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Muscle Quality and Structural Changes in Stroke Patients: An Ultrasonographic Evaluation

İnme Hastalarında Kas Kalitesi ve Yapısal Değişiklikler: Ultrasonografik Değerlendirme

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Abstract

Objective: The aim of this study is to evaluate muscle changes in stroke patients by assessing muscle diameter and muscle quality using ultrasonography.

Materials and Methods: Forty male stroke patients and forty healthy male volunteers who fulfilled the predefined criteria were enrolled in the study. The patient group was evaluated with the Brunnstrom Lower Extremity Motor Evaluation, the Modified Ashworth Scale, the Functional Independence Measure, and the Functional Ambulation Scale. Diameter measurements of the quadriceps femoris muscle, were taken with B-mode ultrasonography, and shear wave elastography (SWE) values were recorded for both groups.

Results: Stroke patients' quadriceps femoris muscle diameter was significantly lower than that of controls ($p<0.001$), while SWE measurements exhibited no significant difference ($p>0.05$). Subgroup analysis based on stroke duration revealed lower diameter measurements in acute-subacute and chronic stroke patients compared to controls (both $p<0.001$), with no difference between stroke groups ($p>0.05$). Similarly, regardless of ambulation status, stroke patients had significantly lower quadriceps femoris muscle diameter than controls ($p<0.001$), with no disparity between ambulation groups ($p>0.05$). There was no significant difference in the groups' SWE measurements ($p>0.05$).

Conclusion: These results suggest a decrease in muscle thickness without deterioration in muscle quality. At this point, we believe that simultaneous evaluation with B-mode ultrasonography and elastography during ultrasonographic assessment of muscle changes will provide more objective results. This approach may help us more accurately understand the relationship between the quality and quantity of muscle tissue.

Keywords: Stroke, muscle quality, ultrasonography, elasticity imaging techniques

Öz

Amaç: Bu çalışmanın amacı, inme hastalarında kas çapı ve kalitesini ultrasonografi eşliğinde değerlendirerek kaslardaki değişiklikleri incelemektir.

Gereç ve Yöntem: Çalışmaya, belirlenmiş kriterleri karşılayan kırk erkek inme hastası ve kırk sağlıklı erkek gönüllü dahil edilmiştir. Hasta grubu Brunnstrom Alt Ekstremite Motor Değerlendirmesi, Modifiye Ashworth Skalası, Fonksiyonel Bağımsızlık Ölçütü ve Fonksiyonel Ambulasyon Skalası ile değerlendirilmiştir. Kuadriseps femoris kasının çap ölçümleri B-mod ultrasonografi ile yapılmış ve her iki grup için shear wave elastografi (SWE) değerleri kaydedilmiştir.

Bulgular: İnme hastalarının kuadriseps femoris kas çapı, sağlıklı kontrol grubuna kıyasla anlamlı derecede daha düşük bulunmuştur ($p<0{,}001$). Ancak, SWE ölçümleri açısından gruplar arasında anlamlı bir fark gözlenmemiştir ($p>0{,}05$). İnme süresine dayalı alt grup analizi, hem akut-subakut hem de kronik inme hastalarında, kontrol grubuna kıyasla daha düşük kas çapı ölçümleri ortaya koymuştur (her iki durumda da $p<0{,}001$); bu iki inme grubu arasında ise anlamlı bir fark bulunmamıştır ($p>0{,}05$). Aynı şekilde, ambulasyon durumundan bağımsız olarak, inme hastalarının kuadriseps femoris kas çapı kontrol grubuna göre anlamlı derecede düşüktür ($p<0{,}001$) ve ambulasyon grupları arasında fark bulunmamıştır ($p>0{,}05$). SWE ölçümlerinde ise gruplar arasında anlamlı bir fark tespit edilmemiştir ($p>0{,}05$).

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Sonuç: Bu bulgular, kas kalitesinde bozulma olmaksızın kas kalınlığında bir azalma olduğunu göstermektedir. Kas değişikliklerinin ultrasonografik değerlendirilmesinde, B-mod ultrasonografi ve elastografinin eşzamanlı kullanımının daha objektif sonuçlar sağlayabileceğini düşünüyoruz. Bu yaklaşım, kas dokusunun kalitesi ve miktarı arasındaki ilişkiyi daha doğru bir şekilde anlamamıza yardımcı olabilir.
Anahtar kelimeler: İnme, kas kalitesi, ultrasonografi, elastisite görüntüleme teknikleri

Introduction

Stroke is a sudden and often life-threatening condition. It occurs as a result of blockage or rupture in cerebral blood vessels and is characterized by a range of symptoms including loss of motor skills, sensory abilities, balance control, and cognitive functions, and in severe cases, can lead to coma (1,2). A major health issue, stroke is one of the world's leading causes of death and disability (3,4).

In patients diagnosed with stroke, muscle atrophy and weakness develop from the onset of the disease (5,6). Sarcopenia can start or worsen because of muscle weakness and skeletal muscle loss brought on by stroke-related inactivity, which limits physical activity (7).

Sarcopenia is associated with losses in muscle mass and function and represents a significant problem both economically and clinically. Methods for assessing sarcopenia include physical performance tests and evaluation of muscle strength (8,9).

Due to changes in natural functions following a stroke, it can be difficult to evaluate muscular strength and physical performance following a stroke. For example, reduced walking speed has been utilized as a sarcopenia diagnostic criterion (10). Although assessment instruments such as the 6-minute walk test have been utilized for this objective, their suitability for stroke patients is restricted because of their limited mobility. Additionally, even in stroke patients capable of movement, paralysis can affect walking, therefore reducing the walking speed test's validity and reliability as a sarcopenia monitoring tool (11).

Recent studies have highlighted that the reduction in muscle size assessed via ultrasonography may be indicative of sarcopenia, with the quadriceps muscle, in particular, holding significance among muscles evaluated for sarcopenia. Literature supports the use of ultrasonographic evaluation as a useful and objective tool in diagnosing sarcopenia (12,13). Additionally, in recent years, elastography in various patient groups has been utilized for the assessment of sarcopenia (14,15). These studies aimed not only to evaluate muscle diameter but also muscle quality.

However, in the literature, there is no study assessing both muscle diameter and muscle quality in terms of sarcopenia in stroke patients. Therefore, the aim of this study is to evaluate muscle diameter and muscle quality in stroke patients using ultrasonography.

Materials and Methods

Study Design

The design of our study is cross-sectional. Permission was obtained from Manisa Celal Bayar University Faculty of Medicine Ethics Committee for our study (decision no: 203, date: 03.11.2021). Between May 24, 2022, and September 1, 2023, 40 male patients diagnosed with stroke who applied to the Department of Physical Medicine and Rehabilitation of our hospital, and 40 healthy male volunteers were included. Participants were provided with detailed information about the study, and after obtaining their consent, they agreed to the terms of an informed consent form that our university's Faculty of Medicine's Ethics Committee had authorized.

Inclusion and Exclusion Criteria

Inclusion criteria for the patient group included being male, having no cognitive impairment, being between the ages of 45 and 80, and having experienced a first-time stroke.

Exclusion criteria included having undergone botulinum toxin, phenol, or alcohol injections for spasticity in the last six months, a history of spine, hip, or lower extremity surgery, presence of skin lesions in the imaging area, history of progressive neurological conditions (such as amyotrophic lateral sclerosis and multiple sclerosis), history of malignancy, systemic infection, or active localized infection.

The control group consisted of 40 healthy male volunteers of the same age range.

The number of patients to be evaluated was determined based on similar studies in the literature (16-20). Assessments of ultrasound elastography can be influenced by elements like body mass index, gender, and age (21). Therefore, to minimize the potential impact of gender differences on the study, only male patients and healthy volunteers were selected.

Assessment Methods

The evaluation of participants in the study, including sick and healthy individuals was conducted using a case form specifically designed for the study. This form was used to record demographic information during the examination and to apply relevant assessment scales. Measurements using B-mode ultrasonography and shear wave elastography (SWE) were recorded for both groups. All measurements were performed by two physiatrists (Z.Ü., C.T.) has over ten years of US musculoskeletal experience.

The patient group included in the study was evaluated using the Brunnstrom Lower Extremity Motor Staging (BSLE), Modified Ashworth Scale (MAS), Functional Independence Measure (FIM), and Functional Ambulation Scale (FAS).

Ultrasonographic Measurement Evaluation of Quadriceps Femoris Muscle Diameter

Measurements of the thickness of the quadriceps femoris muscle, including the rectus femoris and vastus intermedius, were made on the non-dominant side of healthy volunteers and the plegic side of patients during an ultrasonographic examination. The ESAOTE S.p.A Via Enrico Malen 77, 16152

Genova, ITALY-MyLabX8 Exp ultrasonography device and a linear high-frequency probe (4-15 MHz) were utilized.

The thickness of the quadriceps femoris muscle was measured halfway between the greater trochanter and the lateral condyle of the femur (13). During measurements, participants were positioned supine with their legs outstretched, and ultrasonography measurements were conducted when the muscles were fully relaxed. A substantial quantity of contact gel was used in order to reduce the pressure that the ultrasound probe applied to the skin. At the measurement sites, the ultrasonic probe was positioned perpendicular to the tissue surface, and care was taken to avoid excessive pressure that could adversely affect the muscle mass during measurements. It was measured how far the muscle-bone interface and the fat-muscle interface were apart.

Evaluation of Quadriceps Femoris Muscle with Ultrason Shear Wave Elastography

In the study, measurements of the stiffness of the plegic side of patients and the non-dominant side of healthy volunteers' quadriceps femoris muscle were performed using shear wave ultrason elastography. The ESAOTE S.p.A Via Enrico Malen 77, 16152 Genova, ITALY-MyLabX8 Exp ultrasonography device and a linear high-frequency probe (4-15 MHz) were used.

During measurements, participants were laid in a comfortable neutral position on their backs with hip and knee in full extension for elastography measurements. To standardize the position of the measurements, the probe was measured midway between the lateral condyle of the femur and the greater trochanter and placed at this point. A region of interest was determined on this region corresponding to the center of the belly of the quadriceps femoris muscle.

The probe was oriented parallel to the muscle fibers in the longitudinal axis to obtain SWE measurements and then, it was rotated 90 degrees. When taking measurements, the skin was covered with a thin coating of acoustic gel, and the probe was held steady throughout the SWE acquisition process (22).

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) 24.0 software program was used to analyze the study data. The descriptive statistics were displayed as percentages, minimum-maximum values, and mean±standard deviation. To assess categorical variables, the Pearson chi-square test/Fisher's exact test was utilized. Both analytical techniques (Kolmogorov-Smirnov test) and visual techniques (histograms and probability plots) were used to analyze the normal distribution of the continous data.

Comparisons of normally distributed continuous variables between groups were performed using Student's t-test and one-way analysis of variance (ANOVA). For non-normally distributed continuous variables, differences between groups were tested using Mann-Whitney U test and Kruskal Wallis test. Associations between continuous variables were determined by Pearson/ Spearman Correlation Coefficient. A two-sided p-value <0.05 was considered as statistically significant.

Results

Socio-demographic data of a total of 80 subjects (patient group: 40, control group: 40) is provided in Table 1 as part of the study. In the analysis of sociodemographic data, there was no discernible statistically significant difference between the two groups (p>0.05) (Table 1).

Table 2 displays plegic side, stroke etiology, mean stroke length, and mean, standard deviation, minimum and maximum values of MAS, FIM, FAS, and BSLE scores for each of the 40 patients who were part of the research.

Upon comparing the quadriceps femoris muscle diameter measures between the patient and control groups, the patient group exhibited statistically significant lower values (p<0.001) (Table 3). Nevertheless, there was no statistically significant difference between the patient and control groups when the quadriceps femoris SWE measures were examined (p>0.05) (Table 3).

Based on the amount of time since diagnosis, Table 4 separated the 40 patients into two groups: those with less than 12 months (acute-subacute) and those with more than 12 months (chronic). The values of the minimum, maximum, standard deviation, and mean of quadriceps femoris muscle diameter measurement for each group are presented. Similarly, the quadriceps femoris SWE measurement values for each group are provided.

In multiple comparison analyses, when quadriceps femoris muscle diameter measurements were compared between the acute-subacute stroke patient group statistically significantly lower values were seen in the patient group compared to the control group (p<0.001) (Table 4). In a similar vein, when contrasting the cohort of patients with chronic stroke with the control group, statistically significantly lower values were observed in the patient group (p<0.001) (Table 4). Nevertheless, there was no statistically significant difference between the acute-subacute stroke patient group and the chronic stroke patient group when compared (p>0.005).

When the quadriceps femoris SWE measurements were compared between the acute-subacute stroke patient group, the chronic stroke patient group, and the control group, there was no discernible statistical difference between the groups (p>0.05) (Table 4).

The 40 patients who were a part of the study are split into two groups in Table 5 according to whether they can walk on their own or not. The values of the minimum, maximum, standard deviation, and mean of quadriceps femoris muscle diameter measurement for each group are presented. Similarly, the quadriceps femoris SWE measurement values for each group are provided.

In multiple comparison analyses, when quadriceps femoris muscle diameter measurements were compared between the dependent ambulatory patient group and the control group, statistically significantly lower values were found in the patient group (p<0.001) (Table 5). Similarly, in the comparison between

Table 1. Socio-demographic characteristics; education level, occupation, medical history, age, body mass index, dominant side					
		Patient group (n=40)	**Control group (n=40)**	**Total (n=80)**	**p-value**
Education level (n, %)	Non-literate-primary school	18 (45%)	14 (35%)	32 (40%)	0.588
	High school	15 (37.50%)	16 (40%)	31 (39%)	
	Undergraduate-graduate	7 (17.50%)	10 (25%)	17 (21%)	
Occupation (n, %)	Worker	3 (7.50%)	6 (15%)	9 (11%)	0.071
	Civil servant	2 (5%)	8 (20%)	10 (12.50%)	
	Retired	31 (77.50%)	25 (62.50%)	56 (70%)	
	Other	4 (10%)	1 (2.50%)	5 (6.50%)	
Medical history (n, %)	Hypertension	7 (17.50%)	14 (35%)	21 (26.25%)	0.065
	Diabetes	6 (15%)	6 (15%)	12 (15%)	
	Hyperlipidemia	1 (2.50%)	0	1 (1.25%)	
	Cardiac reasons	2 (5%)	0	2 (2.50%)	
	Hypertension + diabetes	14 (35%)	6 (15%)	20 (25%)	
	Hypertension + cardiac reasons	2 (5%)	1 (2.50%)	3 (3.75%)	
	Diabetes + cardiac reasons	1 (2.50%)		1 (1.25%)	
	Hypertension + diabetes + hyperlipidemia	2 (5%)	1 (2.50%)	3 (3.75%)	
	Hypertension + diabetes + cardiac reasons	1 (2.50%)	0	1 (1.25%)	
	None	4 (10%)	11 (27.50%)	15 (18.75%)	
Age (mean±SD) (min.-max.)		62.62±8.97 45-76	60.87±8.64 45-77	61.74±8.80 45-77	0.377
Body mass index (mean±SD) (min.-max.)		25.78±3.80 17.75-32.85	25.16±3.21 18.22-31.42	25.47±3.42 17.75-32.85	0.858
Dominant side	Right	37 (92.50%)	35 (87.50%)	72 (90%)	>0.999
	Left	3 (7.50%)	5 (12.50%)	8 (10%)	

Min.-max.: Minimum-maximum, SD: Standard deviation

Table 2. Stroke group's paretic side, stroke etiology, stroke duration, and evaluation scores		
Patient group		
Paretic side (n, %)	Right	26 (65%)
	Left	14 (35%)
Stroke etiology (n, %)	Ischemic	30 (75%)
	Hemorrhagic	10 (25%)
Stroke duration (mounth) (mean±SD) (min.-max.)	32.45±44.46 4-240	
BSLE score (mean±SD) (min.-max.)	3.70±1.28 1-6	
MAS score (mean±SD) (min.-max.)	0.03±0.19 0-1	
FIM score (mean±SD) (min.-max.)	77.42±20.93 28-119	
FAS score (mean±SD) (min.-max.)	2.17±1.87 0-4	

BSLE: Brunnstrom lower extremity motor staging, MAS: Modified ashworth scale, FIM: Functional ındependence measure, FAS: Functional ambulation scale, Min.-max.: Minimum-maximum the independent ambulatory patient group and the control group, statistically significantly lower values were observed in the patient group (p<0.001) (Table 5). Nevertheless, there was no statistically significant difference between the independent and dependent ambulatory patient groups in the comparison (p>0.05).

There was no statistically significant difference between the dependent ambulatory patient group, the independent ambulatory patient group, and the control group when the quadriceps femoris SWE measurement data were examined (p>0.05) (Table 5).

Among the forty stroke patients, correlation analysis was used to investigate the link between ultrasonographic data and stroke assessment scores. Age and MAS score were shown to have a negative moderate and statistically significant connection with diameter measurements. Additionally, a statistically significant positive moderate correlation was observed between diameter measurements and stroke duration, FIM score, and FAS score. However there was no statistically significant association discovered between the measurements of shear waves (Table 6).

Discussion

This study demonstrated that the patient group had statistically significantly lower muscle thickness compared to the control group. However, no significant difference was observed in SWE values between the two groups. Upon review of the literature, no prior study evaluating post-stroke sarcopenia with ultrasound elastography was found. This highlights the novelty of our research in exploring both muscle quantity and quality using ultrasonographic methods.

Prior a limited number ofstudies have primarily focused on ultrasonographic measurements of muscle thickness to assess sarcopenia in stroke patients. A 2018 study by Monjo et al. (16),

Table 3. Quadriceps femoris muscle diameter measurements and shear wave elastography measurements of study groups

	Patient group (n=40) mean±SD min.-max.	Control group (n=40) mean±SD min.-max.	The difference between groups (p)
Measurement of diameter (cm)	23.45±2.89 10.50-38.80	34.89±8.01 18.30-53.60	**<0.001**
Shear wave measurement (m/sn)	2.89±1.29 1.38-6.94	2.43±0.62 1.28-3.81	0.237

SD: Standard deviation, Min.-max.: Minimum-maximum, Cm: Centimeter

Table 4. Distribution of quadriceps femoris muscle diameter and shear wave elastography measurements according to subgrouping based on stroke duration

	Acute-subacute stroke patient group (n=16) mean±SD min.-max.	Chronic stroke patient group (n=24) mean±SD min.-max.	Control group (n=40) mean±SD min.-max.	p-value
Measurement of diameter (cm)	20.30±5.60[a] 10.50-32.20	25.50±6.60[a] 12.40-38.80	34.80±8.010[b] 18.30-53.6	**<0.001**
Shear wave measurement (m/sn)	2.96±1.71 1.38-6.94	2.84±0.95 1.76-6.05	2.43±0.62 1.28-3.81	0.129

The symbols a and b indicate the difference between groups. There is no difference between groups with the same letter
SD: Standard deviation, Min.-max.: Minimum-maximum, Cm: Centimeter

Table 5. Distribution of quadriceps femoris muscle diameter and shear wave elastography measurements according to ambulation ındependence subgroups of the patient group

	Dependent ambulatory patient group (n=19) mean±SD min.-max.	Independent ambulatory patient group (n=21) mean±SD min.-max.	Control group (n=40) mean±SD min.-max.	p-value
Measurement of diameter (cm)	20.44±5.60[a] 10.50-35.40	26.18±6.48[a] 12.40-38.80	34.80±8.01[b] 18.30-53.6	**<0.001**
Shear wave measurement (m/sn)	3.23±1.52 1.38-6.94	2.58±0.98 1.41-5.29	2.43±0.62 1.28-3.81	0.130

The symbols a and b indicate the difference between groups. There is no difference between groups with the same letter
SD: Standard deviation, Min.-max.: Minimum-maximum, Cm: Centimeter

Table 6. Correlation analysis data of the patient group

(n=40)	Age	Stroke duration	BSLE score	MAS score	FIM score	FAS score	Measurement of diameter	Shear wave measurement
Measurement of diameter	**-0.428** **0.006**	**0.345** **0.029**	0.219 0.175	**-0.440** **0.005**	**0.319** **0.045**	**0.520** **0.001**	1	-0.280 0.080
Shear wave measurement	-0.037 0.818	0.210 0.194	-0.194 0.231	0.95 0.562	-0.171 0.292	-0.265 0.98	-0.280 0.080	1

r: 0.01-0.29 indicates a low level of correlation, r: 0.30-0.70 indicates a moderate level of correlation, r: 0.71-0.99 indicates a high level of correlation, p<0.05. Spearman correlation test
BSLE: Brunnstrom Lower Extremity Motor Staging, MAS: Modified Ashworth Scale, FIM: Functional ındependence measure, FAS: Functional ambulation scale

involving 32 stroke patients, used ultrasonography to measure the muscle diameter of the paretic and non-paretic side muscle groups. Statistically significant differences were observed in the quadriceps muscles and tibialis anterior muscle on the paretic side, which led the authors to suggest that the quadriceps femoris muscle is the strongest predictor of both qualitative and quantitative changes on the paretic side in stroke patients. In another study, the diameter of the rectus femoris and biceps brachii muscles was measured in 29 post-polio syndrome patients and 27 healthy controls. While no significant changes were observed in the biceps brachii, the rectus femoris muscle diameter was significantly lower in the patient group compared to healthy controls (17).

The results from these studies suggest that, similar to our study, the quadriceps femoris muscle is the most appropriate muscle for assessing sarcopenia ultrasonographically. Similar findings were observed in other studies that used ultrasound to evaluate the quadriceps femoris muscle for sarcopenia assessment in stroke patients, where lower muscle diameters were observed in the paretic extremity (18-20,22-24). These findings highlight the importance of ultrasonographic measurements in evaluating sarcopenia post-stroke and suggest that ultrasound may become a valuable clinical tool for this purpose.

While studies using SWE in sarcopenia are limited, evidence from other populations provides valuable insights. In a study by Alfuraih et al. (25), muscle evaluation by SWE in healthy volunteers grouped by age revealed a gradual decrease in SWE values with aging. In a different study, SWE was used to assess the rectus femoris muscles in healthy volunteers and patients with chronic obstructive pulmonary disease (COPD), with significantly lower SWE values observed in the COPD group compared to healthy volunteers (26). Similarly, Wang et al. (14) found that SWE values were significantly lower in the sarcopenia group compared to the healthy control group. Additionally, Maeda et al. (27) examined the vastus lateralis muscles of volunteers of different ages using SWE and found an increase in SWE values with aging. In a study by Chen et al. (28), SWE values of the rectus femoris muscles were compared between kidney transplant patients and healthy volunteers, revealing significantly higher SWE values in the patient group despite lower muscle diameters. These findings reveal the potential of SWE to capture biomechanical changes in muscle tissue.

Sarcopenia is characterized by a decrease in muscle mass and a deterioration in muscle quality. Muscle quality is not only linked to muscle mass but also to the structural and functional properties of the muscle. Muscle stiffness, a key indicator of muscle biomechanics, indirectly reflects changes in muscle composition, and muscle strength is influenced by changes in muscle elasticity (28). Therefore, assessing muscle quality is crucial for a more accurate understanding of sarcopenia.

SWE is a method used to assess muscle quality and functional capacity by measuring muscle stiffness. In healthy populations, SWE has been shown to correlate with muscle strength and functional tests. A study by Tang et al. (29) found a significant correlation between muscle stiffness measured by SWE and muscle strength, suggesting that SWE is a valuable tool for assessing muscle biomechanics and can be relied upon for evaluating muscle strength and elasticity.

Changes in muscle stiffness, as measured by SWE, reflect biomechanical and structural deteriorations of the muscle, indicating a decline in the functional capacity of the muscle (30). In our study, although a significant difference in muscle diameter was observed between stroke patients and healthy controls, no significant difference was found in SWE values. These findings suggest that while muscle atrophy is evident in stroke patients, there may be no major changes in muscle biomechanics, and the structural and functional properties of the muscle tissue may be preserved.

It is believed that the concurrent use of elastography with B-mode ultrasonography for the ultrasonographic evaluation of sarcopenia could provide more objective results. This approach would allow a better understanding of the relationship between the quantity and quality of muscle tissue. By evaluating both structural changes and biomechanical properties of the muscle, this method could enable a more accurate determination of muscle quality.

Subgroup analyses based on stroke duration and ambulation ability revealed significant differences in muscle thickness, while SWE values remained consistent. These findings suggest that muscle stiffness does not vary between groups, indicating no evidence of fibrosis accompanying muscle atrophy. The decrease in muscle thickness appears to begin in the early stages of stroke and persists over time. However, increased activity levels and greater independence may help reverse this condition.

These results highlight the importance of emphasizing regular exercise, particularly muscle-strengthening activities, for stroke patients starting from the acute phase. Encouraging such rehabilitation efforts could potentially prevent or mitigate muscle loss, supporting improved functional outcomes for these individuals.

Study Limitations

This study has some limitations. First off, the study's single-center design and small sample size limit the generalizability of the findings. In addition, considering the heterogeneous nature of stroke patients and different stroke types, the lack of homogeneity of the patients in the study can also be considered a limitation. At this point, although the study was analyzed by dividing the patient group into subgroups according to stroke duration and ability to ambulate independently, there is still a risk that the study may be affected by external factors.

A person's age, gender, and body mass index are among the variables that can impact their ultrasonographic elastography assessments. Therefore, only male patients and healthy volunteers were selected to reduce the potential impact of gender differences on the study results. However, this selection can be considered a limitation of the study, as it is desirable for the results to be generalized to both genders. Despite this, the findings from the male-only sample still provide valuable insights.

Conclusion

In conclusion, our study demonstrated that muscle thickness in the stroke group was significantly lower than in healthy controls, but SWE evaluations showed no significant differences between the groups. These findings suggest that muscle atrophy occurs without corresponding deterioration in muscle quality, as assessed by SWE. Combining B-mode ultrasonography with SWE may provide a more comprehensive evaluation of muscle quantity and quality, facilitating better understanding and management of sarcopenia in stroke patients.

Future studies should explore different muscle groups and patient populations to establish standardized protocols for ultrasonographic assessments. This study lays the groundwork for integrating advanced ultrasound techniques into the clinical evaluation of sarcopenia.

Ethics

Ethics Committee Approval: Permission was obtained from Manisa Celal Bayar University Faculty of Medicine Ethics Committee for our study (date: 03.11.2021, decision no: 203).

Informed Consent: Participants were provided with detailed information about the study, and after obtaining their consent, they agreed to the terms of an informed consent form that our university's Faculty of Medicine's Ethics Committee had authorized.

Footnotes

Authorship Contributions

Concept: İ.C.Ö., Ö.A., C.T., Z.Ü., L.C., Design: İ.C.Ö., Ö.A., C.T., Z.Ü., L.C., Data Collection or Processing: İ.C.Ö., Ö.A., C.T., Z.Ü., L.C., Analysis or Interpretation: İ.C.Ö., Literature Search: İ.C.Ö., Writing: İ.C.Ö.

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