中国临床研究 Chin J Clin Res, July 2024, Vol.37, No.7
Cite as: Kong XY, Liao SG, Li Y, Cai Y, Zheng XQ, Yang T, Wang ZX. Correlation between triglyceride glucose index and atherosclerosis [J]. Chin J Clin Res, 2024, 37(7):1018-1021.
DOI: 10.13429/j.cnki.cjcr.2024.07.007

Correlation between triglyceride glucose index and atherosclerosis

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Abstract: Objective To explore the correlation between triglyceride glucose (TyG) index and arteriosclerosis in natural population, and whether TyG index could be used as a predictor of poor prognosis of cardio-cerebrovascular diseases. **Methods** A cross-sectional study was conducted on 4 355 adults recruited from the natural population in the community of Gaoyou City, Jiangsu Province from 2009 to 2010. According to the quartiles of TyG index, they were divided into Q1 group (TyG ⩽8.19, *n*=1 100), Q2 group (8.19 < TyG⩽8.55, *n*=1 080), Q3 group (8.55 < TyG⩽8.99, *n*=1 103), Q4 group (TyG >8.99, *n*=1 072). Taking brachial-ankle pulse wave conduction velocity (baPWV) as the observation index of arteriosclerosis, the correlation between TyG index and baPWV was analyzed by univariate and multivariate linear regression. A restricted cubic spline function diagram with multivariate correction was performed to explore whether there was a nonlinear correlation between TyG index and baPWV. **Result** After adjusting for confounding factors, compared with Q1 group, the regression coefficient and 95%*CI* of TyG index affecting baPWV among Q2, Q3 and Q4 groups were 0.11(-0.07, 0.29), 0.41 (0.23, 0.59) and 0.97(0.78, 1.16), respectively (trend test *P*<0.01). Restricted cubic spline analysis showed a linear positive correlation between TyG index and baPWV. The mediator effect analysis also showed that TyG index partially mediated the impact on baPWV through inflammation. **Conclusion** TyG index is linearly and positively correlated with atherosclerosis.

Keywords: Triglyceride glucose index; Arteriosclerosis; Brachial ankle pulse wave conduction velocity; Mediator effect
Fund program: Project of Jiangsu Provincial Key Medical Discipline /Laboratory (ZDXK202202)

Cardio-cerebrovascular diseases are the main cause of global health burden and the leading cause of death from disease worldwide [1]. Atherosclerosis has been widely recognized as an important risk factor for cardio-cerebrovascular events and poor prognosis of diseases [2-6]. Atherosclerosis is a chronic and long-term pathological process. Early identification of high-risk groups of atherosclerosis and intervention with appropriate preventive strategies are of great clinical significance for reducing the occurrence of cardio-cerebrovascular diseases and improving prognosis [7-8].

Insulin resistance (IR) is generally defined as a decrease in sensitivity to physiological insulin levels in insulin target tissues [9]. The triglyceride glucose index (TyG index) has been proven in previous studies to be a simple and reliable surrogate indicator of IR, and has a certain predictive value for the risk and prognosis cardiovascular diseases [10]. However, few studies have elucidated the correlation between TyG and atherosclerosis in the general population. This study took brachial-ankle pulse wave conduction velocity (baPWV) as the main observation indicator of atherosclerosis, and aimed to explore the correlation between TyG and atherosclerosis risk in the general population.

1 Subjects and Methods

1.1 Subjects

This study (Gaoyou Study) was a cross-sectional study conducted in the natural population of communities in Gaoyou City, Jiangsu Province from 2009 to 2010. The subjects were recruited through stratified random sampling based on age (18-34, 35-44, 45-54, 55-64, and 65-74 years old) and gender. A total of 4,536 adults were selected for this study. Those lacking reliable baPWV data, blood glucose and triglyceride data, or those undergoing hypoglycemic or lipid-lowering drug treatment were excluded. The ethics of this study have been approved by the Institutional Review Board of the First Affiliated Hospital of Nanjing Medical University (2011-SR-012).

1.2 baPWV

The baPWV of the subjects was measured by a non-invasive vascular screening device (VP-1000, Omron, Japan), along with blood pressure measurement using a sphygmomanometer. VP-1000 simultaneously recorded the baPWV of both the left and right sides as well as brachial and ankle blood pressures. Details of the device functions and procedures have been described elsewhere

[11].

1.3 Other Variables

Demographic characteristics, blood pressure, height, weight, and other indicators were collected from the subjects. Blood samples collected were analyzed by the Laboratory of the First Affiliated Hospital of Nanjing Medical University.

1.4 TyG Index

TyG index = ln [Fasting triglyceride (mg/dL) × fasting glucose (mg/dL)]/2. The subjects were grouped according to the quartiles of the TyG index: Q1 group (TyG≤8.19, n=1,100), Q2 group (8.19 < TyG≤8.55, n=1,080), Q3 group (8.55 < TyG≤8.99, n=1,103), and Q4 group (TyG > 8.99, n=1,072).

1.5 Statistical Methods

The statistical analyses were performed using Stata 15 MP software. Continuous variables that conformed to normal distribution were expressed as $\bar{x} \pm s$, and the comparison between the four groups was performed by ANOVA. Categorical variables were expressed as n (%), and the comparison between groups was performed using the chi-square test. Univariate and multivariate linear regression analysis was used to analyze the relevant factors of baPWV (stepwise regression forward method, with P<0.05 for univariate analysis included in the model and P>0.1 after correction excluded from the model). The restricted cubic spline function model was used to analyze whether the TyG index was nonlinearly correlated with baPWV. A bilateral test of P<0.05 was considered statistically significant.

2 Results

2.1 Baseline Analysis

The study included a total of 4,355 subjects. Subjects with higher TyG index were often accompanied with older age, higher body mass index (BMI), systolic diastolic blood (SBP) and diastolic blood pressure (DBP), higher level of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), alanine aminotransferase (ALT), aspartate aminotransferase (AST), blood creatinine (SCr), and white blood cells (WBC) counts. They also had lower high-density lipoprotein cholesterol (HDL-C) and a higher proportion of antihypertensive treatment (P<0.05) **[Table 1].**

Tab.1 Baseline features of four groups ($\bar{x} \pm$s)

Indicators	Q1 group (n=1 100)	Q2 group (n=1 080)	Q2 group (n=1 103)	Q4 group (n=1 072)	F/χ^2 Value	P Value
baPWV (m/s)	14.0 ±2.9	14.4 ±3.1	14.9±3.2	15.9 ±3.5	69.38	<0.001
Age (years)	51.0 ±13.3	51.7 ±12.7	52.5 ±11.8	53.0 ±11.3	5.56	0.001
Male [ccase (%)]	557 (50.6)	489 (44.9)	471 (42.7)	513 (47.9)	15.81	0.001
BMI (kg/m²)	23.0±2.7	23.9±2.9	25.0±3.0	26.1±3.0	233.21	<0.001
SBP (mmHg)	132.0±19.8	135.0±21.4	137.0±21.0	142.0±20.0	43.17	<0.001
DBP (mmHg)	82.5±10.3	83.8±10.1	86.1±10.7	88.8±10.3	77.60	<0.001
Blood glucose (mg/dL)	95.1±9.9	98.8±10.5	102.0±13.1	111.0±28.0	176.31	<0.001
TC (mmol/L)	4.5±0.8	4.8±0.8	5.0±0.9	5.4±1.1	184.68	<0.001
HDL-C (mmol/L)	1.46±0.3	1.4±0.3	1.3±0.3	1.2±0.3	212.21	<0.001
LDL-C (mmol/L)	2.6±0.6	2.8±0.6	3.1±0.7	3.2±0.7	192.68	<0.001
TG (mg/dL)	59.7±11.9	89.0±12.4	128.0±20.5	271.0±18.6	35 652.75	<0.001
ALT (U/L)	17.2±11.7	18.8±19.3	20.5±27.6	23.8±14.2	22.79	<0.001
AST (U/L)	25.0±9.2	25.5±17.0	25.8±18.0	26.9±9.9	3.62	0.013
SCr (μmol/L)	64.3±13.7	66.1±18.6	66.7±15.8	68.7±17.9	12.83	<0.001
WBC (×10⁹/L)	5.4±1.5	5.7±1.6	5.9±1.6	6.2±1.6	46.42	<0.001
Antihypertensive therapy [case (%)]	82 (7.5)	117 (10.8)	165 (15.0)	262 (24.4)	143.16	<0.001

2.2 Univariate and Multivariate Analysis

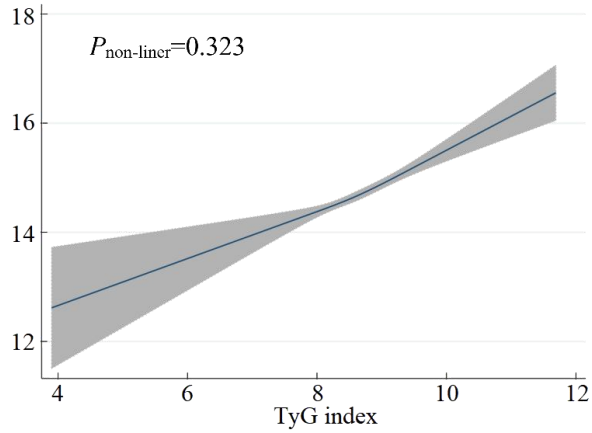
Univariate linear regression analysis showed that compared with the Q1 group, the regression coefficients and 95%*CI* of TyG index on baPWV in the Q2, Q3, and Q4 groups were 0.39 (0.13, 0.66), 0.90 (0.63, 1.17), and 1.86 (1.60, 2.13), with a trend test P<0.01. Other potential confounding factors related to baPWV include age, gender, BMI, SBP, DBP, LDL-C, AST, SCr, WBC count, and antihypertensive treatment **[Table 2]**. After multi-factor adjustment for confounding factors, compared with the Q1 group, the regression coefficients and 95%*CI* of TyG index on baPWV in the Q2, Q3, and Q4 groups were 0.11 (-0.07, 0.29), 0.41 (0.23, 0.59), and 0.97 (0.78, 1.16), with a trend test P<0.001. The restricted cubic spline function analysis showed a linear, positive correlation between TyG index and baPWV (non-linear P = 0.323, **Figure 1**).

2.3 The Effect of TyG Index on baPWV Through Inflammation

The results of the mediation analysis showed that inflammation was involved in the correlation between TyG index and baPWV. The percentage of mediation effect in the Q2, Q3, and Q4 groups was 14.4%, 7.2%, and 5.5%, respectively **[Table 3]**.

Tab.2 Univariate and multivariate generalized linear regression analysis of influencing factors of baPWV

Indicators	Univariate		Multivariate	
	β (95% *CI*)	*P* Value	*β* (95% *CI*)	*P* Value
Age	0.15 (0.14, 0.16)	<0.001	0.08 (0.07, 0.09)	<0.001
Male	0.92 (0.73, 1.11)	<0.001		
BMI	0.10 (0.07, 0.13)	<0.001	-0.08 (-0.11, -0.06)	<0.001
SBP	0.11 (0.10, 0.11)	<0.001	0.080 (0.076, 0.084)	<0.001
DBP	0.14 (0.13, 0.15)	<0.001		
HDL-C	-0.03 (-0.33, 0.26)	0.822		
LDL-C	0.88 (0.74, 1.01)	<0.001		
ALT	0.005 (-0.001, 0.009)	0.067		
AST	0.022 (0.015, 0.029)	<0.001		
SCr	0.04 (0.03, 0.05)	<0.001	0.009 (0.005, 0.013)	<0.001
Anti-hypertensive therapy	3.28 (3.02, 3.54)	<0.001	0.66 (0.46, 0.85)	<0.001
WBC	0.22 (0.16, 0.28)	<0.001	0.09 (0.05, 0.13)	<0.001
TyG				
≤8.19	-		-	
<8.19-8.55	0.39 (0.13, 0.66)	0.004	0.11 (-0.07, 0.29)	0.246
<8.55-8.99	0.90 (0.63, 1.17)	<0.001	0.41 (0.23, 0.59)	<0.001
>8.99	1.86 (1.60, 2.13)	<0.001	0.97 (0.78, 1.16)	<0.001



Note: The solid blue line represented the estimated value of baPWV, and the shaded part was 95%*CI*. The model corrected for age BMI, SBP, SCr, anti-hypertensive therapy, and WBC.

Fig. 1 Regression model of 'TyG index (continuous variable) and baPWV fitted by restricted cubic spline model

Tab.3 Impact of TyG index on baPWV through WBC

Group	Total Effect		Direct Effect		Indirect Effect		Effect Size for Mediation (%)
	β (95%*CI*)	*P* Value	*β* (95%*CI*)	*P* Value	*β* (95%*CI*)	*P* Value	
Q1	-		-		-		-
Q2	0.14 (-0.02, 0.29)	0.126	0.12 (-0.06, 0.31)	0.240	0.02 (0.01, 0.04)	<0.001	14.4
Q3	0.44 (0.27, 0.62)	<0.001	0.41 (0.23, 0.58)	<0.001	0.03 (0.02, 0.05)	<0.001	7.2
Q4	1.00 (0.83, 1.15)	<0.001	0.95 (0.76, 1.09)	<0.001	0.06 (0.03, 0.09)	<0.001	5.5

3 Discussion

The main finding of this study was that IR was associated with arteriosclerosis. The TyG index showed a linear positive correlation with baPWV, and inflammation partially mediated the correlation between the TyG index and baPWV.

Previous studies have found that the TyG index is associated with abdominal aortic calcification [12], myocardial infarction in community populations [13], cardiovascular disease [14], and atherosclerosis in type 2 diabetes [15]. Chen, *et al.* [12] conducted a cross-sectional analysis of data from 1,419 participants in the 2013-2014 National Health and Nutrition Examination Survey of United Sates and detected extensive abdominal aortic calcification in 196 (13.8%) of the subjects. Each unit increase in the TyG index increased the odds of extensive abdominal aortic calcification by 41%. Pan *et al.* [16] included 3,169 railway workers and performed carotid ultrasound examinations, finding that individuals with a high TyG index had a higher prevalence of carotid plaques, and there was a positive correlation between the TyG index and the risk of carotid plaques (*OR* = 1.22). The results of this study are consistent with the conclusions of these studies, except that this study used baPWV to assess arteriosclerosis.

IR is considered a common risk factor for cardio-cerebrovascular diseases [17]. This study showed that IR populations had higher WBC counts, suggesting that IR might be associated with inflammatory responses [18]. Further mediator effect analysis results showed that inflammation participated in the correlation between the TyG index and baPWV, including direct and indirect effects, suggesting that IR leads to atherosclerosis by activating the inflammatory response in the human body.

This study has the following limitations. First, TyG index as a means to assess IR is not the gold standard for IR, but because the TyG index is simple and easy to obtain, it has important indicative significance for clinical evaluation of IR. Second, due to the cross-sectional study design, the causal relationship between the TyG index and arteriosclerosis could not be established, and further Cohort studies and randomized controlled trials are needed to prove causality. Thirdly, although this study found that inflammation mediated the correlation between the TyG index and baPWV, prospective studies are still needed to further confirm the reliability of the results.

In summary, this study found a linear positive correlation between the TyG index and baPWV. Inflammation partially mediated the correlation between the TyG index and baPWV.

Conflicts of Interest: None

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Submission received:2024-05-07/**Revised:** 2024-06-12

·论　著·

三酰甘油—葡萄糖指数与动脉硬化的相关性

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摘要：目的　探讨在自然人群中，三酰甘油—葡萄糖（TyG）指数与动脉硬化有无相关性，TyG 指数能否作为心脑血管疾病不良预后的预测因素。**方法**　横断面分析 4 355 例 2009 年至 2010 年于江苏省高邮市社区收集到的自然人群数据。根据 TyG 指数四分位数进行分组：Q1 组（TyG≤8.19，n=1 100），Q2 组（8.19<TyG≤8.55，n=1 080），Q3 组（8.55<TyG≤8.99，n=1 103），Q4 组（TyG>8.99，n=1 072）。以肱踝脉搏波传导速度（baPWV）为动脉硬化观测指标，通过单因素和多因素线性回归分析 TyG 指数与 baPWV 的相关性。多因素校正的限制性立方样条函数图探究 TyG 指数与 baPWV 是否存在非线性相关。**结果**　校正混杂因素后，与 Q1 组对比，TyG 指数在 Q2、Q3、Q4 组间影响 baPWV 的回归系数及其 95%*CI* 分别为 0.11（-0.07～0.29）、0.41（0.23～0.59）、0.97（0.78～1.16）（趋势检验 P<0.01）。限制性立方样条函数分析显示，TyG 指数与 baPWV 呈线性正相关。中介效应分析显示 TyG 指数通过炎症部分介导了对 baPWV 的影响。**结论**　TyG 指数与动脉硬化呈线性正相关。

关键词：三酰甘油—葡萄糖指数；动脉硬化；肱踝脉搏波传导速度；中介效应

中图分类号：R587.2　**文献标识码：**A　**文章编号：**1674-8182（2024）07-1018-04

Correlation between triglyceride glucose index and atherosclerosis

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Abstract: Objective　To explore the correlation between triglyceride glucose (TyG) index and arteriosclerosis in natural population, and whether TyG index could be used as a predictor of poor prognosis of cardio-cerebrovascular diseases. **Methods**　A cross-sectional study was conducted on 4 355 adults recruited from the natural population in the community of Gaoyou City, Jiangsu Province from 2009 to 2010. According to the TyG index quartiles, they were divided into Q1 group (TyG≤8.19, n=1 100), Q2 group (8.19<TyG≤8.55, n=1 080), Q3 group (8.55<TyG≤8.99, n=1 103), Q4 group (TyG>8.99, n=1 072). Taking brachial-ankle pulse wave conduction velocity (baPWV) as the observation index of arteriosclerosis, the correlation between TyG index and baPWV was analyzed by univariate and multivariate linear regression. A restricted cubic spline function diagram with multivariate correction was performed to explore whether there was a nonlinear correlation between TyG index and baPWV. **Results**　After adjusting for confounding factors, compared with Q1 group, the regression coefficient and its 95%*CI* of TyG index affecting baPWV among Q2, Q3 and Q4 groups were 0.11 (-0.07-0.29), 0.41 (0.23-0.59) and 0.97 (0.78-1.16), respectively (trend test P<0.01). Restricted cubic spline analysis showed a linear positive correlation between TyG index and baPWV. The mediator effect analysis also showed that TyG index partially mediated the impact on baPWV through inflammation. **Conclusion**　TyG index is linearly and positively correlated with atherosclerosis.

Keywords: Triglyceride glucose index; Arteriosclerosis; Brachial ankle pulse wave conduction velocity; Mediator effect

Fund program: Project of Jiangsu Provincial Key Medical Discipline /Laboratory (ZDXK202202)

DOI: 10.13429/j.cnki.cjcr.2024.07.007

基金项目：江苏省医学重点学科/实验室项目（ZDXK202202）

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出版日期：2024-07-20

QR code for English version

心脑血管疾病,是全球健康负担的主要原因,也是全球因疾病死亡的首要病因[1]。动脉硬化已被广泛认为是心脑血管疾病事件和疾病不良预后重要的危险因素[2-6]。而动脉硬化是一个慢性的长期的病理过程,早期识别动脉硬化高危人群和采取适当的预防策略进行干预,对降低心脑血管疾病的发生和改善预后都具有重要的临床意义[7-8]。

胰岛素抵抗(insulin resistance, IR)通常被定义为胰岛素靶向组织中对生理胰岛素水平的敏感性降低[9]。三酰甘油—葡萄糖指数(triglyceride glucose index, TyG index)在既往研究中已经被证明作为 IR 的简单可靠的替代指标,对心血管疾病风险及心血管疾病预后均具有一定的预测价值[10]。然而鲜有研究阐明在自然人群中 TyG 与动脉硬化的相关性,本研究以肱踝脉搏波传导速度(brachial-ankle pulse wave conduction velocity, baPWV)为主要动脉硬化观察指标,拟通过自然人群探讨 TyG 与动脉硬化风险的相关性。

1　对象与方法

1.1　*研究对象*　本研究(高邮研究)是根据年龄 18~34 岁、35~44 岁、45~54 岁、55~64 岁、65~74 岁和性别进行分层随机抽样的横断面研究,从 2009 年至 2010 年江苏省高邮市社区自然人群中招募的 4 536 例成人为研究对象。排除缺乏可靠 baPWV 数据、缺乏血糖和三酰甘油数据、正在接受降糖或降脂药物治疗的人群。本研究伦理问题获得南京医科大学附属第一医院机构审查委员会批准(2011-SR-012)。

1.2　baPWV　与血压计血压测量一起,使用经验证的自动装置(VP-1000 PWV/ABI analyzer, Colin Co. Ltd., Komaki, Japan)测量研究对象的 baPWV。该仪器同时记录左、右侧的 baPWV 和肱、踝血压,设备功能和过程的细节已在其他地方进行了描述[11]。

1.3　*其他变量*　采集研究对象的人口学特征数据,测量血压、身高、体重等指标,采集的血样均经南京医科大学第一附属医院检验科进行分析。

1.4　TyG *指数*　TyG 指数计算方法为 TyG 指数=ln[三酰甘油(mg/dL)×空腹血糖(mg/dL)/2]。根据 TyG 指数四分位数对研究对象进行分组:Q1 组(TyG≤8.19, n=1 100), Q2 组(8.19<TyG≤8.55, n=1 080), Q3 组(8.55<TyG≤8.99, n=1 103),Q4 组(TyG>8.99, n=1 072)。

1.5　*统计学方法*　连续型变量符合正态分布采用 $\bar{x}\pm s$表示,四组间的比较采用单因素方差分析。分类变量采用例数(%)表示,组间比较采用列联表 χ^2 检验。单因素和多因素线性回归分析 baPWV 的相关因素(逐步回归前进法,单因素分析 P<0.05 纳入模型,校正后 P>0.1 排除出模型)。限制性立方样条函数模型分析 TyG 指数与 baPWV 是否非线性相关。所有统计采用 Stata 15 MP 软件进行分析。双侧检验,P<0.05 为差异有统计学意义。

2　结　果

2.1　*基线分析*　研究共纳入 4 355 例研究对象,TyG 指数越高的研究对象多伴有更大的年龄,更高的身体质量指数(BMI)、收缩压和舒张压,更高的血糖、总胆固醇(TC)、低密度脂蛋白胆固醇(LDL-C)、三酰甘油、丙氨酸氨基转移酶(ALT)、天冬氨酸氨基转移酶(AST)、血肌酐和白细胞水平,更低的高密度脂蛋白胆固醇(HDL-C),更高的降压治疗比例(P<0.05)。见表 1。

2.2　*单因素和多因素分析*　单因素线性回归分析显示,与 Q1 组比,TyG 指数在 Q2、Q3、Q4 组间影响 baPWV 的回归系数及其 95%*CI* 为 0.39(0.13~0.66)、0.90(0.63~1.17)、1.86(1.60~2.13),趋势检验 P<0.01;其他潜在的与 baPWV 相关的混杂因素包括年龄、性别、BMI、收缩压、舒张压、LDL-C、AST、血肌酐、白细胞计数和降压治疗(表 2)。多因素线性回归分析校正混杂因素后,与 Q1 组相比,TyG 指数在 Q2、Q3、Q4 组间影响 baPWV 的回归系数及其 95%*CI* 为 0.11(-0.07~0.29)、0.41(0.23~0.59)、0.97(0.78~1.16),趋势检验 P<0.01。限制性立方样条函数分析显示,TyG 指数与 baPWV 呈线性正相关(非线性 P=0.323,图 1)。

2.3　TyG *指数通过炎症对 baPWV 的影响*　中间效应分析结果显示,炎症参与了 TyG 指数与 baPWV 的相关性。中介效应百分比在 Q2、Q3、Q4 组间分别为 14.4%、7.2%和 5.5%。见表 3。

表 1　四组基线特征　($\bar{x}\pm s$)

Tab. 1　Baseline features of four groups　($\bar{x}\pm s$)

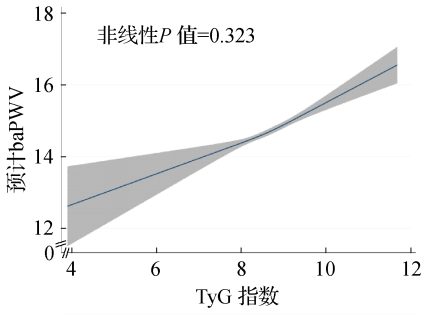
项目	Q1 组(n=1 100)	Q2 组(n=1 080)	Q2 组(n=1 103)	Q4 组(n=1 072)	F/χ^2 值	P 值
baPWV(m/s)	14.0±2.9	14.4±3.1	14.9±3.2	15.9±3.5	69.38	<0.001
年龄(岁)	51.0±13.3	51.7±12.7	52.5±11.8	53.0±11.3	5.56	0.001
男性[例(%)]	557 (50.6)	489 (45.3)	471 (42.7)	513 (43.9)	15.81	0.001
BMI(kg/m^2)	23.0±2.7	23.9±2.9	25.0±3.0	26.1±3.0	233.21	<0.001
收缩压(mmHg)	132.0±19.8	135.0±21.4	137.0±21.0	142.0±20.0	43.17	<0.001
舒张压(mmHg)	82.5±10.3	83.8±10.1	86.1±10.7	88.8±10.3	77.60	<0.001
血糖(mg/dL)	95.1±9.9	98.8±10.5	102.0±13.1	111.0±28.0	176.31	<0.001
TC(mmol/L)	4.5±0.8	4.8±0.8	5.0±0.9	5.4±1.1	184.68	<0.001
HDL-C(mmol/L)	1.5±0.3	1.4±0.3	1.3±0.3	1.2±0.3	212.21	<0.001
LDL-C(mmol/L)	2.6±0.6	2.8±0.6	3.1±0.7	3.2±0.7	192.68	<0.001
三酰甘油(mg/dL)	59.7±11.9	89.0±12.4	128.0±20.5	271.0±18.6	35 652.75	<0.001
ALT(U/L)	17.2±11.7	18.8±19.3	20.5±27.6	23.8±14.2	22.79	<0.001
AST(U/L)	25.0±9.2	25.5±17.0	25.8±18.0	26.9±9.9	3.62	0.013
血肌酐(μmol/L)	64.3±13.7	66.1±18.6	66.7±15.8	68.7±17.9	12.83	<0.001
白细胞($\times10^9$/L)	5.4±1.5	5.7±1.6	5.9±1.6	6.2±1.6	46.42	<0.001
降压治疗[例(%)]	82 (7.5)	117 (10.8)	165 (15.0)	262(24.4)	143.16	<0.001

表 2　单因素和多因素广义线性回归分析 baPWV 的影响因素

Tab. 2　Univariate and multivariate generalized linear regression analysis of influencing factors of baPWV

因素	单因素分析		多因素分析	
	β (95%CI)	P 值	β(95%CI)	P 值
年龄	0.15(0.14~0.16)	<0.001	0.08(0.07~0.09)	<0.001
男性	0.92(0.73~1.11)	<0.001		
BMI	0.10(0.07~0.13)	<0.001	−0.08(−0.11~−0.06)	<0.001
收缩压	0.11(0.10~0.11)	<0.001	0.080(0.076~0.084)	<0.001
舒张压	0.14(0.13~0.15)	<0.001		
HDL-C	−0.03(−0.33~0.26)	0.822		
LDL-C	0.88(0.74~1.01)	<0.001		
ALT	0.005(−0.001~0.009)	0.067		
AST	0.022(0.015~0.029)	<0.001		
血肌酐	0.04(0.03~0.05)	<0.001	0.009(0.005~0.013)	<0.001
降压治疗	3.28(3.02~3.54)	<0.001	0.66(0.46~0.85)	<0.001
白细胞	0.22(0.16~0.28)	<0.001	0.09(0.05~0.13)	<0.001
TyG 指数				
TyG≤8.19	参照组		参照组	
8.19<TyG≤8.55	0.39(0.13~0.66)	0.004	0.11(−0.07~0.29)	0.246
8.55<TyG≤8.99	0.90(0.63~1.17)	<0.001	0.41(0.23~0.59)	<0.001
TyG>8.99	1.86(1.60~2.13)	<0.001	0.97(0.78~1.16)	<0.001

注:多因素 P 值大于 0.10 的变量排除出多因素回归模型校正。



注:实线表示 baPWV 估计值,阴影部分为 95%CI;
模型校正了年龄、BMI、收缩压、肌酐、降压治疗、白细胞。

图 1　限制性立方样条模型拟合 TyG 指数(连续型变量)与 baPWV 的回归模型

Fig. 1　Regression model of TyG index (continuous variable) and baPWV fitted by restricted cubic spline model

表 3　TyG 指数通过白细胞对 baPWV 的影响

Tab. 3　Impact of TyG index on baPWV through white blood cells

组别	总效应		直接效应		间接效应		中介百分比(%)
	β(95%CI)	P 值	β(95%CI)	P 值	β(95%CI)	P 值	
Q1	参照组		参照组		参照组		参照组
Q2	0.14(−0.02~0.29)	0.126	0.12(−0.06~0.31)	0.240	0.02(0.01~0.04)	<0.001	14.4
Q3	0.44(0.27~0.62)	<0.001	0.41(0.23~0.58)	<0.001	0.03(0.02~0.05)	<0.001	7.2
Q4	1.00(0.83~1.15)	<0.001	0.95(0.76~1.09)	<0.001	0.06(0.03~0.09)	<0.001	5.5

3　讨　论

本研究的主要发现为 IR 与动脉硬化相关。TyG 指数与 baPWV 呈线性正相关,炎症部分介导了 TyG 指数与 baPWV 的相关性。

既往研究发现 TyG 指数与腹主动脉钙化[12]、社区人群心肌梗死[13]、心血管疾病[14]、2 型糖尿病动脉粥样硬化等[15]相关。Chen 等[12]对 2013 至 2014 年美国健康和营养调查的 1 419 名参与者的数据进行了横断面分析,在 196 名(13.8%)研究对象中检测到广泛的腹主动脉钙化。TyG 指数每增加一个单位,广泛腹主动脉钙化的几率就会增加 41%[12]。Pan

等[16]纳入 3 169 例铁路工人并行颈动脉超声检查发现,TyG 指数高的人群颈动脉斑块的患病率更高,TyG 指数与颈动脉斑块风险呈正相关(OR = 1.22)。本研究的结果与这些研究的结论符合,不同的是本研究采用 baPWV 来评估动脉硬化。

IR 被认为是心脑血管病共同的危险因素[17],本研究分析表明 IR 人群具有更高的白细胞水平,提示 IR 与炎症反应相关[18],进一步的中介效应分析结果显示炎症参与了 TyG 指数与 baPWV 的相关性,这种介导包括直接效应和间接效应,提示 IR 通过激活人体的炎症反应从而导致动脉粥样硬化的发生。

本研究存在如下不足。首先采用 TyG 指数作为评估 IR 的手段,并不是 IR 的金标准,然而因为 TyG 指数简单、容易获取,对临床评价 IR 具有重要指示意义。其次,受限于横断面研究形式,未能得到 TyG 指数和动脉硬化的因果相关关系,需要更进一步队列研究和随机对照证明因果。最后,本研究发现炎症介导了 TyG 指数与 baPWV 的相关性,也仍需要前瞻性研究进一步证明结果的可靠性。

综上所述,本研究发现 TyG 指数与 baPWV 呈线性正相关。炎症部分介导了 TyG 指数与 baPWV 的相关性。

利益冲突　无

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收稿日期:2024-05-07　**修回日期**:2024-06-12　**编辑**:石嘉莹