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Association between possible sarcopenia, all-cause mortality, and adverse health outcomes in community-dwelling older adults in China

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The relationship between possible sarcopenia and mortality remains ambiguous within Asian populations. To clarify this, we investigated the association in older adults residing in Chinese communities. Utilizing data from the China Health and Retirement Longitudinal Study, this population-based cohort study included individuals aged ≥ 60 years, followed from 2011 to 2012 through 2020. Possible sarcopenia was defined in accordance with the Asian Working Group on Sarcopenia 2019 criteria, and Cox proportional hazards regression was used to analyze its impact on mortality, while exploratory analyses were conducted to investigate the associations of possible sarcopenia with chronic diseases, functional independence, and hospitalization frequency. The study encompassed 5,160 participants (median age: 66 years), nearly half of whom (48.8%) were identified with possible sarcopenia. Over a 9-year follow-up period, there were 1216 recorded deaths. Analysis indicated that individuals with possible sarcopenia faced a significantly elevated mortality risk compared to their counterparts (HR: 1.79, 95% CI: 1.58–2.03; $P < 0.001$). Further, subgroup analyses confirmed a strong association between possible sarcopenia and all-cause mortality across various subgroups, including those related to sex, obesity status, and living environment. Additionally, exploratory analyses revealed that possible sarcopenia was significantly associated with an increased likelihood of heart disease (OR = 1.18, 95% CI: 1.03–1.34, $P = 0.014$) and stroke (OR = 1.41, 95% CI: 1.19–1.68, $P < 0.001$), as well as reduced functional independence (β = -0.17, 95% CI: -0.24–-0.10, $P < 0.001$). Possible sarcopenia was also associated with a higher frequency of hospitalizations at baseline (Exp(β) = 1.50, 95% CI: 1.25–1.81, $P < 0.001$), although this association was no longer significant during the follow-up period. In conclusion, in Chinese community-dwelling older adults, possible sarcopenia was associated with an increased risk of all-cause mortality, several chronic diseases, and functional dependence. Thus, alleviating or preventing possible sarcopenia may improve health outcomes and extend the lifespan of these individuals.

Keywords Possible sarcopenia, Mortality, Older adults, Physical performance, Muscle strength

As the global population ages, the prevalence of sarcopenia, which is characterized by a progressive decline in muscle mass and function, is notably increasing, representing a substantial public health concern[1]. The diagnostic criteria for sarcopenia encompass muscle mass, strength, and physical performance[2–5]. Despite extensive research on the link between sarcopenia and heightened mortality risk[6–12], the lack of accessible and reliable equipment for muscle mass assessment in community settings hampers widespread screening efforts[4].

In 2019, the European Working Group on Sarcopenia in Older People (EWGSOP2)[3] and the Asian Working Group for Sarcopenia (AWGS)[4] revised their guidelines for Western and Asian populations, respectively. These revisions introduced the notion of "possible sarcopenia", identifiable through less complex assessments such as grip strength and chair stand tests, thereby obviating the requirement for muscle mass evaluation. This streamlined and cost-effective methodology facilitates its integration into primary healthcare and preventive services[4]. Investigating the relationship between "possible sarcopenia" and both disease and mortality is vital,

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offering significant insights into avenues for disease prevention, treatment modalities, and the improvement of life quality and longevity.

Research has indicated that possible sarcopenia is associated with an increased risk of mortality in Western populations[13–19]. However, studies examining this link within Asian populations are scarce and have produced inconsistent results[12,20–22], underscoring the urgent need for more thorough research in this area. Our study aims to address the following question: Is the association between possible sarcopenia and all-cause mortality among Chinese community-dwelling individuals aged ≥ 60 years similar to that observed in Western populations? We hypothesize that the relationship between possible sarcopenia and mortality in the Asian population mirrors that in Western populations due to shared biological mechanisms[23]. Our analysis also explored potential variations in the association between possible sarcopenia and mortality across different subgroups, including those related to sex (male or female), residential area (urban or rural), and obesity status (obese or nonobese).

In addition to mortality, sarcopenia has been linked to other adverse health outcomes, such as chronic diseases, functional decline, and increased healthcare utilization[1,2]. Therefore, our study also explores the relationship between possible sarcopenia and various chronic diseases (e.g., hypertension, diabetes, cancer, chronic lung diseases, heart disease, and stroke), physical function, and hospitalization risk. By including these additional analyses, we aim to provide a more comprehensive understanding of the broader health impact of possible sarcopenia. This is particularly relevant for public health and clinical practice, as understanding the multifaceted effects of possible sarcopenia could lead to more targeted prevention and management strategies.

Results

Study population and baseline characteristics

Of 17,705 participants in China Health and Retirement Longitudinal Study (CHARLS) 2011, we excluded 11,916 participants who were aged < 60 years ($n = 10,036$) or lacked data on possible sarcopenia ($n = 1,880$). Moreover, we excluded 629 participants for whom data regarding mortality were not available at follow-ups. Consequently, our final analysis included 5,160 individuals aged ≥ 60 years during CHARLS 2011 who completed follow-up until 2020 (Fig. 1). The median age of the study participants was 66 (interquartile range (IQR), 62–72) years, and 2,607 (50.5%) participants were men. The prevalence of possible sarcopenia was 48.8% (2,518 of 5,160 older adults) (Table 1). The Katz ADL score had the highest proportion of missing values at 23.3%, while missing data for other covariates ranged from 0 to 2.0%. These covariates were imputed using multiple imputation and used in subsequent analyses.

Associations of possible sarcopenia with chronic diseases

At the 9-year follow-up, in multivariable-adjusted models, possible sarcopenia was significantly associated with an increased risk of heart disease (odds ratio (OR) = 1.18, 95% confidence interval (CI): 1.03–1.34, $P = 0.014$) and stroke (OR = 1.41, 95% CI: 1.19–1.68, $P < 0.001$). These significant associations persisted across all models throughout the 0- to 9-year follow-up period (Table S1 and Table S2). The association between possible sarcopenia and chronic lung disease remained significant from baseline through the 7-year follow-up but gradually weakened and lost statistical significance by the 9-year follow-up (Table S3). In cross-sectional analyses, possible sarcopenia was significantly associated with hypertension; however, in longitudinal analyses, this association became non-significant in the adjusted models (Table S4). No significant associations were observed between possible sarcopenia and either diabetes or cancer (Table S5 and Table S6).

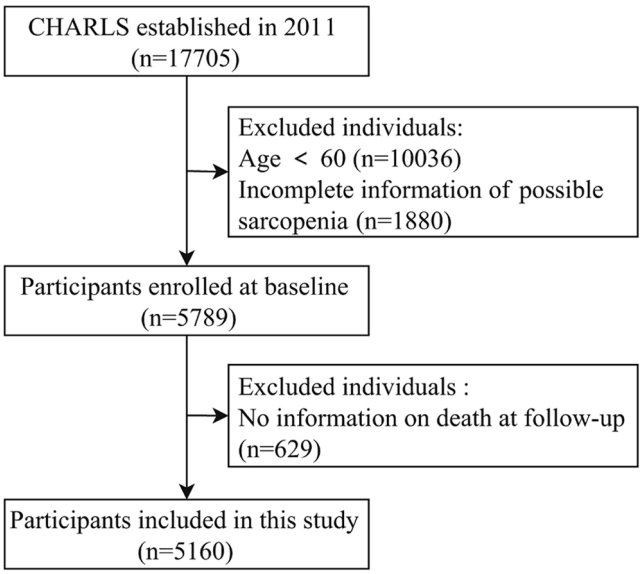

Fig. 1. Flow diagram of participant selection. CHARLS, China Health and Retirement Longitudinal Study.

	Overall ($n=5,160$)	No possible sarcopenia ($n=2,642$)	Possible sarcopenia ($n=2,518$)
Male, n (%)	2,607(50.5)	1,499 (56.7)	1,108 (44.0)
Age (years)	66 (62, 72)	65 (62, 69)	69 (64, 75)
[a]BMI (kg/m^2)	22.38 (20.11, 25.07)	22.63 (20.38, 25.19)	22.14 (19.87, 24.88)
[a]Waist (cm)	84.20 (77.30, 92.00)	84.10 (77.50, 91.50)	84.20 (77.00, 92.10)
Rural, n (%)	3,475 (67.3)	1,710 (64.7)	1,765 (70.1)
[a]Smoking, n (%)	2,231 (43.3)	1,236 (46.8)	995 (39.5)
[a]Alcohol consumption, n (%)	1,226 (23.8)	733 (27.8)	493 (19.6)
[a]Heart disease, n (%)	734 (14.3)	329 (12.5)	405 (16.2)
[a]Cancer, n (%)	40 (0.8)	20 (0.8)	20 (0.8)
[a]Stroke, n (%)	150 (2.9)	43 (1.6)	107 (4.3)
[a]Chronic lung diseases, n (%)	765 (14.9)	340 (12.9)	425 (17.0)
[a]Diabetes, n (%)	729 (14.1)	367 (13.9)	362 (14.4)
[a]Hypertension, n (%)	2,648 (51.3)	1,247 (47.2)	1,401 (55.6)
SBP (mmHg)	133 (119, 148)	131 (119, 146)	135 (119, 151)
DBP (mmHg)	74 (67, 82)	75 (67, 82)	74 (66, 83)
[b]FPG (md/dL)	102.96 (95.40, 114.48)	103.14 (95.76, 114.66)	102.78 (94.86, 114.03)
HBAlc (%)	5.20 (4.90, 5.50)	5.20 (4.90, 5.50)	5.20 (4.90, 5.50)
[a]Hospitalized in the past year, n (%)	603(11.7)	251(9.5)	352(14.0)
[a]Katz Index < 6, n (%)	362(9.1)	66(3.7)	296(13.6)
Handgrip strength (kg)			
Male	35.00 (30.00, 40.20)	38.0 (33.50, 43.00)	29.0 (24.00, 36.00)
Female	24.00 (19.00, 28.00)	26.0 (22.50, 30.00)	20.5 (16.00, 26.00)
[c]5-time chair stand test (s)	10.88 (8.94, 13.67)	9.31 (7.93, 10.50)	14.03 (12.50, 16.62)

Table 1. Baseline characteristics of participants in terms of possible sarcopenia status. Data are presented as median (interquartile range) or numbers (percentages). BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HbA1c, hemoglobin A1c. [a]There were 2, 2, 7, 8, 13, 20, 26, 31, 77, 103, and 1,201 participants with missing data on smoking, alcohol consumption, hospitalized in the past year, diabetes, stroke, chronic lung diseases, cancer, heart disease, BMI, waist circumference, and Katz Index respectively. [b]Blood glucose data were available for 3,879 participants. Among them, 368 did not fast overnight, and their results of glucose levels were considered as random plasma glucose levels. [c]There were 86 people who tried but failed to complete the 5-time chair stand test, and their test time was considered as ≥12 s.

Associations of possible sarcopenia with physical function and hospitalization frequency

In cross-sectional analyses, possible sarcopenia was significantly associated with a lower Katz Index (β = -0.15, 95% CI: -0.19–-0.11, $P<0.001$). This association persisted in longitudinal analyses at the 2-year (β = -0.13, 95% CI: -0.18–-0.09, $P<0.001$), 4-year (β = -0.21, 95% CI: -0.27–-0.15, $P<0.001$), 7-year follow-ups (β = -0.18, 95% CI: -0.24–-0.11, $P<0.001$), and 9-year follow-ups (β = -0.17, 95% CI: -0.24–-0.10, $P<0.001$) (Table 2), indicating that possible sarcopenia increases the risk of reduced functional independence in both short- and long-term periods.

Using a zero-inflated negative binomial model, after adjusting for potential confounders such as age, sex, comorbidities, and lifestyle factors, possible sarcopenia was significantly associated with an increased hospitalization frequency at baseline (Exp(β) = 1.50, 95% CI: 1.25–1.81, $P<0.001$). At the 2-year follow-up, the association was marginally non-significant (Exp(β) = 1.17, 95% CI: 1.00–1.38, $P=0.057$). However, at the 4-year, 7-year, and 9-year follow-ups, the association was no longer statistically significant, suggesting that other factors may play a greater role in hospitalization risk over time (Table 3).

Association between possible sarcopenia and all-cause mortality

During the 9-year follow-up period, 1,216 deaths occurred (23.6% of the cohort). In particular, among 2,518 individuals with possible sarcopenia, there were 823 deaths, whereas among 2,642 individuals without possible sarcopenia, there were 393 deaths. Regarding the comparison of the event rate per 1,000 person-years, the rates were 43.0 and 17.7 in participants with and without possible sarcopenia, respectively.

Table 4 shows that after adjusting for age, sex, body mass index (BMI), smoking, alcohol consumption, hypertension, diabetes, cancer, chronic lung diseases, heart disease, and stroke, possible sarcopenia was significantly associated with increased all-cause mortality at 2-year (hazard ratio (HR) = 1.70, 95% CI: 1.23–2.36, $P=0.001$), 4-year (HR = 1.69, 95% CI: 1.37–2.08, $P<0.001$), 7-year (HR = 1.68, 95% CI: 1.46–1.95, $P<0.001$), and 9-year (HR = 1.79, 95% CI: 1.58–2.03, $P<0.001$) follow-ups. The sensitivity analyses of our study, involving exclusion of participants with missing covariate values or those who died within 3 months of follow-up, as well as applying multiple imputation for missing muscle strength and physical performance data, yielded almost identical results (Tables S7-S9).

	β (95% CI)			
Follow-up interval	**Unadjusted**	**Model 1[a]**	**Model 2[b]**	**Model 3[c]**
0 years	-0.19 (-0.23, -0.15)	-0.16(-0.20, -0.12)	-0.16(-0.20, -0.12)	-0.15(-0.19, -0.11)
	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$
2 years	-0.19 (-0.23, -0.14)	-0.15(-0.20, -0.10)	-0.15(-0.20, -0.10)	-0.13(-0.18, -0.09)
	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$
4 years	-0.26 (-0.31, -0.20)	-0.22(-0.28, -0.16)	-0.22(-0.28, -0.16)	-0.21(-0.27, -0.15)
	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$
7 years	-0.25 (-0.31, -0.18)	-0.18(-0.25, -0.12)	-0.18(-0.25, -0.12)	-0.18(-0.24, -0.11)
	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$
9 years	-0.27 (-0.33, -0.20)	-0.19(-0.26, -0.12)	-0.19(-0.25, -0.12)	-0.17(-0.24, -0.10)
	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$

Table 2. Association between possible Sarcopenia and Katz ADL score. ADL, activities of daily living; β, regression coefficient; CI, confidence interval. [a]Model 1 was adjusted for age and sex. [b]Model 2 was adjusted for age, sex, body mass index, smoking status, and drinking status. [c]Model 3 includes the adjustments in model 2 in addition to the adjustments for hypertension, diabetes, cancer, chronic lung diseases, heart disease, and stroke.

	Exp(β) (95% CI)			
Follow-up interval	**Unadjusted**	**Model 1[a]**	**Model 2[b]**	**Model 3[c]**
0 years	1.60 (1.34, 1.91)	1.61 (1.34, 1.94)	1.60 (1.33, 1.93)	1.50 (1.25, 1.81)
	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$
2 years	1.30 (1.11, 1.52)	1.23 (1.05, 1.45)	1.23 (1.04, 1.45)	1.17 (1.00, 1.38)
	$P<0.001$	$P=0.013$	$P=0.014$	$P=0.057$
4 years	1.25 (1.07, 1.45)	1.16 (1.00, 1.36)	1.16 (0.99, 1.36)	1.12 (0.96, 1.31)
	$P=0.004$	$P=0.057$	$P=0.062$	$P=0.151$
7 years	1.15 (0.99, 1.33)	1.06 (0.91, 1.24)	1.06 (0.91, 1.24)	1.00 (0.86, 1.16)
	$P=0.068$	$P=0.426$	$P=0.451$	$P=0.984$
9 years	1.15 (1.01, 1.32)	1.15 (1.00, 1.32)	1.15 (0.99, 1.32)	1.13 (0.98, 1.30)
	$P=0.038$	$P=0.055$	$P=0.059$	$P=0.092$

Table 3. Association between possible Sarcopenia and hospitalization frequency. Exp(β), exponentiated coefficient representing the rate ratio; CI, confidence interval. [a]Model 1 was adjusted for age and sex. [b]Model 2 was adjusted for age, sex, body mass index, smoking status, and drinking status. [c]Model 3 includes the adjustments in model 2 in addition to the adjustments for hypertension, diabetes, cancer, chronic lung diseases, heart disease, and stroke.

Subgroup analyses indicated a higher prevalence of possible sarcopenia among women (55.2%) than men (42.5%, $P<0.001$), and in rural areas (50.8%) compared to urban areas (44.7%, $P<0.001$), with no significant difference between obese and non-obese populations (Figure S1). Multivariable-adjusted regression models revealed a significant interaction between sex and the association of possible sarcopenia with all-cause mortality at the 7-year follow-up (interaction $P=0.0496$, Figure S1C), indicating that female patients with possible sarcopenia had a higher mortality risk compared to male patients. At the 9-year follow-up, although this trend persisted, the interaction P-value was not statistically significant (interaction $P=0.1047$, Figure S1D). Across all follow-up periods, obesity status and residential area did not significantly modify the association between possible sarcopenia and all-cause mortality. At the 2-year follow-up, the association between possible sarcopenia and mortality in obese patients was borderline significant ($P=0.0823$, Figure S1A), while possible sarcopenia was associated with increased mortality risk in all other subgroups. At the 4-, 7-, and 9-year follow-ups, the risk of all-cause mortality significantly increased in all subgroups (HR > 1.5, $P<0.05$), indicating that possible sarcopenia is associated with an elevated mortality risk in both the short and long term (Fig. 2 and Figure S1).

In addition to possible sarcopenia, age, smoking, hypertension, diabetes, and chronic lung diseases were significantly associated with an increased risk of mortality over the 9-year follow-up period. In contrast, being female and a higher BMI were significantly associated with a decreased risk of mortality (Figure S2).

Discussion

This study investigated the association between possible sarcopenia, all-cause mortality, and various adverse health outcomes, including chronic diseases, functional decline, and hospitalization frequency, in a representative cohort of 5,160 community-dwelling older adults in China. The association between possible sarcopenia and

Follow-up interval	Possible sarcopenia	No. of deaths/total	HR (95% CI)			
			Unadjusted	Model 1[a]	Model 2[b]	Model 3[c]
2 years	No	57/2,642	1.00	1.00	1.00	1.00
	Yes	151/2,518	2.83 (2.09, 3.84)	1.85 (1.34, 2.56)	1.78 (1.28, 2.46)	1.70 (1.23, 2.36)
			$P<0.001$	$P<0.001$	$P<0.001$	$P=0.001$
4 years	No	145/2,642	1.00	1.00	1.00	1.00
	Yes	340/2,518	2.59 (2.13, 3.14)	1.81 (1.48, 2.23)	1.77 (1.44, 2.17)	1.69 (1.37, 2.08)
			$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$
7 years	No	312/2,642	1.00	1.00	1.00	1.00
	Yes	642/2,518	2.36 (2.06, 2.70)	1.77 (1.53, 2.04)	1.75 (1.52, 2.02)	1.68 (1.46, 1.95)
			$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$
9 years	No	393/2,642	1.00	1.00	1.00	1.00
	Yes	823/2,518	2.47 (2.19, 2.78)	1.87 (1.65, 2.13)	1.85 (1.63, 2.10)	1.79 (1.58, 2.03)
			$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$

Table 4. Association between possible Sarcopenia and all-cause mortality across four follow-up periods. HR, hazard ratio; CI, confidence interval. [a]Model 1 was adjusted for age and sex. [b]Model 2 was adjusted for age, sex, body mass index, smoking status, and drinking status. [c]Model 3 includes the adjustments in model 2 in addition to the adjustments for hypertension, diabetes, cancer, chronic lung diseases, heart disease, and stroke.

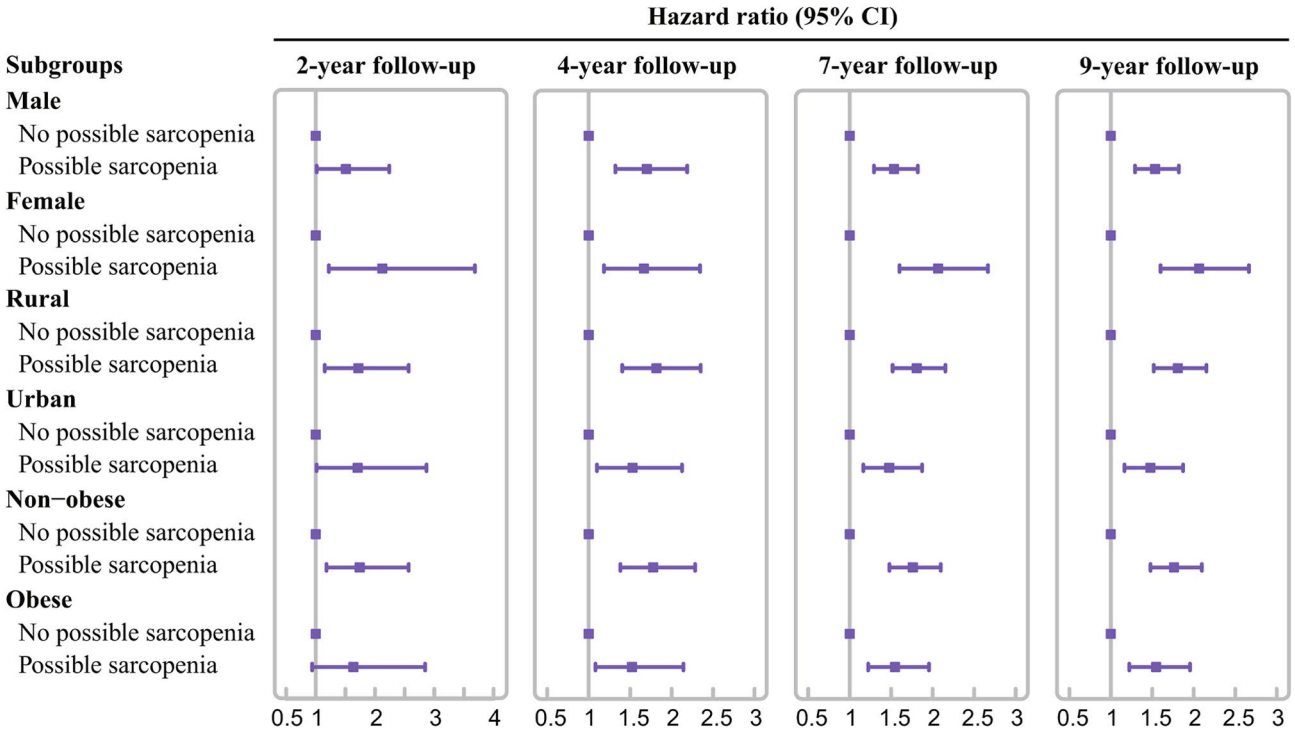

Fig. 2. Associations between possible sarcopenia and risk of all-cause mortality in terms of sex, residence, and obesity. Forest plots display hazard ratios and 95% CIs for mortality during the 2-, 4-, 7-, and 9-year follow-up periods, stratified by sex, residence, and obesity. Risk estimates were adjusted for age, sex (unadjusted in subgroup analysis stratified by sex), body mass index (unadjusted in subgroup analysis stratified by obesity), smoking and alcohol consumption status, hypertension, diabetes, cancer, chronic lung diseases, heart disease, and stroke. CI, confidence interval.

all-cause mortality persisted across the 2-, 4-, 7 year, and 9-year follow-up periods and remained robust even after adjusting for confounders such as sex, age, BMI, smoking, alcohol consumption, and chronic diseases. Additionally, possible sarcopenia was significantly associated with a higher likelihood of having heart disease and stroke. Individuals with possible sarcopenia also faced a higher likelihood of reduced functional independence. Furthermore, participants with possible sarcopenia exhibited a higher hospitalization frequency at baseline. However, this association was no longer significant during the follow-up period.

While previous studies have demonstrated an association between sarcopenia and increased hospitalization risk within a one-year follow-up period[24]. Research specifically examining the relationship between possible sarcopenia and hospitalization risk remains limited. Our study addresses this gap by showing a significant association between possible sarcopenia and increased hospitalization frequency at baseline, which diminished over the follow-up period, suggesting that other factors may play a more substantial role in hospitalization risk over time. Moreover, our findings of reduced physical function in individuals with possible sarcopenia are consistent with existing literature that links possible sarcopenia to an increased risk of functional disability[25]. Previous studies have also reported that possible sarcopenia is associated with a higher risk of chronic diseases, including chronic lung diseases, heart disease, and stroke[26,27], which supports our findings of elevated risks for these conditions in individuals with possible sarcopenia. These results highlight the broad impact of possible sarcopenia on functional decline, chronic disease risk, and hospitalization, underscoring the importance of early detection and intervention to mitigate its adverse health outcomes.

In the investigation of the relationship between possible sarcopenia and mortality risk, the association appears more pronounced and consistent in Western populations[13–19]. For example, a study from Turkey indicated that possible sarcopenia, defined by both EWGSOP1 and EWGSOP2 standards, correlates with an increased mortality risk, with HR of 4.26 and 2.58, respectively[13]. This association was further substantiated by research from Norway[14] and Sweden[15], as well as the United Kingdom[17], which, utilizing the EWGSOP2 definition, demonstrated a significant link between possible sarcopenia and higher mortality rates among older adults. Moreover, studies from Brazil have indicated that possible sarcopenia is associated with a heightened risk of mortality in older adults with cancer[16] and an increased risk of in-hospital mortality among hospitalized patients[18]. Similarly, research from Poland has shown that possible sarcopenia is linked to an increased risk of death in older COVID-19 patients[19]. Several factors inherent to Western lifestyles and healthcare systems may influence these findings. Western countries often exhibit lifestyles that lack sufficient physical activity and include dietary habits high in fat and sugar, which are known to accelerate muscle loss and the onset of possible sarcopenia [28,29]. Furthermore, the advanced healthcare resources and comprehensive health management systems in Western countries likely facilitate the more efficient detection and reporting of health issues related to possible sarcopenia[30]. These combined factors contribute to the more pronounced and consistent association between possible sarcopenia and mortality risk observed in Western populations.

Contrastingly, research on the potential occurrence of sarcopenia and its risk of mortality within Asian populations is less common and yields inconsistent outcomes[12,20–22]. A multicenter cohort study in China, adhering to the AWGS2019 standards, associated possible sarcopenia with an increased risk of mortality in patients with solid tumors, presenting an HR of 1.190 [12]. Additionally, a study from Thailand identified possible sarcopenia as a risk factor for ten-year all-cause mortality, with an HR of 1.89 [20]. An 11-year follow-up study also found a significant association between possible sarcopenia and increased mortality risk, although this significance diminished after adjusting for age, sex, and other factors[22]. However, another study from China observed no significant relationship between possible sarcopenia and mortality among community-dwelling older adults[21]. Notably, their definition of possible sarcopenia still considered muscle mass, diverging from guidelines[21]. Our study, strictly following the AWGS 2019 criteria and focusing exclusively on declines in physical performance and muscle strength without evaluating muscle mass, found possible sarcopenia to be a significant risk factor for mortality over nine years among older adults in Chinese communities (HR: 1.79, 95% CI: 1.58–2.03). Therefore, we conclude that, based on our research and prior studies[12,20,22], possible sarcopenia, as rigorously defined by the AWGS 2019, consistently correlates with an increased mortality rate.

The confluence of aging and escalating obesity rates has given rise to sarcopenic obesity[31]. While sarcopenic obesity is linked to higher risks of cardiovascular diseases, diabetes, and physical disabilities compared to sarcopenia alone[31], our analysis indicates that the mortality risk remains similar between the two conditions, consistent with previous research[31,32]. Specifically, our findings show that HR for mortality were comparable between obese and non-obese participants, with HRs consistently slightly higher in the non-obese group during each follow-up. This phenomenon may be explained by the "obesity paradox", where overweight and obese individuals have a lower mortality risk compared to their normal weight or underweight counterparts[33]. Our Cox regression results (Figure S2) also confirmed that a higher BMI was significantly associated with a decreased risk of mortality over the 9-year follow-up period. Studies exploring the gender-specific impacts of possible sarcopenia are limited, yet some have identified sex differences in the association between sarcopenia and mortality risk[34–36]. Nonetheless, our research shows an augmented mortality risk associated with possible sarcopenia in both men and women among the older Chinese population, aligning with findings from two Japanese studies that reported a significant link between sarcopenia and increased mortality across both sexes[37,38]. Additionally, our study revealed that the heightened mortality risk associated with possible sarcopenia impacts elderly individuals living in both urban and rural areas, affirming previous meta-analyses that have flagged sarcopenia as a mortality risk factor, regardless of residential setting[11]. These findings underscore the urgent necessity for possible sarcopenia assessment in older adults, due to its strong and consistent correlation with increased mortality risk across various demographics and environments. Advancing our understanding of these relationships and devising effective interventions are crucial for subsequent research.

Possible sarcopenia can increase the risk of all-cause mortality in older adults via various mechanisms. Our cross-sectional and longitudinal analyses revealed that individuals with possible sarcopenia were associated with an increased likelihood of chronic conditions (e.g., heart disease and stroke). These underlying health conditions have been reported to significantly contribute to an increased risk of mortality among individuals with possible sarcopenia[39]. Moreover, reduced muscle strength associated with possible sarcopenia can impair balance and locomotion, rendering older adults more susceptible to accidents that lead to life-threatening consequences, such as falls and fractures[40]. Our cross-sectional and longitudinal analyses further supported this, showing that individuals with possible sarcopenia were more likely to experience reduced functional independence. Briefly,

the impact of possible sarcopenia on mortality encompasses various factors, including those affecting muscle strength and the development or progression of chronic diseases. Therefore, studies focusing on prevention and intervention strategies for possible sarcopenia must be prioritized to improve health outcomes and survival in older adults.

This study has several limitations. First, this was an observational study; thus, there was a possibility of confounding factors influencing the observed relationships. However, we addressed this limitation by employing multiple analytical strategies, including multivariate adjustment and sensitivity analysis, to mitigate the impact of confounding factors and strengthen the robustness of our findings. Second, the estimation of survival time for participants who died during the follow-up periods was dependent on the use of median survival time based on the last two follow-ups. Although this approach was necessary owing to the unavailability of exact death dates, it may have introduced some imprecision. To address these limitations and strengthen our understanding of the relationship between possible sarcopenia and health outcomes, future studies that aim to collect more comprehensive data on death records, employ a longitudinal design with larger sample sizes, and incorporate more detailed assessments of muscle strength and physical performance are warranted.

Conclusions

This study provides evidence for a significant association between possible sarcopenia and increased all-cause mortality in Chinese older adults. Further, our findings indicate possible sarcopenia is significantly associated with higher likelihoods of heart disease, stroke, and reduced functional independence. These findings highlight the importance of recognizing possible sarcopenia as an independent predictor of mortality, as well as physical and functional decline, and underscore the need for further research on prevention and management strategies.

Methods

Data sources and participants

The present analysis was conducted using nationally representative data from the CHARLS. Details about CHARLS have been reported in a previous study[41]. Notably, CHARLS is a nationally representative ongoing prospective cohort study that aims to collect sociodemographic and health-related data of Chinese individuals aged ≥ 45 years. It uses a multistage-stratified probability-to-scale proportional sampling method for participant selection. The primary objectives of CHARLS are as follows: health status assessment, healthcare utilization, and determination of socioeconomic characteristics of the Chinese population. The CHARLS database contains information about possible sarcopenia and survival/death, which enables to evaluate the relationship between possible sarcopenia and mortality outcomes in the Chinese population. The baseline survey, i.e., CHARLS 2011, was conducted in 2011–2012, and subsequent follow-ups were conducted in 2013, 2015, 2018, and 2020. Data were collected by one-on-one interviews, laboratory tests, and physical measurements to ensure accuracy and reliability.

In the present study, we retrospectively analyzed data of participants aged ≥ 60 years at baseline (2011–2012) and subsequent follow-ups until 2020. The exclusion criteria were as follows: age of < 60 years at baseline, insufficient data to assess possible sarcopenia at baseline, and lack of data on mortality during follow-up.

Assessment of possible sarcopenia

According to AWGS 2019 consensus, possible sarcopenia is defined by low muscle strength or decreased physical performance[4]. In CHARLS, muscle strength was assessed by grip strength using a mechanical dynamometer (YuejianTM WL-1000, Nantong, China), wherein participants were asked to squeeze the device as hard as they could, and testing for each hand was performed twice. The maximum value among each set of measurements was used in the study. Hand grip strengths of < 28 kg and < 18 kg in men and women were considered as low muscle strengths[4]. Physical performance was assessed using the 5-time chair stand test. In this test, the participants were requested to sit down and fold their arms in front of their chests. Subsequently, they were asked to stand up and sit down five times continuously as quickly as possible without pausing or moving their arms. During the test, the examiner recorded the time required to complete the test. The participants were considered to have decreased performance if they took ≥ 12 s[4] or were unable to complete the test.

Assessment of mortality

In CHARLS, death records were obtained using exit interviews conducted in 2013, 2015, 2018, and 2020. These interviews were primarily answered by family members or close contacts to ensure the accuracy of the information. Although interview dates were available for all three follow-ups, the exact dates of death were only available from the 2013 follow-up and a portion of the 2020 follow-up questionnaires. Due to a large number of unknown or uncertain causes of death, we used all-cause mortality as the study endpoint to ensure the reliability of our results. For surviving participants, the survival time was defined as the duration from the baseline assessment to the most recent follow-up interview. In the case of death, survival time was calculated as the interval between the baseline interview date and the date of participant's death or, when unavailable, as the median time between the last two surveys[42].

Subgroup analyses

Both obesity and sarcopenia are associated with adverse health outcomes, and the combination of obesity and sarcopenia, known as sarcopenic obesity, may have a synergistic effect, amplifying their threat to health[31]. This makes it crucial to examine how obesity status interacts with possible sarcopenia to affect mortality risk. Differences in residential area can affect access to healthcare, nutritional status, and levels of physical activity, all of which are critical factors for muscle health[43]. Sex differences play a significant role in muscle strength and

physical activity levels, affecting the prevalence and impact of sarcopenia[44], and thereby influencing mortality risk. Consequently, subgroup analyses were conducted based on sex (male or female), residential area (urban or rural), and obesity status.

Assessment of functional ability and hospitalization

We assessed functional ability using the Modified Katz ADL score, which evaluates participants' capacity to perform basic daily activities across six domains: feeding, bathing, dressing, toileting, transferring, and continence (Table: Modified Katz Activities of Daily Living (ADL) Scale-MSD Manual Professional Edition (msdmanuals.com))[45]. For each domain, participants were scored based on their ability to perform the activity independently. If the participant could perform the activity without assistance, it was scored as 1 point. If the participant required help or was unable to perform the activity, it was scored as 0 points. The total score ranges from 0 to 6, with higher scores indicating greater independence in ADL. Hospitalization frequency within the past year can serve as an indicator of healthcare utilization[46]. Using data from the CHARLS study, the corresponding questions in the questionnaire are: (1) "Have you received inpatient care in the past year?" (2)"How many times have you received inpatient care during the past year?" Modified Katz ADL score and Hospitalization frequency data were collected and analyzed from the baseline, 2013, 2015, 2018, and 2020 CHARLS waves.

Covariates

The covariates adjusted in the statistical analysis, which were previously reported as risk factors for mortality[47,48]were obtained from baseline questionnaires, laboratory tests, and physical measurements, including age, sex, smoking and alcohol consumption status, BMI, diabetes, hypertension, heart disease, stroke, cancer, and chronic respiratory disease. Additionally, these covariates have also been reported to be associated with the risk of sarcopenia[49,50]. The participants were considered to have hypertension if (1) their systolic blood pressure was $\geq$ 140 mmHg or diastolic blood pressure was $\geq$ 90 mmHg, (2) they were currently receiving antihypertensive medications, or (3) they had previously been diagnosed by a physician. They were considered to have diabetes if (1) their fasting plasma glucose level was $\geq$ 126 mg/dL, random plasma glucose level was $\geq$ 200 mg/dL, and HbA1c level was $\geq$ 6.5%[51]; (2) they had previously been diagnosed by a physician; or (3) they were currently receiving glucose-lowering treatment. Furthermore, the presence of other comorbidities was determined based on a previous diagnosis or the current use of relevant medications. Heart disease included heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems. Chronic lung disease encompassed chronic bronchitis and emphysema (excluding tumors or cancer). According to the 2022 consensus by the European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Association for the Study of Obesity (EASO), BMI and waist circumference are utilized as initial screening tools for identifying individuals at risk of sarcopenic obesity[52]. Based on this, in our study, obesity was defined as a BMI of $\geq$ 28 kg/m^2 or waist circumference of $\geq$ 85 cm and $\geq$ 90 cm for women and men, respectively[53].

Statistical analyses

In the present study, continuous variables were expressed as medians and IQRs if they did not conform to a normal distribution according to the Kolmogorov–Smirnov test. Conversely, categorical variables were expressed as frequencies and percentages. The participants were grouped according to the possible sarcopenia status to describe baseline characteristics. We conducted cross-sectional analyses using baseline data. Logistic regression was employed to analyze the relationship between possible sarcopenia and chronic diseases, including hypertension, diabetes, cancer, chronic lung diseases, heart disease, and stroke. The results are presented as ORs with 95% CIs. The association between possible sarcopenia and ADL scores was analyzed using multivariable linear regression models[54–56], with results presented as regression coefficients (β) and their 95% CIs. To investigate the associations of possible sarcopenia with hospitalization frequency, a zero-inflated negative binomial model was used[57]. The results are presented as exponentiated coefficients (Exp(β)) with 95% CIs. The primary focus of our study was longitudinal analyses to investigate the association between possible sarcopenia and mortality at three different time points: 2013 (2-year follow-up), 2015 (4-year follow-up), 2018 (7-year follow-up), and 2020 (9-year follow-up). To investigate the association, we calculated the HRs and corresponding 95%CIs using Cox proportional risk models. Further, subgroup analyses were performed in terms of sex (male or female), obesity status (obese or nonobese), and residential location (urban or rural).

To adjust for potential confounding factors, we used three models in our study. Model 1 was adjusted for age and sex, whereas model 2 included BMI and smoking and alcohol consumption status in addition to the variables adjusted in model (1) Further, model 3 was adjusted for hypertension, diabetes, cancer, chronic lung disease, heart disease, and stroke based on model (2) Multiple imputation methods were applied to impute the missing data[58]. Moreover, we conducted sensitivity analyses to assess the robustness of the results. First, participants with missing values for covariates were excluded, and a complete case analysis was performed. Second, the participants who died within 3 months of follow-up were excluded to minimize potential reverse causality due to severe disease. Third, we addressed baseline exclusions due to missing muscle strength and physical performance data by applying multiple imputation and reassessing the association between possible sarcopenia and mortality.

In this study, all statistical analyses were conducted using R software (version 4.2.1, R Foundation for Statistical Computing). Statistical significance was defined as $P < 0.05$ for all cases.

Data availability

The datasets utilized in this study are accessible through the open CHARLS databases, which can be found at https://charls.charlsdata.com.

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Author contributions

BYL and CL conceived the protocol. BYL, RYL, HYJ and CL contributed to the collection, analysis and interpretation of data. BYL and RYL grafted the manuscript. CL, YHJ and YD critically revised the manuscript. All authors take full responsibility for the integrity and accuracy of the work, and have read and approved the final manuscript. The corresponding author had complete access to all the data in the study and made the final decision to submit the manuscript for publication.

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Declarations

Ethics approval and consent to participate

The data collection protocol for CHARLS was approved by the Ethics Review Committee of Peking University (Approval Number: IRB00001052-11015). All study procedures involving human participants were conducted

in accordance with the ethical standards of the institutional and/or national research committees as well as the 1964 Helsinki Declaration and its subsequent amendments or similar ethical standards. Informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Additional information

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