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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

Yinghe Lin , Shanshan Zhong, Zhihua Sun

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YL and SZ are joint first authors.

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Department of Endocrinology, Guangzhou Panyu Central Hospital, Guangzhou, Guangdong, China

**Correspondence to**
Dr Yinghe Lin; linyinghe0714@qq.com and Dr Zhihua Sun; sunzhihua2002@126.com

## 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.

**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 haemoglobin.

**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 with 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 (OR 0.24, 95% CI 0.10 to 0.54). Similarly, among female patients, compared with 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 to 0.44). In multivariate linear regression, male patients with the highest quartile of TG/HDL-C ratio (β=0.36, 95% CI 0.20 to 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 to 0.51) had higher muscle mass than those with the lowest quartile.

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

## STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ We investigated 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.
⇒ Unlike previous studies, this study focused on elderly Chinese patients with diabetes, supplementing the existing literature on this subject.
⇒ The cross-sectional study design does not permit causal inferences.
⇒ The type of diabetes was uncertain because the diagnosis of diabetes was based on self-report and measurement of blood glucose and glycated haemoglobin.

## INTRODUCTION

Sarcopenia is a syndrome characterised 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, hospitalisation and mortality.[2–7] According to a previous study, the prevalence of sarcopenia ranges from 1% to 29% in community-dwelling populations and from 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 recognised 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 inflammatory[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.

## MATERIALS AND METHODS

### 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 socio-demographics 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 2–3 years. New participants are additionally enrolled in each follow-up survey.

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) patients without diabetes, or those with missing plasma glucose or glycated haemoglobin (HbA1c) measurements (n=5094). Finally, 752 participants were eligible for this cross-sectional analysis.

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

### 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 behaviours (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]

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

#### 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]

#### 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 m,[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 s 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.

### 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]:

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

The body weight, height and age were measured in kilograms, centimetres 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 metres (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.

### 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±SD, while non-normally distributed continuous variables were described as median (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 analysis of variance, $\chi^2$ 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, categorised and analysed 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 V.17.0 (StataCorp, College Station, Texas, USA).

### Patient and public involvement

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

## RESULTS

### Baseline

Table 1 showed the baseline characteristics of the study population disaggregated by sarcopenia status. The median (IQR) age was 66.0 (62.5–72.0) years and 384 (51.1%) of subjects were women. 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 three 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).

**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)* | 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)* | 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) | **<0.001** |
| Upper secondary or vocational training | 28 (3.7) | 3 (6.1) | 23 (4.1) | 2 (1.4) | |
| Tertiary | 19 (2.5) | 4 (8.2) | 14 (2.5) | 1 (0.7) | |
| Ever/current smoke (%)* | 303 (40.5) | 21 (42.9) | 220 (39.6) | 62 (43.1) | 0.704 |
| Ever/current drinking (%)* | 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)* | | | | | |
| 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)† | 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)* | 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) | **<0.001** |
| Quartile 2 (1.74–2.81) | | 10 (20.4) | 139 (25.0) | 39 (26.7) | |
| 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±SD, median (IQR) or numbers (percentages).
The significant P values were highlighted by bold font.
*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.
†Among the measurements of plasma glucose, 39 participants were non-fasting.
ASM/Ht$^2$, the height-adjusted muscle mass; BMI, the body mass index; eGFR, the estimated glomerular filtration rate; HbA1c, glycated haemoglobin; HDL-C, high-density lipoprotein cholesterol ratio; hs-CRP, high-sensitivity C reactive protein; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride; 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)* | 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)* | 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) | 0.119 |
| Upper secondary or vocational training | 15 (4.1) | 1 (3.4) | 12 (4.5) | 2 (2.8) | |
| Tertiary | 15 (4.1) | 3 (10.3) | 12 (4.5) | 0 (0) | |
| Ever/current smoke (%)* | 270 (73.8) | 20 (69.0) | 194 (72.7) | 56 (80.0) | 0.384 |
| Ever/current drinking (%)* | 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)* | | | | | |
| 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)† | 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)* | 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) | **<0.001** |
| 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) | |
| Quartile 4 (>4.71) | | 11 (37.9) | 76 (28.4) | 5 (7.0) | |

Data are shown as means±SD, median (IQR) or numbers (percentages).
The significant P values were highlighted by bold font.
*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.
†Among the measurements of plasma glucose, 17 male participants were non-fasting.
ASM/Ht$^2$, the height-adjusted muscle mass; BMI, the body mass index; eGFR, the estimated glomerular filtration rate; HbA1c, glycated haemoglobin; HDL-C, high-density lipoprotein cholesterol ratio; hs-CRP, high-sensitivity C reactive protein; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride; 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)* | 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)* | 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) | **0.032** |
| Upper secondary or vocational training | 13 (3.4) | 2 (10.0) | 11 (3.8) | 0 (0) | |
| Tertiary | 4 (1.0) | 1 (5.0) | 2 (0.7) | 1 (1.3) | |
| Ever/current smoke (%)* | 33 (8.6) | 1 (5.0) | 26 (9.0) | 6 (8.1) | 1.000 |
| Ever/current drinking (%)* | 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)* | | | | | |
| 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)† | 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)* | 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±SD, median (IQR) or numbers (percentages).
The significant P values were highlighted by bold font.
*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.
†Among the measurements of plasma glucose, 22 female participants were non-fasting.
ASM/Ht$^2$, the height-adjusted muscle mass; BMI, the body mass index; eGFR, the estimated glomerular filtration rate; HbA1c, glycated haemoglobin; HDL-C, high-density lipoprotein cholesterol ratio; hs-CRP, high-sensitivity C reactive protein; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride; TG/HDL-C, triglyceride to high-density lipoprotein cholesterol ratio.

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 tables 1–3.

### Association between TG/HDL-C ratio and sarcopenia

Among male participants, compared with 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 to 0.92, p=0.027),

quartile 3 (2.36–4.71; OR 0.36, 95% CI 0.19 to 0.69, p=0.002) and quartile 4 (>4.71; OR 0.18, 95% CI 0.09 to 0.35, p<0.001) of TG/HDL-C ratio had significantly lower OR of more severe sarcopenia in the unadjusted ordinal logistic regression (Model 1). In the multivariable-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 quartile 4 (>4.71; OR 0.24, 95% CI 0.10 to 0.54, p=0.001) of TG/HDL-C ratio had significantly lower risk of more severe sarcopenia.

Similarly, among female participants, compared with 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 to 0.46, p<0.001), quartile 3 (3.27–5.61; OR 0.36, 95% CI 0.13 to 0.50, p<0.001) and quartile 4 (>5.61; OR 0.17, 95% CI 0.08 to 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 multivariable-adjusted model (Model 4), female participants with quartile 2 (2.08–3.26; OR 0.38, 95% CI 0.17 to 0.83, p=0.015), quartile 3 (3.27–5.61; OR 0.26, 95% CI 0.12 to 0.57, p=0.001) and quartile 4 (>5.61; OR 0.17, 95% CI 0.07 to 0.44, p<0.001) of TG/HDL-C ratio had significantly lower risk of more severe sarcopenia, compared with 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.

### 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 categorised 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 to 2.78, p=0.015) and multivariate (β=2.60, 95% CI 1.19 to 4.00, p<0.001) linear regression. On simple and multivariate linear regression analysis, TG/HDL-C ratio categorised 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 to 0.32, p=0.009), quartile 3 (2.36–4.71; β=0.18, 95% CI 0.03 to 0.32, p=0.016) and quartile 4 (>4.71; β=0.36, 95% CI 0.20 to 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 to 5.54, p=0.009) and multivariate (β=3.93, 95% CI 0.89 to 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 categorised 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), quartile 3 (3.27–5.61; β=0.28, 95% CI 0.11 to 0.45, p=0.001) and quartile 4 (>5.61; β=0.31, 95% CI 0.10 to 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.

## DISCUSSION

In this cohort, we found a negative association between TG/HDL-C ratio categorised 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 analysed 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 categorised 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 led to selection bias. Second, gene polymorphisms affecting the lipid profiles in the Chinese and Koreans remain undefined but cannot be ignored, because a study reported a 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 patients

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

| **Male** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Variables** | **No sarcopenia** | **Possible sarcopenia** | **Sarcopenia** | **OR (95% CI)** | | | |
| | **(n=29)** | **(n=268)** | **(n=71)** | **Model 1†** | **Model 2‡** | **Model 3§** | **Model 4¶** |
| 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 to 0.92)*** | **0.47 (0.25 to 0.88)*** | **0.50 (0.26 to 0.96)*** | **0.48 (0.24 to 0.97)*** |
| Quartile 3 (2.36–4.71) | 8 (27.6) | 69 (25.7) | 15 (21.1) | **0.36 (0.19 to 0.69)**** | **0.33 (0.17 to 0.65)**** | **0.41 (0.20 to 0.80)**** | 0.56 (0.27 to 1.17) |
| Quartile 4 (>4.71) | 11 (37.9) | 76 (28.4) | 5 (7.0) | **0.18 (0.09 to 0.35)***** | **0.18 (0.09 to 0.37)***** | **0.24 (0.12 to 0.49)***** | **0.24 (0.10 to 0.54)**** |
| **Female** | | | | | | | |
| **Variables** | **No sarcopenia** | **Possible sarcopenia** | **Sarcopenia** | **OR (95% CI)** | | | |
| | **(n=20)** | **(n=289)** | **(n=75)** | **Model 1†** | **Model 2‡** | **Model 3§** | **Model 4¶** |
| 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 to 0.46)***** | **0.23 (0.12 to 0.45)***** | **0.28 (0.14 to 0.56)***** | **0.38 (0.17 to 0.83)*** |
| Quartile 3 (3.27–5.61) | 6 (30.0) | 74 (25.6) | 15 (20.0) | **0.36 (0.13 to 0.50)***** | **0.25 (0.13 to 0.49)***** | **0.26 (0.13 to 0.50)***** | **0.26 (0.12 to 0.57)**** |
| Quartile 4 (>5.61) | 6 (30.0) | 82 (28.4) | 8 (10.7) | **0.17 (0.08 to 0.33)***** | **0.17 (0.09 to 0.34)***** | **0.18 (0.09 to 0.37)***** | **0.17 (0.07 to 0.44)***** |

The significant P values were highlighted by bold font.
*p<0.05; **p<0.01; ***p<0.001.
†Unadjusted.
‡Adjusted for median age.
§Adjusted for median age, residence, education level and history of smoking and drinking.
¶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.
DBP, diastolic blood pressure; eGFR, the estimated glomerular filtration rate; HbA1c, glycated hemoglobin; hs-CRP, high-sensitivity C reactive protein; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TG/HDL-C, triglyceride to high-density lipoprotein cholesterol ratio.

**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† | Variables | Simple linear regression | Multivariate linear regression† |
| 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 to 1.93) | 0.88 (–3.47 to 1.71) | Quartile 2 (2.08–3.26) | 1.67 (–0.70 to 4.04) | 1.50 (–1.09 to 4.09) |
| Quartile 3 (2.36–4.71) | 1.05 (–1.58 to 3.68) | 0.05 (–2.78 to 2.67) | Quartile 3 (3.27–5.61) | 1.28 (–1.10 to 3.67) | 1.77 (–0.80 to 4.34) |
| Quartile 4 (>4.71) | 2.23 (–0.40 to 4.86) | 0.92 (–3.84 to 2.00) | Quartile 4 (>5.61) | **3.16 (0.78 to 5.54)**** | **3.93 (0.89 to 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 to 0.056) | 0.001 (–0.074 to 0.076) | Quartile 2 (2.08–3.26) | 0.025 (–0.039 to 0.089) | 0.008 (–0.059 to 0.075) |
| Quartile 3 (2.36–4.71) | 0.072 (–1.452 to 0.001) | 0.046 (–0.126 to 0.033) | Quartile 3 (3.27–5.61) | 0.009 (–0.056 to 0.074) | 0.013 (–0.054 to 0.079) |
| Quartile 4 (>4.71) | 0.009 (–0.064 to 0.081) | 0.015 (–0.070 to 0.100) | Quartile 4 (>5.61) | 0.047 (–0.018 to 0.113) | 0.060 (–0.020 to 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 to 2.27) | 1.09 (–0.16 to 2.33) | Quartile 2 (2.08–3.26) | 0.16 (–1.34 to 1.65) | 0.13 (–1.73 to 1.47) |
| Quartile 3 (2.36–4.71) | 0.95 (–0.30 to 2.20) | 1.04 (–0.29 to 2.36) | Quartile 3 (3.27–5.61) | 0.51 (–1.01 to 2.03) | 0.13 (–1.71 to 1.46) |
| Quartile 4 (>4.71) | **1.54 (0.30 to 2.78)**** | **2.60 (1.19 to 4.00)***** | Quartile 4 (>5.61) | 0.41 (–1.93 to 1.10) | 0.50 (–2.37 to 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 to 0.47)*** | **0.18 (0.04 to 0.32)**** | Quartile 2 (2.08–3.26) | **0.65 (0.41 to 0.88)***** | **0.30 (0.12 to 0.47)**** |
| Quartile 3 (2.36–4.71) | **0.58 (0.36 to 0.81)***** | **0.18 (0.03 to 0.32)*** | Quartile 3 (3.27–5.61) | **0.59 (0.35 to 0.82)***** | **0.28 (0.11 to 0.45)**** |
| Quartile 4 (>4.71) | **0.81 (0.59 to 1.04)***** | **0.36 (0.20 to 0.51)***** | Quartile 4 (>5.61) | **0.67 (0.43 to 0.90)***** | **0.31 (0.10 to 0.51)**** |

Continued

Table 5 Continued

| Male | | | Female | | |
|---|---|---|---|---|---|
| | β (95% CI) | | | β (95% CI) | |
| Variables | Simple linear regression | Multivariate linear regression† | Variables | Simple linear regression | Multivariate linear regression† |

The significant P values were highlighted by bold font.
*p<0.05; **p<0.01; ***p<0.001.
†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.
ASM/Ht$^2$, the height-adjusted muscle mass; DBP, diastolic blood pressure; eGFR, the estimated glomerular filtration rate; HbA1c, glycated haemoglobin; hs-CRP, high-sensitivity C reactive protein; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TG/HDL-C, triglyceride to high-density lipoprotein cholesterol ratio.

with diabetes 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 pre-diabetes (≥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 research 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 or multifrequency bioelectrical impedance analysis 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 characterised 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 patients with diabetes, 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 patients with diabetes with sarcopenia, including nutritional

supplements, dietary advice and planned exercise.[9] Therefore, future intervention studies (suitable TG supplementation and HDL-C control) for patients with diabetes 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.

## Conclusions

In this study, we observed a negative association between TG/HDL-C ratio categorised 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 investigate the relationship between lipid profiles and the occurrence, prevention and treatment of sarcopenia.

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**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not applicable.

**Ethics approval** The CHARLS protocol was conducted following the Declaration of Helsinki and approved by the Biomedical Ethical Review Committee of Peking University (IRB00001052-11015). Participants gave informed consent to participate in the study before taking part.

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**Data availability statement** Data are available in a public, open access repository. The CHARLS datasets are available on request from their home page at http://charls.pku.edu.cn/.



**ORCID iD**

Yinghe Lin http://orcid.org/0000-0001-6792-2139

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