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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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1 **Title Page**

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

5
6 **Authors:** Yinghe Lin^{1†*}, Shanshan Zhong^{1†}, Zhihua Sun^{1*}

7 1.Department of Endocrinology, Panyu Central Hospital, Guangzhou, China.

8 †These authors share first authorship.

9 * Correspondence:

10 Yinghe Lin:linyinghe0714@qq.com

11 Zhihua Sun:sunzhihua2002@126.com

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4 18 **Abstract**
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8 19 **Objective:** Previous studies showed an inconsistent association between the serum
9
10 20 triglyceride to high-density lipoprotein cholesterol (TG/HDL-C) ratio and the
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12 21 occurrence of sarcopenia in different populations. This study aimed to investigate the
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14 22 potential association between TG/HDL-C ratio and sarcopenia among elderly patients
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16 23 with diabetes.
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22 24 **Design:** A cross-sectional study.
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25 25 **Setting:** This was a second analysis of the China Health and Retirement Longitudinal
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27 26 Study (CHARLS).
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31 27 **Participants:** In this study, 752 elderly individuals with diabetes were included after
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33 28 removing individuals younger than 60 years old, missing values for the assessment of
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35 29 sarcopenia, and missing measurements for plasma glucose or HbA1c.
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40 30 **Outcome measures:** The primary information included TG/HDL-C ratio, muscle
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42 31 strength, physical performance, muscle mass, and covariables. Ordinal logistic
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44 32 regression and linear regression analysis were used to determine the association
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46 33 between TG/HDL-C ratio and sarcopenia.
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51 34 **Results:** Multivariate ordinal logistic regression showed that compared with male
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53 35 patients with the lowest quartile of TG/HDL-C ratio (≤ 1.41), those with the highest
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55 36 quartile (> 4.71 ; OR 0.24, 95% CI 0.10 to 0.54) were associated with lower risk of
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57 37 more severe sarcopenia; compared with female patients with the lowest quartile of
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4 38 TG/HDL-C ratio (≤ 2.07), those with the highest quartile (> 5.61 ; OR 0.17, 95% CI
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7 39 0.07 to 0.44) were associated with reduced risk of more severe sarcopenia. In
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9 40 multivariate linear regression, male patients with the highest quartile of TG/HDL-C
10
11 41 ratio (> 4.71 ; $\beta = 0.36$, 95% CI 0.20 to 0.51) had higher muscle mass than those with
12
13 42 the lowest quartile (≤ 1.41); female patients with the highest quartile of TG/HDL-C
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15 43 ratio (> 5.61 ; $\beta = 0.31$, 95% CI 0.10 to 0.51) had higher muscle mass than those with
16
17 44 the lowest quartile (≤ 2.07).
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23 45 **Conclusions:** There was a negative association between TG/HDL-C ratio categorized
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25 46 by quartile and sarcopenia, which means that the higher TG/HDL-C ratio may be
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27 47 related to better muscle status.
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32 48 **Keywords:** sarcopenia; triglyceride; high-density lipoprotein cholesterol; diabetes;
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34 49 elderly patient.
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4 57 **Strengths and limitations of this study**
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8 58 **1.** Our study focused on the correlation between lipid profiles and sarcopenia in
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10 59 elderly patients with diabetes and analyzed the correlation between lipid profiles and
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13 60 different muscle statuses (muscle strength, physical performance, and muscle mass).
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16 61 **2.** Unlike previous studies, this study focused on elderly patients with diabetes from
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19 62 China, a supplement to existing studies' populations and conclusions.
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22 63 **3.** This cross-sectional study was without longitudinal evidence, and analysis of
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25 64 causality and mechanism.
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29 65 **4.** In this study, the type of diabetes was uncertain because the diagnosis of diabetes
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32 66 was based on self-report, and measurement of blood glucose and HbA1c.
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35 67 **5.** The lack of duplicate blood lipid tests led to measurement bias in the baseline data.
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74 1. Introduction

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

84 Diabetes mellitus and sarcopenia have a bidirectional relationship [10,11]. In elderly
85 patients with diabetes, exercise capacity decline has been recognized as a new
86 complication [12]. Conversely, sarcopenia may increase the likelihood of older people
87 developing diabetes [10]. Older age, lower body mass index (BMI), and other
88 microvascular complications in patients with diabetes were significantly associated
89 with the development of sarcopenia [13]. A significant association between
90 sarcopenia and some metabolic risk markers, such as higher fasting plasma glucose
91 (FPG) and glycated hemoglobin (HbA1c) in diabetes individuals, has been reported
92 [14,15].

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

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4 95 diseases risk prediction in patients with or without diabetes [16-19]. In addition, as an
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7 96 accessible serum lipid test in standard clinical practice, TG/HDL-C ratio has shown
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10 97 an inconsistent association with the occurrence of sarcopenia in elderly Korean men
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12 98 and community-dwelling Chinese adults [20,21]. In consequence, whether the
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15 99 relevant conclusion can be extrapolated to elderly patients with diabetes is uncertain.

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18 100 Therefore, in this study, we aimed to investigate the potential association between
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21 101 TG/HDL-C ratio and sarcopenia among elderly patients with diabetes, including
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24 102 muscle strength, physical performance, and muscle mass.

103 **2. Materials and methods**

104 **2.1 Study population**

105 This study used data from the China Health and Retirement Longitudinal Study
106 (CHARLS), an ongoing nationally representative survey of middle-aged and elderly
107 individuals in China. Detailed information on the CHARLS was published elsewhere
108 [22]. Briefly, the CHARLS collects high-quality data through face-to-face interviews
109 with a structured questionnaire from a nationally representative sample of the Chinese
110 population aged 45 years and over, selected using multistage stratified
111 probability-proportionate-to-size sampling. The survey mainly covered
112 sociodemographics, lifestyle factors, and health-related information. Besides, the
113 CHARLS included multiple physical measurements and blood sample collection. The
114 baseline survey was conducted in 2011, and all participants were followed up every 2
115 to 3 years. Each follow-up survey remained to increase new participants.

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4 116 The CHARLS protocol was conducted following the Declaration of Helsinki and
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7 117 approved by the Biomedical Ethical Review Committee of Peking University
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9 118 (IRB00001052-11015). All participants provided informed consent. The CHARLS
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12 119 datasets are available on request from their home page at <http://charls.pku.edu.cn/>.

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15 120 Our group selected the baseline participants in CHARLS 2011 (n=17,708) and
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18 121 non-repetitive participants in CHARLS 2015 (n=3823). We gradually excluded
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21 122 20,779 individuals due to (1) age <60 years (n=13,661), (2) no information on
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24 123 physical measurements required for the assessment of sarcopenia (n=2024), (3)
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26 124 non-diabetes patients, or missing plasma glucose or HbA1c measurements (n=5094).
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29 125 Finally, 752 participants were eligible for the cross-sectional analysis.

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32 126 In this study, diabetes was defined as FPG ≥ 7.0 mmol/L (126 mg/dL), random plasma
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35 127 glucose (RPG) ≥ 11.1 mmol/L (200 mg/dL), HbA1c $\geq 6.5\%$ or self-reported history
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38 128 [23].

39 40 41 129 **2.2 Data collection**

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44 130 In the CHARLS, information on demographic factors (including age and sex),
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47 131 residence (urban or rural), education level (less than lower secondary, upper
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50 132 secondary or vocational training, or tertiary), health behaviors (including the history
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53 133 of smoking and drinking) and diabetes management (including awareness and
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56 134 treatment of diabetes) were obtained by a structured questionnaire.

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4 135 The main anthropometric parameters were height and body weight in our study. The
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7 136 body mass index (BMI, kg/m²) was calculated as body weight/(height²), and
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10 137 overweight was defined as a BMI ≥ 25 kg/m². Systolic blood pressure (SBP) and
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12 138 diastolic blood pressure (DBP) were measured three times, and their averages were
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15 139 recorded.

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18 140 The blood samples were collected for measurements of plasma glucose (mg/dL),
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21 141 HbA1c (%), total cholesterol (TC, mg/dL), TG, low-density lipoprotein cholesterol
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23 142 (LDL-C, mg/dL), HDL-C (mg/dL), high-sensitivity C-reactive protein (hs-CRP,
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26 143 mg/L), uric acid (mg/dL), and creatinine (mg/dL). Serum triglyceride to high-density
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29 144 lipoprotein cholesterol ratio, the primary variable in this study, was calculated as
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31 145 TG/HDL-C. The estimated glomerular filtration rate (eGFR, mL/min/1.73 m²) was
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34 146 calculated based on the Chronic Kidney Disease Epidemiology Collaboration's 2009
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36 147 creatinine equation [24].

40 148 **2.3 Assessment of sarcopenia**

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43 149 Sarcopenia status was assessed according to the algorithm of the Asian Working
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46 150 Group for Sarcopenia 2019 (AWGS 2019) in this study [1]. Participants with
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49 151 adequate muscle strength and physical performance were considered to have no
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52 152 sarcopenia. Possible sarcopenia was diagnosed if participants had sufficient muscle
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54 153 mass, with low muscle strength or low physical performance. Participants were
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57 154 recognized as having sarcopenia when they had low muscle mass, with low muscle
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59 155 strength or low physical performance.
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156 **2.3.1 Muscle strength**

157 Handgrip strength (kg) was used to assess muscle strength according to the AWGS
158 2019 [1]. Handgrip strength was measured both with the left and right hand twice in
159 the CHARLS [22], and we took the average of maximum values. If participants could
160 not perform grip strength measurements in both hands, we used the data of the
161 available hand. The AWGS 2019 recommended that the cut-off points for low
162 handgrip strength were <28 kg in men and <18 kg in women [1].

163 **2.3.2 Physical performance**

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

173 **2.3.3 Skeletal muscle mass measurement**

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4 174 Based on the AWGS 2019, the muscle mass was estimated by the appendicular
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7 175 skeletal muscle mass (ASM). In this study, we used a previously validated
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10 176 anthropometric equation in a Chinese population to calculate the ASM [25]:

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

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15 177 The body weight, height, and age were measured in kilograms, centimeters, and years,
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18 178 respectively. For sex, the value 1 was for men and the value 2 was for women.

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21 179 As the parameter to assess muscle mass in our study, the height-adjusted muscle mass
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24 180 was calculated as the ASM divided by the square of the height in meters
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27 181 (ASM/height²). Following previous studies [26], the cut-off points for low muscle
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30 182 mass were the lowest 20% of the height-adjusted muscle mass among our study
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33 183 population. Finally, the ASM/height² values of <6.99 kg/m² in men and <5.24 kg/m²
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35 184 in women were considered low muscle mass.

36 37 38 185 **2.4 Statistical analysis**

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41 186 In this study, statistical analyses were performed based on different genders.
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44 187 Continuous variables with normal distribution were described as mean ± standard
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47 188 deviation (SD), while with non-normal distribution as median [interquartile range
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50 189 (IQR)]. Categorical variables are expressed as frequencies and proportions. First,
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53 190 differences in baseline characteristics among the three groups (no sarcopenia, possible
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56 191 sarcopenia, and sarcopenia) were compared using one-way ANOVA, chi-square test,
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59 192 Fisher's exact test, or Kruskal–Wallis test, as appropriate. Second, ordinal logistic
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193 regression analysis was used to assess the association between TG/HDL-C ratio and

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4 194 sarcopenia status. Four different models were introduced: Model 1, without
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7 195 adjustment; Model 2, adjusted for median age; Model 3, additionally adjusted for
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10 196 residence, education level, and history of smoking and drinking; and Model 4,
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12 197 additionally adjusted for overweight, diabetes management, SBP, DBP, plasma
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14 198 glucose, HbA1c, TC, LDL-C, hs-CRP, uric acid, and eGFR. Third, linear regression
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17 199 analysis was used to estimate the associations between TG/HDL-C ratio and muscle
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20 200 strength, physical performance, and muscle mass, respectively, with or without
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22 201 adjustment for covariates. The main variable was serum TG/HDL-C, categorized and
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25 202 analyzed according to quartile. In all cases, two-sided p values <0.05 were considered
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28 203 statistically significant. All analyses were carried out with Stata 17.0 (StataCorp,
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30 204 College Station, TX, USA).

205 **3. Results**

206 **3.1 Baseline**

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

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4 215 significant difference among the different sarcopenia status. The distributions of
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7 216 median age ($P=0.001$), residence ($P=0.001$), overweight ($P=0.349$), awareness of
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10 217 diabetes ($P=0.038$), and TG/HDL-C ratio ($P<0.001$) showed significant differences
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12 218 among the three groups. There was no significant difference among the classifications
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15 219 of sarcopenia with respect to the proportions of education level ($P=0.119$), treatment
16
17 220 of diabetes ($P=0.072$), and history of smoking ($P=0.384$) and drinking ($P=0.099$).

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21 221 The baseline characteristics of female elderly patients with diabetes were presented in
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23 222 Table 2 according to sarcopenia status. In this study, 20 (5.2%) female participants
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26 223 were defined as having no sarcopenia, 289 (75.3%) as possible sarcopenia, and 75
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28 224 (19.5%) as sarcopenia. The levels of age ($P<0.001$), BMI ($P<0.001$), HbA1c
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30 225 ($P=0.002$), TG ($P<0.001$), HDL-C ($P<0.001$), hs-CRP ($P=0.009$), uric acid ($P=0.001$),
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32 226 and TG/HDL-C ratio ($P <0.001$) showed significant differences among the three
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34 227 groups. There was no significant difference among the grades of sarcopenia about
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37 228 SBP ($P=0.621$), DBP ($P=0.337$), plasma glucose ($P=0.205$), TC ($P=0.389$), LDL-C
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39 229 ($P=0.629$), and eGFR ($P=0.090$). Among the three groups, the proportions of median
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42 230 age ($P=0.021$), residence ($P<0.001$), education level ($P=0.032$), overweight ($P<0.001$),
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44 231 awareness ($P<0.001$) and treatment ($P=0.008$) of diabetes, and TG/HDL-C ratio
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46 232 ($P<0.001$) showed significant differences. There was no significant difference with
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49 233 respect to the distributions of history of smoking ($P=1.000$) and drinking ($P=0.068$)
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52 234 among them.

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58 235 The detailed data were shown in Table 1 and Table 2.
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236 **3.2 Association between TG/HDL-C ratio and sarcopenia**

237 Compared with male participants with quartile 1 of TG/HDL-C ratio (≤ 1.41), those
238 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
239 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,
240 $P<0.001$) of TG/HDL-C ratio had reduced odds ratio of more severe sarcopenia in the
241 unadjusted ordinal logistic regression (Model 1), respectively. In the
242 multi-variable-adjusted model (Model 4), compared with male participants with
243 quartile 1 of TG/HDL-C ratio (≤ 1.41), those with quartile 2 (1.42-2.35; OR 0.48, 95%
244 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
245 TG/HDL-C ratio were associated with lower risk of more severe sarcopenia,
246 respectively.

247 Similarly, compared with female participants with quartile 1 of TG/HDL-C ratio
248 (≤ 2.07), those with quartile 2 (2.08-3.26; OR 0.24, 95% CI 0.12 to 0.46, $P<0.001$), 3
249 (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
250 0.08 to 0.33, $P<0.001$) of TG/HDL-C ratio were associated with depressed risk of
251 more severe sarcopenia, in the unadjusted ordinal logistic regression (Model 1),
252 respectively. The multi-variable-adjusted model (Model 4) showed that female
253 participants with quartile 2 (2.08-3.26; OR 0.38, 95% CI 0.17 to 0.83, $P=0.015$), 3
254 (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
255 0.07 to 0.44, $P<0.001$) of TG/HDL-C ratio had reduced risk of more severe

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4 256 sarcopenia, respectively, compared with those with quartile 1 of TG/HDL-C ratio
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7 257 (≤ 2.07).

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10 258 Other adjusted models, Model 2 and Model 3, were shown in Table 3 and Table 4.

14 259 **3.3 Associations between TG/HDL-C ratio and components of sarcopenia**

17 260 Among male participants, simple and multivariate linear regression analysis showed
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19
20 261 that TG/HDL-C ratio categorized by quartile had no statistical correlation with
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23 262 handgrip strength and gait speed. In terms of the 5-time chair stand test, compared
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25 263 with quartile 1 of TG/HDL-C ratio (≤ 1.41), quartile 4 of TG/HDL-C ratio (> 4.71) was
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28 264 associated with long chair-rising time in simple ($\beta = 1.54$, 95% CI 0.30 to 2.78,
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30 265 $P = 0.015$) and multivariate ($\beta = 2.60$, 95% CI 1.19 to 4.00, $P < 0.001$) linear regression.
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33 266 Yet simple and multivariate linear regression analysis showed that TG/HDL-C ratio
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36 267 categorized by quartile had a statistical correlation with muscle mass. In multivariate
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38
39 268 linear regression analysis, compared with quartile 1 of TG/HDL-C ratio (≤ 1.41),
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41 269 quartile 2 (1.42-2.35; $\beta = 0.18$, 95% CI 0.04 to 0.32, $P = 0.009$), 3 (2.36-4.71; $\beta = 0.18$,
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43 270 95% CI 0.03 to 0.32, $P = 0.016$), and 4 (> 4.71 ; $\beta = 0.36$, 95% CI 0.20 to 0.51, $P < 0.001$)
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46 271 of TG/HDL-C ratio had associations with high height-adjusted muscle mass
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49 272 ($ASM/height^2$), respectively.

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52 273 Unlike male participants, compared with female participants with quartile 1 of
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54 274 TG/HDL-C ratio (≤ 2.07), those with quartile 4 of TG/HDL-C ratio (> 5.61) were
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57 275 associated with high handgrip strength in simple ($\beta = 3.16$, 95% CI 0.78 to 5.54,
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60 276 $P = 0.009$) and multivariate ($\beta = 3.93$, 95% CI 0.89 to 6.97, $P = 0.011$) linear regression.

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4 277 Yet there was no statistical correlation between TG/HDL-C ratio and gait speed, and
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7 278 the 5-time chair stand test. Similar to male participants, TG/HDL-C ratio categorized
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10 279 by quartile was correlated with muscle mass in linear regression analysis among
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12 280 female participants. In multivariate linear regression analysis, compared with quartile
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14 281 1 of TG/HDL-C ratio (≤ 2.07), quartile 2 (2.08-3.26; $\beta=0.30$, 95% CI 0.12 to 0.47,
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16
17 282 $P=0.001$), 3 (3.27-5.61; $\beta=0.28$, 95% CI 0.11 to 0.45, $P=0.001$), and 4 (>5.61 ; $\beta=0.31$,
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20 283 95% CI 0.10 to 0.51, $P=0.003$) of TG/HDL-C ratio had associations with high
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22 284 height-adjusted muscle mass (ASM/height²), respectively.

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26 285 Other detailed data were shown in Table 5.

27 28 29 286 **4. Discussion**

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33 287 In this cohort, we found a negative association between TG/HDL-C ratio categorized
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35 288 by quartile and sarcopenia, which means that higher TG/HDL-C ratio may be
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38 289 associated with better muscle status. Unlike previous studies [20,21], this study
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41 290 focused on elderly patients with diabetes from China, a supplement to existing
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43 291 studies' populations and conclusions. In addition, our group further analyzed the
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46 292 correlation between TG/HDL-C ratio and specific components of sarcopenia,
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49 293 including muscle strength, physical performance, and muscle mass. Then, we found
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52 294 the results as followed for the first time: first, compared with the lowest quartile of
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54 295 TG/HDL-C ratio (≤ 1.41), the highest quartile of TG/HDL-C ratio (>4.71) was
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57 296 associated with long chair-rising time among male elderly diabetics; second,
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59 297 compared with the lowest quartile of TG/HDL-C ratio (≤ 2.07), the highest quartile of
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4 298 TG/HDL-C ratio (>5.61) was associated with high handgrip strength among female
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7 299 elderly diabetics; third, high TG/HDL-C ratio categorized by quartile was correlated
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10 300 with increased muscle mass in both sexes. The above findings further explained that as
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12 301 a widely and rapidly accessible lipid parameter, TG/HDL-C ratio had concrete
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15 302 interactions with sarcopenia.

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18 303 Consistent with the previous finding in community-dwelling Chinese populations [21],
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21 304 this study showed that higher TG/HDL-C ratio was associated with a lower risk of
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24 305 more severe sarcopenia in older men and women with diabetes. This finding was
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27 306 contrary to the Korean male study [20]. As previous researchers mentioned, study
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30 307 design, gene diversity, and lifestyle factors in different populations led to variations in
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32 308 lipid profiles [21]. Therefore, TG/HDL-C ratio, as an easily accessible lipid indicator,
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34 309 would be considered a risk factor for sarcopenia in elderly Chinese patients with
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36 310 diabetes.

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40 311 It is noted that there was gender differences in the association between TG/HDL-C
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43 312 ratio and partial muscle functions of elderly diabetics in our study. Only among male
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46 313 elderly diabetics, we found that patients with the highest quartile of TG/HDL-C ratio
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48 314 (>4.71) had longer chair-rising time than those with the lowest (≤ 1.41). The other
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51 315 study using the CHARLS database also found similar results in the measurement of
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54 316 physical performance in participants with prediabetes (≥ 45 years) [27]. This finding
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57 317 contradicted the main result, but the reason was unclear [27]. Then, we found that
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59 318 patients with the highest quartile of TG/HDL-C ratio (>5.61) showed higher muscle
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4 319 strength than those with the lowest (≤ 2.07), only among female elderly diabetics.
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7 320 Previous studies have investigated the correlations between various metabolic indexes
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9 321 and sarcopenia in different cohorts and found that their effects had sex differences
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11 322 [28]. More detailed researches may help us understand this phenomenon in the future.
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15 323 Conversely, the associations between TG/HDL-C ratio and muscle mass of elderly
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17 324 diabetics in different genders were consistent in this study. Regardless of gender, we
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19 325 found that high quartile of TG/HDL-C ratio was correlated with increased muscle
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21 326 mass. At present, AWGS 2019 recommends using dual-energy X-ray absorptiometry
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23 327 (DXA) or multifrequency bioelectrical impedance analysis (BIA) for measuring
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25 328 muscle mass in sarcopenia diagnosis [1]. Our findings suggest that TG/HDL-C ratio
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27 329 can be used as a relatively simple screening indicator for muscle mass and help
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29 330 clinicians identify elderly diabetics at high risk of muscle mass deficiency.
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37 331 In general, in addition to proposing an easily accessible parameter for screening
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39 332 sarcopenia in elderly diabetic patients, we try to provide ideas for the prevention and
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41 333 treatment of sarcopenia in people with diabetes. Recently, sarcopenia has been
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43 334 implicated as both a cause and consequence of diabetes [10,11]. However, there was
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45 335 insufficient evidence for treatment recommendations for diabetic patients with
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47 336 sarcopenia, including nutritional supplements, dietary advice, and planned exercise
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49 337 [10]. Therefore, future intervention studies (suitable TG supplementation and HDL-C
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51 338 control) for diabetic patients with sarcopenia can further investigate the interactions
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4 339 between lipid profile and sarcopenia and provide others evidence for the prevention
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7 340 and treatment of sarcopenia.
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10 341 There are several limitations of our study. First, causality and mechanism could not be
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12 342 determined due to this cross-sectional study. Second, this study only involved elderly
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15 343 patients with diabetes from the CHARLS, which may also have resulted in selection
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18 344 bias. Third, the type of diabetes was uncertain because the diagnosis of diabetes was
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21 345 based on self-report, and measurement of blood glucose and HbA1c. Fourth, multiple
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23 346 comorbidities and history of drug using were not included in the analysis, and future
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26 347 studies need to take more considerations for them in clinical practice. Fifth, instead of
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29 348 the AWGS 2019 recommendation, we used a previously validated anthropometric
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31 349 equation to assess the muscle mass, which may also have led to measurement bias.
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34 350 **5. Conclusions**

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38 351 In conclusion, there was a negative association between TG/HDL-C ratio categorized
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41 352 by quartile and sarcopenia, which means that higher TG/HDL-C ratio may be related
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44 353 to better muscle status. Future prospective and intervention studies were needed to be
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47 354 investigated the relationship between lipid profiles and the occurrence, prevention,
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49 355 and treatment of sarcopenia.
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51 356 **6. Declarations**

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7 359 commercial or not-for-profit sectors.
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10 360 **Competing interests**

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14 361 The authors declare that they have no competing interests.
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17 362 **Authors' contributions**

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21 363 YL contributed to the study concept and design, data acquisition and analysis, and
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23
24 364 drafted the manuscript. SZ contributed to revising the manuscript. ZS contributed to
25
26
27 365 providing technical and material support. ZS also contributed to the supervision of
28
29
30 366 this study. All authors read and approved the final manuscript.
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32 367 **Ethics approval and consent to participate**

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36 368 The CHARLS protocol was conducted following the Declaration of Helsinki and
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39 369 approved by the Biomedical Ethical Review Committee of Peking University
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42 370 (IRB00001052-11015). All participants provided written informed consent.
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45 371 **Availability of data and materials**

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49 372 The CHARLS datasets are available on request from their home page at
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52 373 <http://charls.pku.edu.cn/>.
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54 374 **Acknowledgments**

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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)	<i>P</i> -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 (%)					0.001
Urban	150 (40.8)	13 (44.8)	122 (45.5)	15 (21.1)	
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 (%)					

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5	Awareness	139 (37.8)	14 (48.3)	107 (39.9)	18 (25.4)	
6						0.038
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8	Unawareness	229 (62.2)	15 (51.7)	161 (60.1)	53 (74.6)	
9						
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11	Treatment	94 (25.5)	11 (37.9)	71 (26.5)	12 (16.9)	
12						0.072
13						
14	Untreatment	274 (74.5)	18 (62.1)	197 (73.5)	59 (83.1)	
15						
16	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
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19	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
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22	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
23						
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25	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
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28	LDL-C (mg/dL) ^a	109.1±35.4	108.3±30.6	111.9±36.2	98.9±32.5	0.002
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31	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
32						
33	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
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36	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
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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)	

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

477 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.

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

479 Abbreviations: ASM/Ht²: the height-adjusted muscle mass; BMI: the body mass index; HbA1c: glycated hemoglobin; TC: total cholesterol; TG: triglyceride; LDL-C:
 480 low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol ratio; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular
 481 filtration rate; TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio.

482

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)	<i>P</i> -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 (%)					<0.001
Urban	170 (44.3)	15 (75.0)	135 (46.7)	20 (26.7)	
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 (%)

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5	Awareness	166 (43.2)	8 (40.0)	142 (49.1)	16 (21.3)	
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7						<0.001
8	Unawareness	218 (56.8)	12 (60.0)	147 (50.9)	59 (78.7)	
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11	Treatment	104 (27.1)	5 (25.0)	89 (30.8)	10 (13.3)	
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13						0.008
14	Untreatment	280 (72.9)	15 (75.0)	200 (69.2)	65 (86.7)	
15						
16	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
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18						
19	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
20						
21						
22	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
23						
24						
25	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
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28	LDL-C (mg/dL) ^a	122.0±40.5	129.6±44.0	120.9±41.4	124.3±36.3	0.629
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31	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
32						
33	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
34						
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36	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
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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)	

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

484 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.

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

486 Abbreviations: ASM/Ht²: the height-adjusted muscle mass; BMI: the body mass index; HbA1c: glycated hemoglobin; TC: total cholesterol; TG: triglyceride; LDL-C:
 487 low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol ratio; hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular
 488 filtration rate; TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio.

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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)**

490 a. Unadjusted (n=368).

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

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

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

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5 495 * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
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7 496 Abbreviations: TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio; OR: odds ratio; 95% CI: 95% confidence interval; SBP: systolic blood pressure;
8 497 DBP: diastolic blood pressure; HbA1c: glycated hemoglobin; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; hs-CRP: high-sensitivity C-reactive
9 498 protein; eGFR: the estimated glomerular filtration rate.
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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) ^{***}

500 a. Unadjusted (n=384).
501 b. Adjusted for median age (n=384).
502 c. Adjusted for median age, residence, education level, and history of smoking and drinking (n=382).
503 d. Adjusted for median age, residence, education level, and history of smoking and drinking, overweight, diabetes management, SBP, DBP, plasma glucose, HbA1c,
504 TC, LDL-C, hs-CRP, uric acid, and eGFR (n=368).

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5 505 * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
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7 506 Abbreviations: TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio; OR: odds ratio; 95% CI: 95% confidence interval; SBP: systolic blood pressure;
8 507 DBP: diastolic blood pressure; HbA1c: glycated hemoglobin; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; hs-CRP: high-sensitivity C-reactive
9 508 protein; eGFR: the estimated glomerular filtration rate.
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Table 5. Associations between TG/HDL-C and muscle strength, physical performance, and muscle mass among elderly patients with diabetes in linear regression analysis.

Variables	Male		Female		
	β (95% CI)		β (95% CI)		
	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)		

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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)**

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

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

513 Abbreviations: TG/HDL-C: triglyceride to high-density lipoprotein cholesterol ratio; 95% CI: 95% confidence interval; ASM/Ht²: the height-adjusted muscle mass;
514 SBP: systolic blood pressure; DBP: diastolic blood pressure; HbA1c: glycated hemoglobin; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol;
515 hs-CRP: high-sensitivity C-reactive protein; eGFR: the estimated glomerular filtration rate.

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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 (b) Provide in the abstract an informative and balanced summary of what was done and what was found	1 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

1	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
2			(b) Report category boundaries when continuous variables were categorized	11-15
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-15
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9	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-15
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11	Discussion			
12				
13	Key results	18	Summarise key results with reference to study objectives	15-18
14	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
15				
16	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
17				
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19	Generalisability	21	Discuss the generalisability (external validity) of the study results	18
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21	Other information			
22	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
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26 *Give information separately for exposed and unexposed groups.

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

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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Keywords:	Lipid disorders < DIABETES & ENDOCRINOLOGY, Diabetes & endocrinology < INTERNAL MEDICINE, DIABETES & ENDOCRINOLOGY

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5 1 **Title Page**
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8 2 **Article Title:** Association between serum triglyceride to high-density lipoprotein
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10 3 cholesterol ratio and sarcopenia among elderly patients with diabetes: A secondary
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12 4 data analysis of the China Health and Retirement Longitudinal Study
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19
20 6 **Authors:** Yinghe Lin^{1†*}, Shanshan Zhong^{1†}, Zhihua Sun^{1*}
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23
24 7 1.Department of Endocrinology, Panyu Central Hospital, Guangzhou, China.
25
26

27
28 8 †These authors share first authorship.
29
30

31 9 * Correspondence:
32
33

34
35 10 Yinghe Lin:linyinghe0714@qq.com
36
37

38 11 Zhihua Sun:sunzhihua2002@126.com
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4 18 **Abstract**

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8 19 **Objective:** Previous studies investigating the association between the serum
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10 20 triglyceride to high-density lipoprotein cholesterol (TG/HDL-C) ratio and the
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12 21 occurrence of sarcopenia in different populations have yielded inconsistent results.
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14 22 This study aimed to investigate the potential association between TG/HDL-C ratio
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16 23 and sarcopenia among elderly Chinese patients with diabetes.
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21 24 **Design:** A secondary data analysis.
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25 25 **Setting:** This was a secondary analysis of data from the China Health and Retirement
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27 26 Longitudinal Study (CHARLS).
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31 27 **Participants:** In this study, 752 elderly individuals with diabetes were included after
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33 28 excluding individuals aged <60 years old, those with missing data for the assessment
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35 29 of sarcopenia, and missing measurements for plasma glucose or glycated hemoglobin.
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40 30 **Outcome measures:** The primary information included TG/HDL-C ratio, muscle
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42 31 strength, physical performance, muscle mass, and covariables. The association
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44 32 between TG/HDL-C ratio and sarcopenia was assessed using ordinal logistic
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46 33 regression and linear regression analysis..
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51 34 **Results:** On multivariate ordinal logistic regression, among male patients, compared
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53 35 to those with the lowest quartile of TG/HDL-C ratio (≤ 1.41), those with the highest
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55 36 quartile (> 4.71) had a significantly lower risk of more severe sarcopenia (odds ratio
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57 37 [OR] 0.24, 95% confidence interval [CI] 0.10–0.54). Similarly, among female
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4 38 patients, compared to those with the lowest quartile of TG/HDL-C ratio (≤ 2.07), those
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7 39 with the highest quartile (> 5.61) had a significantly lower risk of more severe
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9 40 sarcopenia (OR 0.17, 95% CI 0.07–0.44). In multivariate linear regression, male
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11 41 patients with the highest quartile of TG/HDL-C ratio ($\beta=0.36$, 95% CI 0.20–0.51) had
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13 42 higher muscle mass than those with the lowest quartile. Similarly, female patients
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15 43 with the highest quartile of TG/HDL-C ratio ($\beta=0.31$, 95% CI 0.10–0.51) had higher
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17 44 muscle mass than those with the lowest quartile.
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23 45 **Conclusions:** There was a negative association between TG/HDL-C ratio categorized
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25 46 by quartile and sarcopenia, which indicates that a higher TG/HDL-C ratio may be
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27 47 related to better muscle status.
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32 48 **Keywords:** sarcopenia; triglyceride; high-density lipoprotein cholesterol; diabetes;
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34 49 elderly patient.
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4 **57 Strengths and limitations of this study**
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8 **1.** We investigated on the correlation between lipid profile and the various parameters
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11 for the assessment of sarcopenia (muscle strength, physical performance, and muscle
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13 mass) in elderly patients with diabetes.
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17 **2.** Unlike previous studies, this study focused on elderly Chinese patients with
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19 diabetes, supplementing the existing literature on this subject.
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23 **3.** The cross-sectional study design does not permit causal inferences.
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27 **4.** The type of diabetes was uncertain because the diagnosis of diabetes was based on
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29 self-report and measurement of blood glucose and HbA1c.
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74 **1. Introduction**

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

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

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4 95 consequence, the relevant conclusion cannot be extrapolated to elderly patients with
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7 96 diabetes.
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10 97 Besides, an inappropriate burden of inflammation also plays a role in the pathogenesis
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13 98 of sarcopenia [1]. HDL cholesterol-based markers have attracted much attention in
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16 99 recent years and several studies have reported their relationships with various
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19 100 inflamamtory [17,18] and metabolic conditions, including diabetes [19] and its
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22 101 complications [20]. Therefore, in this study, we aimed to investigate the potential
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25 102 association between TG/HDL-C ratio and sarcopenia among elderly patients with
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28 103 diabetes, including muscle strength, physical performance, and muscle mass.

104 **2. Materials and methods**

105 **2.1 Study population**

106 This study used data from the China Health and Retirement Longitudinal Study
107 (CHARLS), an ongoing nationally representative survey of middle-aged and elderly
108 individuals in China. Detailed information on the CHARLS is available elsewhere
109 [21]. Briefly, the CHARLS collects data through face-to-face interviews, using a
110 structured questionnaire, from a nationally representative sample of the Chinese
111 population aged ≥ 45 years, selected using multistage stratified
112 probability-proportionate-to-size sampling. The survey mainly collects data on
113 sociodemographics variables, lifestyle-related factors, and health-related information.
114 Besides, the CHARLS includes various physical measurements and blood sample
115 collection. The baseline survey was conducted in 2011, and all participants were

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4 116 followed up every 2 to 3 years. New participants are additionally enrolled in each
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7 117 follow-up survey.
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10 118 The CHARLS protocol was conducted following the Declaration of Helsinki and
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13 119 approved by the Biomedical Ethical Review Committee of the Peking University
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16 120 (IRB00001052-11015). All participants provided informed consent. The CHARLS
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18 121 datasets are available on request from the study home page (<http://charls.pku.edu.cn/>).
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21 122 Our group selected the baseline participants in CHARLS 2011 (n=17,708) and
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24 123 non-repetitive participants in CHARLS 2015 (n=3823). Of these, 20,779 individuals
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27 124 were excluded due to following reasons: (1) age <60 years (n=13,661); (2) missing
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30 125 information on physical measurements required for the assessment of sarcopenia
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32 126 (n=2024); (3) non-diabetes patients, or those with missing plasma glucose or glycated
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35 127 hemoglobin (HbA1c) measurements (n=5094). Finally, 752 participants were eligible
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37 128 for this cross-sectional analysis.
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41 129 In this study, diabetes was defined as fasting plasma glucose (FPG) ≥ 7.0 mmol/L (126
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43 130 mg/dL), random plasma glucose (RPG) ≥ 11.1 mmol/L (200 mg/dL), HbA1c $\geq 6.5\%$,
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46 131 or self-reported history [22].
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49 132 **2.2 Data collection**

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53 133 In the CHARLS, information on demographic factors (including age and sex),
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56 134 residence (urban or rural), education level (less than lower secondary, upper
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58 135 secondary or vocational training, or tertiary), health behaviors (including the history
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4 136 of smoking and drinking) and diabetes management (including awareness and
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7 137 treatment of diabetes) were obtained using a structured questionnaire.
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10 138 The main anthropometric parameters in our study were height and body weight. The
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13 139 body mass index (BMI, kg/m^2) was calculated as body weight/(height²), and
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16 140 overweight was defined as a BMI ≥ 25 kg/m^2 . Systolic blood pressure (SBP) and
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19 141 diastolic blood pressure (DBP) were measured three times, and their mean values
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21 142 were recorded.
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24 143 Blood samples were collected for measurements of plasma glucose (mg/dL), HbA1c
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27 144 (%), total cholesterol (TC, mg/dL), TG, low-density lipoprotein cholesterol (LDL-C,
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30 145 mg/dL), HDL-C (mg/dL), high-sensitivity C-reactive protein (hs-CRP, mg/L), uric
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33 146 acid (mg/dL), and creatinine (mg/dL). Serum triglyceride to HDL-C ratio, the primary
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35 147 variable in this study, was calculated as TG/HDL-C. The estimated glomerular
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38 148 filtration rate (eGFR, mL/min/1.73 m^2) was calculated based on the Chronic Kidney
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40 149 Disease Epidemiology Collaboration's 2009 creatinine equation [23].
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43 150 **2.3 Assessment of sarcopenia**

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47 151 In this study, sarcopenia status was assessed according to the algorithm of the Asian
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50 152 Working Group for Sarcopenia 2019 (AWGS 2019) [1]. Participants with adequate
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53 153 muscle strength and physical performance were considered to have no sarcopenia.
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56 154 Possible sarcopenia was diagnosed if participants had sufficient muscle mass, but with
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58 155 low muscle strength or low physical performance. Participants had low muscle mass,
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4 156 with low muscle strength or low physical performance, were considered as having
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7 157 sarcopenia.
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10 158 **2.3.1 Muscle strength**

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14 159 Handgrip strength (kg) was used to assess muscle strength according to the AWGS
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16 160 2019 [1]. In the CHARLS, handgrip strength was measured both with the left and
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19 161 right hand twice, and we took the average of the maximum values. If participants
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22 162 could not perform grip strength measurements in both hands, the data of the available
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25 163 hand was used. The cut-off points for low handgrip strength recommended by AWGS
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27 164 2019 were <28 kg in men and <18 kg in women [1].
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30 165 **2.3.2 Physical performance**

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34 166 This study measured physical performance by gait speed and 5-time chair stand test.
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37 167 In the CHARLS, researchers recorded the number of seconds taken by the participants
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40 168 to walk 2.5 meters [21], and we converted it to gait speed (m/s). In the 5-time chair
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43 169 stand test, the participants were required to keep their arms folded across their chest,
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45 170 while sitting on a chair, then stand up straight and then sit down again five times [21];
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48 171 the number of seconds spent by the participants was recorded. According to the
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50 172 AWGS 2019, gait speed <1.0 m/s or 5-time chair stand test ≥ 12 seconds is regarded
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53 173 as low physical performance [1]. In our analysis, participants who tried but failed to
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55 174 perform either of the tests were also considered to have low physical performance.
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58 175 **2.3.3 Skeletal muscle mass measurement**

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4 176 Based on the AWGS 2019, the muscle mass was estimated by the appendicular
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7 177 skeletal muscle mass (ASM). In this study, we used a previously validated
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10 178 anthropometric equation in a Chinese population to calculate the ASM [24]:

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

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15 180 The body weight, height, and age were measured in kilograms, centimeters, and years,
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18 181 respectively. For sex, the value 1 was assigned for men and the value 2 was assigned
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21 182 for women.

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24 183 The parameter used to assess muscle mass in our study, was the height-adjusted
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27 184 muscle mass. It was calculated as the ASM divided by the square of the height in
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30 185 meters (ASM/height²). Following previous studies [25], the cut-off point for low
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33 186 muscle mass was the lowest 20% of the height-adjusted muscle mass in our study
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36 187 population. Finally, the ASM/height² values of <6.99 kg/m² in men and <5.24 kg/m²
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39 188 in women were considered low muscle mass.

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41 189 **2.4 Statistical analysis**

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44 190 In this study, statistical analyses were performed separately for men and women. The
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47 191 Kolmogorov-Smirnov test was used to assess the normality of distribution of
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50 192 continuous variables. Normally distributed continuous variables were described as
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53 193 mean ± standard deviation (SD), while non-normally distributed continuous variables
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56 194 were described as median (interquartile range [IQR]). Categorical variables were
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59 195 expressed as frequency (percentage). First, differences in baseline characteristics
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4 197 compared using one-way ANOVA, chi-square test, Fisher's exact test, or Kruskal–
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7 198 Wallis test, as appropriate. Second, ordinal logistic regression analysis was performed
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10 199 to assess the association between TG/HDL-C ratio and sarcopenia status. Four
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12 200 different models were introduced: Model 1, without adjustment; Model 2, adjusted for
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14 201 median age; Model 3, additionally adjusted for residence, education level, and history
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17 202 of smoking and alcohol consumption; and Model 4, additionally adjusted for
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20 203 overweight, diabetes management, SBP, DBP, plasma glucose, HbA1c, TC, LDL-C,
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22 204 hs-CRP, uric acid, and eGFR. Third, linear regression analysis was performed to
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25 205 estimate the associations between TG/HDL-C ratio and muscle strength, physical
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27 206 performance, and muscle mass, respectively, with or without adjustment for
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30 207 covariates. The main variable was serum TG/HDL-C, categorized and analyzed
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33 208 according to quartiles. Given the difference in muscle between men and women, all
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36 209 analyses were stratified by sex. Two-sided *P* values <0.05 were considered indicative
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38 210 of statistical significance for all analyses. All statistical analyses were conducted
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41 211 using Stata 17.0 (StataCorp, College Station, TX, USA).

212 **2.5 Patient and public involvement**

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

214 **3. Results**

215 **3.1 Baseline**

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4 216 Table 1 showed the baseline characteristics of the study population disaggregated by
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7 217 sarcopenia status. The median (interquartile range) age was 66.0 (62.5, 72.0) years
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9 218 and 384 (51.1%) of subjects were female. The prevalence of no sarcopenia, possible
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11 219 sarcopenia, and sarcopenia in this cohort was 6.5% (49/752), 74.1% (557/752) and
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14 220 19.4% (146/752), respectively.

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18 221 Table 2 showed the baseline characteristics of male subjects according to sarcopenia
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20 222 status. There were 7.9% (29/368) male participants without sarcopenia, 72.8%
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22 223 (268/368) with possible sarcopenia, and 19.3% (71/368) with sarcopenia. There were
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24
25 224 significant differences among the three groups concerning the following continuous
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27 225 variables: age ($P<0.001$), BMI ($P<0.001$), SBP ($P=0.011$), DBP ($P=0.007$), HbA1c
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29 226 ($P=0.007$), TC ($P=0.006$), TG ($P=0.001$), LDL-C ($P=0.002$), HDL-C ($P<0.001$), uric
30
31 227 acid ($P=0.024$), and TG/HDL-C ratio ($P<0.001$). The levels of plasma glucose
32
33 228 ($P=0.763$), hs-CRP ($P=0.470$), and eGFR ($P=0.349$) showed no significant difference
34
35 229 among the different groups based on sarcopenia status. The distributions of median
36
37 230 age ($P=0.001$), residence ($P=0.001$), overweight ($P=0.349$), awareness of diabetes
38
39 231 ($P=0.038$), and TG/HDL-C ratio ($P<0.001$) showed significant differences among the
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41 232 three groups. There was no significant difference among the classifications of
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43 233 sarcopenia with respect to the education level ($P=0.119$), treatment of diabetes
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45 234 ($P=0.072$), and history of smoking ($P=0.384$) and drinking ($P=0.099$).

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49 235 The baseline characteristics of female subjects according to sarcopenia status were
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51 236 presented in Table 3. In this study, 5.2% (20/384) female participants were defined as
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4 237 having no sarcopenia, 75.3% (289/384) as having possible sarcopenia, and 19.5%
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7 238 (75/384) as having sarcopenia. There were no significant differences between the 3
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9 239 groups with respect to age ($P<0.001$), BMI ($P<0.001$), HbA1c ($P=0.002$), TG
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11 240 ($P<0.001$), HDL-C ($P<0.001$), hs-CRP ($P=0.009$), uric acid ($P=0.001$), and
12
13 241 TG/HDL-C ratio ($P<0.001$). There were no significant differences among the grades
14
15 242 of sarcopenia concerning SBP ($P=0.621$), DBP ($P=0.337$), plasma glucose ($P=0.205$),
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17 243 TC ($P=0.389$), LDL-C ($P=0.629$), and eGFR ($P=0.090$). However, there were
18
19 244 significant differences between the three groups with respect to age ($P=0.021$),
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21 245 residence ($P<0.001$), education level ($P=0.032$), overweight ($P<0.001$), awareness
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23 246 ($P<0.001$) and treatment ($P=0.008$) of diabetes, and TG/HDL-C ratio ($P<0.001$).
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25 247 There were no significant differences with respect to the distributions of history of
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27 248 smoking ($P=1.000$) and drinking ($P=0.068$).
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36 249 The detailed data were shown in Table 1-3.

3.2 Association between TG/HDL-C ratio and sarcopenia

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43 251 Among male participants, compared to those with quartile 1 of TG/HDL-C ratio
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45 252 (≤ 1.41), those with quartile 2 (1.42–2.35; OR 0.49, 95% CI 0.26–0.92, $P=0.027$), 3
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47 253 (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
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49 254 0.09–0.35, $P<0.001$) of TG/HDL-C ratio had significantly lower odds ratio of more
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51 255 severe sarcopenia in the unadjusted ordinal logistic regression (Model 1). In the
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53 256 multi-variable-adjusted model (Model 4), compared with male participants with
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55 257 quartile 1 of TG/HDL-C ratio (≤ 1.41), those with quartile 2 (1.42–2.35; OR 0.48,

258 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
259 TG/HDL-C ratio had significantly lower risk of more severe sarcopenia.

260 Similarly, among female participants, compared to those with quartile 1 of
261 TG/HDL-C ratio (≤ 2.07), those with quartile 2 (2.08–3.26; OR 0.24, 95% CI 0.12–
262 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 ;
263 OR 0.17, 95% CI 0.08–0.33, $P<0.001$) of TG/HDL-C ratio had significantly lower
264 risk of more severe sarcopenia, in the unadjusted ordinal logistic regression (Model
265 1). In the multi-variable-adjusted model (Model 4), female participants with quartile 2
266 (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
267 0.12–0.57, $P=0.001$), and 4 (>5.61 ; OR 0.17, 95% CI 0.07–0.44, $P<0.001$) of
268 TG/HDL-C ratio had significantly lower risk of more severe sarcopenia, compared to
269 those with quartile 1 of TG/HDL-C ratio (≤ 2.07).

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

272 3.3 Associations between TG/HDL-C ratio and components of sarcopenia

273 Among male participants, simple and multivariate linear regression analysis showed
274 that TG/HDL-C ratio categorized by quartile had no significant correlation with
275 handgrip strength and gait speed. In the 5-time chair stand test, compared with
276 quartile 1 of TG/HDL-C ratio (≤ 1.41), quartile 4 of TG/HDL-C ratio (>4.71) was
277 associated with significantly longer chair-rising time in simple ($\beta=1.54$, 95% CI 0.30–
278 2.78, $P=0.015$) and multivariate ($\beta=2.60$, 95% CI 1.19–4.00, $P<0.001$) linear

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4 279 regression. On simple and multivariate linear regression analysis, TG/HDL-C ratio
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7 280 categorized by quartile show a significant correlation with muscle mass. In
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10 281 multivariate linear regression analysis, compared with quartile 1 of TG/HDL-C ratio
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12 282 (≤ 1.41), quartile 2 (1.42–2.35; $\beta=0.18$, 95% CI 0.04–0.32, $P=0.009$), 3 (2.36–4.71;
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14 283 $\beta=0.18$, 95% CI 0.03–0.32, $P=0.016$), and 4 (>4.71 ; $\beta=0.36$, 95% CI 0.20–0.51,
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17 284 $P<0.001$) of TG/HDL-C ratio showed a significant association with high
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20 285 height-adjusted muscle mass (ASM/height²).

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23 286 Unlike male participants, compared with female participants in quartile 1 of
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26 287 TG/HDL-C ratio (≤ 2.07), those in quartile 4 of TG/HDL-C ratio (>5.61) had
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29 288 significantly greater handgrip strength in simple ($\beta=3.16$, 95% CI 0.78–5.54,
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31 289 $P=0.009$) and multivariate ($\beta=3.93$, 95% CI 0.89–6.97, $P=0.011$) linear regression.
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34 290 However, there was no significant correlation between TG/HDL-C ratio and gait
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37 291 speed, or the 5-time chair stand test. Similar to male participants, TG/HDL-C ratio
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40 292 categorized by quartile was correlated with muscle mass in linear regression analysis
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42 293 among female participants. In multivariate linear regression analysis, compared with
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44 294 quartile 1 of TG/HDL-C ratio (≤ 2.07), quartile 2 (2.08–3.26; $\beta=0.30$, 95% CI 0.12–
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46 295 0.47, $P=0.001$), 3 (3.27–5.61; $\beta=0.28$, 95% CI 0.11–0.45, $P=0.001$), and 4 (>5.61 ;
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48 296 $\beta=0.31$, 95% CI 0.10–0.51, $P=0.003$) of TG/HDL-C ratio were associated with
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51 297 significantly greater height-adjusted muscle mass (ASM/height²).

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55 298 Other detailed data were shown in Table 5.

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59 299 **4. Discussion**

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4 300 In this cohort, we found a negative association between TG/HDL-C ratio categorized
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7 301 by quartile and sarcopenia, which implies that higher TG/HDL-C ratio may be
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10 302 associated with better muscle status. Unlike previous studies [15,16], this study
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12 303 focused on elderly Chinese patients with diabetes; thus, our findings supplement the
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14 304 existing literature on this subject. In addition, our group further analyzed the
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17 305 correlation between TG/HDL-C ratio and specific components of sarcopenia,
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20 306 including muscle strength, physical performance, and muscle mass. The main results
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22 307 were as follows: first, compared with the lowest quartile of TG/HDL-C ratio (≤ 1.41),
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25 308 the highest quartile of TG/HDL-C ratio (> 4.71) was associated with longer
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28 309 chair-rising time among male elderly diabetics; second, compared with the lowest
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31 310 quartile of TG/HDL-C ratio (≤ 2.07), the highest quartile of TG/HDL-C ratio (> 5.61)
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34 311 was associated with greater handgrip strength among female elderly diabetics; third,
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37 312 high TG/HDL-C ratio categorized by quartile was correlated with increased muscle
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40 313 mass in both sexes. The above findings further underline the fact that, as a widely and
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43 314 rapidly accessible lipid parameter, TG/HDL-C ratio may serve as a marker of
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46 315 sarcopenia.

47 316 Consistent with the previous finding in community-dwelling Chinese populations
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50 317 [16], this study showed that higher TG/HDL-C ratio was associated with a lower risk
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53 318 of more severe sarcopenia in older patients with diabetes. Therefore, TG/HDL-C ratio
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56 319 can be considered as a risk factor for sarcopenia in elderly Chinese patients with
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59 320 diabetes. However, this finding was contrary to the Korean study [15] and the reason
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321 for the conflicting results is unclear. Previous studies have shown that study design,

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4 322 gene diversity, lifestyle factors and disease advancement in different populations may
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7 323 lead to variations in lipid profiles [16,26]. First, this study followed AWGS 2019 for
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10 324 the evaluation of sarcopenia [1], while the Korean study was published before the
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12 325 consensus [15], which may have lead to selection bias. Second, gene polymorphisms
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14 326 affecting the lipid profiles in the Chinese and Koreans remains undefined but cannot
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17 327 be ignored, because a study reported significant difference in lipid profiles between
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20 328 the Chinese and Korean adolescents populations [27]. Third, unlike the Korean study
21
22 329 [15], this study was confined to elderly Chinese patients with diabetes, and the lipid
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25 330 profiles of diabetes patients differ from those of the general population [22], which
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28 331 may also be one of the reasons for the inconsistent results.

31 332 We observed some sex-based differences in the association between TG/HDL-C ratio
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33 333 and muscle function of elderly diabetics in our study. Only among male elderly
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36 334 diabetics, we found that patients with the highest quartile of TG/HDL-C ratio (>4.71)
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39 335 had longer chair-rising time than those with the lowest quartile (≤ 1.41). Another study
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42 336 using the CHARLS database also found similar results regarding the physical
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45 337 performance of participants with prediabetes (≥ 45 years) [28]. This finding
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48 338 contradicted the main result, but the reason was unclear [28]. Further, we found that
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51 339 patients with the highest quartile of TG/HDL-C ratio (>5.61) had greater muscle
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54 340 strength than those with the lowest quartile (≤ 2.07), only among female elderly
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57 341 diabetics. Previous studies have found sex-based differences in the correlations
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60 342 between various metabolic indices and sarcopenia in different cohorts [29]. More
343 in-depth researches may help us understand this phenomenon in the future.

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4 344 Conversely, the association between TG/HDL-C ratio and muscle mass in male and
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7 345 female elderly diabetics were consistent in this study. Regardless of sex, high quartile
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10 346 of TG/HDL-C ratio was correlated with increased muscle mass. Currently, AWGS
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12 347 2019 recommends the use of dual-energy X-ray absorptiometry (DXA) or
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14 348 multifrequency bioelectrical impedance analysis (BIA) for measuring muscle mass in
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17 349 sarcopenia diagnosis [1]. This finding suggested that TG/HDL-C ratio can be used as
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20 350 a relatively simple screening indicator for muscle mass and help clinicians identify
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22 351 elderly diabetics at high risk of muscle mass deficiency. Compared with muscle
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25 352 strength and function, this closer relationship between TG/HDL-C ratio and muscle
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28 353 mass was supported by previous studies and attributed to their potential interactions
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30 354 [15,16,26]. As a marker associated with insulin resistance, TG/HDL-C ratio may
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33 355 reflect the vicious cycle between sarcopenia and insulin resistance [15]. Sarcopenia is
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36 356 mainly characterized by a decrease in muscle mass along with an increase in
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38 357 intramuscular fat. Since skeletal muscle plays an important role in insulin-mediated
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41 358 glucose disposal, lower skeletal muscle mass is likely to diminish this effect.
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44 359 Moreover, inappropriate secretion of adipokines by intramuscular fat may potentially
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47 360 lead to increased insulin resistance and sarcolysis. Muscle protein metabolism is
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50 361 influenced by insulin resistance, which promotes muscle sarcolysis resulting in loss of
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53 362 skeletal muscle mass.

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55 363 A recent study also found an association between TG/HDL-C ratio and diabetic
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57 364 complications microvascular [30]. Similarly, our study proposed an easily accessible
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60 365 parameter for screening sarcopenia in elderly diabetic patients, which may facilitate

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4 366 the prevention and treatment of sarcopenia in people with diabetes. Recently,
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7 367 sarcopenia has been implicated as both a cause and consequence of diabetes [9,10].
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9 368 However, there is insufficient evidence for treatment recommendations for diabetic
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12 369 patients with sarcopenia, including nutritional supplements, dietary advice, and
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15 370 planned exercise [9]. Therefore, future intervention studies (suitable TG
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18 371 supplementation and HDL-C control) for diabetic patients with sarcopenia can further
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21 372 investigate the interactions between lipid profile and sarcopenia and provide evidence
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24 373 for the prevention and treatment of sarcopenia.

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26 374 Some limitations of our study should be considered. First, the cross-sectional nature
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29 375 of the study does not permit any causal inferences. Second, this study only involved
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32 376 elderly patients with diabetes from the CHARLS, which may also have resulted in
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35 377 selection bias. Third, the type of diabetes was uncertain because the diagnosis of
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38 378 diabetes was based on self-report, and measurements of blood glucose and HbA1c.
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41 379 Fourth, comorbid conditions and history of drug use were not included in the analysis.
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44 380 Fifth, instead of the AWGS 2019 recommendation, we used a previously validated
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47 381 anthropometric equation to assess the muscle mass, which may also have led to
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50 382 measurement bias.

50 383 **5. Conclusions**

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54 384 In this study, we observed a negative association between TG/HDL-C ratio
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57 385 categorized by quartile and sarcopenia. Our findings indicate that higher TG/HDL-C
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60 386 ratio may be related to better muscle status. Future prospective and intervention

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4 387 studies are required to investigated the relationship between lipid profiles and the
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7 388 occurrence, prevention, and treatment of sarcopenia.
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10 389 **6. Declarations**
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24 393 **Competing interests**
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27 394 The authors declare that they have no competing interests.
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31 395 **Authors' contributions**
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34 396 YL contributed to the study concept and design, data acquisition and analysis, and
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36
37 397 drafted the manuscript. SZ contributed to revising the manuscript. ZS contributed to
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39
40 398 providing technical and material support. ZS also contributed to the supervision of
41
42
43 399 this study. All authors read and approved the final manuscript.
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46 400 **Ethics approval and consent to participate**
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49 401 The CHARLS protocol was conducted following the Declaration of Helsinki and
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52 402 approved by the Biomedical Ethical Review Committee of Peking University
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55 403 (IRB00001052-11015). All participants provided written informed consent.
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58 404 **Availability of data and materials**
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4 405 The CHARLS datasets are available on request from their home page at
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7 406 <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)	
Quartile 3 (2.82-5.19)		15 (30.6)	148 (26.6)	25 (17.1)	<0.001
Quartile 4 (> 5.19)		15 (30.6)	155 (27.8)	18 (12.3)	

Data are shown as means \pm 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/Ht²: 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)	
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)	<0.001

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/Ht²: 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

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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/Ht² : 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.

Variables	Male			OR (95% CI)			
	No sarcopenia (n=29)	Possible sarcopenia (n=268)	Sarcopenia (n=71)	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)**
Variables	Female			OR (95% CI)			
	No sarcopenia (n=20)	Possible sarcopenia (n=289)	Sarcopenia (n=75)	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.

Variables	Male		Female		
	β (95% CI)		β (95% CI)		
	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/Ht²: 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 (b) Provide in the abstract an informative and balanced summary of what was done and what was found	1 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

1	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
2			(b) Report category boundaries when continuous variables were categorized	11-15
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-15
4				
5	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-15
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11	Discussion			
12	Key results	18	Summarise key results with reference to study objectives	15-20
13	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
14				
15	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
16				
17	Generalisability	21	Discuss the generalisability (external validity) of the study results	20
18				
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21	Other information			
22	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
23				
24				

*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>.