

## Balance and lower limb strength correlate with gait speed in stroke patients: an observational study

### Equilíbrio e força de membros inferiores correlacionam-se com velocidade de marcha em pacientes com AVC: um estudo observacional

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**ABSTRACT | BACKGROUND:** Gait and balance are often compromised after brain injuries such as stroke. **OBJECTIVE:** To correlate the lower limb muscle strength walking speed, and balance in unipedal support on a paretic limb with gait speed in stroke patients. **METHODS:** This study employed a correlational design. Individuals of both genders with a stroke diagnosis were seen at the Neurovascular Outpatient Clinic of the Hospital de Clínicas de Porto Alegre, Brazil, who were able to remain in orthostasis for two minutes without assistance and with walking at home with or without the aid of walking devices. The Sit-to-stand test for 30 seconds (STS 30s) was used to examine muscle strength of lower limbs; the balance was measured using the Unipedal Support Test (UST) and walking speed with 10 Meter Walk Test (10MWT) and used an accelerometer around the waist of the subject. **RESULTS:** A total of 34 subjects were evaluated, 67.6% female and mean age 60.5 ( $\pm$  13.6) years. The average comfortable walking speed was 1.01  $\pm$  0.31 m/s, the average in the STS 30s was 9  $\pm$  2.94 repetitions, and the average support time on the affected lower limb was 4.11  $\pm$  10.43 seconds. In addition, there was a correlation between the values in the 10MWT and the length of stay on the affected side ( $r=0.563$   $p<0.001$ ) and with the number of repetitions in the STS 30s ( $r=0.667$   $p<0.001$ ). **CONCLUSION:** The greater the muscle strength of the lower limbs and the balance in unipedal support on the affected lower limb, the greater the gait speed in stroke patients.

**KEYWORDS:** Stroke. Muscle strength. Gait. Balance. Gait speed.

**RESUMO | INTRODUÇÃO:** A marcha e o equilíbrio são frequentemente comprometidos após lesões cerebrais como o Acidente Vascular Cerebral (AVC). **OBJETIVO:** Correlacionar a força dos membros inferiores e o equilíbrio em apoio unipedal no membro parético com a velocidade de marcha em pacientes com AVC. **MÉTODOS:** Estudo do tipo observacional transversal. Indivíduos de ambos os sexos com diagnóstico de AVC atendidos no Ambulatório de Neurovascular do Hospital de Clínicas de Porto Alegre, que conseguissem permanecer em ortostase por dois minutos sem auxílio e com marcha domiciliar com ou sem auxílio de dispositivos de marcha, foram avaliados quanto a força muscular de Msls, por meio do Teste de Sentar e Levantar em 30 segundos (TSL30s); avaliação do equilíbrio pelo Teste de Apoio Unipedal (AU) e da velocidade da marcha pelo Teste de Caminhada de 10 metros (TC10m) com auxílio de um acelerômetro fixado na região de L5. **RESULTADOS:** Dos trinta e quatro indivíduos avaliados, 67,6% eram do sexo feminino, com média de idade de 60,5 ( $\pm$  13,6) anos. A velocidade de marcha confortável média foi 1,01  $\pm$  0,31 m/s, a média no TSL30s foi 9  $\pm$  2,94 repetições e o tempo médio de apoio no membro inferior acometido foi de 4,11  $\pm$  10,43 segundos. Houve correlação dos valores no TC10m com o tempo de permanência no lado acometido ( $r=0,563$   $p<0,001$ ) e com o número de repetições no TSL30s ( $r=0,667$   $p<0,001$ ). **CONCLUSÃO:** Quanto maior a força muscular dos Msls e o equilíbrio em apoio unipedal sobre o membro inferior acometido, maior a velocidade de marcha nos pacientes com AVC.

**PALAVRAS-CHAVE:** Acidente vascular cerebral. Força muscular. Marcha. Equilíbrio. Velocidade de marcha.

## Introduction

After a stroke, many individuals have chronic consequences impairing motor function. These consequences vary according to the area and extent of the injury. Increased muscle tone (spasticity), tendon reflexes (hyperreflexia), changes in balance, and decreased muscle strength in the affected side (hemiparesis) are the most common. Hemiparesis is the most frequent motor dysfunction in these individuals. This involvement impairs muscle activity and reciprocal inhibition, interfering with the speed of execution of automatic movements, such as the presence of changes in gait speed in patients with stroke.<sup>1</sup> In addition, gait performance and balance are often changed after brain injuries such as stroke.<sup>2</sup>

Gait dysfunction is one of the most serious and disabling sequelae after stroke. It affects about 80% of people with stroke in the first year after the injury. About 30% of these individuals do not fully recover this ability over time.<sup>3,4</sup> The decreased load distribution in the affected lower limb and the delay in balance reactions make the hemiparetic gait asymmetric. In addition, changes in stride length and cadence increase the support time in the nonparetic limb and the double support time. These changes lead to a decrease in gait speed.<sup>5</sup>

The decrease in gait speed is a result of several factors. Poor motor recovery and decreased balance and muscle strength have a negative effect on the individual's level of functional independence.<sup>6</sup> Improving the gait pattern is considered the main goal in the rehabilitation process. The change in gait is closely related to the performance of activities of daily living and quality of life.<sup>7</sup> Muscle strength has an important influence on the ability to walk. Understanding the relationship between these variables is of fundamental importance for developing effective interventions in the rehabilitation of these patients.<sup>3</sup>

Studies relate the gait speed or functional gait capacity with the strength of specific muscle groups through the maximum isometric strength using dynamometry. Other studies relate balance using the Berg Balance Scale or the Romberg Test with gait speed. The correlation between balance, posture, and functional mobility in stroke patients has already been performed. The authors used the Evaluation of the March and Oriented Balance for Performance (POMA), the Postural Assessment Scale after Stroke (PASS), and the Test Timed Up and Go (TUG).<sup>3,7-9</sup>

The relationship between the muscle strength of both lower limbs through a functional test such as the 30-second sit-stand test and the unipedal balance on the affected side in stroke patients with timed gait speed has not been studied. Therefore, this study aims to correlate the strength of the lower limbs and balance in one-legged stance in the paretic limb with the gait speed in stroke patients.

## Methods

Analytical observational, cross-sectional study with a correlational design of a non-probabilistic sample selected by convenience. It was approved by the Committee of Ethics of the Hospital de Clínicas de Porto Alegre (CAAE 67116917.7.3001.5327).

The study was carried out in patients diagnosed with stroke treated at the Neurovascular Outpatient Clinic of the Hospital de Clínicas de Porto Alegre. Inclusion criteria were: a single stroke (ischemic or hemorrhagic); being able to remain in orthostasis for two minutes without assistance, with or without supervision; home gait with or without the aid of walking devices; having cognitive ability to understand the tests. Exclusion criteria were: the presence of other associated neurological diseases, trauma and orthopedic injuries in the lower limbs in the last year, or respiratory pathologies that affect cardiorespiratory fitness.

All participants signed the Informed Consent Form (ICF) before participating in the study. Data collection took place in just one day, from February to July 2017.

Data such as gender, age, stroke type, stroke time, and affected side were collected from medical records. In addition, the participants performed the 30-second Sit and Stand Test (STS30s) to measure lower limb muscle strength. The participant was asked to get up from a sitting position in a chair with a height of between 43cm and 45cm with a backrest, without an armrest, with the trunk erect and feet flat on the floor for 30 seconds. The number of repetitions that the individual gets up completely from a seated position in the maximum established time reflects the strength of lower limbs.<sup>10,11</sup>

The Unipedal Support Test (UST) was performed on the limb lower affected to quantify the balance.<sup>12,13</sup> The subjects kept the foot of the affected lower limb raised approximately 5 cm from the contralateral medial malleolus without making contact between the foot and the malleolus, keeping the arms on the chest. The average of the time of the three attempts was calculated. If the individual was unable to perform single-leg support on the affected side, a score of 0 was given. A brace in the lumbar region (on the L5 vertebra) was used to fix the accelerometer during the 10-meter Walk Test (10MWT) performance, which measures gait speed in a 20-meter-long runner.<sup>14</sup> Data regarding gait parameters such as cadence, stride length, and duration of support on the affected lower limb were acquired using the Lorán Engineering® Accelerometer.

## Statistical analysis

The sample calculation was performed using the G Power 3.1.7 software, using a family of Z tests (Pearson correlation test - dependent). A correlation of 0.53 was assumed, an alpha of 0.05, an effect size of 0.70, and a power of 80%. The minimum estimated sample for the study was 32 individuals.

Gait speed, stride length, cadence, and duration of single-leg stance on the affected lower limb were considered dependent variables. Muscle strength in lower limbs and static balance in UST were considered independent variables. The sample characterization data on gender, type of stroke, the side affected were presented as a simple frequency. Age, time of stroke and hospital stay, 10MWT, UST, and STS30s values were presented as mean and standard deviation. Pearson's correlation coefficient was used to verify the correlation between variables with normal distribution. All data were processed in the IBM SPSS 19 software, accepting a significance level of 5% ( $p \leq 0.05$ ).

## Results

A total of 34 subjects of both sexes with a history of only one stroke were included. The characteristics of the sample are described in Table 1.

**Table 1.** Sample characteristics

Variables	n/Average	Standard Deviation
Gender (Female/Male)	23 (67,6%) /11(27,4%)	
Age (years)	60,5	±13,6
Stroke (Ischemic/Hemorrhagic)	29 (85,2%) /5(13,8%)	
Time of Stroke (days)	71,5	±375,9
Side affected (Right/Left)	20 (58,8%) /14(41,2%)	
Thrombolysis (%)	9 (26,4%)	
Length of hospital stay (days)	10	±7,2
Muscle strength STS30s(repetitions)	9	± 2,94
Balance in UST (seconds)	4,11	± 10,43
Gait speed (m/s)	1,01	± 0,31

STS30s - Sit to Stand Test 30 seconds; UST - Unipedal Support Test

It was observed that the evaluated subjects had a decreased comfortable gait speed, considering the mean of the 10MWT and the normative values of gender and age. According to the mean number of repetitions of patients in the STS30s, it was found that the strength of the lower limbs was reduced. The average length of stay in a one-legged stance on the affected lower limb showed that the balance was altered. Individuals were not able to stay the 30 seconds, the maximum time established by the test. The correlations between these variables are described in Table 2.

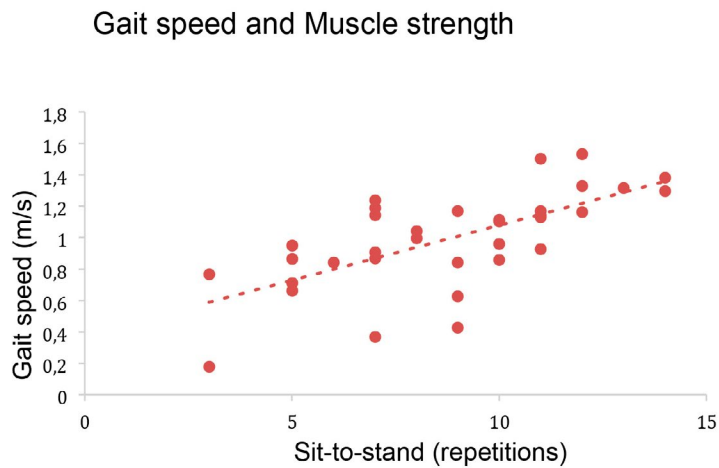
**Table 2.** Correlation of variables: lower limb muscle strength and balance with gait speed

Variables correlated with gait speed	Measures	Pearson's correlation Test	
		r	p
Muscle strength	STS30s	,667	,000
Static balance on the affected side	UST	,563	,001

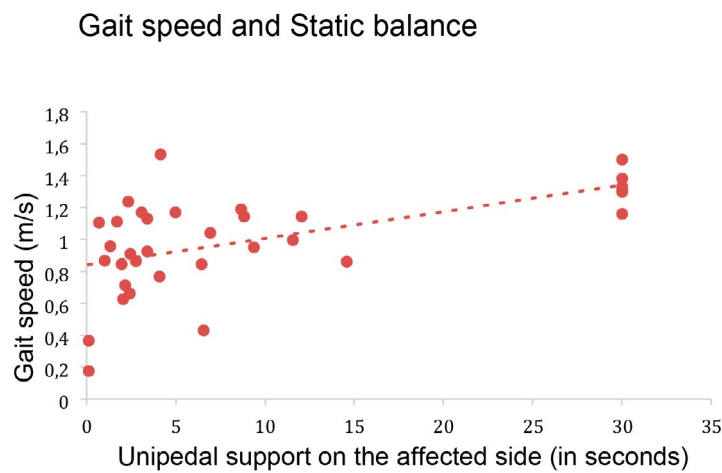
STS30s: Sit-to-stand Test 30 seconds; UST: Unipedal Support Test. Data expressed in correlation coefficient (r) and significance level (p-value) (n=34).

When the values obtained in the TSL30s correlate with those of the 10MWT, we can observe a moderate positive correlation between these variables. This result indicates that the greater the number of repetitions of sitting and standing performed by the patients, the greater the speed with which the patients walked comfortably (Graph 1). Furthermore, the length of stay only on the affected lower limb (AU) correlated with the 10MWT values showed a moderate positive correlation. The patient walked with greater speed when the time spent on a one-legged stance on the affected lower limb was longer (Graph 2).

**Graph 1.** Pearson's correlation between the variables muscle strength of lower limbs and comfortable gait speed



**Graph 2.** Pearson's correlation between the variables static balance in unipedal support and comfortable gait speed



## Discussion

The present study measured muscle strength more functionally, and static balance was assessed only in the affected lower limb. Nevertheless, the data obtained suggest that the greater the muscle strength in the lower limbs and the greater the balance on the

After stroke injury, approximately 22% of survivors are unable to walk without some gait device. Of these, 26% become dependent on ADLs.<sup>15</sup> The gait in stroke patients is characterized by being of low speed and having asymmetries. The time in the stance phase is longer and shorter in the swing phase, resulting in a shorter stride length. The spontaneous gait of healthy individuals has an average speed of 1.0 to 1.5 meters per second (m/s). The hemiparetic gait has an average between 0.45 and 0.75 m/s<sup>16</sup>, characterizing a significant decrease.<sup>17</sup>

In our study, the average comfortable gait speed of the subjects was lower than expected for individuals of this average age. The average speed would be 1.15 m/s for women and 1.27 for men.<sup>18</sup> Maintaining normal gait speed is important for the proper performance of ADLs independently. It makes these patients more socially active<sup>16</sup> and, consequently, increases their quality of life.<sup>17</sup> Patients evaluated after the stroke showed a tendency towards a decrease in gait speed. In this study, we did not use an independence measure to verify the interference of gait speed with the ability to perform activities independently. That is a possible limitation of the study. In addition, patients who had a faster gait speed spent more time supporting the affected lower limb. Lewek et al.<sup>19</sup> mention that these patients have a lower swing phase in the unaffected lower limb because the affected lower limb is not able to transfer and support body weight during its stance phase. Therefore, it can be inferred that patients after stroke tend to take more steps. This is due to the difficulty in keeping the affected lower limb in unipedal support during gait due to deficits in balance and muscle strength in the lower limbs, anticipating the support phase of the unaffected lower limb.

Taylor-Piliae et al.<sup>20</sup> studied the interference of several variables in the proper execution of the gait. These authors found that the decrease in muscle strength of the lower limbs is the biggest contributor to the decrease in gait speed. The study by Antunes et al.<sup>7</sup> found that, for an efficient gait, balance control is also necessary, as voluntary muscle activity causes a redistribution of internal strength and changes the center of mass, causing body instability. In addition to these, an aspect that was not evaluated in our study and that may have interfered in the results of both the TSL30s and the 10MWT is the sensory deficit. This present deficit can influence the patient's ability to perform the sit and stand the test and unilateral support test.

The mean measured in the STS30s showed a decrease in lower limb muscle strength. At this average age, the subject is expected to sit and stand up 14 times if he is a woman and 16 times if he is a man.<sup>10</sup> Corroborating these numbers, a study by Dorsch, Ada, Canning<sup>8</sup> measured lower limb muscle strength in stroke patients and compared it with age- and sex-matched control measures. The authors found that the strength of the paretic lower limb was equivalent to 48% of the control group, and that of the healthy lower limb was equivalent to 66% of the control group.

They refer that this difference in muscle strength in both lower limbs and not only in the paretic is due to the musculature disuse due to the decrease in the performance of their activities after the injury.

A systematic review<sup>21</sup> analyzed 21 studies that correlated lower limb muscle strength with gait speed in stroke patients. All studies showed a moderate to strong positive correlation between the variables. However, the studies used in the review evaluated the muscle strength of isolated muscle groups. In our study, we chose to use the STS30s to measure lower limb muscle strength, because it is a test that is easy to replicate in clinical practice. Furthermore, it can be used as an exercise in the rehabilitation of this population, which is one of the differentials of the study, the fact that it used clinical measures to verify the variables studied. The activity of sitting and standing can be challenging for stroke patients, as the difficulty in distributing body weight on both lower limbs can make this activity poorly performed.<sup>22</sup> This factor may explain the reduced number of repetitions performed during the test, characterizing the decrease in muscle strength, which would also justify the difficulty in performing it.

Another review<sup>23</sup> of 29 articles that evaluated the activity of sitting and standing in stroke patients showed that these patients take longer to perform this task. They tend to compensate for the lack of muscle strength in the lower limbs with trunk movements. Therefore, the gain in muscle strength of the lower limbs becomes essential in the rehabilitation process, to ensure the functionality and independence of these patients.

The gait speed considered adequate also depends on the muscle strength of the lower limbs, which can be confirmed by the moderate positive correlation found in this study. Carvalho et al.<sup>24</sup> analyzed muscle strength and gait speed in stroke patients and compared them with healthy patients. They observed that the subjects with stroke walked only 77% of the predicted for the healthy group. The muscle strength of the affected lower limb, when compared, was equivalent to 61% of the strength of the lower limb of a healthy subject. When correlating the two variables, they found that those with less muscle strength walked with less speed. These authors confirm the correlation found in this study that the greater the muscle strength of the lower limbs, the greater the gait speed of patients with stroke.



In static balance, an individual should be able to remain 30 seconds in a one-legged stance.<sup>12</sup> The mean time reached by the patients analyzed in unipedal support on the affected side characterizes them with an alteration in static balance. Balance is important for performing functional activities such as walking, sitting, and standing. Therefore, balance impairment impairs the performance of these patients in their daily life activities.<sup>25</sup> Our study used the UST to measure static balance, but even though gait is a dynamic activity, a positive correlation was found with balance in unipedal support. The difficulty can explain that the stroke patient must carry out the transfer and weight support to the affected side. Consequently, it impairs the support phase in gait, with a consequent reduction in stride length and, therefore, a decrease in gait speed.

A high standard deviation in stroke time was observed. This finding is due to the non-definition in the inclusion criteria of a maximum duration of involvement, as subjects with the duration of injury ranging from months to years were evaluated, making the sample less homogeneous. Even so, the findings of this study were relevant. Failure to standardize the position of the feet during the performance of the TSL30s may have led the patient to choose to stand with the lower limb not affected at the back, which may influence the performance of the test, being a limitation of the study.

In addition, the change in support on the affected side and the changes in gait may be related to sensory aspects and muscle tone, requiring that the patients selected for the sample had been previously evaluated and characterized for sensitivity and tonicity in lower limbs. A more homogeneous sample regarding the post-stroke phase the patients were in perhaps would allow the patients to present more homogeneous characteristics. These limitations do not allow us to extrapolate some of the results of this study to the general population affected by stroke.

The recovery of walking ability is one of the main goals of physical therapy in rehabilitation after a stroke and can be accompanied by gait speed measurement.<sup>26</sup> Therefore, understanding how the deficit in muscle strength and other components relate to gait can be useful for physical therapists in assessing and planning their interventions.<sup>24</sup> When analyzing the correlations found between the studied variables, it is suggested that the increase in gait

speed in hemiparetic patients after a stroke may be a treatment objective to be achieved by improving unipedal support on the affected side and lower limb muscle strength.

## Conclusion

The present study showed that stroke patients have decreased lower limb muscle strength, static balance, and gait speed. A positive correlation was established between lower limb muscle strength and static balance in the affected lower limb with gait speed. Patients with less muscle strength in the lower limbs and a change in static balance decreased gait speed.

## Authors' contributions

Rodrigues LP, Camerin CER participated in the conception, design, investigation, statistical analysis of data, interpretation of results and writing of manuscript. Bittencourt RD participated in the investigation, analysis of data and interpretation of results.

## Competing interests

No financial, legal, or political conflicts involving third parties (government, corporations, and private foundations, etc.) have been declared for any aspect of the submitted work (including, but not limited to grants and funding, advisory board participation, study design, preparation of manuscript, statistical analysis, etc.).

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