Sarcopenia is associated with mild-to-moderate chronic kidney disease in Chinese community-dwelling older men but not in women

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Abstract

Objective: To determine whether a relationship exists between sarcopenia, including its individual components (muscle mass, muscle strength and gait speed), and mild-to-moderate chronic kidney disease (CKD) in Chinese older adults.

Methods: This cross-sectional study comprised participants aged ≥60 years from Tianjin and Shanghai, China, who joined a national free physical examination program between 2014 and 2019, and consented to study inclusion. Sarcopenia was defined according to the Asian Working Group for Sarcopenia (2019 version). Mild-to-moderate CKD was defined as estimated glomerular filtration rate (eGFR) between 45 ml/min/1.73 m² and 60 ml/min/1.73 m².

Results: A total of 1627 participants were included (mean age, 69.32 ± 6.17 years; 43.8% male). Sarcopenia was significantly associated with mild-to-moderate CKD in men but not women. Among three physical performance components, slow gait speed (odds ratio 1.89, 95% confidence interval 1.38, 2.58) was associated with mild-to-moderate CKD in both men and women after adjusting for all other variables.

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Conclusions: Sarcopenia was closely associated with mild-to-moderate CKD in older men, and slow gait speed was related to mild-to-moderate CKD in men and women. These findings may help guide better diagnosis and management of CKD in the context of slow gait speed, and facilitate earlier CKD detection and appropriate intervention in older adults.

Keywords
Chronic kidney disease, gait speed, mild-to-moderate, older adults, sarcopenia, Chinese.

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Introduction
Chronic kidney disease (CKD) is a recognized global public health concern, which substantially elevates the risk of end-stage renal disease, cardiovascular disease, and mortality. The prevalence of CKD in the general population exceeds 10%, and is far higher in high-risk subpopulations, such as older adults, and patients with type 2 diabetes mellitus or who are obese. The symptoms of non-dialysis dependent CKD can be often subtle and not detected in older adults. Therefore, it is important to identify modifiable risk factors associated with CKD, which can be addressed with early prevention and interventions in older adults.

Substantial evidence suggests that individuals with CKD face a high risk for common geriatric conditions, such as functional impairment, resulting in loss of independence in daily living activities. As a common geriatric syndrome, sarcopenia is characterised by a decline in skeletal muscle mass, muscle strength and gait speed, and has been identified as a major risk factor for frailty and mortality in patients on dialysis. Notably, most studies investigating the relationship between physical performance and CKD have focused on patients with end-stage renal disease undergoing hemodialysis, with few studies that have examined poor physical capacity in elderly patients with mild-to-moderate CKD. Muscle mass and strength may be tested to partly evaluate the function of the musculoskeletal system, while mobility is usually measured by gait speed. In patients with CKD, a loss of muscle occurs early compared with healthy subjects of the same age. In contrast, another study found that muscle strength wasn’t associated with poor performance-based instrumental activities of daily living disability in a CKD population. Furthermore, it has been suggested that functional skills are best assessed using gait speed, while some researchers have failed to find an association between slow gait speed and CKD. Therefore, the associations between physical performance and mild-to-moderate CKD require further investigation.

In a previous study by the present authors, physical performance was found to be associated with diabetes and hypertension based on the Adult Physical Fitness and Health Cohort Study (APFHCS). Therefore, the objective of the present study was to determine whether a relationship exists between sarcopenia, including its individual components, and mild-to-moderate CKD in Chinese community-dwelling older adults. This is a particularly significant study population, as it is more likely to be healthy and have less
activity limitations compared with those residing in serviced facilities. We hypothesized that measures of sarcopenia are associated with mild-to-moderate CKD, and physical performance deteriorates in accordance with declining kidney function. From a public health perspective, a better understanding of physical capabilities is necessary to improve health management and implement lifestyle interventions in real-world settings.

**Participants and methods**

**Study population and design**

This cross-sectional cohort study included data from the APFHCS, a large prospective dynamic cohort study of adults who participate in the national free physical examination program to receive annual comprehensive health examinations. The APFHCS mainly investigates the association between physical fitness and health status in a general adult population living in Tianjin and Shanghai, China, and is based on the free physical examination program that provides patients with physical assessments, nutritional and psychological questionnaires, and collects detailed lifestyle and medical history. The number of elderly participants in the APFHCS is slightly lower than the number of adults who receive the national free medical examination, and some elderly people do not attend the APFHCS every year. Chinese older adults (aged ≥60 years) who joined the national free physical examination program between 2014 and 2019 were included in the present study. All potential subjects were invited to participate in a comprehensive geriatric assessment, with the exception of those with severe kidney diseases (advanced CKD, history of dialysis, or previous renal transplantation), major neurological disorders including dementia, malignancies and serious physical illness (joint replacement, amputation) that hampered their completion of the functional fitness tests. Individuals with incomplete anthropometric measurements or laboratory test results, or who were unable to communicate with interviewers or to provide informed consent, were also excluded from the study. This cross-sectional cohort study was approved by the Ethics Committee of Tianjin Medical University and Shanghai University of Medicine and Health Sciences (2019-WJWXM-04-310108196508064467), and all participants provided written informed consent to participate in the study. The reporting of this study conforms to STROBE guidelines, and all participant details were deidentified.

**Data collection**

All tests were conducted by professional trainers in the healthcare field (XC, XZ, PH, YZ, MH, YZ, JL, JT, YZ, YZ and ZZ). Following their medical examination and performance-based assessments, all participants were invited to a face-to-face interview to complete questionnaires, as previously described.

**Sarcopenia diagnosis**

Sarcopenia was defined based on the 2019 version of the Asian Working Group for Sarcopenia (AWGS) diagnostic criteria. Low muscle mass was classified as a relative skeletal muscle mass index (appendicular skeletal muscle mass/height$^2$) <7.0 kg/m$^2$ in men and <5.7 kg/m$^2$ in women; weak muscle strength was defined as a grip strength <28 kg in men or <18 kg in women; and slow gait speed was defined as a gait speed <1.0 m/s.

Muscle mass was measured using direct segmental multi-frequency bioelectrical impedance analysis (In-Body 720; Biospace Co., Ltd, Seoul, Korea), and muscle strength was quantified using a handheld dynamometer.
(GRIP-D; Takei Ltd, Niigata, Japan). Participants were asked to exert their maximum effort twice using their dominant hand and the strongest grip strength was recorded. Gait speed was measured using a 4-m walking test. For this, an 8-m straight line was marked out at the site clinic, with 2 m reserved at each end, and two photocells connected to a recording chronometer placed at the beginning and end of the middle 4-m section. Participants were instructed to stand with both feet touching the starting line and to begin walking the 8-m distance at their usual pace after a verbal command was given. Participants were then timed walking the middle 4-m section at their usual pace.

**Definition of CKD**

To measure estimated glomerular filtration rate (eGFR), a blood sample was collected by venepuncture after an overnight fast of at least 10 h. Serum creatinine levels were measured in a certified central laboratory by an isotope-dilution mass-spectrometry-traceable compensated Jaffe assay (Roche Diagnostics, Mannheim, Germany). The eGFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation: eGFR (ml/min/1.73 m²) = \( \frac{141}{\text{minimum (serum creatinine/}R\text{)}} \times 0.993^{\text{Age}} \times 1.018 \) (if female) and \( \times 1.159 \) (if black), where \( R = 0.7 \) if female, \( R = 0.9 \) if male, \( \alpha = -0.329 \) if female or \(-0.411 \) if male. Minimum refers to the minimum or 1, and maximum refers to the maximum or 1, of serum creatinine /\( R \).\(^{19}\)

Participants were classified with or without CKD based on their eGFR levels, using the National Kidney Foundation guidelines: without CKD, eGFR \( \geq 60 \text{ ml/min/1.73 m}^2 \); with CKD, eGFR < \( 60 \text{ ml/min/1.73 m}^2 \). Participants with advanced CKD (eGFR < \( 45 \text{ ml/min/1.73 m}^2 \)) were excluded from the study, as the study aim was to investigate mild-to-moderate CKD (participants with eGFR between \( 45 \text{ ml/min/1.73 m}^2 \) and \( 60 \text{ ml/min/1.73 m}^2 \) were included in the study).\(^9\)

**Assessment of other variables**

Data regarding sociodemographic variables, behavioural characteristics, and medical conditions were obtained via face-to-face questions. Sociodemographic variables, including age, sex, marital status, education level (as previously described),\(^{14}\) and occupation were assessed. Marital status was classified as married (living together, divorced, separated, or widowed) or never married/single. Behavioural characteristics included smoking (current smoker or not) and drinking (current drinker or not) habits, physical activity level (evaluated using the international physical activity questionnaire [IPAQ] short form, presented as metabolic equivalent task mins per week [Mets/week]), and fall history. Height and weight were recorded using a standard protocol and body mass index (BMI) was calculated as kg/m². Medical history was also recorded, including diagnosis of diabetes (mainly type 2 diabetes mellitus), hypertension, dyslipidaemia, coronary heart disease (CHD), stroke and osteoarthritis. Nutritional status was assessed with the mini nutritional assessment short form (MNA-SF),\(^{20}\) and dichotomized into malnourished (0–7 points) and not malnourished (8–14 points). Detailed survey methods have been published previously.\(^{13}\)

**Statistical analysis**

Continuous data with a normal distribution are presented as mean ± SD, and data with abnormal distribution are presented as median (25%–75% interquartile range). Categorical variables are presented as n (%) prevalence. Participants were grouped into those with or without CKD and
between-group differences were examined by Student’s t-test or Mann–Whitney U-test (continuous variables) or χ²-test (categorical variables). The association between sarcopenia, including its individual components, and mild-to-moderate CKD was analysed by logistic regression. Model 1 was adjusted for age, sex and BMI. Model 2 was adjusted for model 1 variables plus widowed, farming, illiteracy, smoking, drinking, malnutrition, IPAQ score, diabetes, hypertension, dyslipidaemia, stroke, CHD and osteoarthritis. The interactions between mild-to-moderate CKD and continuous confounders were tested by adding the cross-product term to the final regression model. Variance inflation factors (VIFs) were used to indicate multicollinearity. Receiver operating characteristic (ROC) curves were generated to determine the area under the curve (AUC) and cut-off point of physical functional measures related to mild-to-moderate CKD. Statistical significance was defined as a P-value <0.05. All statistical analyses were performed with SPSS software, version 25.0 (IBM, Armonk, NY, USA).

Results

Study population characteristics

A total of 2016 older Chinese adults were recruited into the study. Of those, 389 individuals were excluded, including 36 adults with severe kidney diseases, 37 with cancer, nine adults with serious physical illness, 24 with major neurological disorders, 89 with incomplete anthropometric measurements, and 194 adults with no creatinine data. Thus, the final study population comprised 1627 participants (mean age, 69.32±6.17 years), of whom, 712 (43.8%) were adult males (Figure 1).

Among the study population, 14.3% (233/1627) were classified with mild-to-moderate CKD: 11.5% (82/712) of male participants and 16.5% (151/915) of female participants. Data for each category are summarised in Table 1. Male and

![Figure 1. Flow diagram of study participant selection.](image-url)
Table 1. Demographic and clinical characteristics of 1627 older Chinese adults (aged ≥60 years) dichotomized into those with or without mild-to-moderate chronic kidney disease.

| Characteristic          | Male (n = 712) | Female (n = 915) |
|-------------------------|----------------|------------------|
|                         | Non-CKD (n = 630) | Mild-to-moderate CKD (n = 82) | Statistical significance | Non-CKD (n = 764) | Mild-to-moderate CKD (n = 151) | Statistical significance |
| Age, years              | 69.40 ± 6.21    | 73.89 ± 6.76     | P < 0.001           | 68.58 ± 5.55    | 70.25 ± 7.36     | P = 0.002           |
| BMI, kg/m²              | 23.87 ± 3.27    | 24.17 ± 2.85     | NS                  | 24.58 ± 3.69    | 24.87 ± 3.65     | NS                  |
| Farming, yes            | 420 (66.7)      | 45 (54.9)        | P = 0.035           | 610 (79.8)      | 127 (84.1)       | NS                  |
| Illiterate, yes         | 77 (12.2)       | 19 (23.2)        | P = 0.006           | 208 (27.2)      | 58 (38.4)        | P = 0.006           |
| Widowed, yes            | 55 (8.7)        | 15 (18.3)        | P = 0.006           | 162 (21.2)      | 43 (28.5)        | P = 0.050           |
| Living alone, yes       | 58 (9.2)        | 11 (13.4)        | NS                  | 101 (13.2)      | 20 (13.2)        | NS                  |
| Current smoker, yes     | 227 (36.0)      | 26 (31.7)        | NS                  | 100 (13.1)      | 24 (15.9)        | NS                  |
| Current drinker, yes    | 317 (50.3)      | 32 (39.0)        | NS                  | 83 (10.9)       | 9 (6.0)          | NS                  |
| IPAQ, Mets/week         | 3066 (1386, 8027) | 2646 (1386, 6720) | NS                | 3360 (1386, 7866) | 2772 (693, 5439) | NS                |
| Fall history, yes       | 83 (13.2)       | 14 (17.1)        | NS                  | 155 (20.3)      | 28 (18.5)        | NS                  |
| eGFR, ml/min/1.73m²     | 79.73 ± 9.49    | 56.89 ± 2.88     | P < 0.001           | 75.08 ± 11.04   | 54.27 ± 4.12     | P < 0.001           |
| Sarcopenia              | 82 (13.0)       | 20 (24.4)        | P = 0.006           | 105 (13.7)      | 23 (15.2)        | NS                  |
| ASM/height², kg/m²      | 7.65 ± 0.93     | 7.27 ± 1.20      | P = 0.001           | 6.31 ± 0.94     | 6.51 ± 1.11      | P = 0.025           |
| Grip strength, kg       | 32.52 ± 8.28    | 30.30 ± 7.79     | P = 0.022           | 20.09 ± 5.86    | 19.07 ± 6.34     | NS                  |
| Gait speed, m/s         | 1.07 ± 0.22     | 0.98 ± 0.22      | P < 0.001           | 1.02 ± 0.21     | 0.91 ± 0.21      | P < 0.001           |
| Diseases                |                |                  |                     |                |                  |                     |
| Malnutrition, MNA-SF ≤7 | 18 (2.9)        | 6 (7.3)          | P = 0.035           | 20 (2.6)        | 10 (6.6)         | P = 0.012           |
| Diabetes, yes           | 89 (14.1)       | 10 (12.2)        | NS                  | 136 (17.8)      | 39 (25.8)        | P = 0.022           |
| Hypertension, yes       | 390 (61.9)      | 57 (69.5)        | NS                  | 453 (59.3)      | 108 (71.5)       | P = 0.005           |
| Dyslipidemia, yes       | 318 (50.5)      | 49 (59.8)        | NS                  | 550 (72.0)      | 117 (77.5)       | NS                  |
| Stroke, yes             | 97 (15.4)       | 11 (13.4)        | NS                  | 129 (16.9)      | 27 (17.9)        | NS                  |
| CHD, yes                | 141 (22.4)      | 17 (20.7)        | NS                  | 248 (32.5)      | 67 (44.4)        | P = 0.005           |
| Osteoarthritis, yes     | 65 (10.3)       | 10 (12.2)        | NS                  | 121 (15.8)      | 20 (13.2)        | NS                  |

Data presented as mean ± SD, median (25th, 75th percentiles), or n (%) prevalence.

ASM, appendicular skeletal muscle mass; BMI, body mass index; CHD, coronary heart disease; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; IPAQ, international physical activity questionnaire; Mets/week, metabolic equivalent task minutes per week; MNA-SF, mini nutritional assessment-short form.

NS, no statistically significant between-group difference (P > 0.05; Student’s t-test or Mann–Whitney U-test [continuous variables] or χ²-test [categorical variables]).
female participants with mild-to-moderate CKD were mostly older, illiterate, widowed, malnourished, and had lower eGFR, lower muscle mass, and lower gait speed versus those without CKD. Among men, there was a significantly higher prevalence of sarcopenia in those with mild-to-moderate CKD versus those without CKD ($P = 0.006$). Among women, there was a significantly higher prevalence of diabetes, hypertension and coronary heart disease in the mild-to-moderate CKD group.

**Sarcopenia, along with its individual components, and mild-to-moderate CKD**

The prevalence of sarcopenia and its individual components showed a statistically significant upward trend in male participants with mild-to-moderate CKD versus those without CKD ($P < 0.05$), but in female participants with mild-to-moderate CKD versus those without CKD, only the prevalence of slow gait speed was increased ($P < 0.001$) (Figure 2). The odds ratio (OR) and 95% confidence interval (CI) determined from logistic regression analyses of the association between sarcopenia, along with its individual components, and mild-to-moderate CKD are presented in Table 2. In men, mild-to-moderate CKD was found to be significantly correlated with sarcopenia (OR 2.14, 95% CI 1.11, 4.13; $P = 0.024$), low muscle mass (OR 3.22, 95% CI 1.74, 5.98; $P < 0.001$) and slow gait speed (OR 1.88, 95% CI 1.12, 3.15; $P = 0.016$) after adjusting for potential confounders (Model 2). However, in women, only slow gait speed (OR 1.86, 95% CI 1.24, 2.79; $P = 0.003$) showed a correlation with mild-to-moderate CKD after adjusting for potential confounders (Model 2). The OR for slow gait speed in male and female participants combined was 1.89 (95% confidence interval 1.38, 2.58).

In ROC analyses, gait speed (AUC 0.646, 95% CI 0.56, 0.69; $P < 0.001$ for men; AUC 0.651, 95% CI 0.60, 0.70; $P < 0.001$ for women) was shown to be a statistically significant indicator of mild-to-moderate CKD in both men (cut-off 0.94 m/s, sensitivity 51.2%, specificity 84%) and women (cut-off 1 m/s, sensitivity 66.9%, specificity 56.4%), whereas muscle mass and muscle strength were shown to be statistically significant measures in men only (Table 3).

**Discussion**

To our knowledge, this is the first study to explore the association between sarcopenia, along with its individual components, and
Table 2. Logistic regression analysis of the relationship between mild-to-moderate CKD and sarcopenia, along with its individual components.

| Measure                   | Male (n = 712) | Female (n = 915) |
|---------------------------|----------------|-----------------|
|                           | Non-CKD | Mild-to-moderate CKD | Statistical significance | Non-CKD | Mild-to-moderate CKD | Statistical significance |
|                           | Referent | OR (95% CI) |             | Referent | OR (95% CI) |             |
| Sarcopenia                |          |             |             |          |             |             |
| Crude                     | I        | 2.16 (1.24, 3.76) | \(P = 0.007\) | I        | 1.13 (0.69, 1.84) | NS |
| Model 1                   | I        | 2.16 (1.14, 4.09) | \(P = 0.018\) | I        | 1.03 (0.60, 1.77) | NS |
| Model 2                   | I        | 2.14 (1.11, 4.13) | \(P = 0.024\) | I        | 0.91 (0.52, 1.61) | NS |
| Low muscle mass           |          |             |             |          |             |             |
| Crude                     | I        | 2.21 (1.36, 3.59) | \(P < 0.001\) | I        | 0.88 (0.56, 1.36) | NS |
| Model 1                   | I        | 3.09 (1.80, 5.61) | \(P < 0.001\) | I        | 0.83 (0.50, 1.38) | NS |
| Model 2                   | I        | 3.22 (1.74, 5.98) | \(P < 0.001\) | I        | 0.83 (0.49, 1.40) | NS |
| Weak muscle strength      |          |             |             |          |             |             |
| Crude                     | I        | 1.82 (1.13, 2.93) | \(P = 0.013\) | I        | 1.35 (0.95, 1.93) | NS |
| Model 1                   | I        | 1.14 (0.68, 1.92) | NS            | I        | 1.14 (0.78, 1.66) | NS |
| Model 2                   | I        | 1.20 (0.69, 2.06) | NS            | I        | 1.05 (0.71, 1.55) | NS |
| Slow gait speed           |          |             |             |          |             |             |
| Crude                     | I        | 2.60 (1.62, 4.15) | \(P < 0.001\) | I        | 2.55 (1.77, 3.68) | \(P < 0.001\) |
| Model 1                   | I        | 1.88 (1.15, 3.09) | \(P = 0.013\) | I        | 2.31 (1.58, 3.37) | \(P < 0.001\) |
| Model 2                   | I        | 1.88 (1.12, 3.15) | \(P = 0.016\) | I        | 1.86 (1.24, 2.79) | \(P = 0.003\) |

BMI, body mass index; CHD, coronary heart disease; CI, confidence interval; CKD, chronic kidney disease; IPAQ, international physical activity questionnaire; OR, odds ratio. Model 1 was adjusted for age and BMI. Model 2 was adjusted for Model 1 variables in addition to widowed, farming, illiteracy, smoking, drinking, malnutrition, IPAQ, diabetes, hypertension, dyslipidaemia, stroke, CHD and osteoarthritis. NS, no statistically significant correlation (\(P > 0.05\)).
mild-to-moderate CKD in Chinese community-dwelling older adults. The present results showed that sarcopenia was associated with mild-to-moderate CKD in men. Among the individual components of sarcopenia, slow gait speed was found to be associated with mild-to-moderate CKD in both men and women, while low muscle mass was correlated with mild-to-moderate CKD in men only.

According to the present study, about 14.3% of Chinese older adults (11.5% of men and 16.5% of women) met the defined criteria for diagnosis of mild-to-moderate CKD. These results concurred with a previously published nationwide survey among Chinese populations, in which the nationwide prevalence of CKD in China was reported to be 10.8%, with a higher prevalence amongst women than men. The main possible reasons for the slight variance may be differences in age, characteristics, calculation of eGFR, and geographic regions between the participants of the different studies.

Although sarcopenia may affect approximately 37% of patients on dialysis, its prevalence in patients with mild-to-moderate CKD is poorly understood. The present results suggest that participants with sarcopenia (OR 2.14, 95% CI 1.11, 4.13, \( P = 0.024 \)) have a two-fold increased risk of mild-to-moderate CKD only in men, which is similar to the results reported in the Korea National Health and Nutrition Examination Survey. Although not statistically significant in the present study population, the prevalence of sarcopenia in women with normal renal function was numerically higher than in men, so the association between decreased renal function and sarcopenia may possibly be weaker in women than in men. In general, patients with CKD undergoing dialysis have a reduced level of physical activity, which may lead to loss of muscle proteins and muscle atrophy via a complex mechanism that includes physical inactivity and lack of training. However, the present study population were more likely to be healthy and have fewer activity limitations compared with those residing in serviced facilities, and there were no apparent associations between mild-to-moderate CKD and weak muscle strength in the present study.

To have an intimate understanding of the impact of physical performance on mild-to-moderate CKD, the relationship with the individual components of sarcopenia were further investigated. The present

| Measure       | AUC   | 95% CI       | Statistical significance | Cut-off point | Sensitivity (%) | Specificity (%) |
|---------------|-------|--------------|--------------------------|---------------|-----------------|-----------------|
| **Male**      |       |              |                          |               |                 |                 |
| Muscle mass   | 0.572 | 0.50, 0.65   | \( P = 0.034 \)         | 6.63          | 31.7            | 90.6            |
| Muscle strength | 0.596 | 0.53, 0.66   | \( P = 0.005 \)         | 33.9          | 74.4            | 79.3            |
| Gait speed    | 0.646 | 0.56, 0.69   | \( P < 0.001 \)         | 0.94          | 51.2            | 84              |
| **Female**    |       |              |                          |               |                 |                 |
| Muscle mass   | 0.471 | 0.42, 0.52   | NS                       | 5.6           | 18.5            | 83.2            |
| Muscle strength | 0.546 | 0.49, 0.60   | NS                       | 16.7          | 35.8            | 73.7            |
| Gait speed    | 0.651 | 0.60, 0.70   | \( P < 0.001 \)         | 1             | 66.9            | 56.4            |

AUC, area under the curve; CI, confidence interval.
NS, no statistically significant correlation \((P > 0.05)\).
results showed that low muscle mass was associated with mild-to-moderate CKD in men. It is reasonable that the rate of decline in muscle strength is greater than the rate of loss of muscle mass, and muscle strength may diminish even while muscle mass is maintained or increased, indicating that a decrease in muscle strength may occur before a decrease in muscle mass.\(^2\) Thus, low muscle mass may be a serious condition because the decline in muscle strength occurs more rapidly than the concomitant loss of muscle mass.\(^2\) In addition, low muscle mass is a necessary component of sarcopenia compared with the other two components, which may explain why sarcopenia is only associated with mild-to-moderate CKD in men. Similarly, a previous cross-sectional study found that muscle strength wasn’t associated with poor performance-based instrumental activities of daily living as a population with advanced CKD.\(^1\) Several factors may have contributed to the result. One consideration is that patients with mild-to-moderate CKD may have delayed muscle strength decline in the present study due to farming activities (the present population showed a similar proportion of farmers between those with and without mild-to-moderate CKD; 73.9\% versus 73.8\%, \(P = 0.982\)). The other consideration is that individuals with mild-to-moderate CKD were older (71.53 ± 7.35 versus 68.95 ± 5.87, \(P < 0.001\)) and had a higher proportion of female participants (64.8\% versus 54.8\%, \(P = 0.004\)) compared with those without CKD, which may have attenuated the association with weak muscle strength.

Skeletal muscle is suggested to release several cytokines and peptides (myokines) into the circulation in response to muscle contractions, and the anti-inflammatory and antiatherogenic properties of these myokines may protect against the risk of several chronic diseases, including CKD.\(^2\) Thus, it is essential for older people to preserve a satisfactory level of muscle in order to maintain adequate renal function.\(^2\) Although weak muscle strength didn’t show an association with mild-to-moderate CKD in the present study, it should not be interpreted that muscle strength lacks importance. Future studies should further investigate and examine differences in the mechanisms underlying the associations between kidney function abnormalities and muscle function.

‘Gait speed assessment’ has been termed the fifth vital sign in older adults due to its ease of measurement and its significant relationship with long-term outcomes. In a pooled analysis, faster gait speed was shown to be associated with decreased risk of developing mobility limitations, as well as disability performing activities of daily living in older adults.\(^3\) In the present study, slow gait speed was found to be independently associated with mild-to-moderate CKD. Similarly, patients with CKD stages 2 to 4 are shown to have substantially diminished lower-extremity physical performance compared with the general population.\(^3\) Conversely, a previous cross-sectional study showed no significant association between slow gait speed and CKD.\(^4\) The discrepancy may be due mainly to differences in the age of participants and the definition of slow gait speed. The prevalence of slow gait speed increases with age, and the average age of the above study, 50.9 years,\(^4\) was lower than the present study (69.3 years). Although slow gait speed was defined in the present study according to AWGS criteria, it is worth discussing whether the cut-off point for gait speed was appropriate for this particular population. A 20-month cohort study in community-residing adults, aged 70 years and older, found that each 0.1 m/s decrease in gait speed was correlated with a 7\% increased risk for falls, and the cut-off point for gait speed was 0.7 m/s.\(^3\) The present participants were younger than those
of the previous study (69.3 years versus 80.5 years), and the cut-off point for gait speed was 0.94 m/s for men and 1.0 for women, respectively. An explanation for the association between mild-to-moderate CKD and slow gait speed may be the direct impact of kidney function on gait. Even though in early-stage, impairments in kidney function are also associated with the accumulation of neurotoxins that have been shown to cause axonal loss with secondary or predominant demyelination, b2-microglobulin deposition in joints and connective tissue, and increased levels of inflammatory cytokines, which may all result in physical function loss.\(^\text{32,33}\) Gait speed assessment has the important advantages of brevity, simplicity and reproducibility.\(^\text{34}\) Therefore, we suggest that the gait speed test might be seen as a screening tool for early detection of functional limitations, providing an informative and potentially actionable functional status in the population with mild-to-moderate CKD.

The present study has several strengths. A difference in sarcopenia, along with its individual components and relevant cut-off points, was identified in participants with mild-to-moderate CKD versus those without CKD. The results supplement evidence on the relationship between physical performance and kidney function among community-dwelling older adults, which may contribute to providing appropriate treatment for the prevention of mild-to-moderate CKD. However, several study limitations should also be acknowledged. First, this was a cross-sectional study, from which it is impossible to infer a definitive causal relationship. Therefore, future studies are warranted to better assess this relationship. Secondly, the study population comprised community-dwelling older adults in Tianjin and Shanghai, which may not be representative of the wider older Chinese population. Thirdly, eGFR in the study was calculated using the CKD-EPI equation, which involves age, sex, and creatinine level. However, serum creatinine level is affected by muscle mass because creatinine is derived from the breakdown of muscle.\(^\text{35}\) Thus, future investigations should consider the use of cystatin-C to enhance the accuracy of results. Finally, epidemiologic data suggest that cognitive function may be interrelated with CKD and sarcopenia,\(^\text{36–38}\) making the assessment of cognitive function particularly critical. The present results may also be limited by the failure to assess cognitive function, and future studies should pay more attention to older adults with cognitive disorders. Further studies should expand the number of participants, add more relevant data, and carry out more accurate and comprehensive assessments to further determine and enhance our understanding of the relationship between physical performance and mild-to-moderate CKD.

In summary, sarcopenia was found to be significantly associated with mild-to-moderate CKD in men. Regarding its individual components, the results indicate that slow gait speed may be independently related to mild-to-moderate CKD in community-dwelling older adults. In addition, low muscle mass was associated with mild-to-moderate CKD in men only, while weak muscle strength did not show any significant association once adjustments were made for confounding factors.

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Data accessibility statement
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declaration of conflicting interest
The Authors declare that there is no conflict of interest.

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