Association between carotid intima-media thickness and fasting blood glucose level: A population-based cross-sectional study among low-income adults in rural China

Liu Gao¹, Lingling Bai^{2,3}, Min Shi^{2,3}, Jingxian Ni^{2,3}, Hongyan Lu², Yanan Wu^{2,3}, Jun Tu^{2,3}, Xianjia Ning^{2,3,4}, Jinghua Wang^{2,3,4}, Yukun Li¹*

¹Department of Endocrinology, The Third Hospital of Hebei Medical University, Shijiazhuang, Hebei, ²Department of Neurology, Tianjin Medical University General Hospital, ³Department of Epidemiology, Tianjin Neurological Institute, and ⁴Center of Clinical Epidemiology, Tianjin Medical University General Hospital, Heping District, Tianjin, China

Keywords

Carotid intima media thickness, Fasting blood glucose, Risk factors

*Correspondence

Yukun Li Tel.: +86-311-88603000 Fax: +86-311-87023626 E-mail address: yu_kun_li@126.com

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ABSTRACT

Aims/Introduction: Carotid intima-media thickness (CIMT) is an established predictor of cardiovascular disease and stroke. We aimed to identify the association between CIMT and blood glucose, as well as the risk factors associated with increased CIMT in a low-income Chinese population.

Materials and Methods: Stroke-free and cardiovascular disease-free residents aged ≥45 years were recruited. B-mode ultrasonography was carried out to measure CIMT. **Results:** There were 2,643 participants (71.0%) in the normal group, 549 (14.7%) in the impaired fasting glucose group and 533 (14.3%) in the diabetes mellitus group. The determinants of increased CIMT were older age; male sex; low education; hypertension; smoking; high levels of systolic blood pressure, fasting blood glucose and low-density lipoprotein cholesterol; and low levels of diastolic blood pressure, triglycerides and high-density lipoprotein cholesterol, after adjusting for covariates. Age and hypertension were the common risk factors for increased CIMT in all three groups. Furthermore, male sex, smoking and high low-density lipoprotein cholesterol level were positively associated with the mean CIMT in the impaired fasting glucose group; and alcohol consumption was an independent risk factor for mean CIMT in the diabetes mellitus group. Hypertension was the greatest risk factor for increased CIMT.

Conclusions: These findings suggest that it is crucial to manage and control traditional risk factors in low-income populations in China in order to decelerate the recent dramatic increase in stroke incidence, and to reduce the burden of stroke.

INTRODUCTION

Globally, the aging and growth of populations has led to a sharp increase in deaths as a result of cardiovascular disease (CVD), including from ischemic heart disease and stroke, in both developed and developing countries¹. CVD has become the leading cause of death, accounting for almost one-third of all deaths globally in 2013². Recently, the burden of CVD has become the most important public health issue in China, where death as a result of CVD has accounted for more than 40% of

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total deaths (44.6% in rural areas and 42.5% in urban areas)³. Furthermore, in a previous study, we reported a dramatically increased incidence of first-ever stroke among a low-income population in rural China from 1992 to 2012, with an annual increase of $6.5\%^4$. Additionally, the prevalence of conventional risk factors has significantly increased in this population over the past several decades^{5,6}.

The association between carotid atherosclerosis and a high risk of CVD and stroke is well established^{7–10}. Carotid intimamedia thickness (CIMT) is a non-invasive, inexpensive, rapid and reproducible measure, and increased CIMT, a proxy for

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J Diabetes Investig Vol. 8 No. 6 November 2017 (© 2017 The Authors. Journal of Diabetes Investigation published by Asian Association for the Study of Diabetes (AASD) and John Wiley & Sons Australia, Ltd This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made. carotid atherosclerosis, is a significant determinant of CVD and stroke risks1^{1–13}. Furthermore, it is well known that diabetes mellitus is significantly associated with stroke, and patients with diabetes are at greater risk of stroke than individuals without diabetes^{14–17}. Increased CIMT has been accepted as a marker of early atherosclerosis^{18–20}, type 2 diabetes is related to an increased risk of atherosclerotic diseases^{21,22}, and an increased cardiovascular risk has been observed in individuals with elevated glucose levels below the diabetic range^{23,24}. Finally, previous studies showed that impaired glucose tolerance was associated with increased CIMT^{25,26}.

However, the relationship between fasting blood glucose (FBG) level and CIMT in a low-income population with a high incidence of stroke is currently unclear, especially in China. Therefore, we aimed to explore the mean CIMT and relevant determinants of increased CIMT among individuals with different FBG levels in a low-income population in China with a high incidence of stroke.

METHODS

Study population

This was a population-based, cross-sectional study carried out from April 2014 to January 2015. The study design has been described previously²⁷. In brief, the total population included 14,251 individuals from 18 administrative villages. Approximately 95% of the participants were low-income farmers, with a per capita disposable income of <1,600 USD in 2014²⁸. All residents aged 45 years and older without CVD were recruited to this study.

All participants were categorized into three groups according to their FBG level: the normal group, defined by an FBG level <5.6 mmol/L; the impaired fasting glucose (IFG) group, defined by an FBG level between 6.1 and 7.0 mmol/L; and the diabetes mellitus group, defined by an FBG level \geq 7.0 mmol/L or self-report of oral antidiabetic medication use²⁹.

All investigative protocols were approved by the ethics committee of Tianjin Medical University General Hospital; the methods were carried out in accordance with the approved guidelines, and informed consent was obtained from all participants.

Data collection and risk factor definitions

All variables in the present study were evaluated by trained epidemiological researchers through face-to-face interviews. A prespecified questionnaire was used to collect all data.

Demographic information, including name, sex, date of birth and educational level, were obtained from previous records. All participants were categorized into four age groups: 45–54 years, 55–64 years, 65–74 years and \geq 75 years. Educational level was categorized into three groups according to educational years: illiteracy (without education), 1–6 years of education and >6 years of education.

Previous individual and family medical histories, which included the presence of hypertension, diabetes mellitus, stroke,

transient ischemic attack and coronary heart disease, were obtained according to patient self-report or from medical records.

Lifestyle characteristics included cigarette smoking, passive smoking and alcohol consumption. Cigarette smoking was defined as smoking more than one cigarette per day for at least 1 year, and participants were categorized as never smokers, ever smokers (ceased smoking for at least 6 months) and current smokers. Passive smoking was defined as experiencing secondhand smoking among family members who lived in the same room or colleagues who worked in the same workshop. Alcohol consumption was defined as drinking more than 500 g of alcohol per week for at least 1 year, and participants were categorized into the never consumed alcohol, ever consumed alcohol (temperance for at least 6 months) and current alcohol consumption groups.

Physical examination

Measurements of blood pressure (including systolic blood pressure [SBP] and diastolic blood pressure [DBP]), height and weight were carried out in the local village clinic during the baseline survey; levels of plasma FBG, total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were measured at the Ji County People's Hospital. Carotid ultrasonography and 12-lead echocardiography were also carried out by a professional. Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m²).

Hypertension was defined by an SBP \geq 140 mmHg, a DBP \geq 90 mmHg or taking medications for hypertension. Diabetes mellitus was defined by an FBG \geq 7.0 mmol/L or taking insulin or oral hypoglycemic medications.

Ultrasonography measurements

One trained technician blinded to individuals' previous disease histories carried out all ultrasound examinations. Patients were examined while they were in the supine position using B mode ultrasonography (Terason 3000; Terason, Burlington, Massachusetts, USA) with a 5–12-MHz linear array transducer. CIMT at the near and far walls of the common carotid artery were measured on the left and right, and three values were obtained: the maximum CIMT, minimum CIMT and average CIMT. Images were obtained and digitally stored according to a standard protocol.

Statistical analysis

Continuous variables are presented as means with standard deviations, and were compared between groups using an analysis of variance. Categorical variables are presented as numbers with frequencies, and were compared using χ^2 -tests. Multiple linear regression analyses were used to evaluate the associations between traditional risk factors and CIMT. We carried out linear regression analyses to evaluate the determinants of CIMT after adjusting for age, educational levels, levels

of SBP, DBP, FBG, TC, TG, HDL-C and LDL-C (continuous variables), and sex, smoking status, alcohol consumption, hypertension and diabetes mellitus (categorical variables). The relationships are presented as standardized regression coefficients (β) with standard errors. *P*-values <0.05 in two-tailed tests were considered statistically significant. Spss for Windows (version 15.0; SPSS Inc., Chicago, Illinois, USA) was used for analyses.

RESULTS

Participant characteristics

The selection process for participants has been described previously²⁷. In brief, a total of 4,012 individuals were interviewed from among 5,380 qualified residents during the study period; thus, the response rate was 75%. Finally, 3,725 participants were ultimately enrolled in the present study after excluding 223 residents with a previous history of CVD or stroke, and 64 subjects without an FBG measurement.

There were 2,643 participants (71.0%) in the normal group, 549 (14.7%) in the IFG group and 533 (14.3%) in the diabetes mellitus group. The corresponding rates were 69.9, 16.0 and 14.1% for men, and 71.7, 13.8 and 14.5% for women, respectively. Age, the prevalence of hypertension, BMI, and the levels of SBP, TC, TG and LDL-C increased with increasing FBG level (P < 0.001), but the education level and levels of DBP and HDL-C decreased with increasing FBG level (P < 0.001; Table 1).

Furthermore, the frequency of self-reported diabetes was 7.4% in the present study, with a rate of 74.6% for using regular medication.

Determinants of mean CIMT based on univariate and multivariate analyses

The results of the univariate analysis showed that male sex, older age, current smoking, alcohol drinking, hypertension, and higher levels of SBP, DBP, FBG, TC and LDL-C were associated with elevated mean CIMT (all P < 0.0001), but the opposite trends were observed for higher education, TG and HDL-C levels (Table 2).

After adjustment by age, sex, educational level, smoking, hypertension, SBP, DBP, FBG, TC, TG, HDL-C and LDL-C, the determinants of increased CIMT were older age, male sex, low education, smoking, hypertension, high levels of SBP, FBG and LDL-C, and low levels of DBP, TG and HDL-C. The mean CIMT increased by 2.0 μ m with each 1-mmol/L increase in FBG level (P = 0.023). The greatest determinants of increased CIMT were male sex and hypertension; the mean CIMT was higher by 17.4 μ m in men than in women, and by 17.8 μ m in participants with hypertension than in those without hypertension. Furthermore, the mean CIMT increased by 3.5 μ m for each 1-mmol/L increase in LDL-C level, but decreased by 10.4 μ m for each 1-mmol/L increase in TG level (Table 3).

Mean CIMT by FBG level, demographics and conventional risk factors, using a univariate analysis

The mean CIMT was 56.6 μ m in the normal group, 57.5 μ m in the IFG group and 58.0 μ m in the diabetes mellitus group, respectively; the mean CIMT increased significantly with elevated FBG level (P < 0.0001; Table 1). Table 4 shows the mean CIMT based on different demographic features and risk factors by FBG level. For all three groups, the mean CIMT was positively associated with sex, age, educational level, drinking alcohol and hypertension. In addition, smoking and high LDL-C were associated with increased mean CIMT in the normal glucose group, high TG level in the IFG group and smoking in the diabetes mellitus group.

Determinants of mean CIMT by FBG level in the multivariate analysis

The results of the multivariate analysis showed that age and hypertension were the common risk factors for increased CIMT in the three groups. Furthermore, male sex, smoking and high LDL-C level were positively associated with the mean CIMT in the normal group; high TG levels were negatively associated with the mean CIMT in the IFG group; and alcohol consumption was an independent risk factor for mean CIMT in the diabetes mellitus group. Hypertension was the greatest risk factor for increased CIMT. CIMT was increased by 25.01 μ m in the normal group, by 25.25 μ m in the IFG group and by 21.40 μ m in the diabetes mellitus group in those with hypertension than in those without hypertension (Table 5).

DISCUSSION

This is the first report of the mean CIMT and its determinants based on FBG level among a low-income population with a high incidence of stroke. Older age, male sex, hypertension, and elevated levels of SBP, FBG and LDL-C were associated with increased mean CIMT; however, a higher level of education, and elevated levels of DBP, TG and HDL-C were protective factors against increased CIMT. Furthermore, mean CIMT was positively associated with age and hypertension in the normal, IFG and diabetes mellitus groups; male sex, smoking and high LDL-C level were positively associated with the mean CIMT in the normal group; high TG levels were negatively associated with the mean CIMT in the IFG group; and alcohol consumption was an independent risk factor for increased mean CIMT in the diabetes mellitus group. Hypertension was the greatest risk factor for increased CIMT.

The relationship between the level of FBG and CIMT has been controversial. Previous studies have shown that there was no significant association between IFG and CIMT after adjustment by covariates^{30–34}. The associations between hyperglycemia and CIMT were significant in univariate analyses, but disappeared after adjustment for age, sex and anthropometric variables^{35–37}. Furthermore, other studies have shown that higher HbA1c levels were significantly and independently related to increased CIMT, but IFG was not^{34,37,38}. Nevertheless,

Risk factors	Normal	IFG	DM	Р
Total	2,643 (71.0)	549 (14.7)	533 (14.3)	_
Sex, n (%)				
Men	1,074 (69.9)	246 (16.0)	216 (14.1)	0.582
Women	1,569 (71.7)	303 (13.8)	317 (14.5)	
Mean age, years (SD)	59.25 (9.70)	61.56 (9.38)	61.80 (9.46)	< 0.001
Age group, n (%)				
45–54 years	940 (78.1)	135 (11.2)	129 (10.7)	< 0.001
55–64 years	1,042 (69.7)	235 (15.7)	218 (14.6)	
65–74 years	456 (63.7)	124 (17.3)	136 (19.0)	
≥75 years	205 (66.1)	55 (17.7)	50 (16.1)	
Mean Education, years (SD)	5.59 (3.51)	5.42 (3.58)	4.98 (3.61)	0.001
Education, n (%)				
0 years	432 (66.5)	105 (16.2)	113 (17.4)	< 0.001
1–6 years	1,167 (70.0)	246 (14.8)	253 (15.2)	
>6 years	1,044 (74.1)	198 (14.1)	167 (11.9)	
Smoking status, <i>n</i> (%)				
Never smoking	1,979 (70.9)	404 (14.5)	407 (14.6)	0.496
Ever smoking	116 (67.8)	28 (16.4)	27 (15.8)	
Current smoking	548 (71.7)	117 (15.3)	99 (13.0)	
Alcohol consumption, n (%)				
Never drinking	382 (71.3)	87 (16.2)	67 (12.5)	0.595
Ever drinking	30 (65.2)	6 (13.0)	10 (21.7)	
Current drinking	2,231 (71.0)	456 (14.5)	456 (14.5)	
Hypertension, <i>n</i> (%)	1,680 (63.6)	424 (77.2)	445 (83.5)	< 0.001
Obesity, n (%)	558 (21.1)	144 (26.2)	176 (33.0)	< 0.001
Mean SBP, mmHg (SD)	144.14 (21.78)	151.22 (21.87)	153.45 (21.74)	< 0.001
Mean DBP, mmHg (SD)	88.16 (11.42)	89.05 (11.56)	87.91 (10.60)	< 0.001
Mean BMI, kg/m ² (SD)	25.22 (3.64)	26.03 (3.47)	26.81 (3.74)	< 0.001
Mean TC, mmol/L (SD)	4.82 (1.06)	4.91 (1.08)	5.02 (1.21)	< 0.001
Mean TG, mmol/L (SD)	1.66 (1.14)	1.90 (1.31)	2.12 (1.52)	< 0.001
Mean HDL-C, mmol/L (SD)	1.48 (0.44)	1.43 (0.50)	1.37 (0.49)	< 0.001
Mean LDL-C, mmol/L (SD)	2.65 (1.20)	2.70 (1.34)	2.90 (1.44)	< 0.001
TC ≥6.22 mmol/L	251 (9.5)	59 (10.7)	79 (14.8)	< 0.001
TG ≥2.26 mmol/L	504 (19.1)	144 (26.2)	168 (31.5)	< 0.001
HDL-C ≤1.04 mmol/L	343 (13.0)	101 (18.4)	102 (19.1)	< 0.001
LDL-C ≥4.14 mmol/L	186 (7.0)	52 (9.5)	58 (10.9)	< 0.001
Mean CIMT (µm)	56.6 (0.09)	57.5 (0.09)	58.0 (0.09)	< 0.001

BMI, body mass index; CIMT, carotid intima-media thickness; DBP, diastolic blood pressure; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides.

a positive association between FBG and CIMT was shown in previous studies^{39,40}. The most recent study in communitydwelling Japanese older adults showed that elevated IFG was significantly associated with increased CIMT⁴⁰. Consistent with that study, in the present study, we found a significant relationship between FBG and mean CIMT after adjustment for age, sex, educational level, hypertension, current smoking, and the levels of SBP, DBP, TC, TG, HDL-C and LDL-C. The findings in the present study suggest that FBG level is an independent determinant of mean CIMT. The disparity between the current study and previous studies with respect to the association between blood glucose level and CIMT might be explained by different populations (i.e., the inclusion of those with normal glucose levels, those with diabetes mellitus or the entire population), different designs (i.e., hospital-based, community-based or population-based) and different parameters related to blood glucose (FBG, impaired glucose tolerance test and HbA1c). In the present study, diabetes mellitus was defined with respect to an FBG level >7.0 mmol/L, but not to HbA1c. Furthermore, the duration of diabetes mellitus was not available in this study, and we have noted this as a limitation.

Increases in CIMT were associated with a number of traditional risk factors, including age, sex, hypertension, smoking, lipid profile and BMI^{39,41–43}. Large studies have evaluated the association between cardiovascular risk factors and CIMT, and found that hypertension and smoking were associated with

 Table 2 | Determinants of mean carotid intima-media thickness in this population by univariate analysis

	/				
Risk factors	β	SE	95% CI	Р	
Age	2.5	0.1	2.2, 2.8	< 0.0001	
Sex	27.8	2.9	22.1, 33.4	< 0.0001	
Education	-3.1	0.4	-3.9, -2.3	< 0.0001	
Smoking	20.8	3.3	14.4, 27.2	< 0.0001	
Alcohol consumption	21.8	3.9	14.1, 29.5	< 0.0001	
Hypertension	37.6	3.0	31.7, 43.5	< 0.0001	
SBP	0.9	0.1	0.7, 1.0	< 0.0001	
DBP	0.6	0.1	0.3, 0.8	< 0.0001	
BMI	0.2	0.4	-0.5, 1.0	0.568	
FBG	4.6	0.9	2.9, 6.4	< 0.0001	
TC	3.4	1.3	0.8, 6.0	0.010	
TG	-3.0	1.2	-5.3, -0.7	0.011	
HDL-C	-6.5	3.1	-12.6, -0.4	0.037	
LDL-C	6.6	1.1	4.3, 8.8	< 0.0001	

 β , Standardized regression coefficient; BMI, body mass index; CI, confidence interval; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; SBP, systolic blood pressure; SE, standard errors; TC, total cholesterol; TG, triglycerides.

 Table 3 | Risk factors of mean carotid intima-media thickness in this population using multivariate linear regression analysis

Risk factors	β	SE	95% CI	Р
Age	1.7	0.2	1.3, 2.0	< 0.0001
Sex	17.4	3.8	10.0, 24.8	< 0.0001
Education	-1.1	0.4	-2.0, -0.2	0.015
Smoking	5.1	2.2	0.7, 9.4	0.022
Alcohol drinking	3.4	2.2	-1.0, 7.9	0.133
Hypertension	17.8	4.0	10.0, 25.7	< 0.0001
SBP	0.4	0.1	0.2, 0.6	< 0.0001
DBP	-0.4	0.2	-0.8, -0.1	0.017
FBG	2.0	0.9	0.3, 3.8	0.023
TC	3.2	1.8	-0.3, 6.6	0.072
TG	-4.1	1.3	-6.5, -1.6	0.001
HDL-C	-10.4	3.4	-17.0, -3.8	0.002
LDL-C	3.5	1.4	0.8, 6.1	0.012

 β , Standardized regression coefficient; BMI, body mass index; CI, confidence interval; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; SBP, systolic blood pressure; SE, standard error; TC, total cholesterol; TG, triglycerides.

CIMT and atherosclerosis^{39,41,42}. The cross-sectional Atherosclerosis Risk in Communities Study has shown that CIMT is related to hypertension (or blood pressure), diabetes mellitus, smoking, BMI, white blood cell count, plasma HDL-C, LDL-C and fibrinogen levels⁴³. Previous studies have also shown that low apolipoprotein A1 levels, and elevated LDL-C and apolipoprotein B levels in childhood predict increased CIMT in adulthood^{42,44-47}, and that a high LDL-C concentration predisposes to the progression of subclinical atherosclerosis⁴⁸. LDL particles have been suggested to predict an increased risk of atherosclerotic diseases because of their toxicity to the endothelium and underlying smooth muscle, adhesion to glycosaminoglycans in the endothelial basement membrane, and high susceptibility to scavenger receptors on macrophages⁴⁹. However, the association between TG and CIMT has been unclear, especially in low-income populations. Numerous studies have shown that there was a positive association between TG and CIMT^{39,43,45,50,51}; two longitudinal studies reported a positive association between baseline TG levels and progression of CIMT^{43,51}, but a strong inverse relationship was observed in one study⁵². Consistent with these studies, in the present study, we found that older age, male sex, hypertension, elevated levels of SBP and LDL-C, and reduced levels of DBP, TG and HDL-C were associated with increased mean CIMT.

Low education has been established to be associated with increased CIMT⁵³⁻⁵⁸. A higher socioeconomic status (SES), as measured by education, income and longest held job (in women), was significantly associated with a larger IMT and higher plaque score; CIMT was 0.09-mm greater in participants with a low SES compared with those with high SES⁵³. The Atherosclerosis Risk in Communities Study reported that education was strongly inversely associated with common CIMT⁵⁹, and the present study found that educational achievement, as a marker of SES, was directly associated with arterial elasticity⁶⁰. In line with these findings, higher education was an independent protective factor against increased CIMT in the present study; the mean CIMT decreased by 1.1 µm per 1-year increase in education level in this population. Poor healthcare and controlling of risk factors (for example, hypertension, diabetes mellitus and dyslipidemias) in those with low educational attainment could explain this relationship. Differences in medical care, and genetic, environmental and psychosocial factors, including social support, depression, job strain and chronic stress, between low-SES and high-SES individuals might explain the negative association between low SES and CIMT increase^{61–63}.

Furthermore, we evaluated the determinants of increased CIMT according to the different FBG levels. Our findings showed that mean CIMT was positively associated with age and hypertension in the normal, IFG, and diabetes mellitus groups. Furthermore, male sex, smoking and high LDL-C levels were positively associated with the mean CIMT in the normal group; high TG levels were negatively associated with the mean CIMT in the IFG group; and alcohol consumption was an independent risk factor for increased mean CIMT in the diabetes mellitus group.

The correlation between fasting TG levels and CIMT remains controversial^{32,64–66}. A previous study reported that fasting TG levels were not associated with CIMT, but that postprandial TG levels were strongly associated with CIMT in healthy participants⁶⁷. A similar trend was observed in the patients with

Table 4	Mean carotid	intima-media	thickness ir	n different	glucose	groups k	oy demograp	nic characteristics

Characteristics	Normal		IFG		DM	
	Mean (SD)	Р	Mean (SD)	Р	Mean (SD)	Р
Sex						
Men	57.90 (9.05)	< 0.001	58.85 (10.22)	0.003	59.61 (9.19)	< 0.001
Women	55.13 (8.24)		56.42 (8.53)		56.97 (7.94)	
Age group			· · ·		· · ·	
45–54 years	53.14 (7.42)	< 0.001	54.84 (8.10)	< 0.001	55.57 (7.89)	0.002
55–64 years	56.73 (8.30)		57.46 (9.52)		58.51 (8.35)	
65–74 years	59.39 (9.14)		58.63 (9.96)		59.09 (9.39)	
≥75 years	61.17 (9.69)		61.75 (8.64)		59.51 (7.68)	
Education			· · ·		× ,	
0 years	57.98 (9.05)	< 0.001	60.34 (12.03)	0.001	58.07 (7.94)	0.026
1–6 years	56.93 (8.64)		57.33 (8.88)		58.95 (9.19)	
>6 years	54.79 (8.35)		56.22 (8.05)		56.64 (7.80)	
Smoking status						
Never smoking	55.74 (8.39)	0.006	57.01 (8.92)	0.113	57.51 (8.58)	0.014
Ever smoking	57.21 (9.31)		58.83 (9.54)		57.67 (6.78)	
Current smoking	57.93 (9.36)		58.92 (10.77)		60.31 (8.62)	
Alcohol consumption			× ,		× ,	
Never drinking	56.02 (8.57)	0.006	57.06 (8.81)	0.013	57.38 (8.07)	< 0.001
Ever drinking	57.58 (6.57)		54.04 (7.51)		68.00 (11.42)	
Current drinking	57.52 (9.36)		60.12 (11.80)		61.02 (9.84)	
Hypertension						
Yes	57.63 (8.77)	< 0.001	58.28 (9.94)	< 0.001	58.53 (8.49)	0.003
No	53.86 (8.00)		54.88 (6.60)		55.55 (8.55)	
BMI						
Normal	56.31 (9.03)	0.187	57.23 (8.40)	0.405	57.23 (7.68)	0.516
Overweight	55.94 (8.58)		58.06 (10.28)		58.34 (8.78)	
Obesity	56.76 (8.22)		56.81 (8.65)		58.14 (8.80)	
TC ≥6.22 mmol/L						
Yes	56.55 (8.89)	0.569	56.66 (7.88)	0.461	56.67 (7.05)	0.125
No	56.23 (8.66)		57.61 (9.56)		58.28 (8.78)	
TG ≥2.26 mmol/L						
Yes	55.81 (8.27)	0.202	55.28 (6.68)	< 0.001	57.73 (7.84)	0.576
No	56.72 (9.50)		58.30 (10.07)		58.18 (8.88)	
HDL-C ≤1.04 mmol/L	· · /				× /	
Yes	56.72 (9.50)	0.330	57.70 (9.61)	0.820	58.31 (8.79)	0.360
No	56.19 (8.56)		57.47 (9.35)		57.97 (8.52)	
LDL-C ≥4.14 mmol/L	· · /		· · ·		× /	
Yes	58.28 (9.78)	0.003	58.13 (12.90)	0.617	56.99 (7.64)	0.322
No	56.1 0 (8.58)		57.44 (8.96)		58.17 (8.67)	

BMI, body mass index; DM, diabetes mellitus; HDL-C, high density lipoprotein cholesterol; IFG, impaired fasting glucose; LDL-C, low density lipoprotein cholesterol; SD, standard deviation; TC, total cholesterol; TG, triglycerides.

diabetes mellitus; thus, postprandial hypertriglyceridemia might be an independent risk factor for early atherosclerosis⁶⁸. However, the report on the association between TG level and CIMT in those IFG subjects was rare. The mechanism underlying the relationship between decreased TG level and increased CIMT in this population is uncertain, and needs to be explored further.

Results of previous studies regarding alcohol consumption and IMT are contradictory. Many studies have shown that an excessive intake of alcohol is directly linked with poor health outcomes, particularly CVD^{69,70}, but that moderate drinking was cardioprotective^{71,72}. In the cross-sectional Atherosclerosis Risk in Communities study, there was no association between alcohol intake and carotid atherosclerosis among participants aged 45–64 years⁷³. In the Study of Health in Pomerania, alcohol consumption was inversely correlated with carotid IMT in men, but not in women⁷⁴. In the present study, we observed a direct relationship between the amount and frequency of

Risk factors	Normal			IFG		DM			
	β (SE)	β (95% Cl)	Р	β (SE)	β (95% Cl)	Р	β (SE)	β (95% Cl)	Р
Sex	16.43 (4.36)	7.88, 24.97	< 0.0001	15.90 (9.06)	-1.90, 33.70	0.080	17.80 (9.33)	0.54, 36.14	0.057
Age	13.58 (1.20)	11.23, 15.93	< 0.0001	8.55 (2.83)	2.99, 14.11	0.003	6.97 (2.49)	2.09, 11.86	0.005
Education	-3.33 (2.62)	-8.48, 1.81	0.204	-11.48 (6.26)	-23.77, 0.81	0.067	-8.87 (5.81)	-20.29, 2.55	0.127
Hypertension	25.01 (3.38)	18.39, 31.63	< 0.0001	25.25 (9.28)	7.01, 43.49	0.007	21.40 (9.82)	2.11, 40.69	0.030
Smoking	5.35 (2.62)	0.21, 10.49	0.041	_	_	_	5.20 (5.83)	-6.24, 16.65	0.372
Alcohol drinking	0.29 (2.68)	-5.55, 4.97	0.914	9.19 (5.86)	-2.32, 20.70	0.117	15.17 (6.32)	2.75, 27.60	0.017
TG	_	_	_	-20.36 (8.85)	-37.75, -2.97	0.022	_	_	_
LDL-C	16.18 (6.18)	4.05, 28.30	0.009	_	_	_	_	_	_

Table 5 | Determinants of mean carotid intima-media thickness in different glucose groups by demographic characteristics in multivariate analysis

Cl, confidence interval; DM, diabetes mellitus; IFG, impaired fasting glucose; LDL-C, low density lipoprotein cholesterol; TG, triglycerides.

alcohol consumption and carotid IMT that was not confounded by binge drinking. The discrepancy in findings between the previous studies is possibly due to the different study populations. Similarly, a significant association between alcohol consumption and mean CIMT was confirmed in the present study. However, this relationship was observed only in the diabetes mellitus group. The precise cause of the association between alcohol consumption and mean CIMT in the patients with diabetes mellitus in this population is unclear.

There were several limitations to the present study. First, the study population was from a local town in Tianjin, China, so the findings might not be generalizable to the overall Chinese population. Second, the cross-sectional study design might have led to a selection bias. However, including only stroke- and CVD-free participants might have reduced this bias. Third, all participants were assessed for fasting plasma glucose only; the lack of evaluating an intravenous glucose tolerance test and HbA1c might have had an impact on the identification of impaired fasting blood glucose. Furthermore, the self-reported history of diabetes mellitus in this low-education population might have underrated the number of individuals with diabetes mellitus. Finally, information regarding medication use and additional blood measurements, such as HDL-C compositions, were absent and could have affected the results.

The present study was the first to report the relevant risk factors of CIMT by FBG categories in a low-income population with a high incidence of stroke in China. In this study, we evaluated mean CIMT and relevant risk factors among participants aged 45 years and older. There was a disparity between lower mean CIMT and higher incidence of stroke in this population. Established risk factors, including age, sex, educational level, hypertension, smoking, and SBP, DBP, FBG, TG, HDL-C and LDL-C levels, were significantly associated with mean CIMT; however, we observed a negative correlation between mean CIMT and educational level, TG and HDL-C. Furthermore, we evaluated the determinants of increased CIMT according to the different FBG levels. The findings showed that mean CIMT was positively associated with age and hypertension in the

normal, IFG, and diabetes mellitus groups. Furthermore, male sex, smoking and high LDL-C levels were positively associated with the mean CIMT in the normal group; high TG levels were negatively associated with the mean CIMT in the IFG group; and alcohol consumption was an independent risk factor for increased mean CIMT in the diabetes mellitus group. These findings suggest that it is crucial to manage and control traditional risk factors in low-income populations in China in order to decelerate the recent dramatic increase in stroke incidence, and reduce the burden of stroke.

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DISCLOSURE

The authors declare no conflict of interest.

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