Prevalence and predictive factors for obesity, sarcopenia and sarcopenic obesity in patients with chronic stroke

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Abstract. Muscle mass loss occurs early following a stroke, and the rate of decline is more rapid than the normal ageing process. The aim of the present study was to examine the prevalence of and predictive factors for obesity, sarcopenia and sarcopenic obesity (SO) in patients with stroke. Patients with chronic stroke with a duration >6 months were recruited. Their clinical data were recorded, and dual-energy X-ray absorptiometry was used to evaluate body composition. Multivariable logistic regression analysis was used to analyse predictive factors for obesity, sarcopenia and SO. A total of 84 participants (58 males and 26 females) with a median age of 58.3 years were enrolled. The median duration following stroke was 2.2 years. The prevalence of obesity, sarcopenia and SO was 26.2, 21.4 and 23.8%, respectively. Age, sex, National Institutes of Health Stroke Scale, Oral Health Assessment Tool, Functional Ambulation Category (FAC), calf circumference, and Mini Nutritional Assessment-Short Form (MNA-SF) score were included as independent factors. Multivariable logistic regression analysis revealed that only calf circumference was a predictive factor for obesity [adjusted odds ratio (aOR), 1.38, 95% confidence interval (CI), 1.08-1.77]. As regards sarcopenia, two factors were found to be significant: The MNA-SF score (aOR, 0.70; 95% CI, 0.53-0.94) and calf circumference (aOR, 0.66; 95% CI, 0.49-0.89). Significant predictive factors for SO were being male (aOR 7.96; 95% CI, 1.05-60.49) and FAC (aOR, 0.15; 95% CI, 0.04-0.55). Sarcopenia and SO were observed in almost half of the participants with chronic stroke. On the whole, calf circumference was found to be a predictor for both obesity and sarcopenia. The nutritional status assessed using MNA-SF was a predictor for sarcopenia. The male sex and FAC were found to be predictive factors for SO.

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Introduction

A progressive decline in muscle mass is associated with ageing. This decrease in muscle mass begins at the age of ~40 years (1). The rate of muscle mass loss accelerates with age, ranging from 4-5% per decade to as high as 10% per decade in individuals >70 years of age (2,3). Sarcopenia, which is defined as a syndrome characterized by a decline of skeletal muscle plus low muscle strength and/or physical performance, occurs at a higher prevalence with ageing, leading to multiple adverse outcomes including falls, fractures, disability, hospitalization or increased mortality rates (4-8).

Stroke significantly affects skeletal muscle. Studies have demonstrated that muscle mass loss occurs early following a stroke, and that the rate of decline is more rapid than that observed with the normal ageing process (9,10). In addition to muscle atrophy resulting from neuronal deafferentation, other mechanisms accounting for the changes in muscle mass, such as catabolic-anabolic imbalance, systemic inflammatory activation and local muscle metabolic alterations, have also been reported (11-13). Furthermore, inactivity, fatigue, deconditioning and poor nutrition, which are common in patients following a stroke, also contribute to sarcopenia (11,13). Since muscle is a critical organ for daily function, the loss of muscle mass has a particularly detrimental impact on patients following a stroke. For example, Jang *et al* (14) and Matsushita *et al* (15) found that sarcopenia occurring early following stroke was associated with a poorer functional outcome.

Patients following a stroke exhibit an increased prevalence of sarcopenia when compared to age- and sex-matched individuals who have not suffered a stroke (16,17). According to a recent meta-analysis, the pooled prevalence of sarcopenia in patients with chronic stroke, obtained from three studies in the USA, Taiwan and Korea, was found to be 33.6 [95% confidence interval (CI), 16.5-56.4] (18). The prevalence from each country was 16.8, 48.6 and 41.8%, respectively (14,18-20). The authors of the meta-analysis also reported that there was a limited number of studies focusing on sarcopenia in the stroke population (18). Differences in ethnicity, genetics, diet, lifestyle and living environment play a role in the development of sarcopenia. Furthermore, since sarcopenia and obesity can co-exist, the term sarcopenic obesity (SO) has emerged. SO is characterized as a clinical condition of a high body fat percentage

and low lean mass; this combination is considered to have a negative synergistic effect on patient outcomes. SO and sarcopenia should be considered differently, since individuals with obesity may have a comparable or even higher absolute skeletal muscle mass due to a higher overall body mass. The criteria for sarcopenia, which are based on appendicular skeletal mass divided by height squared, were not considered suitable for the diagnosis of SO. Instead, the relative reduction in muscle mass per body mass, as demonstrated by appendicular skeletal mass per body mass, was considered more appropriate (21). SO has not yet been studied in detail in patients with chronic stroke, and the consensus criteria were only recently launched by the European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Association for the Study of Obesity (EASO), in 2022 (21). Thus, the aim of the present study was to examine the prevalence of and predictive factors for obesity, sarcopenia and SO in patients with chronic stroke in Thailand.

Patients and methods

Patients and inclusion and exclusion criteria. The present cross-sectional descriptive study was conducted in patients with chronic stroke who attended the Outpatient Rehabilitation Clinic at Srinagarind Hospital (the university hospital of the Faculty of Medicine, Khon Kaen University Khon Kaen, Thailand) between October, 2020 and January, 2022. Srinagarind Hospital is a super-tertiary care facility and the largest university hospital in Northeastern Thailand. The inclusion criteria were as follows: i) An age ≥18 years; ii) ischaemic or haemorrhagic stroke with an onset >6 months; iii) an ability to understand and follow commands; and iv) an ability to provide consent to participate in the study. The exclusion criteria were as follows: i) Unstable vital signs; ii) the use of medication that may affect body mass or composition, e.g. steroids or diuretics; and iii) having underlying diseases that may affect walking performance, e.g., chronic joint pain conditions. The present study was approved by the Khon Kaen University Ethics Committee for Human Research (Ref. HE631455). The study was conducted in accordance with local legislation and institutional requirements. Each patient signed a written consent form prior to participation.

Clinical assessment. Clinical assessment included body mass, height, body mass index (BMI), handgrip strength, National Institutes of Health Stroke Scale (NIHSS), upper and lower extremities Motricity Index (MI) (22), Modified Rankin Scale (MRS), Functional Ambulation Category (FAC), maximum calf circumference, maximal grip strength (the maximum value achieved from three attempts of forcefully grasping the device using the Baseline Hydraulic Hand dynamometer), 10-metre walk test (a series of 10-metre walks, with the average gait speed calculated from the 6 m covered between the 2-metre and 8-metre points divided by the time to cover this distance), Oral Health Assessment Tool (OHAT), and nutritional status (Mini Nutritional Assessment-Short Form: MNA-SF). Cognitive impairment was defined as a score of ≤23 from the Montreal Cognitive Assessment (23).

Muscle mass was measured using dual-energy X-ray absorptiometry (DXA). Appendicular skeletal muscle mass measurement was performed in a standard manner with a Lunar Prodigy DXA scanner (GE Healthcare; Cytiva). The appendicular skeletal muscle index (ASMI) was calculated as appendicular lean body mass (kg) divided by the square of the height (m^2).

Definition of obesity, sarcopenia and SO

Obesity. Obesity was determined based on the BMI, which was calculated as the body mass divided by the square of height (kg/m^2). Individuals classified as obese were defined according to the Southeast Asia cut-off point of BMI ≥25 kg/m^2 (24).

Sarcopenia. The diagnosis of sarcopenia was based on the Asian Working Group for Sarcopenia (AWGS) 2019 consensus update. Sarcopenia was defined as a 'low muscle mass' plus 'low hand grip strength' and/or 'low physical performance'. The cut-off values of ASMI were as follows: Low muscle mass <7.0 kg/m^2 in males and <5.4 kg/m^2 in females measured using DXA, low hand grip strength <28.0 kg for males and <18.0 kg for females measured using the handgrip dynamometer, reduced physical performance using gait speed <1.0 m/sec (25).

SO. SO was diagnosed according to the European Society for Clinical Nutrition and Metabolism (ESPEN) and the European Association for the Study of Obesity (EASO) consensus (21). The diagnosis of SO was determined if the participant fulfilled the following two criteria: i) Altered skeletal muscle functional parameters assessed by hand grip strength; and ii) altered body composition defined as an increased fat mass (FM%) and reduced muscle mass assessed as appendicular lean muscle divided by body mass (ALM/BM) (21). As regards FM%, the definition from the study by Lee *et al* (26) we used, which identified high FM% in the Asian population with an age ≥40 years as >25.8% for males and >36.5% for females; these values represent the two highest quintiles of the study population. The definition of a reduced muscle mass based on ALM/BM was defined as <29.1% in males and <23.0% for females, which are the values representing two standard deviations (SDs) from the mean of the young reference group aged 20-39 years (27).

Sample size calculation. The sample size was estimated using a single population proportion formula, considering the proportion of patients who had sarcopenia to be 35%. This proportion was obtained from a previous study conducted in the able-bodied population in Thailand, with a confidence level of 95% and a margin of error of 10% (28). The required sample size was then 88 participants.

Statistical analysis. Outcomes were assessed for normality using the Shapiro-Wilk test. Normally distributed, non-normally distributed, and categorical data are presented as the mean ± SD, median (25 and 75th percentile; (p25, p75), and number (%), respectively. Differences in the baseline characteristics were analysed using one-way ANOVA for continuous variables and Fisher's exact test or a Chi-squared test for categorical variables. When one-way ANOVA indicated significant differences, Bonferroni post hoc tests were performed to assess pairwise comparisons between groups. Univariate logistic regression analysis was performed to evaluate individual effect sizes and

the statistical significance of each parameter, reported in crude odds ratio and 95% confidence interval (CI). Factors included in the model were established factors (age and sex) (29,30) and factors that were found to have P-values <0.25 (31) (NIHSS, OHAT, FAC, calf circumference and MNA-SF). BMI, maximal hand grip and ASMI were not included as variables in the analysis as these factors were used in the diagnosis of obesity, sarcopenia and SO. Due to the exploratory nature of the study, a full-model approach was used; thus, all factors were entered in a multivariable logistic regression model (32). The results are reported as adjusted odds ratios and 95% CI values. A value of P<0.05 was considered to indicate a statistically significant difference. Statistical analyses were performed using Stata (Stata Statistical Software: Release 18. College Station, TX: Stata Corp LLC).

Results

A total of 88 participants were initially included in the study; however, following the exclusion of incomplete data, the final sample consisted of 84 participants (58 men and 26 women). Their average age was 58.3 years. Almost two thirds (64.6%) of the patients had ischaemic stroke, and more than half of the patients had left hemiparesis (59.5%). The median duration following the stroke was 2.2 years and ~14% had suffered from recurrent strokes.

The prevalence of obesity, sarcopenia and SO for the patients with chronic stroke was 26.2, 21.4 and 23.8%, respectively (Fig. 1). A total of 7 participants met the criteria for both sarcopenia and SO, 10 participants met the criteria for both obesity and SO and 3 participants met the criteria for obesity, sarcopenia and SO. All of them were included in the SO group, resulting in a final total of 20 participants in the SO group (Fig. 1). Males were found to have sarcopenia or SO (50%) more often than females (34.6%). The prevalence of sarcopenia increased with age, with 39.5% of individuals <60 years old affected, increasing to 51.2% in those aged ≥60 years (Table I and Fig. 2).

There were significant differences in BMI, NIHSS, FAC, calf circumference, MNA-SF, maximal hand grip and ASMI among the groups. Univariate logistic regression analysis revealed that MNA-SF and calf circumference were associated with obesity. However, only calf circumference [adjusted odds ratio (aOR), 1.38, 95% CI, 1.08-1.77] was a significant predictive factor for obesity in multivariable logistic regression analysis.

As regards sarcopenia, two factors were significant in the both univariate and multivariable logistic regression analysis: The MNA-SF score (aOR, 0.70; 95% CI, 0.53-0.94), and calf circumference (aOR, 0.66; 95% CI, 0.49-0.89).

OHAT, NIHSS and FAC were significant factors associated with SO in the univariate logistic regression analysis. However, the significant predictive factors for SO in the multivariable logistic regression analysis were being male (aOR, 7.96; 95% CI, 1.05-60.49) and FAC (aOR, 0.15; 95% CI, 0.04-0.55) (Table II).

Discussion

The aim of the present study was to examine the prevalence of and predictive factors for obesity, sarcopenia and SO in patients with chronic stroke in Thailand. It was found that

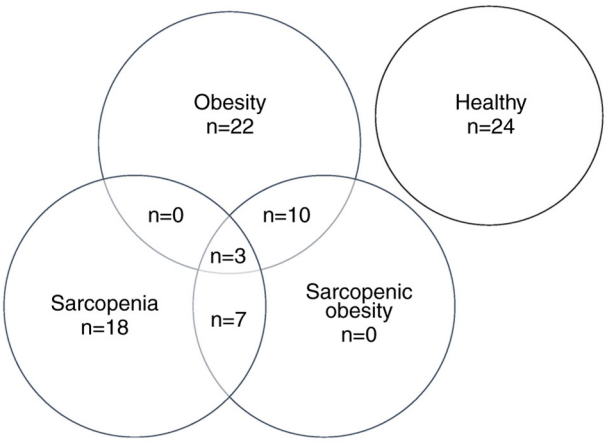

Figure 1. Venn diagram illustrating the overlapping and distinct categories of obesity, sarcopenia and sarcopenic obesity in participants with chronic stroke in Thailand.

the prevalence of obesity, sarcopenia and SO for patients with chronic stroke was 26.2, 21.4 and 23.8%, respectively. Overall, the prevalence of obesity, when including obesity cases that were overlapping with SO and sarcopenia, was 41.6%, which was higher than that in a previous study in Brazil (26.0%), but comparable to that in a study in Korea (43.5%) (33,34). It was found that the only predictive factor for obesity was calf circumference.

Similar to multiple previous studies, males and older-aged individuals exhibited a higher prevalence of sarcopenia and SO (35,36). In able-bodied populations, the prevalence of SO was reported to be less than half of the prevalence of sarcopenia, although the age of inclusion into the studies was higher than that in the present study (29,35,36). Notably, patients with chronic stroke exhibited a similarly high prevalence of sarcopenia and SO. This may suggest that following a stroke, patients have a higher gain in body fat compared to the able-bodied population. This notion is supported by a previous systematic review demonstrated that fat mass significantly increased between 6 and 12 months post-stroke with a pooled mean increase of nearly 2 kg (37).

When focusing only on the diagnosis of sarcopenia, it was noted that 28 patients fulfilled the criteria for sarcopenia (10 patients were classified as SO in the present study), leading to a prevalence of sarcopenia of 33.3%. The prevalence of sarcopenia in patients following stroke in the present study was comparable to a previous study on patients with acute stroke in Japan (32.5%) (38), although the age of the participants in the present study was lower (median age, of 58.5 vs. 72 years). The prevalence of sarcopenia was lower in the present study than that in previous studies in Korea (41.8%) (14) and Taiwan (48.6%) (19), but higher than that in a study conducted in the USA (16.8%) (20). The higher prevalence observed in Korea and Taiwan may be due to the older age of the patients recruited (age, 64.3±13.0 years) (14) and (64.6±15.1 years) (19), respectively (mean ± SD), compared to the present study (age, 58.3±9.5 years). The lower prevalence in the USA may be due to the inclusion criteria of that study, which were limited to participants with stroke who had mild to moderate hemiplegic gait deficits and had completed

Table I. Baseline demographic and clinical characteristics of the patients with chronic stroke (n=84).

Variables	Healthy (n=24)	Obesity (n=22)	Sarcopenia (n=18)	Sarcopenic obesity (n=20)	P-value
Age (years), mean (SD)	58.3 (9.3)	55.0 (10.3)	59.2 (7.5)	61.0 (10.3)	0.24
Sex					
Male	13 (54.2)	16 (72.7)	14 (77.8)	15 (75.0)	0.34
Female	11 (45.8)	6 (27.3)	4 (22.2)	5 (25.0)	
BMI (kg/m^2), mean (SD)	23.0 (1.9)	27.1 (2.0)	19.9 (2.5)	26.3 (3.2)	0.001[a-d,f]
Smoking					
Yes	0 (0.0)	1 (4.5)	0 (0.0)	1 (5.0)	0.70
No	24 (100)	21 (95.5)	18 (100)	19 (95.0)	
Alcoholic consumption					
Yes	2 (8.3)	4 (18.2)	1 (5.6)	4 (20.0)	0.48
No	22 (91.7)	18 (81.8)	17 (94.4)	16 (80.0)	
Educational level/					
≤ Secondary school	11 (45.8)	9 (40.9)	4 (22.2)	7 (35.0)	0.54
> Secondary school	13 (44.2)	13 (59.1)	14 (77.8)	13 (65.0)	
Comorbidities					
Hypertension					
Yes	15 (62.5)	15 (68.2)	14 (77.8)	12 (60.0)	0.68
No	9 (37.5)	7 (31.8)	4 (22.2)	8 (40.0)	
Diabetes mellitus					
Yes	8 (33.3)	8 (36.4)	8 (44.4)	7 (35.0)	0.90
No	16 (66.7)	14 (63.6)	10 (55.6)	13 (65.0)	
Dyslipidaemia					
Yes	6 (25.0)	5 (22.7)	5 (27.8)	6 (30.0)	0.95
No	18 (75.0)	17 (77.3)	13 (72.2)	14 (70.0)	
Charlson Comorbidity Index (n=75), mean (SD)	3.7 (1.9)	3.0 (1.5)	3.9 (1.6)	4.1 (2.0)	0.32
Stroke type					
Ischaemic	16 (66.7)	13 (59.1)	9 (50.0)	15 (75.0)	0.48
Haemorrhagic	8 (32.3)	9 (40.9)	9 (50.0)	5 (25.0)	
Hemiparetic side					
Left	12 (50.0)	15 (68.2)	10 (55.6)	13 (65.0)	0.60
Right	12 (50.0)	7 (31.8)	8 (44.4)	7 (35.0)	
Stroke recurrence					
First ever stroke	14 (70.8)	18 (81.8)	14 (77.8)	14 (70.0)	0.78
Recurrent stroke	7 (29.2)	4 (18.2)	4 (22.2)	6 (30.0)	
NIHSS, mean (SD)	3.3 (2.6)	4.3 (3.4)	5.7 (4.4)	6.7 (5.8)	0.043
OHAT (n=78), mean (SD)	1.2 (1.9)	1.5 (1.3)	1.1 (1.8)	2.3 (1.8)	0.12
FAC (n=83), mean (SD)	3.6 (0.7)	3.5 (0.8)	3.1 (1.1)	2.5 (1.2)	0.001
History of fall in previous year					
Yes	9 (37.5)	8 (36.4)	6 (33.3)	10 (50.0)	0.80
No	15 (62.5)	14 (63.6)	12 (66.7)	10 (50.0)	
Calf circumference (cm), mean (SD)	33.8 (3.0)	36.0 (3.7)	30.5 (3.4)	33.7 (3.1)	<0.001[b,d]
MNA-SF, points, mean (SD)	11.2 (2.8)	12.7 (1.7)	8.4 (4.0)	10.8 (2.7)	<0.001[b,d]
Physical activity level (SPAQ) (n=80)					
Moderate (min/week), mean (SD)	108.4 (195.9)	84.8 (126.8)	100.1 (160.1)	145.3 (261.3)	0.79
Vigorous (min/week), mean (SD)	5.2 (17.5)	22.6 (70.7)	14.4 (40.3)	20.8 (52.5)	0.64

Table I. Continued.

Variables	Healthy (n=24)	Obesity (n=22)	Sarcopenia (n=18)	Sarcopenic obesity (n=20)	P-value
MoCA (n=75), mean (SD)	21.3 (6.0)	21.9 (4.5)	19.9 (7.2)	19.0 (6.4)	0.46
Maximal hand grip (n=75) (kg), mean (SD)	24.7 (9.4)	30.6 (7.3)	20.7 (8.3)	23.5 (9.9)	0.01[d]
Comfortable gait speed (n=69) (m/sec), mean (SD)	0.62 (0.38)	0.59 (0.36)	0.46 (0.33)	0.51 (0.37)	0.58
ASMI (kg/m^2), mean (SD)	7.0 (0.8)	8.1 (0.9)	5.8 (1.0)	6.6 (0.9)	<0.001[a,b,d-f]

Values are presented as number (%), unless otherwise specified. [a]Healthy vs. obesity, [b]healthy vs. sarcopenia, [c]healthy vs. sarcopenic obesity, [d]obesity vs. sarcopenia, [e]obesity vs. sarcopenic obesity, [f]sarcopenia vs. sarcopenic obesity. ASMI, appendicular skeletal mass index; BMI, body mass index; FAC, Functional Ambulation Category; MNA-SF, Mini Nutritional Assessment-Short Form; MoCA, Montreal Cognitive Assessment; NIHSS, National Institutes of Health Stroke Scale; OHAT, Oral Health Assessment Tool; SD, standard deviation; SPAQ, stroke physical activity questionnaire.

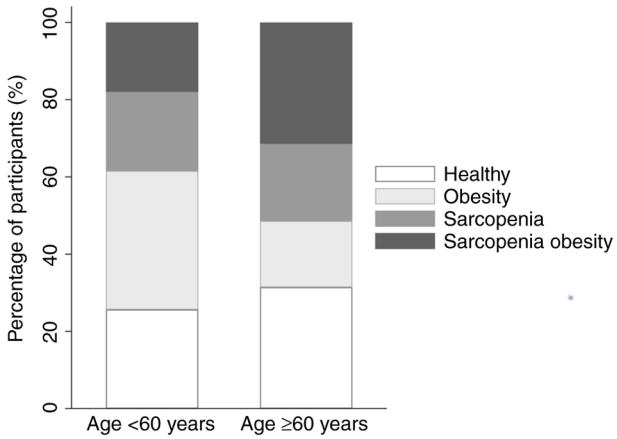

Figure 2. Distribution of individuals within the study population based on four categories: Healthy, obesity, sarcopenia and sarcopenic obesity. The data are stratified by age group.

conventional rehabilitation therapy. Different diagnostic criteria and participant characteristics may also contribute to the differences in prevalence. Previous studies in Japan and Korea used similar criteria to define sarcopenia and found that the prevalence of sarcopenia in patients with stroke was 39.7 and 53.5% (39,40). The results of the present study are comparable to the pooled prevalence estimate of sarcopenia in patients with chronic stroke (≥6 months) in a recent systematic review and meta-analysis (34%) (18). The lower prevalence of sarcopenia in the present study may be attributed to the lower average age of the participants.

It was found that calf circumference and nutritional status determined using the MNA-SF score were predictive factors for sarcopenia. Calf circumference was positively and moderately to highly associated with appendicular skeletal muscle and skeletal muscle index; thus, it was recommended as a surrogate marker of muscle mass for the diagnosis of sarcopenia (41). This finding confirms the importance of calf circumference and supports earlier studies that used calf circumference as a screening test itself or as an additional part of a screening test to increase the diagnostic accuracy for sarcopenia (41,42). The importance of nutritional status for sarcopenia, as highlighted in the present study, aligns with findings from previous studies across various populations (43-47). Several mechanisms may explain this. A reduced protein intake and low vitamin D levels are associated with muscle mass loss (48,49). Malnutrition leads to decreased levels of insulin-like growth factor-1 and growth factors which are essential for muscle growth (50). Malnutrition may increase the production of reactive oxygen and nitrogen species, causing oxidative stress, which reduces the regenerative potential of skeletal muscle and leads to muscle dysfunction (51). Moreover, in patients with disability, such as following a stroke, there may be a possible inter-association between disability and malnutrition, which leads to further detrimental effects (52). A recent longitudinal study demonstrated that malnutrition preceded the onset of sarcopenia (53). These findings, together with those of multiple previous studies, highlight the importance of screening the nutritional status in patients with stroke or older adults who are at risk of developing sarcopenia, in order to provide early intervention to prevent the progression of malnutrition and sarcopenia (52-54). It was found that MNA-SF was significantly associated with confirmed and severe sarcopenia and it was noted that the assessment of sarcopenia in individuals with a MNA-SF score <13 can be beneficial (46).

SO is an emerging clinical condition characterized by excessive fat mass in the presence of reduced muscle mass (55). SO produces a double metabolic burden from low muscle mass and excess adiposity. This negatively affects the muscle and gives rise to muscle anabolic resistance, and to deteriorating cardio-metabolic and physical function (55,56). Formerly, there was no universal definition of SO. Researchers classify individuals as having SO if they have appendicular mass fulfilling the criteria of sarcopenia in the presence of a body mass index in the obese category (55). SO has a negative effect on patients following a stroke, as it has been shown to be a predictive factor for physical limitations, falls and all-cause mortality (57-59). Additionally, it has been found to be associated with a lower level of activities of daily living capability in

Table II. Factors associated with obesity, sarcopenia and sarcopenic obesity in patients with chronic stroke.

Factors	Crude OR (95% CI)	P-value	Adjusted OR (95% CI)	P-value
Obesity				
Age (years)	0.95 (0.90-1.00)	0.069	0.99 (0.92-1.07)	0.79
Male sex	1.27 (0.43-3.73)	0.66	0.48 (0.09-2.44)	0.38
MNA-SF score	1.57 (1.11-2.20)	0.01	1.44 (0.95-2.18)	0.086
OHAT score	0.97 (0.73-1.30)	0.85	1.04 (0.67-1.63)	0.86
NIHSS score	0.95 (0.84-1.09)	0.47	1.09 (0.89-1.34)	0.39
FAC level	1.41 (0.84-2.40)	0.19	1.04 (0.41-2.62)	0.93
Calf circumference (cm)	1.31 (1.08-1.59)	0.006	1.38 (1.08-1.77)	0.009
Sarcopenia				
Age (years)	1.01 (0.96-1.07)	0.65	1.06 (0.95-1.18)	0.33
Male sex	1.75 (0.51-5.95)	0.37	4.28 (0.48-38.20)	0.19
MNA-SF score	0.75 (0.62-0.89)	0.001	0.70 (0.53-0.94)	0.017
OHAT score	0.80 (0.56-1.16)	0.25	1.08 (0.64-182)	0.77
NIHSS score	1.05 (0.94-1.17)	0.38	1.02 (0.80-1.29)	0.89
FAC level	0.91 (0.54-1.50)	0.70	2.54 (0.72-8.91)	0.15
Calf circumference (cm)	0.70 (0.56-0.88)	0.002	0.66 (0.49-0.89)	0.008
Sarcopenic obesity				
Age (years)	1.04 (0.98-1.10)	0.15	1.05 (0.96-1.14)	0.31
Male sex	1.47 (0.47-4.58)	0.51	7.96 (1.05-60.49)	0.045
MNA-SF score	0.98 (0.84-1.17)	0.88	1.08 (0.82-1.44)	0.57
OHAT score	1.40 (1.03-1.88)	0.027	1.11 (0.73-1.68)	0.63
NIHSS score	1.13 (1.00-1.28)	0.047	0.84 (0.64-1.12)	0.24
FAC level	0.43 (0.25-0.72)	0.001	0.15 (0.04-0.55)	0.004
Calf circumference (cm)	0.99 (0.85-1.16)	0.95	0.93 (0.77-1.31)	0.47

BMI, body mass index; CI, confidence interval; FAC, Functional Ambulation Category; MoCA, Montreal Cognitive Assessment; MNA-SF, Mini Nutritional Assessment-Short Form; NIHSS, National Institutes of Health Stroke Scale; OHAT, Oral Health Assessment Tool; OR, odds ratio.

patients with stroke (60). Although the prevalence of SO in participants with stroke was previously reported by Matsushita *et al* (60), that study was published before the standard criteria were established and it was conducted in a cohort with sub-acute stroke. Compared to the previous study by Matsushita *et al* (60), which demonstrated the prevalence of simple obesity, sarcopenia and SO as 17, 32 and 28%, respectively in 376 patients with sub-acute stroke, the present study revealed a lower prevalence of sarcopenia and SO. However, the cut-off point used herein for high body fat percentage (>25.8% for males and >36.5% for females) (27) was lower than the cut-off point used in the previous study (≥27% in males and ≥38% in females) (60). This may be due to the older age of their participants, with an average age of 77.5 years. It should be noted that the criteria for SO in the study by Matsushita *et al* (60) required the patient to fulfil the criteria of sarcopenia and to have a higher cut-off body fat percentage to define obesity. By contrast, SO, as defined in the present study, was based on the ESPEN and the European EASO consensus (21).

Being male and the ambulation status assessed by FAC were found to be predictive factors for SO in the present study. Being male increases the probability of developing SO, while a higher FAC (indicating a better walking ability) decreases the probability of having SO. The strong association with functional ability was previously observed in the study by Matsushita *et al* (60), which found that SO, but not sarcopenia or obesity, was significantly associated with FIM scores in participants with sub-acute stroke. Similarly, Auyeung *et al* (57) demonstrated that SO could predict the incidence of physical limitations in older women. Furthermore, Broadwin *et al* (61) demonstrated that an increased percentage of fat mass and a decreased percentage of fat-free mass were significantly associated with decreased functional ability in both females and males.

A notable strength of the present study is that its diagnosis of sarcopenia and SO followed the latest AWGS 2019 consensus, the ESPEN and the EASO consensus. However, the present study had several limitations which should be mentioned. Although DXA is considered highly accurate, fast and non-invasive, it cannot delineate intramuscular fat and lean body mass. Thus, the lean body mass measured from DXA may overestimate the real muscle mass in patients with stroke (62,63). In addition, the present study was a single-centre study; thus, the generalizability of the data may be limited. The cross-sectional design of the study limits the

ability to claim causative associations between each factor and the outcomes of obesity, sarcopenia and SO. The effect size of association may have to be interpreted with caution. The sample size calculation was based on a prevalence study design, which may result in insufficient power for logistic regression analysis. It is recommended that the sample size for logistic regression analysis should be at least 500; small to moderate sample sizes may overestimate the effect size (64,65). Consequently, these findings should be considered to be preliminary. In the future, incorporating additional predictors, such as genetic markers, lifestyle factors, vitamin D levels, micronutrient status and inflammatory biomarkers could lead to a more comprehensive model (48,66-68). A prospective study with a larger population could provide greater statistical power to examine the associations between obesity, sarcopenia and SO.

In conclusion, in the present study, sarcopenia and SO were observed in almost half of the participants with chronic stroke. Calf circumference was a predictor for both obesity and sarcopenia. The nutritional status assessed using MNA-SF was a predictor for sarcopenia. In addition, male sex and FAC were predictive factors for SO.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

CN, PA, CS and JS were responsible for the research conceptualization, study design and manuscript drafting. CN and JS were involved in data collection, analysis and interpretation. CN and JS confirm the authenticity of all the raw data All authors (CN, PA, CS, and JS) contributed to the manuscript drafting and read and approved the submitted version.

Ethics approval and consent to participate

Ethical approval for the present study was obtained from the Khon Kaen University Ethics Committee for Human Research (Ref. HE631455). The study was conducted in strict accordance with the principles outlined in the Declaration of Helsinki and in compliance with all relevant guidelines and regulations governing human research ethics. Each patient provided written informed consent prior to participation.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Use of artificial intelligence tools

During the preparation of this work, AI tools were used to improve the readability and language of the manuscript, and subsequently, the authors revised and edited the content produced by the AI tools as necessary, taking full responsibility for the ultimate content of the present manuscript.

References

1. Guo SS, Zeller C, Chumlea WC and Siervogel RM: Aging, body composition, and lifestyle: The fels longitudinal study. Am J Clin Nutr 70: 405-411, 1999.
2. Cameron J, McPhee JS, Jones DA and Degens H: Five-year longitudinal changes in thigh muscle mass of septuagenarian men and women assessed with DXA and MRI. Aging Clin Exp Res 32: 617-624, 2020.
3. Auyeung TW, Lee SW, Leung J, Kwok T and Woo J: Age-associated decline of muscle mass, grip strength and gait speed: A 4-year longitudinal study of 3018 community-dwelling older Chinese. Geriatr Gerontol Int 14 (Suppl 1): S76-S84, 2014.
4. Yeung SSY, Reijnierse EM, Pham VK, Trappenburg MC, Lim WK, Meskers CGM and Maier AB: Sarcopenia and its association with falls and fractures in older adults: A systematic review and meta-analysis. J Cachexia Sarcopenia Muscle 10: 485-500, 2019.
5. Xu J, Wan CS, Ktoris K, Reijnierse EM and Maier AB: Sarcopenia is associated with mortality in adults: A systematic review and meta-analysis. Gerontology 68: 361-376, 2022.
6. Zhang X, Zhang W, Wang C, Tao W, Dou Q and Yang Y: Sarcopenia as a predictor of hospitalization among older people: A systematic review and meta-analysis. BMC Geriatr 18: 188, 2018.
7. Zhang X, Wang C, Dou Q, Zhang W, Yang Y and Xie X: Sarcopenia as a predictor of all-cause mortality among older nursing home residents: A systematic review and meta-analysis. BMJ Open 8: e021252, 2018.
8. Janssen I: Influence of sarcopenia on the development of physical disability: The cardiovascular health study. J Am Geriatr Soc 54: 56-62, 2006.
9. Jung HJ, Lee YM, Kim M, Uhm KE and Lee J: Suggested assessments for sarcopenia in patients with stroke who can walk independently. Ann Rehabil Med 44: 20-37, 2020.
10. Jørgensen L and Jacobsen BK: Changes in muscle mass, fat mass, and bone mineral content in the legs after stroke: A 1 year prospective study. Bone 28: 655-659, 2001.
11. Scherbakov N, von Haehling S, Anker SD, Dirnagl U and Doehner W: Stroke induced Sarcopenia: Muscle wasting and disability after stroke. Int J Cardiol 170: 89-94, 2013.
12. Scherbakov N, Sandek A and Doehner W: Stroke-related sarcopenia: Specific characteristics. J Am Med Dir Assoc 16: 272-276, 2015.
13. Azzollini V, Dalise S and Chisari C: How does stroke affect skeletal muscle? State of the art and rehabilitation perspective. Front Neurol 12: 797559, 2021.
14. Jang Y, Im S, Han Y, Koo H, Sohn D and Park GY: Can initial sarcopenia affect poststroke rehabilitation outcome? J Clin Neurosci 71: 113-118, 2020.
15. Matsushita T, Nishioka S, Taguchi S and Yamanouchi A: Sarcopenia as a predictor of activities of daily living capability in stroke patients undergoing rehabilitation. Geriatr Gerontol Int 19: 1124-1128, 2019.
16. Hunnicutt JL and Gregory CM: Skeletal muscle changes following stroke: A systematic review and comparison to healthy individuals. Top Stroke Rehabil 24: 463-471, 2017.
17. Mas MF, González J and Frontera WR: Stroke and sarcopenia. Curr Phys Med Rehabil Rep 8: 452-460, 2020.
18. Su Y, Yuki M and Otsuki M: Prevalence of stroke-related sarcopenia: A systematic review and meta-analysis. J Stroke Cerebrovasc Dis 29: 105092, 2020.

19. Chang KV, Wu WT, Huang KC and Han DS: Segmental body composition transitions in stroke patients: Trunks are different from extremities and strokes are as important as hemiparesis. Clin Nutr 39: 1968-1973, 2020.
20. Ryan AS, Ivey FM, Serra MC, Hartstein J and Hafer-Macko CE: Sarcopenia and physical function in middle-aged and older stroke survivors. Arch Phys Med Rehabil 98: 495-499, 2017.
21. Donini LM, Busetto L, Bischoff SC, Cederholm T, Ballesteros-Pomar MD, Batsis JA, Bauer JM, Boirie Y, Cruz-Jentoft AJ, Dicker D, *et al*: Definition and diagnostic criteria for sarcopenic obesity: ESPEN and EASO consensus statement. Clin Nutr 41: 990-1000, 2022.
22. Collin C and Wade D: Assessing motor impairment after stroke: A pilot reliability study. J Neurol Neurosurg Psychiatry 53: 576-579, 1990.
23. Thomann AE, Berres M, Goettel N, Steiner LA and Monsch AU: Enhanced diagnostic accuracy for neurocognitive disorders: A revised cut-off approach for the montreal cognitive assessment. Alzheimers Res Ther 12: 39, 2020.
24. Tham KW, Abdul Ghani R, Cua SC, Deerochanawong C, Fojas M, Hocking S, Lee J, Nam TQ, Pathan F, Saboo B, *et al*: Obesity in South and Southeast Asia-A new consensus on care and management. Obes Rev 24: e13520, 2023.
25. Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K, Jang HC, Kang L, Kim M, Kim S, *et al*: Asian working group for sarcopenia: 2019 Consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc 21: 300-307.e2, 2020.
26. Lee J, Hong YP, Shin HJ and Lee W: Associations of sarcopenia and sarcopenic obesity with metabolic syndrome considering both muscle mass and muscle strength. J Prev Med Public Health 49: 35-44, 2016.
27. Kim YS, Lee Y, Chung YS, Lee DJ, Joo NS, Hong D, Song G, Kim HJ, Choi YJ and Kim KM: Prevalence of sarcopenia and sarcopenic obesity in the Korean population based on the Fourth Korean national health and nutritional examination surveys. J Gerontol A Biol Sci Med Sci 67: 1107-1113, 2012.
28. Pongchaiyakul C, Limpawattana P, Kotruchin P and Rajatanavin R: Prevalence of sarcopenia and associated factors among Thai population. J Bone Miner Metab 31: 346-350, 2013.
29. Gandham A, Scott D, Bonham MP, Kulkarni B, Kinra S, Ebeling PR and Zengin A: Sex differences in bone health among Indian older adults with obesity, sarcopenia, and sarcopenic obesity. Calcif Tissue Int 111: 152-161, 2022.
30. Gao Q, Hu K, Yan C, Zhao B, Mei F, Chen F, Zhao L, Shang Y, Ma Y and Ma B: Associated factors of sarcopenia in community-dwelling older adults: A systematic review and meta-analysis. Nutrients 13: 4291, 2021.
31. Bursac Z, Gauss CH, Williams DK and Hosmer DW: Purposeful selection of variables in logistic regression. Source Code Biol Med 3: 17, 2008.
32. Adulkasem N, Phinyo P, Khorana J, Pruksakorn D and Apivatthakakul T: Prognostic factors of 1-year postoperative functional outcomes of older patients with intertrochanteric fractures in Thailand: A retrospective cohort study. Int J Environ Res Public Health 18: 6896, 2021.
33. Jang SY, Shin YI, Kim DY, Sohn MK, Lee J, Lee SG, Oh GJ, Lee YS, Joo MC, Han EY, *et al*: Effect of obesity on functional outcomes at 6 months post-stroke among elderly Koreans: A prospective multicentre study. BMJ Open 5: e008712, 2015.
34. Vicente VS, Cabral NL, Nagel V, Guesser VV and Safanelli J: Prevalence of obesity among stroke patients in five Brazilian cities: A cross-sectional study. Arq Neuropsiquiatr 76: 367-372, 2018.
35. Daskalopoulou C, Wu YT, Pan W, Giné Vázquez I, Prince M, Prina M and Tyrovolas S: Factors related with sarcopenia and sarcopenic obesity among low- and middle-income settings: The 10/66 DRG study. Sci Rep 10: 20453, 2020.
36. Liu X, Hao Q, Yue J, Hou L, Xia X, Zhao W, Zhang Y, Ge M, Ge N and Dong B: Sarcopenia, obesity and sarcopenia obesity in comparison: prevalence, metabolic profile, and key differences: Results from WCHAT study. J Nutr Health Aging 24: 429-437, 2020.
37. English C, Thoirs K, Coates A, Ryan A and Bernhardt J: Changes in fat mass in stroke survivors: A systematic review. Int J Stroke 7: 491-498, 2012.
38. Ikeji R, Nozoe M, Yamamoto M, Seike H, Kubo H and Shimada S: Sarcopenia in patients following stroke: Prevalence and associated factors. Clin Neurol Neurosurg 233: 107910, 2023.
39. Yoshimura Y, Bise T, Nagano F, Shimazu S, Shiraishi A, Yamaga M and Koga H: Systemic inflammation in the recovery stage of stroke: Its association with sarcopenia and poor functional rehabilitation outcomes. Prog Rehabil Med 3: 20180011, 2018.
40. Shiraishi A, Yoshimura Y, Wakabayashi H and Tsuji Y: Prevalence of stroke-related sarcopenia and its association with poor oral status in post-acute stroke patients: Implications for oral sarcopenia. Clin Nutr 37: 204-207, 2018.
41. Kawakami R, Murakami H, Sanada K, Tanaka N, Sawada SS, Tabata I, Higuchi M and Miyachi M: Calf circumference as a surrogate marker of muscle mass for diagnosing sarcopenia in Japanese men and women. Geriatr Gerontol Int 15: 969-976, 2015.
42. Barbosa-Silva TG, Menezes AM, Bielemann RM, Malmstrom TK and Gonzalez MC; Grupo de Estudos em Composição Corporal e Nutrição (COCONUT): Enhancing SARC-F: Improving sarcopenia screening in the clinical practice. J Am Med Dir Assoc 17: 1136-1141, 2016.
43. Hai S, Cao L, Wang H, Zhou J, Liu P, Yang Y, Hao Q and Dong B: Association between sarcopenia and nutritional status and physical activity among community-dwelling Chinese adults aged 60 years and older. Geriatr Gerontol Int 17: 1959-1966, 2017.
44. Liu J, Zhu Y, Tan JK, Ismail AH, Ibrahim R and Hassan NH: Factors associated with sarcopenia among elderly individuals residing in community and nursing home settings: A systematic review with a meta-analysis. Nutrients 15: 4335, 2023.
45. Ligthart-Melis GC, Luiking YC, Kakourou A, Cederholm T, Maier AB and de van der Schueren MAE: Frailty, sarcopenia, and malnutrition frequently (Co-)occur in hospitalized older adults: A systematic review and meta-analysis. J Am Med Dir Assoc 21: 1216-1228, 2020.
46. Shadmand Foumani Moghadam MR, Shahraki Jazinaki M, Rashidipour M, Rezvani R, Pezeshki P, Ghayour Mobarhan M and Hosseini Z: Mini nutrition assessment-short form score is associated with sarcopenia even among nourished people-A result of a feasibility study of a registry. Aging Med (Milton) 6: 264-271, 2023.
47. Siotto M, Germanotta M, Guerrini A, Pascali S, Cipollini V, Cortellini L, Ruco E, Khazrai YM, De Gara L and Aprile I: Relationship between nutritional status, food consumption and sarcopenia in post-stroke rehabilitation: Preliminary data. Nutrients 14: 4825, 2022.
48. Ganapathy A and Nieves JW: Nutrition and sarcopenia-what do we know? Nutrients 12: 1755, 2020.
49. Tieland M, Brouwer-Brolsma EM, Nienaber-Rousseau C, van Loon LJ and De Groot LCPGM: Low vitamin D status is associated with reduced muscle mass and impaired physical performance in frail elderly people. Eur J Clin Nutr 67: 1050-1055, 2013.
50. Bian A, Ma Y, Zhou X, Guo Y, Wang W, Zhang Y and Wang X: Association between sarcopenia and levels of growth hormone and insulin-like growth factor-1 in the elderly. BMC Musculoskelet Disord 21: 214, 2020.
51. Damiano S, Muscariello E, La Rosa G, Di Maro M, Mondola P and Santillo M: Dual role of reactive oxygen species in muscle function: Can antioxidant dietary supplements counteract age-related sarcopenia? Int J Mol Sci 20: 3815, 2019.
52. Nishioka S: Current understanding of sarcopenia and malnutrition in geriatric rehabilitation. Nutrients 15: 1426, 2023.
53. Vidaña-Espinoza HJ, López-Teros MT, Esparza-Romero J, Rosas-Carrasco O, Luna-López A and Alemán Mateo H: Association between the risk of malnutrition and sarcopenia at 4.2 years of follow-up in community-dwelling older adults. Front Med (Lausanne) 11: 1363977, 2024.
54. Darroch P, O'Brien WJ, Mazahery H and Wham C: Sarcopenia prevalence and risk factors among residents in aged care. Nutrients 14: 1837, 2022.
55. Jean W: Sarcopenia. Clin Geriatr Med 33: 305-314, 2017.
56. Prado CMM, Wells JCK, Smith SR, Stephan BCM and Siervo M: Sarcopenic obesity: A Critical appraisal of the current evidence. Clin Nutr 31: 583-601, 2012.
57. Auyeung TW, Lee JSW, Leung J, Kwok T and Woo J: Adiposity to muscle ratio predicts incident physical limitation in a cohort of 3,153 older adults-an alternative measurement of sarcopenia and sarcopenic obesity. Age (Dordr) 35: 1377-1385, 2013.
58. Atkins JL, Whincup PH, Morris RW, Lennon LT, Papacosta O and Wannamethee SG: Sarcopenic obesity and risk of cardiovascular disease and mortality: A population-based cohort study of older men. J Am Geriatr Soc 62: 253-260, 2014.

59. Scott D, Seibel M, Cumming R, Naganathan V, Blyth F, Le Couteur DG, Handelsman DJ, Waite LM and Hirani V: Sarcopenic obesity and its temporal associations with changes in bone mineral density, incident falls, and fractures in older men: The concord health and ageing in men project. J Bone Miner Res 32: 575-583, 2017.
60. Matsushita T, Nishioka S, Taguchi S, Yamanouchi A, Nakashima R and Wakabayashi H: Sarcopenic obesity and activities of daily living in stroke rehabilitation patients: A cross-sectional study. Healthcare (Basel) 8: 255, 2020.
61. Broadwin J, Goodman-Gruen D and Slymen D: Ability of fat and fat-free mass percentages to predict functional disability in older men and women. J Am Geriatr Soc 49: 1641-1645, 2001.
62. Buckinx F, Landi F, Cesari M, Fielding RA, Visser M, Engelke K, Maggi S, Dennison E, Al-Daghri NM, Allepaerts S, *et al*: Pitfalls in the measurement of muscle mass: A need for a reference standard. J Cachexia Sarcopenia Muscle 9: 269-278, 2018.
63. Ryan AS, Dobrovolny CL, Smith GV, Silver KH and Macko RF: Hemiparetic muscle atrophy and increased intramuscular fat in stroke patients. Arch Phys Med Rehabil 83: 1703-1707, 2002.
64. Nemes S, Jonasson JM, Genell A and Steineck G: Bias in odds ratios by logistic regression modelling and sample size. BMC Med Res Methodol 9: 56, 2009.
65. Bujang MA, Sa'at N, Sidik TMITAB and Joo LC: Sample size guidelines for logistic regression from observational studies with large population: emphasis on the accuracy between statistics and parameters based on real life clinical data. Malays J Med Sci 25: 122-130, 2018.
66. da Costa Teixeira LA, Avelar NCP, Peixoto MFD, Parentoni AN, Santos JMD, Pereira FSM, Danielewicz AL, Leopoldino AAO, Costa SP, Arrieiro AN, *et al*: Inflammatory biomarkers at different stages of sarcopenia in older women. Sci Rep 13: 10367, 2023.
67. Urzi F, Pokorny B and Buzan E: Pilot Study on genetic associations with age-related sarcopenia. Front Genet 11: 615238, 2020.
68. Jin H, Yoo HJ, Kim YA, Lee JH, Lee Y, Kwon SH, Seo YJ, Lee SH, Koh JM, Ji Y, *et al*: Unveiling genetic variants for age-related sarcopenia by conducting a genome-wide association study on Korean cohorts. Sci Rep 12: 3501, 2022.