Correlation between skeletal muscle mass index and length of stay in stroke patient

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ABSTRACT

Background: sarcopenia is a syndrome characterized by progressive condition and generalized loss of skeletal muscle mass and strength. It is associated with our prognosis and increased length of stay in stroke patients. Skeletal Muscle Mass Index (SMMI) is an important parameter for assessing skeletal muscle mass and the clinical outcomes of stroke patients.

Objective: to investigate the relationship between SMMI and length of stay among stroke patient.

Materials and Methods: the cross-sectional observational analytical research was conducted at Dr. Kariadi Semarang Hospital from June 2024 to March 2025 in hospitalized stroke patients aged >18 years. Body composition, including skeletal muscle mass (SMM), is measured using bioelectrical impedance analysis (BIA). Skeletal Muscle Mass will be utilized to calculate the SMMI. Length of stay calculated from admission to discharge from the hospital. Data were analyzed by Independent t-test, Pearson Correlation and Multiple Linear Regression.

Results: the average length of stay among the 78 individuals (43 males and 35 females) was 11±3.64 days. The average SMMI levels were normal (7.61± 3.09), indicating no sarcopenia. Skeletal Muscle Mass Index was significantly related with length of stay in stroke patients (r=-0.615; p=0.000) according to the bivariate test.

Conclusion: the higher the SMMI values, were correlated with shorter length of stay.

Keywords*: length of stay; sarcopenia; skeletal muscle mass index; stroke*

BACKGROUND

Stroke is the second highest cause of death and disability in the world.[1] Stroke will also cause muscle reduction, mobility disorders, aphasia, dysphagia, and fatigue.[2] The risk of having a stroke increases with age. After age 55, the risk doubles every ten years.[3] Neurological disorders, immobility, and inflammation associated with stroke can lead to progressive muscle atrophy.[1,4] The condition termed "stroke-related sarcopenia" may result in suboptimal recovery post-rehabilitation, leading to unfavorable stroke outcomes.[5,6]

Sarcopenia is a condition of gradual loss of skeletal muscle strength and mass, which can be affected by several conditions such as age, gender, nutritional status, comorbidities, insulin resistance, and mobility disorders.[7,8] This makes sarcopenia considered a risk factor for loss of mobility, disability, loss of ability to work, and death.[9] Sarcopenia occurs in 42% of stroke patients[10], which puts 10–27% of those patients at risk of losing skeletal muscle mass (SMM) greater than the elderly.[11] Commonly used instruments to diagnose sarcopenia include DEXA—the criteria of the European Working Group on Sarcopenia in Older People (EWGSOP)—and Bioelectrical Impedance Analysis (BIA)—via phase angle or Skeletal Muscle Mass Index (SMMI) calculations.

Prior research revealed that an increase in adiposity and a decrease in SMM are a consequence of changes in body composition during aging.[12] Body composition assessments can identify nutritional or skeletal muscle problems in stroke survivors, such as sarcopenia and obesity.[1,13] Changes in body composition occur with age and can be affected by physical activity[14] and medical conditions such as stroke.

Skeletal Muscle Mass is the sum of the total muscle mass that comes from the chest and the four extremities. Skeletal Muscle Mass upon admission to the rehabilitation ward of recovery is significantly related to functional recovery.[15,16] In stroke patients, maintaining and increasing SMM is essential because muscle strength correlates with daily activities such as moving places and walking.[17] Although the mechanism of muscle change after stroke is inconclusive, several factors, such as long periods of muscle absence, denervation, inflammation, and flexibility, are known to play an important role in muscle function.[1] Skeletal Muscle Mass Index is a measure of body composition that calculates SMM per unit of height. The physical function after hospital release was inversely connected with low phase angle and SMMI levels at the onset of the acute phase of stroke.[18,19]

Bioelectrical Impedance Analysis is the most popular technique for assessing body mass compartments because of its affordability, ease of use, safety, and non-invasiveness. Bioelectrical Impedance Analysis measures the electrical properties of tissues and indirectly assesses the body's composition compartments.[20] Bioelectrical Impedance Analysis can help determine appropriate nutritional and rehabilitation interventions for stroke patients.[13] Previous research has demonstrated a correlation between BIA parameters and post-stroke clinical functional outcomes.[5,21]

There is a link between muscle mass parameters and muscle quality determined by BIA, and rehabilitation outcomes in post-stroke patients.[22] Recent studies have concluded that phase angle and muscle mass are independently associated with better recovery after an acute stroke.[21] It is important to acknowledge that certain BIA-derived parameters in post-stroke patients remain inadequately investigated, particularly concerning length of stay (LOS) and recovery outcomes following rehabilitation treatment. Bioelectrical Impedance Analysis test results are known to be influenced by the patient's medical and environmental conditions.[23] Furthermore, the patient's body composition and nutritional status significantly influence the patient's LOS and recovery. Decreased muscle mass often occurs in the elderly due to decreased appetite.[24] At Cipto Mangunkusumo Hospital, well-nourished patients had BIA parameters such as lower muscle mass, body cell mass, total body water, and higher phase angle than malnourished patients.[25] Research on the relationship between BIA parameters, especially muscle mass, and LOS is crucial in Indonesia because it can improve the quality of care, reduce LOS, and reduce the risk of complications.

Tailored rehabilitation therapy—including the implementation of dietary and nutrition modifications—can be supported by a more comprehensive analysis of body composition. So far, studies have only used SMM to examine the relationship with LOS. However, this study also included SMMI which calculates SMM per unit of height, providing a more accurate picture of a patient's muscle condition in relation to their body size. By including SMMI, the study results are more personalized and tailored to each patient's condition. This, in turn, makes the analysis more precise and relevant. This study was undertaken to investigate the correlation between SMMI and LOS.

MATERIALS AND METHODS

This analytic observational study with a cross-sectional approach was conducted at Dr. Kariadi Hospital Semarang between June 2024 and March 2025. The subjects were patients over 18 years old who were admitted within 48 hours after the onset of stroke, had complete medical record data, and were willing to participate in the study (signed an informed consent). The exclusion criteria were: patients with severe inflammatory conditions, have severe systemic disease, have a history of or are currently taking vitamin D and/or calcium supplements a maximum of 6 months before the intervention, and incomplete medical record data. Ethics permit No. 337/EC/KEPK/FK- UNDIP/VII/2024 was obtained from the Health Research Ethics Committee, Faculty of Medicine, Universitas Diponegoro, before the research was conducted.

Subjects were obtained by the consecutive sampling method. The number of subjects needed was 71 people using the G Power program with $\alpha = 0.05$ and power = 0.95. After a 10% dropout correction, the number of subjects needed is 78 people. This study used SMMI as an independent variable; LOS—as a dependent variable; and confounding variables included diabetes mellitus status (yes or no) based on doctor diagnosis, National Institutes of Health Stroke Scale (NIHSS) score on the first day of hospitalization were calculated by the resident doctor then categorized (0: no stroke symptoms, 1-4: minor stroke, 5-15: moderate stroke, 16-20: moderate to severe stroke, 21-42: severe stroke)[26], age (years), stroke type (ischemic or hemorrhagic), frequency of stroke attacks, and smoking status (yes or no) based on current status. LOS is the difference between the date of admission and the date of discharge, death, or transfer to another care institution. LOS is calculated numerically by subtracting the exit date from the entry date; if equal, LOS is set to one day.[27]

Body composition assessments including SMMI were measured using the SECA mBCA 525 series BIA device (SECA GmbH & Co., KG, Hamburg, Germany) within one day of hospital admission. This device can be used in patients who are bedridden due to a stroke. Bioelectrical Impedance Analysis measurements are taken after eating, either at noon or in the afternoon, with the patient lying on their back after 15 minutes of rest.[28] Electrodes are placed on the ankle, third finger, and bilateral thumb by a licensed physician. Bioelectrical Impedance Analysis can analyze segmental lean mass (SLM) on each side of the upper and lower limbs. Segmental lean mass consists of total body water, proteins, and non- osseous minerals (fats and minerals in bones are not included); as a result, most SLMs are made up of muscle mass and can be interpreted to represent SMM within the extremities.[29,30] Hand grip strength and calf circumference (CC) are taken by the resident doctor. Hand Grip Strength was measured with a CAMRY EH101 Dynamometer, while CC was measured with a OneMed measuring tape.

Primary data in this study included first-day NIHSS score, age, diabetes mellitus status, frequency of stroke attacks, and SMM. Secondary data (the identity of the subject) was obtained from questionnaires and medical records. Skeletal Muscle Mass Index value is obtained from the calculation using the formula: SMM (kg) divided by height (m^2).

Statistical analysis was performed with SPSS version 21 for Windows (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov normality test was used to determine whether the distribution of data was normal. Descriptive statistics are used to describe the demographics and clinical conditions of patients. Numerical data is expressed as mean and SD, while categorical data is presented in the form of numbers and percentages. Independent samples t-test was used to see the difference and significance between SMMI scores and LOS by sex. Pearson correlation is performed to see the strength (p) and the direction of the linear relationship (r) between the 2 variables. Multiple linear regression predicts the value of dependent variables using a variety of independent variable values. Statistically, the $p<0.05$ value is considered significant.

RESULTS

A total of 86 patients were treated at Dr. Kariadi Hospital Semarang from June 2024 to March 2025 met the inclusion criteria; Four of them died, and four others dropped out. In total, as many as 78 patients were studied in one day of data collection. Subject characteristic data is presented in 2 forms, namely Mean ± SD for numerical data and sum (%) for categorical data.

Breakfast had no clinically significant effect on BIA measurements (fat free mass or FFM estimates) in healthy persons. As a result, BIA measures after eating may be acceptable depending on the context because they may reflect the natural physiological state of individuals suffering from malnutrition or other conditions (such as sarcopenia), in which fasting is not recommended.[31] Furthermore, most of these measurements are collected after breakfast or dinner, when the patients are more relaxed. However, when accuracy is critical, BIA measurements should be done when fasting, as meals can alter the predicted results.

Table 1. Subject Characteristics

Variable	Subject (n=78)
Age	58 ± 11.39
NIHSS Score	7.78 ± 4.95
SMMI	7.61± 3.09
LOS	10.17 ± 3.64
Frequency of Stroke Attacks	1.21 ± 2.34
HGS	
Man	16.46 ± 8.57
Woman	8.85 ± 5.90
CC	
Right	32.69 ± 4.50
Left	32.66 ± 4.59
Gender	
Man	43 (55.1%)
Woman	35 (44.9%)
State of Diabetes Mellitus	
Yes	26 (33.3%)
No	52 (66.7%)
Smoking Habits	
Yes	18 (23.1%)
No	60 (76.9%)
Stroke Type	
Ischemic Stroke	71 (91%)
Hemorrhagic Stroke	7 (9%)

Note: age, NIHSS Score, SMMI, LOS, Frequency of Stroke Attacks, HGS, and CC present as mean±SD; while Gender, State of Diabetes

Mellitus, Smoking Habits, and Stroke Type present as frequency.
Abbreviation: NIHSS = national institutes of health stroke scale; SMMI = skeletal muscle mass index; LOS = length of stay; HGS = hand grip strength; CC = calf circumference

The average subject was 58 years old with a first-day NIHSS score of 7.78, an SMMI score of 7.61, underwent an 11-day stay and had 1 stroke. Both males and females have weak HGS, although their CC is normal. Most of the subjects were men who did not smoke, did not have diabetes mellitus, and had an ischemic stroke (Table 1).

The results of the Kolmogorov-Smirnov normality test showed a normal distribution for the research data ($p > 0.05$). Next, an Independent-t test was performed to determine if there was a significant difference between SMMI and LOS by sex. Since the data is normally distributed, Pearson correlation is used to measure the strength and direction of the linear relationship between two variables (Table 3). Confounding variables that affect the LOS were identified through Multiple Linear Regression (Table 4).

Table 2. Differences in SMMI and LOS by Gender

Gender	SMMI		LOS	
	SD	p§	Mean ± SD	p§
Man	8.84 ± 2.52	0.000*	10.07 ± 3.32	0.802*
Woman	6.10 ± 3.09		10.28 ± 4.04	

§independent t-test; *significant correlation at the level of $p<0.05$

By gender, the SMMI value of men was higher than that of women; both were classified as normal (men >7 kg/m^2 and women >5.7 kg/m^2), and the average LOS was 11 days. There is a significant difference between SMMI for men and women. ($p<0.05$). However, there was no significant difference in LOS ($p>0.05$) (Table 2).

Table 3. Relationships between Variables

Variables	LOS	
	r	p§
SMMI	-0.615	<0.001*
State of Diabetes Mellitus	-.0770	<0.001*
NIHSS Score	0.187	0.101
Age	0.032	0.778
Type of Stroke	-0.747	<0.001*
Frequency of Stroke Attacks	-0.760	<0.001*
Smoking Habits	-0.737	<0.001*

§Analyzed using Pearson Correlation; *significant correlation at the level of $p<0.05$

According to the Pearson Correlation test, age and first-day NIHSS scores were not correlated with LOS ($p>0.05$). On the other hand, there was a significant correlation between SMMI (p=<0.001), diabetes mellitus status (p=<0.001), stroke type (p=<0.001), frequency of stroke (p=<0.001), and smoking habits (p=<0.001) with LOS (Table 3).

Based on the direction of the relationship, LOS was positively correlated with first-day NIHSS scores (r=0.187) and age (r=0.032). This means that the longer the stay is associated the higher the first-day NIHSS score and the older a patient is. In contrast, LOS was negatively correlated with SMMI (r= -0.615), diabetes mellitus status (r= -0.770), stroke type (r= -0.747), frequency of stroke (r= -0.760), and smoking habit (r= -0.737). This indicates that higher SMMI scores, not having diabetes mellitus, being diagnosed with ischemic stroke, having had only 1 stroke, and not smoking correlated with shorter LOS (Table 3).

Table 4. Influence of Confounding Variables on LOS Variable

Variables	p§	R Square
State of Diabetes Mellitus	<0.001*	0.940
NIHSS Score	<0.001*	
Age	<0.001*	

Type of stroke	<0.001*

§Analyzed using Multiple Linear Regression: *significant correlation at the level of $p<0.05$

Diabetes mellitus status, first-day NIHSS score, age, and stroke type were confounding variables that had a significant correlation with LOS, according to the results of a multiple linear regression test ($p<0.05$; CI 95%; SC=-0.462, 0.644, 0.114, -0.616, respectively). These four variables affect the LOS simultaneously by 94%, while 6% are influenced by other variables (Table 4).

DISCUSSION

Our research showed that SMMI in stroke patients, as measured by SMM, was significantly associated with LOS. A low SMI reflects poorer muscle condition, thus slowing the movement ability and recovery of stroke patients, which ultimately increases LOS. These results are in line with previous research that has found that sarcopenia is an important determinant of prognosis in a wide range of chronic diseases, such as cancer, stroke, and cardiovascular disease.[32–34] Changes in body composition can occur after a stroke.[1] Body composition changes drastically after stroke, such as increased fat mass in the midsection and decreased muscle and bone mass on the hemiplegic side. Hemiparesis reduces physical activity, triggers muscle atrophy, and decreases bone mass.[35] Inflammation and insulin resistance after stroke accelerate muscle loss and increase the risk of sarcopenia.[36,37] Decreased muscle mass and increased midsection fat mass have a direct impact on patient prognosis, LOS, risk of complications, and speed of rehabilitation and recovery. BIA analysis can help determine appropriate rehabilitation and nutritional management for post-stroke patients. In addition, the BIA examination is useful for obtaining an indirect estimate of muscle mass, namely through the electrical conductivity of the whole body.

Stroke is a disorder in which brain function is lost abruptly owing to reduced blood flow to the brain, which can occur because of brain blood artery blockage (ischemic) or rupture (hemorrhagic). Disruption of blood flow to the brain causes brain cells to lack oxygen and nutrients, disrupting brain function and resulting in cell death. This results in neurological symptoms like weakness and paralysis of specific areas of the body.[38] Stroke causes paralysis throughout the body, including the motor neurons of the central nervous system. This results in muscle weakness and atrophy, as well as decreased physical activity and mobilization.[39,40] Therefore, these factors affect LOS of bedridden patients. Another study examining the LOS and sarcopenia in hemiplegic stroke patients concluded that the LOS in the ICU was associated with sarcopenia.[41] Sarcopenia is a substantial risk factor for LOS in the intensive care unit (ICU), according to data obtained by calculating SMM using skeletal muscle volume at the L3 level and body surface area. Patients with sarcopenia experience reduced physical capacity, becoming more susceptible to complications, infections, and reduced recovery. This contributes to functional decline and LOS.[42]

Lean body mass at the beginning of treatment, especially muscle tissue, affects the ability to survive a stroke.[13] Healthy muscle condition is essential during the recovery period. The Asian Working Group of Sarcopenia (AWGS) 2019 defines low muscle mass as an SMMI < 7.0 kg/m^2 for males and an SMMI<5.7 kg/m^2 for females.[43] The results of this study showed that the SMMI score of men was 9 kg/m^2 and women 6 kg/m^2, which suggests that there was no sarcopenia. These findings are in line with the previous study which showed that the patient's body composition did not change after 6 weeks of rehabilitation treatment.[22] However, other studies have shown that in post-stroke patients, SMMI increases from 1 month to 6 months post-rehabilitation, and this increase is independently related to the LOS.[44]

Several factors related to complex muscle changes after a stroke, as well as the patient's characteristics before the attack, can cause stroke patients to have a normal SMMI at the time of stroke. The normal SMMI value at the onset of stroke is influenced by several factors, including muscle mass and quality before stroke, stroke severity, and time of muscle mass change.

The patient's initial muscle mass and quality before stroke are influenced by age, physical condition, nutritional status, and comorbidities. Normal SMMI levels at onset may occur in some patients due to muscle mass maintained because of a healthy diet and regular exercise before stroke.[45] In addition, normal SMMI values upon admission can occur especially in early-stage or less severe patients.[46] Patients who are younger, meet nutritional needs, exercise regularly, and have maintained muscle mass before stroke will produce normal SMMI at onset, as some of these factors help maintain muscle mass. In addition, patients without sarcopenia before stroke and patients with less severe or early-stage strokes tend to have normal muscle mass at onset. This is because severe strokes are more often associated with muscle shrinkage.[45,47]

Stroke causes changes in the type and quality of muscle fibers, rather than the overall loss of muscle mass. The stroke also weakens the muscles on the paretic side (which is affected). However, the non-paretic (unaffected) side also becomes weaker due to reduced muscle use and changes in the way the brain controls muscles. Due to the loss of "balanced" muscle on both sides of their body, stroke patients can have a normal SMMI despite the presence of functional impairments.[48–50]

This study used CC and HGS as supporting indicators to assess skeletal muscle mass. This is because CC can be an anthropometric indicator that indirectly reflects muscle mass in the lower extremities[51], while the strength of the hand grip correlates with muscle mass and nutritional status, especially in men.[52,53]

Calf Circumference is a muscle mass measurement alternative that has been recognized as effective, accessible, inexpensive, and clinically feasible. CC is an anthropometric measuring tool that can be used to assess SMM and track the risk of sarcopenia in women and other populations.[54,55] In addition, CC is a sensitive tool for identifying low muscle mass in the elderly.

Hand Grip Strength is a popular method for assessing muscle strength and can predict a person's physical function.[56,57] Its simple, inexpensive nature, and fast application time are its main advantages.[55] Subjects in this study had normal CC (>31 cm) but had low HGS (male<28 kg and female<18 kg)[48]. Previous studies concluded a positive correlation between CC and SMMI as well as appendicular skeletal muscle mass (ASM).[58,59] So CC can be used for the diagnosis of sarcopenia.[60]

Low HGS values directly measure upper extremity strength, which is associated with functional outcomes and discharge status in stroke rehabilitation. HGS reflects the neuromuscular abilities necessary for daily activities and effective rehabilitation. Low grip strength is associated with poor rehabilitation outcomes and longer discharge times. This is because HGS reflects functional ability and discharge status. Meanwhile, a large CC can be used as an indicator of overall muscle mass, including the legs. This combination can indicate a loss of muscle mass and strength affecting the upper and lower extremities.[61,62]

Low HGS values despite having normal CC indicate how important rehabilitation is focused on improving muscle strength. The results of low HGS measurements, but normal SMMI values indicate that this condition is most likely not related to overall muscle mass. Instead, it has more to do with problems that affect muscle function, nerve health, or other conditions that affect nerves in the hands and forearms.

Age, stroke type, first-day NIHSS score, and diabetes mellitus status were confounding factors that significantly correlated with LOS. A study in Burkina Faso found that the average acute stroke patient was 57 years old and required LOS of approximately 10 days.[63] Patients with more severe clinical conditions, worse functional outcomes, and a higher risk of complications tended to be older, so they spent more time in the hospital.[64] Stroke type influences LOS. A study in Yogyakarta revealed that hemorrhagic stroke patients generally had a longer LOS than ischemic stroke patients, with an average of 11 days compared to 7 days, due to more severe symptoms and a higher risk of complications.[65] Furthermore, cortical bleeding was significantly associated with LOS.[66] Stroke severity is a significant factor influencing both the acute period and overall LOS. The acute period LOS rose by 0.8 days and the overall LOS by 3.4 days for every 1-point rise in the NIHSS score.[67] A retrospective study conducted in China found that the average LOS was 8.16 days for mild stroke patients with type 2 diabetes.[68] Diabetes can increase the risk of complications and worsen stroke outcomes, thereby prolonging the LOS.

The strength of the grip can be affected by several conditions that often occur in stroke patients. Stroke patients experience nerve damage, which causes various symptoms such as pain, muscle weakness, and numbness in the area affected by the stroke. Sarcopenia can cause HGS to be reduced, even with normal SMMI values—because SMMI does not fully capture the quality of a person's muscles. Stroke can lead to muscle atrophy and loss of strength caused by lack of use of the hands and forearms. Muscle strength, including grip strength, will naturally decline with age.[69–72] This research has several limitations. First, this study did not evaluate the SMM of each limb. Sarcopenia causes a decrease in SMM in the affected area so hemiplegia patients are also expected to experience an increase in SMM during the treatment and rehabilitation period. We may need to use alternative methods to check muscle mass, such as dual-energy X-ray absorptiometry or DEXA.

Skeletal Muscle Mass Index is an extremely useful tool for doctors, rehabilitation professionals, and dietitians. It enables clinicians to measure the risk of chronic diseases, track therapy success, and evaluate physical function. It assists rehabilitation professionals in designing targeted programs, tracking patient progress, and creating individualized activity plans, whereas nutritionists utilize it to assess nutritional needs, construct supporting nutrition programs, and monitor nutritional status. Overall, SMMI is important in preventing chronic diseases, optimizing physical performance, and leading effective intervention measures to increase muscle mass and overall health.

This study used SMMI compared to an individual's height, making it more accurate and sensitive than looking solely at SMM. Furthermore, the study used BIA, the gold standard for assessing body composition, making the results superior to BMI alone. This study is cross-sectional so it is not possible to see the causal relationship of these results.

CONCLUSIONS

Skeletal Muscle Mass Index correlates significantly with LOS. Some factors are independently related to LOS, including diabetes mellitus status, day one NIHSS score, age, and stroke type. This study recommends using alternative methods for SMM assessment, such as DEXA, which can also be utilized for comparison, to ensure more accurate and exact results.

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