endorsed by the international society of hypertension (ISH) and the European renal association (ERA). *J Hypertens*. 2023;41(12):1874–2071. doi:10.1097/HJH.0000000000003480
27. American Diabetes Association Professional Practice Committee. 2. diagnosis and classification of diabetes: standards of care in diabetes-2024. *Diabetes Care*. 2024;47(Suppl 1):S20–s42.
28. Sz JL, Gao R. Chinese lipid management guidelines 2023. *Chin J Cardiol*. 2024;51:221–255.
29. Ma X, Dong L, Shao Q, et al. Triglyceride glucose index for predicting cardiovascular outcomes after percutaneous coronary intervention in patients with type 2 diabetes mellitus and acute coronary syndrome. *Cardiovasc Diabetol*. 2020;19(1):31. doi:10.1186/s12933-020-01006-7
30. Touboul PJ, Hennerici MG, Meairs S, et al. Mannheim carotid intima-media thickness and plaque consensus (2004-2006-2011). An update on behalf of the advisory board of the 3rd, 4th and 5th watching the risk symposia, at the 13th, 15th and 20th European Stroke Conferences, Mannheim, Germany, 2004, Brussels, Belgium, 2006, and Hamburg, Germany, 2011. *Cerebrovasc Dis*. 2012;34(4):290–296.
31. Blaha MJ, Cainzos-Achirica M, Greenland P, et al. Role of coronary artery calcium score of zero and other negative risk markers for cardiovascular disease: the multi-ethnic study of atherosclerosis (Mesa). *Circulation*. 2016;133(9):849–858. doi:10.1161/CIRCULATIONAHA.115.018524
32. Yan C, Hao J, Sun X, et al. Pulse pressure and other cardiovascular risk factors associated with multiple carotid plaques in a rural Chinese population: a population-based cross-sectional study. *Risk Manag Healthc Policy*. 2025;18:617–628.
33. Rajendran A, Minhas AS, Kazzi B, et al. Sex-specific differences in cardiovascular risk factors and implications for cardiovascular disease prevention in women. *Atherosclerosis*. 2023;384:117269. doi:10.1016/j.atherosclerosis.2023.117269
34. Rodgers JL, Jones J, Bolleddu SI, et al. Cardiovascular risks associated with gender and aging. *J Cardiovasc Dev Dis*. 2019;6(2):19.