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Morphofunctional Role of the Thoracolumbar Fascia in Respiratory Mechanics: Evidence from a Randomized Controlled Study in Stroke

Rol Morfofuncional de la Fascia Toracolumbar en la Mecánica Respiratoria: Evidencia de un Estudio Controlado Aleatorizado en Pacientes con Accidente Cerebrovascular

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SUMMARY: The thoracolumbar fascia is a complex connective tissue structure providing anatomical continuity between the lumbar spine, abdominal wall, diaphragm, and respiratory musculature, contributing to respiratory mechanics through thoracoabdominal mobility and force transmission. However, functional evidence supporting its role in pulmonary function remains limited. Stroke, characterized by impaired respiratory mechanics and altered trunk biomechanics, provides a relevant model to explore these relationships. The aim of this study is to investigate the morphofunctional role of the thoracolumbar fascia in respiratory mechanics by examining the acute effects of its modulation on pulmonary function in stroke patients, using respiratory exercise as a comparative functional model. Thirty male stroke patients (mean age: 59.01 ± 3.08 years) were randomly assigned to control (CON), respiratory exercise (RE), or thoracolumbar fascia release (TLF) groups. All participants received standard rehabilitation. The RE group performed additional breathing exercises, and the TLF group received myofascial release targeting the thoracolumbar fascia (15 min). Pulmonary function was assessed via spirometry before and immediately after intervention. Both RE and TLF groups showed significant improvements in pulmonary parameters ($p < 0.05$), while no changes were observed in CON. Improvements ranged from 2.82–18.79 % in RE and 3.36–14.83 % in TLF. Significant time effects were found for FEV1/FVC, FEV1, FVC, and PEF ($p < 0.01$), with significant group × time interactions for FEV1, FVC, and PEF ($p < 0.01$). Thoracolumbar fascia release induced measurable improvements in pulmonary function comparable to respiratory exercise, supporting its morphofunctional relevance in respiratory mechanics. These findings suggest that fascial structures may actively contribute to thoracoabdominal dynamics. Further studies are required to clarify underlying mechanisms and long-term effects.

KEY WORDS: Thoracolumbar fascia; Morphofunction; Respiratory mechanics; Stroke; Connective tissue.

INTRODUCTION

The thoracolumbar fascia is a complex connective tissue structure that provides anatomical continuity between the lumbar spine, abdominal wall, diaphragm, and respiratory musculature (Willard *et al*., 2012). This multilayered fascial organization contributes to the morphofunctional integration of postural control and respiration through force transmission and the distribution of mechanical tension (El Bojairami & Driscoll, 2022). Through its structural connections with the diaphragm and deep abdominal muscles, the thoracolumbar fascia may influence respiratory mechanics by modulating thoracoabdominal coordination and pressure regulation during breathing (Perez *et al*., 2023). Despite its well-defined anatomical and biomechanical importance, the morphofunctional contribution of this structure to pulmonary mechanics has not yet been fully elucidated (Bordoni & Zanier, 2013; Pirri *et al*., 2024).

Most existing studies have focused on interventions aimed at improving respiratory function, and it has been shown that myofascial release techniques can enhance respiratory parameters, particularly in healthy individuals, with reported increases in FVC and FEV1 ranging between approximately 5–15 % (González-Álvarez *et al*., 2015; Domaszewska *et al*., 2019; Fereydounnia *et al*., 2022). However, these studies largely focus on functional outcomes and address the underlying morphological mechanisms to a limited extent. In particular, the morphofunctional role of extensive connective tissue structures such as the thoracolumbar fascia within the respiratory system remains unclear (Bordoni & Escher, 2021).

Respiratory dysfunction is a common consequence of stroke and is characterized by reduced lung volumes,

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impaired respiratory muscle performance, and altered thoracoabdominal coordination, with reductions in lung volumes reported to range from 10 % to 30 % compared to healthy individuals (Rochester & Mohsenin, 2002; Park *et al*., 2017; Lista-Paz *et al*., 2023).

Although these impairments are often attributed to neuromuscular deficits, increasing attention has been directed toward the role of altered trunk biomechanics and connective tissue organization in shaping respiratory function (Gomes-Neto *et al*., 2016; Park *et al*., 2017). Changes in postural control and movement patterns following stroke may disrupt the structural–functional integrity between the diaphragm, abdominal musculature, and surrounding fascial structures, thereby influencing respiratory mechanics beyond isolated muscle weakness (Perez *et al*., 2023). In this context, stroke provides a suitable model to examine the effects of structural and biomechanical alterations on respiratory function.

Therefore, the aim of this study was to investigate the morphofunctional role of the thoracolumbar fascia in respiratory mechanics by evaluating the acute effects of its modulation on pulmonary function and examining this response using respiratory exercise as a comparative functional model. It was hypothesized that thoracolumbar fascia release would induce measurable changes in pulmonary function comparable to respiratory exercise, through its effects on thoracoabdominal dynamics and force transmission.

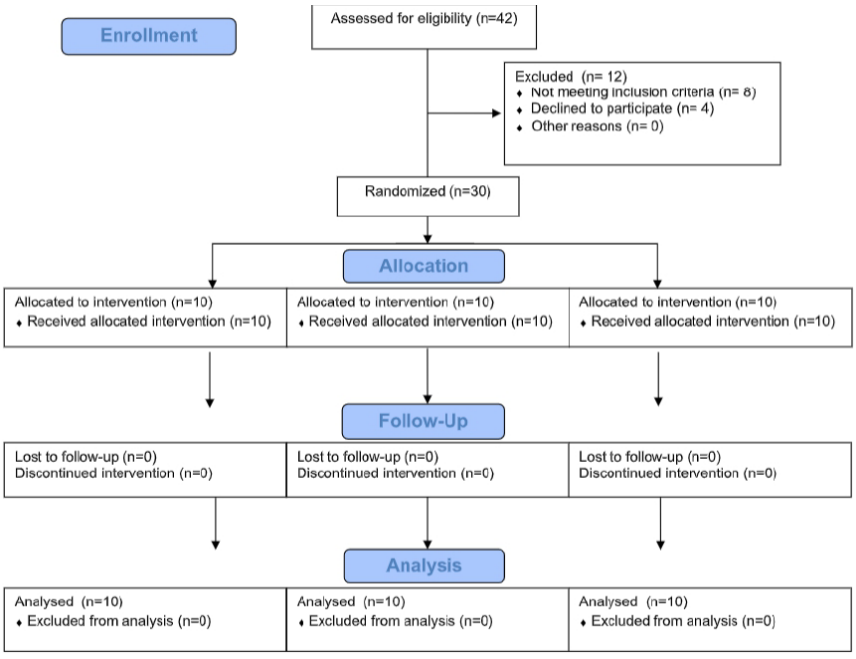


Fig. 1. CONSORT diagram of recruitment.

MATERIAL AND METHOD

Study Design. This study was designed as a randomized controlled experimental trial conducted in accordance with the CONSORT guidelines. The study adhered to the principles of the Declaration of Helsinki and received ethical approval from the Inonu University Health Sciences Non-Invasive Clinical Research Ethics Committee (Date/No: 2022/3960). Written informed consent was obtained from all participants prior to enrollment. Participants were recruited from the Department of Physical Therapy and Rehabilitation at Inonu University Faculty of Medicine between November 2022 and June 2024. Eligible stroke patients were randomly allocated into three groups: respiratory exercise, thoracolumbar fascia release, and control, using a simple randomization method. Due to the nature of the interventions, participants were not blinded to group allocation. The experimental protocol consisted of a single-session intervention, with outcome measures assessed at baseline and immediately after the intervention. This design was employed to examine the acute functional response to thoracolumbar fascia modulation. A CONSORT flow diagram of participant recruitment and allocation is presented in Figure 1.

Participants. Eligible participants were male patients aged 18–65 years with a diagnosis of monohemispheric ischemic stroke above the brainstem, confirmed by computed tomography or magnetic resonance imaging, with a post-stroke duration of at least six months. This population was selected to provide a clinically stable model in which alterations in trunk biomechanics and connective tissue organization could be examined in relation to respiratory function. Exclusion criteria included severe cardiorespiratory or neuromuscular disease, tracheostomy, obesity (BMI ≥ 30 kg/m^2), rib cage deformity, cognitive impairment (Mini-Mental State Examination score ≤ 20), and severe dysphagia, aphasia, or confusion. The sample size was calculated using G*Power software (version 3.1.9.3; Heinrich Heine University, Düsseldorf, Germany), based on effect sizes reported in a previous study examining the immediate effects of thoracic spinal manipulation on forced vital capacity and forced expiratory volume in stroke patients (Joo *et al*., 2018). With an alpha level (α) of 0.05 and statistical power (1–β) of 0.90, the required sample size was estimated to be 15–

19 participants. To account for potential dropouts and ensure balanced group allocation, a total of 30 participants were included, with 10 participants assigned to each group.

Pulmonary Function Measurement. Spirometric assessments were performed using a calibrated spirometer (COSMED Pony FX, Cosmed, Rome, Italy) to evaluate maximal voluntary ventilation (MVV), forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and peak expiratory flow (PEF). Measurements were conducted in a standardized seated position in accordance with American Thoracic Society guidelines (Graham *et al*., 2019). The FEV1/FVC ratio was calculated as an index of ventilatory efficiency, while PEF was used to assess maximal expiratory flow (Quanjer *et al*., 2012). These parameters were selected to capture functional aspects of respiratory mechanics potentially influenced by thoracoabdominal dynamics.

Intervention. Following baseline spirometric assessment, all participants underwent a single-session intervention protocol. A standardized stroke rehabilitation program was applied to all groups and individualized according to patient needs. Participants were subsequently allocated to one of three intervention conditions: the control group received standard rehabilitation alone; the respiratory exercise group performed additional diaphragmatic and deep breathing exercises; and the thoracolumbar fascia group underwent manual techniques specifically targeting the thoracolumbar fascia (Tamartash *et al*., 2022). All interventions were administered individually under the supervision of trained therapists to ensure consistency and adherence to the protocol. Post-intervention spirometric assessments were conducted immediately after the completion of the session. Detailed descriptions of the intervention procedures are provided in Table I.

Table I. Intervention procedures of the study.

Group	Intervention	Details
Control	Traditional stroke rehabilitation (45 min)	Spasticity inhibition Sensory-perceptual-motor integration techniques Core stabilization and strengthening exercises Balance training i.e. applied as needed for stroke patients
Respiratory Exercise	Traditional stroke rehabilitation (45 min) + Respiratory exercises (15 min)	***Pursed-Lip Breathing*** Inhale through nose Exhale through pursed lips Combined with exercises ***Deep Breathing Exercise*** Semi-sitting with a pillow under knees Repeat 3-5 times ***Diaphragm Strengthening Exercise*** Semi-sitting with a pillow under knees Therapist provides resistance from subcostal area Repeat 3-5 times ***Thoracic Expansion Exercises*** Sitting position Use of belt Therapist provides resistance during inhalation from subcostal area Repeat 3-5 times
Thoracolumbar Fascia Release	Traditional stroke rehabilitation (45 min) + Thoracolumbar fascia release (15 min)	***Supine Pelvic Rotation*** Knees bent in hook-lying position Therapist supports one shoulder and holds knees Rotate pelvis right and left Hold 10-15 seconds ***Supine Arm Elevation*** Add arm elevation on the opposite side during pelvic rotation Hold for 10-15 seconds ***Sitting Position*** Therapist assists patient while bending forward Hold for 10-15 seconds ***Sitting Crossed Arm and Knee Position*** Therapist assists patient while bending forward Reach forward with opposite arm to opposite knee Hold for 10-15 seconds

Statistical Analysis. Data normality was assessed using the Shapiro–Wilk test, and homogeneity of variance was evaluated with Levene's test. Baseline differences between groups were analyzed using one-way analysis of variance (ANOVA). Within-group changes from baseline to post-intervention were assessed using paired samples t-tests. To examine time-dependent and between-group effects, repeated measures ANOVA was conducted for each variable, including main effects for time and group × time interaction. When significant effects were identified, post hoc comparisons were performed using Tukey's HSD test. Effect sizes for within-group changes were calculated using Cohen's d and interpreted as negligible (0.0–0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0), and very large (>2.0). For ANOVA analyses, partial eta squared ($\eta\rho^2$) was reported as a measure of effect size, with thresholds of ≤0.01 (small), 0.01–0.06 (medium), and ≥0.14 (large) (Cohen, 1988). All statistical analyses were performed using SPSS software (version 23.0; IBM Corp., Armonk, NY, USA), and the level of statistical significance was set at $p < 0.05$.

RESULTS

Baseline characteristics were comparable across the groups, as shown in Table II. Analysis revealed no significant differences between groups ($p > 0.05$) in pulmonary functions before the interventions (Fig. 2).

Results indicated that both respiratory and fascial release techniques significantly enhanced pulmonary function ($p < 0.05$). The respiratory group demonstrated an improvement ranging from 2.82 % to 18.79 %, while the fascial release group showed a positive change between 3.36 % and 14.83 % (Table III). There was no significant change in pulmonary functions for control group.

A significant main effect of time was observed for the FEV1/FVC ratio ($F = 27.743$, $p < 0.01$, $\eta\rho^2 = 0.507$); however, the time × group interaction effect was not significant ($F = 0.699$, $p = 0.506$, $\eta\rho^2 = 0.049$), indicating that changes over time were not significantly different between the three groups. For FEV1 (%), both a significant main effect of time ($F = 280.791$, $p < 0.01$, $\eta\rho^2 = 0.912$) and a significant time × group interaction effect ($F = 42.130$, $p < 0.01$, $\eta\rho^2 = 0.757$) were found, suggesting that the groups exhibited different patterns of change over time. Similarly, for FVC, a significant main effect of time was observed ($F = 268.193$, $p < 0.01$, $\eta\rho^2 = 0.909$), along with a significant time × group interaction effect ($F = 53.281$, $p < 0.01$, $\eta\rho^2 = 0.798$), indicating that the change in FVC varied across groups. For PEF, both a significant main effect of time ($F = 49.340$, $p < 0.01$, $\eta\rho^2 = 0.646$) and a significant time × group interaction effect ($F = 59.119$, $p < 0.01$, $\eta\rho^2 = 0.814$) were observed, suggesting notable differences in peak expiratory flow changes between the groups over time (Fig. 3).

Table II. Subjects' characteristics.

Variable	CON (n=10)	RE (n=10)	TLF (n=10)
Age (years)	60.1±1.02	58.03±4.5	58.9±2.67
Weight (kg)	79.5±6.61	81.1±1.39	78.0±4.3
Height (m)	1.78±0.04	1.77±0.03	1.74±0.04
Body mass index (kg/m^2)	24.9±3.49	25.9±0.3	25.8±0.76
Onset duration (months)	20.11±2.01	18.1±4.21	21.01±0.01
MMSE	23.01±2.43	24.12±3.03	23.54±2.1
Paretic side (R/L)	7/3	6/4	6/4

CON: control group; RE: respiratory exercise group; TLF: thoracolumbar fascia release group; MMSE: mini mental state examination. †Data are mean ± SD.

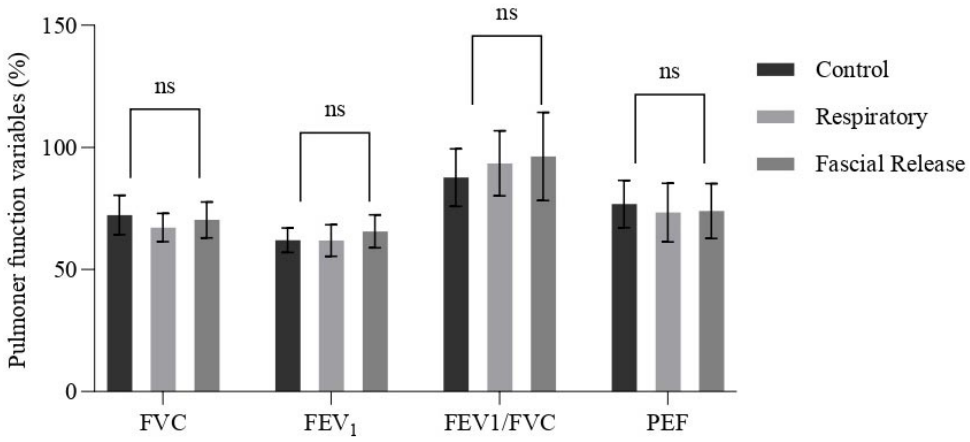


Fig. 2. Comparison of pulmonary function variables before intervention. Data are presented as mean ± 95 % confidence interval. ns = no significant difference.

Table III. Descriptive statistics of the change scores of each test for groups.

Group	Variable	Baseline (Std. Dev.)	Post-treatment (Std. Dev.)	Change Scores		
				Mean	% Change	Effect size
Control (n = 10)	FVC (%)	72.26 (11.29)	73.17 (11.29)	0.92	1.30	0.08-negligible
	FEV_1 (%)	62.01 (7.01)	63.84 (7.21)	1.83	1.45	0.26-small
	FEV_1 / FVC (%)	87.61 (16.52)	89.02 (16.58)	1.40	1.63	0.09-negligible
	PEF (%)	76.79 (13.53)	74.78 (12.89)	-2.01	2.58	0.15-negligible
Respiratory (n = 10)	FVC (%)	67.13 (8.11)	77.51 (9.28)	10.38	15.52**	1.19-large
	FEV_1 (%)	61.85 (9.07)	73.38 (10.39)	11.53	18.79**	1.18-large
	FEV_1 / FVC (%)	93.45 (18.66)	95.64 (16.32)	2.19	2.83*	0.12-negligible
	PEF (%)	73.27 (16.81)	79.39 (16.41)	6.12	8.96**	0.37-small
Fascial release (n = 10)	FVC (%)	70.27 (10.29)	77.88 (10.25)	7.60	11.12**	0.74-moderate
	FEV_1 (%)	65.60 (9.47)	75.10 (9.75)	9.50	14.83**	0.99-moderate
	FEV_1 / FVC (%)	96.25 (25.26)	98.72 (22.77)	2.48	3.36*	0.10-negligible
	PEF (%)	73.90 (15.66)	76.24 (15.20)	2.34	3.39*	0.15-negligible

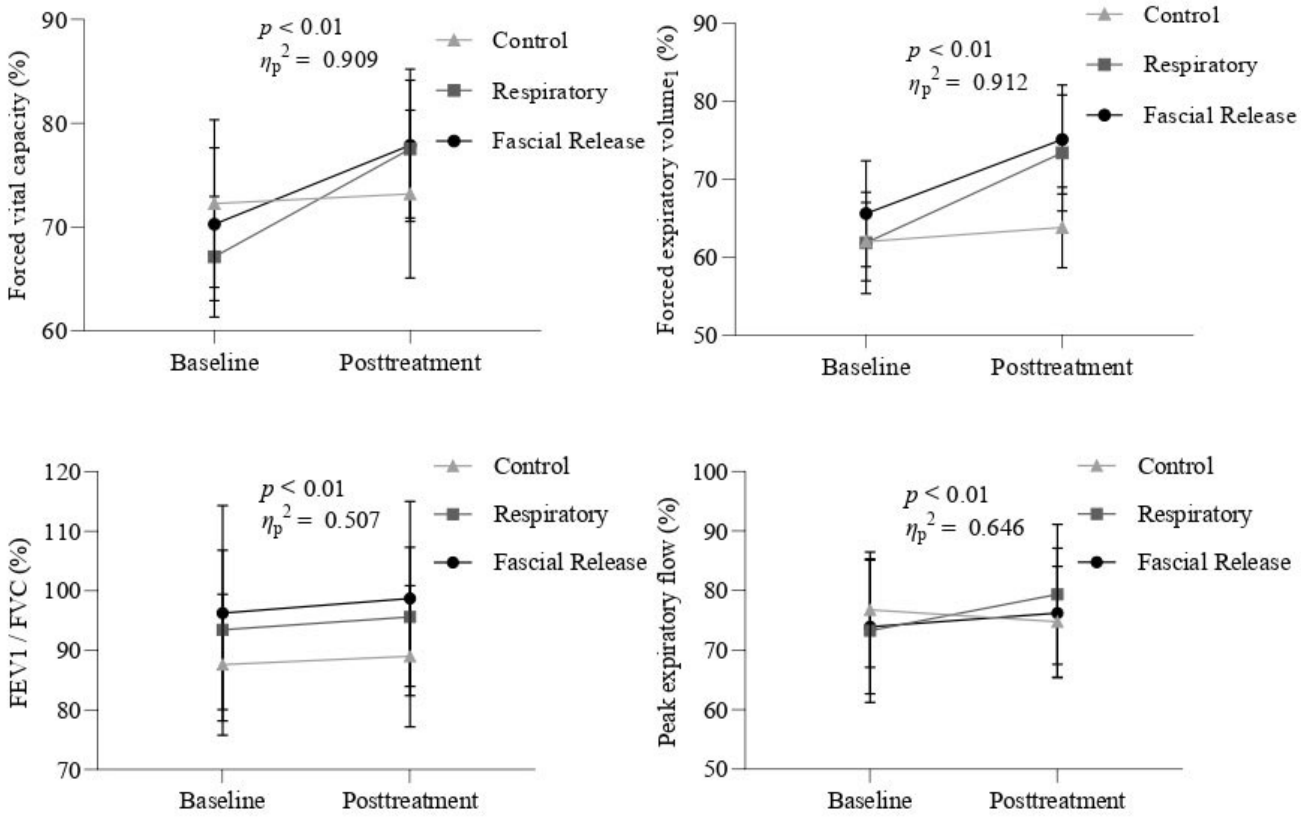


Fig. 3. Time effect on pulmonary function parameters across measurement points. Data are presented as mean ± 95 % confidence interval. $\eta\rho^2$ = the effect size by the time factor.

DISCUSSION

This study was designed to investigate the morphofunctional role of the thoracolumbar fascia in respiratory mechanics by examining the acute functional response to its modulation in stroke patients. The findings demonstrated that both respiratory exercise and thoracolumbar fascia release elicited significant improvements in forced vital capacity, forced expiratory volume in one second, and peak expiratory flow compared to the control group ($p < 0.05$). However, no significant changes were observed in the FEV1/FVC ratio across groups,

suggesting that both interventions primarily influenced lung volumes without altering airway resistance. These results indicate that the observed changes reflect modifications in ventilatory capacity rather than airway mechanics, supporting a potential morphofunctional contribution of the thoracolumbar fascia to respiratory mechanics.

From a morphofunctional perspective, these results support the concept that the thoracolumbar fascia may contribute to respiratory mechanics through its role in force transmission and thoracoabdominal coordination (Domaszewska *et al*., 2019; Perez *et al*., 2023). The thoracolumbar fascia forms an integrated connective tissue network linking the diaphragm, abdominal musculature, and lumbar spine, thereby facilitating mechanical interactions between postural control and respiration (Willard *et al*., 2012). Changes in fascial tension, stiffness, or mobility may influence diaphragmatic excursion and trunk dynamics, ultimately affecting ventilatory function. In this context, the improvements observed following thoracolumbar fascia release may reflect enhanced mechanical efficiency within this integrated system rather than isolated muscular adaptations (Tamartash *et al*., 2022).

While myofascial release techniques have been explored in various musculoskeletal and neurological conditions, there is currently no consensus on their optimal dosage and duration for improving respiratory function (Ratajska *et al*., 2020). Prior studies investigating manual therapy techniques in stroke patients have yielded heterogeneous findings regarding their impact on pulmonary function. For instance, Joo *et al*. (2018) reported significant improvements in FVC and FEV1 following thoracic spinal manipulation in stroke patients, supporting the notion that targeted manual interventions can enhance respiratory mechanics. Similarly, Atıcı *et al*. (2024) found that a single 45-minute session of manual therapy techniques including joint mobilization and myofascial release led to improvements in maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), PEF, and FVC, but not in FEV1 or the FEV1/FVC ratio, suggesting that these interventions primarily influence lung volumes rather than airway resistance (Atıcı *et al*., 2024). However, other studies, such as An *et al*. (2021) and Park (2020) did not observe significant spirometric improvements, highlighting the variability in treatment response.

Importantly, the comparable effects observed between thoracolumbar fascia release and respiratory exercises in the present study suggest that respiratory function may not be solely dependent on isolated muscle performance but also on the integrity of connective tissue organization and biomechanical coupling (Kodama *et al*., 2023). This finding aligns with emerging evidence emphasizing the role of fascia as an active component in the transmission of mechanical forces rather than a passive structural element (Pirri *et al*., 2024). Accordingly, the present results provide indirect functional evidence supporting the contribution of thoracolumbar fascia to respiratory mechanics.

The underlying mechanisms through which thoracolumbar fascia release influences pulmonary function remain a topic of investigation. However, based on current evidence, it is plausible that fascial interventions enhance tissue elasticity, reduce stiffness, and facilitate thoracoabdominal mobility, thereby improving ventilatory efficiency (Perez *et al*., 2023). Additionally, beyond its biomechanical role, thoracolumbar fascia release may exert effects through autonomic nervous system regulation. Manual therapy techniques have been shown to modulate parasympathetic activity, which may contribute to improved respiratory efficiency and airflow dynamics (Borges *et al*., 2018). A systematic review by Bordoni & Escher (2021) further supports the functional interplay between the fascial system and respiratory function, suggesting that fascial release may enhance diaphragmatic efficiency and vagal tone. These findings are consistent with the present results, where both intervention groups demonstrated similar improvements in pulmonary function.

Stroke was selected as a model condition due to its well-documented effects on trunk control, postural stability, and respiratory coordination (Park *et al*., 2017). Alterations in movement patterns and biomechanical integration following stroke may amplify the functional impact of connective tissue structures, making this population particularly suitable for examining structurel function relationships. In this context, stroke provides a suitable model in which structural–functional relationships can be more clearly elucidated.

Our findings further reinforce the effectiveness of respiratory exercise interventions, which are well documented in the literature as an essential component of stroke rehabilitation (Gomes-Neto *et al*., 2016; Seo *et al*., 2017). However, what distinguishes the present study is the interpretation of these functional improvements within a morphofunctional framework. Specifically, the comparable effects between interventions suggest that modulation of fascial structures may represent an alternative pathway for influencing respiratory mechanics, particularly in individuals with limited capacity for active exercise.

The findings of this study have several clinical implications. Firstly, thoracolumbar fascia release may serve as a complementary approach to conventional respiratory

therapy, particularly in patients unable to perform active respiratory exercises due to neurological deficits or fatigue. Secondly, these findings highlight the importance of considering connective tissue structures in the assessment and management of respiratory dysfunction. Future studies should explore the combined effects of fascial interventions and respiratory training to better understand their synergistic potential.

Despite its strengths, this study has several limitations. The absence of direct morphological assessments (e.g., imaging-based evaluation of fascial structure or stiffness) limits the ability to establish causal relationships between structural and functional changes. Additionally, the acute nature of the intervention prevents conclusions regarding long-term adaptations. Although the sample size was statistically powered, larger and more diverse cohorts are needed to improve generalizability. Finally, the lack of a placebo-controlled design limits the ability to distinguish specific treatment effects from non-specific responses.

CONCLUSION

This study provides novel morphofunctional insights into the role of the thoracolumbar fascia in respiratory mechanics in stroke. The findings demonstrate that a single session of thoracolumbar fascia release induces measurable improvements in pulmonary function, comparable to those achieved with respiratory exercise, suggesting that these effects may reflect alterations in thoracoabdominal dynamics rather than isolated muscular adaptations. These results support the concept that the thoracolumbar fascia may function as an active mechanical component within the respiratory system, contributing to force transmission and ventilatory regulation. From this perspective, the observed changes provide functionally supported evidence of the involvement of connective tissue structures in respiratory mechanics. Further research is needed to elucidate the underlying mechanisms, particularly through studies incorporating direct morphological assessments and longitudinal designs to better understand structure–function interactions over time.

CINARLI, S. & AKYOL, B. Papel morfofuncional de la fascia toracolumbar en la mecánica respiratoria: Evidencia de un estudio controlado aleatorizado en pacientes con accidente cerebrovascular. *Int. J. Morphol, 44(4)*:1359-1366, 2026.

RESUMEN: La fascia toracolumbar es una estructura compleja de tejido conectivo que proporciona continuidad anatómica entre la columna lumbar, la pared abdominal, el diafragma y la musculatura respiratoria, contribuyendo a la mecánica respiratoria mediante la movilidad toracoabdominal y la transmisión de fuerzas. Sin embargo, la evidencia funcional que respalda su papel en la función pulmonar sigue siendo limitada. El ataque cerebrovascular (ACV), caracterizado por una mecánica respiratoria deteriorada y una biomecánica del tronco alterada, ofrece un modelo relevante para explorar estas relaciones. El objetivo de este estudio fue investigar el papel morfofuncional de la fascia toracolumbar en la mecánica respiratoria examinando los efectos agudos de su modulación sobre la función pulmonar en pacientes con ACV, utilizando el ejercicio respiratorio como modelo funcional comparativo. Treinta pacientes de sexo masculino con ACV (edad media: 59,01 ± 3,08 años) fueron asignados aleatoriamente a los grupos de control (CON), ejercicio respiratorio (RE) o liberación de la fascia toracolumbar (TLF). Todos los participantes recibieron rehabilitación estándar. El grupo RE realizó ejercicios respiratorios adicionales y el grupo TLF recibió liberación miofascial dirigida a la fascia toracolumbar (15 min). La función pulmonar se evaluó mediante espirometría antes e inmediatamente después de la intervención. Tanto el grupo RE como el TLF mostraron mejoras significativas en los parámetros pulmonares ($p < 0,05$), mientras que no se observaron cambios en el grupo CON. Las mejoras oscilaron entre el 2,82 % y el 18,79 % en el grupo RE, y entre el 3,36 % y el 14,83 % en el grupo TLF. Se encontraron efectos temporales significativos para FEV1/FVC, FEV1, FVC y PEF ($p < 0,01$), con interacciones significativas grupo × tiempo para FEV1, FVC y PEF ($p < 0,01$). La liberación de la fascia toracolumbar indujo mejoras medibles en la función pulmonar comparables a las del ejercicio respiratorio, lo que respalda su relevancia morfofuncional en la mecánica respiratoria. Estos hallazgos sugieren que las estructuras fasciales pueden contribuir activamente a la dinámica toracoabdominal. Se requieren estudios adicionales para esclarecer los mecanismos subyacentes y los efectos a largo plazo.

PALABRAS CLAVE: Fascia toracolumbar; Morfofunción; Mecánica respiratoria; Accidente cerebrovascular; Tejido conectivo.

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