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Exploring the Impact of Cervical Multifidus Muscle Morphology on Postural Balance in Post-Stroke Patients: A Pilot Study

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Abstract: Background: The aim of this study was to examine cervical multifidus muscle morphology and its impact on postural balance in patients with post-stroke. Methods: This is a pilot study. A convenience sample of 24 volunteers of 67 ± 8.5 years (12 with hemiparesis due to post-stroke, 12 healthy) was recruited for this study. The outcomes measured were the thickness of the multifidus muscle using ultrasonography, Modified Functional Reach Test (MFRT), Timed Up and Go (TUG) test and Berg Balance scale (BBS). Results: No significant differences in the ultrasound values between stroke patients' paretic and non-paretic sides were found. Similarly, there were no significant differences between the non-paretic side of stroke patients and the non-paretic side of the control group, (all, $p > 0.05$). Additionally, no significant correlations between the ultrasonographic variables of the multifidus muscles and the main outcome measures were identified. Conclusions: In conclusion, our study did not find significant differences in cervical multifidus muscle morphology between healthy individuals and post-stroke patients in relation to postural balance.

Keywords: stroke; ultrasonography; postural balance; multifidus; cervical muscle

1. Introduction

Stroke is a significant global health concern, ranking as the second leading cause of death worldwide and responsible for millions of deaths each year [1]. Muscle changes, including spasticity, increased muscle tone, and weakness, are common consequences of stroke and can significantly impact postural control, functional movements, and independence. One of the causes of disability in patients following a stroke is postural imbalance, characterized by increased postural sway and weight-bearing asymmetry [2]. The cervical muscles play a critical role in maintaining proper posture, supporting movements against gravity, and facilitating the coordination of core movements with different postures [3]. Impaired control of the trunk muscles can lead to limitations in functional movements of the extremities, an increased risk of falls, and decreased independence in daily activities [4]. In stroke patient rehabilitation, balance training holds significant importance as it plays a pivotal role in overall rehabilitation outcomes. Stroke often results in various impairments, including motor deficits, muscle weakness, and sensory disturbances, which can significantly impact an individual's ability to maintain postural stability. As a result, individuals who have experienced a

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stroke may face challenges in performing daily activities and are at an increased risk of falls and subsequent injuries. Balance training aims to address these issues by focusing on improving postural control, stability, and coordination. These interventions may include weight-shifting exercises, standing balance exercises, dynamic balance activities, and specific tasks that simulate real-life situations [5]. Balance serves as a prognostic factor for achieving autonomy, improving transfer abilities, and recovering walking capabilities [6]. Accurately assessing trunk muscle morphology and functional performance is essential in stroke patients to guide appropriate rehabilitation interventions [7]. Various methods and techniques have been developed to evaluate trunk-stabilizing muscles, including isokinetic machines, manual dynamometers, electromyography, computed tomography, magnetic resonance imaging, and musculoskeletal ultrasonography [8]. Among these techniques, rehabilitative ultrasound imaging (RUSI) has gained popularity as a non-invasive, cost-effective, and dynamic assessment tool for evaluating muscle characteristics and function [9]. RUSI allows for the measurement of muscle thickness and cross-sectional area, providing valuable information on muscle quality and function [10]. Numerous studies, mainly focusing on the upper and lower limbs, have demonstrated significant differences in muscle morphology between stroke patients and healthy individuals, including decreased muscle thickness and atrophy [11]. These changes are often more pronounced in the affected side and contribute to muscle weakness and impaired motor control. Additionally, RUSI has been employed to assess muscle activation patterns in stroke patients, revealing altered muscle recruitment and activation strategies compared to healthy controls [12]. This information helps in understanding muscle function and designing targeted rehabilitation strategies. Musculoskeletal ultrasonography, particularly RUSI [13], offers a non-invasive and cost-effective means to evaluate stroke patients' muscle characteristics and activation patterns. The aim of this study was to examine cervical multifidus muscle morphology and its impact on postural balance in patients with post-stroke.

2. Materials and Methods

A case-control pilot study was conducted following the STROBE Declaration's recommendations between December 2021 and June 2022. This study was approved by Ethics Committee of Hospital Universitario Fundación Alcorcón, Madrid, Spain. All participants were asked to sign an informed consent form before collecting data.

2.1. Participants

A convenience sample of 24 volunteers (12 healthy, 12 with hemiparesis due to stroke) was recruited for this study. Inclusion criteria for the stroke group were as follows: individuals with post-stroke hemiparesis in the chronic stage (>6 months), ability to sit unsupported, medical stability, and age over 18 years [14]. Exclusion criteria included a history of abdominal or lumbar surgery, severe cognitive impairment that hindered following instructions, and severe sensory alterations or painful paresthesia on the paretic side that could impede ultrasound measurements [15]. The control group participants were selected from the families and acquaintances of the stroke patients and were matched by age.

2.2. Procedure

Participants underwent subjective and physical examination conducted by an expert physiotherapist with experience in treating musculoskeletal disorders. Ultrasound measurements were conducted using a diagnostic ultrasound device (LOGIC S7 Expert, XDclear, GE Healthcare, Chicago, Illinois, USA). The device featured a frequency range of 10-13 MHz and a 55 mm linear transducer footprint, allowing for the acquisition of grayscale B-mode ultrasound images. All measurements were performed by a clinician who had received specialized training in Rehabilitation Ultrasound Imaging (RUSI) and possessed 5 years of clinical experience. To ensure consistency, the participants' position for image acquisition was standardized across all measurements. They were placed in a prone position, and a wedge was inserted under their ankles. This positioning was

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adopted to maintain uniformity and aid in achieving accurate measurements, as previously recommended [16]. Following the protocol described by Whittaker et al. [17], ultrasound images of the participants' cervical multifidus muscles were obtained. To achieve this, the ultrasound transducer was placed longitudinally 4 cm lateral to the level of the cervical spinous process. This approach was employed to ensure precise imaging of the targeted muscles according to the established methodology. Immediately following the RUSI evaluation, all functional balance test and scales were scored.

2.3. Outcome Measures

Rehabilitative Ultrasound Imaging Data

The outcomes measured were the thickness of the multifidus muscle using ultrasonography. Ultrasonographic measurements of the multifidus muscle were obtained for both the paretic (affected) and non-paretic (unaffected) sides. The thickness of the multifidus muscle was chosen as the primary outcome measure in this study. Ultrasonography was employed as a reliable and non-invasive imaging technique to quantify muscle thickness accurately. Measurements were taken bilaterally to compare the multifidus muscle thickness between the affected and unaffected sides, providing valuable insights into the muscle morphology and potential asymmetries related to the stroke [16]. The ultrasound images were analyzed using Image J software by two evaluators who were blinded to the participants' information.

Balance Assessment

The study also included functional balance assessments, such as the Time Up and Go Test (TUG) [18], Berg Balance Scale (BBS) [19], and Modified Functional Reach Test (MFRT) [20] to evaluate balance and mobility. TUG test is a commonly used clinical assessment tool to evaluate functional mobility and assess balance and the risk of falls. It provides a quantitative measurement of the time taken by an individual to rise from a chair, walk a short distance, turn around, walk back to the chair, and sit down again. During the TUG test, a standardized protocol, including clear instructions, standardized chair height and position, and a marked path for walking was adopted. The use of an assistive device, such as a walking aid, has been accepted [21]. The test shown to have good reliability and validity in assessing functional mobility and predicting fall risk in stroke patients. BBS is a widely used clinical assessment tool designed to assess balance and fall risk in individuals with neurological and musculoskeletal conditions. It is a performance-based test that evaluates an individual's ability to maintain static and dynamic balance during a series of functional tasks. The BBS consists of 14 different tasks that assess various aspects of balance, including sitting balance, standing balance, transferring, and reaching. Each task is scored on a 5-point ordinal scale, ranging from 0 to 4, with a maximum total score of 56. The higher the score, the better the individual's balance performance [22]. The Modified Functional Reach Test (MFRT) is a clinical assessment tool used to measure an individual's dynamic balance and reaching ability. It provides a quantitative measure of how far an individual can reach forward while maintaining balance in a standing position.

2.4. Statistical Analysis

Data analysis was performed using the SPSS software (version 25), USA. Descriptive analysis was conducted for all individuals and separately for the stroke and control groups, including mean and standard deviation for parametric data and median and interquartile range for non-parametric data. Comparative analyses were performed using the Student's t-test for parametric data and the Mann-Whitney U test for non-parametric data. Levene's test was used to assess the equality of variances. Correlations between ultrasonographic parameters on the paretic side and balance scales were assessed using the Spearman's test. The significance level was set at $p < 0.05$.

3. Results

The sample was composed of 24 subjects of 67 ± 8.5 years, the sociodemographic characteristics, including age, weight, height, and BMI, did not show any significant differences between the two groups, (**Table 1**).

Table 1. Sociodemographic data, TUG and BERG scales of the sample.

Data	Total Sample (n = 24)	Case (n = 12)	Control (n = 12)	p-Value
Age, y	67 ± 8.5	67 ± 10.1	67 ± 7.9	0.728
Height, m	1.64 ± 0.1	1.64 ± 0.1	1.65 ± 0.1	0.852
Weight, kg	71.5 ± 11.9	70.0 ± 6.4	73 ± 15.5	0.689
BMI, kg/m^2	26.2 ± 2.8	25.9 ± 1.4	26.4 ± 3.8	0.650
Stroke type				
Ischemic	N/A	11	N/A	N/A
Hemorrhagic	N/A	1	N/A	N/A
TUG	N/A	22.0 ± 13.0	N/A	N/A
BERG	N/A	45.8 ± 12.4	N/A	N/A

TUG: Timed Up and Go Test; BERG: Berg Balance Scale.

Table 2 presents the ultrasonographic values of the multifidus muscle for the paretic and non-paretic sides in stroke patients. The measurements include the multifidus distance, vertical relaxation (REL) thickness in millimeters (mm), horizontal REL thickness in mm, cross-sectional area (AST) in square centimeters (cm2), vertical contraction (CON) thickness in mm, horizontal CON thickness in mm, and AST in cm2. The table also provides the corresponding p-values for the comparisons between the paretic and non-paretic sides. The results from Table 2 indicate that there were no statistically significant differences in the ultrasound values of the multifidus muscles between the paretic and non-paretic sides in stroke patients. The p-values for all the comparisons were greater than 0.05, suggesting a lack of significant variation in multifidus muscle morphology between these sides. Specifically, for the REL measurements, the vertical REL thickness was 117.44 ± 46.9 mm for the non-paretic side and 124.53 ± 34.2 mm for the paretic side. The horizontal REL thickness was 257.15 ± 37.2 mm for the non-paretic side and 291.42 ± 60.7 mm for the paretic side. The AST REL was 282.18 ± 122.1 cm2 for the non-paretic side and 317.04 ± 114.5 cm2 for the paretic side. Regarding the CON measurements, the vertical CON thickness was 134.69 ± 49.2 mm for the non-paretic side and 136.79 ± 65.6 mm for the paretic side. The horizontal CON thickness was 285.96 ± 37.1 mm for the non-paretic side and 307.03 ± 73.7 mm for the paretic side. The AST CON was 327.56 ± 90.9 cm2 for the non-paretic side and 443.12 ± 266.0 cm2 for the paretic side. In summary, the findings from **Table 2** indicate that there were no statistically significant differences in the ultrasonographic values of the multifidus muscles between the paretic and non-paretic sides in stroke patients. This suggests a similar muscle morphology in terms of thickness and cross-sectional area on both sides of the neck in these patients.

Table 2. Ultrasonographic values of the multifidus muscle for the paretic and non-paretic side in stroke patients.

Measurement	Non-Paretic Side	Paretic Side	*P*-Value
Multifidus distance			
Grosor vertical REL (mm)	117.44 ± 46.9	124.53 ± 34.2	0.478
Grosor horizontal REL (mm)	257.15 ± 37.2	291.42 ± 60.7	0.101
AST REL (cm^2)	282.18 ± 122.1	317.04 ± 114.5	0.266
Grosor vertical CON (mm)	134.69 ± 49.2	136.79 ± 65.6	0.809
Grosor horizontal CON (mm)	285.96 ± 37.1	307.03 ± 73.7	0.756
AST CON (cm^2)	327.56 ± 90.9	443.12 ± 266.0	0.426

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REL: Relaxation; CON: Contraction; AST: Cross-sectional area.

Table 3 presents the comparison of ultrasonographic values between the non-paretic side of stroke patients (cases) and the non-paretic side of the control group. The measurements include multifidus distance, vertical relaxation (REL) thickness in millimeters (mm), horizontal REL thickness in mm, cross-sectional area (AST) in square centimeters (cm2), vertical contraction (CON) thickness in mm, horizontal CON thickness in mm, and AST in cm2. The table also provides the corresponding p-values for the comparisons. The results from Table 3 indicate that there were no statistically significant differences in the ultrasound values of the multifidus muscles between the non-paretic side of stroke patients and the non-paretic side of the control group. Specifically, for the REL measurements, the vertical REL thickness was 117.44 ± 46.9 mm for the non-paretic side of stroke patients and 68.05 ± 43.6 mm for the control group. The horizontal REL thickness was 257.15 ± 37.2 mm for the non-paretic side of stroke patients and 208.29 ± 79.3 mm for the control group. The AST REL was 282.18 ± 122.1 cm2 for the non-paretic side of stroke patients and 208.60 ± 57.2 cm2 for the control group. Regarding the CON measurements, the vertical CON thickness was 134.69 ± 49.2 mm for the non-paretic side of stroke patients and 96.03 ± 38.5 mm for the control group. The horizontal CON thickness was 285.96 ± 37.1 mm for the non-paretic side of stroke patients and 285.81 ± 122.0 mm for the control group. The AST CON was 327.56 ± 90.9 cm2 for the non-paretic side of stroke patients and 309.34 ± 86.9 cm2 for the control group. In summary, **Table 3** reveals that there were no statistically significant differences in the ultrasonographic values of the multifidus muscles between the non-paretic side of stroke patients and the non-paretic side of the control group. This suggests a similar muscle morphology in terms of thickness and cross-sectional area between these groups.

Table 3. Ultrasonographic values comparison between cases and controls non-paretic side.

Measurement	Non-Paretic Side Cases	Controls	*P*-Value
	Multifidus distance		
Grosor vertical REL (mm)	117.44 ± 46.9	68.05 ± 43.6	0.551
Grosor horizontal REL (mm)	257.15 ± 37.2	208.29 ± 79.3	0.068
AST REL (cm^2)	282.18 ± 122.1	208.60 ± 57.2	0.128
Grosor vertical CON (mm)	134.69 ± 49.2	96.03 ± 38.5	0.040
Grosor horizontal CON (mm)	285.96 ± 37.1	285.81 ± 122.0	0.133
AST CON (cm^2)	327.56 ± 90.9	309.34 ± 86.9	0.016

REL: Relaxation; CON: Contraction; AST: Cross-sectional area.

Table 4 presents the correlation coefficients between the ultrasonographic muscle variables of the multifidus muscles and the balance scales for the healthy and affected sides in patients with post-stroke. The measurements include the Grosor vertical REL (relaxation) thickness, Grosor horizontal REL thickness, AST (cross-sectional area) REL, Grosor vertical CON (contraction) thickness, Grosor horizontal CON thickness, and AST CON. The correlation coefficients are expressed as Spearman correlation coefficients. The results from Table 4 indicate that there were no significant associations between the ultrasonographic muscle variables of the multifidus muscles and the balance scales for either the healthy or affected sides. None of the correlation coefficients reached statistical significance ($p < 0.05$). Specifically, for the healthy side, the correlation coefficients between the muscle variables and the Timed Up and Go (TUG) test ranged from 0.18 to 0.86, while for the affected side, the correlation coefficients ranged from 0.04 to 0.93. For the Berg Balance Scale, the correlation coefficients for the healthy side ranged from 0.08 to 0.68, and for the affected side, the coefficients ranged from -0.74 to -0.80. In summary, **Table 4** demonstrates that there were no significant associations between the ultrasonographic muscle variables of the multifidus muscles and the balance scales for either the healthy or affected sides in patients with post-stroke. These findings suggest that the morphology of the cervical multifidus muscle may not directly impact postural balance in these individuals.

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Table 4. Correlation coefficients between ultrasonographic muscle variables and balance scales.

Measurement	Spearman Correlation Coefficient			
	TUG Healthy	TUG Affected	BERG Healthy	BERG Affected
Grosor vertical REL	0.18	0.33	0.08	-0.74
Grosor horizonal REL	0.66	-0.11	0.68	-0.43
AST REL	0.86	0.04	0.30	-0.64
Grosor vertical CON	0.42	0.09	-0.61	-0.25
Grosor horizontal CON	0.52	0.93	0.95	-0.69
AST CON	0.57	0.43	-0.76	-0.80

* $p < 0.05$; TUG: Timed Up and Go Test; BERG: Berg Balance Scale.

4. Discussion

The aim of this study was to examine the impact of cervical multifidus muscle morphology on postural balance in post-stroke patients through a pilot study. Specifically, we investigated whether there were significant differences in ultrasound assessment of cervical multifidus muscle between healthy individuals and post-stroke patients. By utilizing RUSI, the researchers aimed to gain insights into the muscle characteristics and functional implications for postural control in stroke patients. Our results did not show any statistically significant differences in cervical multifidus muscle morphology between the two groups and between side in post-stroke patients. These findings are intriguing and warrant further discussion in the context of current literature on the subject. Several studies have examined the relationship between cervical multifidus muscle morphology and postural balance in different populations, including individuals with musculoskeletal disorders and neurological conditions [23–25]. Some of these studies have reported significant associations between cervical multifidus muscle morphology and postural balance, suggesting that alterations in muscle structure could contribute to postural instability [26]. However, the lack of significant differences observed in our study raises questions about the specific impact of cervical multifidus muscle morphology on postural balance in post-stroke patients. This study did not uncover any significant differences in the thickness of the multifidus muscle between the paretic and non-paretic sides of stroke patients. This lack of asymmetry in muscle thickness implies that the multifidus muscles on both sides of the neck may be similarly affected in individuals with hemiparesis due to post-stroke. Moreover, when comparing the non-paretic side of stroke patients with the non-paretic side of the healthy control group, no significant differences were observed. These findings suggest that the multifidus muscle morphology in post-stroke patients may resemble that of healthy individuals, at least in ultrasonographic measurements. It is important to consider potential explanations for these findings. Firstly, it is possible that other factors, such as neurological impairments resulting from the stroke, play a more prominent role in influencing postural balance in this population. Stroke often leads to motor deficits and muscle weakness, which may overshadow the potential influence of cervical multifidus muscle morphology on postural control. The loss of neural connections and impaired motor control due to stroke may disrupt the coordination of muscle activation necessary for maintaining postural stability. Additionally, post-stroke individuals often experience sensory deficits, such as impaired proprioception and somatosensorial alteration, which can further impact postural control [27]. We could hypothesize that cervical sensory impairments and motor deficits may contribute more significantly to postural instability than the morphology of the cervical multifidus muscle alone. Sensory impairments in the cervical region, such as altered proprioception and diminished sensation, can disrupt the feedback loop necessary for maintaining postural control [28]. These impairments may result in difficulties in perceiving body position and movement, leading to postural instability. Furthermore, motor deficits in the cervical muscles, including weakness and coordination problems, can further compromise postural control. The inability to generate sufficient muscle force and coordinate movements of the neck and upper body may hinder the adjustments required for maintaining balance [29,30]. Therefore, addressing and rehabilitating cervical sensory impairments and motor deficits should be considered important components of post-stroke rehabilitation programs aimed at improving postural stability and functional outcomes. Further research is needed to explore the specific mechanisms underlying these impairments and to develop targeted interventions to address them effectively. Therefore, interventions targeting sensory integration, proprioceptive training, and motor rehabilitation may be crucial for improving postural balance in post-stroke patients [31,32]. Another aspect to consider is the methodological differences across studies, including variations in sample size, assessment tools, and measurement techniques. The use of ultrasound assessment for evaluating cervical multifidus muscle morphology is relatively novel, and the interpretation and standardization of the ultrasound images may vary among researchers. Furthermore, it is worth exploring other cervical muscles that contribute to postural control, such as the deep neck flexors and the sternocleidomastoid. These muscles play essential roles in head stabilization and posture, and their morphology and function may be affected by stroke. Investigating the interaction between multiple cervical muscles and their collective impact on postural balance could offer a more comprehensive understanding of the factors influencing postural stability in post-stroke patients. Looking ahead, it is crucial to address several methodological differences across studies in order to advance our understanding of the relationship between cervical multifidus muscle morphology and postural balance in post-stroke patients. Variations in sample size, assessment tools, and measurement techniques have been observed, which can lead to inconsistent findings and hinder the ability to draw definitive conclusions. Therefore, future research should strive for larger sample sizes and utilize standardized assessment protocols to enhance the reliability and generalizability of the results.

5. Conclusions

In conclusion, our study did not find significant differences in cervical multifidus muscle morphology between healthy individuals and post-stroke patients in relation to postural balance. These findings suggest that cervical multifidus muscle morphology alone may not be a strong predictor of postural control in this specific population. Future studies should continue to investigate the multifaceted nature of postural balance impairments in post-stroke patients and consider the influence of various factors, including neurological deficits and other muscle groups, to enhance our understanding of postural stability in this context.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Hospital Universitario Fundación Alcorcón, Madrid, Spain (protocol code 21/153).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: We encourage all authors of articles published in MDPI journals to share their research data. In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Where no new data were created, or where data is unavailable due to privacy or ethical restrictions, a statement is still required. Suggested Data Availability Statements are available in section "MDPI Research Data Policies" at https://www.mdpi.com/ethics.

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Conflicts of Interest: The authors declare no conflict of interest.

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