

Associations of Depression and Sarcopenia with ADL Disability and All-Cause Mortality in Chinese Older Adults: A 7-Year Prospective Cohort Study

Xin Liao

The General Hospital of Western Theater Command

Bingyao Liu

The General Hospital of Western Theater Command

Song Yu

the Third Affiliated Hospital of Chengdu Medical College, Chengdu Pidu District People's Hospital

Bin Guo

The General Hospital of Western Theater Command

Ke Yu

yuke909@126.com

The General Hospital of Western Theater Command

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Abstract

Background

Both depression and sarcopenia are common in older adults and have individually been linked to functional decline and mortality. Whether their co-occurrence confers excess risk beyond independent effects remains unclear, particularly in Chinese populations.

Methods

We included 4,161 community-dwelling adults aged ≥ 60 years from the China Health and Retirement Longitudinal Study (CHARLS, 2011–2018) who were free of activities of daily living (ADL) disability at baseline. Depressive symptoms were defined as a 10-item Center for Epidemiologic Studies Depression Scale (CESD-10) score ≥ 10 . Sarcopenia was ascertained using the Asian Working Group for Sarcopenia (AWGS) 2019 algorithm, integrating low handgrip strength, slow gait speed, and low estimated appendicular skeletal muscle mass. Participants were categorized into four groups: no depression/no sarcopenia, sarcopenia only, depression only, and depression plus sarcopenia. The primary outcome was incident ADL disability at any follow-up wave (2013, 2015, or 2018); the secondary outcome was all-cause mortality, ascertained through CHARLS death-tracking records with follow-up censored at 2018. Cox proportional hazards models with progressive covariate adjustment and multiple imputation by chained equations (10 datasets, Rubin's rules) were used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs).

Results

Over a median follow-up of 7.0 years, 1,651 (39.7%) participants developed ADL disability and 521 (12.5%) died. Compared with the no depression/no sarcopenia group, the fully adjusted HRs for ADL disability were 1.01 (95% CI 0.87–1.18) for sarcopenia only, **1.37 (1.23–1.53)** for depression only, and **1.40 (1.15–1.70)** for depression plus sarcopenia. For all-cause mortality, the corresponding HRs were 1.19 (0.92–1.53), 1.03 (0.84–1.25), and 1.27 (0.91–1.77). Depression independently predicted ADL disability, and low grip strength—a core component of sarcopenia—was independently associated with higher all-cause mortality (HR 1.44, 1.15–1.79), whereas the overall sarcopenia diagnosis was not. The co-occurrence of depression and sarcopenia conferred the highest relative risks for both outcomes, with the strongest association for ADL disability among adults aged 60–69 years (HR 2.02, 1.54–2.65), and associations with mortality were most pronounced in participants with fewer than two chronic conditions.

Conclusions

Depression and sarcopenia contribute additively to the risk of ADL disability and mortality in Chinese older adults. Adults aged 60–69 years with co-occurring depression and sarcopenia represent a high-risk population that may benefit from integrated screening and early intervention.

Introduction

Population aging is reshaping the global burden of disease, and China is home to the world's largest population of older adults (UN Population Division, 2019). Maintaining functional independence and prolonging survival are central goals of geriatric care, and identifying modifiable risk factors for functional decline and premature death has become a major public health priority (Cesari et al., 2026). Depression is among the most common mental health conditions in later life, with approximately one in three Chinese older adults screening positive for clinically relevant depressive symptoms on the 10-item Center for Epidemiologic Studies Depression Scale (CESD-10) (Li et al., 2026; Zhao et al., 2014). Depression has been consistently linked to subsequent limitations in activities of daily living (ADL) and to higher mortality risk in observational studies (Harber-Aschan et al., 2026; Wang et al., 2024), with proposed behavioral and biological pathways including reduced physical activity, poor nutrition, dysregulated stress and inflammatory responses, impaired sleep, and reduced engagement with health care (Alexopoulos, 2019).

Sarcopenia, characterized by age-related loss of skeletal muscle mass, strength, and physical performance, is also highly prevalent in older adults. According to the Asian Working Group for Sarcopenia (AWGS) 2019 consensus, the prevalence of sarcopenia in community-dwelling Asian older adults is approximately 10–20% (Chang et al., 2020; Chen et al., 2020), and sarcopenia has been associated with higher risks of falls, fractures, ADL disability, and all-cause mortality (Xu et al., 2022; Yeung et al., 2019). Importantly, depression and sarcopenia share several pathophysiological mechanisms, including chronic low-grade inflammation, neuroendocrine dysregulation, mitochondrial dysfunction, and shared lifestyle risk factors such as physical inactivity and poor dietary intake (Zhu et al., 2025). The two conditions frequently co-occur in

older adults and may be linked in a bidirectional manner (Wang et al., 2023; Zhu et al., 2024), but the prognostic implications of their joint occurrence for hard functional and survival outcomes remain incompletely characterized, especially in Chinese populations.

Most previous studies have evaluated depression and sarcopenia separately, leaving three important knowledge gaps. First, whether the combination of depression and sarcopenia confers a risk of ADL disability and mortality that exceeds the independent contribution of each exposure is unclear. Second, prior work has often used dichotomous definitions of depression or has measured sarcopenia with only one or two components, limiting comparability with current consensus criteria. Third, longitudinal evidence from large, well-characterized Chinese cohorts is sparse, and few studies have simultaneously examined ADL disability and mortality as complementary outcomes in a common analytic sample with consistent statistical methodology. To address these gaps, we used data from the China Health and Retirement Longitudinal Study (CHARLS) to evaluate the joint and independent associations of depressive symptoms and sarcopenia, defined according to the AWGS 2019 algorithm, with incident ADL disability and all-cause mortality over a 7-year follow-up in a community-dwelling cohort of older Chinese adults. We hypothesized that depression and sarcopenia would each independently predict higher risks of ADL disability and mortality, and that their co-occurrence would be associated with the highest absolute and relative risk, particularly among adults aged 60–69 years, a transitional subgroup that may benefit most from early intervention.

Methods

Study design and population

CHARLS is an ongoing, nationally representative longitudinal study of community-dwelling Chinese adults aged ≥ 45 years, coordinated by the China Center for Economic Research at Peking University. Participants were recruited using a multi-stage stratified probability sampling design, covering 150 county-level units and 450 village-level units across 28 provinces, municipalities, and autonomous regions of China, and are broadly representative of the Chinese population aged 45 years and older. The baseline survey was conducted in 2011–2012 (wave 1), with biennial follow-up waves in 2013 (wave 2), 2015 (wave 3), and 2018 (wave 4). At each wave, data were collected by trained interviewers through face-to-face computer-assisted personal interviews, including standardized questionnaires on sociodemographic characteristics, health status, lifestyle behaviors, and healthcare utilization, together with physical measurements (e.g., height, weight, handgrip strength, and timed gait speed) and performance-based functional tests. The CHARLS protocol was approved by the Biomedical Ethics Review Committee of Peking University, and written informed consent was obtained from all participants.

The present analysis used the 2011 wave as baseline and follow-up data through 2018. Of the 17,568 participants with complete baseline age information, we sequentially excluded those aged < 60 years ($n = 10,008$), those with missing or invalid baseline ADL, depressive symptoms, or sarcopenia-related measurements ($n = 1,909$), those with prevalent ADL disability at baseline ($n = 1,254$), and those without valid ADL or death follow-up ($n = 236$), leaving a final analytic cohort of **4,161 participants** (Supplementary Material, sFigure 1).

Assessment of depressive symptoms and sarcopenia

Depressive symptoms were measured at baseline using the CESD-10, a validated instrument widely used in Chinese older populations (Fu et al., 2022). Each item is scored from 0 to 3, and the total score ranges from 0 to 30, with higher scores indicating more severe depressive symptoms. A cut-off of ≥ 10 was used to define clinically relevant depressive symptoms, consistent with previous longitudinal analyses in Chinese cohorts (He et al., 2025).

Sarcopenia was defined according to the AWGS 2019 algorithm (Chen et al., 2020). Three components were evaluated: muscle strength, physical performance, and muscle mass. Handgrip strength was measured using a handheld dynamometer (Yuejian WL-1000); four measurements were taken (twice per hand), and the maximum value (in kg) was used, with low muscle strength defined as < 28 kg for men and < 18 kg for women. Gait speed was measured by a 2.5-m timed walk, and low physical performance was defined as gait speed < 1.0 m/s. Because CHARLS does not include dual-energy X-ray absorptiometry or bioelectrical impedance, appendicular skeletal muscle mass (ASM) was estimated using a validated anthropometric equation developed in Chinese adults: $ASM\ (kg) = 0.193 \times weight\ (kg) + 0.107 \times height\ (cm) - 4.157 \times sex\ (1 = male, 2 = female) - 0.037 \times age\ (years) - 2.631$. The skeletal muscle mass index (SMI) was calculated as $ASM/height^2$, and sex-specific lowest quintile cut-offs were used to define low muscle mass. Sarcopenia was defined as the presence of low muscle mass in combination with low muscle strength and/or low physical performance. Participants were then categorized into four mutually exclusive exposure groups: no depression/no sarcopenia (reference), sarcopenia only, depression only, and depression plus sarcopenia.

Outcomes

The primary outcome was incident ADL disability, defined as the report of at least one ADL difficulty (dressing, bathing, eating, getting into or out of bed, toileting, or continence) at any of the 2013, 2015, or 2018 follow-up waves. For time-to-event analysis, the time variable was the

wave at which ADL disability was first reported (2, 4, or 7 years from baseline). Participants without ADL disability by 2018 or with missing data at all three follow-up waves were censored at their last available wave.

The secondary outcome was all-cause mortality, ascertained through the CHARLS death-tracking records (year, derived from official death confirmation). Follow-up time was calculated from the baseline interview date to the date of death, the last available interview date for survivors, or 2018, whichever occurred first. Deaths occurring after 2018 were treated as censored events at the last available follow-up. Of the 4,161 participants, 521 (12.5%) died and 280 (6.7%) were lost to follow-up before 2018; the remaining 3,360 (80.8%) were confirmed to be alive at the 2018 interview.

Covariates

Covariates were selected a priori based on established associations with depression, sarcopenia, and the outcomes. Smoking status was categorized into three groups based on the combination of two baseline questions (ever smoked, current smoking): never smokers, former smokers (ever smoked but not currently), and current smokers. The fully adjusted model included: age (continuous), sex, marital status (married vs not married), educational attainment (three categories: primary school or below, junior high school, and senior high school or above), rural residence, smoking status (never/former/current), alcohol consumption (current vs never/former), body mass index (continuous), chronic disease count (sum of 14 self-reported conditions including hypertension, diabetes, dyslipidemia, heart disease, stroke, cancer, lung disease, liver disease, kidney disease, digestive disease, psychiatric disease (self-reported physician-diagnosed psychiatric illness or current use of psychotropic medications), memory-related disease, arthritis, and asthma), nighttime sleep duration, total cognition score, and presence of bodily pain in the past month. All covariates were assessed at baseline (2011).

Statistical analysis

Baseline characteristics were compared across the four exposure groups using one-way analysis of variance for continuous variables and chi-square tests for categorical variables. Continuous variables are presented as mean $\pm$ SD; categorical variables as number (%).

Cox proportional hazards models with time-on-study as the time scale were used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs) for the associations of depression, sarcopenia, and their joint exposure with each outcome. For the four-group exposure, the no-depression/no-sarcopenia group was used as the reference. Four models were fitted with progressive adjustment: Crude Model; Model 1 adjusted for age and sex; Model 2 additionally adjusted for marital status, education, residence, smoking, alcohol drinking, and body mass index; and Model 3 (fully adjusted) further adjusted for chronic disease count, sleep duration, cognition, pain, and psychiatric disease. To examine which sarcopenia component drove the observed associations, the three components (low grip strength, low gait speed, and low muscle mass) were additionally analyzed separately as exposures in fully adjusted models. Because the 2.5-m timed walk in CHARLS includes a turning component and yields systematically slower speeds than the standard 4-m walk, sex-specific 20th-percentile cut-offs of gait speed (0.49 m/s for men and 0.43 m/s for women) were used to define low gait speed in the component analyses, consistent with the sex-specific approach applied to muscle mass. The proportional hazards assumption was verified by inspecting the correlation between Schoenfeld residuals and time, with no major violations detected.

To handle missing covariate values (drinking status, sleep duration, cognition score, psychiatric disease, and pain; overall missing proportion < 5%), multiple imputation by chained equations was performed using an iterative imputer (10 imputed datasets, 20 iterations each, posterior sampling to reflect imputation uncertainty). Cox models were fitted separately in each imputed dataset, and estimates were combined across datasets using Rubin's rules to obtain final HRs, 95% CIs, and P values. As a sensitivity analysis, complete-case analyses ($n = 3,921$ for the fully adjusted model) yielded materially similar results (Supplementary Material, sTable 5). Additional sensitivity analyses confirmed the robustness of the findings: (1) redefining ADL disability as at least two difficulties rather than at least one; and (2) using persistent depression (CESD-10 ≥ 10 at both the 2011 and 2013 waves) as the exposure, which yielded stronger associations with ADL disability (Model 3 HR 1.54, 95% CI 1.35–1.76). E-value calculations further indicated that an unmeasured confounder would need to be associated with both the exposure and the outcome by a risk ratio of at least 2.09 to fully explain away the observed association of depression with ADL disability (Supplementary Material, sTables 1–3).

Subgroup analyses were performed by sex (male vs female), age (60–69 vs ≥ 70 years), residence (rural vs urban), and chronic disease count (0–1 vs ≥ 2), with each subgroup-specific model adjusted for the remaining covariates. Multiplicative interaction was assessed by including cross-product terms in the model. Additive interaction was evaluated using the relative excess risk due to interaction (RERI) and the attributable proportion, with 95% CIs obtained by parametric bootstrap resampling. Kaplan-Meier curves were constructed for both outcomes across the four exposure groups, with censoring indicated by tick marks.

All analyses were performed using Python 3.13 (statsmodels), STATA 18.0, and R 4.6.1. A two-sided P value < 0.05 was considered statistically significant.

Results

Study population

The final analytic cohort included 4,161 participants (mean age 67.2 ± 6.1 years; 52.0% men). Of these, 1,401 (33.7%) had depressive symptoms, 768 (18.5%) had sarcopenia, and 316 (7.6%) had both. The distribution of the four exposure groups was: 2,308 (55.5%) no depression/no sarcopenia, 452 (10.9%) sarcopenia only, 1,085 (26.1%) depression only, and 316 (7.6%) depression plus sarcopenia (Table 1). Compared with the no-depression/no-sarcopenia group, participants in the depression plus sarcopenia group were older, had lower BMI and skeletal muscle mass index, were more likely to be female, unmarried, and rural residents, and had a higher prevalence of most chronic conditions, more cognitive impairment, shorter sleep duration, and more ADL and IADL difficulties at baseline (Table 1).

Table 1
Baseline characteristics of participants by depression and sarcopenia status (n = 4,161)

Variable	Overall (n = 4,161)	Non-dep/Non-sarc (n = 2,308)	Sarc only (n = 452)	Dep only (n = 1,085)	Dep+Sarc (n = 316)	P
Age, years	67.2 ± 6.1	66.5 ± 5.6	71.5 ± 7.0	66.2 ± 5.5	70.4 ± 7.0	< 0.001
Sex						< 0.001
Male	2162 (52.0)	1308 (56.7)	262 (58.0)	457 (42.1)	135 (42.7)	
Female	1999 (48.0)	1000 (43.3)	190 (42.0)	628 (57.9)	181 (57.3)	
Marital status						< 0.001
Married	3352 (80.6)	1958 (84.8)	339 (75.0)	847 (78.1)	208 (65.8)	
Not married	809 (19.4)	350 (15.2)	113 (25.0)	238 (21.9)	108 (34.2)	
Education level						< 0.001
Primary school or below	2328 (55.9)	1136 (49.2)	282 (62.4)	679 (62.6)	231 (73.1)	
Junior high school	1073 (25.8)	646 (28.0)	99 (21.9)	268 (24.7)	60 (19.0)	
Senior high school or above	760 (18.3)	526 (22.8)	71 (15.7)	138 (12.7)	25 (7.9)	
Residence						< 0.001
Rural	2589 (62.2)	1310 (56.8)	331 (73.2)	704 (64.9)	244 (77.2)	
Urban	1572 (37.8)	998 (43.2)	121 (26.8)	381 (35.1)	72 (22.8)	
Body mass index, kg/m ²	22.9 ± 3.9	24.0 ± 3.5	18.5 ± 1.5	23.8 ± 3.6	18.4 ± 1.7	< 0.001
Skeletal muscle mass index, kg/m ²	6.6 ± 1.2	6.9 ± 1.1	5.7 ± 1.0	6.6 ± 1.1	5.4 ± 1.0	< 0.001
Handgrip strength, kg	30.5 ± 9.4	32.4 ± 9.5	27.8 ± 8.4	28.9 ± 9.0	26.0 ± 7.8	< 0.001
Smoking status						< 0.001
Never	2353 (56.5)	1293 (56.0)	213 (47.1)	668 (61.6)	179 (56.6)	
Former	466 (11.2)	287 (12.4)	52 (11.5)	108 (10.0)	19 (6.0)	
Current	1342 (32.3)	728 (31.5)	187 (41.4)	309 (28.5)	118 (37.3)	
Current drinking	1672 (40.2)	967 (41.9)	196 (43.4)	395 (36.4)	114 (36.1)	0.004
CESD-10 score	7.9 ± 5.9	4.4 ± 2.8	4.7 ± 2.9	14.6 ± 4.1	15.1 ± 4.5	< 0.001
Cognition score	10.3 ± 4.4	11.2 ± 4.2	9.0 ± 4.5	9.6 ± 4.2	7.5 ± 4.3	< 0.001
Nighttime sleep duration, h	6.3 ± 1.9	6.6 ± 1.7	6.5 ± 1.9	5.8 ± 2.0	5.5 ± 2.2	< 0.001
Chronic disease count	1.5 ± 1.4	1.3 ± 1.3	1.0 ± 1.1	1.9 ± 1.6	1.5 ± 1.3	< 0.001
Hypertension	1282 (30.8)	750 (32.5)	70 (15.5)	396 (36.5)	66 (20.9)	< 0.001
Diabetes	288 (6.9)	166 (7.2)	6 (1.3)	110 (10.1)	6 (1.9)	< 0.001
Dyslipidemia	395 (9.5)	242 (10.5)	11 (2.4)	126 (11.6)	16 (5.1)	< 0.001
Heart disease	583 (14.0)	305 (13.2)	40 (8.8)	202 (18.6)	36 (11.4)	< 0.001
Stroke	105 (2.5)	49 (2.1)	7 (1.5)	41 (3.8)	8 (2.5)	0.017
Arthritis	1357 (32.6)	656 (28.4)	104 (23.0)	476 (43.9)	121 (38.3)	< 0.001
Psychiatric disease	51 (1.2)	19 (0.8)	2 (0.4)	26 (2.4)	4 (1.3)	< 0.001
Data are presented as mean ± SD or number (%). P values were calculated using one-way analysis of variance for continuous variables and chi-square tests for categorical variables. Depression was defined as a CESD-10 score ≥ 10, and sarcopenia was defined according to the Asian Working Group for Sarcopenia 2019 criteria. ADL, activities of daily living; CESD-10, 10-item Center for Epidemiologic Studies Depression Scale; SD, standard deviation.						

Variable	Overall (n = 4,161)	Non-dep/Non-sarc (n = 2,308)	Sarc only (n = 452)	Dep only (n = 1,085)	Dep+Sarc (n = 316)	P
Bodily pain	1142 (27.4)	402 (17.4)	80 (17.7)	499 (46.0)	161 (50.9)	< 0.001
IADL difficulty	719 (17.3)	293 (12.7)	90 (19.9)	246 (22.7)	90 (28.5)	< 0.001

Data are presented as mean $\pm$ SD or number (%). P values were calculated using one-way analysis of variance for continuous variables and chi-square tests for categorical variables. Depression was defined as a CESD-10 score $\geq$ 10, and sarcopenia was defined according to the Asian Working Group for Sarcopenia 2019 criteria. ADL, activities of daily living; CESD-10, 10-item Center for Epidemiologic Studies Depression Scale; SD, standard deviation.

Incidence of ADL disability and all-cause mortality

During a median follow-up of 7.0 years, 1,651 (39.7%) participants developed ADL disability and 521 (12.5%) died. The incidence of ADL disability was lowest in the no-depression/no-sarcopenia group (31.9%) and highest in the depression plus sarcopenia group (57.0%). The corresponding all-cause mortality rates were 10.2% and 22.5%, respectively (Fig. 1). The Kaplan-Meier curves confirmed that the four exposure groups were clearly separated for both outcomes, with the depression plus sarcopenia group having the lowest event-free probability and overall survival; the log-rank test indicated significant differences across groups for both outcomes ($P < 0.001$) (Fig. 2).

Independent and joint associations of depression and sarcopenia with ADL disability and all-cause mortality

Table 2 presents the Cox regression results for the primary outcome. Compared with the no-depression/no-sarcopenia group, the crude HRs for ADL disability were 1.21 (95% CI 1.07–1.36) for sarcopenia only, 1.87 (1.69–2.06) for depression only, and 2.11 (1.79–2.48) for depression plus sarcopenia. The association of depression with ADL disability remained robust after sequential adjustment, with HRs of 1.82 (1.65–2.00) after adjustment for age and sex (Model 1), 1.76 (1.59–1.94) after further adjustment for sociodemographic and behavioral factors (Model 2), and **1.37 (1.23–1.53)** in the fully adjusted model (Model 3). The depression plus sarcopenia group showed a substantially elevated HR in Model 1 (1.73, 1.46–2.04) and Model 2 (1.82, 1.51–2.19), attenuating to **1.40 (1.15–1.70)** in the fully adjusted model (P for trend < 0.001). Sarcopenia alone was not independently associated with ADL disability in adjusted models.

Table 2
Cox regression of depression, sarcopenia, and their combination on incident ADL disability and all-cause mortality

Variable	Crude Model HR (95% CI)	Model 1 HR (95% CI)	Model 2 HR (95% CI)	Model 3 HR (95% CI)
ADL disability, Depression	1.87 (1.69–2.06)***	1.82 (1.65–2.00)***	1.76 (1.59–1.94)***	1.37 (1.23–1.53)***
ADL disability, Sarcopenia	1.21 (1.07–1.36)**	1.01 (0.89–1.15)	1.06 (0.91–1.23)	1.01 (0.87–1.18)
ADL disability, Depression + Sarcopenia	2.11 (1.79–2.48)***	1.73 (1.46–2.04)***	1.82 (1.51–2.19)***	1.40 (1.15–1.70)***
All-cause mortality, Depression	1.11 (0.93–1.33)	1.19 (0.99–1.42)	1.12 (0.93–1.35)	1.03 (0.84–1.25)
All-cause mortality, Sarcopenia	2.16 (1.79–2.59)***	1.41 (1.16–1.72)***	1.20 (0.94–1.54)	1.19 (0.92–1.53)
All-cause mortality, Depression + Sarcopenia	2.26 (1.74–2.95)***	1.66 (1.26–2.18)***	1.38 (1.00–1.90)*	1.27 (0.91–1.77)

Reference groups: no depression (for depression), no sarcopenia (for sarcopenia), neither condition (for depression + sarcopenia). Crude Model: crude; Model 1: adjusted for age and sex; Model 2: further adjusted for marital status, education, residence, smoking (never/former/current), alcohol drinking, and body mass index; Model 3 (fully adjusted): further adjusted for chronic disease count, sleep duration, cognition, pain, and psychiatric disease. Missing covariate values were handled by multiple imputation with chained equations (10 imputed datasets; estimates combined by Rubin's rules). HR, hazard ratio; CI, confidence interval. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

For all-cause mortality (Table 2), the crude HR for sarcopenia only was 2.16 (1.79–2.59), attenuating to 1.41 (1.16–1.72) after age and sex adjustment. In the fully adjusted model, the association of sarcopenia with mortality was attenuated and no longer reached statistical significance (HR 1.19, 0.92–1.53). Depression alone was not independently associated with mortality in any model (fully adjusted HR 1.03, 0.84–1.25). The co-occurrence of depression and sarcopenia was associated with the highest crude HR (2.26, 1.74–2.95) and a substantially elevated age- and sex-adjusted HR (1.66, 1.26–2.18); in the fully adjusted model, the HR was 1.27 (0.91–1.77, $P = 0.17$).

Subgroup analyses

Stratified analyses by sex and age are presented in Fig. 3a and 3b. The association of depression only with ADL disability was significant in both men (adjusted HR 1.31, 1.08–1.58) and women (1.40, 1.18–1.65) and among adults aged 60–69 years (1.40, 1.20–1.63), but not in those aged ≥ 70 years (1.23, 0.99–1.53). The combined exposure was particularly strongly associated with ADL disability among adults aged 60–69

years (HR 2.02, 1.54–2.65). For all-cause mortality, the combined exposure was significantly associated with higher risk in adults aged ≥ 70 years (HR 1.63, 1.03–2.59), and sarcopenia alone was associated with higher mortality in this age group (HR 1.51, 1.02–2.22); no significant associations were observed in adults aged 60–69 years. Across residence strata, associations were broadly similar and no significant interactions were detected; for chronic disease count, the association of depression with ADL disability was stronger among those with 0–1 conditions (HR 1.57, 1.31–1.88) than among those with ≥ 2 (1.22, 1.03–1.44; interaction $P = 0.015$), and the associations of sarcopenia (1.79, 1.20–2.65) and the combined exposure (1.80, 1.11–2.91) with mortality were confined to the 0–1 stratum (Fig. 3a and 3b).

Tests for multiplicative interaction between depression and sarcopenia were not statistically significant for either ADL disability ($P = 0.98$) or all-cause mortality ($P = 0.70$). RERI for the joint exposure was -0.04 (95% CI -0.38 to 0.30) for ADL disability and 0.17 (95% CI -0.37 to 0.70) for mortality, indicating no strong evidence of additive interaction (Supplementary Material, sTable 4).

Sarcopenia component analyses

To identify the sarcopenia components driving the observed associations, low grip strength, low gait speed, and low muscle mass were examined separately in fully adjusted models (Fig. 4). For ADL disability, both low grip strength (HR 1.28, 95% CI 1.12–1.47) and low gait speed (1.24, 1.09–1.40) were independently associated with higher risk, whereas low muscle mass was not (0.96, 0.83–1.12). For all-cause mortality, low grip strength was the only component independently associated with higher risk (**HR 1.44, 1.15–1.79; $P = 0.002$**), whereas low gait speed (1.12, 0.90–1.39) and low muscle mass (1.18, 0.91–1.53) were not (Supplementary Material, sTable 6).

In joint analyses of depression with each sarcopenia component (sFigure 2), the combination of depression with low gait speed (HR 1.55, 1.29–1.86) or low grip strength (1.51, 1.25–1.83) conferred the highest risk of ADL disability, exceeding that of either condition alone; a significant negative multiplicative interaction was observed for depression $\times$ low grip strength ($P = 0.011$). For all-cause mortality, low grip strength alone (HR 1.57, 1.19–2.07) was more strongly associated with risk than its combination with depression (1.35, 0.96–1.88), and no significant interactions were detected for any component (all $P > 0.3$). These findings indicate that muscle strength is the principal sarcopenia component driving mortality risk, whereas depression and impaired muscle function jointly contribute to ADL disability.

Discussion

In this prospective analysis of 4,161 community-dwelling Chinese adults aged ≥ 60 years followed for up to 7 years, depressive symptoms were independently associated with subsequent ADL disability (fully adjusted HR 1.37, 1.23–1.53), whereas neither depression nor the overall sarcopenia diagnosis independently predicted all-cause mortality. Notably, among the three sarcopenia components, low grip strength was independently associated with higher all-cause mortality (fully adjusted HR 1.44, 1.15–1.79), underscoring the prognostic importance of muscle strength. The co-occurrence of depression and sarcopenia conferred the highest absolute and relative risks for both outcomes, with the strongest association for ADL disability among adults aged 60–69 years (HR 2.02, 1.54–2.65), and associations with mortality were most pronounced in participants with fewer than two chronic conditions. These findings suggest that depression and sarcopenia contribute additively rather than synergistically to functional decline and mortality, and that their combined presence identifies a high-risk subgroup that may benefit from integrated screening.

Our finding that depression independently predicted ADL disability is consistent with prior literature. A 2024 meta-analysis of prospective cohorts reported a 1.5- to 2-fold increased risk of incident ADL and IADL limitations associated with depression (Yan et al., 2025), and longitudinal studies in Chinese cohorts have similarly shown that depression predicts accelerated trajectories of functional disability (He et al., 2025). The fully adjusted HR of 1.37 in our study is somewhat lower than effect estimates reported in earlier cohorts, which likely reflects the more conservative analytic strategy adopted here—multiple imputation for missing covariates, adjustment for sarcopenia and a broad range of potential confounders, and restriction to participants free of baseline disability—thereby more accurately isolating the independent effect of depression. The persistence of the association after adjustment for sarcopenia suggests that depression contributes to functional decline through pathways beyond skeletal muscle loss, plausibly including reduced physical activity and social engagement, poor nutritional intake, disturbed sleep, elevated cortisol and inflammatory load, and diminished executive function that compromises adaptive behavior and care-seeking (Alexopoulos, 2019). Supporting this interpretation, a sensitivity analysis using persistent depression (CESD-10 ≥ 10 at both the 2011 and 2013 waves) yielded a stronger fully adjusted HR of 1.54 (95% CI 1.35–1.76) for ADL disability than the single-time-point definition, and E-value calculations (2.09–2.45) indicated that an unmeasured confounder would need to be associated with both exposure and outcome by a risk ratio exceeding 2 to fully explain away these associations (VanderWeele and Ding, 2017). The stronger effect of persistent relative to single-wave depression is consistent with a dose–response-like relationship and reinforces the causal interpretation of the depression–disability association. Depression and sarcopenia are also closely inter-related, with a 9-year longitudinal study from China reporting substantially higher odds of possible sarcopenia among depressed older adults (He et al., 2025). In contrast, the crude and age- and sex-adjusted associations of sarcopenia with all-cause mortality in our cohort (HR 2.16 and 1.41, respectively) were consistent with previous meta-analyses reporting approximately 1.5- to 1.7-fold higher mortality among older adults with sarcopenia (Kojima et al., 2022; Liu et al., 2017; Xu

et al., 2022), including a large UK Biobank analysis (Linge et al., 2021). However, the association was attenuated to non-significance after full adjustment (HR 1.19, 0.92–1.53). This attenuation is noteworthy and suggests that much of the mortality gradient conferred by sarcopenia in older Chinese adults is explained by co-occurring sociodemographic disadvantage, behavioral risk factors, and chronic comorbidity, rather than by muscle loss per se. This interpretation is supported by the tight coupling between sarcopenia and the broader construct of frailty—an accumulation of deficits across multiple physiological systems—in which muscle loss is but one manifestation (Cruz-Jentoft et al., 2019; Yu et al., 2026). Our finding aligns with a Japanese cohort in which the association of sarcopenia with mortality was likewise attenuated after controlling for comorbidity and health-related factors (Kitamura et al., 2021), underscoring that the prognostic value of sarcopenia for survival may be substantially confounded by the multisystem vulnerability it represents.

The combination of depression and sarcopenia was associated with the highest event rates for both outcomes, with a 73% and 66% higher risk of ADL disability and mortality, respectively, in age- and sex-adjusted models. The absence of significant multiplicative or additive interaction (multiplicative $P = 0.98$ and 0.70 ; RERI = 0.04 and 0.17 for ADL disability and mortality, respectively) indicates that the joint effect is largely additive rather than synergistic. This is consistent with the conceptual model that depression and sarcopenia operate through partially distinct but converging pathways: depression drives functional decline primarily through behavioral disengagement, dysregulated stress biology, and impaired self-care, whereas sarcopenia acts through reduced muscle mass and strength that directly compromise mobility and physiological reserve (Wang et al., 2023; Zhu et al., 2025). Their co-occurrence therefore may represent an accumulation of independent risk rather than a multiplicative vicious cycle, at least over the 7-year horizon examined here. This is in line with growing evidence that sarcopenia is a robust predictor of subsequent disability and falls—both in Chinese cohorts (Song et al., 2025) and in global meta-analyses of sarcopenia-related factors (Gao et al., 2021)—and that its adverse effects may be compounded by co-occurring depression (He et al., 2025). The additive nature of the association carries important public health implications: interventions targeting either condition could yield independent benefits in reducing both functional and survival outcomes, and the expected population-level impact of combined intervention programmes would be at least the sum of their component effects. Notably, the combined exposure was most strongly associated with ADL disability in adults aged 60–69 years (HR 2.02, 1.54–2.65), whereas for mortality, significant associations were observed in those aged ≥ 70 years (HR 1.63, 1.03–2.59, for the combined exposure and 1.51, 1.02–2.22, for sarcopenia alone). The observation that low grip strength, rather than low gait speed or low muscle mass, independently predicted all-cause mortality is consistent with evidence that muscle strength is the sarcopenia component most strongly associated with survival (Kojima et al., 2022; Linge et al., 2021). Component-specific and joint analyses provided complementary insights: the combination of depression with low gait speed (HR 1.55, 1.29–1.86) or low grip strength (1.51, 1.25–1.83) conferred the highest risk of ADL disability, whereas for mortality, low grip strength alone (HR 1.57, 1.19–2.07) outweighed its combination with depression (1.35, 0.96–1.88), further underscoring muscle strength as the principal sarcopenia component driving survival. The significant negative interaction between depression and low grip strength for ADL disability ($P = 0.011$) indicates that their co-occurrence did not amplify risk beyond an additive pattern, consistent with the findings for the overall sarcopenia diagnosis. Notably, subgroup analyses suggested effect modification by comorbidity burden, consistent with evidence that multimorbidity accelerates functional decline (Huang and He, 2026): the associations of sarcopenia alone (HR 1.79, 1.20–2.65) and its combination with depression (1.80, 1.11–2.91) with mortality were confined to participants with 0–1 chronic conditions, and the depression–ADL disability association was stronger in this group (HR 1.57, 1.31–1.88, vs 1.22, 1.03–1.44, among those with ≥ 2 conditions; interaction $P = 0.015$). A plausible explanation is that in multimorbid participants, the already high baseline risk of mortality and disability attributable to existing diseases attenuates the incremental contribution of these exposures; competing mortality risk and residual confounding by comorbidity severity may further dilute the associations. These findings imply that screening for sarcopenia and depression may be particularly informative in community-dwelling older adults with few chronic conditions, in whom these exposures represent relatively more modifiable determinants of downstream outcomes. The absence of significant effect modification by residence supports the generalizability of the main findings across urban and rural settings. This transitional age group is often under-represented in geriatric research yet represents a critical window for early intervention: the biological processes underlying sarcopenia (e.g., muscle protein anabolism resistance, mitochondrial dysfunction) and the psychological vulnerability to depression are potentially more reversible in the early post-retirement years than in advanced age (Cruz-Jentoft and Sayer, 2019; Fang et al., 2026). Previous work in Japanese older adults requiring long-term care similarly reported that the combination of sarcopenia and depression was associated with more severe disability than either condition alone (Shiba et al., 2023), and the direction of our age-stratified findings suggests that the window of opportunity for combined screening may be widest shortly after the sixth decade of life. Integrated screening for depression and sarcopenia in this age group—for example, combining a brief depression questionnaire with handgrip dynamometry during community health examinations—followed by tailored interventions—resistance exercise and protein supplementation as recommended by international sarcopenia guidelines (Zanker et al., 2023), combined with structured physical activity and psychotherapy for depression (Qin et al., 2026)—may help delay or prevent downstream functional decline and premature mortality. Such combined approaches warrant evaluation in randomized trials.

This study has several strengths, including a large, nationally representative Chinese cohort, rigorous outcome ascertainment through official death-tracking records, sarcopenia assessment according to the AWGS 2019 algorithm with all three components, and the simultaneous examination of ADL disability and mortality within a common analytic sample. Several limitations should also be acknowledged. The observational design precludes causal inference, and residual confounding by unmeasured factors (e.g., detailed medication use, dietary

quality) cannot be excluded. Depression and sarcopenia were assessed only at baseline, so changes over follow-up were not captured. Muscle mass was estimated from an anthropometric equation rather than directly measured, although the equation has been validated against dual-energy X-ray absorptiometry in Chinese adults (Luo and Yao, 2025). Finally, the number of deaths in some subgroups was limited, and follow-up was truncated at 2018, which may have constrained statistical power and the generalizability of longer-term effects.

Conclusion

Depression and sarcopenia contribute additively to ADL disability and mortality in Chinese older adults, and their co-occurrence—particularly in adults aged 60–69 years—identifies a high-risk subgroup that may benefit from integrated screening and early intervention.

Abbreviations

ADL
activities of daily living
AWGS
Asian Working Group for Sarcopenia
CESD
10–10–item Center for Epidemiologic Studies Depression Scale
CHARLS
China Health and Retirement Longitudinal Study
CI
confidence interval
HR
hazard ratio
IADL
instrumental activities of daily living
RERI
relative excess risk due to interaction
SD
standard deviation
SMI
skeletal muscle mass index

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and all participants provided written informed consent.

Consent for publication

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

Availability of data and materials

This study used data from the China Health and Retirement Longitudinal Study (CHARLS), which are publicly available to registered researchers at <https://charls.pku.edu.cn/>. The analysis code and derived analytic dataset are available from the corresponding author upon reasonable request. Clinical trial number: not applicable.

Competing Interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Author contributions

All authors made substantial contributions to the conception, design, analysis, and interpretation of data. XL: study design, writing—original draft. BL: writing—original draft. SY: formal analysis, writing—original draft. BG: data curation, formal analysis. KY: writing—review and editing. All authors approved the final version of the manuscript.

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Figures

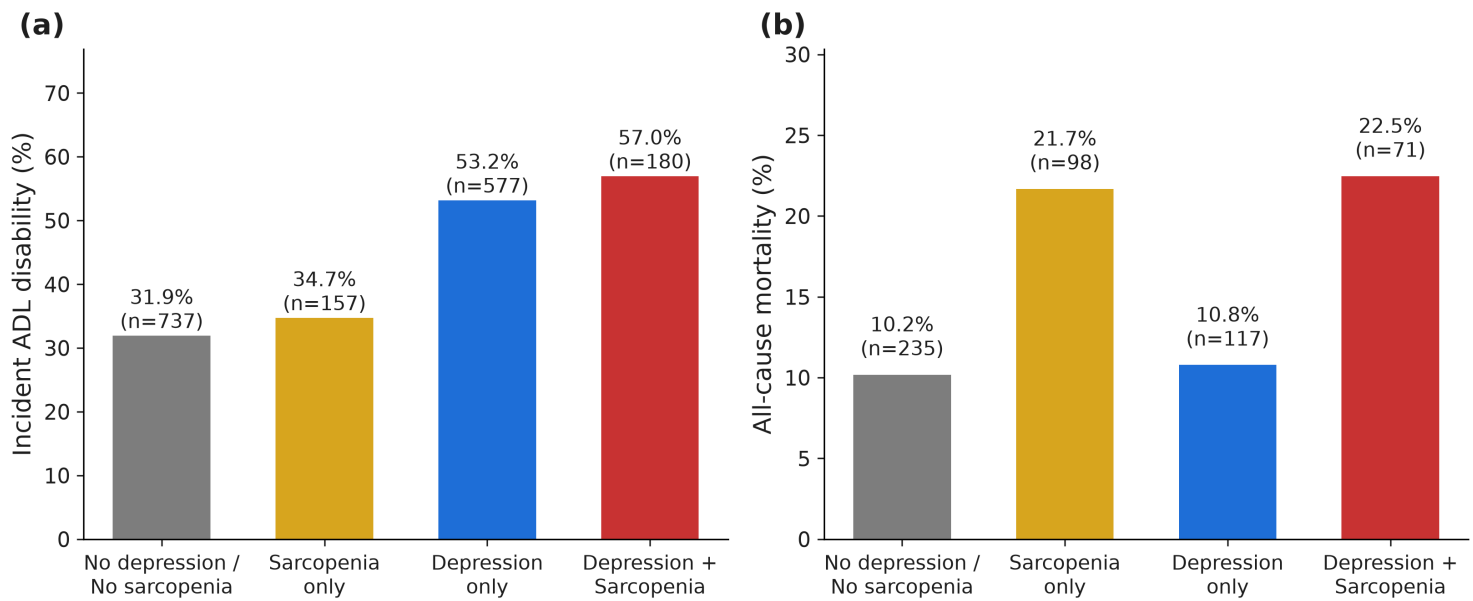


Figure 1

Incidence of ADL disability (a) and all-cause mortality (b) across the four exposure groups defined by depression and sarcopenia status.

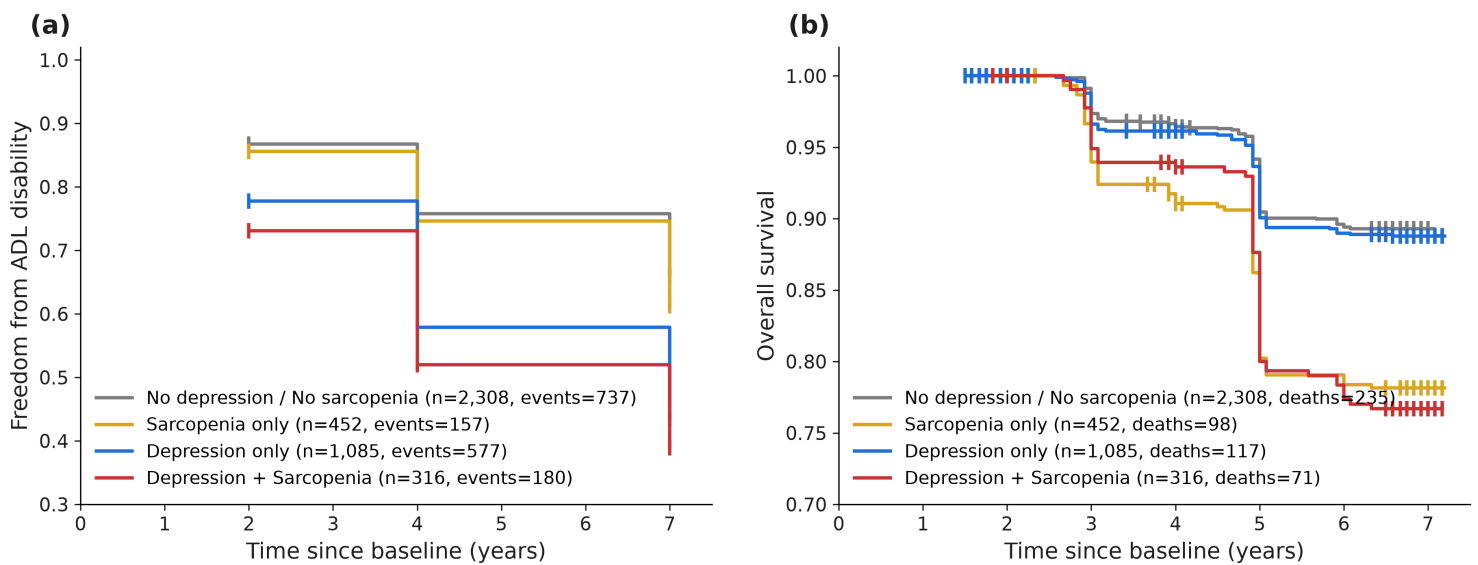
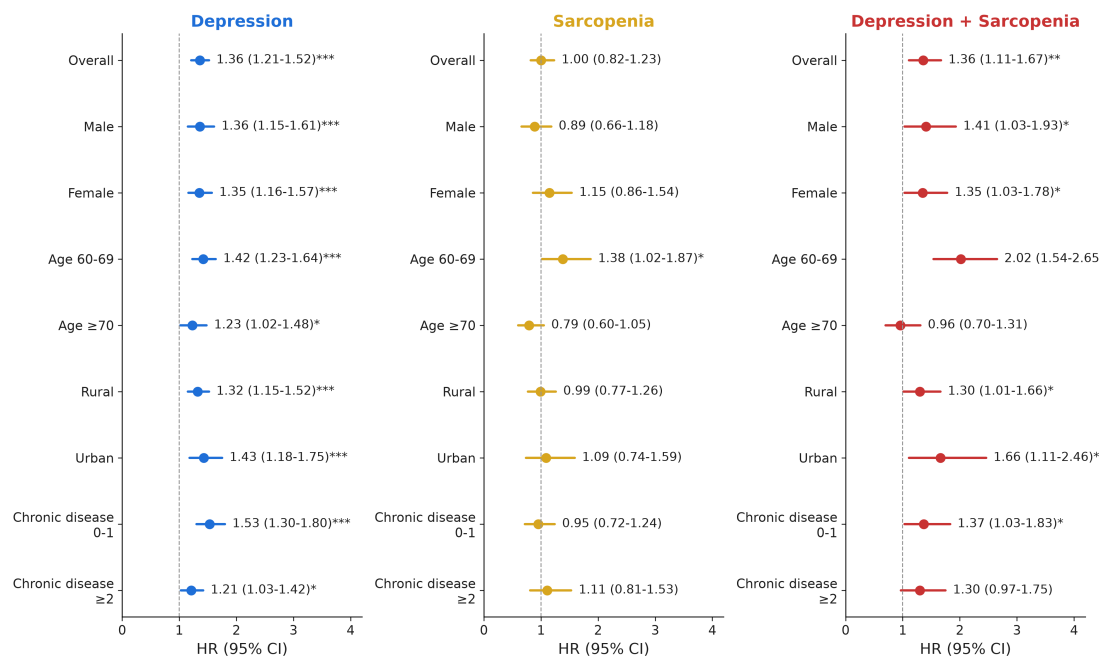
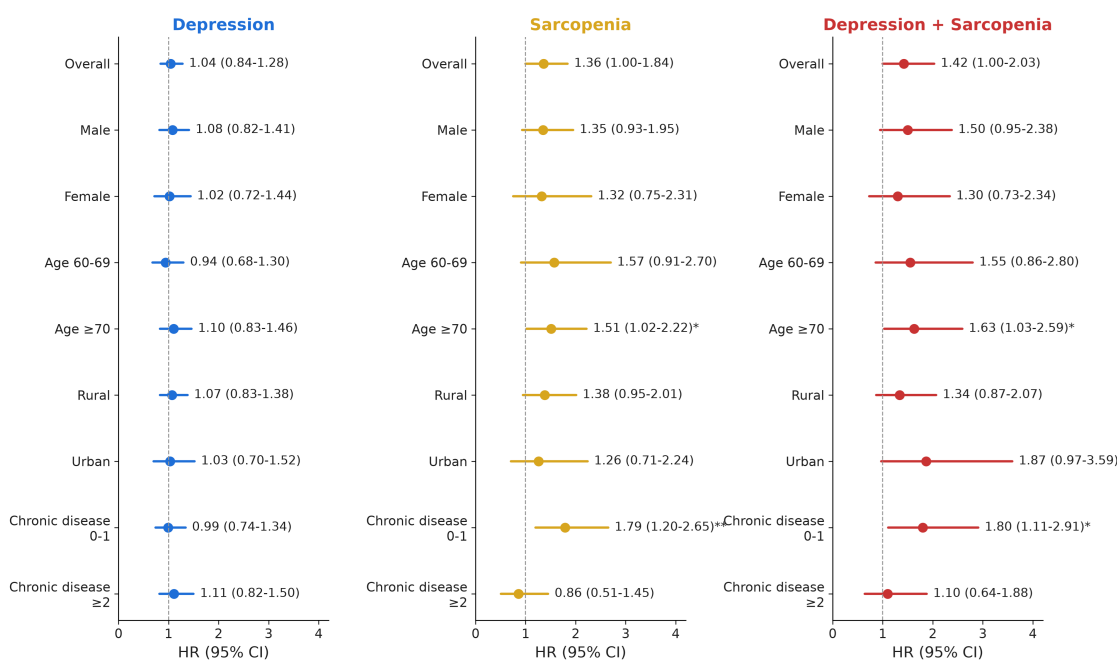


Figure 2

Kaplan-Meier curves for freedom from ADL disability (a) and overall survival (b) by depression and sarcopenia status. Tick marks indicate right-censored observations.



A



B

Figure 3

a. Subgroup-specific hazard ratios (95% CIs) of the associations of depression, sarcopenia, and their combination with incident ADL disability, stratified by sex, age, residence, and chronic disease count. Each subgroup-specific model was adjusted for age, sex, marital status, education, residence, smoking (never/former/current), alcohol drinking, body mass index, chronic disease count, sleep duration, cognition, pain, and psychiatric disease, excluding the stratification variable.

b. Subgroup-specific hazard ratios (95% CIs) of the associations of depression, sarcopenia, and their combination with all-cause mortality, stratified by sex, age, residence, and chronic disease count. Each subgroup-specific model was adjusted for age, sex, marital status, education,

residence, smoking (never/former/current), alcohol drinking, body mass index, chronic disease count, sleep duration, cognition, pain, and psychiatric disease, excluding the stratification variable.

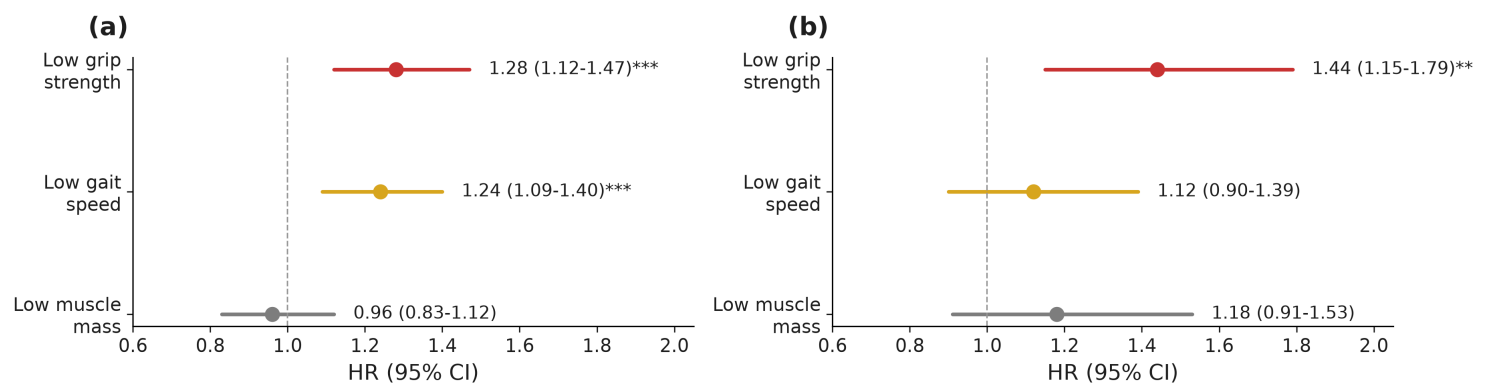


Figure 4

Associations of the three sarcopenia components—low grip strength, low gait speed, and low muscle mass—with (a) ADL disability and (b) all-cause mortality in fully adjusted models (Model 3). Hazard ratios (HRs) and 95% confidence intervals (CIs) are shown; the dashed vertical line indicates HR = 1.0. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

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