BMC Neurology

RESEARCH

Open Access

The effect of sarcopenia on prognosis in patients with mild acute ischemic stroke: a prospective cohort study

Rui Chen[1,5†], Zhuyun Liu[1,5†], Ruotong Liao[2,5], Hao Liang[3,5], Caixia Hu[1,5], Xiaopei Zhang[1,5], Jiehan Chen[1,5], Hui Xiao[3,5], Junhua Ye[4,5], Jianwen Guo[1,5,6] and Lin Wei[2,5,6,7*]

Abstract

Background Ischemic stroke is a common chronic disease worldwide and is correlated with a high disability rate. Sarcopenia is considered a key factor in the disablement process. Limited evidence of sarcopenia in acute ischemic stroke is available. The aim of this study was to investigate the effect of sarcopenia on the prognosis of patients with acute ischemic stroke.

Methods A prospective cohort study was conducted and included patients who were diagnosed with acute ischemic stroke between August 2020 and May 2021. A modified Poisson regression was applied to determine the relative risk (RR) for the change in modified Rankin Scale (mRS) score and allow adjustment for confounders. The modified Poisson regression was used to identify associations between sarcopenia, and multiple linear regression analyses were used to assess the effect of sarcopenia on the Barthel Index (BI) and stroke-specific quality of life (SSQOL). The generalized linear mixed model was used to investigate the effect of sarcopenia on prognosis at 1, 3 and 6 months. Cox regression proportional risk model was used to analyze the effect of sarcopenia on readmission in patients with acute ischemic stroke.

Results The prevalence of sarcopenia was 39.83% among the 118 enrolled acute ischemic stroke patients (aged 64.98 ± 11.053 years; 72.88% males). Modified Poisson regression showed that a poor prognostic outcome occurred in sarcopenia patients (relative risk [RR] = 3.021, 95% CI: 1.621–5.633; $P = 0.001$). Even after adjusting for confounders, sarcopenia still was a risk predictor of the increase of mRS (RR = 2.149, 95% CI: 1.045–4.420; $P = 0.038$). And sarcopenia was positively correlated with BI and SSQOL with or without adjustment for confounding factors ($P < 0.01$).

Patients with sarcopenia in mild acute ischemic stroke exhibit worse prognoses compared to those without sarcopenia. ($t = 3.128$, $P = 0.002$). Cox regression risk ratio model showed that sarcopenia was a predictor of readmission within 6 months after mild ischemic stroke (hazard ratio [HR] = 3.361, 95% CI: 1.277–8.848; $P = 0.014$). Sarcopenia remained an independent risk factor for mild acute ischemic stroke readmission after adjusting for confounders.

Conclusions Sarcopenia has a high prevalence in mild acute ischemic stroke patients. Sarcopenia is an independent risk factor for poor outcomes following mild acute ischemic stroke and contributes to high rates of readmission. These findings may be useful for selecting therapeutic strategies for mild acute ischemic stroke patients with sarcopenia.

Keywords Ischemic stroke, Sarcopenia, Prognosis

†Rui Chen and Zhuyun Liu contributed equally to this work.

*Correspondence:
Lin Wei
weilin22@gzucm.edu.cn
Full list of author information is available at the end of the article

Introduction

Ischemic stroke is one of the most burdensome chronic diseases and it has become a leading cause of mortality and disability [1, 2]. The prevalence of stroke was 2.6% among 676,394 individuals aged 40 and older in mainland China [3]. Although the mortality rate of stroke has decreased in recent years, a large number of stroke survivors remain chronically disabled [4]. According to statistics, the prevalence of disability among stroke patients was 31% to 67.6% [5]. Ischemic stroke is frequently accompanied by severe dysfunction that significantly impairs a person's quality of life [6].

Sarcopenia is a progressive and common skeletal muscle disease, characterized by a gradual loss of muscle mass and function [7]. Individuals with sarcopenia are prone to adverse outcomes involving frailty, falls, and functional decline, or even death [8]. Due to denervation and chronic inflammatory [9], stroke is considered to be associated with a high incidence of sarcopenia with a risk of 14% to 53.5% [10–12], compared to 3% to 24% among the general population [13].

Meanwhile, stroke and sarcopenia often coexist as two comorbid diseases that affect each other and lead to a vicious cycle between the two. An animal trial demonstrated that catabolic pathways of muscle tissue are activated after stroke [14]. Around 4-h after stroke, adaptive changes usually occurred [15]. Significant reductions in muscle mass could be observed as early as 3 weeks after a stroke [16] and 24% muscle volume reduction in hemiplegic limbs within 6 to 12 months after a stroke [9, 17]. Limited published data have suggested that an increase in muscle mass may be positively correlated with functional recovery in patients with sarcopenia after stroke [18]. Some studies found sarcopenia is linked with poor prognosis in convalescent stroke [19, 20].

Skeletal muscles are the main organ of human function. By means of adaptive changes in muscle structure in the early phase after stroke, sarcopenia leads to an increase in the extent of disability and produces adverse effects in convalescent stroke patients [21]. It is particularly important to investigate the prevalence rate and prognosis of sarcopenia in patients who underwent an acute stroke. However, very limited information on functional outcomes and quality of life in sarcopenia of acute stroke is available.

In this research, we hypothesized that sarcopenia could affect the prognosis and quality of life in acute ischemic stroke patients. We conducted a prospective cohort study to explore the impact of sarcopenia on the prognoses of acute ischemic stroke patients. In addition, we also investigated the impact of sarcopenia on readmission and quality of life after ischemic stroke.

Methods

Study design and setting

We performed a prospective cohort study. According to the exposure factor, the subjects were divided into the sarcopenia and non-sarcopenia groups. This study was approved by the ethical committee of Guangdong Provincial Hospital of Chinese Medicine (ZE2020-163–01). Informed consent was obtained from each patient. The cohort study is registered at Chinese Clinical Trial Registry (ChiCTR2000036984) and Registration Date: August 26, 2020.

Participants

Primary acute ischemic stroke participants who were diagnosed by computed tomography (CT) or magnetic resonance imaging (MRI) were enrolled from the Second Affiliated Hospital of Guangzhou University of Chinese Medicine between August 2020 and May 2021. The inclusion criteria consisted of several parameters: (1) diagnosed as acute ischemic stroke, (2) adult patients: aged from 18 to 90 years, and (3) initial stroke (onset within 14 days). The exclusion criteria consisted of several parameters: (1) with severe cardiac, respiratory, hepatic and/or renal dysfunction, malignant tumor, and/or other severe complications; (2) National Institutes of Health Stroke Scale (NIHSS) > 15; (3) modified Rankin Scale (mRS) > 4; (4) muscle strength of the limbs metal < 3; (5) unable to complete Inbody measurement, including inability to stand alone or any implanted metal or a cardiac pacemaker; (6) severe disturbance of consciousness. The flow diagram is illustrated in Fig. 1.

Data collection

Demographic and clinical data were recorded on admission to the hospital. And we assess sarcopenia in study participants within 72 h of hospital admission. A detailed history and clinical evaluation were carried out by neurologists. The patient's information was all evaluated by three graduate nurses. We explained the specific purpose and significance of the survey, as well as how to cooperate with the nurses during the research process, and obtained informed consent.

Measures

For each patient in the cohort, several pieces of information were collected. Demographics and baseline characteristics, including diagnosis, age, sex, height, education, comorbidities (comorbidities were defined as none present (0) and presence of at least one comorbidity [22]), cerebrovascular intervention [Digital Subtraction Angiography (DSA), intravenous thrombolysis, DSA + operation (thrombectomy or balloon angioplasty) and none (supplemental table for details)], and laboratory blood

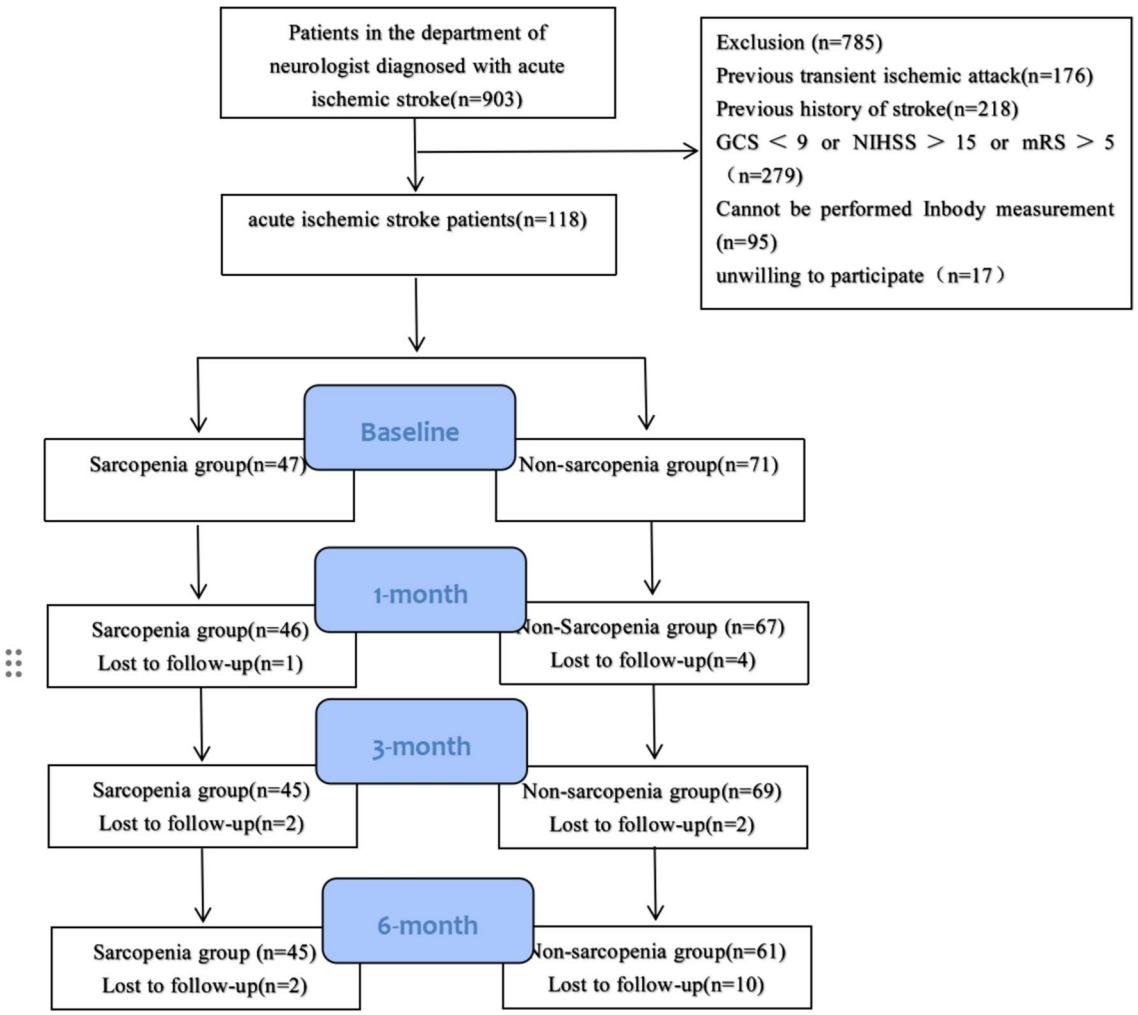

Fig. 1 Flow chart of the study population

examinations (hemoglobin, albumin and glycosylated hemoglobin) were recorded. Neurological severity of stroke was assessed by the National Institutes of Health Stroke Scale (NIHSS) at the time of diagnosis. It was then classified into categories: mild, NIHSS score < 10; moderate, 10 to 19; and severe, > 19 [23]. Disability status of the acute ischemic stroke patient was obtained by using modified mRS. It ranges from 0 to 6. (0 indicated no symptoms, 3 indicated moderate disability, and 6 indicated death) [24]. The Barthel index (BI) was used to evaluate the activities of daily living (ADL) of acute ischemic stroke patients. It had a total score of 0 to 100 and contained 10 items [25]. Quality of life was measured using the Stroke-Specific Quality-of-Life Scale (SSQOL). This 49-item instrument assesses 12 domains relevant to stroke patients on a 5-point Likert response scale. The total score ranges from 49 to 245 points, with higher scores indicating better quality of life [26]. And the Chinese version, which possessed adequate internal consistency based on Cronbach's $\alpha > 0.76$, was adopted in this study [27]. Re-admissions for various reasons were recorded as re-admissions.

Definition of sarcopenia

Within 3 days of admission, weight, body mass index (BMI), and skeletal muscle mass were measured using segmental multifrequency bioelectrical impedance analysis (BIA; InBody 720 analyser, Korea). Appendicular skeletal muscle mass (ASM, kg) was the sum of the skeletal muscle mass of the extremities. Relative appendicular skeletal muscle (RASM) was measured using the ASM/H^2. Handgrip strength (HGS) was measured in the non-paralyzed hand (Xiangshan brand CAMRY: EH101).

While measuring grip strength, the patients were seated with their elbows at 90 degrees of flexion.

Sarcopenia was assessed based on the Asian Working Group for Sarcopenia (AWGS) 2019 criteria [28], which are composed of components: (1) appendicular lean mass and (2) grip strength. The cutoff values for sarcopenia defined by HGS were < 8 kg in males and < 18 kg in females, and those of RASM were < 7.0 kg/m^2 in males and < 5.7 kg/m^2 in females.

Follow-up and clinical outcomes.

Participants were followed at 1, 3, and 6 months, and the information was collected through standardized telephone survey or clinical outpatient visits. The primary outcome was the change of mRS, which is defined as the result of subtracting the mRS score at baseline from the score at the 6th month. According to the result, the change of mRS was classified into "unchanged or reduced" (function maintained or improved) and "increased" (function deteriorated). The secondary outcomes were the total scores of BI and SSQOL and readmission to a hospital at 6 months.

Sample size.

Sample size was calculated using the formula for cohort study [29] with 95% power and 5% significance level. An appropriate sample size was calculated based on the data that 71.0% of the stroke patients exposed to sarcopenia have a poor prognosis, whereas 31.0% were already disabled after the stroke [20, 30].

$$N = \frac{\left(Z_\alpha \sqrt{2\overline{PQ}} + Z_\beta \sqrt{P_0Q_0 + P_1Q_1}\right)^2}{(P_1 - P_0)^2}$$

With α set at α = 0.05, $Z_\alpha = 1.96$, β = 0.10, $Z_\beta = 1.282$, and assuming a stroke disability rate of $P0 = 0.31$ and a disability rate for stroke patients with sarcopenia of P1 = 0.71, the formula yielded N1 = N2 = 31, to ensure equal group sizes and account for a 20% dropout rate, the required total sample size was calculated as $N = 74$.

Statistical analysis

Statistical analyses were conducted by SPSS 25.0 software. Continuous variables were presented as mean ± standard deviation (SD) or median and interquartile range (IQR), and categorical variables were presented as frequency (percentages). Variables for adjustments were selected according to their clinical significance and univariate analysis variables with $P < 0.05$ [31]. Modified Poisson regression was used to evaluate the relative risk (RR) and 95% confidence interval (CI) for the change of mRS with and without adjustment for age, sex, BMI, comorbidities and NIHSS. Multiple linear regression analyses were used to adjust for the above-mentioned with the BI and SSQOL after 6 months as dependent variables. The generalized linear mixed model was used to investigate the effect of sarcopenia on prognosis at 1, 3 and 6 months. COX regression proportional risk model was used to analyze the effect of sarcopenia on readmission in patients with mild acute ischemic stroke. Kaplan–Meier was used to plot survival curves of patients with sarcopenia and those without sarcopenia. We present results for complete cases and after multiple imputation to account for selective dropouts and missing information at follow-up. Predictive mean matching was used for continuous variables with missing values, logistic regression for binary variables, and multinomial regression for categorical variables [32]. GraphPad Prism was used to evaluate the trend of mRS at 1, 3, and 6 months.

Results

In this study, among 903 patients who were diagnosed with acute ischemic stroke, 176 had transient ischemic attack (TIA) history, 218 had a history of previous stroke, 279 patients were in a coma (GCS < 9), NIHSS score > 15, or mRS score > 5, and 17 patients were unwilling to participate in this study. Ninety-five patients were unable to complete the InBody measurements, including 74 patients who could not stand alone and the 21 patients who had metal or electronic devices in the body and were excluded. The final cohort included 118 mild acute ischemic stroke patients. Another 5, 4, and 12 patients were lost to follow-up, respectively, at 1, 3, and 6 months. The main reasons for loss to follow-up as unwillingness to follow-up and not answering the phone (Fig. 1). The age of the 118 patients ranged from 34 to 87 years with a mean standard deviation (SD) age of 64.98 ± 11.053, and 72.88% of the patients were male. Age and BMI were significantly different between the two groups ($P < 0.01$). Table 1 shows patient characteristics at baseline.

Table 2 shows that the increase in mRS scores was significantly elevated in sarcopenia patients when compared with non-sarcopenia patients (RR = 3.021, 95% CI = 1.621–5.633;*P < 0.01*). More specifically, mild acute ischemic stroke patients with sarcopenia had a 4.067-fold higher risk of poor recovery compared to their peers without sarcopenia, and even after adjusting for age, sex, BMI, comorbidities, and NIHSS, sarcopenia still was a risk predictor of the increase in mRS (RR = 2.149, 95%CI = 1.045–4.420; *P = 0.038*). Multivariate linear regression analyses showed sarcopenia was associated with decreased quality of life and self-care ability in patients with mild acute ischemic stroke [sarcopenia was a risk predictor of the increase in BI ($t = -8.45$, 95%CI = −18.65 to −11.57; *P < 0.01*); sarcopenia was a risk predictor of the increase in SSQOL($t = -7.430$, 95%CI = −38.62 to −22.365; *P < 0.01*)]. After adjusting for age, sex, BMI, comorbidities and NIHSS, sarcopenia

Table 1 Characteristics of patients according to sarcopenia status

	Sarcopenia ($n=47$)	Nonsarcopenia ($n=71$)	$t/\chi 2/U$	*P*-value
Age [a]	68.3 ± 11.19	62.8 ± 10.47	−2.722	0.007**
Sex[b]				
Male	32 (68.1%)	54(76.1%)	0.909	0.340
Female	15 (31.9%)	17(23.9%)		
BMI[a]	21.23 ± 2.24	24.89 ± 2.45	8.194	< 0.001**
Education [b]				
Primary school and below	10(21.3%)	20(28.2)	1.006	0.605
Middle school	32(68.1%)	46(64.8)		
College degree and above	5(10.6%)	5(7.0%)		
Comorbidities [b]				
Yes	34(72.3%)	64(90.1%)	6.366	0.012*
No	13(27.7%)	7(9.9%)		
Hypertension [b]				
Yes	25(53.2%)	40(56.3%)	0.113	0.737
No	22(46.8%)	31(43.7%)		
Diabetes [b]				
Yes	13(27.7%)	30(42.3%)	2.600	0.107
No	34(72.3%)	41(57.7%)		
Cardiovascular disease [b]				
Yes	5(10.6%)	7(9.9%)	0.019	0.891
No	42(89.4%)	64(90.1%)		
NIHSS,M(IQR) [c]	1(2)	2(3)	−1.477	0.140
BI,M(IQR) [c]	90(25)	90(20)	−0.841	0.401
mRS [d]				
0	7(14.9%)	10(14.1%)	6.419	0.142
1	14(29.2%)	34(47.9%)		
2	13(27.7%)	15(21.1%)		
3	13(27.7%)	10(14.1%)		
4	0(0%)	2(2.8%)		
Hemoglobin [a]	131.76 ± 19.462	134.13 ± 16.757	0.704	0.483
Albumin,M(IQR)[c]	41.65(4.5)	41.65(2.7)	−0.551	0.581
Glycosylated hemoglobin,M(IQR)[c]	6(1.21)	6.5(2.1)	−1.536	0.124
Cerebrovascular intervention [b]				
DSA	10(21.3%)	22(31.0%)	2.480	0.475
Intravenous thrombolysis	1(2.1%)	2(2.8%)		
DSA + operation	6(12.8%)	12(16.9%)		
No	30(63.8%)	35(49.3%)		

Abbreviations: BMI body mass index, *NIHSS* the National Institutes of Health Stroke Scale, *BI* Barthel index, *mRS* modified Rankin Scale, *DSA* Digital Subtraction Angiography

Significant at $p<0.05$ indicated by *; $p<0.01$ indicated by **

[a] *t*-test

[b] Chi-square test

[c] Mann-Whitney U test

[d] Fisher's exact test

still exerted adverse effects on BI and SSQOL recovery at 6 months [sarcopenia was a risk predictor of the increase in BI ($t=-5.403$, 95%CI = −16.913 to −7.837; $P<0.01$); sarcopenia was a risk predictor of the increase in SSQOL($t=-4.948$, 95%CI = −36.18 to −15.49; $P<0.01$)]. Figure 2 indicates the changes in mRS scores at the 6 months from baseline. The decrease in scores indicates that the 6th-month score is lower than the baseline, showing an improvement in the patient's physical function during this period. The increase in mRS scores that

Table 2 Associations between sarcopenia and outcomes at sixth month

Characteristic	Unadjusted RR / *t*	95% CI	*P* Value	Adjusted RR / *t*	95% CI	*P* Value
The change of mRS from baseline to 6th month(primary outcome)[a]						
Sarcopenia	3.021	1.621 to 5.633	0.001**	2.149	1.045 to 4.420	0.038*
Nonsarcopenia	1(reference)			1(reference)		
BI at 6th month (secondary outcome)[b]						
Sarcopenia	−8.45	−18.65 to −11.57	< 0.001**	−5.403	−16.913 to −7.837	< 0.001**
Nonsarcopenia	1(reference)			1(reference)		
SSQOL at 6th month (secondary outcome)[b]						
Sarcopenia	−7.430	−38.62 to −22.365	< 0.001**	−4.948	−36.18 to −15.49	< 0.001**
Nonsarcopenia	1(reference)			1(reference)		

Abbreviations: SSQOL Stroke-specific quality of life scale, *CI* Confidence interval, *t* Test statistic, *RR* Relative Risk

[a] Use modify Poisson regression and adjusted age, sex, BMI, comorbidities, NIHSS to test whether sarcopenia is a predictive factor for prognosis of acute stroke at 6 month. According to the mRS score change with baseline, it was classified into "unchanged or reduced"(function maintain or improved) and "increased"(function deteriorate)

[b] Multivariate liner regression analyses were used to explore the influence of sarcopenia on secondary outcomes and adjust for the above-mentioned

Significant at $p < 0.05$ indicated by *; $p < 0.01$ indicated by **

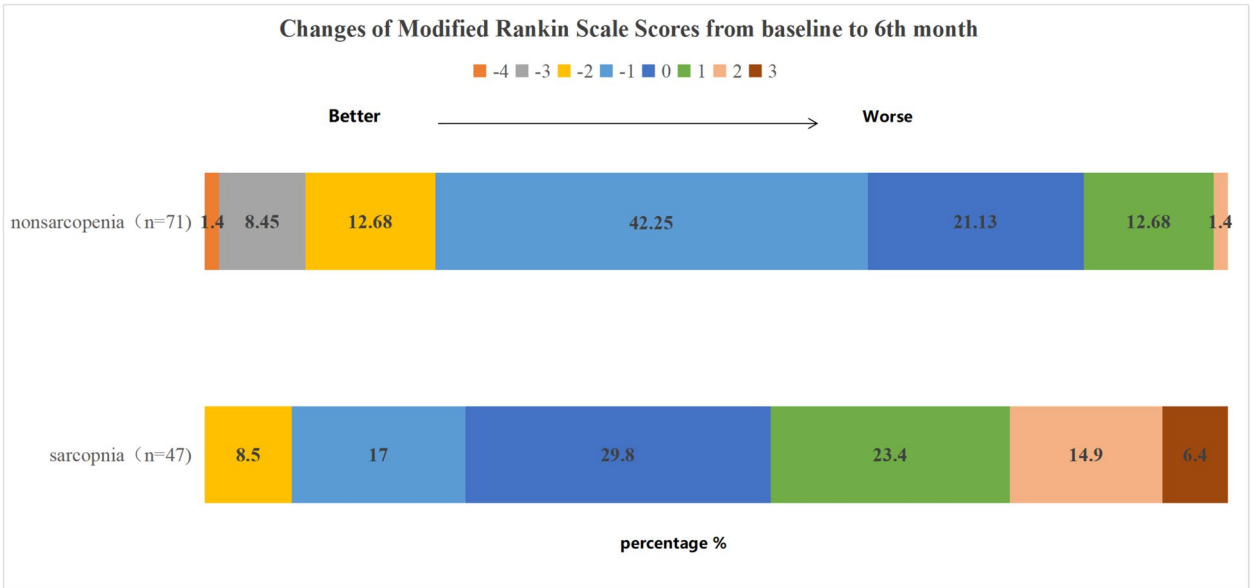

Fig. 2 Changes of Modified Rankin Scale Scores from baseline to 6th month. A negative value indicates that the patient's function has improved, meaning the 6th-month score is lower than the baseline, showing an improvement in the patient's condition during this period. A positive value indicates that the patient's function has deteriorated, as the 6th-month score is higher than the baseline, indicating a decline in physical function. The figure shows the distribution based on proportional changes, with missing color blocks representing 0%

the 6th-month score is higher than the baseline, indicating a decline in physical function. In addition, the mRS score increased 1-point was 23.4% of sarcopenia patients at 6 months, and 12.68% of patients without sarcopenia had a 1-point increase in mRS score at 6 months versus baseline. The generalized linear mixed model shows that patients with sarcopenia in mild acute ischemic stroke have worse prognosis compared to those without sarcopenia ($t = 3.128$, $P = 0.002$) Table 3 and Fig. 3 shows the dynamic trend of total mRS score. Over time, the mRS scores of sarcopenia group showed an upward trend, while the non-sarcopenia group showed the opposite trend.

One hundred eighteen participants were followed up with readmission within 6 months as the secondary outcome. The risk of readmission in mild ischemic stroke patients was 3.4%, 6.8% and 17.8% at 1, 3 and 6 months, respectively. The proportion of readmission in patients with sarcopenia after mild ischemic stroke was 8.5%, 14.9% and 29.8% at 1, 3, 6 months. And reasons for readmission included 61.9% were stroke rehabilitation (fatigue, poor fine motor skills, limb numbness, and

Table 3 Effect of sarcopenia on prognosis of mild acute stroke patients

	β	SE	t	P	95%CI	
Sarcopenia = 1	0.527	0.168	3.128	0.002**	0.196	0.858
Non-sarcopenia = 0	reference					
Time = 3	−0.689	0.149	−4.613	< 0.001**	−0.982	−0.395
Time = 2	−0.249	0.144	−1.730	0.084	−0.531	0.034
Time = 1	reference					
Time = 3*Sarcopenia = 1	1.009	0.237	4.267	< 0.001**	0.544	1.474
Time = 2*Sarcopenia = 1	0.337	0.228	1.481	0.140	−0.111	−785
Time = 1*Sarcopenia = 1	reference					
Time = 0*Sarcopenia = 1	reference					
Time = 3*Sarcopenia = 1	reference					
Time = 2*Sarcopenia = 0	reference					
Time = 1*Sarcopenia = 0	reference					

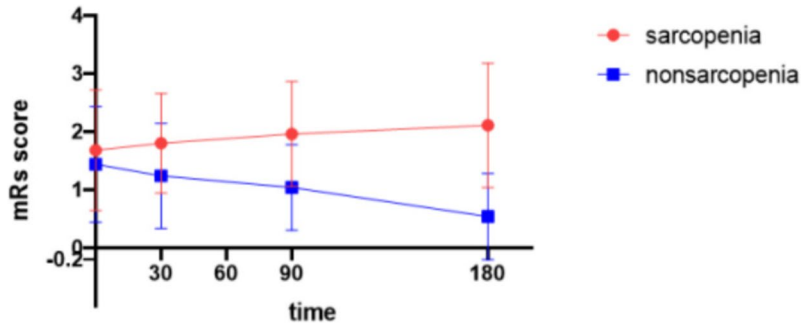

Fig. 3 The dynamic trend of total mRs score

speech difficulties), 9.5% were cardiovascular disease (atrial fibrillation, heart failure), 4.8% were recurrent stroke and 4.8% were pulmonary disease, 19% were dizziness. Cox regression risk ratio model showed that sarcopenia was a predictor of readmission within 6 months after mild ischemic stroke (HR = 3.361, 95%CI = 1.277–8.848; $p = 0.014$). Kaplan–Meier analysis indicated that the readmission time of patients with sarcopenia was significantly shorter than that of patients without sarcopenia as shown in Fig. 4. After adjusting for confounders, sarcopenia remained an independent predictor of increased risk of readmission (HR = 4.564, 95% CI = 1.399–14.888; $p = 0.012$) as shown in Table 4.

Discussion

In this study, we explored the effects of sarcopenia on prognoses in patients with mild acute ischemic stroke. The modified Poisson regression showed that sarcopenia was an independent prognostic factor for mild acute ischemic stroke. Sarcopenia appears independently associated with reduced improvement in BI and SSQOL following mild acute ischemic stroke. Furthermore, patients with mild acute ischemic stroke sarcopenia had a higher risk of readmission compared with patients without sarcopenia.

The skeletal muscles are the principal effector of disability [33]. Considering the role of skeletal muscles, it is important to examine the occurrence and prognosis of sarcopenia after acute ischemic stroke [34–37]. We identified that the prevalence of sarcopenia in mild acute ischemic stroke patients was 39.83%. The result of a meta-analysis that included seven studies showed that the pooled prevalence of stroke-related sarcopenia was 42%, which was close to the result in our study [11]. However, in Alice's study, the prevalence of sarcopenia in middle-aged and elderly survivors of cerebral stroke was 14%–18% [12]. Furthermore, different diagnostic criteria may also lead to the differences seen in different studies [38, 39], and the prevalence may be influenced by the characteristics of the subjects, namely, specific manifestations that age and BMI are risk factors for sarcopenia [40, 41]. In our study, the older adult accounted for 69.5% and patients' BMI was 23.43 ± 2.97 kg/m^2, while the older adult accounted for 42.9% and patients' BMI

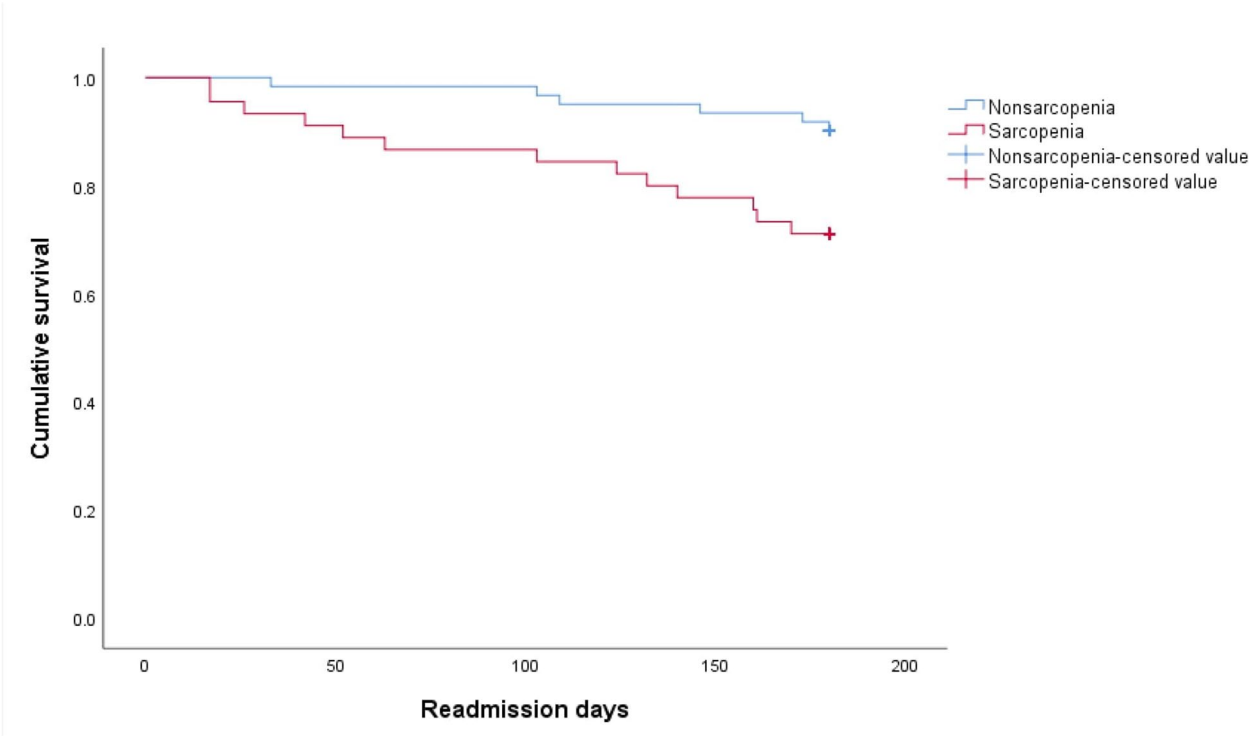

Fig. 4 KaplaneMeier curve for overall survival in patients according to the readmission days and sarcopenia

Table 4 Effect of sarcopenia on readmission in patients with acute stroke in 6 months

	β	SE	Wals χ^2	P	HR	95%CI	
Model 1	1.212	0.494	6.024	0.014*	3.361	1.277	8.848
Model 2	1.281	0.496	6.682	0.010*	3.601	1.363	9.513
Model 3	1.329	0.513	6.719	0.010*	3.776	1.383	10.313
Model 4	1.518	0.603	6.331	0.012*	4.564	1.399	14.888

Model 1: Sarcopenia

Model 2: Adjusted model 1 and baseline mRS

Model 3: Adjusted model 2 and comorbidities, Baseline BI, NIHSS

Model 4: Adjusted model 3 and BMI

was 32 ± 1 kg/m^2 in Alice's study [12]. The proportion of elderly patients in that study was lower than our study, and BMI was significantly higher than in our study. Shiraishi's study showed that the prevalence of sarcopenia in convalescent stroke patients was 53.5%, a value greater than found in our study [10]. The reason for this difference may arise from the fact that convalescent stroke patients are more prone to sarcopenia [42]. It was demonstrated that physical activity decreases after stroke, and convalescent patients present an increased risk of sarcopenia due to pathological changes as denervation and limb disuse [16, 18].

Sarcopenia is correlated with a range of factors affecting health [43]. Our results indicate sarcopenia is an independent risk factor for prognosis in mild acute ischemic stroke even after adjustment for confounding factors. Modified Poisson regression indicated that poor prognosis in sarcopenia patients is 3.021-fold higher than in non-sarcopenia patients with mild acute ischemic stroke, which is similar to the study of Lee et al. [44]. However, there are some differences between our study and that of Lee et al. [42]. This study found that the prevalence of sarcopenia in patients with acute mild stroke was 39.83%, whereas Lee et al. reported the prevalence of sarcopenia was 8.5% in patients with mild acute ischemic stroke

or transient ischemic attack (TIA). This discrepancy in prevalence may be due to their inclusion of TIA patients and Lee's study measured muscle strength using the Medical Research Council (MRC) score rather than the grip strength recommended by consensus guidelines [28]. Furthermore, our study extends the findings of Lee et al. by identifying BMI as a protective factor against sarcopenia in patients with mild acute ischemic stroke. We also observed that patients with sarcopenia had significantly lower quality of life and a 3.361 times higher risk of readmission compared to non-sarcopenic patients. And Jang et al. [45]. reported that patients with sarcopenia had a 2.71-fold increased risk of poor recovery at 6 months,and it is slightly lower than our study. Possible mechanisms underlying this association may be that the definition of poor functional outcome was different. The mRs scores > 3 were defined as a poor functional outcome, and we considered the increase in mRS score as functional deterioration. The causes of sarcopenia are multifactorial, with both acute and chronic diseases playing a critical role in skeletal muscle loss. The possible reasons for sarcopenia's association with poor prognosis in mild acute ischemic stroke patients are as follows: On one hand, it is related to the progression of sarcopenia after the stroke, with decreased muscle mass, strength, activity, and overall health. After stroke, muscle denervation, limb disuse, and activation of catabolic metabolism lead to changes in skeletal muscle fiber phenotype and muscle atrophy [14]. On the other hand, muscle structure changes within hours after a stroke, and muscle mass declines rapidly [15]. Catabolism is activated in muscle tissue after acute stroke, muscle mass and strength have been reduced [14, 46]. It can significantly limit physical activity, leading to decreased muscle mass and strength. And, due to central system disease, muscle autonomic contraction is difficult due to reduced control of motor units [47]. Skeletal muscle is the main effector of body function, a decline of skeletal muscle mass, even the muscle function may increase stroke burden. It showed that low muscle mass after stroke is associated with reduced walking function at acute discharge [48]. Moreover, increased skeletal muscle mass reduces brain white matter changes/silent infarction (WMC/SI), and increased skeletal muscle mass may prevent stroke. Additionally, sarcopenia often coexists with stroke, making it a key factor in disability among stroke patients [34]. A recent study [49] found that increasing skeletal muscle mass can reduce white matter lesions and asymptomatic brain infarcts, suggesting that improving muscle mass may help prevent stroke. In addition, skeletal muscle serves as a major site for glycogen storage. A decline in muscle mass directly reduces glycogen storage capacity, impairing the ability of insulin to convert excess blood glucose into muscle glycogen, leading to insulin resistance [50]. Research indicates that insulin resistance is associated with an increased risk of death, stroke recurrence, and poor prognosis[51]. Additionally, sarcopenic patients show significantly elevated levels of C-reactive protein (CRP), interleukin-6 (IL-6), and angiotensin II [50]. Studies have found that the risk of a 40% decline in muscle strength is 2 to 3 times higher in patients with high serum CRP compared to those with normal serum CRP [52], factors that may exacerbate the impact of sarcopenia on stroke prognosis.

In this research, we revealed that BI and SSQOL scores were lower in mild acute ischemic stroke patients with sarcopenia. These results suggest that sarcopenia affects the quality of life and self-care ability of patients with mild acute ischemic stroke. Meanwhile, we found that sarcopenia increases the risk of readmission in mild ischemic stroke patients. The significant association between sarcopenia and readmission persisted even after adjustment of confounding factors. However, after addition of BMI to our multivariable models, the risk associated with sarcopenia for stroke prognosis increased. Clinically, this suggests that BMI may play a modifying role in the relationship between sarcopenia and prognosis in mild AIS patients. Previous studies showed that a high level of BMI is one of the risk factors for mild AIS [53]. One potential mechanism is the 'obesity paradox' [54], where higher BMI may be protective in certain chronic and acute conditions, including stroke, possibly due to greater energy reserves, which can be beneficial in recovery. In addition, Yao's study [55] found that low BMI is a risk factor for sarcopenia in stroke patients. The lower the BMI, the greater the risk of sarcopenia in mild AIS, which may be associated with a higher metabolic reserve. It can resist the loss of muscle mass caused by excessive catabolism. Lee's study found muscle mass and strength have a significant impact on post-stroke recovery [44]. Moreover, sarcopenia is an independent risk factor that leads to poor prognosis in mild acute ischemic stroke patients. This study provides a new idea for the formulation of prognostic intervention measures for ischemic stroke in the future. We recommend early screening for sarcopenia in stroke patients (e.g., using grip strength, gait speed, or muscle mass assessment). For patients diagnosed with sarcopenia, individualized interventions, including nutritional support (e.g., protein and vitamin D supplementation) and resistance training, should be initiated promptly to improve muscle function and reduce the risk of adverse outcomes [56].

A strength of this study was that we used the modified Poisson regression RR to evaluate the effect of sarcopenia on changes in mRS at 6 months. The BI and SSQOL as dependent variables further confirmed the impact of sarcopenia on the prognosis of mild acute ischemic stroke

after 6 months. In addition, this study examined the risk of sarcopenia for readmission in mild acute ischemic stroke. Some limitations were as follows: First, physical performance was not measured because the ischemic stroke patients were still in the acute phase. Since the sample size limits our research, we need to continue to expand the sample size in the future research. Second, this study only included patients with mild acute ischemic stroke and excluded those with severe strokes (GCS < 9, NIHSS > 15, or mRS > 5), significant pre-existing disabilities, or those unable to undergo InBody measurements. While these criteria enhanced internal validity, they may have introduced selection bias and limited the generalizability of our findings to more severe or complex stroke cases. Future studies with broader inclusion criteria are needed to validate these results in a more diverse population.And the follow-up of this study was 6 months and was not long enough to evaluate the long-term effect of sarcopenia on prognosis in patients with mild acute ischemic stroke. Furthermore, this study did not systematically collect data about subsequent rehabilitation, which could have resulted in significant bias in both groups. And this study is without detailed records of specific rehabilitation interventions or medication information. In the future, we will endeavor to acquire comprehensive details regarding the patient's recovery via collaboration among multiple agencies. At last, the study was monocentric and analyzed from a small size, which may affect the generalization of these findings.

Conclusions

Sarcopenia was an independent risk factor for poor prognosis, and it led to an increase in the risk of readmission in mild acute ischemic stroke patients. Sarcopenia represents an important but overlooked variable in mild ischemic stroke research. Elucidating how sarcopenia influences prognosis may benefit clinical decision-making and service provision.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12883-025-04136-1.

Supplementary Material 1.

Acknowledgements
We acknowledge all the staff and colleagues who participated in the study.

Statement of authorship
All authors contributed substantially to the conception and design of the study or the acquisition, analysis, or interpretation of data and the drafting or the revision of the article. All authors approved the final version of the manuscript for submission.

Authors' contributions
RC and ZYL contributed equally. Data curation, RC and RTL; Investigation, RC, RTL, HL, CXH, JHC, HX and JHY; Methodology, ZYL, XPZ, JWG and LW; Supervision, LW; Writing-original draft, RC; Writing-review & editing, ZYL and LW.

Funding
This study was supported by grant from the State Key Laboratory of dampness syndrome of Chinese Medicine open topic (SZ2022KF15) and Guangdong Provincial Bureau of Traditional Chinese Medicine Scientific Research Project (20241113).

Data availability
All data generated in this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Ethics approval and consent to participate This study has been conducted in accordance with the ethical principles mentioned in the Declaration of Helsinski. The study was approved by the Ethics Committee, which belongs to the ethical committee of Guangdong Provincial Hospital of Chinese Medicine (ZE2020-163–01).
All patients gave their consent to participate. All participants gave written informed consent before enrolment.

Consent for publication
Written informed consent was obtained from the patients for publication of this study and any accompanying images.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Neurology, The Second Affiliated Hospital of Guangzhou University of Chinese Medicine, Guangzhou, Guangdong, China. [2]Department of Knee Osteoarthritis, The Second Affiliated Hospital of Guangzhou University of Chinese Medicine, Guangzhou, Guangdong, China. [3]Department of Nursing, The Second Affiliated Hospital of Guangzhou University of Chinese Medicine, Guangzhou, Guangdong, China. [4]Department of Emergency, The Second Affiliated Hospital of Guangzhou University of Chinese Medicine, Guangzhou, Guangdong, China. [5]Guangdong Provincial Hospital of Chinese Medicine, Guangzhou, Guangdong, China. [6]State Key Laboratory of Dampness, Syndrome of Chinese Medicine, The Second Affiliated Hospital of Guangzhou University of Chinese Medicine, Guangzhou, Guangdong, China. [7]State Key Laboratory of Traditional Chinese Medicine Syndrome, Department of Nursing, The Second Affiliated Hospital of Guangzhou University of Chinese Medicine, Guangzhou, Guangdong, China.

Received: 29 March 2024 Accepted: 13 March 2025
Published online: 27 March 2025

References

1. Hilkens NA, Casolla B, Leung TW, et al. Stroke Lancet. 2024;403(10446):2820–36.
2. Yang G, Wang Y, Zeng Y, et al. Rapid health transition in China, 1990–2010: findings from the Global Burden of Disease Study 2010. Lancet. 2013;381(9882):1987–2015.
3. Tu W, Zhao Z, Yin P, Cao L, et al. Estimated Burden of Stroke in China in 2020. JAMA Netw Open. 2023;6(3):e231455.
4. Benjamin EJ, Virani SS, Callaway CW, et al. Heart Disease and Stroke Statistics-2018 Update: A Report From the American Heart Association. Circulation. 2018;137(12):e67–492.
5. Ward NS. Restoring brain function after stroke - bridging the gap between animals and humans. Nat Rev Neurol. 2017;13:244–55.
6. Wang X, Xuan W, Zhu ZY, et al. The evolving role of neuro-immune interaction in brain repair after cerebral ischemic stroke. CNS Neurosci Ther. 2018;24(12):1100–14.

7. Cruz-Jentoft AJ, Sayer AA. Sarcopenia. Lancet. 2019;393(10191):2636–46.
8. Dhillon RJ, Hasni S. Pathogenesis and Management of Sarcopenia. Clin Geriatr Med. 2017;33(1):17–26.
9. Scherbakov N, Sandek A, Doehner W. Stroke-Related Sarcopenia: Specific Characteristics. J Am Med Dir Assoc. 2015;16(4):272–6.
10. Shiraishi A, Yoshimura Y, Wakabayashi H, et al. Prevalence of stroke-related sarcopenia and its association with poor oral status in post-acute stroke patients: Implications for oral sarcopenia. Clin Nutr. 2018;37(1):204–7.
11. Su Y, Yuki M, Otsuki M. Prevalence of stroke-related sarcopenia: A systematic review and meta-analysis. J Stroke Cerebrovasc. 2020;29(9):105092.
12. Ryan AS, Ivey FM, Serra MC, et al. Sarcopenia and Physical Function in Middle-Aged and Older Stroke Survivors. Arch Phys Med Rehab. 2017;98(3):495–9.
13. Tournadre A, Vial G, Capel F, et al. Sarcopenia. Joint Bone Spine. 2019;86(3):309–14.
14. Springer J, Schust S, Peske K, et al. Catabolic signaling and muscle wasting after acute ischemic stroke in mice: indication for a stroke-specific sarcopenia. Stroke. 2014;45(12):3675–83.
15. Arasaki K, Igarashi O, Ichikawa Y, et al. Reduction in the motor unit number estimate (MUNE) after cerebral infarction. J Neurol Sci. 2006;250(1–2):27–32.
16. Carin-Levy G, Greig C, Young A, et al. Longitudinal changes in muscle strength and mass after acute stroke. Cerebrovasc Dis. 2006;21(3):201–7.
17. Ryan AS, Buscemi A, Forrester L, et al. Atrophy and intramuscular fat in specific muscles of the thigh: associated weakness and hyperinsulinemia in stroke survivors. Neurorehab Neural Re. 2011;25(9):865–72.
18. Nagano F, Yoshimura Y, Bise T, et al. Muscle mass gain is positively associated with functional recovery in patients with sarcopenia after stroke. J Stroke Cerebrovasc. 2020;29(9):105017.
19. Nozoe M, Kanai M, Kubo H, et al. Prestroke sarcopenia and functional outcomes in elderly patients who have had an acute stroke: A prospective cohort study. Nutrition. 2019;66:44–7.
20. Ohyama K, Watanabe M, Nosaki Y, et al. Correlation Between Skeletal Muscle Mass Deficit and Poor Functional Outcome in Patients with Acute Ischemic Stroke. J Stroke Cerebrovasc. 2020;29(4):104623.
21. Scherbakov N, von Haehling S, Anker SD, et al. Stroke induced Sarcopenia: muscle wasting and disability after stroke. Int J Cardiol. 2013;170(2):89–94.
22. Bullock GS, Collins G, Peirce N, et al. Physical activity and health-related quality of life in former elite and recreational cricketers from the UK with upper extremity or lower extremity persistent joint pain: a cross-sectional study. BMJ Open. 2019;9(11):e32606.
23. Langezaal L, van der Hoeven E, Mont'Alverne F, et al. Endovascular Therapy for Stroke Due to Basilar-Artery Occlusion. New Engl J Med. 2021;384(20):1910–20.
24. Sung SF, Hsieh CY, Lin HJ, et al. Validity of a stroke severity index for administrative claims data research: a retrospective cohort study. BMC Health Serv Res. 2016;16(1):509.
25. Mahoney FI, Barthel DW. Functional Evaluation: The Barthel Index. Md State Med J. 1965;14:61–5.
26. Williams LS, Weinberger M, Harris LE, et al. Development of a stroke-specific quality of life scale. Stroke. 1999;30(7):1362–9.
27. Wang Y, Ma J, Li J, et al. The study on reliability validity and responsiveness of the Chinese version of Stroke-specific Quality of Life. Chin J Geriatr Heart Brain Vessel Dis. 2003;5(6):391–4.
28. Chen L, Woo J, Assantachai P, et al. Asian Working Group for Sarcopenia: 2019 Consensus Update on Sarcopenia Diagnosis and Treatment. J Am Med Dir Assoc. 2020;21(3):300–7.
29. Schlesselman JJ. Sample size requirements in cohort and case-control studies of disease. Am J Epidemiol. 1974;99(6):381–4.
30. Tu WJ, Chao BH, Ma L, et al. Case-fatality, disability and recurrence rates after first-ever stroke: A study from bigdata observatory platform for stroke of China. Brain Res Bull. 2021;175:130–5.
31. Kyriacou DN, Lewis RJ. Confounding by Indication in Clinical Research. JAMA J Am Med Assoc. 2016;316(17):1818–9.
32. Pierrat V, Marchand-Martin L, Marret S, et al. Neurodevelopmental outcomes at age 5 among children born preterm: EPIPAGE-2 cohort study. BMJ Brit Med J. 2021;373:n741.
33. Akazawa N, Harada K, Okawa N, et al. Low body mass index negatively affects muscle mass and intramuscular fat of chronic stroke survivors. PLoS ONE. 2019;14(1):e211145.
34. Li W, Yue T, Liu Y. New understanding of the pathogenesis and treatment of stroke-related sarcopenia. Biomed Pharmacother. 2020;131:110721.
35. Chang KV, Wu WT, Huang KC, et al. Segmental body composition transitions in stroke patients: Trunks are different from extremities and strokes are as important as hemiparesis. Clin Nutr. 2020;39(6):1968–73.
36. Matsushita T, Nishioka S, Taguchi S, et al. Effect of Improvement in Sarcopenia on Functional and Discharge Outcomes in Stroke Rehabilitation Patients. Nutrients. 2021;13(7):2192.
37. Hunnicutt JL, Gregory CM. Skeletal muscle changes following stroke: a systematic review and comparison to healthy individuals. Top Stroke Rehabil. 2017;24(6):463–71.
38. Yang L, Yao X, Shen J, et al. Comparison of revised EWGSOP criteria and four other diagnostic criteria of sarcopenia in Chinese community-dwelling elderly residents. Exp Gerontol. 2020;130:110798.
39. Zeng Y, Hu X, Xie L, et al. The Prevalence of Sarcopenia in Chinese Elderly Nursing Home Residents: A Comparison of 4 Diagnostic Criteria. J Am Med Dir Assoc. 2018;19(8):690–5.
40. Kitamura A, Seino S, Abe T, et al. Sarcopenia: prevalence, associated factors, and the risk of mortality and disability in Japanese older adults. J Cachexia Sarcopeni. 2021;12(1):30–8.
41. Kang K, Lee WW, Lee JJ, et al. Comparison of body mass index, waist circumference, and waist-height ratio in predicting functional outcome following ischemic stroke. J Thromb Thrombolys. 2017;44(2):238–44.
42. Yoshimura Y, Wakabayashi H, Bise T, et al. Prevalence of sarcopenia and its association with activities of daily living and dysphagia in convalescent rehabilitation ward inpatients. Clin Nutr. 2018;37((6 Pt A)):2022–8.
43. Hsu CS, Kao JH. Sarcopenia and chronic liver diseases. Expert Rev Gastroent. 2018;12(12):1229–44.
44. Lee H, Lee IH, Heo J, et al. Impact of Sarcopenia on Functional Outcomes Among Patients With Mild Acute Ischemic Stroke and Transient Ischemic Attack: A Retrospective Study. Front Neurol. 2022;13:841945.
45. Jang Y, Im S, Han Y, et al. Can initial sarcopenia affect poststroke rehabilitation outcome? J Clin Neurosci. 2020;71:113–8.
46. Scherbakov N, Doehner W. Sarcopenia in stroke-facts and numbers on muscle loss accounting for disability after stroke. J Cachexia Sarcopeni. 2011;2(1):5–8.
47. De Deyne PG, Hafer-Macko CE, Ivey FM, et al. Muscle molecular phenotype after stroke is associated with gait speed. Muscle Nerve. 2004;30(2):209–15.
48. Abe T, Iwata K, Yoshimura Y, et al. Low Muscle Mass is Associated with Walking Function in Patients with Acute Ischemic Stroke. J Stroke Cerebrovasc. 2020;29(11):105259.
49. Minn YK, Suk SH. Higher skeletal muscle mass may protect against ischemic stroke in community-dwelling adults without stroke and dementia: The PRESENT project. BMC Geriatr. 2017;17(1):45.
50. Picca A, Coelho-Junior HJ, Calvani R, et al. Biomarkers shared by frailty and sarcopenia in older adults: A systematic review and meta-analysis. Ageing Res Rev. 2022;73:101530.
51. Jing J, Pan Y, Zhao X, et al. Insulin Resistance and Prognosis of Nondiabetic Patients With Ischemic Stroke: The ACROSS-China Study (Abnormal Glucose Regulation in Patients With Acute Stroke Across China). Stroke. 2017;48(4):887–93.
52. Hamrick MW, Ding KH, Pennington CC, et al. Age-related loss of muscle mass and bone strength in mice is associated with a decline in physical activity and serum leptin. Bone. 2006;39(4):845–53.
53. Wang X, Huang Y, Chen Y, et al. The relationship between body mass index and stroke: a systemic review and meta-analysis. J Neurol. 2022;269(12):6279–89.
54. Gupta R, Mahmoudi E, Behnoush AH, et al. Effect of BMI on patients undergoing transcatheter aortic valve implantation: A systematic review and meta-analysis. Prog Cardiovasc Dis. 2023;78:58–66.
55. Yao R, Yao L, Rao A, et al. Prevalence and risk factors of stroke-related sarcopenia at the subacute stage: A case control study. Front Neurol. 2022;13:899658.
56. Bernabei R, Landi F, Calvani R, et al. Multicomponent intervention to prevent mobility disability in frail older adults: randomised controlled trial (SPRINTT project). BMJ Brit Med J. 2022;377:e68788.

Publisher's Note