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

Exploración de la Morfología del Músculo Multífido Cervical en el Equilibrio Postural en Pacientes Post-Ictus: Un estudio piloto

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Abstract. The aim of this study was to examine cervical multifidus muscle morphology and its impact on postural balance in post-stroke patients. 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, Timed Up and Go (TUG) test and Berg Balance scale (BBS). No significant differences in the ultrasound values between affected and unaffected sides in post-stroke patients were found. Similarly, there were no significant differences between the unaffected side of post-stroke patients and the dominant side of the control group, ($p > 0.05$). Additionally, no significant correlations in post-stroke patients between the ultrasonographic variables of the multifidus muscles and the main outcome were identified. 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. The exploratory nature of our study limits the ability to draw definitive conclusions.

Keywords: Stroke; Ultrasonography; Postural balance; Multifidus; Cervical muscle

Resumen. El objetivo de este estudio fue analizar la morfología del músculo multífido cervical y su repercusión en el equilibrio postural en pacientes post-ictus. Se llevó a cabo un estudio piloto con una muestra de conveniencia de 24 voluntarios de 67 ± 8.5 años (12 con hemiparesia debido a un ictus, 12 sanos) para este estudio. Los resultados medidos fueron el grosor del músculo multífido utilizando ultrasonografía, la prueba Timed Up and Go (TUG) y la escala de equilibrio de Berg (BBS). No se encontraron diferencias significativas en los valores de ultrasonografía entre los lados afectados y no afectados en los pacientes post-ictus. Del mismo modo, no hubo diferencias significativas entre el lado no afectado de los pacientes post-ictus y el lado dominante del grupo de control ($p > 0.05$). Además, no se identificaron correlaciones significativas en los pacientes post-ictus entre las variables ultrasonográficas de los músculos multífidos y el resultado principal. En conclusión, nuestro estudio no encontró diferencias significativas en la morfología del músculo multífido cervical entre individuos sanos y pacientes post-ictus en relación con el equilibrio postural. La naturaleza exploratoria de nuestro estudio limita la capacidad para sacar conclusiones definitivas.

Palabras clave: Ictus; Ultrasonografía; Equilibrio postural; Multífido; Músculo cervical

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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 (Ma et al., 2021). 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 (Jamal et al., 2020).

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 (Mullie & Duclos, 2014). The cervical musculature plays a crucial role in maintaining balance by providing stability and control of head movements, which, in turn, influence the body's overall posture and equilibrium. These muscles help in coordinating head adjustments in response to external stimuli, contributing to the body's ability to stay upright and steady during various activities and movements. 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 (Villafañe et al., 2015).

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. Post-stroke, restoring equilibrium is pivotal in fostering recovery, enhancing mobility, and promoting overall well-being, underscoring its crucial role in comprehensive rehabilitative strategies (Gamble, Chiu, & Peiris, 2021). Moreover, the significance of balance restoration extends beyond the clinical setting, as it profoundly impacts the daily lives of post-stroke individuals, facilitating a smoother integration into routine activities and promoting a sense of confidence and independence (Vloothuis et al., 2016). As a result, individuals who have experienced a 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 (Fiore et al., 2023). These interventions may include weight-shifting exercises, standing balance exercises, dynamic balance activities, and specific tasks that simulate real-life situations (Pollet, Buraschi, Villafañe, Piovanelli, & Negrini, 2021). Balance serves as a prognostic factor for achieving autonomy, improving transfer abilities, and recovering walking capabilities (Muñoz et al., 2023).

Accurately assessing trunk muscle morphology and functional performance is essential in stroke patients to guide appropriate rehabilitation interventions (Borboni et al., 2017). 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 (Worsley, Kitsell, Samuel, & Stokes, 2014). 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 (Hebert, Koppenhaver, Parent, & Fritz, 2009). RUSI allows for the measurement of muscle thickness and cross-sectional area, providing valuable information on muscle quality and function (Onat, Polat, Gürçay, Özcan, & Orhan, 2022). 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 (Kim et al., 2021; Sánchez-Sánchez, Ruescas-Nicolau, Carrasco, Espí-López, & Pérez-Alenda, 2019; Stokes, Hides, Elliott, Kiesel, & Hodges, 2007; Thielman & Yourey, 2019). 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 (Thielman & Yourey, 2019). This information helps in understanding muscle function and designing targeted rehabilitation strategies. Musculoskeletal ultrasonography, particularly RUSI, 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.

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 and procedures were conducted according to the Declaration of Helsinki. Participants were thoroughly informed about the procedure by their therapists prior to signing the informed consent form. Additionally, data handling and analysis were performed using secure, encrypted software to maintain confidentiality and integrity of the data, aligning with ethical standards for the protection of participant information.

Participants

A convenience sample of 24 volunteers (12 healthy, 12 with hemiparesis due to stroke) was recruited for this study. Post-stroke patients who participated in our study were recruited from outpatient rehabilitation clinics. During the study period, all participants were actively engaged in their prescribed rehabilitation programs offered by the outpatient clinics, including at least two days per week of a combined treatment of physical and occupational therapy. 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 (Estrada-Barranco, Cano-de-la-Cuerda, & Molina-Rueda, 2019). 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. The control group participants were selected from the families and acquaintances of the stroke patients and were matched by age.

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 adopted to maintain uniformity and aid in achieving accurate measurements, as previously recommended (Pillastrini et al., 2015). Following the protocol described by Whittaker et al. (Whittaker, Warner, & Stokes, 2013), 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.

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 (Yoon & You, 2017). Three key parameters are measured to analyze the tissue's properties: Vertical REL thickness (mm), Horizontal REL thickness (mm), and AST REL (Area of Soft Tissue Relative to Epidermis and Low-Echogenic Subcutis, measured in cm^2). These measurements help in determining the tissue's relative density and composition. Similarly, in RUSI for assessing connective tissues, the parameters include Vertical CON thickness (mm), Horizontal CON thickness (mm), and AST CON (Area of Soft Tissue Relative to Connective Tissue, measured in cm^2). These measurements aid in evaluating the integrity and condition of connective tissues. By analyzing these parameters, clinicians and researchers can gain valuable insights into the tissue's health and detect any abnormalities or changes, facilitating early diagnosis and targeted treatment plans. 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) (Cuenca-Zaldivar et al., 2022) and Berg Balance Scale (BBS) (Negrini et al., 2017) 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 (second) 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 (Buraschi et al., 2018). 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 (Alghadir, Al-Eisa, Anwer, & Sarkar, 2018).

Statistical analysis

The data have been analyzed using the SPSS 21.0 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics (mean and standard deviation) were provided for all subjects, as well as for stroke patients and controls, respectively. 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 affected side and balance scales were assessed using the Spearman's test. The significance level was set at $p < 0.05$.

Results

Descriptive statistics for demographics, age, weight, height, and BMI for the two groups are presented in **Table 1**. 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.
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 affected and unaffected 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 (cm^2), vertical contraction (CON) thickness in mm, horizontal CON thickness in mm, and AST in cm^2. The table also provides the corresponding p-values for the comparisons between the affected and unaffected sides. The results from Table 2 indicate that there were no statistically significant differences in the ultrasound values of the multifidus muscles between the affected and unaffected 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 unaffected side and 124.53 ± 34.2 mm for the affected side. The horizontal REL thickness was 257.15 ± 37.2 mm for the unaffected side and 291.42 ± 60.7 mm for affected sides side. The AST REL was 282.18 ± 122.1 cm2 for the unaffected side and 317.04 ± 114.5 cm^2 for the affected side. Regarding the CON measurements, the vertical CON thickness was 134.69 ± 49.2 mm for the unaffected side and 136.79 ± 65.6 mm for the affected side. The horizontal

CON thickness was 285.96 ± 37.1 mm for the non-affected side and 307.03 ± 73.7 mm for the affected side. The AST CON was 327.56 ± 90.9 cm2 for the unaffected side and 443.12 ± 266.0 cm^2 for the affected 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 affected and unaffected sides 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 affected and unaffected side in stroke patients.

Measurement	Unaffected side	Affected 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

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

Table 3 presents the comparison of ultrasonographic values between the unaffected side of stroke patients (cases) and the muscles of the dominant side on 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 (cm^2), 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 unaffected side of stroke patients and the muscles of the dominant side on the control group of the control group. Specifically, for the REL measurements, the vertical REL thickness was 117.44 ± 46.9 mm for the unaffected 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 unaffected side of stroke patients and 208.29 ± 79.3 mm for the control group. The AST REL was 282.18 ± 122.1 cm^2 for the unaffected 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 unaffected 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 unaffected side of stroke patients and 285.81 ± 122.0 mm for the control group. The AST CON was 327.56 ± 90.9 cm^2 for the unaffected side of stroke patients and 309.34 ± 86.9 cm2 for the control group. In summary, Table 3 reveals no statistically significant differences in the ultrasonographic values of the multifidus muscles between the unaffected side of stroke patients and 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 unaffected side and controls dominant side.

Measurement	Unaffected 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	0.050
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	0.106

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 affected and unaffected 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 ul-trasonographic muscle variables of the multifidus muscles and the balance scales for either the affected or unaffected sides. None of the correlation coefficients reached statistical significance ($p < 0.05$). Specifically, for the healthy side, the correlation coefficients be-tween 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 ultraso-nographic muscle variables of the multifidus muscles and the balance scales for either the affected or unaffected side 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.

Table 4.
Correlation coefficients between ultrasonographic muscle variables and balance scales in post-stroke patients.

Measurement	Pearson correlation coefficient	
	TUG (s)	BERG
Grosor vertical REL AS	0.33	-0.74
Grosor horizonal REL AS	-0.11	-0.43
AST REL AS	0.04	-0.64
Grosor vertical CON AS	0.09	-0.25
Grosor horizontal CON AS	0.93	-0.69
AST CON AS	0.43	-0.80
Grosor vertical REL US	0.18	0.08
Grosor horizonal REL US	0.66	0.68
AST REL US	0.86	0.30
Grosor vertical CON US	0.42	-0.61
Grosor horizontal CON US	0.52	0.95
AST CON US	0.57	-0.76

*p < 0.05; AS: affected side US: Unaffected side TUG: Timed Up and Go Test; BERG: Berg Balance Scale.

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. However, given the exploratory nature of the study, no firm conclusions can be reached. 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 (Gu et al., 2023; Peolsson et al., 2022; Tamai et al., 2019). 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 (Huang et al., 2022). 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 affected and unaffected 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 unaffected side of stroke patients with the 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 (Tasseel-Ponche, Yelnik, & Bonan, 2015a). 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 (Bolognini, Russo, & Edwards, 2016). These impairments may result in difficulties in perceiving body position and movement, leading to postural instability (Barra, Oujamaa, Chauvineau, Rougier, & Pérennou, 2009; Tasseel-Ponche, Yelnik, & Bonan, 2015b). Furthermore, motor deficits in the cervical muscles, including weakness and coordination problems, can further compromise postural control (Forbes, Siegmund, Schouten, & Blouin, 2014; Treleaven, 2008). The inability to generate sufficient muscle force and coordinate movements of the neck and upper body may hinder the adjustments required for maintaining balance (Dinesh, Thenmozhi, & KalaBarathi, 2022; Jorge H. Villafañe et al., 2019). 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 (Van Criekinge et al., 2019; Yu, Chen, Lou, & Shen, 2021). 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.

Conclusion

In conclusion, our pilot study did not reveal significant differences in cervical multifidus muscle morphology between healthy participants and post-stroke patients concerning postural balance. It is important to note that the small sample size and the exploratory nature of our study limit the ability to draw definitive conclusions. As a pilot study, our primary aim was to gather preliminary data and identify potential trends, laying the groundwork for future research that can delve deeper into the multifaceted nature of postural balance impairments in post-stroke patients and consider other relevant factors to enhance our understanding of postural stability in this context. Future research should further explore postural balance impairments in post-stroke patients, considering various factors such as neurological deficits and other muscle groups, to gain a more comprehensive understanding of postural stability in this context.

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.

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