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Research on Musculoskeletal Pain and the Risk of Sarcopenia and Possible Sarcopenia: Evidence from CHARLS

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Article

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Abstract

Background

Sarcopenia is a condition characterized by reduced skeletal muscle mass, decreased muscle strength, and impaired physical performance; identifying and intervening in its preclinical stages is crucial for halting disease progression. Chronic musculoskeletal pain is highly prevalent among older adults and can affect muscle health through inflammatory pathways, reduced physical activity, and altered neuromodulation. Longitudinal evidence regarding the relationship between pain and the various stages of sarcopenia is currently lacking.

Objective

This study aimed to investigate the association between the number of pain sites and the risk of sarcopenia and pre-sarcopenia, as well as to analyze the role of pain-related factors across different disease stages.

Methods

Data from Waves 1–3 of the China Health and Retirement Longitudinal Study (CHARLS) were used, including participants aged ≥ 45 years who underwent at least two sarcopenia assessments. Sarcopenia status was categorized as non-sarcopenia, pre-sarcopenia, and sarcopenia according to the AWGS 2019 criteria. Pain status was classified based on the number of affected sites, including no pain, single-site pain, and multi-site pain. Cox proportional hazards models were employed to assess longitudinal risks, and multinomial logistic regression was used to analyze cross-sectional associations between pain and different sarcopenia stages, adjusting for sociodemographic, lifestyle, and chronic disease covariates. Model performance was evaluated using ROC curves and Wald tests, and clinical applicability was assessed through decision curve analysis (DCA).

Results

Multi-site pain was found to significantly increase the risk of both possible sarcopenia and sarcopenia, exhibiting a dose–response relationship. The longitudinal Cox model indicated that, compared to individuals without pain, those with pain had significantly higher risks of possible sarcopenia (HR = 1.191, 95% CI: 1.123–1.264) and sarcopenia (HR = 1.253, 95% CI: 1.128–1.393). Multinomial logistic regression revealed that, compared to individuals without pain, both single-site and multi-site pain significantly increased the risks of possible sarcopenia (OR = 2.10 and 1.97) and sarcopenia (OR = 3.05 and 2.32) (all $P < 0.001$), with these associations remaining significant after full adjustment. The ROC curve demonstrated that the model exhibited moderate discriminatory ability for sarcopenia. DCA

indicated that the model had clinical applicability within a specific probability threshold range, with factors such as pain providing predictive value for possible sarcopenia and sarcopenia, particularly for sarcopenia.

Conclusion

Musculoskeletal pain, especially multi-site pain, serves as a significant independent risk factor for both possible sarcopenia and sarcopenia. Pain may contribute to the onset and progression of sarcopenia, highlighting the need for enhanced pain assessment and management in sarcopenia prevention and control to mitigate disease burden through early intervention.

Introduction

Sarcopenia is a progressive, generalized condition characterized by the loss of muscle mass, reduced muscle strength, and functional decline, potentially leading to mobility limitations and, in severe cases, death [1]. It represents a major public health challenge in aging societies [2]. Research has reported that the prevalence of sarcopenia ranges from 5% to 22% [3–5]. The prevalence of sarcopenia among community-dwelling older adults aged ≥ 60 years in China reaches 10.4% [6]. Sarcopenia increases the risks of hospitalization, falls, disability, reduced quality of life, and mortality, and is closely associated with various adverse outcomes [7–9]. Sarcopenia caused solely by aging is referred to as primary sarcopenia, whereas that resulting from other conditions—such as diabetes, chronic obstructive pulmonary disease, cirrhosis, chronic heart failure, cancer, or depression—is termed secondary sarcopenia [10].

It is estimated that more than 30% of older adults worldwide are affected by musculoskeletal pain [11]. Although existing studies have reported a close association between chronic or musculoskeletal pain and the development and progression of sarcopenia, inconsistent findings across studies suggest that this relationship may be modulated by factors such as age, sex, and underlying diseases [12]. In 2019, the Asian Working Group introduced the concept of “possible sarcopenia,” defined as decreased muscle strength or physical performance alone, intended for use in primary care and health promotion to facilitate early intervention and management [13]. Previous studies have not examined the relationship between musculoskeletal pain and possible sarcopenia. Additionally, studies exploring the association between the number of pain sites and sarcopenia or possible sarcopenia are lacking. Moreover, no studies have further explored pain-related variables such as arthritis status or the use of arthritis medications. This study is the first to systematically investigate, in a large longitudinal cohort, the relationship between the number of pain sites and the risk of different stages of sarcopenia (possible and confirmed), and to verify the robustness of the findings through multivariable models.

The study population was derived from the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative longitudinal survey initiated in 2011. CHARLS aims to assess the social, economic, and health status of community-dwelling residents aged 45 years and older in China, covering

150 counties or districts and 450 villages across 28 provinces. Participants undergo follow-up surveys every two to three years through face-to-face computer-assisted personal interviews, and five waves of data have been released to date. All interviewers received training from CHARLS staff at Peking University and conducted interviews strictly following the survey manual using the computer-assisted personal interview (CAPI) system. All participants completed standardized questionnaires that collected sociodemographic, lifestyle, and health-related information. The study protocol was approved by the Peking University Institutional Review Board (IRB00001052-11015), and written informed consent was obtained from all participants prior to the survey. The conduct of this study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Methods

Study population

Among the five waves of CHARLS data, Waves 1 to 3 included the physical and functional measures required to assess sarcopenia; therefore, these three waves were selected for this study. The inclusion criteria were: (1) age ≥ 45 years; and (2) completion of at least two assessments. The longitudinal analysis excluded participants with sarcopenia or possible sarcopenia at baseline and those with missing covariates. The cross-sectional analysis included participants from 2015, excluding those with missing covariates. The participant selection flowchart is presented in Fig. 1.

Diagnosis of sarcopenia status

According to the AWGS 2019 criteria, normal muscle strength and normal performance on the chair stand test are classified as non-sarcopenia. Possible sarcopenia is defined as low muscle strength or low physical performance assessed by the chair stand test, without fulfilling the diagnostic criteria for sarcopenia. Sarcopenia is defined as low muscle mass accompanied by low muscle strength or poor physical performance.

Handgrip strength is used to assess skeletal muscle strength. Grip strength was measured using a bilateral dynamometer (Nantong Yuejian Physical Measurement Instrument Co., Ltd.), expressed in kilograms. Each participant's grip strength was measured twice on both hands, and the average of the maximal valid values was used. Low grip strength was defined as < 28 kg in men and < 18 kg in women. Physical performance was assessed using the chair stand test, with low performance defined as ≥ 12 seconds for five repeated chair stands.

Muscle mass was estimated using appendicular skeletal muscle mass (ASM). The consistency between the ASM equation and dual-energy X-ray absorptiometry has been validated in previous studies [14–15]. Low muscle mass was defined as the lowest 20% of height-adjusted ASM (ASM/height²). Ultimately, ASM/Ht² < 5.30 kg/m² for women and < 7.03 kg/m² for men was classified as low muscle mass.

The formula was: ASM = 0.193 × weight (kg) + 0.107 × height (cm) − 4.157 × sex (1 for male, 2 for female) − 0.037 × age (years) − 2.631.

Covariate

Sociodemographic characteristics, lifestyle and health-related factors, and clinical information were collected using a structured questionnaire. Trained staff performed physical examinations on each participant and collected venous blood samples. Sociodemographic information included sex (male/female), age, marital status (married/single), residence (urban/rural), education level (below junior high school/high school & vocational training/higher education), and employment status (employed/unemployed/retired). Lifestyle and health-related factors included social activity (active/inactive), physical activity (insufficient/sufficient), smoking status (never/former/current), drinking status (never/former/current), and BMI. Clinical information included chronic disease status, presence of pain (yes/no), arthritis or rheumatism status (yes/no), and use of arthritis or rheumatism medications (yes/no). Chronic disease status included hypertension, diabetes, heart disease, lung disease, history of stroke, and physician-diagnosed cancer. The number of chronic comorbidities was quantified and categorized into three groups: “none,” “one disease,” and “two or more diseases.” Body mass index (BMI) was categorized into four groups: underweight (< 18.5 kg/m²), normal (18.5–23.9 kg/m²), overweight (24.0–27.9 kg/m²), and obese (≥ 28.0 kg/m²) [16].

Statistical analysis

Statistical analysis methods

All analyses were performed using R software (version 4.4.2, R Foundation for Statistical Computing, Vienna, Austria).

Descriptive analysis

Participants were categorized into three groups based on sarcopenia severity: non-sarcopenia, possible sarcopenia, and sarcopenia. Categorical variables were expressed as frequencies and percentages, and group differences were compared using the chi-square (χ^2) test. Continuous variables with a normal distribution were presented as mean ± standard deviation, whereas skewed variables were presented as median (interquartile range). Depending on data distribution, t-tests/ANOVA or Wilcoxon/Kruskal–Wallis rank-sum tests were used. A two-tailed p-value < 0.05 was considered statistically significant.

Cox proportional hazards model

Participants who underwent at least two sarcopenia assessments and had no sarcopenia at baseline were included. The analyses were conducted in two scenarios:

Stratified analyses (non-sarcopenia vs. possible sarcopenia; non-sarcopenia vs. sarcopenia).

Multivariable Cox proportional hazards models were constructed based on univariable analysis, adjusting for age, sex, residence, marital status, education level, employment status, BMI, pain, arthritis, arthritis treatment, comorbidities, social activity, physical activity, alcohol consumption, and smoking. Findings were reported as hazard ratios (HRs) with corresponding 95% confidence intervals (CIs), and the proportional hazards assumption was evaluated.

Multinomial logistic regression

A multinomial logistic regression model (nnet::multinom()) was used to examine the association between pain status (no pain, single-site pain, multi-site pain) and different sarcopenia states. Results were expressed as odds ratios (ORs) with 95% confidence intervals (CIs). To assess potential multicollinearity among covariates in the regression models, the variance inflation factor (VIF) was calculated for each variable. A VIF < 10 indicated negligible multicollinearity.

Model evaluation

Model performance in discriminating different sarcopenia states was evaluated using ROC curves and AUC values (pROC package). Decision curve analysis (DCA, using the dcurves package) was employed to calculate the net benefits of each model across a range of threshold probabilities and to evaluate clinical applicability. The Wald test was used to compare differences in the effects of pain status across models. All statistical tests were two-sided, with $p < 0.05$ considered statistically significant.

Results

Baseline data

Table 1 presents the baseline characteristics of all participants, categorized according to sarcopenia status. A total of 12,486 participants were included at baseline, with 6,492 in the longitudinal analysis and 4,399 in the cross-sectional analysis. Among these 12,486 participants, the prevalence of possible sarcopenia and sarcopenia was 26.59% (3320/12486) and 10.23% (1277/12486), respectively. The median age of participants was 58 (51, 65), and individuals with possible or confirmed sarcopenia were significantly older than those without sarcopenia. There were 6,576 men (52.7%), while the proportion of women was higher in both the possible sarcopenia and sarcopenia groups. Other factors—including residence, education level, employment status, alcohol consumption, smoking, arthritis, comorbidities, and BMI—also showed statistically significant differences.

Table 1
Baseline characteristics of all participants, categorized by sarcopenia status

Characteristics	Total	Non-Sarcopenia	Possible Sarcopenia	Sarcopenia	
		N = 7,889[1]	N = 3,320[1]	N = 1,277[1]	p-value[2]
Age(y)	12,486	56 (49, 62)	60 (54, 66)	69 (62, 75)	< 0.001
Gender	12,486				< 0.001
Femal		3,888 (49%)	1,965 (59%)	723 (57%)	
Male		4,001 (51%)	1,355 (41%)	554 (43%)	
Marriage	12,486				< 0.001
Others		652 (8.3%)	419 (13%)	332 (26%)	
Married or Partnered		7,237 (92%)	2,901 (87%)	945 (74%)	
Residence area	12,486				< 0.001
Urban		2,909 (37%)	1,160 (35%)	308 (24%)	
Rural		4,980 (63%)	2,160 (65%)	969 (76%)	
Education	12,486				< 0.001
Below junior high school education		6,900 (87%)	3,090 (93%)	1,235 (97%)	
High school and vocational training		855 (11%)	209 (6.3%)	35 (2.7%)	
Higher education		134 (1.7%)	21 (0.6%)	7 (0.5%)	
Drinking	12,479				< 0.001
Non-drinker		4,383 (56%)	2,077 (63%)	777 (61%)	
Past drinker		2,922 (37%)	915 (28%)	362 (28%)	
Current drinker		580 (7.4%)	326 (9.8%)	137 (11%)	
Smoke	12,172				< 0.001
Non-smoke		4,621 (60%)	2,151 (67%)	753 (61%)	
Past smoker		2,440 (32%)	792 (25%)	384 (31%)	
Current smoker		644 (8.4%)	286 (8.9%)	101 (8.2%)	
Kruskal-Wallis rank sum test; Pearson's Chi-squared test					

Characteristics	Total	Non-Sarcopenia	Possible Sarcopenia	Sarcopenia	
		N = 7,889[1]	N = 3,320[1]	N = 1,277[1]	p-value[2]
Employment	12,148				< 0.001
Not working		1,326 (17%)	977 (31%)	474 (39%)	
Working		5,776 (75%)	1,949 (61%)	666 (55%)	
Retirement		634 (8.2%)	269 (8.4%)	77 (6.3%)	
Family income	7,836				< 0.001
Quartile 1(lowest)		830 (18%)	504 (23%)	278 (29%)	
Quartile 2		1,070 (23%)	633 (29%)	299 (31%)	
Quartile 3		1,435 (31%)	582 (27%)	246 (25%)	
Quartile 4(highest)		1,340 (29%)	476 (22%)	143 (15%)	
Non-communicable diseases	12,486				< 0.001
None		5,059 (64%)	1,647 (50%)	774 (61%)	
One		2,077 (26%)	1,055 (32%)	364 (29%)	
Two or more		753 (9.5%)	618 (19%)	139 (11%)	
Pain	12,486				< 0.001
No		5,879 (75%)	2,056 (62%)	780 (61%)	
One		604 (7.7%)	301 (9.1%)	106 (8.3%)	
More than One		1,406 (18%)	963 (29%)	391 (31%)	
Arthritis	12,486				< 0.001
No		5,477 (69%)	2,029 (61%)	813 (64%)	
Yes		2,412 (31%)	1,291 (39%)	464 (36%)	
Therapy of arthritis and rheumatoid disease	12,486				< 0.001
No		6,848 (87%)	2,681 (81%)	1,040 (81%)	
Yes		1,041 (13%)	639 (19%)	237 (19%)	
Physical inactivity	4,691				< 0.001
Kruskal-Wallis rank sum test; Pearson's Chi-squared test					

Characteristics	Total	Non-Sarcopenia	Possible Sarcopenia	Sarcopenia	
		N = 7,889[1]	N = 3,320[1]	N = 1,277[1]	p-value[2]
Low		659 (22%)	357 (30%)	137 (31%)	
Moderate		1,054 (35%)	408 (34%)	148 (34%)	
High		1,332 (44%)	440 (37%)	156 (35%)	
BMI	12,446				< 0.001
Underweight		361 (4.6%)	0 (0%)	407 (32%)	
Healthy weight		4,069 (52%)	1,549 (47%)	864 (68%)	
Overweight		2,489 (32%)	1,230 (37%)	5 (0.4%)	
Obesity		930 (12%)	541 (16%)	1 (< 0.1%)	
Uric Acid	7,871	259 (215, 310)	250 (211, 300)	245 (199, 296)	< 0.001
Median (Q1, Q3); n (%)					
Kruskal-Wallis rank sum test; Pearson's Chi-squared test					

Longitudinal analysis

Patients with at least two sarcopenia assessments were selected, and those with sarcopenia at baseline were excluded. Non-sarcopenia was used as the reference group, and Cox analyses were performed comparing possible sarcopenia and sarcopenia with the reference. (Table 2)

Table 2
Cox proportional hazards model analysis of the risk of different stages of sarcopenia based on pain status

Model	non-sarcopenia VS possible sarcopenia HR (95% CI) P-value	non-sarcopenia VS sarcopenia HR (95% CI) P-value
Model1	1.191(1.123–1.264)P < 0.001	1.253(1.128–1.393)P < 0.001
Model2	1.188 (1.077–1.310) P < 0.001	1.354 (1.130–1.624) P < 0.005
Model3	1.170 (1.054–1.300) P < 0.001	1.228 (1.001–1.507) P < 0.05

Model 1: Without covariates.

Model 2: With covariates of arthritis, arthritis treatment medications, and physical activity.

Model 3: With covariates of age, gender, residence, marital status, education level, employment status, BMI, pain, arthritis, arthritis treatment, comorbidities, social activity, physical activity, alcohol consumption, and smoking.

In the Cox proportional hazards model comparing the non-sarcopenia and possible sarcopenia groups, pain status (pain_status) significantly increased the risk of muscle decline (HR = 1.191, 95% CI: 1.123–1.264, p < 0.001). After adjusting for covariates, education level, BMI, pain, and age remained statistically significant. (Fig. 2)

In the Cox proportional hazards model comparing the non-sarcopenia and sarcopenia groups, pain status (pain_status) also significantly increased the risk of muscle loss (HR = 1.253, 95% CI: 1.128–1.393, p < 0.001). After adjusting for covariates, BMI, pain, age, and residence remained statistically significant. (Fig. 3)

To further compare the practical clinical applicability of the different models, we performed decision curve analysis (DCA). From Model 1 to Model 3, the net benefit increased as more covariates were incorporated. When the threshold probability was < 13%, the prediction model for possible sarcopenia exhibited relatively higher net benefit. When the threshold probability was < 33%, the prediction model for sarcopenia showed higher standard net benefit. Incorporating covariates improved the models' net benefits, and the survival analysis model exhibited greater clinical utility for sarcopenia compared with possible sarcopenia. (Fig. 4)

Cross-sectional analysis

Patients with at least two sarcopenia assessments were selected, excluding those with missing covariate data, and only data from 2015 were used for the cross-sectional analysis. Logistic regression was applied, using non-sarcopenia as the reference group, with possible sarcopenia and sarcopenia each compared against the reference. (Table 3)

Table 3
Results of the multinomial logistic regression analysis on the association between pain status and sarcopenia stratification status

Model	non-sarcopenia VS possible sarcopenia		non-sarcopenia VS sarcopenia	
	OR (95% CI) P-value		OR (95% CI) P-value	
Model1	One VS No	2.10(1.50–2.93) P < 0.001	One VS No	3.05(2.00–4.63) P < 0.001
	Multi VS No	1.97(1.67–2.31) P < 0.001	Multi VS No	2.32(1.85–2.91) P < 0.001
Model2	One VS No	2.03(1.44–2.84) P < 0.001	One VS No	2.97(1.94–4.53) P < 0.001
	Multi VS No	1.72(1.44–2.05) P < 0.001	Multi VS No	2.16(1.69–2.76) P < 0.001
Model3	One VS No	1.82(1.28–2.59) P < 0.001	One VS No	2.58(1.49–4.45) P < 0.001
	Multi VS No	1.58(1.31–1.91) P < 0.001	Multi VS No	1.89(1.38–2.58) P < 0.001

Model 1: Without covariates.

Model 2: With covariates of arthritis, arthritis treatment medication, and physical activity.

Model 3: With covariates of age, gender, residence, marital status, education level, employment status, BMI, pain, arthritis, arthritis treatment, comorbidities, social activity, physical activity, alcohol consumption, and smoking.

Multivariable logistic regression analysis showed that pain status (pain_status_factor) significantly increased the risk of both possible sarcopenia and sarcopenia. Compared with the no-pain group, single-site pain and multi-site pain increased the risk of possible sarcopenia by 2.10 (95% CI: 1.50–2.93, p < 0.001) and 1.97 (95% CI: 1.67–2.31, p < 0.001), respectively. The risk of sarcopenia increased by 3.05 (95% CI: 2.00–4.63, p < 0.001) and 2.32 (95% CI: 1.85–2.91, p < 0.001) for single-site and multi-site pain, respectively. (Figs. 5 & 6)

Based on the multivariable logistic regression model, ROC curves (receiver operating characteristic curves) were used to evaluate the model's ability to discriminate between different sarcopenia states, and AUC (area under the curve) values were calculated. Additionally, to examine differences in the role of pain status across sarcopenia strata, Wald tests were applied to compare constrained coefficients in the multivariable regression models. ROC analysis showed that the AUC was 0.573 for the None–Possible group and 0.599 for the None–Sarcopenia group (Fig. 7A). Although overall predictive performance was limited, the model was able to distinguish different sarcopenia states to some extent. The results indicate that while the multinomial logistic regression model has limited predictive ability for differentiating sarcopenia states, pain status exhibits significantly different predictive effects across sarcopenia strata. This suggests that pain may not only be an independent risk factor for sarcopenia but may also play different roles at various stages of the disease. Therefore, future research should further

investigate the dynamic relationship between pain and sarcopenia to provide more targeted evidence for individualized interventions and risk stratification.

After adjusting for age, arthritis, sex, physical activity, residence, use of arthritis medication, comorbidities, alcohol consumption, smoking, marital status, education level, and employment status, pain status (pain_status_factor) remained a significant predictor of sarcopenia risk. Compared with the no-pain group, the odds ratios (ORs) for possible sarcopenia were 1.82 (95% CI: 1.28–2.59, $p < 0.001$) for single-site pain and 1.58 (95% CI: 1.31–1.91, $p < 0.001$) for multi-site pain. In the sarcopenia group, the ORs were 2.58 (95% CI: 1.49–4.45, $p = 0.010$) for single-site pain and 1.89 (95% CI: 1.38–2.58, $p < 0.001$) for multi-site pain. Except for arthritis, alcohol consumption, and education level—which showed no significant effects on sarcopenia—other covariates exhibited significant associations with the risk of possible and confirmed sarcopenia.

After excluding arthritis, alcohol consumption, and education level, multinomial logistic regression showed that smoking history had no significant effect on the risk of possible or confirmed sarcopenia. Moderate and high levels of physical activity increased the risk of possible sarcopenia, but had no significant effect on the risk of sarcopenia. All other covariates significantly increased the risks of both possible and confirmed sarcopenia. Based on the multinomial logistic regression model, ROC curves were used to assess the ability to distinguish different sarcopenia states, and AUC values were calculated. Additionally, to assess differences in the impact of pain status across sarcopenia strata, Wald tests were used to compare constrained coefficients in the multivariable models. ROC analysis showed an AUC of 0.695 for the None–Possible group and 0.844 for the None–Sarcopenia group (Fig. 7B). These results indicate that the model demonstrates moderate to good discrimination for sarcopenia status. Overall, after fully adjusting for covariates, pain status remained an important risk factor for sarcopenia and showed consistent effects across different stratified models. This finding highlights the potential mechanistic role of chronic pain in the development and progression of sarcopenia, suggesting that pain management may be an important entry point in clinical interventions and prevention strategies.

Decision curve analysis (DCA) was performed for different logistic models to evaluate their clinical applicability. From Model 1 to Model 3, the net benefit increased as more covariates were incorporated. When the threshold probability ranged from 16% to 55%, the prediction model for possible sarcopenia demonstrated relatively high net benefit. When the threshold probability ranged from 2% to 69%, the prediction model for sarcopenia showed higher net benefit. In particular, after covariates were added, the models demonstrated substantial clinical applicability. (Fig. 8)

Discussion

Sarcopenia is a systemic and progressive condition characterized by accelerated declines in muscle mass and function, and it is a major risk factor for adverse outcomes such as falls, frailty, and even

mortality [17]. Preventing and/or treating muscle loss and sarcopenia at an early stage can not only improve patient outcomes but also reduce healthcare-related economic burdens [18]. The underlying pathophysiological mechanisms of sarcopenia are not yet fully understood. With aging, macrophage activation increases, pro-inflammatory cytokines rise, and anti-inflammatory cytokines decrease [19], leading to inflammatory damage to skeletal muscle structure and function in older adults. Chronic low-grade inflammation promotes sarcopenia by regulating signaling pathways that enhance protein degradation and suppress protein synthesis [20]. Inflammation activates NF-κB, leading to upregulation of inflammation-related genes such as TNF-α, IL-1, and IL-6 [21]. Studies have shown that IL-6 and TNF-α are associated with reduced muscle strength and mass [22], and their chronic elevation leads to skeletal muscle atrophy and impaired muscle regeneration [23]. Pain arises from complex interactions among chronic inflammation, joint tissue changes, and alterations in pain processing pathways; inflammatory mediators sensitize peripheral nociceptors, and continuous input from damaged joints leads to central sensitization, amplifying pain perception [24–25]. Pain is a subjective experience shaped by biological, psychological, and social factors. Studies indicate that aging weakens functional activity and neural connectivity in key pain-modulating regions of the central nervous system (e.g., PAG, insula, ACC, vlPFC, amygdala), resulting in impaired pain inhibition and increased susceptibility to persistent or chronic pain in older adults [26]. Pain affects muscle metabolism not only through chronic inflammation but also by reducing physical activity and muscle utilization, thereby further contributing to muscle atrophy and functional decline.

Evidence suggests that the prevalence of chronic musculoskeletal pain among community-dwelling older adults may reach as high as 60%, far exceeding global estimates, with the most commonly affected sites being the lumbar spine, cervical spine, hip, and knee joints [27]. In this study, musculoskeletal pain was categorized into single-site pain (n = 1) and multi-site pain (n ≥ 2). Statistical analyses showed that musculoskeletal pain significantly increased the risks of possible sarcopenia and sarcopenia, and multi-site pain had a stronger impact on these risks than single-site pain.

In this analysis, covariates including age, sex, arthritis status, use of arthritis medication, comorbidities, physical activity, social engagement, residence, smoking, and alcohol consumption were included in the Cox risk models. The results showed that age increased the risk of both possible sarcopenia and sarcopenia. Residence and comorbidities increased the risk of sarcopenia but did not show a significant effect on the risk of possible sarcopenia. With advancing age, the body undergoes gradual decline; because aging is associated with progressive changes in skeletal muscle mass, metabolism, and functional capacity, it inherently increases the risk of sarcopenia. Furthermore, increasing age is accompanied by elevated levels of inflammation. Many chronic health conditions share pathological features with sarcopenia, including systemic low-grade inflammation and oxidative damage [28]. Due to disparities and imbalances in healthcare resources across regions, rural populations may experience more severe comorbidity burdens than urban populations. The reasons underlying regional differences in sarcopenia may be multifactorial and warrant further investigation.

Logistic regression analysis not only demonstrated an association between the number of pain sites and sarcopenia risk but also suggested that age, regional differences, sex, history of arthritis medication use, comorbidities, and smoking are closely related to sarcopenia occurrence. This study found that men had a significantly lower risk of developing sarcopenia compared with women, and other studies have noted that gender differences in sarcopenia prevalence may vary depending on the diagnostic criteria used [29]. A study based on NHANES reported that smoking and drinking rates were higher in the sarcopenia group than in the non-sarcopenia group [30], and similar findings have been observed in other studies. Smoking, excessive alcohol consumption, and the use of certain medications (e.g., glucocorticoids) can directly impair muscle health, which may partly explain why a history of arthritis medication use increases the risk of sarcopenia.

This study has several limitations. Although a longitudinal design was used, the long follow-up intervals in the CHARLS dataset may limit the real-time assessment of disease progression. In addition, the study did not examine medication use in depth, and factors such as drug type, dosage, treatment duration, and interactions with other diseases were not considered. Regarding diagnosis, gait speed was not included because the CHARLS protocol for gait speed assessment differs from the AWGS 2019 criteria. Although covariates such as age, sex, chronic diseases, and lifestyle factors were adjusted for, unmeasured confounders—such as mental health and nutritional status—may still exist and could influence sarcopenia development. Additionally, external factors such as socioeconomic status and cultural background may also influence the findings.

Based on data from the China Health and Retirement Longitudinal Study (CHARLS), this study systematically examined the associations of pain, age, sex, and other factors with the development of sarcopenia and possible sarcopenia. The results showed that pain status is an important independent predictor of both sarcopenia and possible sarcopenia, with a clear dose–response effect: individuals with multi-site pain had higher risks than those with single-site pain. This suggests that pain may not only accompany sarcopenia but may also act as an independent contributor to its development. A broader pain distribution may indicate greater inflammatory burden and physiological dysfunction, making muscle mass decline more likely. Moreover, multivariable models confirmed the significant roles of age, region, sex, arthritis treatment history, comorbidities, and lifestyle factors in the development of sarcopenia, highlighting its multifactorial pathology. These findings indicate that pain assessment and management should be emphasized in clinical practice, as pain not only affects quality of life but may also accelerate muscle mass and functional decline. For older adults, women, rural residents, and those with chronic diseases or long-term arthritis/rheumatism medication use, enhanced monitoring of muscle strength and physical performance is warranted to enable early identification and intervention for high-risk groups.

Conclusion

In summary, based on a large population dataset, this study revealed a significant association between pain status—particularly multi-site chronic pain—and the occurrence of sarcopenia and possible

sarcopenia. The findings suggest that pain management may not only improve quality of life but also serve as a new strategy and research direction for the prevention and treatment of sarcopenia. Comprehensive intervention strategies should include standardized analgesia, chronic disease management, lifestyle modification, and nutritional support, while considering the risk–benefit balance of medications to reduce the incidence of sarcopenia and improve patient outcomes.

Declarations

Competing interests:

The authors declare that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

Consent to participate:

All authors listed have contributed to the entire writing process of this manuscript and have given their informed consent for its publication.

Consent for publication:

The authors assert that none of the material in this paper has been published, nor is it under consideration for publication elsewhere.

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Author Contribution

FZ and KW BHare responsible for sample and data collection, and writing of the original manuscript. CC, YS, YZ, and YS for sample and data collection, review and editing. CS for review and editing. YC for conceptualization, review and editing. XZ and JX are responsible for revision, and manuscript review. DH is responsible for the funding acquisition, revision, and manuscript review. All authors reviewed and accepted the final version.

Acknowledgements:

Not applicable

Data Availability

The data used in this study were obtained from the China Health and Retirement Longitudinal Study (CHARLS), a publicly available database. Participants in CHARLS completed standardized questionnaires collecting information on sociodemographic characteristics, lifestyle factors, and health-related conditions. The CHARLS study protocol was approved by the Ethics Review Committee of Peking University (IRB00001052-11015), and written informed consent was obtained from all participants prior to participation. All methods were carried out in accordance with relevant guidelines and regulations. This study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The data are publicly accessible through the official CHARLS website.

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Figures

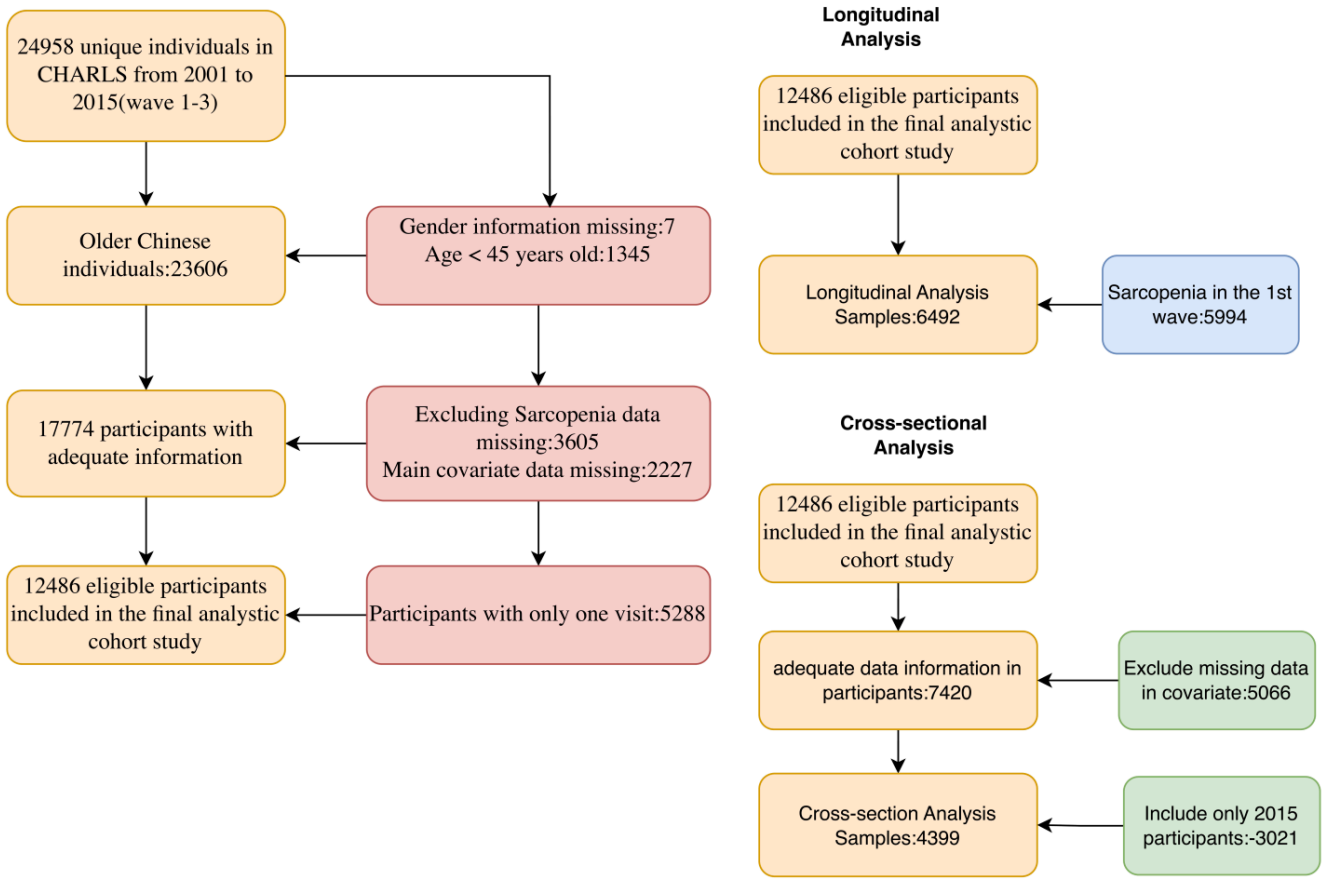


Figure 1

Flowchart of participant selection.

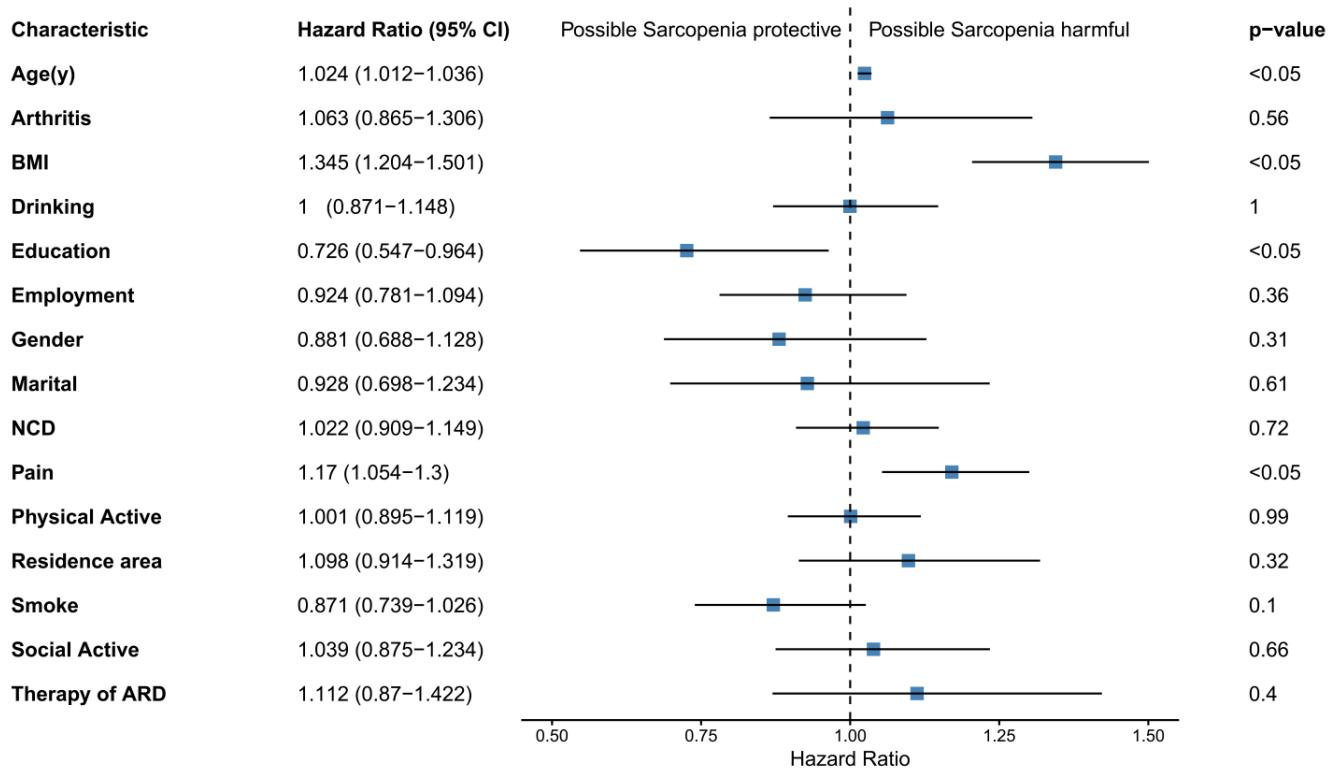


Figure 2

Associations between characteristics and the risk of possible sarcopenia among non-sarcopenic individuals (Cox proportional hazards model).

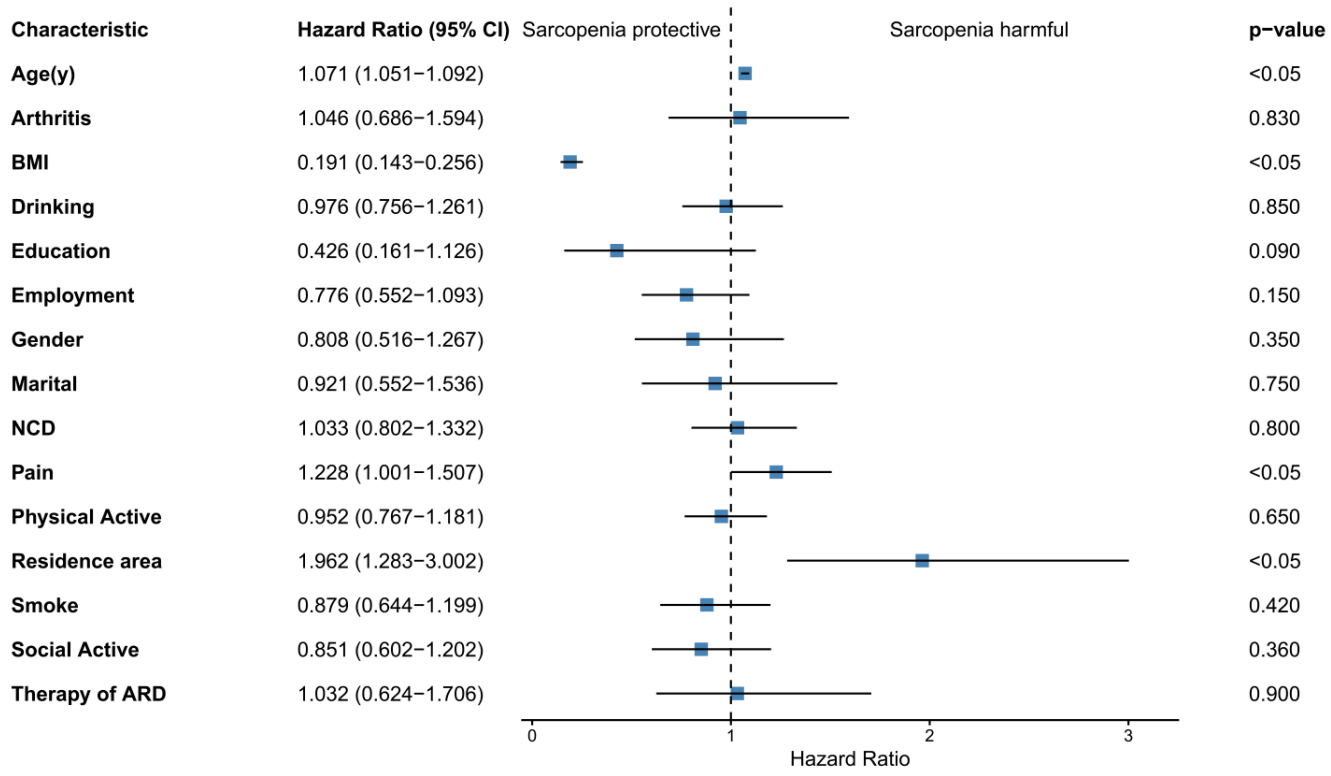


Figure 3

Associations between characteristics and the risk of sarcopenia among non-sarcopenic individuals (Cox proportional hazards model).

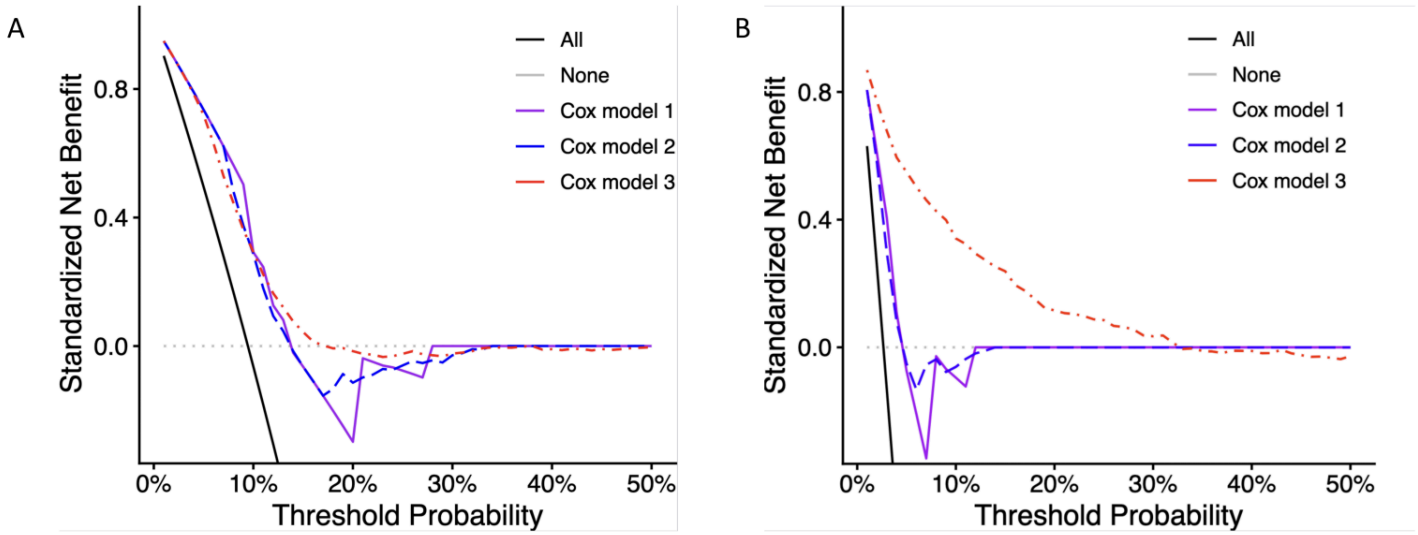


Figure 4

Decision curve analysis (DCA) of different survival models.

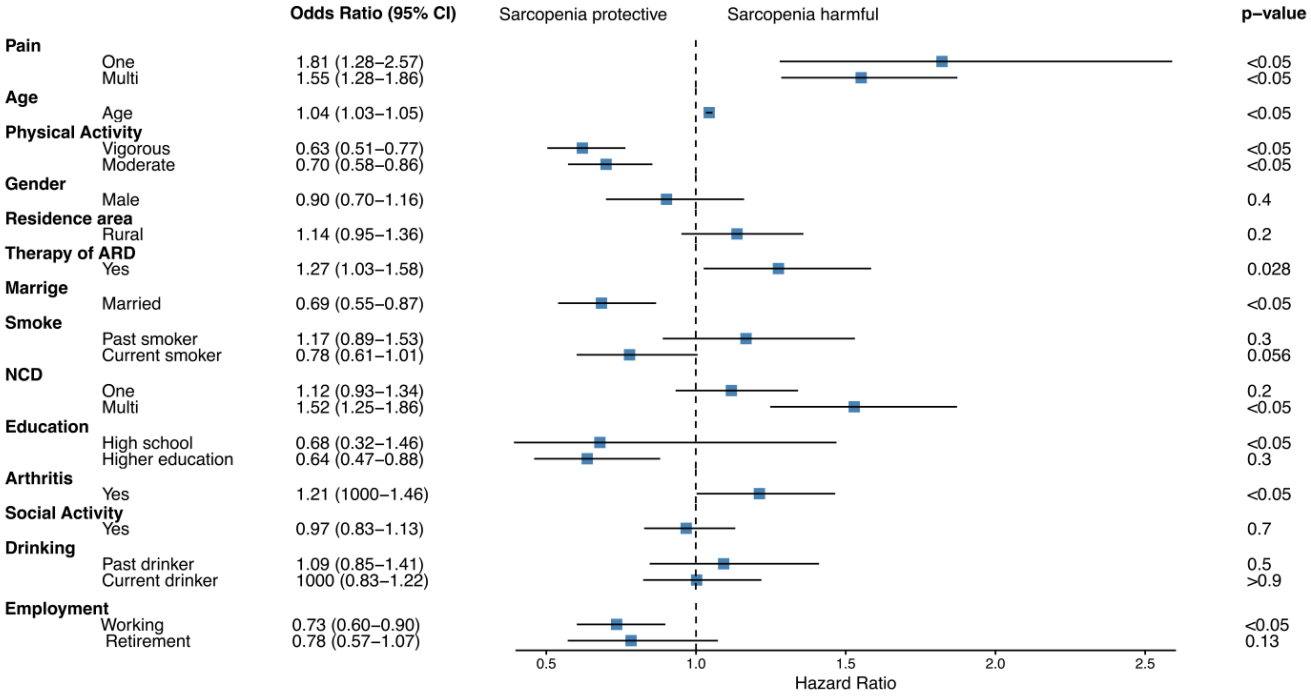


Figure 5

Multivariable logistic regression analysis of pain status and risk of possible sarcopenia.

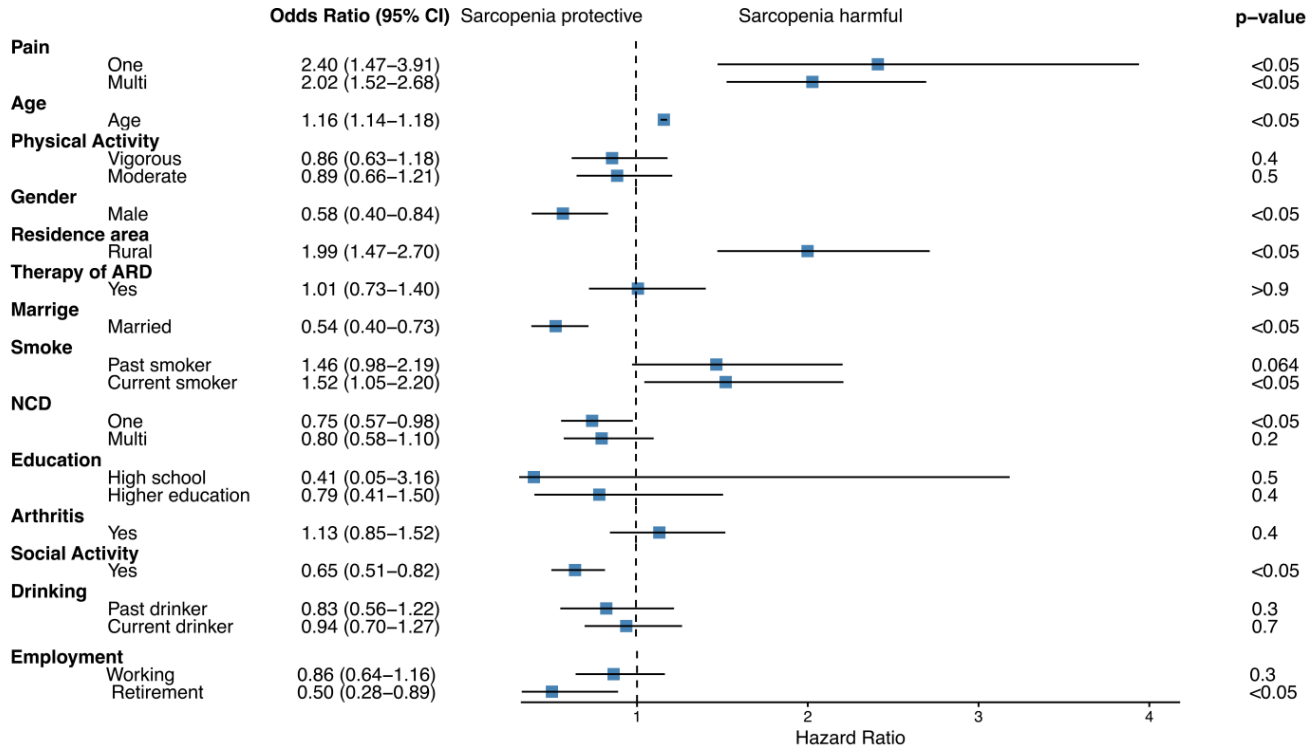


Figure 6

Multivariable logistic regression analysis of pain status and risk of sarcopenia.

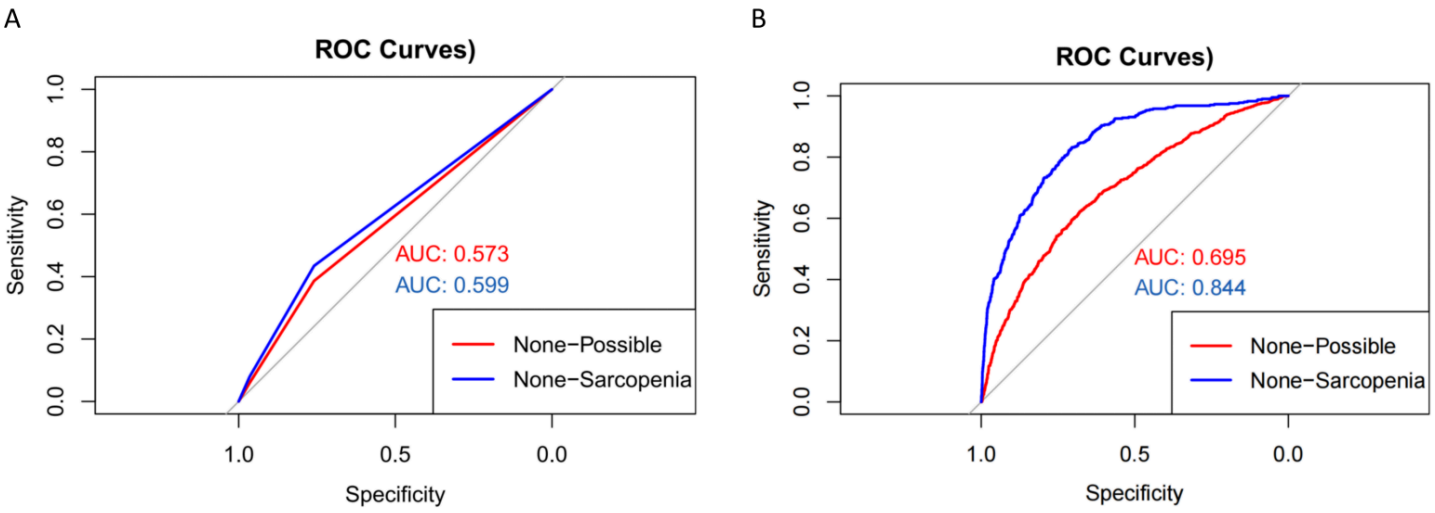


Figure 7

Predictive performance of pain status across sarcopenia categories: ROC analysis based on the multinomial logistic regression model.

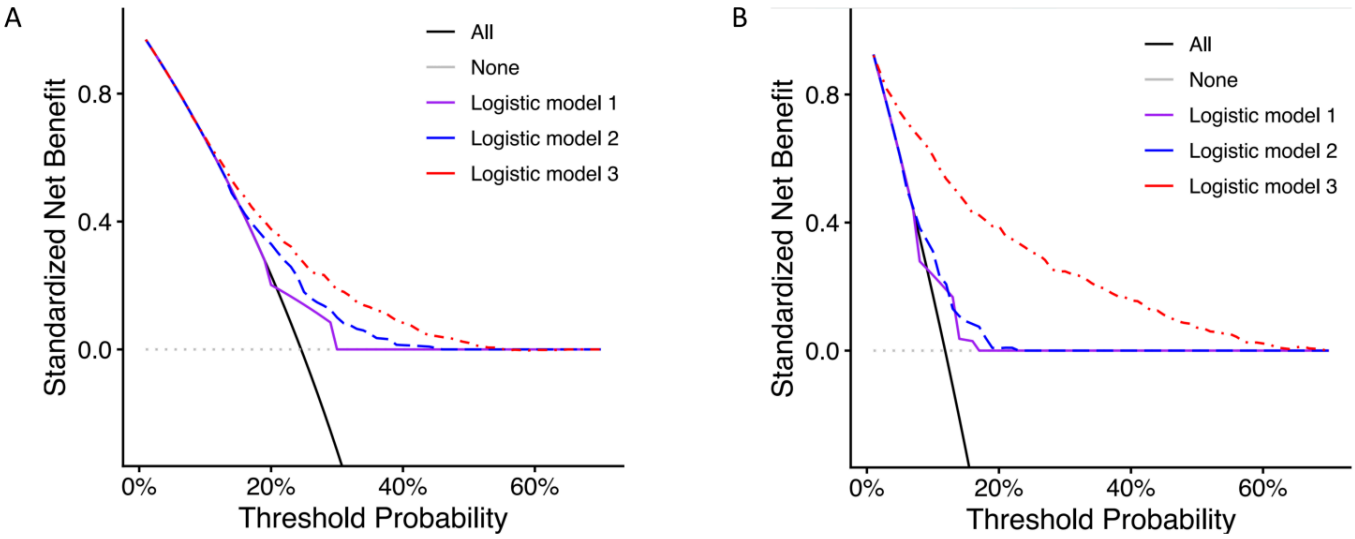


Figure 8

Decision curve analysis (DCA) of different logistic regression models.