Low skeletal muscle mass is associated with arterial stiffness in Chinese community-dwelling adults

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skeletal muscle mass, body composition, pulse wave velocity, arterial stiffness
Abstract
Aim: To investigate whether skeletal muscle mass is associated with arterial stiffness in Chinese community-dwelling men and women.

Methods: In this cross-sectional study, 20477 participants (age range: 45-80 years, 68.8% women) were included in the analysis. Brachial-ankle pulse wave velocity (baPWV), an indicator of arterial stiffness was measured using a waveform device. Total muscle mass and muscle mass of arm, leg and trunk were measured by bioelectrical impedance analysis. Height and weight were measured and appendicular skeletal muscle mass index (ASMI) was calculated as appendicular skeletal muscle mass (sum of arm and leg muscle mass) divided by height square.

Results: After adjustment for age, body fat percentage, systolic blood pressure and diastolic blood pressure, ASMI was negatively associated with baPWV [β (SE) for men: -0.208 (0.016), p < 0.0001; for women: -0.245 (0.012), p < 0.0001]. High ASMI was a protective factor for the presence of arterial stiffness (defined as baPWV) [OR (95%CI) for men: 0.730 (0.682, 0.782), p < 0.0001; women: 0.634 (0.593, 0.677), p < 0.0001]. Similar associations were found between quantity of muscle mass (total and appendicular muscle mass, muscle mass of arm, leg and trunk) and arterial stiffness in men and women after further adjustment for height (all p < 0.0001).

Conclusion: Low skeletal muscle mass is associated with increased risk of arterial stiffness in Chinese community-dwelling adults.

Background
Cardiovascular disease (CVD) remains to be the top cause of death in China and brings out huge medical and financial burden[1]. Arterial stiffness, a reflection of health status of both central and peripheral arteries, has strong predictive value for future cardiovascular events and all-cause mortality[2, 3]. Pulse wave velocity (PWV), a standard and noninvasive indicator applied in many epidemiological and clinical studies for assessing arterial stiffness, has been confirmed as an independent predictor of the risk of development of CVD [4-8].

Evidence suggests that body composition has impact on the prevalence and development of arterial stiffness[9-14]. More specifically, previous studies which explored the association between muscle
mass and PWV showed consensus preliminarily. Significant negative associations were found between muscle mass indices and PWV in studies among apparently healthy elderly of Chinese[15], Japanese[16, 17] and American with multi-race[18]. Similar results were found among patients of type 2 diabetes[19] and peritoneal dialysis[20]. However, evidence in Chinese population are limited, and results remain controversial among different gender and for regional muscle mass (arm, leg and trunk).

Therefore, the aim of this study was to explore the associations between muscle mass indices (total and appendicular muscle mass, appendicular skeletal muscle mass index, and muscle mass of arm, leg and trunk) and arterial stiffness (defined as baPWV) in community-dwelling Chinese men and women.

Methods
Study population
The participants in this cross-sectional study were apparently healthy Chinese adults, aged 45–80 years, from 24 provinces. They completed measurements of anthropometry, body composition and arterial stiffness under the guidance of trained workers. The following participants were excluded: 1) pregnant women, 2) participants with major organ diseases, including heart, liver or kidney disease, 3) participants with peripheral artery disease whose ankle-brachial index ≤ 0.9 were also excluded[21], 4) participants with incomplete information of body composition, arterial stiffness and covariates. Thus, a total of 20477 participants were included in the present analysis. The study was approved by Ethics Committee of Chinese Clinical Trial Registry. All participants gave written informed consent.

Anthropometric measurements
Height and weight were measured by trained medical workers according to standard procedures, with subjects wearing light indoor clothing and barefoot. Height was measured to the nearest 0.1 cm and weight was measured to the nearest 0.1 kg. BMI was calculated as weight (kg) divided by height squared (m²).

Measurements of body composition indices
The quantity of total skeletal muscle mass (SMM), muscle mass of the left arm (LAMM), right arm
(RAMM), left leg (LLMM), right leg (RLMM) and trunk (TMM) and the percentage of body fat (BFP) were measured using a dual bioelectrical impedance analyzer (IOI 353; Jawon, Korea). Appendicular skeletal muscle mass (ASM, kg) was defined as the sum of the arm and leg muscle mass on both sides. Appendicular skeletal muscle mass index (ASMI, kg/m$^2$) was calculated as ASM divided by height square.

**Measurements of arterial stiffness indices and blood pressure**

In this study, the baPWV, MAP, UT as well as the brachial and ankle blood pressures on the left and right sides of the subjects were measured with a plethysmography apparatus (BP-203RPE III; Omron, Japan) after rested in a supine position for 5 minutes. baPWV, MAP and UT were calculated as the mean of the left and right baPWV, MAP and UT values, respectively. SBP and DBP were calculated as the mean of the left and right brachial systolic and diastolic pressure, respectively. High baPWV (arterial stiffness) was defined as baPWV ≥ 1800 mm/s[22].

**Statistical analysis**

Categorical variables were described as number and percentage. Continuous variables with normal distribution were expressed using mean with standard deviation (SD), and non-normally distributed continuous variables were presented as median with 25th and 75th percentile. The participants were stratified into three groups by tertiles of the ASMI (men: $7.71 \pm 0.37$ kg/m$^2$, $8.53 \pm 0.22$ kg/m$^2$, $9.78 \pm 0.73$ kg/m$^2$; women: $6.77 \pm 0.34$ kg/m$^2$, $7.51 \pm 0.18$ kg/m$^2$, $8.41 \pm 0.57$ kg/m$^2$). Differences between groups were tested using Student’s t-test or one-way ANOVA analysis for normally distributed continuous variables and Kruskal–Wallis test for continuous variables with non-normal distribution. Pearson’s correlation analysis was used to access the correlation between muscle mass indices (ASMI, ASM, SMM, LAMM, RAMM, LLMM, RLMM and TMM) and baPWV. The association of muscle mass indices with baPWV and the association of mass indices with arterial stiffness (normal / high, defined as baPWV) were carried out by multivariate linear regression analysis and multiple logistic regression analysis, respectively. The regression models testing ASMI with baPWV / arterial stiffness were performed after adjusting for age, body fat, systolic blood pressure (SBP) and diastolic blood pressure (DBP). The models testing quantity of muscle mass (SMM, ASM, LAMM, RAMM, LLMM,
RLMM, TMM) with baPWV / arterial stiffness were further adjusted for body height. All analyses were conducted using SAS version 9.1 (SAS Institute, Inc., Cary, NC, USA). A p value < 0.05 was considered statistically significant.

Results
The mean age of participants included in the present analysis was 61.25 ± 8.22 years, 68.79% were women. Compared with women, men were older and had higher BMI, SMM, AMM, LAMM, RAMM, LLMM, RLMM, TMM, baPWV, SBP, DBP and ABI, however, their BFP, PP, MAP and UT were lower than that of women (all p < 0.05) (Table 1).

Characteristics of body composition and artery stiffness in men and women are presented in Table 2. The participants were divided into three groups according to ASMI tertiles (men: 7.71 ± 0.37 kg/m², 8.53 ± 0.22 kg/m², 9.78 ± 0.73 kg/m²; women: 6.77 ± 0.34 kg/m², 7.51 ± 0.18 kg/m², 8.41 ± 0.57 kg/m²). Both among men and women, higher ASMI was observed in participants who were younger and those with lower baPWV and MAP (all p < 0.0001). In contrast, participants with higher ASMI had higher BMI, ASM, SMM, LAMM, RAMM, LLMM, RLMM, TMM, SBP, DBP, PP, ABI and UT (all p < 0.05). The highest BFP was found in median ASMI group (T2) for men and in high ASMI group (T3) for women. Pearson’s correlations between muscle mass indices and baPWV are shown in Table 3. Significant negative correlations were observed between muscle mass indices (ASMI, ASM, SMM, LAMM, RAMM, LLMM, RLMM, and TMM) and baPWV in men and women (all p < 0.0001).

The results of the multiple linear regression showed that ASMI was negatively associated with baPWV [β (SE) for men: -0.208 (0.016), p < 0.0001; women: -0.245 (0.012), p < 0.0001] adjusted for age, body fat percentage, systolic blood pressure and diastolic blood pressure. Similar associations were found between quantity of muscle mass (ASM, SMM, LAMM, RAMM, LLMM, RLMM, and TMM) and baPWV in men and women after further adjustment for height (all p < 0.0001) (Table 4).

Multiple logistic regression analysis showed that higher ASMI was a protective factor for the presence of arterial stiffness adjusted for age, body fat percentage, systolic blood pressure and diastolic blood pressure [OR (95%CI) for men: 0.730 (0.682, 0.782), p < 0.0001; women: 0.634 (0.593, 0.677), p < 0.0001]. Similar associations were found between quantity of muscle mass (ASM, SMM, LAMM, RAMM,
and arterial stiffness in men and women after further adjustment for height (all \( p < 0.0001 \)) (Table 5).

**Discussion**

The present study found that ASMI and quantity of muscle mass (total and appendicular muscle mass, muscle mass of arm, leg and trunk) were negatively associated with baPWV. High levels of these muscle mass indices were protective factors for the presence of arterial stiffness in Chinese community-dwelling men and women.

Recently, epidemiological data showed that the middle-aged population in North China had a high prevalence of arterial stiffness (high baPWV)[23]. Compared with this study, the prevalence of arterial stiffness in the present analysis was higher in men and approximate in women (men: 33.43%, women: 26.63%, data not shown). Meanwhile, the quantity of total skeletal muscle mass of Chinese adults was at a low level, especially for the elderly[24], which was comparable with our results.

The negative associations between SMM / ASM / ASMI and baPWV were found in previous studies[15, 17, 20]. Zhang et al. [15] found that ASMI was associated with baPWV in 1002 Chinese community dwelling participants aged 65 years and above, and this relation remains significant only in men in analysis of gender subgroup. Similar association was observed between total skeletal muscle mass and baPWV among Chinese peritoneal dialysis patients[20], which was mainly contributed by female patients. Moreover, studies among Japanese women suggested that baPWV was a risk factor for the low level of ASMI[17]. In accordance with these studies, our results suggested that Chinese adults with low levels of SMM / ASM / ASMI had higher baPWV. Consistent results were observed both in men and women. Our findings from a large sample of Chinese community-dwelling population confirmed the hypothesis that low level of muscle mass is a potential risk factor of arterial stiffness. To our knowledge, this relation was proved in both genders for the first time. Possible reasons for the conflicting results between men and women included that: 1) the level of baPWV, muscle mass or other covariates were significantly different between gender groups, 2) the sample size in the subgroup was limited for examining the potential associations, 3) some androgens[25, 26] and the different distribution of body composition in men and women[27, 28] might have potential effect on
this relation. Several studies further explored the impact of regional muscle mass quantity on pulse wave velocity which showed controversial results. A study among multi-race American elderly reported that high cfPWV was associated with lower leg and arm mass in all men and lower leg mass in white women[18]. However, among Asian Indians with diabetes, negative correlation was observed between cfPWV and fat free mass in left leg in all, right arm, left arm, truncal fat free mass in men and right leg fat free mass in women[19]. In addition, mid-thigh muscle cross-sectional area was found to be an independent determinant of baPWV in middle-aged to elderly Japanese men[16]. Our study suggested that arm and leg muscle mass on both sides and trunk muscle mass were negatively associated with baPWV in Chinese community-dwelling men and women. Reasons for the controversial results may lie in: 1) the different indicators used for assessing arterial stiffness: cfPWV reflects central arterial stiffness and baPWV reflects both central and peripheral arterial stiffness[29], 2) age-related muscle mass decline (onset of sarcopenia), which is mainly characterized by the loss of appendicular muscle mass[30]. More studies are needed to confirm the associations between muscle mass quantities of different regions and arterial stiffness.

Although previous studies reported linear association between muscle mass indices and baPWV, to our knowledge, this was the first study performed multiple logistic regression analysis to examine the potential effect of muscle mass indices on arterial stiffness (baPWV as the dependent variable). Since arterial stiffness is a predictor for future cardiovascular disease[3], this analysis showed much clinical value. Our study found that the ASMI increased by 0.98 and 0.78 kg/m², the risks of developing arterial stiffness decreased by 27.0% 36.6% in men and women, respectively. The indices of muscle mass quantity increased by 1 SD, the risks of developing arterial stiffness decreased from 5.9% (SMM) to 52.0% (LAMM) in men and from 10.0% (SMM) to 65.2% (LAMM) in women. The effect of arm muscle mass quantity on risk of arterial stiffness was more pronounced. These findings suggested that participants with higher ASMI and muscle mass quantity have low risk for developing arterial stiffness, which indicated that preservation of muscle mass might have potential benefits for prevention of cardiovascular disease.
Several mechanisms may involve in the association between muscle mass and arterial stiffness. Firstly, loss of muscle mass was considered as a cause of insulin resistance by impairing glucose metabolism[31]. Evidence suggested that insulin resistance could determine the arterial elastic properties and coronary flow reserve[32] and played an important role in the development of atherosclerotic cardiovascular disease[33]. Secondly, chronic inflammation was widely studied as a pathway both to muscle loss and arterial stiffness. Results from a cohort study in Chinese sarcopenia patients showed that high levels of the inflammatory cytokines TWEAK and TNF-α were associated with an increased risk of sarcopenia, while the insulin growth factor 1, insulin, and adiponectin were associated with a decreased risk of sarcopenia[34]. Meanwhile, these mediators of inflammation had been examined as biomarkers and causal agents in the pathogenesis of arterial stiffness[35] and atherosclerosis, and they had been considered as a therapeutic target for cardiovascular disease[36]. These studies supported that loss of muscle mass might be a risk factor of arterial stiffness and further affected the development of CVD. However, experimental and clinical studies are warranted.

There are some limitations in the present study. First, due to the cross-sectional design of our study, we cannot make inferences about causality which warrants further prospective and interventional researches. Secondly, bioelectrical impedance analysis (BIA) but not Dual energy X-ray absorptiometry (DEXA, considered as gold standard) was used to measure body composition. However, evidence have shown that body composition measured by BIA were strongly correlated with that measured by DEXA [37] and have been widely used in epidemiological and clinical studies[24, 38]. In addition, compared with DEXA, BIA can avoid the risk of exposure to ionized radiation and be more practical and economical for studies with a large sample. Finally, the impact of blood biomarkers were not evaluated which evidences have shown to be associated with arterial stiffness[39–41].

**Conclusion**

In conclusion, our study indicated that low muscle mass was associated with increased risk of arterial stiffness in Chinese community-dwelling adults. Further longitudinal researches are needed to confirm the potential effects of muscle mass on arterial stiffness observed in this study for the prevention of
cardiovascular disease.

Declarations

Ethics approval and consent to participate

The study was approved by Ethics Committee of Chinese Clinical Trial Registry. All participants gave written informed consent.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due the government policy for original Chinese biodata of Chinese population but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors’ contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Zhenkai Ding and Mingzhe Yang. The first draft of the manuscript was written by Mingzhe Yang and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Authors’ information (optional)

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Tables
Table 1 Characteristics of the study population by gender

|         | Men          | Women        | p*  |
|---------|--------------|--------------|-----|
| N       | 6390 (31.21%)| 14087 (68.79%)|     |
| Age (years) | 62.87 ± 8.07 | 60.30 ± 8.00 | <0.0001 |
| Height (cm) | 168.6 ± 5.88 | 158.24 ± 5.35 | <0.0001 |
| Weight (kg) | 69.78 ± 10.52 | 61.13 ± 9.35 | <0.0001 |
| BMI (kg/m²) | 24.51 ± 3.23 | 24.39 ± 3.40 | 0.014 |
| SMM (kg) | 49.36 ± 6.18 | 38.13 ± 4.32 | <0.0001 |
| LAMM (kg) | 3.30 ± 0.48 | 2.50 ± 0.33 | <0.0001 |
| RAMM (kg) | 3.31 ± 0.49 | 2.49 ± 0.35 | <0.0001 |
| LLMM (kg) | 9.05 ± 1.28 | 7.00 ± 0.93 | <0.0001 |
| RLMM (kg) | 9.06 ± 1.27 | 6.99 ± 0.90 | <0.0001 |
| TMM (kg) | 24.65 ± 2.78 | 19.16 ± 1.96 | <0.0001 |
| ASM (kg) | 24.72 ± 3.47 | 18.98 ± 2.42 | <0.0001 |
| ASMI (kg/m²) | 8.68 ± 0.98 | 7.57 ± 0.78 | <0.0001 |
| BFP (%) | 23.50 (19.70, 26.90) | 31.80 (28.50, 34.70) | <0.0001 |
| baPWV (cm/s) | 1650.00 (1449.00, 1894.00) | 1567.00 (1372.00, 1822.00) | <0.0001 |
| SBP (mmHg) | 137.41±19.00 | 135.87±20.63 | <0.0001 |
| DBP (mmHg) | 81.32±10.95 | 78.34±11.14 | <0.0001 |
| PP (mmHg) | 58.00±12.19 | 59.58±13.13 | <0.0001 |
| ABI | 1.21±0.012 | 1.18±0.10 | <0.0001 |
| MAP (%) | 39.85±3.93 | 42.50±3.46 | <0.0001 |
| UT (s) | 144.00 (133.00, 160.00) | 156.00 (142.00, 174.00) | <0.0001 |

Values are numbers (percentage), mean ± SD or medians (25th and 75th percentile)

* Test for difference between gender groups was performed using the Kruskal–Wallis test for non-normally distributed continuous variables and T test for normally distributed continuous variables.

Abbreviations: BMI body mass index, SMM Total muscle mass, LAMM Left arm muscle mass, RAMM Right arm muscle mass, LLMM Left arm muscle mass, RLMM Right leg muscle mass, TMM Trunk
muscle mass, BFP total body fat percentage, ASM appendicular skeletal muscle, ASMI appendicular skeletal muscle index, baPWV brachial-ankle pulse wave velocity, SBP systolic blood pressure, DBP diastolic blood pressure, PP Pulse pressure, ABI ankle brachial index, MAP mean artery pressure, UT upstroke time.

Table 2 Characteristics of the study population according to ASMI tertiles

|                | T1            | T2            | T3            |
|----------------|---------------|---------------|---------------|
| Men (n=6390)   |               |               |               |
| Age (years)    | 64.62 ± 8.28  | 62.73 ± 7.94  | 61.86 ± 7.86  |
| Height (cm)    | 167.71 ± 5.78 | 168.68 ± 5.91 | 169.42 ± 5.81 |
| Weight (kg)    | 60.67 ± 6.86  | 70.33 ± 6.92  | 78.34 ± 6.78  |
| BMI (kg/m²)    | 21.55 ± 2.05  | 24.71 ± 1.97  | 27.27 ± 2.08  |
| ASMI (kg/m²)   | 7.71 ± 0.37   | 8.53 ± 0.22   | 9.78 ± 0.78   |
| ASM (kg)       | 21.71 ± 1.87  | 24.31 ± 1.83  | 28.12 ± 2.18  |
| SMM (kg)       | 44.30 ± 3.66  | 48.70 ± 3.71  | 55.09 ± 4.01  |
| LAMM (kg)      | 2.89 ± 0.26   | 3.25 ± 0.26   | 3.77 ± 0.27   |
| RAMM (kg)      | 2.89 ± 0.27   | 3.25 ± 0.27   | 3.77 ± 0.27   |
| LLMM (kg)      | 7.96 ± 0.70   | 8.90 ± 0.69   | 10.29 ± 1.09  |
| RLMM (kg)      | 7.97 ± 0.70   | 8.91 ± 0.68   | 10.29 ± 1.09  |
| TMM (kg)       | 22.59 ± 1.88  | 24.39 ± 1.94  | 26.96 ± 2.18  |
| BFP (%)        | 21.10 (17.40, 24.40) | 25.10 (22.00, 28.00) | 23.90 (20.30, 27.30) |
| baPWV (cm/s)   | 1677.00 (1459.00, 1945.00) | 1647.00 (1451.00, 1876.00) | 1629.00 (1434.00, 1812.00) |
| SBP (mmHg)     | 134.35 ± 18.81 | 137.39 ± 18.14 | 140.50 ± 18.30 |
| DBP (mmHg)     | 79.16 ± 10.44  | 81.48 ± 10.70  | 83.31 ± 10.94 |
| PP (mmHg)      | 57.18 ± 12.40  | 57.79 ± 11.92  | 59.03 ± 12.24 |
| ABI            | 1.19 ± 0.11    | 1.21 ± 0.12    | 1.23 ± 0.13   |
| MAP (%)        | 40.14 ± 3.80   | 39.74 ± 3.94   | 39.66 ± 4.05  |
| UT (s)         | 143.50 (132.00, 160.00) | 144.00 (132.00, 159.00) | 145.00 (134.00, 155.00) |
| Women (n=14087)|               |               |               |
| Age (years)    | 61.53 ± 8.26  | 60.16 ± 8.06  | 59.60 ± 7.84  |
| Height (cm)    | 157.73 ± 5.51 | 158.38 ± 5.24 | 158.63 ± 5.26 |
| Weight (kg)    | 53.07 ± 5.93  | 60.74 ± 5.52  | 69.57 ± 7.74  |
| BMI (kg/m²)    | 21.32 ± 2.05  | 24.21 ± 1.83  | 27.64 ± 2.05  |
| ASMI (kg/m²)   | 6.77 ± 0.34   | 7.51 ± 0.18   | 8.41 ± 0.78   |
| ASM (kg)       | 16.87 ± 1.51  | 18.87 ± 1.33  | 21.19 ± 1.51  |
| SMM (kg)       | 34.63 ± 2.96  | 37.96 ± 2.68  | 41.81 ± 3.17  |
| LAMM (kg)      | 2.21 ± 0.21   | 2.48 ± 0.19   | 2.79 ± 0.27   |
| RAMM (kg)      | 2.21 ± 0.22   | 2.48 ± 0.20   | 2.79 ± 0.27   |
| LLMM (kg)      | 6.23 ± 0.58   | 6.96 ± 0.53   | 7.82 ± 0.58   |
| RLMM (kg)      | 6.22 ± 0.56   | 6.95 ± 0.51   | 7.79 ± 0.57   |
| TMM (kg)       | 17.75 ± 1.51  | 19.10 ± 1.40  | 20.62 ± 1.51  |
| BFP (%)        | 29.10 (26.00, 31.90) | 31.90 (29.10, 34.30) | 34.30 (31.90, 36.80) |
| baPWV (cm/s)   | 1587.00 (1375.50, 1867.00) | 1558.00 (1362.00, 1812.00) | 1557.00 (1378.00, 1821.00) |
| SBP (mmHg)     | 132.40 ± 20.17 | 135.19 ± 20.55 | 140.02 ± 20.97 |
| DBP (mmHg)     | 76.45 ± 11.01  | 78.01 ± 11.03  | 80.57 ± 11.20 |
| PP (mmHg)      | 57.99 ± 12.75  | 59.16 ± 13.06  | 61.58 ± 13.32 |
| ABI            | 1.11 ± 0.10    | 1.18 ± 0.10    | 1.19 ± 0.10   |
| MAP (%)        | 42.70 ± 3.43   | 42.53 ± 3.40   | 42.25 ± 3.45  |
| UT (s)         | 155.00 (140.00, 173.00) | 156.00 (142.00, 174.00) | 158.00 (143.00, 180.00) |

Values are mean ± SD or medians (25th and 75th percentile)

* Test for difference between tertiles was performed using the Kruskal–Wallis test for non-normally distributed continuous variables and ANOVA analysis for normally distributed continuous variables.

Abbreviations: BMI body mass index, SMM Total muscle mass, LAMM Left arm muscle mass, RAMM Right arm muscle mass, ASMI Appendicular skeletal muscle index, ASM Appendicular skeletal muscle mass.
Right arm muscle mass, *LLMM* Left arm muscle mass, *RLMM* Right leg muscle mass, *TMM* Trunk muscle mass, *BFP* total body fat percentage, *ASM* appendicular skeletal muscle, *ASMI* appendicular skeletal muscle index, *baPWV* brachial-ankle pulse wave velocity, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *PP* Pulse pressure, *ABI* ankle brachial index, *MAP* mean artery pressure, *UT* upstroke time.

Table 3 Correlation between muscle mass indices and *baPWV*

|                  | Men (n=6390) |           | Women (n=14087) |           |
|------------------|--------------|-----------|------------------|-----------|
|                  | *r*          | *p*       |                  | *r*       |
| ASMI (kg/m²)     | -0.080       | <0.0001   | -0.054           | <0.0001   |
| ASM (kg)         | -0.115       | <0.0001   | -0.112           | <0.0001   |
| SMM (kg)         | -0.120       | <0.0001   | -0.114           | <0.0001   |
| LAMM (kg)        | -0.106       | <0.0001   | -0.116           | <0.0001   |
| RAMM (kg)        | -0.107       | <0.0001   | -0.115           | <0.0001   |
| LLMM (kg)        | -0.114       | <0.0001   | -0.100           | <0.0001   |
| RLMM (kg)        | -0.116       | <0.0001   | -0.111           | <0.0001   |
| TMM (kg)         | -0.123       | <0.0001   | -0.114           | <0.0001   |

Pearson’s correlation coefficient was calculated using bivariate correlation analysis.

The natural logarithm was applied for *baPWV*.

Abbreviations: *baPWV* brachial-ankle pulse wave velocity, *ASMI* appendicular skeletal muscle index, *ASM* appendicular skeletal muscle, *SMM* Total muscle mass, *LAMM* Left arm muscle mass, *RAMM* Right arm muscle mass, *LLMM* Left arm muscle mass, *RLMM* Right leg muscle mass, *TMM* Trunk muscle mass.

Table 4 Multiple linear regression for association between muscle mass indices and *baPWV* adjusted for potential confounders
|                  | Men                              |          |          |          |          | Women                              |          |          |          |          |
|------------------|----------------------------------|----------|----------|----------|----------|------------------------------------|----------|----------|----------|----------|
|                  |                                  | R²       | β (SE)   | p        | R²       | β (SE)   | p        |          |          |          |
| ASMI (kg/m²)     | 0.172 -0.040 (0.020)             | 0.0431   |          |          | 0.471 -0.208 (0.016) <0.0001      |          |          |          |          |
| ASM (kg)         | 0.173 -0.061 (0.016)             | 0.0002   | 0.473    | -0.200 (0.016) <0.0001             |          |          |          |          |
| SMM (kg)         | 0.172 -0.053 (0.018)             | 0.0033   | 0.472    | -0.232 (0.020) <0.0001             |          |          |          |          |
| LAMM (kg)        | 0.173 -0.062 (0.015) <0.0001    | 0.471    | -0.176 (0.015) <0.0001             |          |          |          |          |
| RAMM (kg)        | 0.174 -0.062 (0.015) <0.0001    | 0.471    | -0.164 (0.015) <0.0001             |          |          |          |          |
| LLMM (kg)        | 0.173 -0.057 (0.016)             | 0.0003   | 0.473    | -0.198 (0.016) <0.0001             |          |          |          |          |
| RLMM (kg)        | 0.173 -0.058 (0.016)             | 0.0003   | 0.472    | -0.198 (0.017) <0.0001             |          |          |          |          |
| TMM (kg)         | 0.172 -0.037 (0.020)             | 0.0676   | 0.469    | -0.255 (0.025) <0.0001             |          |          |          |          |
|                  |                                  |          |          |          |          | 0.288 0.001 (0.014) 0.9294 0.579 -0.245 (0.012) <0.0001 |          |          |          |          |
| ASMI (kg/m²)     | 0.288 -0.026 (0.012)             | 0.0266   | 0.579    | -0.206 (0.013) <0.0001             |          |          |          |          |
| ASM (kg)         | 0.288 -0.006 (0.013)             | 0.6521   | 0.578    | -0.244 (0.016) <0.0001             |          |          |          |          |
| SMM (kg)         | 0.288 -0.041 (0.011)             | 0.0002   | 0.579    | -0.178 (0.011) <0.0001             |          |          |          |          |
| LAMM (kg)        | 0.288 -0.040 (0.011)             | 0.0002   | 0.577    | -0.155 (0.011) <0.0001             |          |          |          |          |
| RAMM (kg)        | 0.288 -0.017 (0.011)             | 0.1317   | 0.578    | -0.187 (0.012) <0.0001             |          |          |          |          |
| LLMM (kg)        | 0.288 -0.022 (0.012)             | 0.0594   | 0.579    | -0.203 (0.013) <0.0001             |          |          |          |          |
| RLMM (kg)        | 0.288 0.025 (0.015)              | 0.0858   | 0.576    | -0.259 (0.020) <0.0001             |          |          |          |          |
| TMM (kg)         | 0.288 0.025 (0.015)              |          |          |          |          |          |          |          |          |

Abbreviations: baPWV brachial-ankle pulse wave velocity, SMM Total muscle mass, ASMI appendicular skeletal muscle index, ASM appendicular skeletal muscle, LAMM Left arm muscle mass, RAMM Right arm muscle mass, LLMM Left arm muscle mass, RLMM Right leg muscle mass, TMM Trunk muscle mass.

Multiple linear regression. Model 1: adjusted for age. Model 2: further adjusted for BFP, SBP and DBP for the association between ASMI and baPWV, further adjusted for height, BFP, SBP and DBP for the association between ASM, SMM, LAMM, RAMM, LLMM, RLMM, TMM and baPWV.

Table 5 Multiple logistic regression for the association between muscle mass indices and arterial stiffness (0: baPWV≤1800, 1: baPWV>1800) adjusted for potential confounders.
|       | Model 1          |       | Model 2          |
|-------|------------------|-------|------------------|
|       | OR (95% CI)      | p     | OR (95% CI)      |
| ASMI (kg/m²) | 0.942 (0.889, 0.997) | 0.0391 | 0.931 (0.868, 0.997) |
| ASM (kg)     | 0.976 (0.960, 0.992) | 0.0033 | 0.999 (0.878, 0.921) |
| SMM (kg)     | 0.989 (0.980, 0.998) | 0.0220 | 0.941 (0.927, 0.955) |
| LAMM (kg)    | 0.818 (0.727, 0.919) | 0.0007 | 0.480 (0.406, 0.568) |
| RAMM (kg)    | 0.819 (0.731, 0.919) | 0.0006 | 0.510 (0.433, 0.599) |
| LLMM (kg)    | 0.941 (0.900, 0.983) | 0.0067 | 0.757 (0.709, 0.805) |
| RLMM (kg)    | 0.941 (0.900, 0.984) | 0.0078 | 0.757 (0.709, 0.808) |
| TMM (kg)     | 0.985 (0.965, 1.006) | 0.1593 | 0.876 (0.844, 0.908) |

Women

|       | Model 1          |       | Model 2          |
|-------|------------------|-------|------------------|
|       | OR (95% CI)      | p     | OR (95% CI)      |
| ASMI (kg/m²) | 0.949 (0.899, 1.001) | 0.0551 | 0.634 (0.594, 0.677) |
| ASM (kg)     | 0.974 (0.957, 0.992) | 0.0037 | 0.844 (0.820, 0.869) |
| SMM (kg)     | 0.992 (0.982, 1.002) | 0.1065 | 0.900 (0.886, 0.914) |
| LAMM (kg)    | 0.794 (0.699, 0.902) | 0.0004 | 0.348 (0.286, 0.425) |
| RAMM (kg)    | 0.807 (0.714, 0.914) | 0.0007 | 0.397 (0.329, 0.480) |
| LLMM (kg)    | 0.946 (0.903, 0.990) | 0.0158 | 0.668 (0.621, 0.719) |
| RLMM (kg)    | 0.937 (0.893, 0.982) | 0.0068 | 0.616 (0.573, 0.661) |
| TMM (kg)     | 1.001 (0.979, 1.023) | 0.9587 | 0.795 (0.766, 0.826) |

Abbreviations: baPWV brachial-ankle pulse wave velocity, SMM Total muscle mass, ASMI appendicular skeletal muscle index, ASM appendicular skeletal muscle, LAMM Left arm muscle mass, RAMM Right arm muscle mass, LLMM Left arm muscle mass, RLMM Right leg muscle mass, TMM Trunk muscle mass.

Multiple linear regression. Model 1: adjusted for age. Model 2: further adjusted for BFP, SBP and DBP for the association between ASMI and baPWV, further adjusted for height, BFP, SBP and DBP for the association between ASM, SMM, LAMM, RAMM, LLMM, RLMM, TMM and baPWV.