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ARTICLE

Relationship between pulmonary function, functional independence, and trunk control in patients with stroke

Relação entre função pumonar, independência functional e controle de tronco em pacientes após acidente vascular cerebral

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ABSTRACT

Stroke often leads to abnormalities in muscle tone, posture, and motor control that may compromise voluntary motor function, thus affecting the motor control required for maintaining the synergy of both peripheral and respiratory muscles. **Objective:** To evaluate respiratory muscle strength, pulmonary function, trunk control, and functional independence in patients with stroke and to correlate trunk control with the other variables. **Methods:** This was a cross-sectional study of patients diagnosed with stroke. We assessed respiratory muscle strength, trunk control as assessed by the Trunk Impairment Scale, spirometric variables, and the Functional Independence Measure. **Results:** Forty-four patients were included. Pulmonary function and respiratory muscle strength were significantly lower than predicted for the study population, and the mean Trunk Impairment Scale score was 14.3 points. The following significant correlations were found between the variables: trunk control vs. maximal inspiratory pressure ($r = 0.26$, $p < 0.05$); trunk control vs. forced vital capacity ($r = 0.28$, $p < 0.05$); trunk control vs. forced expiratory volume in one second ($r = 0.29$, $p < 0.05$), and trunk control vs. the Functional Independence Measure ($r = 0.77$, $p < 0.05$). **Conclusion:** The present study showed that respiratory muscle strength, pulmonary function, functional independence, and trunk control are reduced in patients diagnosed with stroke.

Keywords: Spirometry; manometry; stroke; Physical therapy specialty.

RESUMO

Acidente vascular cerebral (AVC) frequentemente leva a anormalidades no tônus muscular, postura e controle motor que podem comprometer a função motora voluntária, afetando o controle motor necessário para manter a sinergia dos músculos periféricos e respiratórios. **Objetivo:** Avaliar a força muscular respiratória, a função pulmonar, o controle do tronco e a independência funcional em pacientes com AVC e correlacionar o controle do tronco com as demais variáveis. **Métodos:** Este foi um estudo transversal, incluindo pacientes diagnosticados com AVC. Avaliamos a força muscular respiratória, o controle do tronco avaliado pela escala de comprometimento de tronco, as variáveis espirométricas e a medida de independência funcional. **Resultados:** Quarenta e quatro pacientes foram incluídos. A função pulmonar e a força muscular respiratória foram significativamente menores do que o previsto para a população estudada, e o escore médio do escala de comprometimento de tronco foi de 14,3 pontos. As seguintes correlações significativas foram encontradas entre as variáveis: controle do tronco vs. pressão inspiratória máxima ($r = 0,26$, $p < 0,05$); controle do tronco vs capacidade vital forçada ($r = 0,28$, $p < 0,05$); controle do tronco versus volume expiratório forçado no primeiro segundo ($r = 0,29$, $p < 0,05$) e controle do tronco vs. medida de independência funcional ($r = 0,77$, $p < 0,05$). **Conclusão:** O presente estudo demonstrou que a força muscular respiratória, a função pulmonar, a independência funcional e o controle do tronco estão diminuídos em pacientes diagnosticados com AVC.

Palavra-chave: Espirometria; manovacuometria; acidente vascular cerebral; fisioterapia.

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Stroke is one of the most common causes of long-term disability worldwide and a major public health problem[1]. Each year, nearly 11 million people worldwide have a stroke, of whom five million remain functionally limited[2,3]. According to the World Health Organization, stroke is a rapidly-progressing syndrome characterized by clinical signs of focal or global brain function impairment of possible vascular origin and lasting for at least 24 hours[4]. Nearly 50% to 70% of affected patients recover functional independence and, within six months, nearly 50% still present with hemiparesis/hemiplegia[2].

Stroke often leads to abnormalities in muscle tone, posture, and motor control that may compromise voluntary motor function, thus affecting the motor control required for maintaining the synergy of both peripheral and respiratory muscles[1,5]. Pulmonary infections are the most prevalent complications, causing the death of 30% of patients before hospital discharge[6,7]. Nevertheless, the lack of strength in muscles of the trunk could impact in respiratory function.

The effect of stroke on the respiratory system depends on the injured structures, and maintenance of normal ventilation requires functional components of the neuromuscular system to be intact. Ventilatory disorders occur when the disease affects the nervous system, muscle paths and/or rib cage movements[8,9]. Therefore, we hypothesized that stroke patients present with several sequelae usually leading to deficits in functional capacity and pulmonary function. Hence, the objectives of this study were to assess respiratory muscle strength, pulmonary function, trunk control, and functional independence in patients with stroke, and to correlate trunk control with the other variables.

METHODS

This was a cross-sectional study conducted at the Department of Neurology of Hospital de Clínicas de Porto Alegre from November 2014 to May 2015. The research project was approved by the Research Ethics Committee of Hospital de Clínicas de Porto Alegre (process no. 14-0582). Patients who met the inclusion criteria and agreed to participate in the study provided written informed consent prior to their participation.

This study included male and female patients, over 18 years of age, clinically diagnosed with stroke by the neurology team. Exclusion criteria were an inability to perform study-related procedures, presence of respiratory tract metastases, hemodynamic instability, and altered cognitive status compromising the patient's ability to perform the tests. Patients with pulmonary complications such as bronchoaspiration and pneumonia during hospitalization were not included. After inclusion in the study, all patients were simultaneously assessed for functional independence, trunk control, respiratory muscle strength, and pulmonary function. Data on age, weight, height, body mass index, length of hospital stay, time elapsed after stroke, type of stroke, and number of previous strokes were collected directly from medical records. The patients eligible to participate in the study were evaluated by the clinical team and underwent physiotherapy treatment. All patients were hemodynamically stable, with controlled blood pressure, no syncope, and absence of tumors or clinical diseases that could interfere with the evaluation process.

Physical functioning was assessed using the Functional Independence Measure scale, an instrument designed to quantitatively assess the burden of care required for someone to perform a series of everyday motor and cognitive activities, such as self-care, transfer, locomotion, sphincter control, communication, and social cognition, including memory, social interaction, and problem solving. Each category is given a score from 1 (total dependence) to 7 (complete independence). This yields a total score ranging from 18 to 126[10].

The trunk control was assessed using the Trunk Impairment Scale, an instrument comprising seven main domains scored from 0 (minimum) to 21 (maximum) points. These domains assessed the perception and impairment of trunk verticality, abdominal muscle strength, trunk rotation muscle strength, and righting reflex, all of which were assessed bilaterally. The Trunk Impairment Scale was administered by the same examiner, providing a score that indicated the patient's status at the time of assessment[11].

The respiratory muscle strength was assessed using an analog manometer (Marshall Town, MVM 120, USA) to measure maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP). Measures were assessed with patients in the sitting position using a nose clip and a mouthpiece positioned firmly between their lips. The MIP was acquired at residual volume, and the MEP at total lung capacity. In both cases, measures were taken in triplicate or more, the highest of which was considered for analysis, and differences between measures could not be greater than 10%[2,4,12,13].

For pulmonary function analysis, forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and the Tiffeneau index (TIFF) (FEV1/FVC) were measured through spirometry (One Flow micro spirometer, Clement Clarke International, Edinburgh, Scotland)[14]. Their predicted values were also calculated based on the equation proposed by Derumond et al.[15], to assess levels of pulmonary function in a healthy population. This equation was compared with two other equations in a previous study that found no significantly relevant differences between equations[16].

Sample size was calculated based on a previous study conducted by our group[17], resulting in a sample size of at least 38 patients for an alpha of 5% and a power of 80. Continuous data were expressed as mean ± standard deviation, and categorical variables as absolute and percentage values. The Shapiro-Wilk test was used to assess the normality of data distribution. Pulmonary function and maximal respiratory

pressures were compared using the Student's t test, and the correlation between trunk control and the other variables was assessed using Pearson's correlation. The level of significance was set at 5%.

RESULTS

Fifty-four patients participated in the study from November 2014 to May 2015. There was a predominance of females (65.7%), the mean patient age was 59.4 ± 12.2 years, and ischemic stroke was the most prevalent type (92.1%).

The demographic characteristics of the population are shown in Table 1. Results for pulmonary function, respiratory muscle strength, and trunk control are presented in Table 2, and functional independence as assessed by the Functional Independence Measure is described in Table 3.

We also assessed the correlation of trunk control with pulmonary function, respiratory muscle strength, and functional independence. Trunk control was found to be significantly correlated with MIP ($r = 0.26$, $p < 0.05$), FVC ($r = 0.28$, $p < 0.05$), FEV1 ($r = 0.29$, $p < 0.05$), and the Functional Independence Measure ($r = 0.77$, $p < 0.05$) (Figure).

Table 1. Demographic characteristics of the study population.

Variables	n = 44
Sex, female	25 (65.7)
Age, years	59.4 ± 12.2
Weight, kg	73.9 ± 15.1
Height, m	1.6 ± 0.1
Body Mass Index, kg/m²	27.8 ± 5.3
Length of stay, days	14.6 ± 7.1
Stroke, n (%)	
Ischemic	52 (92.1)
Hemorrhagic	3 (7.9)
Stroke time, days	14.9 ± 26.3

Values expressed as mean ± standard deviation or number (percentage).

Table 2. Evaluation of pulmonary function, respiratory muscular strength and trunk control.

Variable	Value obtained	Predicted value	p-value
FEV1	1.9 ± 0.9	3.3 ± 0.6	
FVC	2.5 ± 0.9	3.8 ± 0.7	
Tiffeneau Index	88.9 ± 12.5		
Expiratory flow peak	227.2 ± 121.3		
MIP, cmH_2O	47.4 ± 29.1	91.1 ± 13.9	0.001
MEP, cmH_2O	36.1 ± 18.6	93.3 ± 18.8	0.001
Trunk Impairment Scale	14.4 ± 5.8		

Data expressed as mean ± standard deviation. FEV1: forced expiratory volume in the first second; FVC: forced vital capacity; Tiffeneau Index - relationship between FEV1/FVC; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure/ cmH_2O: centimeter of water.

DISCUSSION

Trunk control has a primary function in pulmonary mechanics—when diaphragmatic function is compromised in individuals after stroke, it is perceived that muscular paresis leads to unilateral hypoventilation and consequent decrease of pulmonary complacency, with greater elastic and nonelastic resistance of the lung, which fails to maintain lung volumes and decreases ventilation and perfusion capacity. In the present study, most of participants showed restrictive ventilatory disorder (81.6%), characterized by impairment of total lung capacity and vital capacity, demonstrating that respiratory biomechanics is altered in patients with stroke, as well as thoracic and pulmonary compliance. This data corroborates the finding between the Trunk Impairment Scale and spirometric data, confirming the findings in the literature, which demonstrate the relationship between a decrease in pulmonary capacity and hemiparesis presented by individuals, and this may occur because the trunk flexor and extensor muscles directly interfere in respiratory mechanics and trunk stabilization[18,19].

Regarding sociodemographic data and risk factors for cerebrovascular injury, the mean age of our patients was 59.4 years, corresponding to the age group at the highest risk of stroke in Brazil, which includes individuals older than 55 years of age[12]. The incidence of stroke increases the risk, showing a two-fold increase for every 10 years of age beyond 55[7]. Additionally, most patients were classified as overweight according to their body mass index and were female, both of which are important risk factors for stroke[13]. Together with these factors, other modifiable risk factors for cerebrovascular diseases in this population have been reported in the literature, such as high levels of blood cholesterol, high blood pressure, diabetes, and smoking[14,15].

The mean length of hospital stay, for our patients, was 14.6 days, similar to that reported in a study conducted in a

Table 3. Evaluation of functionality through the Functional Independence Measure.

Variables	n = 44
Self Care	29.0 ± 11.4
Sphincter Control	12.2 ± 3.3
Transfers	13.0 ± 7.1
Locomotion	6.4 ± 4.0
Communication	6.4 ± 4.0
Social Cognition	12.1 ± 2.8
Total	91.2 ± 26.4

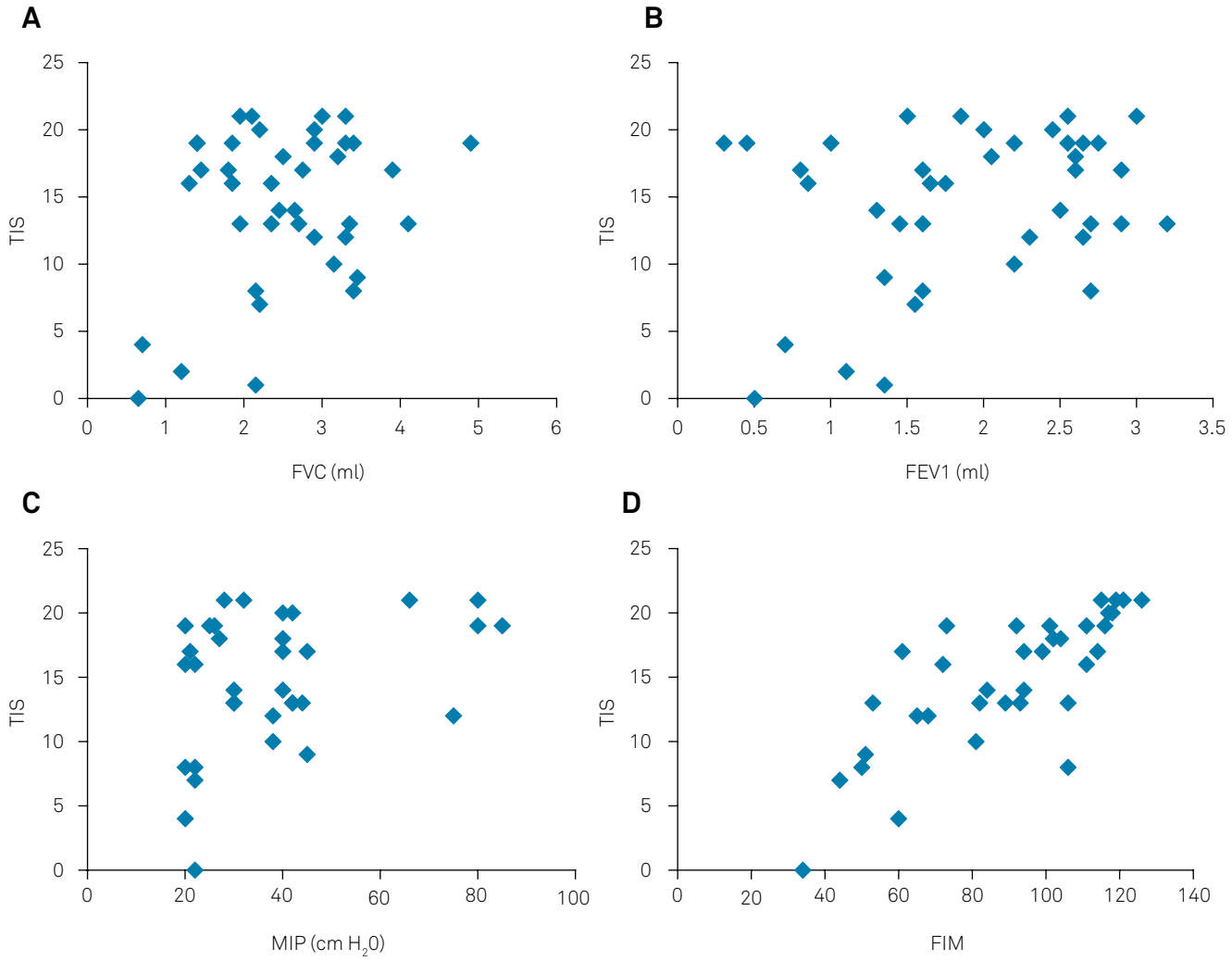

Figure. Correlation between the Trunk Impairment Scale (TIS) and forced vital capacity (FVC) (A - r = 0.28; p < 0.05); forced expiratory volume in the first second (FEV1) (B - r = 0.29, p < 0.05); maximal inspiratory pressure (MIP) (C - r = 0.34, p < 0.05) and the Functional Independence Measure (FIM) (D - r = 0.77, p < 0.05).

neurology ward (16.8 days)[17]. In the present study, 92% of the patients were diagnosed with ischemic stroke. This percentage was higher than that in previous Brazilian studies (53 to 85%)[16,17], which may be related to our treatment regimen for patients with hemorrhagic stroke, who remain in the intensive care unit for a longer time.

The mean MIP and MEP were lower than predicted for our patients, thus corroborating findings from the literature, such as those by Meneghetti et al.[12], who also found mean MIP and MEP lower than predicted for the Brazilian population (62.7 cmH_2O and 69.8 cmH_2O, respectively). These results suggest that the patients showed reduced respiratory muscle strength (diaphragmatic and abdominal dysfunction) and, therefore, their rehabilitation program should include respiratory muscle training[12].

Similarly, pulmonary function measures were lower than predicted for our sample, which is in agreement with previous studies showing that pulmonary function was reduced in stroke patients assessed by spirometry[16,17,20]. Some studies also found that impaired respiratory muscles and pulmonary function may have a direct impact on the cough mechanism, as the compression phase of this mechanism involves the activation of the diaphragm, chest and abdominal wall muscles[21,22].

The mean Trunk Impairment Scale score in our patients (14.3 points) may be considered a fairly good result, considering that this score ranges from 0 to 21 points, with 0 being the worst result and 21 the best. We also observed that trunk control was weakly correlated with the FVC and FEV1 (r = 0.28 and r = 0.29, respectively), which indicated that musculoskeletal changes experienced by hemiplegic or hemiparetic patients affected pulmonary biomechanics[23]. This was especially so if these changes involved the flexor and extensor muscles of the trunk, as they have a key role in chest expansion, diaphragm excursion, and cough efficiency[24,25].

The correlation of trunk control and MIP, although weak (r = 0.34; p < 0.05), provided evidence of the relationship between muscular postures and respiratory muscle

strength[26]. Previous studies evaluating the latter in hemiparetic patients have demonstrated that respiratory muscle strength may compromise trunk control and directly interfere with respiratory biomechanics.

Yoon et al.[22] found reduced spirometric values in stroke patients and a correlation between these values and activities of daily living. This resulted from weakened intercostal muscles and increased chest wall rigidity, which decreased movements of the rib and lowered the distending pressure that expands the lungs, ultimately leading to reduced pulmonary capacity[22]. These changes could be explained by impairments in total pulmonary capacity and vital capacity, indicating that respiratory biomechanics were deficient in these patients, as well as chest and lung compliance[23]. This deficiency eventually limited pulmonary ventilation and confirmed that ventilatory disorders could occur in neurological diseases affecting the neuromuscular path or the rib cage even if there was no specific pulmonary involvement or lesion[7].

The functionality evaluated by the Functional Independence Measure showed that the patients had reduced capacity to perform activities of daily living with complete independence. A systematic review aiming to assess the disease severity and functional capacity using the Functional Independence Measure in stroke patients revealed that, based on the studies included in the review, this condition affected patient's lives by causing limitations and disability, both in acute and chronic phases, often leading to moderate or severe dependence and increasing the complexity of the rehabilitation process[27].

Additionally, we observed an association between trunk control and functional independence, as patients with greater postural control gained the stability required to reproduce functional movements. This was because axial muscles supported anti-gravitational postures and stabilized the body for limb mobilization[28]. A study conducted by Karatas et al.[29] found a correlation of muscle weakness in trunk flexion and extension with locomotion and transfer domains of the Functional Independence Measure, showing the importance of axial stability movements for the development of limb functionality[29].Other studies have observed that trunk control is important for balance, gait, and functional independence as assessed by the Functional Independence Measure[30,31,32].Future studies should prospectively evaluate patients to assess trunk control and functionality and further establish the causal relationship between the variables.

In conclusion, stroke patients showed reduced pulmonary function, respiratory muscle strength, and functional independence, and there was a strong correlation between trunk control and physical functioning.

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