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The mid-upper arm circumference is associated with an increased cardiometabolic risk in middle aged and elderly Chinese population

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Complete List of Authors:	Hou, Yanan; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Jia, Xu; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Xuan, Liping; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Zhu, Wen; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Deng, Chanjuan; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Wang, Long; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Zhao, Zhiyun; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Li, Mian; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Lu, Jieli; Rui-Jin Hospital, Shanghai Jiao-Tong University School of Medicine, Department of Endocrine and Metabolic Diseases Xu, Yu; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Chen, Yuhong; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Wang, Weiqing; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital Bi, Yufang; Rui-Jin Hospital, Shanghai Jiao-Tong University School of Medicine, Department of Endocrine and Metabolic Diseases Xu, Min; Rui-Jin Hospital, Shanghai Jiao-Tong University School of Medicine, Shanghai Institute of Endocrine and Metabolic Diseases Wang, Tiange; Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital,
Keywords:	cardiometabolic risk, mid-upper arm circumference, subclinical atherosclerosis, upper body fat

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11 **Running title: Upper body fat and cardiometabolic risk**
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16 Yanan HOU^{1,2}, Xu JIA^{1,2}, Liping XUAN^{1,2}, Wen ZHU^{1,2}, Chanjuan DENG^{1,2}, Long
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18 WANG^{1,2}, Zhiyun ZHAO^{1,2}, Mian LI^{1,2}, Jieli LU^{1,2}, Yu XU^{1,2}, Yuhong CHEN^{1,2},
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20 Weiqing WANG^{1,2}, Yufang BI^{1,2}, Min XU^{1,2}, Tiange WANG^{1,2¶}
21
22
23
24
25
26

27 ¹ Shanghai National Clinical Center for Endocrine and Metabolic Diseases,
28
29 Collaborative Innovation Center of Systems Biomedicine, Rui-Jin Hospital, Shanghai
30
31 Jiao Tong University School of Medicine, Shanghai, 200025, China;
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33

34
35 ² Shanghai Institute of Endocrine and Metabolic Diseases, Rui-Jin Hospital, Shanghai
36
37 Jiao Tong University School of Medicine, Shanghai, 200025, China.
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42 **¶Corresponding author:**
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45 Dr. Tiange WANG, MD & PhD
46

47
48 Shanghai National Clinical Center for Endocrine and Metabolic Diseases, Shanghai
49
50 Institute of Endocrine and Metabolic Diseases, Rui-Jin Hospital, Shanghai Jiao Tong
51
52 University School of Medicine, 197 Rui-Jin 2nd Road, Shanghai 200025, China;
53
54 Telephone: 86-21-64370045; Fax: 86-21-64749885; E-mail: wtg@live.cn
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Abstract

Objectives: Upper body fat is suggested to be associated with increased cardiometabolic risk. We aimed to investigate the associations of mid-upper arm circumference (MUAC) with the cardiometabolic risk factors or biomarkers and subclinical atherosclerosis, which was indicated as elevated carotid intima media thickness (CIMT) in Chinese population.

Methods: A cross-sectional analysis was conducted in 6570 middle aged and elderly participants who were from a well-defined community in 2014, Shanghai, China. We assessed the association of MUAC with adiposity, blood glucose, lipids, insulin resistance and blood pressure levels, and as well as the CIMT. An average value of the both sides of the carotids greater than 0.8 mm was defined as subclinical atherosclerosis.

Results: MUAC was positively associated with body mass index (BMI), waist circumference, systolic blood pressure, insulin resistance index and CIMT; while inversely related to fasting plasma glucose. MUAC was also positively associated with risk of multi cardiometabolic disorders, such as central obesity, hypertension, hypertriglyceridemia and low HDL cholesterol. As compared to quartile one of MUAC, quartile 2 to 4 of MUAC was significantly associated with an increased risk of subclinical atherosclerosis (OR = 1.31, 95% CI [1.09-1.58], 1.33 [1.10-1.62], and 1.45 [1.16-1.80], respectively; $P_{for\ trend} = 0.005$), after adjustments for the confounding factors. Moreover, these associations were more prominent in women who are older, more obese and with insulin resistance, diabetes, and hypertension than that in men.

Conclusion: The MUAC was significantly and independently associated with an increased risk of cardiometabolic disorders and subclinical atherosclerosis in women.

Keywords: cardiometabolic risk, mid-upper arm circumference, subclinical atherosclerosis, upper body fat

Strengths and limitations of this study:

- The strength of the current study was evidenced by a well-defined community setting, fair sized sample volume, and desirable population homogeneity.
- We comprehensively determine the association of MUAC with a wide spectrum of cardiometabolic risk profile including subclinical atherosclerosis.
- Although our finding supported that it can be a reliable surrogate of upper body adiposity, MUAC is a measure comprised of both adipose and lean tissue rather than a direct indicator for adiposity
- As body composition changes over time, the narrow range of age for the participants enrolled could affected the outcome.
- Since our study was performed in a Chinese population, it should be cautiously to generalize the results to the other ethnicities.

Introduction

Cardiometabolic disease describes a spectrum of interconnected pathological alterations in the cardiovascular system and metabolic organs that symbiotically increase risk of cardiovascular disease (CVD).¹ Most of the common metabolic disorders, including obesity, diabetes, insulin resistance, dyslipidemia, and hypertension contribute to development of CVD that made CVD became a major cause of mortality and burden of healthcare expenditure worldwide, accounting for 17.3 million deaths per year.²⁻⁵ Early identification and personalized prevention to curb CVD become a big challenge.

As a common contributor of CVD goes through a protracted subclinical phase, atherosclerosis could only be detected at an advanced stage of CVD.^{6,7} Thus, identification of subclinical atherosclerosis in the asymptomatic period is critical for early prevention of CVD progression. Noninvasive ultrasonography measured carotid intima media thickness (CIMT) is a well-established clinical index for early arteriosclerosis detection and therefore has been extensively adopted around the world.⁸

Meanwhile, fat distribution, specifically upper body and visceral adiposity, is proven highly relevant with cardiovascular risk.^{9,10} In addition to the conventional body fat indices such as body mass index (BMI) and waist circumference (WC), mid-upper arm circumference (MUAC), as a novel anthropometric measurement, was widely used for diagnosing malnutrition, adiposity and chronic diseases.¹¹ A cross-sectional study using data from the 1999 to 2006 National Health and Nutrition Examination Survey (NHANES) reported that MUAC was positively associated with insulin resistance in the non-obese subjects; while no significant association in obese ones.⁹ Another follow up

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4 study from the British National Diet and Nutrition Survey, which were included 1054
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6 participants aged ≥ 65 years and followed up for more than 15 years, demonstrated that
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8 MUAC was significantly and inversely associated with risk of all-cause mortality.¹²
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11 To our knowledge, few studies have been systematically and comprehensively
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13 evaluated the association of cardiovascular risk factors with MUAC in East Asian
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15 populations. Hence, our study aimed to explore the association of MUAC with a
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17 spectrum of cardiometabolic risk factors.
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24 **Methods**

25 **Study population**

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27 This is a population-based cross-sectional analysis based on one of the follow-up circle
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29 of our previous community-based cohort study.^{13,14} The study participants were enrolled
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31 from Jiading district, Shanghai, China, from August 2014 to May 2015. A total of 6570
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33 participants aged 40 years or above were invited and participated in this examination,
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35 which including a questionnaire to collect the lifestyle information, the disease history
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37 and medicine use, etc, anthropometry measurements, blood sampling and measurements
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39 to assess the early indicators of atherosclerosis. 283 individuals were excluded from the
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41 final analysis due to missing information on MUAC or CIMT. Thus, 6287 participants
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43 were finally included in our study. The study was approved by the Institutional Review
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Data collection and biochemical measurements

Detailed information on sociodemographic characteristics, family history, medical history, physical activity and health-related lifestyle were obtained using a standard questionnaire by trained personnel. Anthropometric measurements such as height, weight, waist circumference, and MUAC were assessed by well-trained physician according to a standard protocol. Body height and weight were measured with participants wearing light clothes without shoes to the nearest 0.1 centimeter (cm) and 0.1 kilogram (kg). BMI was calculated as body weight in kilograms divided by body height squared in meters (kg/m^2). MUAC was measured on the upper left arm (halfway between the acromion process and the olecranon process) with subject's bilateral arms hanging down naturally.¹⁵ WC was measured at the level of the umbilicus with the patient in the standing position. Systolic and diastolic blood pressures were measured in the non-dominant arm with an automated electronic sphygmomanometer (OMRON Model HEM-752 FUZZY, Omron Company, Dalian, China) three times (averaged for analysis) consecutively with 1 min intervals after at least 5 min rest in a seated position.

All individuals underwent a 75-g glucose tolerance test (OGTT) after an overnight fasting (nothing by mouth after midnight), of whom fasting plasma glucose and OGTT 2-hour plasma glucose were measured using hexokinase method on a clinical chemistry diagnostic system (Beckman coulter AU5800). Serum concentrations of total cholesterol, triglycerides, high-density lipoprotein (HDL-C) and low-density lipoprotein (LDL-C) cholesterol were measured by an autoanalyzer (Beckman coulter AU5800). High sensitive C-reactive protein concentration was determined by highly sensitive

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4 competitive immunoassay (antigens and antibodies from Beckman coulter
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6 IMMAGE800). Serum insulin was measured by using the electrochemiluminescence
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8 methods on an Immunology analyzer (Roche cobas e 60, Roche Diagnostics,
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10 Switzerland). Insulin resistance index (homeostasis model assessment of insulin
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12 resistance, HOMA-IR) was calculated as fasting insulin ($\mu\text{IU}/\text{mL}$) \times fasting plasma
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14 glucose (mmol/L) / 22.5, and insulin resistance was defined as HOMA-IR \geq 2.8, which
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19 is the cut-off point for the highest quartile of the total participants.
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25 **Definitions**

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27 Type 2 diabetes was defined as fasting plasma glucose \geq 7.0 mmol/L or OGTT 2-hour
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29 plasma glucose \geq 11.1 mmol/L or use of anti-diabetic agents.¹⁶ Hypertension was
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31 defined as systolic blood pressure \geq 140 mmHg, diastolic blood pressure \geq 90 mmHg or
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33 current taking an antihypertensive medication.¹⁷ Central obesity was defined as WC \geq
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35 102 cm for men and \geq 88 cm for women. Hypertriglyceridemia was defined as
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37 triglycerides \geq 2.26 mmol/L; Low HDL cholesterol was defined as HDL-C $<$ 1.04
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39 mmol/L. Cardiometabolic disorders was defined as status with central obesity, diabetes,
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41 hypertension, hypertriglyceridemia, or low HDL cholesterol. Current smokers or
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CIMT measurement were conducted by a trained sonographer using a high-resolution

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4 B-mode tomographic ultrasound system (Esaote Biomedica SpA, Genoa, Italy) with a
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6 linear 7.5 MHz transducer.¹⁹ The position of CIMT measurement was recorded on the
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8 far wall of both right and left common carotid arteries, 1.5 cm proximal to the
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10 bifurcation. CIMT was measured on-line at the end of diastole as a distance from the
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12 leading edge of the first echogenic line to that of the second. These two lines represent
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14 the lumen-intima interface and collagen-contained upper layer of tunic adventitia,
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16 respectively. Individuals with a bilateral CIMT average greater than 0.8 mm was
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18 defined as subclinical atherosclerosis, which is the highest quartile of the total
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20 participants.
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30 **Statistical analyses**

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32 SAS version 9.4 (SAS Institute Inc, Cary, NC, USA) was used for data management
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34 and statistical analysis. Continuous variables were described as means \pm standard
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36 deviation (SD) or median (inter-quartile ranges), and categorical variables as numbers
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38 (percentages). HOMA-IR, TG, and C-reactive protein were normalized by logarithmic
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40 transformation before analysis because of skewed distribution.
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45 All participants were divided into four groups according to quartiles of MUAC. The
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47 quartiles of MUAC were as follows: Q1 (15.5-27.1 cm), Q2 (27.2-29.1 cm), Q3 (29.2-
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49 31.2 cm) and Q4 (31.3-43.3 cm). Linear regression analysis was used to test for trend
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51 across the MUAC quartiles for continuous variables and the Cochran-Armitage trend
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53 chi-square test was used for categorical variables. Multivariate linear regression was
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55 conducted to study the association of MUAC with a wide spectrum of cardiometabolic
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4 risk factors or biomarkers. These models were also created to evaluate the association of
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6 MUAC with risk of subclinical atherosclerosis in multivariate logistic regression
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8 analysis. Model 1, unadjusted. Model 2, adjusted for age, sex, BMI, current smoking,
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10 current drinking, physical activity, and WC. Model 3, further adjusted for C-reactive
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12 protein, total cholesterol, HDL-C, LDL-C, triglycerides, fasting plasma glucose, and
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14 systolic blood pressure. Stratified analysis by metabolic indicators such as age, BMI,
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16 waist circumference, diabetes, insulin resistance, and hypertension were then performed
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18 to verify those associations. *P* for interaction was tested by adding these metabolic
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20 indicators in the multivariate adjusted logistic regression models simultaneously.
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27 Statistical significance was set to a two-sided *P* value of less than 0.05.
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32 **Patient and public involvement**

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35 The study was conducted without patient and public involvement. No patients were
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37 invited to take participate in the development of the research question and outcome
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39 measures, the study design and the interpretation of the results. The findings from this
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41 study will be disseminated to the participants after the results are published in a peer-
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43 reviewed journal.
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51 **Results**

52 **Characteristics of the study participants**

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55 The study sample consisted of 2310 (36.7%) men and 3977 (63.3%) women with an
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57 average age of 62.2 ± 8.78 years. Detailed sociodemographic and clinical characteristics
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4 of the study participants according to MUAC quartiles were displayed in Table 1. As
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6 expected, BMI, WC, systolic blood pressure, diastolic blood pressure, fasting plasma
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8 glucose, HOMA-IR, LDL-C, triglycerides, C-reactive protein and CIMT were increased
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10 with MUAC quartiles as well as the prevalence of insulin resistance, hypertension,
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12 diabetes, and subclinical atherosclerosis (all P value < 0.05). However, age and HDL-C
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14 gradually decreased from the lowest quartile to the highest quartile (both P value $<$
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16 0.0001) (Table 1). Physical activity and total cholesterol were not different among the
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18 quartile of MUAC.
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27 **Association of MUAC with cardiometabolic profiles.**

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29 Table 2 shows the linear regression analysis of association of MUAC with
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31 cardiometabolic profiles. MUAC was positively associated with BMI, WC, systolic
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33 blood pressure, diastolic blood pressure, fasting plasma glucose, HOMA-IR, LDL-C,
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35 triglycerides, C-reactive protein, CIMT (all P value < 0.01), except for total cholesterol
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37 (P value = 0.30). Whereas, age and HDL-C were negatively associated with MUAC (all
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39 P value < 0.01). After adjustment for age, sex, BMI, current smoking, current drinking,
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41 physical activity, the results did not change appreciably. Further adjusted for WC,
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43 MUAC was positively associated with systolic blood pressure, HOMA_IR and CIMT.
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46 The subgroup analysis showed similar results that MUAC was associated with
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48 HOMA_IR, C-reactive protein and CIMT in women after adjustment for multiple
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50 confounding factors (Supplementary Table 1), but not in men (Supplementary Table 2).
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Association of MUAC with risk of the cardiometabolic disorders.

In the multivariable adjusted logistic regression model, we found that MUAC was positively and significantly associated with central obesity, diabetes, hypertension, hypertriglyceridemia and low HDL cholesterol, after adjustment for age, sex, BMI, current smoking, current drinking, physical activity (all P value < 0.001). And each one-SD increase in MUAC (3.13 cm) was associated with a 5%, 9%, 21%, and 26% increased risk in central obesity, diabetes, hypertension, and low HDL cholesterol, respectively. Further adjustment for WC, MUAC remained positively associated with these cardiometabolic disorders (all P value ≤ 0.03), except for diabetes and hypertriglyceridemia (both P value > 0.05). The analysis for the association of each 1-SD increase in MUAC with the metabolic disorders showed similar results. (Table 3). In addition, the association between MUAC and hypertension was more significantly in women, but not in men after adjustment for WC and other confounding (Table 3).

Association of MUAC with risk of subclinical atherosclerosis

In the total study samples, each SD or quartile specific increment in MUAC was significantly associated with an increased risk of subclinical atherosclerosis after adjustment for traditional confounding factors (model 2). Moreover, these associations were not prominently attenuated when further adjustment for C-reactive protein, serum lipids, fasting plasma glucose, and systolic blood pressure. Compared with the lowest quartile of MUAC, the second, third and highest quartiles were associated with a 31% (95% CI [1.09-1.58]), 33% (95% CI [1.10-1.62]) and 45% (95% CI [1.16-1.80])

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4 increased risk of subclinical atherosclerosis, respectively, after adjustment for age, sex,
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6 BMI and other confounders ($P_{\text{for trend}} = 0.005$). Stratified analysis by sex revealed that
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8 MUAC was positively associated with subclinical atherosclerosis in women but not in
9
10 men (women, OR=1.54, 95% CI [1.24-1.93] in the second quartile; 1.42 [1.11-1.83] in
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12 the third quartile; 1.66 [1.26-2.20] in the highest quartile, $P_{\text{for trend}} = 0.002$, $P_{\text{for interaction}}$
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14 = 0.20, Table 4).
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22 **Stratified analysis of the association of MUAC with subclinical atherosclerosis**

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24 We also examined the relationship between MUAC and subclinical atherosclerosis
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26 stratified by the traditional cardiometabolic risk factors. Among women, it was found
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28 that MUAC was significant and positive associated with subclinical atherosclerosis in
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30 participants with age ≥ 62 years, BMI ≥ 25 kg/m² or waist circumference < 88 cm
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32 (Figure 1A), and those women who with diabetes, insulin resistance, or hypertension
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34 (Figure 1B). Moreover, there existed significant interactions between diabetes and
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36 insulin resistance with MUAC on the risk of subclinical atherosclerosis, P_{for}
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38 interaction=0.04 and 0.01, respectively. However, these relationships were disappeared
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40 when stratified analysis were performed in men (Supplementary Figure 1).
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48 To further evaluate whether the association of MUAC with subclinical
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50 atherosclerosis was influenced by BMI and waist circumference, we conducted a similar
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52 multivariable logistic regression analysis in different BMI-WC categories. Among
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54 women, individuals were divided into 4 groups based on their BMI and WC (the BMI
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56 limits were set at < 25 kg/m² and ≥ 25 kg/m²; the WC limits were set at < 88 cm and \geq
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4 88 cm). We found that MUAC increased from the lower WC subgroups to the higher
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6 WC subgroups within each BMI subgroup. (Figure 2A). It was also found that MUAC
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8 was independently associated with subclinical atherosclerosis in subgroup of WC < 88
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10 cm independent of BMI, after adjustment of age, BMI and other confounders (OR=1.22,
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12 95% CI [1.05-1.43] in the subgroup of BMI < 25 kg/m² and 1.40 [1.11-1.77] in the
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14 subgroup of BMI ≥ 25 kg/m², respectively). However, no significant association were
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16 found when WC ≥ 88 cm (Figure 2B).
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25 Discussion

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27 In this cross-sectional investigation including 6287 community dwelling Chinese adults,
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29 we found that MUAC was significant associated with cardiometabolic disorders and
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31 subclinical atherosclerosis as well, which was assessed by elevated CIMT, after
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33 adjusted for the confounding factors. In sex-specific sub-analyses, the association
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35 between MUAC and subclinical atherosclerosis remained significant in women, not in
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37 men. The association was more prominent in those who were much older, obese, insulin
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39 resistant, and have diabetes and hypertension, the status that were more likely to have
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41 subclinical atherosclerosis.
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48 MUAC was widely used for assessing obesity and malnutrition in children and
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50 adolescents;^{20, 21} several previous studies highlighted its predictive value for endings of
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52 cardiovascular events in both Asian and Caucasian populations.²¹ A retrospective
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54 observational study from the National Health and Nutrition Examination Survey III
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56 founding that MUAC is inversely associated with 28% lower in risk of all-cause
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4 mortality in non-obese individuals, but not in obese individuals.²¹ Another study using
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6 data from Health Effects of Arsenic Longitudinal Study (HEALS) reported that there
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8 was no relationship between MUAC and CIMT.²² Our study indicated that MUAC
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10 increment is associated with an increased risk of cardiometabolic disorders and
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12 subclinical atherosclerosis as well.
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17 Possible explanations for the positive association between MUAC and
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19 cardiometabolic risk are multifactorial, including change of body composition over
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21 time, accumulation of upper body subcutaneous adipose, sarcopenia obesity, and race.
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23 First, aging is a critical factor in changing process of metabolism and body composition.
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25 Substantial fat-free mass and muscle mass reduced as the age growing, while substantial
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27 visceral fat rather than subcutaneous fat increased with the growth of age, even under
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29 the condition of body weight unchanged. Individuals with age > 65 suffer a reduction
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31 rate over 25 percent per year for muscle mass; and this rate can be accelerated to 50
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33 percent per year for those older than 80.²²⁻²⁴ Our study indicated that MUAC levels tend
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35 to decrease with aging and there exists a stronger magnitude of association between
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37 MUAC and subclinical atherosclerosis in those aged ≥ 62 years in women. Second,
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39 upper body subcutaneous adipose tissue is not only a unique fat depot but also an active
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41 endocrine organ, which may confer additional risk for metabolic risk factors over
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43 generalized and central adiposity.²⁵ It can release free fatty acids and is more
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45 lipolytically active than lower body adipose tissue. Meanwhile, free fatty acids are
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47 directly related with hepatic very low-density lipoprotein production, insulin resistance
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49 and endothelial dysfunction, thus lead to cardiovascular and metabolic consequences.²⁶
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4 Third, sarcopenia obesity is also a critical factor. Sarcopenia obesity is a phenomenon
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6 that muscle mass is gradually decreased with age, even if body fat mass or body weight
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8 is unchanged or slightly increased. It continually occurred in the elderly as well as
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10 young or middle-aged adults with chronic disease.^{27,28} It is widely held that sarcopenia
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12 obesity is a well-correlated risk factor for hypertension.²⁹ Subjects with this phenotype
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14 may be more inclined to develop metabolic and CVD than subjects with the opposite
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16 phenotype.²⁷⁻²⁸ A study has shown that decreased muscle mass in lower extremity may
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18 result in atherosclerosis; while increased muscle mass through weight training may
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20 reduce the risk of atherosclerosis and CVD.²⁹ Furthermore, the decrease of muscle mass
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22 will not only result in reduction in muscle strength but also a strong impact on
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24 metabolism.²² Finally, compared with Caucasians, the East Asians tend to have a higher
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26 percentage of body fat, a weaker willingness on body build, and less muscle mass as
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28 well as connective tissue.
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38 MUAC was associated with subclinical atherosclerosis in a sex-specific manner. One
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40 plausible explanation for the sex difference in MUAC-subclinical atherosclerosis
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42 relationship is biological differences between men and women, such as hormones effect,
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44 immune system responses, muscle capacity and physical function. For instance, men
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46 tend to have greater muscle capacity and higher muscle mass than their women
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48 counterparts due to higher levels of testosterone.²¹
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54 The strength of the current study was evidenced by a well-defined community setting,
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56 fair sized sample volume, and desirable population homogeneity. We comprehensively
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58 determine the association of MUAC with a wide spectrum of cardiometabolic risk
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4 profile including subclinical atherosclerosis. However, we acknowledge the following
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6 limitations in our study. Firstly, the cross-sectional nature of present study means no
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8 causal inference can be drawn. Further prospective study is needed to investigate the
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10 efficacy of MUAC in predicting atherosclerosis and CVDs. Secondly, although our
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12 finding supported that it can be a reliable surrogate of upper body adiposity, MUAC is a
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14 measure comprised of both adipose and lean tissue rather than a direct indicator for
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16 adiposity. Thirdly, as body composition changes over time, the narrow range of age for
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18 the participants enrolled could affected the outcome. Lastly, since our study was
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20 performed in a Chinese population, it should be cautiously to generalize the results to
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22 the other ethnicities.
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30 In conclusion, our study provides evidence of a positive association of MUAC with
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32 cardiometabolic risk and subclinical atherosclerosis. Given the accelerating rise rate of
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34 atherosclerosis in China, MUAC might act as a valuable indicator for early prevention
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36 of CVD.
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Footnotes

Contributors: All authors had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: TW, MX, YB and WW. Acquisition of data: YH, XJ, LX, WZ, CD, LW, ZZ, ML, JL, YX, and YC. Analysis and interpretation of data: YH, TW, MX, YB and WW. Drafting of the manuscript: YH. Critical revision of the manuscript: TW, MX, YB and WW. Statistical analysis: YH and XJ.

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Figure legends

Figure 1. Stratified analysis of the association of mid-upper arm circumference with risk of subclinical atherosclerosis in women. A: All subjects were divided into subgroups based on their average age (age < 62 years, age \geq 62 years), body mass index (BMI < 25 kg/m², BMI \geq 25 kg/m²), or waist circumference (WC < 88 cm or WC \geq 88 cm). B: All subjects were divided into subgroups based on diabetes (yes or no), insulin resistance (yes or no), or hypertension (yes or no). Data were presented as odds ratio (OR) and 95% confidence interval (CI). *P* values were calculated from multivariable logistic regression analysis. Adjusted for age (years), body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk), waist circumference (cm), C-reactive protein (mg/L), total cholesterol (mmol/L), HDL-C (mmol/L), LDL-C (mmol/L), triglycerides (mmol/L), fasting plasma glucose (mmol/L), and systolic blood pressure (mmHg).

Figure 2. A: MUAC in the BMI and WC subgroups in women. B: Association of MUAC with risk of subclinical atherosclerosis in the BMI and WC subgroups in women. MUAC: mid-upper arm circumference, BMI: body mass index, WC: waist circumference. Adjusted for age (years), body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk), waist circumference (cm), C-reactive protein (mg/L), total cholesterol (mmol/L), HDL-C (mmol/L), LDL-C (mmol/L), triglycerides (mmol/L), fasting plasma glucose (mmol/L), and systolic blood pressure (mmHg).

Table 1. Characteristics of study participants according to quartiles of mid-upper arm circumference in total samples

	Mid-upper arm circumference, cm				<i>P</i> for trend
	Quartile 1 (15.5-27.1)	Quartile 2 (27.2-29.1)	Quartile 3 (29.2-31.2)	Quartile 4 (31.3-43.3)	
n	1510	1570	1582	1625	
Age (years)	63.4 (9.2)	62.2 (8.8)	61.7 (8.6)	61.6 (8.4)	< 0.0001
Female, n (%)	1110 (27.9)	1048 (26.4)	922 (23.2)	897 (22.6)	
Body mass index (kg/m ²)	22.3 (2.8)	24.2 (3.8)	25.5 (3.2)	27.9 (7.5)	< 0.0001
Waist circumference (cm)	75.6 (8.5)	81.4 (7.9)	85.5 (8.3)	91.6 (9.2)	< 0.0001
Systolic blood pressure (mmHg)	132.6 (18.0)	133.4 (17.3)	136.0 (17.2)	137.0 (16.4)	< 0.0001
Diastolic blood pressure (mmHg)	74.2 (9.5)	75.7 (9.3)	77.2 (9.2)	78.0 (9.8)	< 0.0001
Current smoking, n (%)	196 (13.0)	279 (17.8)	346 (21.9)	393 (24.2)	< 0.0001
Current drinking, n (%)	151 (10)	195 (12.4)	256 (16.2)	290 (17.9)	< 0.0001
Physical activity (MET-h/wk)	21.0 (6.0-21.0)	15.3 (3.0-21.0)	15.0 (3.0-21.0)	15.0 (3.0-21.0)	0.30
Fasting plasma glucose (mmol/L)	5.99 (1.36)	6.06 (1.34)	6.21 (1.57)	6.28 (1.61)	< 0.0001
HOMA-IR	1.42 (0.99-2.15)	1.75 (1.20-2.57)	1.95 (1.35-2.86)	2.43 (1.69-3.55)	< 0.0001
Total cholesterol (mmol/L)	5.28 (0.95)	5.31 (0.98)	5.26 (1.04)	5.24 (1.08)	0.20
LDL-C (mmol/L)	3.56 (0.75)	3.62 (0.77)	3.62 (0.83)	3.63 (0.81)	0.02
HDL-C (mmol/L)	1.42 (0.33)	1.35 (0.29)	1.31 (0.29)	1.27 (0.27)	< 0.0001
Triglycerides (mmol/L)	1.33 (0.98-1.84)	1.49 (1.07-2.12)	1.58 (1.12-2.25)	1.66 (1.19-2.30)	< 0.0001
C-reactive protein (mg/L)	0.19 (0.14-0.28)	0.21 (0.16-0.31)	0.23(0.17-0.35)	0.25(0.18-0.39)	< 0.0001
CIMT (mm)	0.69 (0.16)	0.70 (0.15)	0.70 (0.14)	0.72 (0.14)	< 0.0001
Insulin resistance, n (%)	203 (13.5)	313 (20.0)	410 (26.0)	655 (40.5)	< 0.0001

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Hypertension, n (%)	747 (49.5)	862 (52.7)	978 (61.9)	1108 (68.3)	< 0.0001
Diabetes, n (%)	368 (24.7)	403 (25.9)	457 (29.2)	533 (33.2)	< 0.0001
Subclinical atherosclerosis, n (%)	472 (31.3)	541 (34.5)	555 (35.1)	590 (36.3)	0.0035

Data are presented as means ± standard deviation (SD), or medians (inter-quartile ranges) for skewed variables, or number (proportions) for categorical variables.

P values were calculated from one-way analysis of variance (ANOVA) for continuous variables and chi-square test for categorical variables.

Subclinical atherosclerosis was defined as CIMT ≥ 0.8 mm, which is the cut-off point for the highest quartile of the total participants.

Insulin resistance was defined as HOMA-IR ≥ 2.8, which is the cut-off point for the highest quartile of the total participants.

Abbreviations: MET, metabolic equivalent task; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; CIMT, carotid intima-media thickness; HOMA-IR indicates homeostasis model assessment of insulin resistance.

Table 2. The association of mid-upper arm circumference with cardiometabolic profiles in total samples

	Model 1		Model 2		Model 3	
	$\beta \pm SE$	P value	$\beta \pm SE$	P value	$\beta \pm SE$	P value
Age (years)	-0.20 \pm 0.04	<0.0001	/	/	/	/
Body mass index (kg/m ²)	0.70 \pm 0.02	<0.0001	/	/	/	/
Waist circumference (cm)	1.94 \pm 0.03	<0.0001	1.62 \pm 0.04	<0.0001	/	/
Systolic blood pressure (mmHg)	0.55 \pm 0.07	<0.0001	0.49 \pm 0.09	<0.0001	0.20 \pm 0.10	0.04
Diastolic blood pressure (mmHg)	0.49 \pm 0.04	<0.0001	0.32 \pm 0.05	<0.0001	0.08 \pm 0.06	0.15
Fasting plasma glucose (mmol/L)	0.03 \pm 0.01	<0.0001	0.02 \pm 0.01	0.01	-0.02 \pm 0.01	0.04
HOMA-IR	0.03 \pm 0.001	<0.0001	0.02 \pm 0.001	<0.0001	0.01 \pm 0.002	0.0003
Total cholesterol (mmol/L)	-0.004 \pm 0.004	0.30	0.004 \pm 0.005	0.48	-0.01 \pm 0.01	0.24
LDL-C (mmol/L)	0.009 \pm 0.003	0.005	0.01 \pm 0.004	0.001	0.001 \pm 0.005	0.79
HDL-C (mmol/L)	-0.02 \pm 0.001	<0.0001	-0.01 \pm 0.001	<0.0001	-0.003 \pm 0.002	0.08
Triglycerides (mmol/L)	0.01 \pm 0.001	<0.0001	0.01 \pm 0.001	<0.0001	0.001 \pm 0.001	0.38
C-reactive protein (mg/L)	0.01 \pm 0.001	<0.0001	0.01 \pm 0.001	<0.0001	0.002 \pm 0.002	0.12
CIMT (cm)	0.003 \pm 0.001	<0.0001	0.003 \pm 0.001	0.0002	0.002 \pm 0.001	0.005

Data are linear regression estimates \pm standard error ($\beta \pm SE$).

P values were calculated from multivariable linear regression model.

Model 1: unadjusted;

Model 2: adjusted for age (years), sex, body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk);

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Model 3: further adjusted for waist circumference (cm).

Abbreviations: LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; CIMT, carotid intima-media thickness.

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Table 3. Logistic regression analysis of risk of cardiometabolic disorders in relation to mid-upper arm circumference in total and sex-specific samples

		OR (95% CI)					P for trend
		Quartile 1	Quartile 2	Quartile 3	Quartile 4	1-SD (3.13 cm)	
Total cohort							
Central obesity	Model 1	1.00	1.43 (0.99-2.05)	3.44 (2.45-4.82)	7.25 (5.12-10.3)	2.05 (1.85-2.28)	< 0.0001
	Model 2	1.00	1.43 (0.99-2.05)	3.44 (2.45-4.82)	7.25 (5.12-10.3)	2.05 (1.85-2.28)	< 0.0001
Diabetes	Model 1	1.00	1.00 (0.82-1.21)	1.13 (0.93-1.37)	1.26 (1.02-1.55)	1.09 (1.02-1.16)	0.02
	Model 2	1.00	0.87 (0.73-1.06)	0.89 (0.73-1.10)	0.87 (0.70-1.09)	0.96 (0.90-1.04)	0.33
Hypertension	Model 1	1.00	1.04 (0.87-1.24)	1.57 (1.30-1.89)	1.65 (1.34-2.04)	1.21 (1.14-1.30)	< 0.0001
	Model 2	1.00	0.92 (0.77-1.10)	1.29 (1.06-1.56)	1.23 (0.98-1.53)	1.10 (1.03-1.19)	0.006
Hypertriglyceridemia	Model 1	1.00	1.55 (1.25-1.92)	1.78 (1.43-2.21)	1.92 (1.53-2.41)	1.24 (1.15-1.35)	< 0.0001
	Model 2	1.00	1.31 (1.05-1.63)	1.32 (1.05-1.66)	1.19 (0.93-1.54)	1.03 (0.94-1.13)	0.28
Low HDL cholesterol	Model 1	1.00	1.40 (1.06-1.84)	1.80 (1.38-2.35)	2.06 (1.57-2.69)	1.26 (1.16-1.37)	< 0.0001
	Model 2	1.00	1.21 (0.91-1.60)	1.41 (1.06-1.86)	1.38 (1.02-1.88)	1.10 (1.01-1.22)	0.03
Women							
Central obesity	Model 1	1.00	1.49 (1.04-2.15)	3.54 (2.50-4.99)	7.10 (4.97-10.2)	2.01 (1.81-2.25)	< 0.0001
	Model 2	1.00	1.49 (1.04-2.15)	3.54 (2.50-4.99)	7.10 (4.97-10.2)	2.01 (1.81-2.25)	< 0.0001
Diabetes	Model 1	1.00	1.11 (0.89-1.41)	1.29 (1.01-1.65)	1.39 (1.07-1.80)	1.12 (1.03-1.22)	0.007
	Model 2	1.00	0.98 (0.77-1.24)	1.03 (0.80-1.32)	0.97 (0.73-1.29)	0.99 (0.91-1.09)	0.93
Hypertension	Model 1	1.00	1.10 (0.89-1.35)	1.93 (1.54-2.44)	1.80 (1.39-2.33)	1.27 (1.17-1.38)	< 0.0001
	Model 2	1.00	0.96 (0.78-1.18)	1.55 (1.23-1.97)	1.29 (0.98-1.68)	1.14 (1.05-1.24)	0.003

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Hypertriglyceridemia	Model 1	1.00	1.63 (1.28-2.01)	1.89 (1.48-2.42)	1.84 (1.42-2.38)	1.25 (1.15-1.37)	< 0.0001
	Model 2	1.00	1.38 (1.08-1.78)	1.43 (1.09-1.86)	1.17 (0.87-1.58)	1.05 (0.94-1.17)	0.33
Low HDL cholesterol	Model 1	1.00	1.67 (1.17-2.38)	1.94 (1.36-2.77)	1.87 (1.29-2.71)	1.21 (1.09-1.35)	0.0007
	Model 2	1.00	1.47 (1.03-2.21)	1.56 (1.07-2.28)	1.32 (0.86-2.01)	1.08 (0.91-1.23)	0.23
Men							
Central obesity	Model 1	1.00	0.38 (0.02-6.61)	3.99 (0.49-32.0)	10.4 (1.33-81.2)	3.08 (1.92-4.95)	< 0.0001
	Model 2	1.00	0.38 (0.02-6.61)	3.99 (0.49-32.0)	10.4 (1.33-81.2)	3.08 (1.92-4.95)	< 0.0001
Diabetes	Model 1	1.00	0.79 (0.56-1.10)	0.85 (0.61-1.18)	0.97 (0.68-1.38)	1.01 (0.90-1.13)	0.84
	Model 2	1.00	0.69 (0.49-0.98)	0.68 (0.48-0.97)	0.69 (0.47-1.01)	0.91 (0.81-1.03)	0.12
Hypertension	Model 1	1.00	0.92 (0.66-1.29)	1.06 (0.76-1.48)	1.29 (0.89-1.88)	1.10 (0.98-1.24)	0.10
	Model 2	1.00	0.84 (0.60-1.17)	0.91 (0.65-1.28)	1.03 (0.70-1.52)	1.03 (0.91-1.16)	0.68
Hypertriglyceridemia	Model 1	1.00	1.37 (0.85-2.21)	1.46 (0.92-2.31)	1.66 (1.03-2.67)	1.13 (0.96-1.32)	0.04
	Model 2	1.00	1.19 (0.73-1.92)	1.15 (0.72-1.84)	1.13 (0.68-1.87)	0.97 (0.81-1.52)	0.81
Low HDL cholesterol	Model 1	1.00	1.01 (0.65-1.58)	1.42 (0.94-2.16)	1.62 (1.04-2.51)	1.21 (1.06-1.38)	0.006
	Model 2	1.00	0.92 (0.59-1.44)	1.22 (0.79-1.86)	1.27 (0.80-2.01)	1.12 (0.97-1.29)	0.13

Data were presented as odds ratio (OR) and 95% confidence interval (CI).

P values were calculated from multivariable logistic regression analysis in quartile of mid-upper arm circumference.

Model 1: adjusted for age (years), sex, body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk);

Model 2: further adjusted for waist circumference (cm), except for central obesity.

Table 4. The association of mid-upper arm circumference with subclinical atherosclerosis in total and sex-specific samples

	OR (95% CI)					<i>P</i> for trend
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	1-SD (3.13 cm)	
Total cohort						0.20*
Cases/Participants	472 / 1510	541 / 1570	555 / 1582	590 / 1625	2158 / 6287	
Model 1	1.00	1.16 (1.00-1.34)	1.19 (1.02-1.38)	1.25 (1.08-1.45)	1.06 (1.01-1.12)	0.004
Model 2	1.00	1.30 (1.08-1.56)	1.30 (1.07-1.58)	1.35 (1.09-1.67)	1.06 (0.98-1.15)	0.013
Model 3	1.00	1.31 (1.09-1.58)	1.33 (1.10-1.62)	1.45 (1.16-1.80)	1.08 (0.99-1.17)	0.005
Women						
Case/participants	287 / 1110	327 / 1048	275 / 922	282 / 897	1171 / 3977	
Model 1	1.00	1.30 (1.08-1.57)	1.22 (1.00-1.48)	1.32 (1.09-1.60)	1.07 (1.00-1.14)	0.014
Model 2	1.00	1.54 (1.24-1.93)	1.43 (1.18-1.82)	1.53 (1.17-2.02)	1.11 (1.01-1.23)	0.007
Model 3	1.00	1.54 (1.24-1.93)	1.42 (1.11-1.83)	1.66 (1.26-2.20)	1.14 (1.03-1.26)	0.002
Men						
Case/participants	185 / 400	214 / 522	280 / 660	308 / 728	987 / 2310	
Model 1	1.00	0.81 (0.62-1.05)	0.86 (0.67-1.10)	0.85 (0.67-1.09)	0.93 (0.85-1.02)	0.39
Model 2	1.00	0.89 (0.64-1.23)	1.04 (0.75-1.44)	1.00 (0.70-1.45)	0.97 (0.85-1.11)	0.71
Model 3	1.00	0.90 (0.65-1.25)	1.06 (0.76-1.48)	1.05 (0.72-1.52)	0.99 (0.86-1.06)	0.54

Data were presented as odds ratio (OR) and 95% confidence interval (CI).

P values were calculated from multivariable logistic regression analysis.

*: the interaction of MUAC with sex on subclinical atherosclerosis.

Model 1, unadjusted;

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5 Model 2, adjusted for age (years), sex, body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk),
6 waist circumference (cm);

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8 Model 3, further adjusted for C-reactive protein (mg/L), total cholesterol (mmol/L), HDL-C (mmol/L), LDL-C (mmol/L), triglycerides (mmol/L), fasting
9 plasma glucose (mmol/L), and systolic blood pressure (mmHg).
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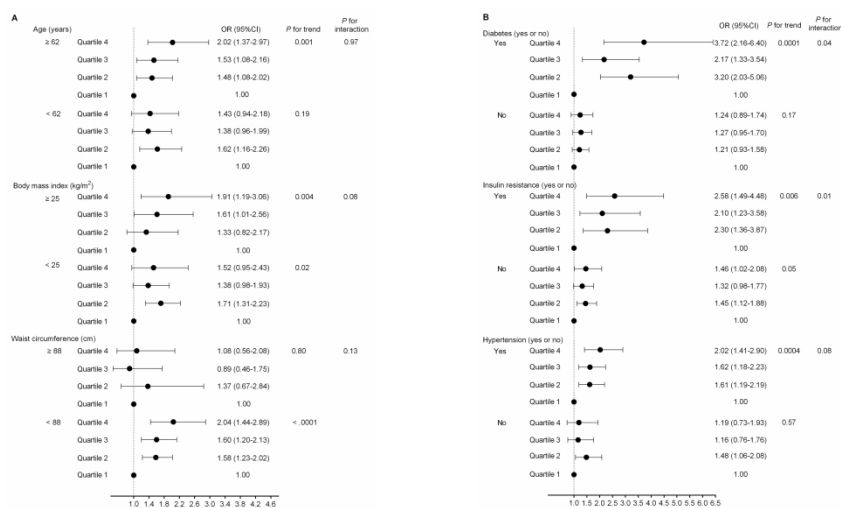


Figure 1

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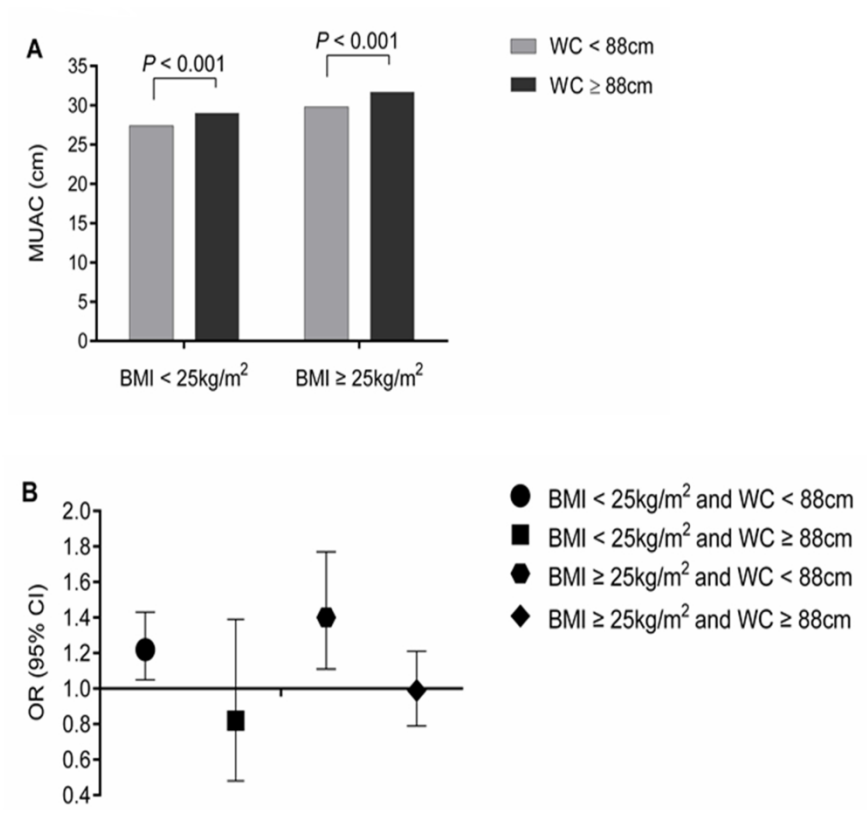


Figure 2

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4 **Supplemental Information**
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6 **The mid-upper arm circumference is associated with an increased cardiometabolic risk**
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9 **in middle aged and elderly Chinese population**
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4 **Supplemental Table 1.** The association of mid-upper arm circumference with
5 cardiometabolic profiles in women
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7 **Supplemental Table 2.** The association of mid-upper arm circumference with
8 cardiometabolic profiles in men
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11 12 13 **Supplemental Figure Legend**

14
15 **Supplemental Figure 1.** Stratified analysis of the association of mid-upper arm circumference
16 with risk of subclinical atherosclerosis in men. A: All subjects were divided into subgroups
17 based on their average age (age < 62 years, age ≥ 62 years), body mass index (BMI < 25 kg/m²,
18 BMI ≥ 25 kg/m²), or waist circumference (WC < 88 cm or WC ≥ 88 cm). B: All subjects were
19 divided into subgroups based on diabetes (yes or no), insulin resistance (yes or no), or
20 hypertension (yes or no). Data were presented as odds ratio (OR) and 95% confidence interval
21 (CI). *P* values were calculated from multivariable logistic regression analysis. Adjusted for age
22 (years), body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no),
23 physical activity (MET-h/wk), waist circumference (cm), C-reactive protein (mg/L), total
24 cholesterol (mmol/L), HDL-C (mmol/L), LDL-C (mmol/L), triglycerides (mmol/L), fasting
25 plasma glucose (mmol/L), and systolic blood pressure (mmHg).
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Supplemental Table 1. The association of mid-upper arm circumference with cardiometabolic profiles in women

	Model 1		Model 2		Model 3	
	$\beta \pm SE$	<i>P</i> value	$\beta \pm SE$	<i>P</i> value	$\beta \pm SE$	<i>P</i> value
Age (years)	-0.10 \pm 0.04	0.01	/	/	/	/
Body mass index (kg/m ²)	0.76 \pm 0.03	<0.0001	/	/	/	/
Waist circumference (cm)	1.89 \pm 0.04	<0.0001	1.71 \pm 0.05	<0.0001	/	/
Systolic blood pressure (mmHg)	0.59 \pm 0.09	<0.0001	0.54 \pm 0.10	<0.0001	0.24 \pm 0.12	0.06
Diastolic blood pressure (mmHg)	0.41 \pm 0.05	<0.0001	0.33 \pm 0.06	<0.0001	0.10 \pm 0.07	0.16
Fasting plasma glucose (mmol/L)	0.03 \pm 0.007	<0.0001	0.02 \pm 0.008	0.003	-0.01 \pm 0.01	0.21
HOMA-IR	0.03 \pm 0.001	<0.0001	0.02 \pm 0.002	<0.0001	0.01 \pm 0.002	0.0001
Total cholesterol (mmol/L)	0.01 \pm 0.005	0.06	0.01 \pm 0.01	0.40	-0.003 \pm 0.01	0.64
LDL-C (mmol/L)	0.02 \pm 0.004	<0.0001	0.01 \pm 0.005	0.006	0.004 \pm 0.006	0.49
HDL-C (mmol/L)	-0.01 \pm 0.001	<0.0001	-0.01 \pm 0.002	<0.0001	-0.002 \pm 0.002	0.48

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Triglycerides (mmol/L)	0.01 ± 0.001	<0.0001	0.01 ± 0.001	<0.0001	0.001 ± 0.002	0.71
C-reactive protein (mg/L)	0.02 ± 0.001	<0.0001	0.02 ± 0.002	<0.0001	0.006 ± 0.002	0.002
CIMT (cm)	0.003 ± 0.001	<0.0001	0.003 ± 0.001	<0.0001	0.003 ± 0.001	0.0007

Data are linear regression estimates ± standard error ($\beta \pm SE$). *P* values were calculated from multivariable linear regression model.

Model 1: unadjusted;

Model 2: adjusted for age (years), sex, body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk);

Model 3: further adjusted for waist circumference (cm).

Abbreviations: LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; CIMT, carotid intima-media thickness.

Supplemental Table 2. The association of mid-upper arm circumference with cardiometabolic profiles in men

	Model 1		Model 2		Model 3	
	$\beta \pm SE$	<i>P</i> value	$\beta \pm SE$	<i>P</i> value	$\beta \pm SE$	<i>P</i> value
Age (years)	-0.47 \pm 0.06	<0.0001	/	/	/	/
Body mass index (kg/m ²)	0.61 \pm 0.02	<0.0001	/	/	/	/
Waist circumference (cm)	1.84 \pm 0.06	<0.0001	1.15 \pm 0.07	<0.0001	/	/
Systolic blood pressure (mmHg)	0.57 \pm 0.12	<0.0001	0.21 \pm 0.16	0.18	0.06 \pm 0.17	0.73
Diastolic blood pressure (mmHg)	0.51 \pm 0.07	<0.0001	0.16 \pm 0.09	0.07	0.03 \pm 0.10	0.78
Fasting plasma glucose (mmol/L)	0.02 \pm 0.01	0.06	0.004 \pm 0.02	0.83	-0.03 \pm 0.02	0.11
HOMA-IR	0.03 \pm 0.002	<0.0001	0.01 \pm 0.003	<0.0001	0.002 \pm 0.003	0.57
Total cholesterol (mmol/L)	0.003 \pm 0.006	0.57	-0.004 \pm 0.01	0.65	-0.01 \pm 0.01	0.15
LDL-C (mmol/L)	0.02 \pm 0.005	0.0007	0.006 \pm 0.007	0.40	-0.004 \pm 0.008	0.55
HDL-C (mmol/L)	-0.02 \pm 0.002	<0.0001	-0.01 \pm 0.003	<0.0001	-0.005 \pm 0.003	0.08

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Triglycerides (mmol/L)	0.01 ± 0.002	<0.0001	0.005 ± 0.002	0.01	0.001 ± 0.002	0.75
C-reactive protein (mg/L)	0.01 ± 0.002	0.0002	0.003 ± 0.003	0.31	-0.005 ± 0.003	0.09
CIMT (cm)	-0.001 ± 0.001	0.33	0.001 ± 0.002	0.48	0.001 ± 0.002	0.69

Data are linear regression estimates ± standard error ($\beta \pm SE$). *P* values were calculated from multivariable linear regression model.

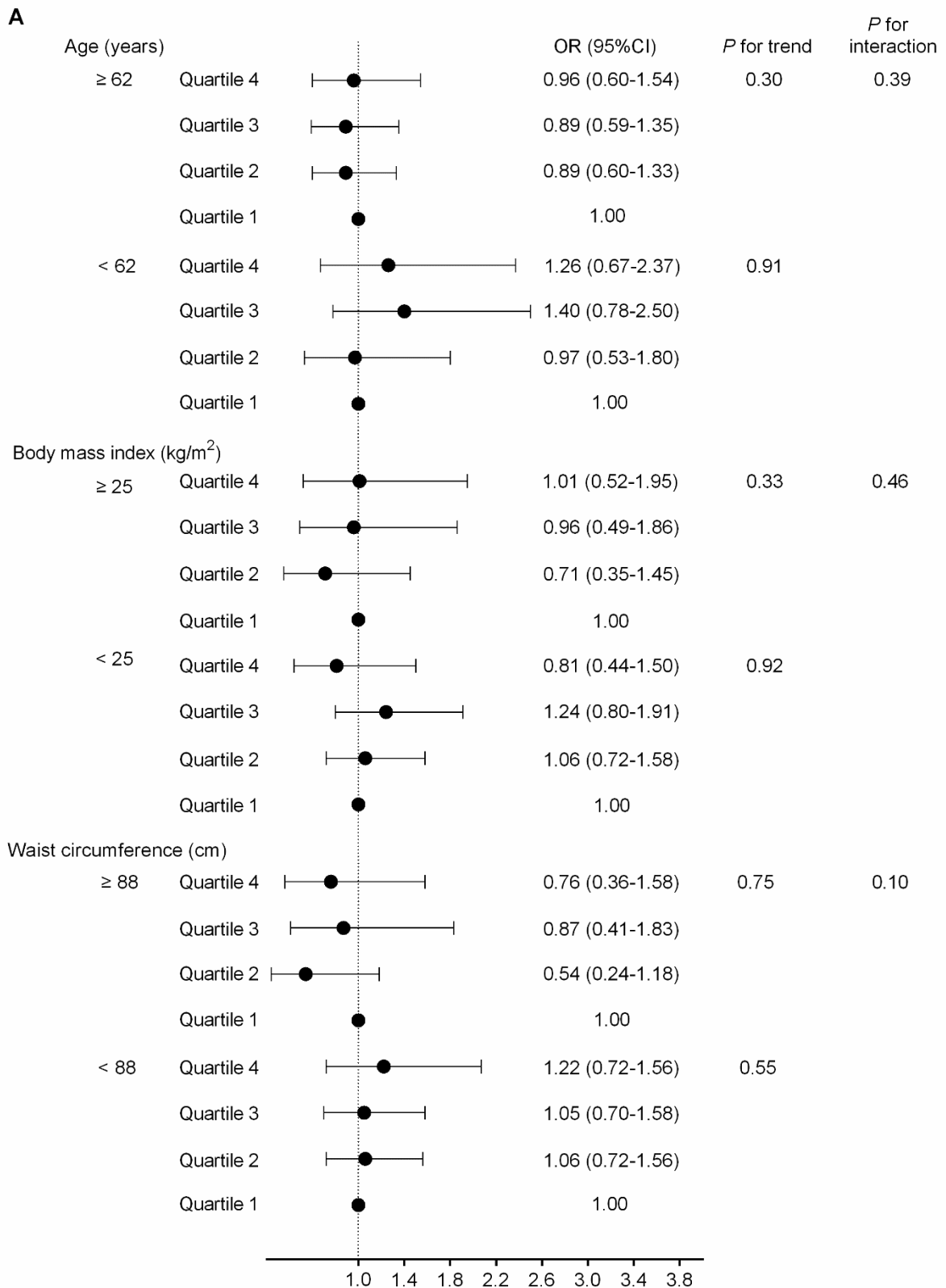
Model 1: unadjusted;

Model 2: adjusted for age (years), sex, body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk);

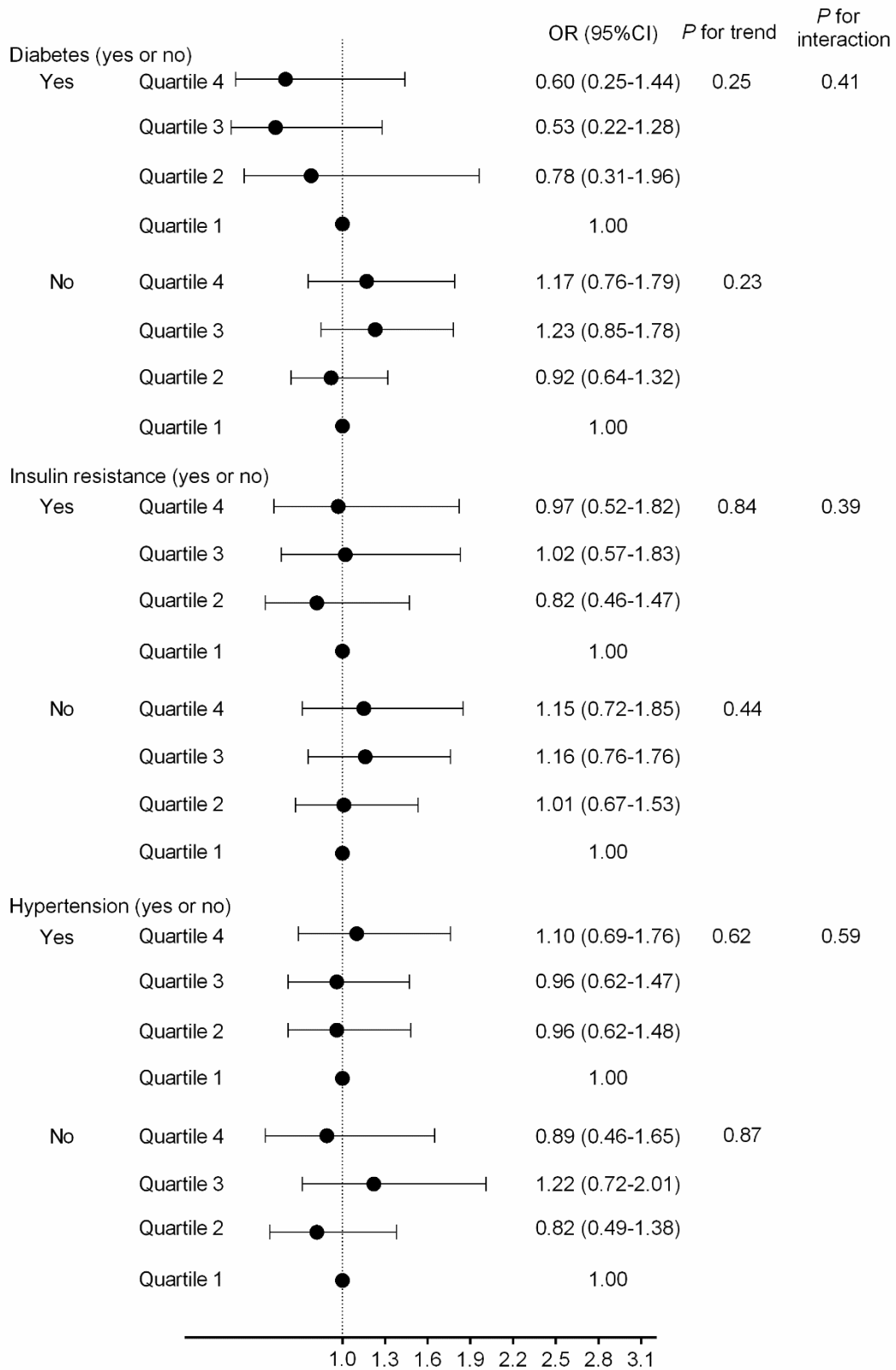
Model 3: further adjusted for waist circumference (cm).

Abbreviations: LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; CIMT, carotid intima-media thickness.

Supplemental Figure 1



B



BMJ Open

Association between mid-upper arm circumference and cardiometabolic risk in Chinese population: a cross-sectional study

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Secondary Subject Heading:	Diabetes and endocrinology, Cardiovascular medicine
Keywords:	cardiometabolic risk, mid-upper arm circumference, subclinical atherosclerosis, upper body fat, Chinese adults

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Manuscripts

1 **Association between mid-upper arm circumference and cardiometabolic risk in**
2 **Chinese population: a cross-sectional study**

3
4 **Running title: Upper body fat and cardiometabolic risk**

5
6 Yanan Hou^{1,2}, Xu Jia^{1,2}, Liping Xuan^{1,2}, Wen Zhu^{1,2}, Chanjuan Deng^{1,2}, Long Wang^{1,2},
7 Zhiyun Zhao^{1,2}, Mian Li^{1,2}, Jieli Lu^{1,2}, Yu Xu^{1,2}, Yuhong Chen^{1,2}, Weiqing Wang^{1,2},
8 Yufang Bi^{1,2}, Min Xu^{1,2}, Tiange Wang^{1,2¶}

9
10 ¹ State Key Laboratory of Medical Genomics, Key Laboratory for Endocrine and
11 Metabolic Diseases of Ministry of Health, National Clinical Research Center for
12 Metabolic Diseases, Shanghai Clinical Center for Endocrine and Metabolic Diseases,
13 Rui-Jin Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai,
14 200025, China;

15 ² Shanghai Institute of Endocrine and Metabolic Diseases, Department of Endocrine and
16 Metabolic Diseases, Rui-Jin Hospital, Shanghai Jiao Tong University School of
17 Medicine, Shanghai, 200025, China.

18
19 **¶Corresponding author:**

20 Tiange Wang, MD, PhD

21 State Key Laboratory of Medical Genomics, Key Laboratory for Endocrine and
22 Metabolic Diseases of Ministry of Health, National Clinical Research Center for
23 Metabolic Diseases, Shanghai Clinical Center for Endocrine and Metabolic Diseases,
24 Shanghai Institute of Endocrine and Metabolic Diseases, Rui-Jin Hospital, Shanghai

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25 Jiao Tong University School of Medicine, 197 Rui-Jin 2nd Road, Shanghai 200025,
26 China. Telephone: 86-21-64370045; Fax: 86-21-64749885; E-mail: wtg@live.cn.

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1
2
3 **Abstract**
4

5 **Objectives:** Upper body fat has been associated with an unfavorable cardiometabolic
6
7 risk. We aimed to investigate the associations between mid-upper arm circumference
8
9 (MUAC), a novel indicator of upper body fat, and a wide spectrum of cardiometabolic
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11 risk profiles in Chinese population.
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14 **Design and setting:** Cross-sectional analyses were performed using data from a well-
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16 defined community in 2014, Shanghai, China.
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19 **Participants:** The study population consisted of 6287 participants with complete
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21 measurement data (men n=2310, women n=3977).
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24 **Outcome measures:** Multivariable logistic regression model was used to explore the
25
26 associations of MUAC with cardiometabolic disorders including central obesity,
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28 diabetes, hypertension, hypertriglyceridemia, low HDL cholesterol and subclinical
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30 atherosclerosis.
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33 **Results:** In overall participants, each 1-SD increment in MUAC (3.13 cm) was
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35 positively associated with central obesity (OR, 2.05; 95% CI, 1.85-2.28), hypertension
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37 (OR, 1.10; 95% CI, 1.03-1.19), and low HDL cholesterol (OR, 1.10; 95% CI, 1.01-
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39 1.22), after multivariable adjustment. Multivariable-adjusted ORs for subclinical
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41 atherosclerosis was gradually increased across increasing quartiles of MUAC with the
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43 lowest quartile as reference (quartile 2: OR, 1.31; 95% CI, 1.09-1.58; quartile 3: 1.33;
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45 1.10-1.62; quartile 4: 1.45; 1.16-1.80, $P_{for\ trend} = 0.005$) among total participants, and
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47 such association was more prominent among women than men. Additionally, MUAC
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49 was significantly interacted with diabetes and insulin resistance on subclinical
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51 atherosclerosis ($P_{for\ interaction} = 0.04$ and 0.01 , respectively).
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3 50 **Conclusion:** A greater MUAC was positively associated with several cardiometabolic
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5 51 disorders and subclinical atherosclerosis in Chinese population, and such association
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7 52 patterns were more significant among women.
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12 54 **Keywords:** Cardiometabolic risk, mid-upper arm circumference, subclinical
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14 55 atherosclerosis, upper body fat, Chinese adults
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19 57 **Strengths and limitations of this study:**
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21 58 • The strength of the current study was evidenced by a well-defined community setting,
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23 59 fair sized sample volume, and desirable population homogeneity.
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26 60 • The comprehensive examination of the associations between MUAC and a wide
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28 61 spectrum of cardiometabolic risk profiles including central obesity, diabetes,
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30 62 hypertension, hypertriglyceridemia, low HDL cholesterol and subclinical
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32 63 atherosclerosis.
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35 64 • Although our findings support that MUAC could be a reliable surrogate of upper body
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37 65 adiposity, MUAC is a measure which comprised both adipose and lean tissue rather
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39 66 than a direct indicator for adiposity.
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42 67 • As body composition changes over time, the narrow range of age for the participants
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44 68 enrolled could affect the outcome.
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47 69 • Since our study was performed in a Chinese population, it should be cautiously to
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49 70 generalize the results to the other ethnicities.
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71 **Introduction**

72 Cardiometabolic disorders describe a spectrum of interconnected pathological
73 alterations in the cardiovascular system and metabolic organs that symbiotically
74 increase the risk of cardiovascular disease (CVD), which is a major cause of mortality
75 and burden of healthcare expenditure worldwide.¹⁻⁵ Several important cardiometabolic
76 disorders, including obesity, diabetes, insulin resistance, dyslipidemia, and
77 hypertension, are major risk factors for CVD and could be served as early targets for
78 early identification and personalized prevention for CVD.²⁻⁵ In addition, as a common
79 contributor of CVD, atherosclerosis goes through a protracted subclinical phase and
80 could only be detected at an advanced stage of CVD.^{6,7} Thus, the identification of
81 subclinical atherosclerosis in the asymptomatic period is also critical for prevention of
82 CVD progression. Noninvasive ultrasonography measured carotid intima media
83 thickness (CIMT) is a well-established clinical index for early arteriosclerosis detection
84 and therefore has been extensively adopted to measure subclinical atherosclerosis.⁸

85 Meanwhile, fat distribution, specifically upper body and visceral adiposity, is
86 proven highly relevant to cardiovascular risk.^{9,10} In addition to the conventional body fat
87 indices such as body mass index (BMI) and waist circumference (WC), mid-upper arm
88 circumference (MUAC), as a novel anthropometric measurement, has been widely used
89 for screening of malnutrition, adiposity and chronic diseases.¹¹ Several epidemiological
90 studies have revealed inconsistent results on the relationship between MUAC and
91 cardiometabolic risk. A cross-sectional study using data from the 1999 to 2006 National
92 Health and Nutrition Examination Survey (NHANES) reported that MUAC was
93 positively associated with insulin resistance in non-obese individuals; while no
94 significant association was found in obese individuals.⁹ In a prospective cohort of 1061
95 European elderly participants with a follow-up of approximately 6 years, a larger

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3 96 MUAC was associated with elevated risks of all-cause and cardiovascular diseases
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5 97 mortality.¹² In contrast, in the Canada Fitness Survey of 10638 adults, a larger MUAC
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7 98 was independently associated with a lower risk of all-cause mortality.¹³ And such
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10 99 inverse association between a larger MUAC and a lower risk of mortality was also
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12 100 documented in the British National Diet and Nutrition Survey of 1054 participants with
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14 101 more than 15 years of followed up.¹⁴
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17 102 Most of these previous studies were conducted in European population; so far,
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19 103 comprehensive data on the associations between MUAC and cardiovascular risk
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21 104 profiles in Chinese population are limited. Chinese population tend to have a higher
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23 105 percentage of body fat, a weaker willingness on body build, and less muscle mass as
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25 106 well as connective tissue,¹⁵ as compared with their European counterparts. And these
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27 107 different features may translate into varying susceptibilities to adiposity related
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29 108 cardiometabolic disorders. Therefore, this study aimed to investigate the association
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31 109 between MUAC and cardiometabolic disorders as well as subclinical atherosclerosis in
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33 110 Chinese population.
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40 112 **Methods**

41 113 **Study population**

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43 114 This is a cross-sectional analysis based on one of the follow-up circles of our
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45 115 established community-based cohort.^{16,17} Eligible participants aged 40 years or above
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47 116 were identified from the local residence registration records. There was no restriction on
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49 117 ethnicity or gender. Each eligible participant was recruited by trained community staff
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51 118 and local health workers using a door-to-door invitation method. Participants who
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53 119 consented for the study and signed informed consent were scheduled for health
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55 120 examinations. In brief, a total of 6570 participants aged 40 years or above were enrolled
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3 121 from Jiading district, Shanghai, China, from August 2014 to May 2015. All participants
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5 122 received anthropometric measurements (including height, weight, WC, and MUAC), a
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7 123 standard 75-g oral glucose tolerance test (OGTT), and a standard questionnaire to
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10 124 acquire information regarding lifestyle factors (including smoking and alcohol drinking
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12 125 habits, and physical activity), education, social demographic information, and history of
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14 126 diseases and medicines. Blood samples were collected for biochemical measurements.
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17 127 In the present study, 283 participants were excluded due to missing data on MUAC or
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19 128 CIMT. Thus, a total of 6287 participants were included in the final analysis. This study
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21 129 was approved by the Institutional Review Board of Ruijin Hospital Affiliated to
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24 130 Shanghai Jiao Tong University School of Medicine. Written informed consent was
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26 131 obtained from all study participants.
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133 **Data collection and biochemical measurements**

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33 134 Detailed information on sociodemographic characteristics, family history, medical
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35 135 history, physical activity and health-related lifestyle were obtained using a standard
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37 136 questionnaire by trained personnel. Current smokers or drinkers were those who
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39 137 consumed any kinds of cigarettes or alcohol regularly in the past 6 months, respectively.
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42 138 Physical activity in term of MET hour/week was calculated according to the short form
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44 139 of the International Physical Activity Questionnaire (IPAQ) including both during
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46 140 leisure time and at work.¹⁸

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49 141 Anthropometric measurements such as height, weight, WC, and MUAC were
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51 142 assessed by well-trained physician according to a standard protocol. Body height and
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53 143 weight were measured with participants wearing light clothes without shoes to the
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55 144 nearest 0.1 centimeter (cm) and 0.1 kilogram (kg), respectively. BMI was calculated as
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57 145 body weight in kilograms divided by body height squared in meters (kg/m²). MUAC
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3 146 was measured on the upper left arm (halfway between the acromion process and the
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5 147 olecranon process) with subject's bilateral arms hanging down naturally.¹⁹ WC was
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7 148 measured at the level of the umbilicus with the participants in the standing position.
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10 149 Systolic and diastolic blood pressures were measured in the non-dominant arm with an
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12 150 automated electronic sphygmomanometer (OMRON Model HEM-752 FUZZY, Omron
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14 151 Company, Dalian, China) three times (averaged for analysis) consecutively with 1 min
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16 152 intervals after at least 5 min rest in a seated position.

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19 153 All participants underwent a 75-g glucose tolerance test (OGTT) after an overnight
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21 154 fasting (nothing by mouth after midnight), of whom fasting plasma glucose and OGTT
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23 155 2-hour plasma glucose were measured using hexokinase method on a clinical chemistry
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25 156 diagnostic system (Modular P800; Roche, Basel, Switzerland). Serum concentrations of
26
27 157 total cholesterol, triglycerides, high-density lipoprotein (HDL-C) and low-density
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29 158 lipoprotein (LDL-C) cholesterol were measured by an autoanalyzer (Modular E170;
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31 159 Roche). High sensitive C-reactive protein concentration was determined by highly
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33 160 sensitive competitive immunoassay (antigens and antibodies from Beckman coulter
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35 161 IMAGE800, America). Serum insulin was measured by using the
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37 162 electrochemiluminescence methods on an Immunology analyzer (RIABEAD II; Abbott,
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39 163 Tokyo, Japan). Homeostasis model assessment of insulin resistance (HOMA-IR) was
40
41 164 calculated as fasting insulin ($\mu\text{IU/mL}$) \times fasting plasma glucose (mmol/L) / 22.5, and
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43 165 insulin resistance was defined as HOMA-IR \geq 2.8, which is the cut-off point for the
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45 166 highest quartile of the total participants.
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52 168 **Definitions of cardiometabolic risk profile**

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55 169 Type 2 diabetes was defined as fasting plasma glucose \geq 7.0 mmol/L or OGTT 2-hour
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57 170 plasma glucose \geq 11.1 mmol/L or use of anti-diabetic agents.²⁰ Hypertension was
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3 171 defined as systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg or
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5 172 current taking an antihypertensive medication.²¹ Central obesity was defined as WC \geq
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7 173 102 cm for men and ≥ 88 cm for women. Hypertriglyceridemia was defined as
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9 174 triglycerides ≥ 2.26 mmol/L. Low HDL cholesterol was defined as a level of HDL-C $<$
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11 175 1.04 mmol/L.
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14 176 CIMT measurement was conducted by a trained sonographer using a high-
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16 177 resolution B-mode tomographic ultrasound system (Esaote Biomedica SpA, Genoa,
17
18 178 Italy) with a linear 7.5 MHz transducer.²² The position of CIMT measurement was
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20 179 recorded on the far wall of both right and left common carotid arteries, 1.5 cm proximal
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22 180 to the bifurcation. CIMT was measured on-line at the end of diastole as a distance from
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24 181 the leading edge of the first echogenic line to that of the second. These two lines
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26 182 represent the lumen-intima interface and collagen-contained upper layer of tunic
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28 183 adventitia, respectively. Subclinical atherosclerosis was defined as a bilateral CIMT
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30 184 average greater than 0.8 mm, which is the highest quartile cut-off point of the total
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32 185 participants.
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40 187 **Statistical analyses**

41
42 188 SAS version 9.4 (SAS Institute Inc, Cary, NC, USA) was used for data management
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44 189 and statistical analysis. Continuous variables were described as means \pm standard
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46 190 deviations (SDs) or medians (inter-quartile ranges), and categorical variables as
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48 191 numbers (percentages). Variables with skewed distributions, such as HOMA-IR,
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50 192 triglycerides, and C-reactive protein, were normalized by logarithmic transformation
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52 193 before analysis.
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56 194 All participants were divided into four subgroups according to quartiles of MUAC.
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58 195 The ranges of MUAC within each quartile were 15.5 to 27.1 cm for quartile 1, 27.2 to
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3 196 29.1 cm for quartile 2, 29.2 to 31.2 cm for quartile 3, and 31.3 to 43.3 cm for quartile 4.
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5 197 Linear regression analysis was used to test for trend across the MUAC quartiles for
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7 198 continuous variables and the Cochran-Armitage trend chi-square test was used for
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10 199 categorical variables. Multivariable linear regression and multivariable logistic
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12 200 regression analyses were conducted to assess the associations of MUAC with a wide
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14 201 spectrum of cardiometabolic disorders and subclinical atherosclerosis, with adjustment
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16 202 for age, sex, BMI, current smoking, current drinking, physical activity, WC, C-reactive
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18 203 protein, total cholesterol, HDL-C, LDL-C, triglycerides, fasting plasma glucose, and
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20 204 systolic blood pressure. Stratified analyses by age, BMI, WC, diabetes, insulin
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22 205 resistance, and hypertension were performed. Interactions were tested by adding the
23
24 206 respective multiplicative terms in the models simultaneously. Statistical significance
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26 207 was set to a two-sided *P* value of less than 0.05.
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33 209 **Patient and public involvement**

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35 210 This study was conducted without patient and public involvement. No patients were
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37 211 invited to take part in the development of the research question and outcome
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39 212 measures, the study design and the interpretation of the results. The findings from this
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41 213 study will be disseminated to the participants after the results are published in a peer-
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43 214 reviewed journal.
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49 216 **Results**

51 217 **Characteristics of the study participants**

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53 218 The study sample consisted of 2310 (36.7%) men and 3977 (63.3%) women with an
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55 219 average age of 62.2 years (SD: 8.78). Detailed sociodemographic and clinical
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57 220 characteristics of the study participants according to MUAC quartiles are shown in
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3 221 Table 1. Participants with a large MUAC were more likely to have higher levels of
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5 222 BMI, WC, systolic and diastolic blood pressures, fasting plasma glucose, HOMA-IR,
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7 223 LDL-C, triglycerides, C-reactive protein, and CIMT, and had higher proportions of
8
9 224 insulin resistance, hypertension, diabetes, and subclinical atherosclerosis (all P values <
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11 225 0.05). In addition, participants with a large MUAC were younger and had lower levels
12
13 226 of HDL-C (both P values < 0.0001) (Table 1). Multivariable linear regression analyses
14
15 227 revealed consistent results on the associations between MUAC and these
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17 228 cardiometabolic profiles (Supplemental Table1).
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230 **Association between MUAC and cardiometabolic disorders**

231 As shown in Table 2, a large MUAC was positively associated with central obesity,
232 diabetes, hypertension, hypertriglyceridemia, and low HDL cholesterol after adjustment
233 for age, sex, BMI, current smoking, current drinking, and physical activity (all P values
234 < 0.001). The multivariable-adjusted OR per 1-SD increment in MUAC (3.13 cm) was
235 2.05 (95% CI, 1.85-2.28) for central obesity, 1.09 (1.02-1.16) for diabetes, 1.21 (1.14-
236 1.30) for hypertension, 1.24 (1.15-1.35) for hypertriglyceridemia, and 1.26 (1.16-1.37)
237 for low HDL cholesterol. Most of these associations were not substantially changed
238 after additional adjustment for WC (all P values \leq 0.03), except for diabetes and
239 hypertriglyceridemia. When stratified by sex, more prominent results were observed
240 among women.

241

242 **Association between MUAC and subclinical atherosclerosis**

243 In total participants, we observed strong and positive association between MUAC and
244 subclinical atherosclerosis with fully adjustment (Table 3). The OR for subclinical
245 atherosclerosis was 1.31 (95% CI, 1.09-1.58) within quartile 2 of MUAC, 1.33 (95%

246 CI, 1.10-1.62) within quartile 3, and 1.45 (95% CI, 1.16-1.80) within quartile 4, as
247 compared with the lowest quartile ($P_{\text{for trend}} = 0.005$). When stratified by sex, significant
248 results were observed among women but not among men.

249

250 **Stratification analyses by traditional cardiovascular risk factors**

251 We further examined the association between MUAC and subclinical atherosclerosis
252 stratified by traditional cardiometabolic risk factors. In women, MUAC was associated
253 with subclinical atherosclerosis among participants who aged ≥ 62 years, with BMI ≥ 25
254 kg/m² or waist circumference < 88 cm (Figure 1A), and among those with diabetes,
255 insulin resistance, or hypertension (Figure 1B). Moreover, there were significant
256 interactions of MUAC with diabetes and insulin resistance on subclinical
257 atherosclerosis ($P_{\text{for interaction}} = 0.04$ and 0.01 , respectively). These association patterns
258 were not observed in men (Supplementary Figure 1).

259 To further evaluate whether the association of MUAC with subclinical
260 atherosclerosis may be influenced by BMI and WC, we replicated the analyses within
261 combinations of BMI and WC. In women, those with higher WC were more likely to
262 have larger MUAC, regardless of BMI levels (Figure 2A). And MUAC was
263 independently associated with subclinical atherosclerosis in the combination of WC $<$
264 88 cm and BMI < 25 kg/m² (OR, 1.22; 95% CI, 1.05-1.43) and in the combination of
265 WC < 88 cm and BMI ≥ 25 kg/m² (OR, 1.40; 95% CI, 1.11-1.77) (Figure 2B).

266

267 **Discussion**

268 In this cross-sectional investigation of 6287 community dwelling Chinese adults, we
269 found that a large MUAC was positively associated with a series of cardiometabolic
270 disorders including central obesity, hypertension, low HDL cholesterol, and subclinical

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3 271 atherosclerosis. Such association patterns were independent from traditional
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5 272 cardiovascular risk factors, and were more prominent among women than men.
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8 273 Moreover, we observed significant interactions of MUAC with diabetes and insulin
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10 274 resistance in relation to subclinical atherosclerosis.

11
12 275 MUAC is a widely used indicator of upper body adiposity in children, adolescents,
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14 276 and adults.^{23, 24} Previous studies have shown mixed results on the associations between
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16 277 MUAC and CVD.²⁵⁻²⁸ Findings from a retrospective cohort study of 771 Japanese adults
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18 278 have suggested that MUAC may play a complementary role to BMI in predicting
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20 279 prognosis in patients with heart failure.²⁵ In addition, a cross-sectional study of 93
21
22 280 pubertal obese adolescents from Brazil have associated a larger MUAC with a higher
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24 281 level of HOMAR-IR and a higher cardiometabolic risk score.²⁶ In contrast, results from
25
26 282 the Health Effects of Arsenic Longitudinal Study of 562 middle-aged participants who
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28 283 were free of CVD in rural Bangladesh have shown no relationship between MUAC and
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30 284 CIMT.²⁸ Our present study has extended the existing evidence by demonstrating that
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32 285 MUAC increment was associated with an increased risk of a series of cardiometabolic
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34 286 disorders including central obesity, hypertension, low HDL cholesterol, and subclinical
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36 287 atherosclerosis in Chinese population, particularly among women. Central obesity,
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38 288 hypertension, low HDL cholesterol, and subclinical atherosclerosis have been robustly
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40 289 associated with increased risks of CVD. Detecting more effective risk factors for these
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42 290 cardiometabolic disorders is critical to the prevention of CVD. Our findings suggest that
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44 291 paying more attention to women with higher MUAC would be useful in the early
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46 292 identification and prevention of cardiometabolic disorders.

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48 293 Explanations for the observations between MUAC and cardiometabolic risk are
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50 294 multifactorial. Our study found that MUAC level tended to decrease with age and there
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52 295 was a stronger association between MUAC and subclinical atherosclerosis among
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3 296 women aged greater 62 years or older. Aging is a critical factor in changing process of
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5 297 metabolism and body composition. Fat-free mass and muscle mass reduced while
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7 298 substantial visceral fat rather than subcutaneous fat increased with aging, even under the
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9 299 condition of body weight unchanged. Individuals with age greater than 65 years suffer a
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11 300 reduction rate over 25 percent per year for muscle mass; and this rate can be accelerated
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13 301 to 50 percent per year for those older than 80 years.²⁸⁻³⁰ In addition, we found that
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15 302 MUAC was associated with subclinical atherosclerosis in a sex-specific manner. One
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17 303 plausible explanation for the sex difference in MUAC-subclinical atherosclerosis
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19 304 relationship is biological differences between men and women, such as hormones effect,
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21 305 immune system responses, muscle capacity and physical function. For instance, men
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23 306 tend to have greater muscle capacity and higher muscle mass than women due to higher
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25 307 levels of testosterone.²⁴ Body fat redistributes to upper body and to a preferential
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27 308 adiposity around the waist with age and this trend was more obvious in women than in
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29 309 men.³⁰ The sex difference in redistribution of body fat may partly contribute to the
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31 310 observed more predominant associations between MUAC and cardiometabolic
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33 311 disorders among women.

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39 312 The unique advantage of the present study is that we comprehensively determined
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41 313 the association of MUAC with a wide spectrum of cardiometabolic risk profiles in a
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43 314 well-defined community setting with fair sized sample and desirable population
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45 315 homogeneity. However, several limitations should be considered. Firstly, the cross-
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47 316 sectional nature of present study means no causal inference can be drawn. Secondly,
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49 317 although our finding supported that it can be a reliable surrogate of upper body
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51 318 adiposity, MUAC is a measure comprised of both adipose and lean tissue rather than a
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53 319 direct indicator for adiposity. Thirdly, as body composition changes over time, the
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55 320 narrow range of age for the participants enrolled could affected the outcome. Fourthly,
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3 321 MUAC measurement was performed on the left arm, though it should be determined on
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5 322 the non-dominant arm. Given the fact that the majority of Chinese population were
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7 323 right-handers, measurement protocol employed in our study for MUAC was acceptable.
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9 324 Finally, since our study was performed in a Chinese population, it should be cautiously
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11 325 to generalize the results to other ethnicities.
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14 326 In conclusion, our study provides evidence of positive associations of MUAC with
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16 327 cardiometabolic disorders as well as subclinical atherosclerosis in Chinese population.
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18 328 These results suggest that MUAC, as a convenient and inexpensive measurable metric,
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20 329 can be potentially used as a risk stratification tool in cardiometabolic disorders. Given
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22 330 the reliable assessment of MUAC in middle aged and elderly population and the
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24 331 accelerating rise rate of atherosclerosis in China, MUAC may be used as a valuable
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26 332 indicator for early prevention of CVD.
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11
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16
17 339 responsibility for the integrity of the data and the accuracy of the data analysis. Study
18
19 340 concept and design: TW, MX, YB and WW. Acquisition of data: YH, XJ, LX, WZ, CD,
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21 341 LW, ZZ, ML, JL, YX, and YC. Analysis and interpretation of data: YH, TW, MX, YB
22
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51 354 **Data sharing statement:** No additional data available.
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3 **439 Figure legends**
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5 **440 Figure 1. Stratification analysis of the association between MUAC and subclinical**

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7 **441 atherosclerosis in women.** A: All participants were divided into subgroups based on
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9 their average age (age < 62 years, age ≥ 62 years), body mass index (BMI < 25 kg/m²,
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11 BMI ≥ 25 kg/m²), or waist circumference (WC < 88 cm or WC ≥ 88 cm). B: All
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14 participants were divided into subgroups based on diabetes (yes or no), insulin
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16 resistance (yes or no), or hypertension (yes or no). Data were presented as odds ratio
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18 (OR) and 95% confidence interval (CI). *P* values were calculated from multivariable
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21 logistic regression analysis. Adjusted for age (years), body mass index (kg/m²), current
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24 smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk), WC
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27 (cm), C-reactive protein (mg/L), total cholesterol (mmol/L), HDL-C (mmol/L), LDL-C
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29 (mmol/L), triglycerides (mmol/L), fasting plasma glucose (mmol/L), and systolic blood
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31 pressure (mmHg).
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33 **452 Figure 2. Association between MUAC and subclinical atherosclerosis according to**

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35 **453 combined categories of BMI and WC.** A: MUAC in the BMI and WC subgroups in
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37 women. B: Association of MUAC with risk of subclinical atherosclerosis in the BMI
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39 and WC subgroups in women. MUAC: mid-upper arm circumference, BMI: body mass
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41 index, WC: waist circumference. Adjusted for age (years), body mass index (kg/m²),
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44 current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk),
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47 WC (cm), C-reactive protein (mg/L), total cholesterol (mmol/L), HDL-C (mmol/L),
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49 LDL-C (mmol/L), triglycerides (mmol/L), fasting plasma glucose (mmol/L), and
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52 systolic blood pressure (mmHg).
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Table 1. Characteristics of study participants according to quartiles of mid-upper arm circumference in total samples

	Mid-upper arm circumference, cm				P for trend
	Quartile 1 (15.5-27.1)	Quartile 2 (27.2-29.1)	Quartile 3 (29.2-31.2)	Quartile 4 (31.3-43.3)	
n	1510	1570	1582	1625	
Age (years)	63.4 ± 9.2	62.2 ± 8.8	61.7 ± 8.6	61.6 ± 8.4	< 0.0001
Female, n (%)	1110 (27.9)	1048 (26.4)	922 (23.2)	897 (22.6)	
Body mass index (kg/m ²)	22.3 ± 2.8	24.2 ± 3.8	25.5 ± 3.2	27.9 ± 7.5	< 0.0001
Waist circumference (cm)	75.6 ± 8.5	81.4 ± 7.9	85.5 ± 8.3	91.6 ± 9.2	< 0.0001
Systolic blood pressure (mmHg)	132.6 ± 18.0	133.4 ± 17.3	136.0 ± 17.2	137.0 ± 16.4	< 0.0001
Diastolic blood pressure (mmHg)	74.2 ± 9.5	75.7 ± 9.3	77.2 ± 9.2	78.0 ± 9.8	< 0.0001
Current smoking, n (%)	196 (13.0)	279 (17.8)	346 (21.9)	393 (24.2)	< 0.0001
Current drinking, n (%)	151 (10)	195 (12.4)	256 (16.2)	290 (17.9)	< 0.0001
Physical activity (MET-h/wk)	21.0 (6.0-21.0)	15.3 (3.0-21.0)	15.0 (3.0-21.0)	15.0 (3.0-21.0)	0.30
Fasting plasma glucose (mmol/L)	5.99 ± 1.36	6.06 ± 1.34	6.21 ± 1.57	6.28 ± 1.61	< 0.0001
HOMA-IR	1.42 (0.99-2.15)	1.75 (1.20-2.57)	1.95 (1.35-2.86)	2.43 (1.69-3.55)	< 0.0001
Total cholesterol (mmol/L)	5.28 ± 0.95	5.31 ± 0.98	5.26 ± 1.04	5.24 ± 1.08	0.20
LDL-C (mmol/L)	3.56 ± 0.75	3.62 ± 0.77	3.62 ± 0.83	3.63 ± 0.81	0.02
HDL-C (mmol/L)	1.42 ± 0.33	1.35 ± 0.29	1.31 ± 0.29	1.27 ± 0.27	< 0.0001

Triglycerides (mmol/L)	1.33 (0.98-1.84)	1.49 (1.07-2.12)	1.58 (1.12-2.25)	1.66 (1.19-2.30)	< 0.0001
C-reactive protein (mg/L)	0.19 (0.14-0.28)	0.21 (0.16-0.31)	0.23(0.17-0.35)	0.25(0.18-0.39)	< 0.0001
CIMT (mm)	0.69 ± 0.16	0.70 ± 0.15	0.70 ± 0.14	0.72 ± 0.14	< 0.0001
Insulin resistance, n (%)	203 (13.5)	313 (20.0)	410 (26.0)	655 (40.5)	< 0.0001
Hypertension, n (%)	747 (49.5)	862 (52.7)	978 (61.9)	1108 (68.3)	< 0.0001
Diabetes, n (%)	368 (24.7)	403 (25.9)	457 (29.2)	533 (33.2)	< 0.0001
Subclinical atherosclerosis, n (%)	472 (31.3)	541 (34.5)	555 (35.1)	590 (36.3)	0.0035

Data are presented as means ± standard deviation (SD), or medians (inter-quartile ranges) for skewed variables, or number (proportions) for categorical variables. *P* values were calculated from one-way analysis of variance (ANOVA) for continuous variables and chi-square test for categorical variables. Subclinical atherosclerosis was defined as CIMT ≥ 0.8 mm, which is the cut-off point for the highest quartile of the total participants. Insulin resistance was defined as HOMA-IR ≥ 2.8, which is the cut-off point for the highest quartile of the total participants. Abbreviations: MET, metabolic equivalent task; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; CIMT, carotid intima-media thickness; HOMA-IR indicates homeostasis model assessment of insulin resistance.

Table 2. Logistic regression analysis of risk of cardiometabolic disorders in relation to mid-upper arm circumference in total and sex-specific participants

		OR (95% CI)					P for trend
		Quartile 1	Quartile 2	Quartile 3	Quartile 4	1-SD (3.13 cm)	
Total cohort							
Central obesity	Model 1	1.00	1.43 (0.99-2.05)	3.44 (2.45-4.82)	7.25 (5.12-10.3)	2.05 (1.85-2.28)	< 0.0001
	Model 2	1.00	1.43 (0.99-2.05)	3.44 (2.45-4.82)	7.25 (5.12-10.3)	2.05 (1.85-2.28)	< 0.0001
Diabetes	Model 1	1.00	1.00 (0.82-1.21)	1.13 (0.93-1.37)	1.26 (1.02-1.55)	1.09 (1.02-1.16)	0.02
	Model 2	1.00	0.87 (0.73-1.06)	0.89 (0.73-1.10)	0.87 (0.70-1.09)	0.96 (0.90-1.04)	0.33
Hypertension	Model 1	1.00	1.04 (0.87-1.24)	1.57 (1.30-1.89)	1.65 (1.34-2.04)	1.21 (1.14-1.30)	< 0.0001
	Model 2	1.00	0.92 (0.77-1.10)	1.29 (1.06-1.56)	1.23 (0.98-1.53)	1.10 (1.03-1.19)	0.006
Hypertriglyceridemia	Model 1	1.00	1.55 (1.25-1.92)	1.78 (1.43-2.21)	1.92 (1.53-2.41)	1.24 (1.15-1.35)	< 0.0001
	Model 2	1.00	1.31 (1.05-1.63)	1.32 (1.05-1.66)	1.19 (0.93-1.54)	1.03 (0.94-1.13)	0.28
Low HDL cholesterol	Model 1	1.00	1.40 (1.06-1.84)	1.80 (1.38-2.35)	2.06 (1.57-2.69)	1.26 (1.16-1.37)	< 0.0001
	Model 2	1.00	1.21 (0.91-1.60)	1.41 (1.06-1.86)	1.38 (1.02-1.88)	1.10 (1.01-1.22)	0.03
Women							
Central obesity	Model 1	1.00	1.49 (1.04-2.15)	3.54 (2.50-4.99)	7.10 (4.97-10.2)	2.01 (1.81-2.25)	< 0.0001
	Model 2	1.00	1.49 (1.04-2.15)	3.54 (2.50-4.99)	7.10 (4.97-10.2)	2.01 (1.81-2.25)	< 0.0001
Diabetes	Model 1	1.00	1.11 (0.89-1.41)	1.29 (1.01-1.65)	1.39 (1.07-1.80)	1.12 (1.03-1.22)	0.007
	Model 2	1.00	0.98 (0.77-1.24)	1.03 (0.80-1.32)	0.97 (0.73-1.29)	0.99 (0.91-1.09)	0.93

Hypertension	Model 1	1.00	1.10 (0.89-1.35)	1.93 (1.54-2.44)	1.80 (1.39-2.33)	1.27 (1.17-1.38)	< 0.0001
	Model 2	1.00	0.96 (0.78-1.18)	1.55 (1.23-1.97)	1.29 (0.98-1.68)	1.14 (1.05-1.24)	0.003
Hypertriglyceridemia	Model 1	1.00	1.63 (1.28-2.01)	1.89 (1.48-2.42)	1.84 (1.42-2.38)	1.25 (1.15-1.37)	< 0.0001
	Model 2	1.00	1.38 (1.08-1.78)	1.43 (1.09-1.86)	1.17 (0.87-1.58)	1.05 (0.94-1.17)	0.33
Low HDL cholesterol	Model 1	1.00	1.67 (1.17-2.38)	1.94 (1.36-2.77)	1.87 (1.29-2.71)	1.21 (1.09-1.35)	0.0007
	Model 2	1.00	1.47 (1.03-2.21)	1.56 (1.07-2.28)	1.32 (0.86-2.01)	1.08 (0.91-1.23)	0.23
Men							
Central obesity	Model 1	1.00	0.38 (0.02-6.61)	3.99 (0.49-32.0)	10.4 (1.33-81.2)	3.08 (1.92-4.95)	< 0.0001
	Model 2	1.00	0.38 (0.02-6.61)	3.99 (0.49-32.0)	10.4 (1.33-81.2)	3.08 (1.92-4.95)	< 0.0001
Diabetes	Model 1	1.00	0.79 (0.56-1.10)	0.85 (0.61-1.18)	0.97 (0.68-1.38)	1.01 (0.90-1.13)	0.84
	Model 2	1.00	0.69 (0.49-0.98)	0.68 (0.48-0.97)	0.69 (0.47-1.01)	0.91 (0.81-1.03)	0.12
Hypertension	Model 1	1.00	0.92 (0.66-1.29)	1.06 (0.76-1.48)	1.29 (0.89-1.88)	1.10 (0.98-1.24)	0.10
	Model 2	1.00	0.84 (0.60-1.17)	0.91 (0.65-1.28)	1.03 (0.70-1.52)	1.03 (0.91-1.16)	0.68
Hypertriglyceridemia	Model 1	1.00	1.37 (0.85-2.21)	1.46 (0.92-2.31)	1.66 (1.03-2.67)	1.13 (0.96-1.32)	0.04
	Model 2	1.00	1.19 (0.73-1.92)	1.15 (0.72-1.84)	1.13 (0.68-1.87)	0.97 (0.81-1.52)	0.81
Low HDL cholesterol	Model 1	1.00	1.01 (0.65-1.58)	1.42 (0.94-2.16)	1.62 (1.04-2.51)	1.21 (1.06-1.38)	0.006
	Model 2	1.00	0.92 (0.59-1.44)	1.22 (0.79-1.86)	1.27 (0.80-2.01)	1.12 (0.97-1.29)	0.13

Data were presented as odds ratio (OR) and 95% confidence interval (CI). *P* values were calculated from multivariable logistic regression analysis in quartile of mid-upper arm circumference. Model 1: adjusted for age (years), sex, body mass index (kg/m²), current smoking (yes or

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no), current drinking (yes or no), physical activity (MET-h/wk); Model 2: further adjusted for waist circumference (cm), except for central obesity.

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Table 3. The association of mid-upper arm circumference with subclinical atherosclerosis in total and sex-specific participants

	OR (95% CI)					
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	1-SD (3.13 cm)	<i>P</i> for trend
Total cohort						0.20*
Cases/Participants	472 / 1510	541 / 1570	555 / 1582	590 / 1625	2158 / 6287	
Model 1	1.00	1.16 (1.00-1.34)	1.19 (1.02-1.38)	1.25 (1.08-1.45)	1.06 (1.01-1.12)	0.004
Model 2	1.00	1.30 (1.08-1.56)	1.30 (1.07-1.58)	1.35 (1.09-1.67)	1.06 (0.98-1.15)	0.013
Model 3	1.00	1.31 (1.09-1.58)	1.33 (1.10-1.62)	1.45 (1.16-1.80)	1.08 (0.99-1.17)	0.005
Women						
Case/participants	287 / 1110	327 / 1048	275 / 922	282 / 897	1171 / 3977	
Model 1	1.00	1.30 (1.08-1.57)	1.22 (1.00-1.48)	1.32 (1.09-1.60)	1.07 (1.00-1.14)	0.014
Model 2	1.00	1.54 (1.24-1.93)	1.43 (1.18-1.82)	1.53 (1.17-2.02)	1.11 (1.01-1.23)	0.007
Model 3	1.00	1.54 (1.24-1.93)	1.42 (1.11-1.83)	1.66 (1.26-2.20)	1.14 (1.03-1.26)	0.002
Men						
Case/participants	185 / 400	214 / 522	280 / 660	308 / 728	987 / 2310	
Model 1	1.00	0.81 (0.62-1.05)	0.86 (0.67-1.10)	0.85 (0.67-1.09)	0.93 (0.85-1.02)	0.39
Model 2	1.00	0.89 (0.64-1.23)	1.04 (0.75-1.44)	1.00 (0.70-1.45)	0.97 (0.85-1.11)	0.71
Model 3	1.00	0.90 (0.65-1.25)	1.06 (0.76-1.48)	1.05 (0.72-1.52)	0.99 (0.86-1.06)	0.54

Data were presented as odds ratio (OR) and 95% confidence interval (CI). *P* values were calculated from multivariable logistic regression analysis. *: the interaction of MUAC with sex on subclinical atherosclerosis. Model 1, unadjusted; Model 2, adjusted for age (years), sex, body

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4 mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk), waist circumference (cm); Model
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6 3, further adjusted for C-reactive protein (mg/L), total cholesterol (mmol/L), HDL-C (mmol/L), LDL-C (mmol/L), triglycerides (mmol/L),
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8 fasting plasma glucose (mmol/L), and systolic blood pressure (mmHg).
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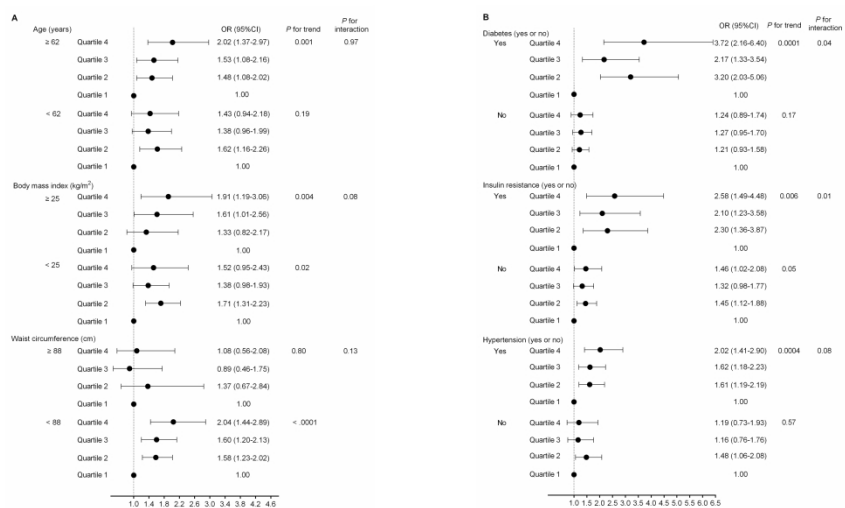


Figure 1

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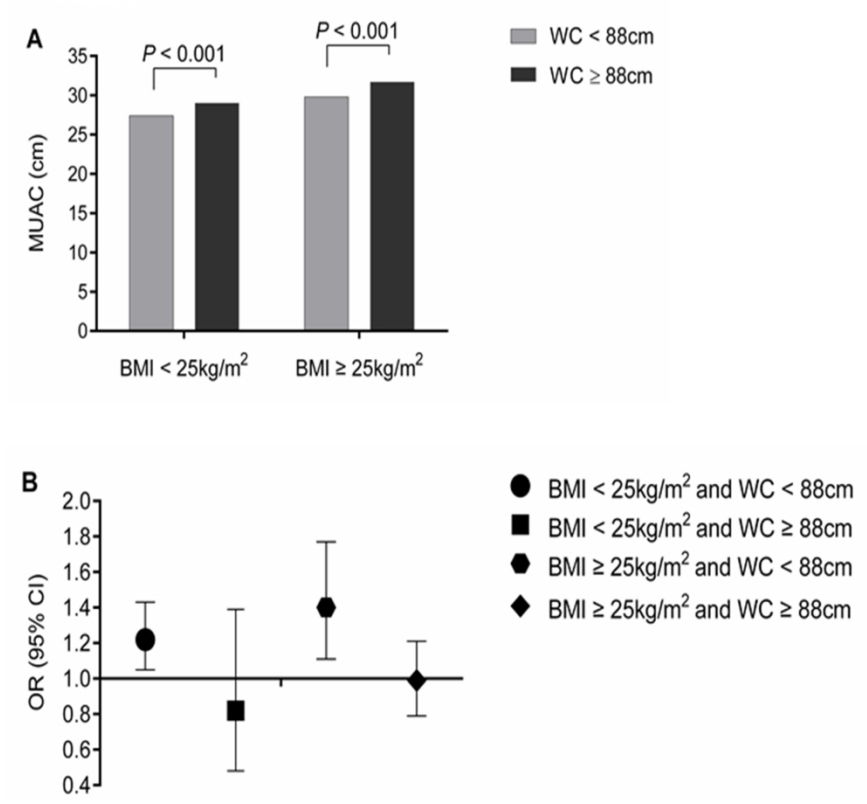


Figure 2

199x176mm (300 x 300 DPI)

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page number
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Page 1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 3-4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 6
Methods			
Study design	4	Present key elements of study design early in the paper	Page 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 6-7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	Page 6-7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 6-9
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	Page 7-9
Bias	9	Describe any efforts to address potential sources of bias	Page 6-9
Study size	10	Explain how the study size was arrived at	Page 6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Page 9-10
		(b) Describe any methods used to examine subgroups and interactions	Page 10
		(c) Explain how missing data were addressed	Page 7
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	Page 10
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	Page 10 Page 22
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 10-11
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	Page 10-11 Page 22
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	Page 11-12

		which confounders were adjusted for and why they were included	
		(b) Report category boundaries when continuous variables were categorized	Page 9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Page 12
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 12-13
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	Page 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	Page 13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 16

*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 www.strobe-statement.org.

BMJ Open

Association between mid-upper arm circumference and cardiometabolic risk in Chinese population: a cross-sectional study

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Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Diabetes and endocrinology, Cardiovascular medicine
Keywords:	cardiometabolic risk, mid-upper arm circumference, subclinical atherosclerosis, upper body fat, Chinese adults

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Manuscripts

1 **Association between mid-upper arm circumference and cardiometabolic risk in**
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5 **Chinese population: a cross-sectional study**
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10 **Running title: Upper body fat and cardiometabolic risk**
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18 Yanan Hou¹, Xu Jia¹, Liping Xuan¹, Wen Zhu¹, Chanjuan Deng¹, Long Wang¹, Zhiyun
19
20 Zhao¹, Mian Li¹, Jieli Lu¹, Yu Xu¹, Yuhong Chen¹, Weiqing Wang¹, Yufang Bi¹, Min
21
22 Xu¹, Tiange Wang^{1¶}
23
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25

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29 ¹Shanghai National Clinical Research Center for Endocrine and Metabolic Diseases,
30
31 Key Laboratory for Endocrine and Metabolic Diseases of the National Health
32
33 Commission of the PR China, Shanghai Institute of Endocrine and Metabolic Diseases,
34
35 Ruijin Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China.
36
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41
42 **¶Corresponding author:**
43
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45
46 Tiange Wang, MD, PhD, Shanghai National Clinical Research Center for Endocrine
47
48 and Metabolic Diseases, Key Laboratory for Endocrine and Metabolic Diseases of the
49
50 National Health Commission of the PR China, Shanghai Institute of Endocrine and
51
52 Metabolic Diseases, Ruijin Hospital, Shanghai Jiao Tong University School of
53
54 Medicine, Shanghai, China. Telephone: 86-21-64370045; Fax: 86-21-64749885; E-mail:
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3 **22 Abstract**
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6 **23 Objectives:** Upper body fat has been associated with an unfavorable cardiometabolic
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8 **24 risk.** We aimed to investigate the associations between mid-upper arm circumference
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10 **25 (MUAC),** a novel indicator of upper body fat, and a wide spectrum of cardiometabolic
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12 **26 risk profiles** in Chinese population.
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16 **27 Design and setting:** Cross-sectional analyses were performed using data from a well-
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18 **28 defined community** in 2014, Shanghai, China.
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22 **29 Participants:** A total of 6287 Chinese adults (2310 men and 3977 women) aged 40
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24 **30 years or older.**
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27 **31 Outcome measures:** Multivariable logistic regression model was used to examine the
28
29 **32 associations of MUAC** with cardiometabolic disorders including central obesity,
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31 **33 diabetes,** hypertension, hypertriglyceridemia, low high-density lipoprotein (HDL)
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33 **34 cholesterol,** and subclinical atherosclerosis.
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37 **35 Results:** In the overall participants, after multivariable adjustment, each 1-SD (3.13 cm)
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39 **36 increment in MUAC** was positively associated with central obesity (OR, 2.05; 95% CI,
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41 **37 1.85-2.28),** hypertension (OR, 1.10; 95% CI, 1.03-1.19), and low HDL cholesterol (OR,
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43 **38 1.10; 95% CI, 1.01-1.22).** Multivariable-adjusted ORs for subclinical atherosclerosis
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45 **39 were gradually increased** across increasing quartiles of MUAC with the lowest quartile
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47 **40 as reference** (quartile 2: OR, 1.31; 95% CI, 1.09-1.58; quartile 3: 1.33; 1.10-1.62;
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49 **41 quartile 4: 1.45; 1.16-1.80;** P for trend = 0.005). Similar but more prominent
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51 **42 associations** were observed among women than men. In addition, MUAC was
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53 **43 significantly interacted** with diabetes (P for interaction = 0.04) and insulin resistance (P
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55 **44 for interaction = 0.01)** on subclinical atherosclerosis.
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3 45 **Conclusion:** A greater MUAC was positively associated with higher risks of several
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5 46 cardiometabolic disorders and subclinical atherosclerosis in Chinese adults.
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11 48 **Keywords:** Cardiometabolic risk, mid-upper arm circumference, subclinical
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13 49 atherosclerosis, upper body fat, Chinese adults
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20 51 **Strengths and limitations of this study:**
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23 52 • The strengths of this study included a well-defined community setting, a fair sized
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25 53 sample size, and comprehensive measurements of cardiometabolic risk profiles.
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29 54 • The thorough analyses of the associations between MUAC and a wide spectrum of
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31 55 cardiometabolic risk profiles including central obesity, diabetes, hypertension,
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33 56 hypertriglyceridemia, low HDL cholesterol, and subclinical atherosclerosis.
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37 57 • Although our findings support that MUAC could be a reliable surrogate of upper body
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39 58 adiposity, MUAC is a measurement which reflect both adipose and lean tissue rather
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41 59 than a direct indicator for adiposity.
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45 60 • Age-related changes in body composition might influence these findings.
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49 61 • This study was restricted to middle-aged and elderly Chinese adults, and the
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51 62 generalizability of our findings should be cautious to other demographic and ethnic
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53 63 populations.
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64 **Introduction**

65 Cardiometabolic disorders describe a spectrum of interconnected pathological
66 alterations in the cardiovascular system and metabolic organs that symbiotically
67 increase the risk of cardiovascular disease (CVD), which is a major cause of mortality
68 and increasing burden of healthcare expenditure worldwide.¹⁻⁵ Several important
69 cardiometabolic disorders, including obesity, diabetes, insulin resistance, dyslipidemia,
70 and hypertension, are important risk factors for CVD and could be served as targets for
71 early identification and personalized prevention for CVD.²⁻⁵ In addition, as a common
72 contributor of CVD, atherosclerosis goes through a protracted subclinical phase and
73 could only be detected at an advanced stage of CVD.^{6,7} Thus, identification of
74 subclinical atherosclerosis in the asymptomatic period is also critical for the prevention
75 of CVD progression. Noninvasive ultrasonography measured carotid intima media
76 thickness (CIMT) is a well-established clinical index for early arteriosclerosis detection
77 and therefore has been extensively adopted to measure subclinical atherosclerosis.⁸

78 Fat distribution, specifically upper body and visceral adiposity, has been proven
79 highly relevant to cardiovascular risk.^{9,10} In addition to the conventional body fat
80 indices such as body mass index (BMI) and waist circumference (WC), mid-upper arm
81 circumference (MUAC), a novel anthropometric measurement, has been widely used in
82 the screening of malnutrition, adiposity and chronic diseases.¹¹ However, current
83 epidemiological studies have revealed inconsistent results with regard to the association
84 between MUAC and cardiometabolic risk. A cross-sectional study using data from the
85 National Health and Nutrition Examination Survey (NHANES) 1999 to 2006 circles has
86 reported a positive association between MUAC and insulin resistance in non-obese
87 individuals but no significant association in obese individuals.⁹ In a prospective cohort

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3 88 study of 1061 European elderly participants with a follow-up of approximately 6 years,
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5 89 a larger MUAC was associated with elevated risks of all-cause or CVD mortality.¹² By
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7 90 contrast, in the Canada Fitness Survey of 10638 adults, a larger MUAC was
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9 91 independently associated with a lower risk of all-cause mortality.¹³ And such inverse
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11 92 association between a larger MUAC and a lower risk of mortality was also documented
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13 93 in the British National Diet and Nutrition Survey of 1054 participants with more than 15
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15 94 years of follow-up.¹⁴

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20 95 So far, most of the previous studies were conducted in European population.
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22 96 Chinese population tend to have a higher percentage of body fat, a weaker willingness
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24 97 on body build, and less muscle mass as well as connective tissue as compared with their
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26 98 European counterparts.¹⁵ These different features in body composition may translate
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28 99 into varying susceptibilities to adiposity related cardiometabolic disorders. However,
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30 100 comprehensive analyses on associations between MUAC and cardiovascular risk
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32 101 profiles in Chinese population are still limited. Therefore, this study aimed to
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34 102 investigate the association between MUAC and multiple cardiometabolic disorders as
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36 103 well as subclinical atherosclerosis in Chinese population.
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45 105 **Methods**

46 47 48 106 **Study population**

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51 107 This is a cross-sectional analysis based on one of the follow-up circles of the established
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53 108 community-based cohort.^{16,17} Eligible participants aged 40 years or older were
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55 109 identified from the local residence registration records. There was no restriction on
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57 110 ethnicity or gender. Each eligible participant was recruited by trained community staff
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3 111 and local health workers using a door-to-door invitation method. Participants who
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5 112 consented for the study and signed informed consent were scheduled for health
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7 113 examinations. Briefly, a total of 6570 participants aged 40 years or older were enrolled
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9 114 from Jiading district, Shanghai, China, from August 2014 to May 2015. All participants
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11 115 received anthropometric measurements including height, weight, WC, and MUAC, a
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13 116 standard 75-g oral glucose tolerance test (OGTT), and a standard questionnaire to
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15 117 collect information regarding social demographic characteristics, education attainment,
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17 118 lifestyle factors, and history of disease and medicine. Blood samples were collected for
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19 119 biochemical measurements. In the present study, 283 participants were excluded due to
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21 120 missing data on MUAC or CIMT, and a total of 6287 participants were included in the
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23 121 final analysis. This study was approved by the Institutional Review Board of Ruijin
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25 122 Hospital Affiliated to Shanghai Jiao Tong University School of Medicine. Written
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27 123 informed consents were obtained from all study participants.
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37 125 **Data collection and biochemical measurements**

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40 126 Detailed information on sociodemographic characteristics, education attainment, and
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42 127 lifestyle factors including smoking and alcohol drinking habits and physical activity,
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44 128 family history, and medical history were obtained by using a standard questionnaire
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46 129 administered by trained personnel. Current smokers or alcohol drinkers were defined as
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48 130 persons who consumed any kinds of cigarettes or alcohol regularly in the past 6 months,
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50 131 respectively. Physical activity in term of metabolic equivalent (MET) hour/week was
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52 132 calculated according to the short form of the International Physical Activity
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54 133 Questionnaire including physical activities both during leisure time and at work.¹⁸
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3 134 Anthropometric measurements including height, weight, WC, and MUAC were
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5 135 assessed by well-trained physician according to a standard protocol. Body height and
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7 136 weight were measured with participants wearing light clothes without shoes to the
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10 137 nearest 0.1 centimeter and 0.1 kg, respectively. BMI was calculated as body weight in
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12 138 kilograms divided by body height in meters squared (kg/m^2). MUAC was measured on
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14 139 the upper left arm (halfway between the acromion process and the olecranon process)
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16 140 with the participants' bilateral arms hanging down naturally.¹⁹ WC was measured at the
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18 141 level of the umbilicus with the participants in the standing position. Systolic and
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20 142 diastolic blood pressures were measured in the non-dominant arm with an automated
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22 143 electronic sphygmomanometer (OMRON Model HEM-752 FUZZY, Omron Company,
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24 144 Dalian, China) three times (averaged for analysis) consecutively with 1 min interval
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26 145 after at least 5 min rest in a seated position.

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31 146 All participants were undertaken a 75-g OGTT after an overnight fasting. Fasting
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33 147 plasma glucose and OGTT 2-hour plasma glucose were measured using hexokinase
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35 148 method on a clinical chemistry diagnostic system (Modular P800; Roche, Basel,
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37 149 Switzerland). Serum concentrations of total cholesterol, triglycerides, high-density
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39 150 lipoprotein (HDL) cholesterol and low-density lipoprotein (LDL) cholesterol were
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41 151 measured by an autoanalyzer (Modular E170; Roche). High sensitive C-reactive protein
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43 152 concentration was determined by highly sensitive competitive immunoassay (antigens
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45 153 and antibodies from Beckman coulter IMMAGE800, America). Serum insulin was
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47 154 measured by using the electrochemiluminescence methods on an Immunology analyzer
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49 155 (RIABEAD II; Abbott, Tokyo, Japan). Homeostasis model assessment of insulin
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51 156 resistance (HOMA-IR) was calculated as fasting insulin ($\mu\text{IU}/\text{mL}$) \times fasting plasma
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53 157 glucose (mmol/L) / 22.5, and insulin resistance was defined as $\text{HOMA-IR} \geq 2.8$, which
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55 158 is the cut-off point for the highest quartile of the total participants.
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160 Definitions of cardiometabolic risk profile

161 Type 2 diabetes was defined as fasting plasma glucose ≥ 7.0 mmol/L or OGTT 2-hour
162 plasma glucose ≥ 11.1 mmol/L or use of anti-diabetic agents.²⁰ Hypertension was
163 defined as systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg or
164 current taking an antihypertensive medication. Central obesity was defined as WC ≥ 102
165 cm for men and ≥ 88 cm for women. Hypertriglyceridemia was defined as triglycerides
166 ≥ 2.26 mmol/L. Low HDL cholesterol was defined as a level of HDL cholesterol < 1.04
167 mmol/L.

168 CIMT measurement was conducted by a trained sonographer using a high-
169 resolution B-mode tomographic ultrasound system (Esaote Biomedica SpA, Genoa,
170 Italy) with a linear 7.5 MHz transducer.²¹ The position of CIMT measurement was
171 recorded on the far wall of both right and left common carotid arteries, 1.5 cm proximal
172 to the bifurcation. CIMT was measured on-line at the end of diastole as a distance from
173 the leading edge of the first echogenic line to that of the second. These two lines
174 represent the lumen-intima interface and collagen-contained upper layer of tunica
175 adventitia, respectively. Subclinical atherosclerosis was defined as a bilateral CIMT
176 average greater than 0.8 mm, which is the highest quartile cut-off point of the total
177 participants.

178

179 Statistical analyses

180 SAS version 9.4 (SAS Institute Inc, Cary, NC, USA) was used for statistical analysis.
181 Continuous variables were described as means \pm standard deviations (SDs) or medians

182 (interquartile ranges), and categorical variables as numbers (percentages). Variables
183 with skewed distributions, such as HOMA-IR, triglycerides, and C-reactive protein,
184 were normalized by logarithmic transformation before analysis.

185 Participants were divided into four subgroups according to quartiles of MUAC.
186 The ranges of MUAC within each quartile were 15.5 to 27.1 cm for quartile 1, 27.2 to
187 29.1 cm for quartile 2, 29.2 to 31.2 cm for quartile 3, and 31.3 to 43.3 cm for quartile 4.
188 Linear regression analysis was used to test the trend of continuous variables across
189 MUAC quartiles and the Cochran-Armitage trend chi-square test was used to test the
190 differences of proportions of categorical variables. Multivariable linear regression and
191 multivariable logistic regression analyses were conducted to assess the associations of
192 MUAC with multiple cardiometabolic disorders and subclinical atherosclerosis, with
193 adjustment for age, sex, BMI, WC, current smoking, current drinking, physical activity,
194 C-reactive protein, total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides,
195 fasting plasma glucose, and systolic blood pressure. Stratification analyses by age, BMI,
196 WC, diabetes, insulin resistance, and hypertension were also performed. Interactions
197 were tested by adding the respective multiplicative terms in the models simultaneously.
198 Statistical significance was set to a two-sided *P* value of less than 0.05.

199

200 **Patient and public involvement**

201 This study was conducted without patient and public involvement. No patients were
202 invited to take part in the development of the research question and outcome
203 measures, the study design and the interpretation of the results. The findings from this
204 study will be disseminated to the participants after the results are published in a peer-
205 reviewed journal.

206

207 **Results**

208 **Characteristics of the study participants**

209 Study participants included 2310 (36.7%) men and 3977 (63.3%) women with an
210 average age of 62.2 years (SD: 8.78). Sociodemographic and clinical characteristics of
211 the study participants according to MUAC quartiles are shown in Table 1. Participants
212 with a large MUAC were younger, had higher levels of BMI, WC, systolic and diastolic
213 blood pressures, fasting plasma glucose, HOMA-IR, LDL cholesterol, triglycerides, C-
214 reactive protein, and CIMT, had higher proportions of insulin resistance, hypertension,
215 diabetes, and subclinical atherosclerosis, and had lower levels of HDL cholesterol (all *P*
216 values < 0.05; Table 1). Consistent linear associations were observed between MUAC
217 and these cardiometabolic profiles (Supplemental Table 1).

218

219 **Association between MUAC and cardiometabolic disorders**

220 As shown in Table 2, the multivariable-adjusted OR per 1-SD increment (3.13 cm) in
221 MUAC was 2.05 (95% CI, 1.85-2.28) for central obesity, 1.09 (1.02-1.16) for diabetes,
222 1.21 (1.14-1.30) for hypertension, 1.24 (1.15-1.35) for hypertriglyceridemia, and 1.26
223 (1.16-1.37) for low HDL cholesterol. Most of these associations were not substantially
224 changed after additional adjustment for WC, except for diabetes and
225 hypertriglyceridemia. When stratified by sex, similar but more prominent associations
226 between MUAC and these cardiometabolic disorders were observed among women.

227

228 **Association between MUAC and subclinical atherosclerosis**

229 In total participants, we observed strong and positive association between MUAC and
230 subclinical atherosclerosis with fully adjustment (Table 3). The OR for subclinical
231 atherosclerosis was 1.31 (95% CI, 1.09-1.58) for quartile 2 of MUAC, 1.33 (95% CI,
232 1.10-1.62) for quartile 3, and 1.45 (95% CI, 1.16-1.80) for quartile 4 as compared with
233 the lowest quartile (P for trend = 0.005). When stratified by sex, statistically significant
234 results were observed among women but not among men.

236 **Stratification analyses by traditional cardiovascular risk factors**

237 We further examined the association between MUAC and subclinical atherosclerosis
238 across strata of traditional cardiometabolic risk factors. In women, MUAC was
239 associated with subclinical atherosclerosis among participants who aged ≥ 62 years,
240 with BMI ≥ 25 kg/m² or waist circumference < 88 cm (Figure 1A), and among
241 participants with diabetes, insulin resistance, or hypertension (Figure 1B). Moreover,
242 there were significant interactions of MUAC with diabetes and insulin resistance on
243 subclinical atherosclerosis (P for interaction = 0.04 and 0.01, respectively). These
244 association patterns were not observed in men (Supplementary Figure 1).

245 To further evaluate whether the association of MUAC with subclinical
246 atherosclerosis is influenced by BMI and WC, we replicated the analyses within
247 combinations of BMI and WC. In women, those with higher WC were more likely to
248 have larger MUAC, regardless of BMI levels (Figure 2A). And MUAC was
249 independently associated with subclinical atherosclerosis in the combination of WC $<$

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3 250 88 cm and BMI < 25 kg/m² (OR, 1.22; 95% CI, 1.05-1.43) and the combination of WC
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5 251 < 88 cm and BMI ≥ 25 kg/m² (OR, 1.40; 95% CI, 1.11-1.77) (Figure 2B).
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10 11 253 **Discussion**

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15 254 In this cross-sectional study of 6287 community dwelling Chinese adults, MUAC was
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17 255 positively associated with a series of cardiometabolic disorders including central obesity,
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19 256 hypertension, low HDL cholesterol, and subclinical atherosclerosis. These associations
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21 257 were independent from traditional cardiovascular risk factors, and were more prominent
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24 258 in women. Moreover, we observed significant interactions of MUAC with diabetes and
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26 259 insulin resistance in relation to subclinical atherosclerosis.
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30 260 MUAC has been accepted as a widely used indicator of upper body adiposity in
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32 261 children, adolescents, and adults.^{22, 23} Previous studies have shown mixed results on the
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34 262 associations between MUAC and CVD.²⁴⁻²⁷ Findings from a retrospective cohort study
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36 263 of 771 Japanese adults have suggested that MUAC may play a complementary role to
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38 264 BMI in predicting prognosis in patients with heart failure.²⁴ In addition, a cross-
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40 265 sectional study of 93 pubertal obese adolescents from Brazil have associated a larger
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42 266 MUAC with a higher level of HOMA-IR and a higher cardiometabolic risk score.²⁵ On
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44 267 the contrary, results from the Health Effects of Arsenic Longitudinal Study of 562
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46 268 middle-aged participants who were free of CVD in rural Bangladesh have shown no
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48 269 relationship between MUAC and CIMT.²⁷ Our study has extended the existing evidence
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50 270 by demonstrating that a greater MUAC was associated with higher prevalent risk of
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53 271 multiple cardiometabolic disorders including central obesity, hypertension, low HDL
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55 272 cholesterol, and subclinical atherosclerosis in Chinese adults, particularly among
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58 273 women. Central obesity, hypertension, low HDL cholesterol, and subclinical
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3 274 atherosclerosis have been robustly associated with increased risks of CVD, therefore
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5 275 detecting more effective risk factors for these cardiometabolic disorders is critical to the
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7 276 prevention of CVD. Our findings highlight the importance of paying more attention to
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10 277 women with higher MUAC in the early identification and precise prevention of
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12 278 cardiometabolic disorders.

15 279 Explanations for the observations between MUAC and cardiometabolic risk are
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17 280 multifactorial. Our study found that MUAC level tended to decrease with age and there
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19 281 was a stronger association between MUAC and subclinical atherosclerosis among
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21 282 women aged 62 years or older. Aging is a critical factor in the changing process of
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23 283 metabolism and body composition. Fat-free mass and muscle mass reduced while
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25 284 substantial visceral fat increased with aging, even under the condition of body weight
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27 285 unchanged.²⁷ It has been documented that individuals aged greater than 65 years would
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29 286 suffer a reduction in muscle mass over 25% per year; and this rate can be accelerated to
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31 287 50% per year for those older than 80 years.²⁷⁻²⁹ In addition, we found that MUAC was
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33 288 associated with subclinical atherosclerosis in a sex-specific manner. One plausible
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35 289 explanation for the sex difference in MUAC-subclinical atherosclerosis relationship
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37 290 may be due to the biological differences between men and women, such as hormones
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39 291 effect, immune system responses, muscle capacity and physical function. For instance,
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41 292 men tend to have greater muscle capacity and higher muscle mass than women due to
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43 293 higher levels of testosterone.²³ Body fat redistributes to upper body and to a preferential
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45 294 adiposity around the waist with age and this trend was more obvious in women than in
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47 295 men.²⁹ The sex difference in redistribution of body fat may partly contribute to the
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49 296 observed more predominant associations between MUAC and cardiometabolic
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51 297 disorders among women.
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3 298 The strength of this study is the comprehensive analyses of the association between
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5 299 MUAC and a wide spectrum of cardiometabolic risk profiles in a well-defined
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7 300 community setting with fair sized sample and desirable population homogeneity.
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10 301 Several limitations should be considered. First, due to a cross-sectional nature of the
11
12 302 present study, no causal inference can be drawn. Second, although our findings
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14 303 supported that MUAC could be a reliable surrogate of upper body adiposity, MUAC is a
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16 304 measurement which reflect both adipose and lean tissue rather than a direct indicator for
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18 305 adiposity. Third, although we have carefully adjusted for multiple confounders, age-
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20 306 related changes in body composition might influence these findings. Fourth, MUAC
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22 307 measurement was performed on the left arm, though it should be determined on the non-
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24 308 dominant arm. Given that the majority of Chinese population were right-handers,
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26 309 measurement protocol employed in our study for MUAC was acceptable. Finally, this
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28 310 study was restricted to middle-aged and elderly Chinese adults, and the generalizability
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30 311 of our findings should be cautious to other demographic and ethnic populations.
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36 312 In conclusion, our study provided novel evidence of positive associations between
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38 313 MUAC and cardiometabolic disorders as well as subclinical atherosclerosis in Chinese
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40 314 population. Our findings suggest that MUAC, as a convenient and inexpensive
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42 315 measurable metric, can be potentially used as a risk stratification indicator in the early
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44 316 detection and prevention of CVD.
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3 317 **Acknowledgments**
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15 321 **Footnotes**
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18 322 **Contributors:** All authors had full access to all the data in the study and take
19
20 323 responsibility for the integrity of the data and the accuracy of the data analysis. Study
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22 324 concept and design: TW, MX, YB and WW. Acquisition of data: YH, XJ, LX, WZ, CD,
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24 325 LW, ZZ, ML, JL, YX, and YC. Analysis and interpretation of data: YH, TW, MX, YB
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26 326 and WW. Drafting of the manuscript: YH. Critical revision of the manuscript: TW, MX,
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28 327 YB and WW. Statistical analysis: YH and XJ.
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54 337 **Patient consent for publication:** Written informed consent was obtained from all study
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56 338 participants.
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3 339 **Ethics approval:** The study protocol was approved by the Institutional Review Board
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5 340 of Ruijin Hospital Affiliated to Shanghai Jiao Tong University School of Medicine.
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3 426 **Figure legends**
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5 427 **Figure 1. Stratification analysis of the association between MUAC and subclinical**

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7 428 **atherosclerosis in women.** A: All participants were divided into subgroups based on

8 429 their average age (age < 62 years, age \geq 62 years), body mass index (BMI < 25 kg/m²,

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10 430 BMI \geq 25 kg/m²), or waist circumference (WC < 88 cm or WC \geq 88 cm). B: All

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14 431 participants were divided into subgroups based on diabetes (yes or no), insulin

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16 432 resistance (yes or no), or hypertension (yes or no). Data were presented as odds ratio

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18 433 (OR) and 95% confidence interval (CI). *P* values were calculated from multivariable

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20 434 logistic regression analysis. Adjusted for age (years), body mass index (kg/m²), current

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22 435 smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk), WC

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24 436 (cm), C-reactive protein (mg/L), total cholesterol (mmol/L), HDL cholesterol (mmol/L),

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26 437 LDL cholesterol (mmol/L), triglycerides (mmol/L), fasting plasma glucose (mmol/L),

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28 438 and systolic blood pressure (mmHg).
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33 439 **Figure 2. Association between MUAC and subclinical atherosclerosis according to**

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35 440 **combined categories of BMI and WC.** A: MUAC in the BMI and WC subgroups in

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37 441 women. B: Association of MUAC with risk of subclinical atherosclerosis in the BMI

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39 442 and WC subgroups in women. MUAC: mid-upper arm circumference, BMI: body mass

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41 443 index, WC: waist circumference. Adjusted for age (years), body mass index (kg/m²),

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43 444 current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk),

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45 445 WC (cm), C-reactive protein (mg/L), total cholesterol (mmol/L), HDL cholesterol

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47 446 (mmol/L), LDL cholesterol (mmol/L), triglycerides (mmol/L), fasting plasma glucose

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49 447 (mmol/L), and systolic blood pressure (mmHg).
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Table 1. Characteristics of study participants according to quartiles of mid-upper arm circumference

	Mid-upper arm circumference, cm				P for trend
	Quartile 1 (15.5-27.1)	Quartile 2 (27.2-29.1)	Quartile 3 (29.2-31.2)	Quartile 4 (31.3-43.3)	
n	1510	1570	1582	1625	
Age (years)	63.4 ± 9.2	62.2 ± 8.8	61.7 ± 8.6	61.6 ± 8.4	< 0.0001
Female, n (%)	1110 (27.9)	1048 (26.4)	922 (23.2)	897 (22.6)	
Body mass index (kg/m2)	22.3 ± 2.8	24.2 ± 3.8	25.5 ± 3.2	27.9 ± 7.5	< 0.0001
Waist circumference (cm)	75.6 ± 8.5	81.4 ± 7.9	85.5 ± 8.3	91.6 ± 9.2	< 0.0001
Systolic blood pressure (mmHg)	132.6 ± 18.0	133.4 ± 17.3	136.0 ± 17.2	137.0 ± 16.4	< 0.0001
Diastolic blood pressure (mmHg)	74.2 ± 9.5	75.7 ± 9.3	77.2 ± 9.2	78.0 ± 9.8	< 0.0001
Current smoking, n (%)	196 (13.0)	279 (17.8)	346 (21.9)	393 (24.2)	< 0.0001
Current drinking, n (%)	151 (10)	195 (12.4)	256 (16.2)	290 (17.9)	< 0.0001
Physical activity (MET-h/wk)	21.0 (6.0-21.0)	15.3 (3.0-21.0)	15.0 (3.0-21.0)	15.0 (3.0-21.0)	0.30
Fasting plasma glucose (mmol/L)	5.99 ± 1.36	6.06 ± 1.34	6.21 ± 1.57	6.28 ± 1.61	< 0.0001
HOMA-IR	1.42 (0.99-2.15)	1.75 (1.20-2.57)	1.95 (1.35-2.86)	2.43 (1.69-3.55)	< 0.0001
Total cholesterol (mmol/L)	5.28 ± 0.95	5.31 ± 0.98	5.26 ± 1.04	5.24 ± 1.08	0.20
LDL cholesterol (mmol/L)	3.56 ± 0.75	3.62 ± 0.77	3.62 ± 0.83	3.63 ± 0.81	0.02

HDL cholesterol (mmol/L)	1.42 ± 0.33	1.35 ± 0.29	1.31 ± 0.29	1.27 ± 0.27	< 0.0001
Triglycerides (mmol/L)	1.33 (0.98-1.84)	1.49 (1.07-2.12)	1.58 (1.12-2.25)	1.66 (1.19-2.30)	< 0.0001
C-reactive protein (mg/L)	0.19 (0.14-0.28)	0.21 (0.16-0.31)	0.23(0.17-0.35)	0.25(0.18-0.39)	< 0.0001
CIMT (mm)	0.69 ± 0.16	0.70 ± 0.15	0.70 ± 0.14	0.72 ± 0.14	< 0.0001
Insulin resistance, n (%)	203 (13.5)	313 (20.0)	410 (26.0)	655 (40.5)	< 0.0001
Hypertension, n (%)	747 (49.5)	862 (52.7)	978 (61.9)	1108 (68.3)	< 0.0001
Diabetes, n (%)	368 (24.7)	403 (25.9)	457 (29.2)	533 (33.2)	< 0.0001
Subclinical atherosclerosis, n (%)	472 (31.3)	541 (34.5)	555 (35.1)	590 (36.3)	0.0035

Data are presented as means ± standard deviation (SD), or medians (interquartile ranges) for skewed variables, or number (proportions) for categorical variables. *P* values were calculated from one-way analysis of variance (ANOVA) for continuous variables and chi-square test for categorical variables. Subclinical atherosclerosis was defined as CIMT ≥ 0.8 mm, which is the cut-off point for the highest quartile of the total participants. Insulin resistance was defined as HOMA-IR ≥ 2.8, which is the cut-off point for the highest quartile of the total participants. Abbreviations: MET, metabolic equivalent task; LDL, low-density lipoprotein; HDL, high-density lipoprotein; CIMT, carotid intima-media thickness; HOMA-IR indicates homeostasis model assessment of insulin resistance.

Table 2. Association between mid-upper arm circumference and multiple cardiometabolic disorders in total and sex-specific participants

		OR (95% CI)					P for trend
		Quartile 1	Quartile 2	Quartile 3	Quartile 4	1-SD (3.13 cm)	
Total							
Central obesity	Model 1	1.00	1.43 (0.99-2.05)	3.44 (2.45-4.82)	7.25 (5.12-10.3)	2.05 (1.85-2.28)	< 0.0001
	Model 2	1.00	1.43 (0.99-2.05)	3.44 (2.45-4.82)	7.25 (5.12-10.3)	2.05 (1.85-2.28)	< 0.0001
Diabetes	Model 1	1.00	1.00 (0.82-1.21)	1.13 (0.93-1.37)	1.26 (1.02-1.55)	1.09 (1.02-1.16)	0.02
	Model 2	1.00	0.87 (0.73-1.06)	0.89 (0.73-1.10)	0.87 (0.70-1.09)	0.96 (0.90-1.04)	0.33
Hypertension	Model 1	1.00	1.04 (0.87-1.24)	1.57 (1.30-1.89)	1.65 (1.34-2.04)	1.21 (1.14-1.30)	< 0.0001
	Model 2	1.00	0.92 (0.77-1.10)	1.29 (1.06-1.56)	1.23 (0.98-1.53)	1.10 (1.03-1.19)	0.006
Hypertriglyceridemia	Model 1	1.00	1.55 (1.25-1.92)	1.78 (1.43-2.21)	1.92 (1.53-2.41)	1.24 (1.15-1.35)	< 0.0001
	Model 2	1.00	1.31 (1.05-1.63)	1.32 (1.05-1.66)	1.19 (0.93-1.54)	1.03 (0.94-1.13)	0.28
Low HDL cholesterol	Model 1	1.00	1.40 (1.06-1.84)	1.80 (1.38-2.35)	2.06 (1.57-2.69)	1.26 (1.16-1.37)	< 0.0001

	Model 2	1.00	1.21 (0.91-1.60)	1.41 (1.06-1.86)	1.38 (1.02-1.88)	1.10 (1.01-1.22)	0.03
Women							
Central obesity	Model 1	1.00	1.49 (1.04-2.15)	3.54 (2.50-4.99)	7.10 (4.97-10.2)	2.01 (1.81-2.25)	< 0.0001
	Model 2	1.00	1.49 (1.04-2.15)	3.54 (2.50-4.99)	7.10 (4.97-10.2)	2.01 (1.81-2.25)	< 0.0001
Diabetes	Model 1	1.00	1.11 (0.89-1.41)	1.29 (1.01-1.65)	1.39 (1.07-1.80)	1.12 (1.03-1.22)	0.007
	Model 2	1.00	0.98 (0.77-1.24)	1.03 (0.80-1.32)	0.97 (0.73-1.29)	0.99 (0.91-1.09)	0.93
Hypertension	Model 1	1.00	1.10 (0.89-1.35)	1.93 (1.54-2.44)	1.80 (1.39-2.33)	1.27 (1.17-1.38)	< 0.0001
	Model 2	1.00	0.96 (0.78-1.18)	1.55 (1.23-1.97)	1.29 (0.98-1.68)	1.14 (1.05-1.24)	0.003
Hypertriglyceridemia	Model 1	1.00	1.63 (1.28-2.01)	1.89 (1.48-2.42)	1.84 (1.42-2.38)	1.25 (1.15-1.37)	< 0.0001
	Model 2	1.00	1.38 (1.08-1.78)	1.43 (1.09-1.86)	1.17 (0.87-1.58)	1.05 (0.94-1.17)	0.33
Low HDL cholesterol	Model 1	1.00	1.67 (1.17-2.38)	1.94 (1.36-2.77)	1.87 (1.29-2.71)	1.21 (1.09-1.35)	0.0007
	Model 2	1.00	1.47 (1.03-2.21)	1.56 (1.07-2.28)	1.32 (0.86-2.01)	1.08 (0.91-1.23)	0.23

Men

Central obesity	Model 1	1.00	0.38 (0.02-6.61)	3.99 (0.49-32.0)	10.4 (1.33-81.2)	3.08 (1.92-4.95)	< 0.0001
	Model 2	1.00	0.38 (0.02-6.61)	3.99 (0.49-32.0)	10.4 (1.33-81.2)	3.08 (1.92-4.95)	< 0.0001
Diabetes	Model 1	1.00	0.79 (0.56-1.10)	0.85 (0.61-1.18)	0.97 (0.68-1.38)	1.01 (0.90-1.13)	0.84
	Model 2	1.00	0.69 (0.49-0.98)	0.68 (0.48-0.97)	0.69 (0.47-1.01)	0.91 (0.81-1.03)	0.12
Hypertension	Model 1	1.00	0.92 (0.66-1.29)	1.06 (0.76-1.48)	1.29 (0.89-1.88)	1.10 (0.98-1.24)	0.10
	Model 2	1.00	0.84 (0.60-1.17)	0.91 (0.65-1.28)	1.03 (0.70-1.52)	1.03 (0.91-1.16)	0.68
Hypertriglyceridemia	Model 1	1.00	1.37 (0.85-2.21)	1.46 (0.92-2.31)	1.66 (1.03-2.67)	1.13 (0.96-1.32)	0.04
	Model 2	1.00	1.19 (0.73-1.92)	1.15 (0.72-1.84)	1.13 (0.68-1.87)	0.97 (0.81-1.52)	0.81
Low HDL cholesterol	Model 1	1.00	1.01 (0.65-1.58)	1.42 (0.94-2.16)	1.62 (1.04-2.51)	1.21 (1.06-1.38)	0.006
	Model 2	1.00	0.92 (0.59-1.44)	1.22 (0.79-1.86)	1.27 (0.80-2.01)	1.12 (0.97-1.29)	0.13

Data were presented as odds ratio (OR) and 95% confidence interval (CI). *P* values were calculated from multivariable logistic regression analysis in quartile of mid-upper arm circumference. Model 1: adjusted for age (years), sex, body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk); Model 2: further adjusted for waist circumference (cm), except for central obesity.

Table 3. Association between mid-upper arm circumference and subclinical atherosclerosis in total and sex-specific participants

	OR (95% CI)					<i>P</i> for trend
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	1-SD (3.13 cm)	
Total						0.20*
Cases/Participants	472 / 1510	541 / 1570	555 / 1582	590 / 1625	2158 / 6287	
Model 1	1.00	1.16 (1.00-1.34)	1.19 (1.02-1.38)	1.25 (1.08-1.45)	1.06 (1.01-1.12)	0.004
Model 2	1.00	1.30 (1.08-1.56)	1.30 (1.07-1.58)	1.35 (1.09-1.67)	1.06 (0.98-1.15)	0.013
Model 3	1.00	1.31 (1.09-1.58)	1.33 (1.10-1.62)	1.45 (1.16-1.80)	1.08 (0.99-1.17)	0.005
Women						
Case/participants	287 / 1110	327 / 1048	275 / 922	282 / 897	1171 / 3977	
Model 1	1.00	1.30 (1.08-1.57)	1.22 (1.00-1.48)	1.32 (1.09-1.60)	1.07 (1.00-1.14)	0.014
Model 2	1.00	1.54 (1.24-1.93)	1.43 (1.18-1.82)	1.53 (1.17-2.02)	1.11 (1.01-1.23)	0.007
Model 3	1.00	1.54 (1.24-1.93)	1.42 (1.11-1.83)	1.66 (1.26-2.20)	1.14 (1.03-1.26)	0.002

Men

Case/participants	185 / 400	214 / 522	280 / 660	308 / 728	987 / 2310	
Model 1	1.00	0.81 (0.62-1.05)	0.86 (0.67-1.10)	0.85 (0.67-1.09)	0.93 (0.85-1.02)	0.39
Model 2	1.00	0.89 (0.64-1.23)	1.04 (0.75-1.44)	1.00 (0.70-1.45)	0.97 (0.85-1.11)	0.71
Model 3	1.00	0.90 (0.65-1.25)	1.06 (0.76-1.48)	1.05 (0.72-1.52)	0.99 (0.86-1.06)	0.54

Data were presented as odds ratio (OR) and 95% confidence interval (CI). *P* values were calculated from multivariable logistic regression analysis. *: the interaction of MUAC with sex on subclinical atherosclerosis. Model 1, unadjusted; Model 2, adjusted for age (years), sex, body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk), waist circumference (cm); Model 3, further adjusted for C-reactive protein (mg/L), total cholesterol (mmol/L), HDL cholesterol (mmol/L), LDL cholesterol (mmol/L), triglycerides (mmol/L), fasting plasma glucose (mmol/L), and systolic blood pressure (mmHg).

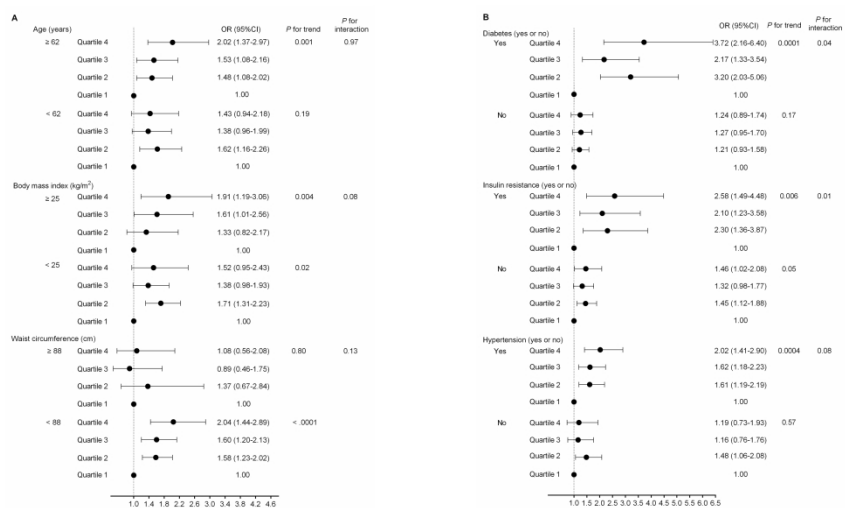


Figure 1

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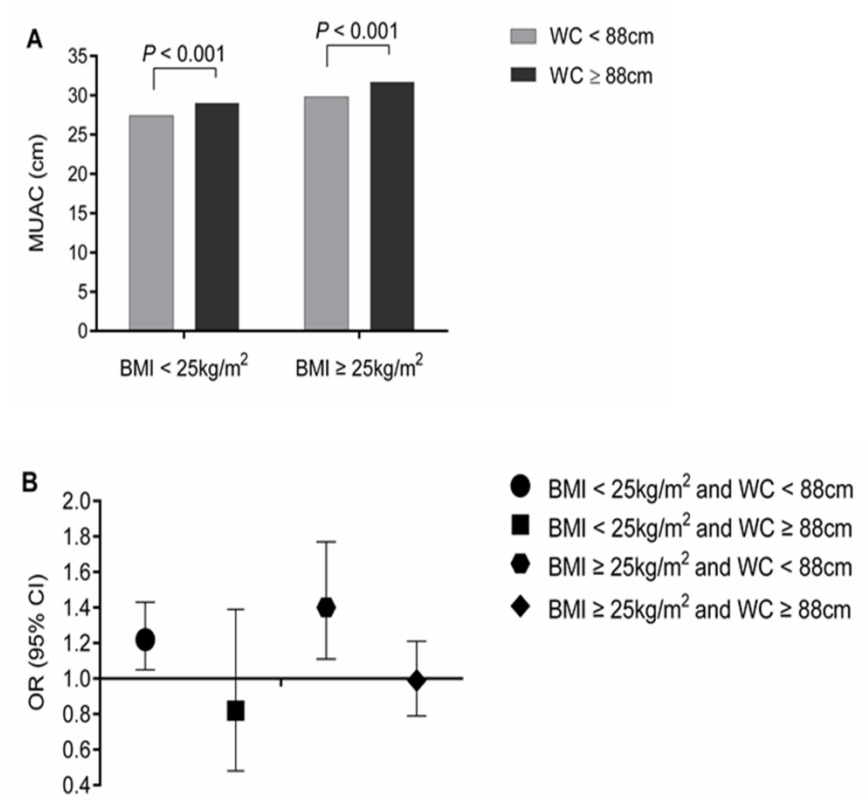


Figure 2

199x176mm (300 x 300 DPI)

Online Supplemental Information

Association between mid-upper arm circumference and cardiometabolic risk in Chinese population: a cross-sectional study

Supplemental Table 1. The association of mid-upper arm circumference with cardiometabolic profiles in total participants

Supplemental Figure Legend

Supplemental Figure 1. Stratified analysis of the association of mid-upper arm circumference with risk of subclinical atherosclerosis in men. A: All subjects were divided into subgroups based on their average age (age < 62 years, age \geq 62 years), body mass index (BMI < 25 kg/m², BMI \geq 25 kg/m²), or waist circumference (WC < 88 cm or WC \geq 88 cm). B: All subjects were divided into subgroups based on diabetes (yes or no), insulin resistance (yes or no), or hypertension (yes or no). Data were presented as odds ratio (OR) and 95% confidence interval (CI). *P* values were calculated from multivariable logistic regression analysis. Adjusted for age (years), body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk), waist circumference (cm), C-reactive protein (mg/L), total cholesterol (mmol/L), HDL cholesterol (mmol/L), LDL cholesterol (mmol/L), triglycerides (mmol/L), fasting plasma glucose (mmol/L), and systolic blood pressure (mmHg).

Supplemental Table 1. The association of mid-upper arm circumference with cardiometabolic profiles in total participants

	Model 1		Model 2		Model 3	
	$\beta \pm SE$	P value	$\beta \pm SE$	P value	$\beta \pm SE$	P value
Age (years)	-0.20 \pm 0.04	<0.0001	/	/	/	/
Body mass index (kg/m ²)	0.70 \pm 0.02	<0.0001	/	/	/	/
Waist circumference (cm)	1.94 \pm 0.03	<0.0001	1.62 \pm 0.04	<0.0001	/	/
Systolic blood pressure (mmHg)	0.55 \pm 0.07	<0.0001	0.49 \pm 0.09	<0.0001	0.20 \pm 0.10	0.04
Diastolic blood pressure (mmHg)	0.49 \pm 0.04	<0.0001	0.32 \pm 0.05	<0.0001	0.08 \pm 0.06	0.15
Fasting plasma glucose (mmol/L)	0.03 \pm 0.01	<0.0001	0.02 \pm 0.01	0.01	-0.02 \pm 0.01	0.04
HOMA-IR	0.03 \pm 0.001	<0.0001	0.02 \pm 0.001	<0.0001	0.01 \pm 0.002	0.0003
Total cholesterol (mmol/L)	-0.004 \pm 0.004	0.30	0.004 \pm 0.005	0.48	-0.01 \pm 0.01	0.24
LDL cholesterol (mmol/L)	0.009 \pm 0.003	0.005	0.01 \pm 0.004	0.001	0.001 \pm 0.005	0.79
HDL cholesterol (mmol/L)	-0.02 \pm 0.001	<0.0001	-0.01 \pm 0.001	<0.0001	-0.003 \pm 0.002	0.08

Triglycerides (mmol/L)	0.01 ±0.001	<0.0001	0.01 ±0.001	<0.0001	0.001 ±0.001	0.38
C-reactive protein (mg/L)	0.01 ±0.001	<0.0001	0.01 ±0.001	<0.0001	0.002 ±0.002	0.12
CIMT (cm)	0.003 ±0.001	<0.0001	0.003 ±0.001	0.0002	0.002 ±0.001	0.005

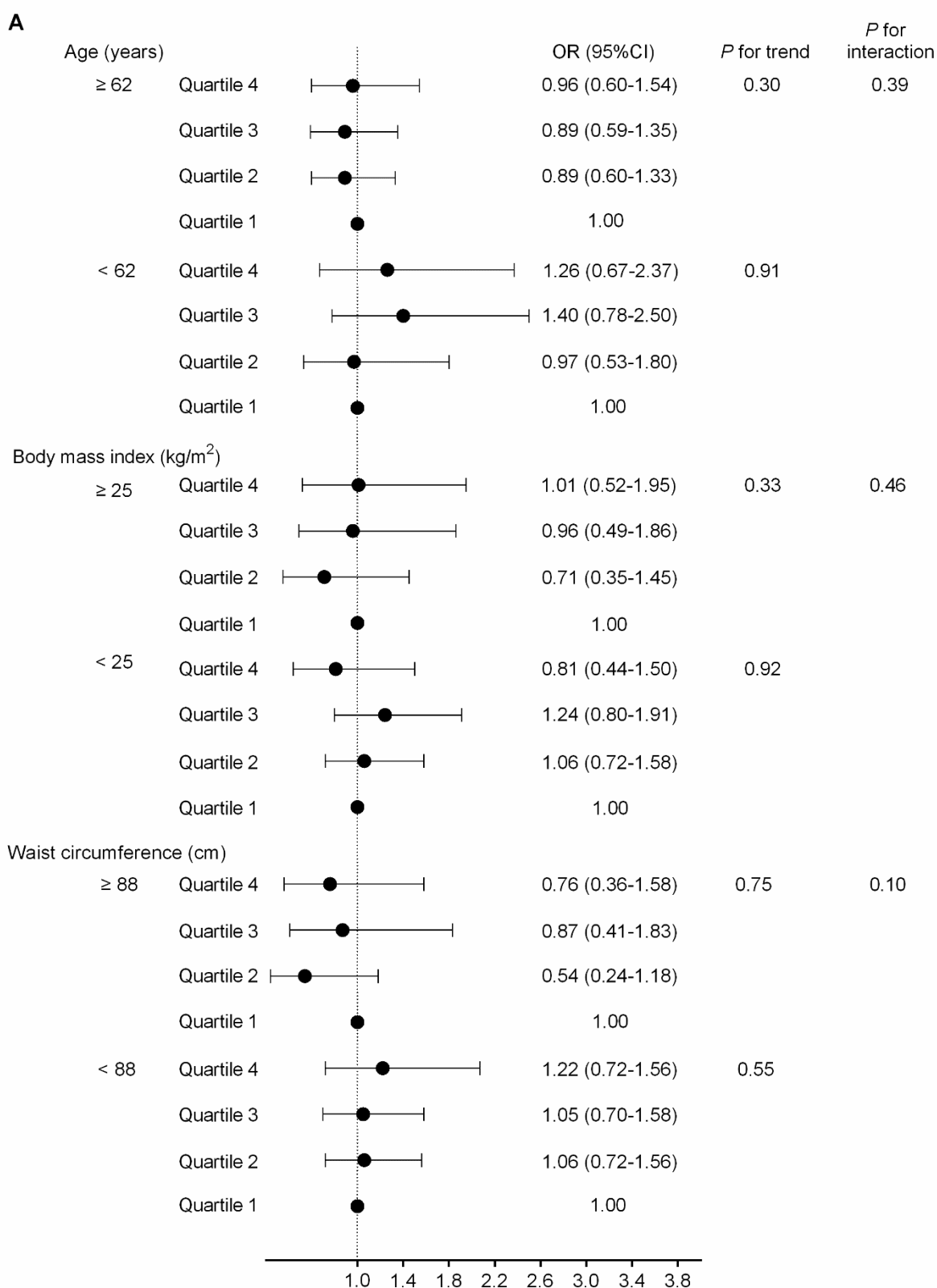
Data are linear regression estimates ± standard error ($\beta \pm SE$). P values were calculated from multivariable linear regression model. Model 1: unadjusted;

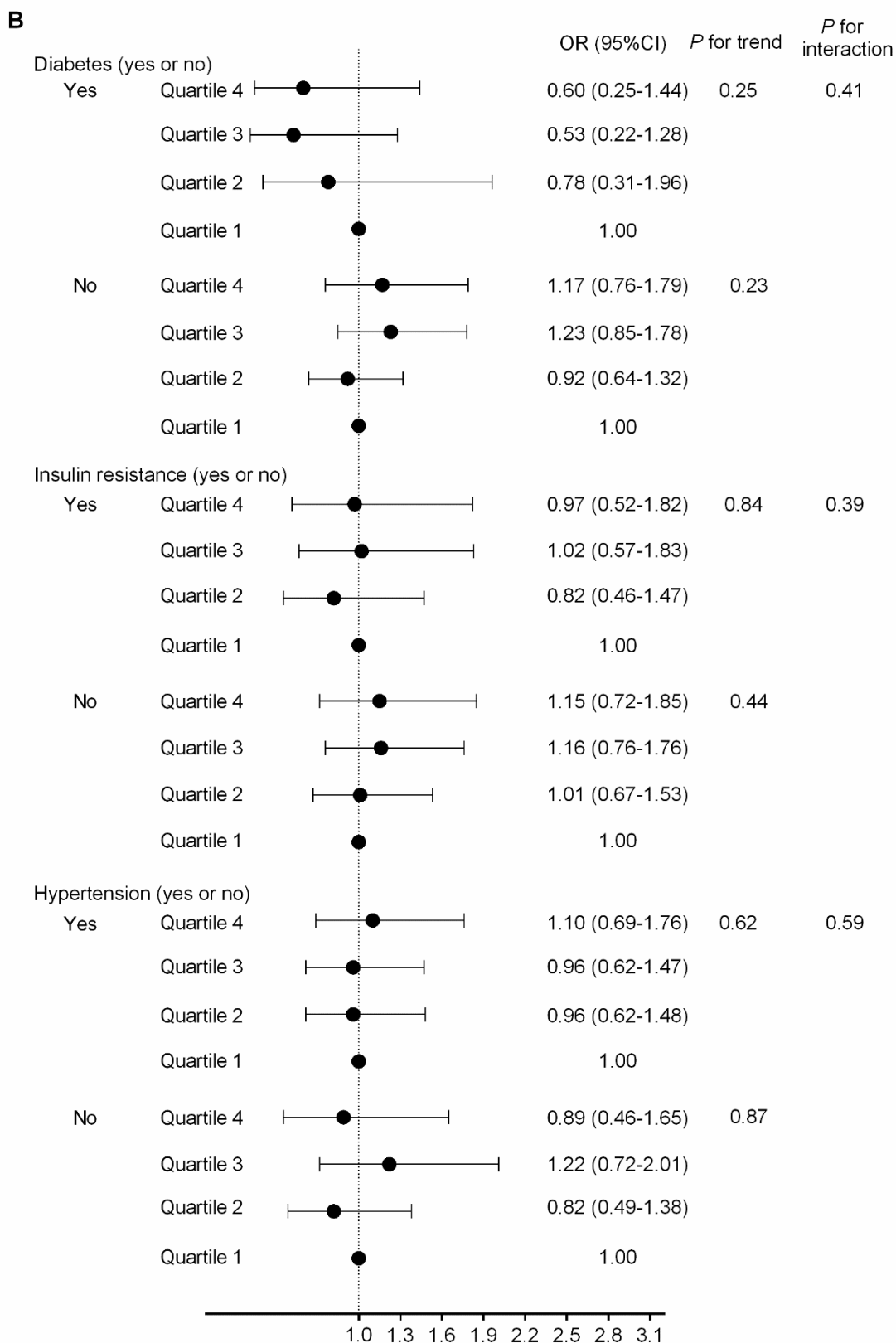
Model 2: adjusted for age (years), sex, body mass index (kg/m²), current smoking (yes or no), current drinking (yes or no), physical activity (MET-h/wk);

Model 3: further adjusted for waist circumference (cm). Abbreviations: LDL, low-density lipoprotein; HDL, high-density lipoprotein; CIMT, carotid

intima-media thickness.

Supplemental Figure 1





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For peer review only

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

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

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		(b) Report category boundaries when continuous variables were categorized	Page 11
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Page 11-12
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 12-13
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	Page 14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 15

*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 www.strobe-statement.org.