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Title Page

Article Title: Association between serum triglyceride to high-density lipoprotein cholesterol ratio and sarcopenia among elderly patients with diabetes: Findings from the China Health and Retirement Longitudinal Study

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Abstract

Objective: Previous studies showed an inconsistent association between the serum triglyceride to high-density lipoprotein cholesterol (TG/HDL-C) ratio and the occurrence of sarcopenia in different populations. This study aimed to investigate the potential association between TG/HDL-C ratio and sarcopenia among elderly patients with diabetes.

Design: A cross-sectional study.

Setting: This was a second analysis of the China Health and Retirement Longitudinal Study (CHARLS).

Participants: In this study, 752 elderly individuals with diabetes were included after removing individuals younger than 60 years old, missing values for the assessment of sarcopenia, and missing measurements for plasma glucose or HbA1c.

Outcome measures: The primary information included TG/HDL-C ratio, muscle strength, physical performance, muscle mass, and covariables. Ordinal logistic regression and linear regression analysis were used to determine the association between TG/HDL-C ratio and sarcopenia.

Results: Multivariate ordinal logistic regression showed that compared with male patients with the lowest quartile of TG/HDL-C ratio (≤1.41), those with the highest quartile (>4.71; OR 0.24, 95% CI 0.10 to 0.54) were associated with lower risk of more severe sarcopenia; compared with female patients with the lowest quartile of

TG/HDL-C ratio (≤2.07), those with the highest quartile (>5.61; OR 0.17, 95% CI 0.07 to 0.44) were associated with reduced risk of more severe sarcopenia. In multivariate linear regression, male patients with the highest quartile of TG/HDL-C ratio (>4.71; β=0.36, 95% CI 0.20 to 0.51) had higher muscle mass than those with the lowest quartile (≤1.41); female patients with the highest quartile of TG/HDL-C ratio (>5.61; β=0.31, 95% CI 0.10 to 0.51) had higher muscle mass than those with the lowest quartile (≤2.07).

Conclusions: There was a negative association between TG/HDL-C ratio categorized by quartile and sarcopenia, which means that the higher TG/HDL-C ratio may be related to better muscle status.

Keywords: sarcopenia; triglyceride; high-density lipoprotein cholesterol; diabetes; elderly patient.

Strengths and limitations of this study

1. Our study focused on the correlation between lipid profiles and sarcopenia in elderly patients with diabetes and analyzed the correlation between lipid profiles and different muscle statuses (muscle strength, physical performance, and muscle mass).

2. Unlike previous studies, this study focused on elderly patients with diabetes from China, a supplement to existing studies' populations and conclusions.

3. This cross-sectional study was without longitudinal evidence, and analysis of causality and mechanism.

4. In this study, the type of diabetes was uncertain because the diagnosis of diabetes was based on self-report, and measurement of blood glucose and HbA1c.

5. The lack of duplicate blood lipid tests led to measurement bias in the baseline data.

1. Introduction

Sarcopenia is a syndrome characterized by age-related loss of muscle mass, plus low muscle strength and/or inadequate physical performance [1], increasing the risk for multiple adverse outcomes, including falls, physical limitations, frailty, hospitalization, and mortality [2-7]. In a previous study, the prevalence of sarcopenia was 1–29% in community-dwelling populations and 14–33% in people requiring long-term care [8]. Recently, various working groups have updated different consensus to identify sarcopenia based on the combination of loss of muscle strength, function, and mass [1,4]. However, in routine clinical practice, most clinicians remain to ignore the condition and are unaware of its diagnostic strategies [3,9].

Diabetes mellitus and sarcopenia have a bidirectional relationship [10,11]. In elderly patients with diabetes, exercise capacity decline has been recognized as a new complication [12]. Conversely, sarcopenia may increase the likelihood of older people developing diabetes [10]. Older age, lower body mass index (BMI), and other microvascular complications in patients with diabetes were significantly associated with the development of sarcopenia [13]. A significant association between sarcopenia and some metabolic risk markers, such as higher fasting plasma glucose (FPG) and glycated hemoglobin (HbA1c) in diabetes individuals, has been reported [14,15].

Serum triglyceride to high-density lipoprotein cholesterol ratio (TG/HDL-C) is a combination of lipid metabolic indicator that has been considered as cardiovascular

diseases risk prediction in patients with or without diabetes [16-19]. In addition, as an accessible serum lipid test in standard clinical practice, TG/HDL-C ratio has shown an inconsistent association with the occurrence of sarcopenia in elderly Korean men and community-dwelling Chinese adults [20,21]. In consequence, whether the relevant conclusion can be extrapolated to elderly patients with diabetes is uncertain.

Therefore, in this study, we aimed to investigate the potential association between TG/HDL-C ratio and sarcopenia among elderly patients with diabetes, including muscle strength, physical performance, and muscle mass.

2. Materials and methods

2.1 Study population

This study used data from the China Health and Retirement Longitudinal Study (CHARLS), an ongoing nationally representative survey of middle-aged and elderly individuals in China. Detailed information on the CHARLS was published elsewhere [22]. Briefly, the CHARLS collects high-quality data through face-to-face interviews with a structured questionnaire from a nationally representative sample of the Chinese population aged 45 years and over, selected using multistage stratified probability-proportionate-to-size sampling. The survey mainly covered sociodemographics, lifestyle factors, and health-related information. Besides, the CHARLS included multiple physical measurements and blood sample collection. The baseline survey was conducted in 2011, and all participants were followed up every 2 to 3 years. Each follow-up survey remained to increase new participants.

The CHARLS protocol was conducted following the Declaration of Helsinki and approved by the Biomedical Ethical Review Committee of Peking University (IRB00001052-11015). All participants provided informed consent. The CHARLS datasets are available on request from their home page at http://charls.pku.edu.cn/.

Our group selected the baseline participants in CHARLS 2011 (n=17,708) and non-repetitive participants in CHARLS 2015 (n=3823). We gradually excluded 20,779 individuals due to (1) age <60 years (n=13,661), (2) no information on physical measurements required for the assessment of sarcopenia (n=2024), (3) non-diabetes patients, or missing plasma glucose or HbA1c measurements (n=5094). Finally, 752 participants were eligible for the cross-sectional analysis.

In this study, diabetes was defined as FPG ≥7.0 mmol/L (126 mg/dL), random plasma glucose (RPG) ≥11.1 mmol/L (200 mg/dL), HbA1c ≥6.5% or self-reported history [23].

2.2 Data collection

In the CHARLS, information on demographic factors (including age and sex), residence (urban or rural), education level (less than lower secondary, upper secondary or vocational training, or tertiary), health behaviors (including the history of smoking and drinking) and diabetes management (including awareness and treatment of diabetes) were obtained by a structured questionnaire.

The main anthropometric parameters were height and body weight in our study. The body mass index (BMI, kg/m2) was calculated as body weight/(height^2), and overweight was defined as a BMI ≥25 kg/m2. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured three times, and their averages were recorded.

The blood samples were collected for measurements of plasma glucose (mg/dL), HbA1c (%), total cholesterol (TC, mg/dL), TG, low-density lipoprotein cholesterol (LDL-C, mg/dL), HDL-C (mg/dL), high-sensitivity C-reactive protein (hs-CRP, mg/L), uric acid (mg/dL), and creatinine (mg/dL). Serum triglyceride to high-density lipoprotein cholesterol ratio, the primary variable in this study, was calculated as TG/HDL-C. The estimated glomerular filtration rate (eGFR, mL/min/1.73 m^2) was calculated based on the Chronic Kidney Disease Epidemiology Collaboration's 2009 creatinine equation [24].

2.3 Assessment of sarcopenia

Sarcopenia status was assessed according to the algorithm of the Asian Working Group for Sarcopenia 2019 (AWGS 2019) in this study [1]. Participants with adequate muscle strength and physical performance were considered to have no sarcopenia. Possible sarcopenia was diagnosed if participants had sufficient muscle mass, with low muscle strength or low physical performance. Participants were recognized as having sarcopenia when they had low muscle mass, with low muscle strength or low physical performance.

2.3.1 Muscle strength

Handgrip strength (kg) was used to assess muscle strength according to the AWGS 2019 [1]. Handgrip strength was measured both with the left and right hand twice in the CHARLS [22], and we took the average of maximum values. If participants could not perform grip strength measurements in both hands, we used the data of the available hand. The AWGS 2019 recommended that the cut-off points for low handgrip strength were <28 kg in men and <18 kg in women [1].

2.3.2 Physical performance

This study measured physical performance by gait speed and 5-time chair stand test. In the CHARLS, researchers recorded the number of seconds the participants took to walk 2.5 meters [22], and we converted it to gait speed (m/s). 5-time chair stand test needed the participants to keep their arms folded across their chest, stand up straight and then sit down again five times [22], and the number of seconds they spent was recorded. According to the AWGS 2019, gait speed <1.0 m/s or 5-time chair stand test ≥12 seconds was regarded as low physical performance [1]. In our analysis, participants who tried but failed to perform either of the tests were also considered to have low physical performance.

2.3.3 Skeletal muscle mass measurement

Based on the AWGS 2019, the muscle mass was estimated by the appendicular skeletal muscle mass (ASM). In this study, we used a previously validated anthropometric equation in a Chinese population to calculate the ASM [25]:

$$\boldsymbol{ASM = 0.193 \times body\ weight + 0.107 \times height - 4.157 \times sex - 0.037 \times age - 2.631}$$

The body weight, height, and age were measured in kilograms, centimeters, and years, respectively. For sex, the value 1 was for men and the value 2 was for women.

As the parameter to assess muscle mass in our study, the height-adjusted muscle mass was calculated as the ASM divided by the square of the height in meters (ASM/height^2). Following previous studies [26], the cut-off points for low muscle mass were the lowest 20% of the height-adjusted muscle mass among our study population. Finally, the ASM/height^2 values of <6.99 kg/m2 in men and <5.24 kg/m2 in women were considered low muscle mass.

2.4 Statistical analysis

In this study, statistical analyses were performed based on different genders. Continuous variables with normal distribution were described as mean ± standard deviation (SD), while with non-normal distribution as median [interquartile range (IQR)]. Categorical variables are expressed as frequencies and proportions. First, differences in baseline characteristics among the three groups (no sarcopenia, possible sarcopenia, and sarcopenia) were compared using one-way ANOVA, chi-square test, Fisher's exact test, or Kruskal–Wallis test, as appropriate. Second, ordinal logistic regression analysis was used to assess the association between TG/HDL-C ratio and

sarcopenia status. Four different models were introduced: Model 1, without adjustment; Model 2, adjusted for median age; Model 3, additionally adjusted for residence, education level, and history of smoking and drinking; and Model 4, additionally adjusted for overweight, diabetes management, SBP, DBP, plasma glucose, HbA1c, TC, LDL-C, hs-CRP, uric acid, and eGFR. Third, linear regression analysis was used to estimate the associations between TG/HDL-C ratio and muscle strength, physical performance, and muscle mass, respectively, with or without adjustment for covariates. The main variable was serum TG/HDL-C, categorized and analyzed according to quartile. In all cases, two-sided p values <0.05 were considered statistically significant. All analyses were carried out with Stata 17.0 (StataCorp, College Station, TX, USA).

3. Results

3.1 Baseline

Table 1 showed the baseline characteristics of male elderly patients with diabetes according to sarcopenia status in our study. There were 29 (7.9%) male participants without sarcopenia, 268 (72.8%) with possible sarcopenia, and 71 (19.3%) with sarcopenia. There were significant differences among the three groups concerning the following continuous variables: age (P<0.001), BMI (P<0.001), SBP (P=0.011), DBP (P=0.007), HbA1c (P=0.007), TC (P=0.006), TG (P=0.001), LDL-C (P=0.002), HDL-C (P<0.001), uric acid (P=0.024), and TG/HDL-C ratio (P<0.001). The levels of plasma glucose (P=0.763), hs-CRP (P=0.470), and eGFR (P=0.349) showed no

significant difference among the different sarcopenia status. The distributions of median age (P=0.001), residence (P=0.001), overweight (P=0.349), awareness of diabetes (P=0.038), and TG/HDL-C ratio (P<0.001) showed significant differences among the three groups. There was no significant difference among the classifications of sarcopenia with respect to the proportions of education level (P=0.119), treatment of diabetes (P=0.072), and history of smoking (P=0.384) and drinking (P=0.099).

The baseline characteristics of female elderly patients with diabetes were presented in Table 2 according to sarcopenia status. In this study, 20 (5.2%) female participants were defined as having no sarcopenia, 289 (75.3%) as possible sarcopenia, and 75 (19.5%) as sarcopenia. The levels of age (P<0.001), BMI (P<0.001), HbA1c (P=0.002), TG (P<0.001), HDL-C (P<0.001), hs-CRP (P=0.009), uric acid (P=0.001), and TG/HDL-C ratio (P <0.001) showed significant differences among the three groups. There was no significant difference among the grades of sarcopenia about SBP (P=0.621), DBP (P=0.337), plasma glucose (P=0.205), TC (P=0.389), LDL-C (P=0.629), and eGFR (P=0.090). Among the three groups, the proportions of median age (P=0.021), residence (P<0.001), education level (P=0.032), overweight (P<0.001), awareness (P<0.001) and treatment (P=0.008) of diabetes, and TG/HDL-C ratio (P<0.001) showed significant differences. There was no significant difference with respect to the distributions of history of smoking (P=1.000) and drinking (P=0.068) among them.

The detailed data were shown in Table 1 and Table 2.

3.2 Association between TG/HDL-C ratio and sarcopenia

Compared with male participants with quartile 1 of TG/HDL-C ratio (≤1.41), those with quartile 2 (1.42-2.35; OR 0.49, 95% CI 0.26 to 0.92, P=0.027), 3 (2.36-4.71; OR 0.36, 95% CI 0.19 to 0.69, P=0.002), and 4 (>4.71; OR 0.18, 95% CI 0.09 to 0.35, P<0.001) of TG/HDL-C ratio had reduced odds ratio of more severe sarcopenia in the unadjusted ordinal logistic regression (Model 1), respectively. In the multi-variable-adjusted model (Model 4), compared with male participants with quartile 1 of TG/HDL-C ratio (≤1.41), those with quartile 2 (1.42-2.35; OR 0.48, 95% CI 0.24 to 0.97, P=0.042) and 4 (>4.71; OR 0.24, 95% CI 0.10 to 0.54, P=0.001) of TG/HDL-C ratio were associated with lower risk of more severe sarcopenia, respectively.

Similarly, compared with female participants with quartile 1 of TG/HDL-C ratio (≤2.07), those with quartile 2 (2.08-3.26; OR 0.24, 95% CI 0.12 to 0.46, P<0.001), 3 (3.27-5.61; OR 0.36, 95% CI 0.13 to 0.50, P<0.001), and 4 (>5.61; OR 0.17, 95% CI 0.08 to 0.33, P<0.001) of TG/HDL-C ratio were associated with depressed risk of more severe sarcopenia, in the unadjusted ordinal logistic regression (Model 1), respectively. The multi-variable-adjusted model (Model 4) showed that female participants with quartile 2 (2.08-3.26; OR 0.38, 95% CI 0.17 to 0.83, P=0.015), 3 (3.27-5.61; OR 0.26, 95% CI 0.12 to 0.57, P=0.001), and 4 (>5.61; OR 0.17, 95% CI 0.07 to 0.44, P<0.001) of TG/HDL-C ratio had reduced risk of more severe

sarcopenia, respectively, compared with those with quartile 1 of TG/HDL-C ratio (≤2.07).

Other adjusted models, Model 2 and Model 3, were shown in Table 3 and Table 4.

3.3 Associations between TG/HDL-C ratio and components of sarcopenia

Among male participants, simple and multivariate linear regression analysis showed that TG/HDL-C ratio categorized by quartile had no statistical correlation with handgrip strength and gait speed. In terms of the 5-time chair stand test, compared with quartile 1 of TG/HDL-C ratio (≤1.41), quartile 4 of TG/HDL-C ratio (>4.71) was associated with long chair-rising time in simple (β=1.54, 95% CI 0.30 to 2.78, P=0.015) and multivariate (β=2.60, 95% CI 1.19 to 4.00, P<0.001) linear regression. Yet simple and multivariate linear regression analysis showed that TG/HDL-C ratio categorized by quartile had a statistical correlation with muscle mass. In multivariate linear regression analysis, compared with quartile 1 of TG/HDL-C ratio (≤1.41), quartile 2 (1.42-2.35; β=0.18, 95% CI 0.04 to 0.32, P=0.009), 3 (2.36-4.71; β=0.18, 95% CI 0.03 to 0.32, P=0.016), and 4 (>4.71; β=0.36, 95% CI 0.20 to 0.51, P<0.001) of TG/HDL-C ratio had associations with high height-adjusted muscle mass (ASM/height^2), respectively.

Unlike male participants, compared with female participants with quartile 1 of TG/HDL-C ratio (≤2.07), those with quartile 4 of TG/HDL-C ratio (>5.61) were associated with high handgrip strength in simple (β=3.16, 95% CI 0.78 to 5.54, P=0.009) and multivariate (β=3.93, 95% CI 0.89 to 6.97, P=0.011) linear regression.

Yet there was no statistical correlation between TG/HDL-C ratio and gait speed, and the 5-time chair stand test. Similar to male participants, TG/HDL-C ratio categorized by quartile was correlated with muscle mass in linear regression analysis among female participants. In multivariate linear regression analysis, compared with quartile 1 of TG/HDL-C ratio (≤2.07), quartile 2 (2.08-3.26; β=0.30, 95% CI 0.12 to 0.47, P=0.001), 3 (3.27-5.61; β=0.28, 95% CI 0.11 to 0.45, P=0.001), and 4 (>5.61; β=0.31, 95% CI 0.10 to 0.51, P=0.003) of TG/HDL-C ratio had associations with high height-adjusted muscle mass (ASM/height^2), respectively.

Other detailed data were shown in Table 5.

4. Discussion

In this cohort, we found a negative association between TG/HDL-C ratio categorized by quartile and sarcopenia, which means that higher TG/HDL-C ratio may be associated with better muscle status. Unlike previous studies [20,21], this study focused on elderly patients with diabetes from China, a supplement to existing studies' populations and conclusions. In addition, our group further analyzed the correlation between TG/HDL-C ratio and specific components of sarcopenia, including muscle strength, physical performance, and muscle mass. Then, we found the results as followed for the first time: first, compared with the lowest quartile of TG/HDL-C ratio (≤1.41), the highest quartile of TG/HDL-C ratio (>4.71) was associated with long chair-rising time among male elderly diabetics; second, compared with the lowest quartile of TG/HDL-C ratio (≤2.07), the highest quartile of

TG/HDL-C ratio (>5.61) was associated with high handgrip strength among female elderly diabetics; third, high TG/HDL-C ratio categorized by quartile was correlated with increased muscle mass in both sexs. The above findings further explained that as a widely and rapidly accessible lipid parameter, TG/HDL-C ratio had concrete interactions with sarcopenia.

Consistent with the previous finding in community-dwelling Chinese populations [21], this study showed that higher TG/HDL-C ratio was associated with a lower risk of more severe sarcopenia in older men and women with diabetes. This finding was contrary to the Korean male study [20]. As previous researchers mentioned, study design, gene diversity, and lifestyle factors in different populations led to variations in lipid profiles [21]. Therefore, TG/HDL-C ratio, as an easily accessible lipid indicator, would be considered a risk factor for sarcopenia in elderly Chinese patients with diabetes.

It is noted that there was gender differences in the association between TG/HDL-C ratio and partial muscle functions of elderly diabetics in our study. Only among male elderly diabetics, we found that patients with the highest quartile of TG/HDL-C ratio (>4.71) had longer chair-rising time than those with the lowest (≤1.41). The other study using the CHARLS database also found similar results in the measurement of physical performance in participants with prediabetes (≥45 years) [27]. This finding contradicted the main result, but the reason was unclear [27]. Then, we found that patients with the highest quartile of TG/HDL-C ratio (>5.61) showed higher muscle

strength than those with the lowest (≤2.07), only among female elderly diabetics. Previous studies have investigated the correlations between various metabolic indexes and sarcopenia in different cohorts and found that their effects had sex differences [28]. More detailed researches may help us understand this phenomenon in the future.

Conversely, the associations between TG/HDL-C ratio and muscle mass of elderly diabetics in different genders were consistent in this study. Regardless of gender, we found that high quartile of TG/HDL-C ratio was correlated with increased muscle mass. At present, AWGS 2019 recommends using dual-energy X-ray absorptiometry (DXA) or multifrequency bioelectrical impedance analysis (BIA) for measuring muscle mass in sarcopenia diagnosis [1]. Our findings suggest that TG/HDL-C ratio can be used as a relatively simple screening indicator for muscle mass and help clinicians identify elderly diabetics at high risk of muscle mass deficiency.

In general, in addition to proposing an easily accessible parameter for screening sarcopenia in elderly diabetic patients, we try to provide ideas for the prevention and treatment of sarcopenia in people with diabetes. Recently, sarcopenia has been implicated as both a cause and consequence of diabetes [10,11]. However, there was insufficient evidence for treatment recommendations for diabetic patients with sarcopenia, including nutritional supplements, dietary advice, and planned exercise [10]. Therefore, future intervention studies (suitable TG supplementation and HDL-C control) for diabetic patients with sarcopenia can further investigate the interactions

between lipid profile and sarcopenia and provide others evidence for the prevention and treatment of sarcopenia.

There are several limitations of our study. First, causality and mechanism could not be determined due to this cross-sectional study. Second, this study only involved elderly patients with diabetes from the CHARLS, which may also have resulted in selection bias. Third, the type of diabetes was uncertain because the diagnosis of diabetes was based on self-report, and measurement of blood glucose and HbA1c. Fourth, multiple comorbidities and history of drug using were not included in the analysis, and future studies need to take more considerations for them in clinical practice. Fifth, instead of the AWGS 2019 recommendation, we used a previously validated anthropometric equation to assess the muscle mass, which may also have led to measurement bias.

5. Conclusions

In conclusion, there was a negative association between TG/HDL-C ratio categorized by quartile and sarcopenia, which means that higher TG/HDL-C ratio may be related to better muscle status. Future prospective and intervention studies were needed to be investigated the relationship between lipid profiles and the occurrence, prevention, and treatment of sarcopenia.

6. Declarations

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions

YL contributed to the study concept and design, data acquisition and analysis, and drafted the manuscript. SZ contributed to revising the manuscript. ZS contributed to providing technical and material support. ZS also contributed to the supervision of this study. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The CHARLS protocol was conducted following the Declaration of Helsinki and approved by the Biomedical Ethical Review Committee of Peking University (IRB00001052-11015). All participants provided written informed consent.

Availability of data and materials

The CHARLS datasets are available on request from their home page at http://charls.pku.edu.cn/.

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Table 1. Baseline characteristics of male elderly patients with diabetes according to sarcopenia status.

Variables	Total (n=368)	No sarcopenia (n=29)	Possible sarcopenia (n=268)	Sarcopenia (n=71)	*P*-value
Age (years)	66.0 (62.0, 72.0)	64.0 (62.0, 68.0)	65.0 (62.0, 70.0)	71.0 (65.0, 77.0)	<0.001
≤Median		19 (65.5)	155 (57.8)	24 (33.8)	0.001
>Median		10 (34.5)	113 (42.2)	47 (66.2)	
Handgrip strength (kg)	34.5 (28.5, 40.5)	41.5 (36.5, 45.0)	35.0 (29.8, 41.0)	29.0 (21.0, 33.5)	<0.001
Gait speed (m/s)[a]	0.66 (0.52, 0.79)	1.10 (1.04, 1.18)	0.64 (0.52, 0.78)	0.62 (0.49, 0.71)	<0.001
5-time chair stand test (s)[a]	10.5 (8.8, 13.2)	9.5 (6.9, 19.5)	10.3 (8.6, 13.0)	11.9 (9.6, 14.0)	<0.001
ASM/Ht^2 (kg/m^2)	7.61 (7.10, 8.16)	7.71 (7.47, 8.41)	7.84 (7.40, 8.24)	6.71 (6.44, 6.87)	<0.001
Residence (%)					
Urban	150 (40.8)	13 (44.8)	122 (45.5)	15 (21.1)	0.001
Rural	218 (59.2)	16 (55.2)	146 (54.5)	56 (78.9)	

Education (%)					
Less than lower secondary	338 (91.8)	25 (86.3)	244 (91.0)	69 (97.2)	
Upper secondary or vocational training	15 (4.1)	1 (3.4)	12 (4.5)	2 (2.8)	0.119
Tertiary	15 (4.1)	3 (10.3)	12 (4.5)	0 (0)	
Ever/current smoke (%)[a]	270 (73.8)	20 (69.0)	194 (72.7)	56 (80.0)	0.384
Ever/current drinking (%)[a]	236 (64.7)	18 (62.1)	165 (62.0)	53 (75.7)	0.099
BMI (kg/m^2)	23.7 (21.1, 26.2)	24.2 (22.3, 27.8)	24.6 (22.5, 26.8)	19.1 (17.8, 19.9)	<0.001
Overweight (%)	131 (35.6)	12 (41.4)	119 (44.4)	0 (0)	<0.001
Blood pressure (mm Hg)[a]					
Systolic	135.5 (124.5, 147.0)	130.0 (124.0, 136.0)	138.0 (125.0, 149.5)	132.5 (121.0, 145.0)	0.011
Diastolic	75.5 (68.5, 82.5)	74.0 (68.5, 81.0)	76.5 (70.0, 83.5)	73.5 (63.5, 79.0)	0.007
Diabetes management (%)					

Awareness	139 (37.8)	14 (48.3)	107 (39.9)	18 (25.4)	0.038
Unawareness	229 (62.2)	15 (51.7)	161 (60.1)	53 (74.6)	
Treatment	94 (25.5)	11 (37.9)	71 (26.5)	12 (16.9)	0.072
Untreatment	274 (74.5)	18 (62.1)	197 (73.5)	59 (83.1)	
Plasma glucose (mg/dL)[b]	138.7 (126.4, 175.2)	139.9 (126.4, 197.5)	139.1 (126.4, 175.2)	137.3 (126.4, 175.0)	0.763
HbA1c (%)	5.6 (5.1, 6.9)	6.2 (5.3, 7.7)	5.6 (5.2, 7.1)	5.3 (5.0, 5.9)	0.007
TC (mg/dL)	186.5 (160.8, 213.2)	174.4 (156.6, 190.3)	190.8 (165.5, 216.1)	171.7 (149.2, 202.6)	0.006
TG (mg/dL)	111.1 (78.8, 172.1)	121.2 (82.3, 187.6)	115.1 (82.3, 185.0)	88.5 (67.3, 130.1)	0.001
LDL-C (mg/dL)[a]	109.1±35.4	108.3±30.6	111.9±36.2	98.9±32.5	0.002
HDL-C (mg/dL)	45.6 (37.1, 57.2)	40.6 (33.2, 48.3)	44.7 (34.6, 55.1)	53.0 (44.1, 66.9)	<0.001
hs-CRP (mg/L)	1.33 (0.72, 3.13)	1.80 (0.77, 4.00)	1.38 (0.73, 3.01)	1.10 (0.68, 3.68)	0.470
Uric acid (mg/dL)	4.88 (4.08, 5.85)	4.27 (3.73, 5.20)	4.99 (4.19, 6.00)	4.70 (3.91, 5.40)	0.024

eGFR (mL/min/1.73 m^2)	88.9 (74.0, 96.3)	94.2 (73.9, 99.2)	88.1 (74.3, 95.9)	88.9 (72.8, 95.7)	0.349
TG/HDL-C	2.35 (1.41, 4.71)	3.73 (1.91, 6.51)	2.55 (1.59, 4.97)	1.49 (1.10, 2.48)	<0.001
Quartile 1 (≤1.41)		4 (13.8)	56 (20.9)	32 (45.1)	
Quartile 2 (1.42-2.35)		6 (20.7)	67 (25.0)	19 (26.8)	
Quartile 3 (2.36-4.71)		8 (27.6)	69 (25.7)	15 (21.1)	<0.001
Quartile 4 (>4.71)		11 (37.9)	76 (28.4)	5 (7.0)	

Data are shown as means ± standard deviation, median (interquartile range), or numbers (percentages).

a. Missing data: 15 for gait speed, 11 for 5-time chair stand test, 2 for history of smoking, 3 for history of drinking, 5 for blood pressure and 1 for LDL-C.

b. Among the measurements of plasma glucose, 17 male participants were non-fasting.

Abbreviations: ASM/Ht^2 : the height-adjusted muscle mass; BMI: the body mass index; HbA1c: glycated hemoglobin; TC: total cholesterol; TG: triglyceride; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol ratio; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate; TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio.

Table 2. Baseline characteristics of female elderly patients with diabetes according to sarcopenia status.

Variables	Total (n=384)	No sarcopenia (n=20)	Possible sarcopenia (n=289)	Sarcopenia (n=75)	*P*-value
Age (years)	67.0 (63.0, 71.5)	63.0 (61.0, 66.5)	66.0 (62.0, 71.0)	69.0 (65.0, 75.0)	<0.001
≤Median		16 (80.0)	167 (57.8)	35 (46.7)	0.021
>Median		4 (20.0)	122 (42.2)	40 (53.3)	
Handgrip strength (kg)	22.8 (18.0, 27.5)	27.8 (24.6, 32.3)	23.5 (18.5, 28.0)	19.8 (16.0, 23.0)	<0.001
Gait speed (m/s)[a]	0.63 (0.47, 0.76)	1.10 (1.03, 1.17)	0.63 (0.47, 0.75)	0.58 (0.46, 0.69)	<0.001
5-time chair stand test (s)[a]	11.3 (9.1, 14.5)	7.9 (7.3, 8.7)	11.6 (9.4, 14.8)	11.4 (9.4, 14.7)	<0.001
ASM/Ht^2 (kg/m^2)	5.89 (5.38, 6.55)	6.28 (5.55, 6.57)	6.16 (5.71, 6.72)	4.90 (4.67, 5.06)	<0.001
Residence (%)					
Urban	170 (44.3)	15 (75.0)	135 (46.7)	20 (26.7)	<0.001
Rural	214 (55.7)	5 (25.0)	154 (53.3)	55 (73.3)	

Education (%)					
Less than lower secondary	367 (95.6)	17 (85.0)	276 (95.5)	74 (98.7)	
Upper secondary or vocational training	13 (3.4)	2 (10.0)	11 (3.8)	0 (0)	0.032
Tertiary	4 (1.0)	1 (5.0)	2 (0.7)	1 (1.3)	
Ever/current smoke (%)[a]	33 (8.6)	1 (5.0)	26 (9.0)	6 (8.1)	1.000
Ever/current drinking (%)[a]	59 (15.4)	0 (0)	50 (17.4)	9 (12.2)	0.068
BMI (kg/m^2)	24.7 (22.0, 27.6)	25.5 (22.2, 26.4)	25.6 (23.5, 28.0)	19.7 (18.6, 20.9)	<0.001
Overweight (%)	176 (45.8)	11 (55.0)	164 (56.7)	1 (1.3)	<0.001
Blood pressure (mm Hg)[a]					
Systolic	140.0 (123.5, 155.0)	133.3 (126.0, 150.5)	140.5 (124.0, 155.5)	138.0 (119.0, 154.5)	0.621
Diastolic	75.5 (67.0, 83.0)	73.0 (67.5, 82.5)	76.0 (67.5, 83.5)	74.5 (65.0, 80.5)	0.337
Diabetes management (%)					

Awareness	166 (43.2)	8 (40.0)	142 (49.1)	16 (21.3)	<0.001
Unawareness	218 (56.8)	12 (60.0)	147 (50.9)	59 (78.7)	
Treatment	104 (27.1)	5 (25.0)	89 (30.8)	10 (13.3)	0.008
Untreatment	280 (72.9)	15 (75.0)	200 (69.2)	65 (86.7)	
Plasma glucose (mg/dL)[b]	141.2 (126.5, 177.7)	134.2 (106.0, 160.3)	142.7 (127.1, 179.8)	138.2 (127.6, 173.2)	0.205
HbA1c (%)	6.0 (5.4, 6.9)	5.9 (5.3, 7.0)	6.1 (5.5, 7.1)	5.6 (5.2, 6.5)	0.002
TC (mg/dL)	205.5 (178.6, 230.5)	233.8 (178.1, 259.1)	204.9 (176.7, 229.3)	208.4 (184.4, 236.2)	0.389
TG (mg/dL)	146.5 (106.2, 222.1)	164.6 (135.4, 250.9)	152.2 (112.4, 229.2)	108.0 (80.5, 162.8)	<0.001
LDL-C (mg/dL)[a]	122.0±40.5	129.6±44.0	120.9±41.4	124.3±36.3	0.629
HDL-C (mg/dL)	45.2 (37.5, 53.0)	43.9 (37.7, 52.6)	42.9 (37.1, 51.4)	52.2 (43.3, 62.6)	<0.001
hs-CRP (mg/L)	1.60 (0.80, 3.53)	1.95 (1.02, 2.78)	1.73 (0.90, 3.80)	1.08 (0.59, 2.60)	0.009
Uric acid (mg/dL)	4.33 (3.58, 5.21)	5.22 (3.88, 6.01)	4.35 (3.67, 5.24)	3.78 (3.25, 4.74)	0.001

eGFR (mL/min/1.73 m^2)	62.7 (45.5, 95.0)	93.4 (52.9, 97.4)	57.1 (45.2, 93.9)	84.7 (45.5, 95.5)	0.090
TG/HDL-C	3.26 (2.07, 5.61)	4.06 (2.63, 6.62)	3.45 (2.35, 5.99)	2.02 (1.20, 4.27)	<0.001
Quartile 1 (≤2.07)	95 (24.7)	4 (20.0)	51 (17.6)	40 (53.3)	
Quartile 2 (2.08-3.26)	98 (25.5)	4 (20.0)	82 (28.4)	12 (16.0)	
Quartile 3 (3.27-5.61)	95 (24.7)	6 (30.0)	74 (25.6)	15 (20.0)	<0.001
Quartile 4 (>5.61)	96 (25.0)	6 (30.0)	82 (28.4)	8 (10.7)	

Data are shown as means ± standard deviation, median (interquartile range), or numbers (percentages).

a. Missing data: 23 for gait speed, 32 for 5-time chair stand test, 1 for history of smoking, 2 for history of drinking, 9 for blood pressure and 4 for LDL-C.

b. Among the measurements of plasma glucose, 22 female participants were non-fasting.

Abbreviations: ASM/Ht^2 : the height-adjusted muscle mass; BMI: the body mass index; HbA1c: glycated hemoglobin; TC: total cholesterol; TG: triglyceride; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol ratio; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate; TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio.

Table 3. Association between TG/HDL-C and sarcopenia status in male elderly patients with diabetes in ordinal logistic regression analysis.

Variables	No sarcopenia (n=29)	Possible sarcopenia (n=268)	Sarcopenia (n=71)	OR (95% CI) Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
TG/HDL-C							
Quartile 1 (≤1.41)	4 (13.8)	56 (20.9)	32 (45.1)	Reference	Reference	Reference	Reference
Quartile 2 (1.42-2.35)	6 (20.7)	67 (25.0)	19 (26.8)	0.49 (0.26, 0.92)*	0.47 (0.25, 0.88)*	0.50 (0.26, 0.96)*	0.48 (0.24, 0.97)*
Quartile 3 (2.36-4.71)	8 (27.6)	69 (25.7)	15 (21.1)	0.36 (0.19, 0.69)**	0.33 (0.17, 0.65)**	0.41 (0.20, 0.80)**	0.56 (0.27, 1.17)
Quartile 4 (>4.71)	11 (37.9)	76 (28.4)	5 (7.0)	0.18 (0.09, 0.35)***	0.18 (0.09, 0.37)***	0.24 (0.12, 0.49)***	0.24 (0.10, 0.54)**

a. Unadjusted (n=368).

b. Adjusted for median age (n=368).

c. Adjusted for median age, residence, education level, and history of smoking and drinking (n=365).

d. Adjusted for median age, residence, education level, and history of smoking and drinking, overweight, diabetes management, SBP, DBP, plasma glucose, HbA1c, TC, LDL-C, hs-CRP, uric acid, and eGFR (n=359).

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Abbreviations: TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio; OR: odds ratio; 95% CI: 95% confidence interval; SBP: systolic blood pressure; DBP: diastolic blood pressure; HbA1c: glycated hemoglobin; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate.

Table 4. Association between TG/HDL-C and sarcopenia status in female elderly patients with diabetes in ordinal logistic regression analysis.

Variables	No sarcopenia (n=20)	Possible sarcopenia (n=289)	Sarcopenia (n=75)	OR (95% CI) Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
TG/HDL-C							
Quartile 1 (≤2.07)	4 (20.0)	51 (17.6)	40 (53.3)	Reference	Reference	Reference	Reference
Quartile 2 (2.08-3.26)	4 (20.0)	82 (28.4)	12 (16.0)	0.24 (0.12, 0.46)***	0.23 (0.12, 0.45)***	0.28 (0.14, 0.56)***	0.38 (0.17, 0.83)*
Quartile 3 (3.27-5.61)	6 (30.0)	74 (25.6)	15 (20.0)	0.36 (0.13, 0.50)***	0.25 (0.13, 0.49)***	0.26 (0.13, 0.50)***	0.26 (0.12, 0.57)**
Quartile 4 (>5.61)	6 (30.0)	82 (28.4)	8 (10.7)	0.17 (0.08, 0.33)***	0.17 (0.09, 0.34)***	0.18 (0.09, 0.37)***	0.17 (0.07, 0.44)***

a. Unadjusted (n=384).

b. Adjusted for median age (n=384).

c. Adjusted for median age, residence, education level, and history of smoking and drinking (n=382).

d. Adjusted for median age, residence, education level, and history of smoking and drinking, overweight, diabetes management, SBP, DBP, plasma glucose, HbA1c, TC, LDL-C, hs-CRP, uric acid, and eGFR (n=368).

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Abbreviations: TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio; OR: odds ratio; 95% CI: 95% confidence interval; SBP: systolic blood pressure; DBP: diastolic blood pressure; HbA1c: glycated hemoglobin; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate.

Table 5. Associations between TG/HDL-C and muscle strength, physical performance, and muscle mass among elderly patients with diabetes in linear regression analysis.

Male			Female		
	β (95% CI)			β (95% CI)	
Variables	Simple linear regression	Multivariate linear regression[a]	Variables	Simple linear regression	Multivariate linear regression[a]
Handgrip strength (kg)			Handgrip strength (kg)		
TG/HDL-C			TG/HDL-C		
Quartile 1 (≤1.41)	Reference	Reference	Quartile 1 (≤2.07)	Reference	Reference
Quartile 2 (1.42-2.35)	-0.69 (-3.32, 1.93)	-0.88 (-3.47, 1.71)	Quartile 2 (2.08-3.26)	1.67 (-0.70, 4.04)	1.50 (-1.09, 4.09)
Quartile 3 (2.36-4.71)	1.05 (-1.58, 3.68)	-0.05 (-2.78, 2.67)	Quartile 3 (3.27-5.61)	1.28 (-1.10, 3.67)	1.77 (-0.80, 4.34)
Quartile 4 (>4.71)	2.23 (-0.40, 4.86)	-0.92 (-3.84, 2.00)	Quartile 4 (>5.61)	3.16 (0.78, 5.54)**	3.93 (0.89, 6.97)*
Gait speed (m/s)			Gait speed (m/s)		

TG/HDL-C		
Quartile 1 (≤1.41)	Reference	Reference
Quartile 2 (1.42-2.35)	-0.017 (-0.089, 0.056)	0.001 (-0.074, 0.076)
Quartile 3 (2.36-4.71)	-0.072 (-1.452, 0.001)	-0.046 (-0.126, 0.033)
Quartile 4 (>4.71)	0.009 (-0.064, 0.081)	0.015 (-0.070, 0.100)
5-time chair stand test (s)		
TG/HDL-C		
Quartile 1 (≤1.41)	Reference	Reference
Quartile 2 (1.42-2.35)	1.03 (-0.22, 2.27)	1.09 (-0.16, 2.33)
Quartile 3 (2.36-4.71)	0.95 (-0.30, 2.20)	1.04 (-0.29, 2.36)
Quartile 4 (>4.71)	1.54 (0.30, 2.78)**	2.60 (1.19, 4.00)***
ASM/Ht^2 (kg/m^2)		

TG/HDL-C		
Quartile 1 (≤2.07)	Reference	Reference
Quartile 2 (2.08-3.26)	0.025 (-0.039, 0.089)	0.008 (-0.059, 0.075)
Quartile 3 (3.27-5.61)	0.009 (-0.056, 0.074)	0.013 (-0.054, 0.079)
Quartile 4 (>5.61)	0.047 (-0.018, 0.113)	0.060 (-0.020, 0.139)
5-time chair stand test (s)		
TG/HDL-C		
Quartile 1 (≤2.07)	Reference	Reference
Quartile 2 (2.08-3.26)	0.16 (-1.34, 1.65)	-0.13 (-1.73, 1.47)
Quartile 3 (3.27-5.61)	0.51 (-1.01, 2.03)	-0.13 (-1.71, 1.46)
Quartile 4 (>5.61)	-0.41 (-1.93, 1.10)	-0.50 (-2.37, 1.36)
ASM/Ht^2 (kg/m^2)		

TG/HDL-C			TG/HDL-C		
Quartile 1 (≤1.41)	Reference	Reference	Quartile 1 (≤2.07)	Reference	Reference
Quartile 2 (1.42-2.35)	0.24 (0.15, 0.47)*	0.18 (0.04, 0.32)**	Quartile 2 (2.08-3.26)	0.65 (0.41, 0.88)***	0.30 (0.12, 0.47)**
Quartile 3 (2.36-4.71)	0.58 (0.36, 0.81)***	0.18 (0.03, 0.32)*	Quartile 3 (3.27-5.61)	0.59 (0.35, 0.82)***	0.28 (0.11, 0.45)**
Quartile 4 (>4.71)	0.81 (0.59, 1.04)***	0.36 (0.20, 0.51)***	Quartile 4 (>5.61)	0.67 (0.43, 0.90)***	0.31 (0.10, 0.51)**

a. Adjusted for median age, residence, education level, and history of smoking and drinking, overweight, diabetes management, SBP, DBP, plasma glucose, HbA1c, TC, LDL-C, hs-CRP, uric acid, and eGFR.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Abbreviations: TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio; 95% CI: 95% confidence interval; ASM/Ht^2: the height-adjusted muscle mass; SBP: systolic blood pressure; DBP: diastolic blood pressure; HbA1c: glycated hemoglobin; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-11
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-11
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6-11
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	6-11
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-11
Bias	9	Describe any efforts to address potential sources of bias	6-11
Study size	10	Explain how the study size was arrived at	6-11
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-11
		(*b*) Describe any methods used to examine subgroups and interactions	6-11
		(*c*) Explain how missing data were addressed	6-11
		(*d*) If applicable, explain how loss to follow-up was addressed	6-11
		(*e*) Describe any sensitivity analyses	6-11
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11-15
		(b) Give reasons for non-participation at each stage	11-15
		(c) Consider use of a flow diagram	11-15
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-15
		(b) Indicate number of participants with missing data for each variable of interest	11-15
		(c) Summarise follow-up time (eg, average and total amount)	11-15
Outcome data	15*	Report numbers of outcome events or summary measures over time	11-15

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-15
		(*b*) Report category boundaries when continuous variables were categorized	11-15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-15
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-15
Discussion			
Key results	18	Summarise key results with reference to study objectives	15-18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-18
Generalisability	21	Discuss the generalisability (external validity) of the study results	18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18-19

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Association between serum triglyceride to high-density lipoprotein cholesterol ratio and sarcopenia among elderly patients with diabetes: A secondary data analysis of the China Health and Retirement Longitudinal Study

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Title Page

Article Title: Association between serum triglyceride to high-density lipoprotein cholesterol ratio and sarcopenia among elderly patients with diabetes: A secondary data analysis of the China Health and Retirement Longitudinal Study

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Abstract

Objective: Previous studies investigating the association between the serum triglyceride to high-density lipoprotein cholesterol (TG/HDL-C) ratio and the occurrence of sarcopenia in different populations have yielded inconsistent results. This study aimed to investigate the potential association between TG/HDL-C ratio and sarcopenia among elderly Chinese patients with diabetes.

Design: A secondary data analysis.

Setting: This was a secondary analysis of data from the China Health and Retirement Longitudinal Study (CHARLS).

Participants: In this study, 752 elderly individuals with diabetes were included after excluding individuals aged <60 years old, those with missing data for the assessment of sarcopenia, and missing measurements for plasma glucose or glycated hemoglobin.

Outcome measures: The primary information included TG/HDL-C ratio, muscle strength, physical performance, muscle mass, and covariables. The association between TG/HDL-C ratio and sarcopenia was assessed using ordinal logistic regression and linear regression analysis..

Results: On multivariate ordinal logistic regression, among male patients, compared to those with the lowest quartile of TG/HDL-C ratio (≤1.41), those with the highest quartile (>4.71) had a significantly lower risk of more severe sarcopenia (odds ratio [OR] 0.24, 95% confidence interval [CI] 0.10–0.54). Similarly, among female

patients, compared to those with the lowest quartile of TG/HDL-C ratio (≤2.07), those with the highest quartile (>5.61) had a significantly lower risk of more severe sarcopenia (OR 0.17, 95% CI 0.07–0.44). In multivariate linear regression, male patients with the highest quartile of TG/HDL-C ratio (β=0.36, 95% CI 0.20–0.51) had higher muscle mass than those with the lowest quartile. Similarly, female patients with the highest quartile of TG/HDL-C ratio (β=0.31, 95% CI 0.10–0.51) had higher muscle mass than those with the lowest quartile.

Conclusions: There was a negative association between TG/HDL-C ratio categorized by quartile and sarcopenia, which indicates that a higher TG/HDL-C ratio may be related to better muscle status.

Keywords: sarcopenia; triglyceride; high-density lipoprotein cholesterol; diabetes; elderly patient.

Strengths and limitations of this study

1. We investigated on the correlation between lipid profile and the various parameters for the assessment of sarcopenia (muscle strength, physical performance, and muscle mass) in elderly patients with diabetes.

2. Unlike previous studies, this study focused on elderly Chinese patients with diabetes, supplementing the existing literature on this subject.

3. The cross-sectional study design does not permit causal inferences.

4. The type of diabetes was uncertain because the diagnosis of diabetes was based on self-report and measurement of blood glucose and HbA1c.

1. Introduction

Sarcopenia is a syndrome characterized by age-related loss of muscle mass, along with low muscle strength and/or inadequate physical performance [1]. The condition increases the risk of various adverse outcomes, including falls, physical limitations, frailty, hospitalization, and mortality [2-7]. According to a previous study, the prevalence of sarcopenia ranges from 1% to 29% in community-dwelling populations and 14 to 33% in individuals requiring long-term care [8]. Recently, various working groups have updated their consensus criteria to identify sarcopenia based on the combination of loss of muscle strength, function, and mass [1,4]. However, in routine clinical practice, most clinicians remain unaware of the condition and its diagnostic strategies [3].

Diabetes mellitus and sarcopenia have a bidirectional relationship [9,10]. In elderly patients with diabetes, decline in exercise capacity has been recognized as a new complication [11]. Conversely, because skeletal muscle plays an important role in insulin-mediated glucose disposal, sarcopenia may increase the risk of diabetes in older people [9]. Serum triglyceride to high-density lipoprotein cholesterol ratio (TG/HDL-C), a combination of lipid metabolic indicators, has been found to be associated with insulin resistance [12-14]. Therefore, recent studies have investigated TG/HDL-C ratio as a potential screening marker for sarcopenia; however, the TG/HDL-C ratio has shown an inconsistent association with the occurrence of sarcopenia in elderly Korean men and community-dwelling Chinese adults [15,16]. In

consequence, the relevant conclusion cannot be extrapolated to elderly patients with diabetes.

Besides, an inappropriate burden of inflammation also plays a role in the pathogenesis of sarcopenia [1]. HDL cholesterol-based markers have attracted much attention in recent years and several studies have reported their relationships with various inflamamtory [17,18] and metabolic conditions, including diabetes [19] and its complications [20]. Therefore, in this study, we aimed to investigate the potential association between TG/HDL-C ratio and sarcopenia among elderly patients with diabetes, including muscle strength, physical performance, and muscle mass.

2. Materials and methods

2.1 Study population

This study used data from the China Health and Retirement Longitudinal Study (CHARLS), an ongoing nationally representative survey of middle-aged and elderly individuals in China. Detailed information on the CHARLS is available elsewhere [21]. Briefly, the CHARLS collects data through face-to-face interviews, using a structured questionnaire, from a nationally representative sample of the Chinese population aged ≥45 years, selected using multistage stratified probability-proportionate-to-size sampling. The survey mainly collects data on sociodemographics variables, lifestyle-related factors, and health-related information. Besides, the CHARLS includes various physical measurements and blood sample collection. The baseline survey was conducted in 2011, and all participants were

followed up every 2 to 3 years. New participants are additionally enrolled in each follow-up survey.

The CHARLS protocol was conducted following the Declaration of Helsinki and approved by the Biomedical Ethical Review Committee of the Peking University (IRB00001052-11015). All participants provided informed consent. The CHARLS datasets are available on request from the study home page (http://charls.pku.edu.cn/).

Our group selected the baseline participants in CHARLS 2011 (n=17,708) and non-repetitive participants in CHARLS 2015 (n=3823). Of these, 20,779 individuals were excluded due to following reasons: (1) age <60 years (n=13,661); (2) missing information on physical measurements required for the assessment of sarcopenia (n=2024); (3) non-diabetes patients, or those with missing plasma glucose or glycated hemoglobin (HbA1c) measurements (n=5094). Finally, 752 participants were eligible for this cross-sectional analysis.

In this study, diabetes was defined as fasting plasma glucose (FPG) ≥7.0 mmol/L (126 mg/dL), random plasma glucose (RPG) ≥11.1 mmol/L (200 mg/dL), HbA1c ≥6.5%, or self-reported history [22].

2.2 Data collection

In the CHARLS, information on demographic factors (including age and sex), residence (urban or rural), education level (less than lower secondary, upper secondary or vocational training, or tertiary), health behaviors (including the history

of smoking and drinking) and diabetes management (including awareness and treatment of diabetes) were obtained using a structured questionnaire.

The main anthropometric parameters in our study were height and body weight. The body mass index (BMI, kg/m^2) was calculated as body weight/(height^2), and overweight was defined as a BMI ≥25 kg/m^2. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured three times, and their mean values were recorded.

Blood samples were collected for measurements of plasma glucose (mg/dL), HbA1c (%), total cholesterol (TC, mg/dL), TG, low-density lipoprotein cholesterol (LDL-C, mg/dL), HDL-C (mg/dL), high-sensitivity C-reactive protein (hs-CRP, mg/L), uric acid (mg/dL), and creatinine (mg/dL). Serum triglyceride to HDL-C ratio, the primary variable in this study, was calculated as TG/HDL-C. The estimated glomerular filtration rate (eGFR, mL/min/1.73 m^2) was calculated based on the Chronic Kidney Disease Epidemiology Collaboration's 2009 creatinine equation [23].

2.3 Assessment of sarcopenia

In this study, sarcopenia status was assessed according to the algorithm of the Asian Working Group for Sarcopenia 2019 (AWGS 2019) [1]. Participants with adequate muscle strength and physical performance were considered to have no sarcopenia. Possible sarcopenia was diagnosed if participants had sufficient muscle mass, but with low muscle strength or low physical performance. Participants had low muscle mass,

with low muscle strength or low physical performance, were considered as having sarcopenia.

2.3.1 Muscle strength

Handgrip strength (kg) was used to assess muscle strength according to the AWGS 2019 [1]. In the CHARLS, handgrip strength was measured both with the left and right hand twice, and we took the average of the maximum values. If participants could not perform grip strength measurements in both hands, the data of the available hand was used. The cut-off points for low handgrip strength recommended by AWGS 2019 were <28 kg in men and <18 kg in women [1].

2.3.2 Physical performance

This study measured physical performance by gait speed and 5-time chair stand test. In the CHARLS, researchers recorded the number of seconds taken by the participants to walk 2.5 meters [21], and we converted it to gait speed (m/s). In the 5-time chair stand test, the participants were required to keep their arms folded across their chest, while sitting on a chair, then stand up straight and then sit down again five times [21]; the number of seconds spent by the participants was recorded. According to the AWGS 2019, gait speed <1.0 m/s or 5-time chair stand test ≥12 seconds is regarded as low physical performance [1]. In our analysis, participants who tried but failed to perform either of the tests were also considered to have low physical performance.

2.3.3 Skeletal muscle mass measurement

Based on the AWGS 2019, the muscle mass was estimated by the appendicular skeletal muscle mass (ASM). In this study, we used a previously validated anthropometric equation in a Chinese population to calculate the ASM [24]:

$$\boldsymbol{ASM = 0.193 \times body\ weight + 0.107 \times height - 4.157 \times sex - 0.037 \times age - 2.631}$$

The body weight, height, and age were measured in kilograms, centimeters, and years, respectively. For sex, the value 1 was assigned for men and the value 2 was assigned for women.

The parameter used to assess muscle mass in our study, was the height-adjusted muscle mass. It was calculated as the ASM divided by the square of the height in meters (ASM/height^2). Following previous studies [25], the cut-off point for low muscle mass was the lowest 20% of the height-adjusted muscle mass in our study population. Finally, the ASM/height^2 values of <6.99 kg/m^2 in men and <5.24 kg/m^2 in women were considered low muscle mass.

2.4 Statistical analysis

In this study, statistical analyses were performed separately for men and women. The Kolmogorov-Smirnov test was used to assess the normality of distribution of continuous variables. Normally distributed continuous variables were described as mean ± standard deviation (SD), while non-normally distributed continuous variables were described as median (interquartile range [IQR]). Categorical variables were expressed as frequency (percentage). First, differences in baseline characteristics among the three groups (no sarcopenia, possible sarcopenia, and sarcopenia) were

compared using one-way ANOVA, chi-square test, Fisher's exact test, or Kruskal–Wallis test, as appropriate. Second, ordinal logistic regression analysis was performed to assess the association between TG/HDL-C ratio and sarcopenia status. Four different models were introduced: Model 1, without adjustment; Model 2, adjusted for median age; Model 3, additionally adjusted for residence, education level, and history of smoking and alcohol consumption; and Model 4, additionally adjusted for overweight, diabetes management, SBP, DBP, plasma glucose, HbA1c, TC, LDL-C, hs-CRP, uric acid, and eGFR. Third, linear regression analysis was performed to estimate the associations between TG/HDL-C ratio and muscle strength, physical performance, and muscle mass, respectively, with or without adjustment for covariates. The main variable was serum TG/HDL-C, categorized and analyzed according to quartiles. Given the difference in muscle between men and women, all analyses were stratified by sex. Two-sided *P* values <0.05 were considered indicative of statistical significance for all analyses. All statistical analyses were conducted using Stata 17.0 (StataCorp, College Station, TX, USA).

2.5 Patient and public involvement

Patients and/or the public were not directly involved in this study.

3. Results

3.1 Baseline

Table 1 showed the baseline characteristics of the study population disaggregated by sarcopenia status. The median (interquartile range) age was 66.0 (62.5, 72.0) years and 384 (51.1%) of subjects were female. The prevalence of no sarcopenia, possible sarcopenia, and sarcopenia in this cohort was 6.5% (49/752), 74.1% (557/752) and 19.4% (146/752), respectively.

Table 2 showed the baseline characteristics of male subjects according to sarcopenia status. There were 7.9% (29/368) male participants without sarcopenia, 72.8% (268/368) with possible sarcopenia, and 19.3% (71/368) with sarcopenia. There were significant differences among the three groups concerning the following continuous variables: age (P<0.001), BMI (P<0.001), SBP (P=0.011), DBP (P=0.007), HbA1c (P=0.007), TC (P=0.006), TG (P=0.001), LDL-C (P=0.002), HDL-C (P<0.001), uric acid (P=0.024), and TG/HDL-C ratio (P<0.001). The levels of plasma glucose (P=0.763), hs-CRP (P=0.470), and eGFR (P=0.349) showed no significant difference among the different groups based on sarcopenia status. The distributions of median age (P=0.001), residence (P=0.001), overweight (P=0.349), awareness of diabetes (P=0.038), and TG/HDL-C ratio (P<0.001) showed significant differences among the three groups. There was no significant difference among the classifications of sarcopenia with respect to the education level (P=0.119), treatment of diabetes (P=0.072), and history of smoking (P=0.384) and drinking (P=0.099).

The baseline characteristics of female subjects according to sarcopenia status were presented in Table 3. In this study, 5.2% (20/384) female participants were defined as

having no sarcopenia, 75.3% (289/384) as having possible sarcopenia, and 19.5% (75/384) as having sarcopenia. There were no significant differences between the 3 groups with respect to age (P<0.001), BMI (P<0.001), HbA1c (P=0.002), TG (P<0.001), HDL-C (P<0.001), hs-CRP (P=0.009), uric acid (P=0.001), and TG/HDL-C ratio (P<0.001). There were no significant differences among the grades of sarcopenia concerning SBP (P=0.621), DBP (P=0.337), plasma glucose (P=0.205), TC (P=0.389), LDL-C (P=0.629), and eGFR (P=0.090). However, there were significant differences between the three groups with respect to age (P=0.021), residence (P<0.001), education level (P=0.032), overweight (P<0.001), awareness (P<0.001) and treatment (P=0.008) of diabetes, and TG/HDL-C ratio (P<0.001). There were no significant differences with respect to the distributions of history of smoking (P=1.000) and drinking (P=0.068).

The detailed data were shown in Table 1-3.

3.2 Association between TG/HDL-C ratio and sarcopenia

Among male participants, compared to those with quartile 1 of TG/HDL-C ratio (≤1.41), those with quartile 2 (1.42–2.35; OR 0.49, 95% CI 0.26–0.92, P=0.027), 3 (2.36–4.71; OR 0.36, 95% CI 0.19–0.69, P=0.002), and 4 (>4.71; OR 0.18, 95% CI 0.09–0.35, P<0.001) of TG/HDL-C ratio had significantly lower odds ratio of more severe sarcopenia in the unadjusted ordinal logistic regression (Model 1). In the multi-variable-adjusted model (Model 4), compared with male participants with quartile 1 of TG/HDL-C ratio (≤1.41), those with quartile 2 (1.42–2.35; OR 0.48,

95% CI 0.24–0.97, *P*=0.042) and 4 (>4.71; OR 0.24, 95% CI 0.10–0.54, *P*=0.001) of TG/HDL-C ratio had significantly lower risk of more severe sarcopenia.

Similarly, among female participants, compared to those with quartile 1 of TG/HDL-C ratio (≤2.07), those with quartile 2 (2.08–3.26; OR 0.24, 95% CI 0.12–0.46, *P*<0.001), 3 (3.27–5.61; OR 0.36, 95% CI 0.13–0.50, *P*<0.001), and 4 (>5.61; OR 0.17, 95% CI 0.08–0.33, *P*<0.001) of TG/HDL-C ratio had significantly lower risk of more severe sarcopenia, in the unadjusted ordinal logistic regression (Model 1). In the multi-variable-adjusted model (Model 4), female participants with quartile 2 (2.08–3.26; OR 0.38, 95% CI 0.17–0.83, *P*=0.015), 3 (3.27–5.61; OR 0.26, 95% CI 0.12–0.57, *P*=0.001), and 4 (>5.61; OR 0.17, 95% CI 0.07–0.44, *P*<0.001) of TG/HDL-C ratio had significantly lower risk of more severe sarcopenia, compared to those with quartile 1 of TG/HDL-C ratio (≤2.07).

The detailed results and other adjusted models (model 2 and model 3), were shown in Table 4.

3.3 Associations between TG/HDL-C ratio and components of sarcopenia

Among male participants, simple and multivariate linear regression analysis showed that TG/HDL-C ratio categorized by quartile had no significant correlation with handgrip strength and gait speed. In the 5-time chair stand test, compared with quartile 1 of TG/HDL-C ratio (≤1.41), quartile 4 of TG/HDL-C ratio (>4.71) was associated with significantly longer chair-rising time in simple (β=1.54, 95% CI 0.30–2.78, *P*=0.015) and multivariate (β=2.60, 95% CI 1.19–4.00, *P*<0.001) linear

regression. On simple and multivariate linear regression analysis, TG/HDL-C ratio categorized by quartile show a significant correlation with muscle mass. In multivariate linear regression analysis, compared with quartile 1 of TG/HDL-C ratio (≤1.41), quartile 2 (1.42–2.35; β=0.18, 95% CI 0.04–0.32, *P*=0.009), 3 (2.36–4.71; β=0.18, 95% CI 0.03–0.32, *P*=0.016), and 4 (>4.71; β=0.36, 95% CI 0.20–0.51, *P*<0.001) of TG/HDL-C ratio showed a significant association with high height-adjusted muscle mass (ASM/height^2).

Unlike male participants, compared with female participants in quartile 1 of TG/HDL-C ratio (≤2.07), those in quartile 4 of TG/HDL-C ratio (>5.61) had significantly greater handgrip strength in simple (β=3.16, 95% CI 0.78–5.54, *P*=0.009) and multivariate (β=3.93, 95% CI 0.89–6.97, *P*=0.011) linear regression. However, there was no significant correlation between TG/HDL-C ratio and gait speed, or the 5-time chair stand test. Similar to male participants, TG/HDL-C ratio categorized by quartile was correlated with muscle mass in linear regression analysis among female participants. In multivariate linear regression analysis, compared with quartile 1 of TG/HDL-C ratio (≤2.07), quartile 2 (2.08–3.26; β=0.30, 95% CI 0.12–0.47, P=0.001), 3 (3.27–5.61; β=0.28, 95% CI 0.11–0.45, P=0.001), and 4 (>5.61; β=0.31, 95% CI 0.10–0.51, P=0.003) of TG/HDL-C ratio were associated with significantly greater height-adjusted muscle mass (ASM/height^2).

Other detailed data were shown in Table 5.

4. Discussion

In this cohort, we found a negative association between TG/HDL-C ratio categorized by quartile and sarcopenia, which implies that higher TG/HDL-C ratio may be associated with better muscle status. Unlike previous studies [15,16], this study focused on elderly Chinese patients with diabetes; thus, our findings supplement the existing literature on this subject. In addition, our group further analyzed the correlation between TG/HDL-C ratio and specific components of sarcopenia, including muscle strength, physical performance, and muscle mass. The main results were as follows: first, compared with the lowest quartile of TG/HDL-C ratio (≤1.41), the highest quartile of TG/HDL-C ratio (>4.71) was associated with longer chair-rising time among male elderly diabetics; second, compared with the lowest quartile of TG/HDL-C ratio (≤2.07), the highest quartile of TG/HDL-C ratio (>5.61) was associated with greater handgrip strength among female elderly diabetics; third, high TG/HDL-C ratio categorized by quartile was correlated with increased muscle mass in both sexes. The above findings further underline the fact that, as a widely and rapidly accessible lipid parameter, TG/HDL-C ratio may serve as a marker of sarcopenia.

Consistent with the previous finding in community-dwelling Chinese populations [16], this study showed that higher TG/HDL-C ratio was associated with a lower risk of more severe sarcopenia in older patients with diabetes. Therefore, TG/HDL-C ratio can be considered as a risk factor for sarcopenia in elderly Chinese patients with diabetes. However, this finding was contrary to the Korean study [15] and the reason for the conflicting results is unclear. Previous studies have shown that study design,

gene diversity, lifestyle factors and disease advancement in different populations may lead to variations in lipid profiles [16,26]. First, this study followed AWGS 2019 for the evaluation of sarcopenia [1], while the Korean study was published before the consensus [15], which may have lead to selection bias. Second, gene polymorphisms affecting the lipid profiles in the Chinese and Koreans remains undefined but cannot be ignored, because a study reported significant difference in lipid profiles between the Chinese and Korean adolescents populations [27]. Third, unlike the Korean study [15], this study was confined to elderly Chinese patients with diabetes, and the lipid profiles of diabetes patients differ from those of the general population [22], which may also be one of the reasons for the inconsistent results.

We observed some sex-based differences in the association between TG/HDL-C ratio and muscle function of elderly diabetics in our study. Only among male elderly diabetics, we found that patients with the highest quartile of TG/HDL-C ratio (>4.71) had longer chair-rising time than those with the lowest quartile (≤1.41). Another study using the CHARLS database also found similar results regarding the physical performance of participants with prediabetes (≥45 years) [28]. This finding contradicted the main result, but the reason was unclear [28]. Further, we found that patients with the highest quartile of TG/HDL-C ratio (>5.61) had greater muscle strength than those with the lowest quartile (≤2.07), only among female elderly diabetics. Previous studies have found sex-based differences in the correlations between various metabolic indices and sarcopenia in different cohorts [29]. More in-depth researches may help us understand this phenomenon in the future.

Conversely, the association between TG/HDL-C ratio and muscle mass in male and female elderly diabetics were consistent in this study. Regardless of sex, high quartile of TG/HDL-C ratio was correlated with increased muscle mass. Currently, AWGS 2019 recommends the use of dual-energy X-ray absorptiometry (DXA) or multifrequency bioelectrical impedance analysis (BIA) for measuring muscle mass in sarcopenia diagnosis [1]. This finding suggested that TG/HDL-C ratio can be used as a relatively simple screening indicator for muscle mass and help clinicians identify elderly diabetics at high risk of muscle mass deficiency. Compared with muscle strength and function, this closer relationship between TG/HDL-C ratio and muscle mass was supported by previous studies and attributed to their potential interactions [15,16,26]. As a marker associated with insulin resistance, TG/HDL-C ratio may reflect the vicious cycle between sarcopenia and insulin resistance [15]. Sarcopenia is mainly characterized by a decrease in muscle mass along with an increase in intramuscular fat. Since skeletal muscle plays an important role in insulin-mediated glucose disposal, lower skeletal muscle mass is likely to diminish this effect. Moreover, inappropriate secretion of adipokines by intramuscular fat may potentially lead to increased insulin resistance and sarcolysis. Muscle protein metabolism is influenced by insulin resistance, which promotes muscle sarcolysis resulting in loss of skeletal muscle mass.

A recent study also found an association between TG/HDL-C ratio and diabetic complications microvascular [30]. Similarly, our study proposed an easily accessible parameter for screening sarcopenia in elderly diabetic patients, which may facilitate

the prevention and treatment of sarcopenia in people with diabetes. Recently, sarcopenia has been implicated as both a cause and consequence of diabetes [9,10]. However, there is insufficient evidence for treatment recommendations for diabetic patients with sarcopenia, including nutritional supplements, dietary advice, and planned exercise [9]. Therefore, future intervention studies (suitable TG supplementation and HDL-C control) for diabetic patients with sarcopenia can further investigate the interactions between lipid profile and sarcopenia and provide evidence for the prevention and treatment of sarcopenia.

Some limitations of our study should be considered. First, the cross-sectional nature of the study does not permit any causal inferences. Second, this study only involved elderly patients with diabetes from the CHARLS, which may also have resulted in selection bias. Third, the type of diabetes was uncertain because the diagnosis of diabetes was based on self-report, and measurements of blood glucose and HbA1c. Fourth, comorbid conditions and history of drug use were not included in the analysis. Fifth, instead of the AWGS 2019 recommendation, we used a previously validated anthropometric equation to assess the muscle mass, which may also have led to measurement bias.

5. Conclusions

In this study, we observed a negative association between TG/HDL-C ratio categorized by quartile and sarcopenia. Our findings indicate that higher TG/HDL-C ratio may be related to better muscle status. Future prospective and intervention

studies are required to investigated the relationship between lipid profiles and the occurrence, prevention, and treatment of sarcopenia.

6. Declarations

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This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

YL contributed to the study concept and design, data acquisition and analysis, and drafted the manuscript. SZ contributed to revising the manuscript. ZS contributed to providing technical and material support. ZS also contributed to the supervision of this study. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The CHARLS protocol was conducted following the Declaration of Helsinki and approved by the Biomedical Ethical Review Committee of Peking University (IRB00001052-11015). All participants provided written informed consent.

Availability of data and materials

The CHARLS datasets are available on request from their home page at http://charls.pku.edu.cn/.

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Table 1. Baseline characteristics of elderly patients with diabetes according to sarcopenia status in this study.

Variables	Total (n=752)	No sarcopenia (n=49)	Possible sarcopenia (n=557)	Sarcopenia (n=146)	*P*-value
Age (years)	66.0 (62.5, 72.0)	64.0 (62.0, 68.0)	66.0 (62.0, 70.0)	70.0 (65.0, 75.0)	**<0.001**
>Median (vs. ≤median)		15 (30.6)	253 (45.4)	97 (66.4)	**<0.001**
Gender (%)					
Female (vs. male)	384 (51.1)	20 (40.8)	289 (51.9)	75 (51.4)	0.330
Handgrip strength (kg)					
Male	34.5 (28.5, 40.5)	41.5 (36.5, 45.0)	35.0 (29.8, 41.0)	29.0 (21.0, 33.5)	**<0.001**
Female	22.8 (18.0, 27.5)	27.8 (24.6, 32.3)	23.5 (18.5, 28.0)	19.8 (16.0, 23.0)	**<0.001**
Gait speed (m/s)[a]	0.66 (0.52, 0.79)	1.10 (1.04, 1.18)	0.64 (0.52, 0.78)	0.62 (0.49, 0.71)	**<0.001**
5-time chair stand test (s)[a]	10.5 (8.8, 13.2)	9.5 (6.9, 19.5)	10.3 (8.6, 13.0)	11.9 (9.6, 14.0)	**<0.001**
ASM/Ht^2 (kg/m^2)					
Male	7.61 (7.10, 8.16)	7.71 (7.47, 8.41)	7.84 (7.40, 8.24)	6.71 (6.44, 6.87)	**<0.001**
Female	5.89 (5.38, 6.55)	6.28 (5.55, 6.57)	6.16 (5.71, 6.72)	4.90 (4.67, 5.06)	**<0.001**
Residence (%)					
Rural (vs. urban)	432 (57.4)	21 (42.9)	300 (53.9)	111 (76.0)	**<0.001**
Education (%)					
Less than lower secondary	705 (93.8)	42 (85.7)	520 (93.4)	143 (97.9)	
Upper secondary or vocational training	28 (3.7)	3 (6.1)	23 (4.1)	2 (1.4)	**<0.001**
Tertiary	19 (2.5)	4 (8.2)	14 (2.5)	1 (0.7)	
Ever/current smoke (%)[a]	303 (40.5)	21 (42.9)	220 (39.6)	62 (43.1)	0.704
Ever/current drinking (%)[a]	295 (39.5)	18 (36.7)	215 (38.8)	62 (43.1)	0.598
BMI (kg/m^2)	24.1 (21.6, 26.9)	24.4 (22.3, 26.9)	25.1 (23.0, 27.6)	19.4 (18.0, 20.3)	**<0.001**
Overweight (%)	307 (40.8)	23 (46.9)	283 (50.8)	1 (0.7)	**<0.001**
Blood pressure (mm Hg)[a]					
Systolic	137.5 (124.0, 151.5)	130.5 (124.0, 141.0)	139.5 (124.5, 153.0)	135.3 (120.3, 149.3)	**0.014**

Diastolic	75.5 (68.0, 82.5)	73.5 (68.0, 81.0)	76.0 (68.5, 83.5)	73.5 (63.8, 80.3)	**0.006**
Diabetes management (%)					
Unawareness (vs. awareness)	447 (59.4)	27 (55.1)	308 (55.3)	112 (76.7)	**<0.001**
Untreatment (vs. treatment)	554 (73.7)	33 (67.3)	397 (71.3)	124 (84.9)	**0.002**
Plasma glucose (mg/dL)[b]	140.1 (126.4, 176.0)	137.9 (120.2, 164.7)	141.1 (126.5, 177.8)	138.2 (127.3, 173.5)	0.665
HbA1c (%)	5.8 (5.2, 6.9)	6.1 (5.3, 7.2)	5.9 (5.3, 7.1)	5.5 (5.1, 6.2)	**<0.001**
TC (mg/dL)	195.9 (168.2, 223.3)	186.0 (160.8, 237.0)	197.9 (170.9, 222.3)	191.4 (160.8, 224.6)	0.292
TG (mg/dL)	128.3 (89.4, 200.5)	147.8 (96.5, 232.8)	137.2 (97.4, 211.5)	102.2 (76.1, 143.4)	**<0.001**
LDL-C (mg/dL)[a]	115.2 (90.5, 139.9)	111.1 (88.7, 134.5)	116.4 (92.0, 141.1)	108.2 (85.8, 133.3)	0.198
HDL-C (mg/dL)	45.2 (37.1, 54.9)	41.4 (34.4, 49.9)	43.7 (37.1, 52.2)	52.6 (44.1, 63.4)	**<0.001**
hs-CRP (mg/L)	1.47 (0.75, 3.47)	1.89 (0.84, 3.33)	1.53 (0.81, 3.50)	1.09 (0.64, 2.78)	**0.018**
Uric acid (mg/dL)	4.61 (3.75, 5.57)	4.65 (3.78, 5.50)	4.71 (3.83, 5.62)	4.30 (3.50, 5.25)	**0.003**
eGFR (mL/min/1.73 m^2)	85.5 (54.1, 95.4)	94.2 (70.9, 98.4)	84.3 (52.0, 95.2)	86.5 (59.4, 95.5)	**0.013**
TG/HDL-C	2.81 (1.74, 5.20)	3.89 (1.92, 6.51)	3.05 (1.96, 5.61)	1.88 (1.15, 3.09)	**<0.001**
Quartile 1 (≤1.73)		9 (18.4)	115 (20.6)	64 (43.8)	
Quartile 2 (1.74-2.81)		10 (20.4)	139 (25.0)	39 (26.7)	**<0.001**
Quartile 3 (2.82-5.19)		15 (30.6)	148 (26.6)	25 (17.1)	
Quartile 4 (>5.19)		15 (30.6)	155 (27.8)	18 (12.3)	

Data are shown as means ± standard deviation, median (interquartile range), or numbers (percentages).

a. Missing data: 38 for gait speed, 43 for 5-time chair stand test, 3 for history of smoking, 5 for history of drinking, 14 for blood pressure and 5 for LDL-C.

b. Among the measurements of plasma glucose, 39 participants were non-fasting.

Abbreviations: ASM/Ht^2 : the height-adjusted muscle mass; BMI: the body mass index; HbA1c: glycated hemoglobin; TC: total cholesterol; TG: triglyceride; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol ratio; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate; TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio.

Table 2. Baseline characteristics of male elderly patients with diabetes according to sarcopenia status in this study.

Variables	Total (n=368)	No sarcopenia (n=29)	Possible sarcopenia (n=268)	Sarcopenia (n=71)	*P*-value
Age (years)	66.0 (62.0, 72.0)	64.0 (62.0, 68.0)	65.0 (62.0, 70.0)	71.0 (65.0, 77.0)	**<0.001**
>Median (vs. ≤median)		10 (34.5)	113 (42.2)	47 (66.2)	**0.001**
Handgrip strength (kg)	34.5 (28.5, 40.5)	41.5 (36.5, 45.0)	35.0 (29.8, 41.0)	29.0 (21.0, 33.5)	**<0.001**
Gait speed (m/s)[a]	0.66 (0.52, 0.79)	1.10 (1.04, 1.18)	0.64 (0.52, 0.78)	0.62 (0.49, 0.71)	**<0.001**
5-time chair stand test (s)[a]	10.5 (8.8, 13.2)	9.5 (6.9, 19.5)	10.3 (8.6, 13.0)	11.9 (9.6, 14.0)	**<0.001**
ASM/Ht^2 (kg/m^2)	7.61 (7.10, 8.16)	7.71 (7.47, 8.41)	7.84 (7.40, 8.24)	6.71 (6.44, 6.87)	**<0.001**
Residence (%)					
Rural (vs. urban)	218 (59.2)	16 (55.2)	146 (54.5)	56 (78.9)	**0.001**
Education (%)					
Less than lower secondary	338 (91.8)	25 (86.3)	244 (91.0)	69 (97.2)	
Upper secondary or vocational training	15 (4.1)	1 (3.4)	12 (4.5)	2 (2.8)	0.119
Tertiary	15 (4.1)	3 (10.3)	12 (4.5)	0 (0)	
Ever/current smoke (%)[a]	270 (73.8)	20 (69.0)	194 (72.7)	56 (80.0)	0.384
Ever/current drinking (%)[a]	236 (64.7)	18 (62.1)	165 (62.0)	53 (75.7)	0.099
BMI (kg/m^2)	23.7 (21.1, 26.2)	24.2 (22.3, 27.8)	24.6 (22.5, 26.8)	19.1 (17.8, 19.9)	**<0.001**
Overweight (%)	131 (35.6)	12 (41.4)	119 (44.4)	0 (0)	**<0.001**
Blood pressure (mm Hg)[a]					
Systolic	135.5 (124.5, 147.0)	130.0 (124.0, 136.0)	138.0 (125.0, 149.5)	132.5 (121.0, 145.0)	**0.011**
Diastolic	75.5 (68.5, 82.5)	74.0 (68.5, 81.0)	76.5 (70.0, 83.5)	73.5 (63.5, 79.0)	**0.007**
Diabetes management (%)					
Unawareness (vs. awareness)	229 (62.2)	15 (51.7)	161 (60.1)	53 (74.6)	**0.038**
Untreatment (vs. treatment)	274 (74.5)	18 (62.1)	197 (73.5)	59 (83.1)	0.072
Plasma glucose (mg/dL)[b]	138.7 (126.4, 175.2)	139.9 (126.4, 197.5)	139.1 (126.4, 175.2)	137.3 (126.4, 175.0)	0.763
HbA1c (%)	5.6 (5.1, 6.9)	6.2 (5.3, 7.7)	5.6 (5.2, 7.1)	5.3 (5.0, 5.9)	**0.007**

TC (mg/dL)	186.5 (160.8, 213.2)	174.4 (156.6, 190.3)	190.8 (165.5, 216.1)	171.7 (149.2, 202.6)	**0.006**
TG (mg/dL)	111.1 (78.8, 172.1)	121.2 (82.3, 187.6)	115.1 (82.3, 185.0)	88.5 (67.3, 130.1)	**0.001**
LDL-C (mg/dL)[a]	109.1±35.4	108.3±30.6	111.9±36.2	98.9±32.5	**0.002**
HDL-C (mg/dL)	45.6 (37.1, 57.2)	40.6 (33.2, 48.3)	44.7 (34.6, 55.1)	53.0 (44.1, 66.9)	**<0.001**
hs-CRP (mg/L)	1.33 (0.72, 3.13)	1.80 (0.77, 4.00)	1.38 (0.73, 3.01)	1.10 (0.68, 3.68)	0.470
Uric acid (mg/dL)	4.88 (4.08, 5.85)	4.27 (3.73, 5.20)	4.99 (4.19, 6.00)	4.70 (3.91, 5.40)	**0.024**
eGFR (mL/min/1.73 m^2)	88.9 (74.0, 96.3)	94.2 (73.9, 99.2)	88.1 (74.3, 95.9)	88.9 (72.8, 95.7)	0.349
TG/HDL-C	2.35 (1.41, 4.71)	3.73 (1.91, 6.51)	2.55 (1.59, 4.97)	1.49 (1.10, 2.48)	**<0.001**
Quartile 1 (≤1.41)		4 (13.8)	56 (20.9)	32 (45.1)	
Quartile 2 (1.42-2.35)		6 (20.7)	67 (25.0)	19 (26.8)	**<0.001**
Quartile 3 (2.36-4.71)		8 (27.6)	69 (25.7)	15 (21.1)	
Quartile 4 (>4.71)		11 (37.9)	76 (28.4)	5 (7.0)	

Data are shown as means ± standard deviation, median (interquartile range), or numbers (percentages).

a. Missing data: 15 for gait speed, 11 for 5-time chair stand test, 2 for history of smoking, 3 for history of drinking, 5 for blood pressure and 1 for LDL-C.

b. Among the measurements of plasma glucose, 17 male participants were non-fasting.

Abbreviations: ASM/Ht^2 : the height-adjusted muscle mass; BMI: the body mass index; HbA1c: glycated hemoglobin; TC: total cholesterol; TG: triglyceride; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol ratio; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate; TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio.

Table 3. Baseline characteristics of female elderly patients with diabetes according to sarcopenia status in this study.

Variables	Total (n=384)	No sarcopenia (n=20)	Possible sarcopenia (n=289)	Sarcopenia (n=75)	*P*-value
Age (years)	67.0 (63.0, 71.5)	63.0 (61.0, 66.5)	66.0 (62.0, 71.0)	69.0 (65.0, 75.0)	**<0.001**
>Median (vs. ≤median)		4 (20.0)	122 (42.2)	40 (53.3)	**0.021**
Handgrip strength (kg)	22.8 (18.0, 27.5)	27.8 (24.6, 32.3)	23.5 (18.5, 28.0)	19.8 (16.0, 23.0)	**<0.001**
Gait speed (m/s)[a]	0.63 (0.47, 0.76)	1.10 (1.03, 1.17)	0.63 (0.47, 0.75)	0.58 (0.46, 0.69)	**<0.001**
5-time chair stand test (s)[a]	11.3 (9.1, 14.5)	7.9 (7.3, 8.7)	11.6 (9.4, 14.8)	11.4 (9.4, 14.7)	**<0.001**
ASM/Ht^2 (kg/m^2)	5.89 (5.38, 6.55)	6.28 (5.55, 6.57)	6.16 (5.71, 6.72)	4.90 (4.67, 5.06)	**<0.001**
Residence (%)					
Rural (vs. urban)	214 (55.7)	5 (25.0)	154 (53.3)	55 (73.3)	**<0.001**
Education (%)					
Less than lower secondary	367 (95.6)	17 (85.0)	276 (95.5)	74 (98.7)	
Upper secondary or vocational training	13 (3.4)	2 (10.0)	11 (3.8)	0 (0)	**0.032**
Tertiary	4 (1.0)	1 (5.0)	2 (0.7)	1 (1.3)	
Ever/current smoke (%)[a]	33 (8.6)	1 (5.0)	26 (9.0)	6 (8.1)	1.000
Ever/current drinking (%)[a]	59 (15.4)	0 (0)	50 (17.4)	9 (12.2)	0.068
BMI (kg/m^2)	24.7 (22.0, 27.6)	25.5 (22.2, 26.4)	25.6 (23.5, 28.0)	19.7 (18.6, 20.9)	**<0.001**
Overweight (%)	176 (45.8)	11 (55.0)	164 (56.7)	1 (1.3)	**<0.001**
Blood pressure (mm Hg)[a]					
Systolic	140.0 (123.5, 155.0)	133.3 (126.0, 150.5)	140.5 (124.0, 155.5)	138.0 (119.0, 154.5)	0.621
Diastolic	75.5 (67.0, 83.0)	73.0 (67.5, 82.5)	76.0 (67.5, 83.5)	74.5 (65.0, 80.5)	0.337
Diabetes management (%)					
Unawareness (vs. awareness)	218 (56.8)	12 (60.0)	147 (50.9)	59 (78.7)	**<0.001**
Untreatment (vs. treatment)	280 (72.9)	15 (75.0)	200 (69.2)	65 (86.7)	**0.008**
Plasma glucose (mg/dL)[b]	141.2 (126.5, 177.7)	134.2 (106.0, 160.3)	142.7 (127.1, 179.8)	138.2 (127.6, 173.2)	0.205
HbA1c (%)	6.0 (5.4, 6.9)	5.9 (5.3, 7.0)	6.1 (5.5, 7.1)	5.6 (5.2, 6.5)	**0.002**

TC (mg/dL)	205.5 (178.6, 230.5)	233.8 (178.1, 259.1)	204.9 (176.7, 229.3)	208.4 (184.4, 236.2)	0.389
TG (mg/dL)	146.5 (106.2, 222.1)	164.6 (135.4, 250.9)	152.2 (112.4, 229.2)	108.0 (80.5, 162.8)	**<0.001**
LDL-C (mg/dL)[a]	122.0±40.5	129.6±44.0	120.9±41.4	124.3±36.3	0.629
HDL-C (mg/dL)	45.2 (37.5, 53.0)	43.9 (37.7, 52.6)	42.9 (37.1, 51.4)	52.2 (43.3, 62.6)	**<0.001**
hs-CRP (mg/L)	1.60 (0.80, 3.53)	1.95 (1.02, 2.78)	1.73 (0.90, 3.80)	1.08 (0.59, 2.60)	**0.009**
Uric acid (mg/dL)	4.33 (3.58, 5.21)	5.22 (3.88, 6.01)	4.35 (3.67, 5.24)	3.78 (3.25, 4.74)	**0.001**
eGFR (mL/min/1.73 m^2)	62.7 (45.5, 95.0)	93.4 (52.9, 97.4)	57.1 (45.2, 93.9)	84.7 (45.5, 95.5)	0.090
TG/HDL-C	3.26 (2.07, 5.61)	4.06 (2.63, 6.62)	3.45 (2.35, 5.99)	2.02 (1.20, 4.27)	**<0.001**
Quartile 1 (≤2.07)	95 (24.7)	4 (20.0)	51 (17.6)	40 (53.3)	**<0.001**
Quartile 2 (2.08-3.26)	98 (25.5)	4 (20.0)	82 (28.4)	12 (16.0)	
Quartile 3 (3.27-5.61)	95 (24.7)	6 (30.0)	74 (25.6)	15 (20.0)	
Quartile 4 (>5.61)	96 (25.0)	6 (30.0)	82 (28.4)	8 (10.7)	

Data are shown as means ± standard deviation, median (interquartile range), or numbers (percentages).

a. Missing data: 23 for gait speed, 32 for 5-time chair stand test, 1 for history of smoking, 2 for history of drinking, 9 for blood pressure and 4 for LDL-C.

b. Among the measurements of plasma glucose, 22 female participants were non-fasting.

Abbreviations: ASM/Ht^2 : the height-adjusted muscle mass; BMI: the body mass index; HbA1c: glycated hemoglobin; TC: total cholesterol; TG: triglyceride; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol ratio; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate; TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio.

Table 4. Association between TG/HDL-C and sarcopenia status in elderly patients with diabetes in ordinal logistic regression analysis.

				Male			
Variables	No sarcopenia (n=29)	Possible sarcopenia (n=268)	Sarcopenia (n=71)	OR (95% CI)			
				Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
TG/HDL-C							
Quartile 1 (≤1.41)	4 (13.8)	56 (20.9)	32 (45.1)	Reference	Reference	Reference	Reference
Quartile 2 (1.42-2.35)	6 (20.7)	67 (25.0)	19 (26.8)	**0.49 (0.26, 0.92)***	**0.47 (0.25, 0.88)***	**0.50 (0.26, 0.96)***	**0.48 (0.24, 0.97)***
Quartile 3 (2.36-4.71)	8 (27.6)	69 (25.7)	15 (21.1)	**0.36 (0.19, 0.69)****	**0.33 (0.17, 0.65)****	**0.41 (0.20, 0.80)****	0.56 (0.27, 1.17)
Quartile 4 (>4.71)	11 (37.9)	76 (28.4)	5 (7.0)	**0.18 (0.09, 0.35)*****	**0.18 (0.09, 0.37)*****	**0.24 (0.12, 0.49)*****	**0.24 (0.10, 0.54)****
				Female			
Variables	No sarcopenia (n=20)	Possible sarcopenia (n=289)	Sarcopenia (n=75)	OR (95% CI)			
				Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
TG/HDL-C							
Quartile 1 (≤2.07)	4 (20.0)	51 (17.6)	40 (53.3)	Reference	Reference	Reference	Reference
Quartile 2 (2.08-3.26)	4 (20.0)	82 (28.4)	12 (16.0)	**0.24 (0.12, 0.46)*****	**0.23 (0.12, 0.45)*****	**0.28 (0.14, 0.56)*****	**0.38 (0.17, 0.83)***
Quartile 3 (3.27-5.61)	6 (30.0)	74 (25.6)	15 (20.0)	**0.36 (0.13, 0.50)*****	**0.25 (0.13, 0.49)*****	**0.26 (0.13, 0.50)*****	**0.26 (0.12, 0.57)****
Quartile 4 (>5.61)	6 (30.0)	82 (28.4)	8 (10.7)	**0.17 (0.08, 0.33)*****	**0.17 (0.09, 0.34)*****	**0.18 (0.09, 0.37)*****	**0.17 (0.07, 0.44)*****

a. Unadjusted.

b. Adjusted for median age.

c. Adjusted for median age, residence, education level, and history of smoking and drinking.

d. Adjusted for median age, residence, education level, and history of smoking and drinking, overweight, diabetes management, SBP, DBP, plasma glucose, HbA1c, TC, LDL-C, hs-CRP, uric acid, and eGFR.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Abbreviations: TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio; OR: odds ratio; 95% CI: 95% confidence interval; SBP: systolic blood pressure; DBP: diastolic blood pressure; HbA1c: glycated hemoglobin; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate.

Table 5. Associations between TG/HDL-C and muscle strength, physical performance, and muscle mass in elderly patients with diabetes in linear regression analysis.

Male			Female		
	β (95% CI)			β (95% CI)	
Variables	Simple linear regression	Multivariate linear regression[a]	Variables	Simple linear regression	Multivariate linear regression[a]
Handgrip strength (kg)			Handgrip strength (kg)		
TG/HDL-C			TG/HDL-C		
Quartile 1 (≤1.41)	Reference	Reference	Quartile 1 (≤2.07)	Reference	Reference
Quartile 2 (1.42-2.35)	-0.69 (-3.32, 1.93)	-0.88 (-3.47, 1.71)	Quartile 2 (2.08-3.26)	1.67 (-0.70, 4.04)	1.50 (-1.09, 4.09)
Quartile 3 (2.36-4.71)	1.05 (-1.58, 3.68)	-0.05 (-2.78, 2.67)	Quartile 3 (3.27-5.61)	1.28 (-1.10, 3.67)	1.77 (-0.80, 4.34)
Quartile 4 (>4.71)	2.23 (-0.40, 4.86)	-0.92 (-3.84, 2.00)	Quartile 4 (>5.61)	**3.16 (0.78, 5.54)****	**3.93 (0.89, 6.97)***
Gait speed (m/s)			Gait speed (m/s)		
TG/HDL-C			TG/HDL-C		
Quartile 1 (≤1.41)	Reference	Reference	Quartile 1 (≤2.07)	Reference	Reference
Quartile 2 (1.42-2.35)	-0.017 (-0.089, 0.056)	0.001 (-0.074, 0.076)	Quartile 2 (2.08-3.26)	0.025 (-0.039, 0.089)	0.008 (-0.059, 0.075)
Quartile 3 (2.36-4.71)	-0.072 (-1.452, 0.001)	-0.046 (-0.126, 0.033)	Quartile 3 (3.27-5.61)	0.009 (-0.056, 0.074)	0.013 (-0.054, 0.079)
Quartile 4 (>4.71)	0.009 (-0.064, 0.081)	0.015 (-0.070, 0.100)	Quartile 4 (>5.61)	0.047 (-0.018, 0.113)	0.060 (-0.020, 0.139)
5-time chair stand test (s)			5-time chair stand test (s)		
TG/HDL-C			TG/HDL-C		
Quartile 1 (≤1.41)	Reference	Reference	Quartile 1 (≤2.07)	Reference	Reference
Quartile 2 (1.42-2.35)	1.03 (-0.22, 2.27)	1.09 (-0.16, 2.33)	Quartile 2 (2.08-3.26)	0.16 (-1.34, 1.65)	-0.13 (-1.73, 1.47)
Quartile 3 (2.36-4.71)	0.95 (-0.30, 2.20)	1.04 (-0.29, 2.36)	Quartile 3 (3.27-5.61)	0.51 (-1.01, 2.03)	-0.13 (-1.71, 1.46)
Quartile 4 (>4.71)	**1.54 (0.30, 2.78)****	**2.60 (1.19, 4.00)*****	Quartile 4 (>5.61)	-0.41 (-1.93, 1.10)	-0.50 (-2.37, 1.36)
ASM/Ht^2 (kg/m^2)			ASM/Ht^2 (kg/m^2)		
TG/HDL-C			TG/HDL-C		
Quartile 1 (≤1.41)	Reference	Reference	Quartile 1 (≤2.07)	Reference	Reference

Quartile 2 (1.42-2.35)	**0.24 (0.15, 0.47)***	**0.18 (0.04, 0.32)****	Quartile 2 (2.08-3.26)	**0.65 (0.41, 0.88)*****	**0.30 (0.12, 0.47)****
Quartile 3 (2.36-4.71)	**0.58 (0.36, 0.81)*****	**0.18 (0.03, 0.32)***	Quartile 3 (3.27-5.61)	**0.59 (0.35, 0.82)*****	**0.28 (0.11, 0.45)****
Quartile 4 (>4.71)	**0.81 (0.59, 1.04)*****	**0.36 (0.20, 0.51)*****	Quartile 4 (>5.61)	**0.67 (0.43, 0.90)*****	**0.31 (0.10, 0.51)****

a. Adjusted for median age, residence, education level, and history of smoking and drinking, overweight, diabetes management, SBP, DBP, plasma glucose, HbA1c, TC, LDL-C, hs-CRP, uric acid, and eGFR.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Abbreviations: TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio; 95% CI: 95% confidence interval; ASM/Ht^2: the height-adjusted muscle mass; SBP: systolic blood pressure; DBP: diastolic blood pressure; HbA1c: glycated hemoglobin; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-11
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-11
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6-11
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	6-11
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-11
Bias	9	Describe any efforts to address potential sources of bias	6-11
Study size	10	Explain how the study size was arrived at	6-11
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-11
		(*b*) Describe any methods used to examine subgroups and interactions	6-11
		(*c*) Explain how missing data were addressed	6-11
		(*d*) If applicable, explain how loss to follow-up was addressed	6-11
		(*e*) Describe any sensitivity analyses	6-11
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11-15
		(b) Give reasons for non-participation at each stage	11-15
		(c) Consider use of a flow diagram	11-15
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-15
		(b) Indicate number of participants with missing data for each variable of interest	11-15
		(c) Summarise follow-up time (eg, average and total amount)	11-15
Outcome data	15*	Report numbers of outcome events or summary measures over time	11-15

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-15 11-15 11-15
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-15
Discussion			
Key results	18	Summarise key results with reference to study objectives	15-20
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	19
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.