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Assessment of motor function in individuals with hemiplegia post-stroke

Avaliação da função motora em hemiplégicos pós-acidente vascular encefálico

Evaluación de la función motriz en hemipléjicos posaccidente cerebrovascular

Gabriela dos Santos de Souza[1], Carla Emilia Rossato[2], Carlos Bolli Mota[3], Aron Ferreira da Silveira[4]

ABSTRACT | This study aims to compare the performance of the sit-to-stand test and walking speed in individuals with chronic hemiplegia post-stroke and a control group (CG). Moreover, we will investigate whether lower limb resistance, measured based on the sit-to-stand test, is related to walking speed in individuals with chronic hemiplegia and a CG. Finally, we will verify if there are intra-group differences for the tests by dividing the hemiplegia group (HG) according to motor and sensorimotor function assessment classification. A cross-sectional design was used among a group with chronic hemiplegia (n=28) and a healthy CG (n=22). The HG was classified by the Fugl-Meyer scale, and both groups were evaluated using the 1-minute sit-to-stand test. The walking speed was calculated using a 3D kinematics system. Lower limb resistance among HG differed significantly from the CG, as well as walking speed. We found a strong correlation between the tests (ρ=0.773; p<0.001). No differences were found for the sit-to-stand tests and walking speed when dividing the HG into individuals with greater or lesser motor and sensory impairment, using the Fugl-Meyer scale. Therefore, individuals with hemiplegia, regardless of having a more pronounced classification of motor and sensory impairment on the Fugl-Meyer scale, showed lower limb resistance and lower walking speed compared with individuals without hemiplegia post-stroke.

Keywords | Hemiplegia; Gait; Muscle Weakness; Functional Tests.

RESUMO | O objetivo deste estudo é comparar os desempenhos no teste de sentar e levantar e a velocidade de caminhada de indivíduos com hemiplegia crônica decorrente de acidente vascular encefálico (AVE) e um grupo-controle (GC). Além disso, será investigado se existe associação entre a resistência de membros inferiores, mensurada a partir do teste de sentar e levantar, e a velocidade de caminhada em indivíduos com hemiplegia crônica e um GC. Por fim, será verificado se existem diferenças intragrupo para os testes ao dividir o grupo hemiplegia (GH) de acordo com a classificação de avaliação do comprometimento motor e sensorial. O método utilizado foi o delineamento transversal entre um grupo com hemiplegia crônica (n=28) e um GC sem nenhuma patologia (n=22). O GH foi classificado a partir da escala de Fugl-Meyer, e ambos os grupos foram avaliados por meio do teste de sentar e levantar de um minuto. A velocidade de caminhada foi calculada a partir de um sistema de cinemetria tridimensional. Entre os resultados obtidos, foi percebido que a resistência de membros inferiores do GH diferiu significativamente do GC, assim como a velocidade de caminhada. Foi demonstrada uma correlação forte entre os testes (ρ=0,773; p<0,001). Não foram encontradas diferenças nos testes de sentar e levantar e velocidade de caminhada ao dividir o GH em indivíduos com maior ou menor comprometimento motor e sensorial, com a escala de Fugl-Meyer. Portanto, indivíduos com hemiplegia, independentemente de ter uma classificação

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de comprometimento motor e sensorial mais acentuada na escala de Fugl-Meyer, apresentaram menor resistência de membros inferiores e menor velocidade de caminhada comparados com indivíduos sem hemiplegia pós-AVE.
Descritores | Hemiplegia; Marcha; Fraqueza Muscular; Testes Funcionais.

RESUMEN | El objetivo de este estudio es comparar el desempeño del test de levantarse y sentarse y la velocidad de marcha en individuos con hemiplejía crónica debido a accidente cerebrovascular (ACV) y un grupo control (GC). Además, se investigará si existe asociación entre la resistencia de los miembros inferiores, medida desde el test de levantarse y sentarse, y la velocidad de marcha en individuos con hemiplejía crónica y un GC. Por último, se verificará si existen diferencias intragrupales en las pruebas al dividir el grupo hemiplejía (GH) según la clasificación de evaluación de deterioro motor y sensorial. El método utilizado fue el transversal en un grupo con hemiplejía crónica (n=28) y un GC sin ninguna patología (n=22). El GH se clasificó mediante la escala de Fugl-Meyer, y ambos grupos se evaluaron mediante el test de levantarse y sentarse de un minuto. La velocidad de marcha se calculó mediante el sistema cinemático tridimensional. Entre los resultados obtenidos, se observó que la resistencia de los miembros inferiores entre GH difería significativamente del GC, así como la velocidad de marcha. Se demostró una fuerte correlación entre las pruebas (ρ=0,773; p<0,001). No se encontraron diferencias en las pruebas de levantarse y sentarse y la velocidad de la marcha al dividir el GH en individuos con mayor o menor deterioro motor y sensorial, utilizando la escala de Fugl-Meyer. Por lo tanto, las personas con hemiplejía, independientemente de tener un mayor deterioro motor y sensorial según la escala de Fugl-Meyer, tuvieron una menor resistencia de las extremidades inferiores y una menor velocidad de marcha en comparación con las personas sin hemiplejía pos-ACV.
Palabras clave | Hemiplejía; Marcha; Debilidad Muscular; Pruebas Funcionales.

INTRODUCTION

Cardiovascular diseases are a group of disorders of the circulatory system and heart that may manifest in adulthood and old age[1]. Stroke is the second leading cause of death[2] and the third cause of disability in adults[3]. Among the various sequelae caused by stroke, the loss of motor function and physical mobility on one side of the body, called hemiplegia, can be highlighted[4]. The sequelae commonly found in individuals with hemiplegia are muscle weakness of knee extensors and ankle dorsiflexors[5]. Consequently, two thirds of these patients have some limitation in walking. The kinematic characteristics observed include reduction of hip flexion, greater knee flexion and plantar flexion of the ankle in the initial contact phase, while hip flexion increases, lower knee flexion, and lower plantar flexion of the ankle at the time of final contact[6,7]. These limitations change motor function and impact individuals' activities of daily living.

Among the several methods to evaluate the motor function of post-stroke hemiplegic patients, we highlight the Fugl-Meyer Assessment, which measures motor function, balance, sensory aspects, and joint function. This assessment stands out for being one of the most reliable and widely used in this population[8,9]. Notably, walking speed and distance tests can also be used to assess motor function, since this actions are complex functional activities and rely on many processes. Moreover, these are predictors of functional mobility, level of independence, and quality of life in this population[10,11].

A simple and low cost test, the 1-Minute Sit-to-Stand Test is another test widely used for assessing motor function[12]. The number of repetitions in the sit-to-stand test is related to the strength of the lower limbs, physical function, and aerobic capacity[13,14]. One of the common motor difficulties post-stroke is the ability to stand from the sitting position, an essential task for the maintenance of physical independence[15].

Studies reported[4-7] that stroke causes changes that result in sequelae related to motor function, which can lead to alterations in walking and activities of daily living (ADLs), such as the sit-to-stand task. In this way, the use of tests for motor assessment of individuals with hemiplegia post-stroke is justified. Assessing and comparing individuals with hemiplegia post-stroke with healthy individuals using different predictor tests of mobility and functional independence can be a good strategy to improve the understanding of functional performance deficits in this population, contributing to clinicians in their assessment and rehabilitation process. Therefore, this study aimed (1) to compare the performance of the sit-to-stand test and the walking speed in individuals with chronic hemiplegia post-stroke and a control group (CG); (2) to investigate whether there is an association between lower limbs resistance, measured from the sit-to-stand test and walking speed in individuals with chronic hemiplegia post-stroke and a CG; and (3) to verify whether there are intragroup differences for the sit-to-stand test and walking speed when dividing the hemiplegia group (HG) according to the assessment classification of motor and sensory impairment (Fugl-Meyer scale).

METHODOLOGY

Study design and population

This is a cross-sectional study, with a target population of individuals with hemiplegia post-stroke and individuals without any pathology that compromises walking, who comprised the GC. Figure 1 summarizes our experimental design.

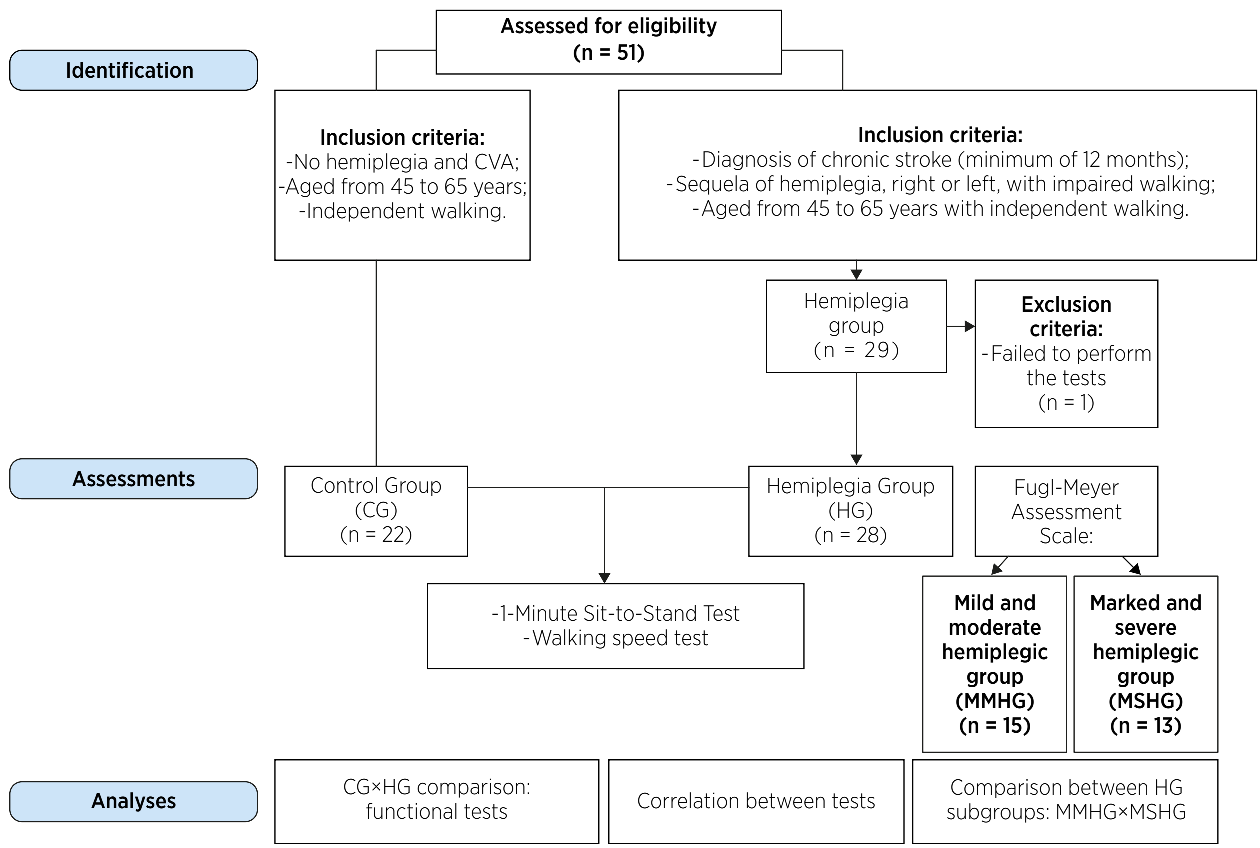

Figure 1. Experimental study design

CVA: cerebrovascular accident.

Criteria of selection and location

In total, 50 individuals were recruited via convenience sampling and divided into HG and CG. The HG had 28 individuals with sequelae of hemiplegia, right or left, post-stroke that compromised walking; diagnosis of chronic stroke of at least 12 months; aged from 45 to 65 years; and that had independent walking. Those who had unstable or severe clinical conditions; musculoskeletal problems before stroke, or that did not result from stroke; and who could not perform the proposed tests were excluded. The CG had 22 individuals without hemiplegia nor stroke, same age range, and with independent walking, who were then paired according to sex, body mass, and height of HG.

Data collection and analysis

1-Minute Sit-to-Stand Test

Firstly, the participant was instructed to remain seated with knee and ankle at 90°, feet fully supported on the ground, and arms crossed over the chest. The height of the seat was individually adjusted with supports of 1 and 2cm, according to the height of the participant's leg (measured from the popliteal line to the ground).

Participants received the following instruction: "When you hear 'get up', the test will begin and one minute will be timed, then you will stand up and sit as many times as you can in a minute." The score assigned corresponds to the number of complete "get up and sit" actions performed in one minute.

Walking speed

The 3D motion analysis system Vicon (model 624, Oxford, United Kingdom) and the NEXUS 1.8.5 program were used to measure walking speed. The system used was composed of six infrared cameras (MX model) and operated at a 200Hz acquisition frequency. The positioning of the markers followed the Plug-in Gait model, which was used to estimate the speed of the four markers in the pelvis (LASI, LPSI, RASI, RPSI). A midpoint was calculated between these markers, and its speed was used to consider the individuals' average walking speed. The kinematics data were filtered by a zero-lag fourth-order low-pass Butterworth filter with a 6Hz cutoff. The average speed in meters per second (m/s) was normalized by the size of the lower limb of each participant.

Fugl-Meyer Assessment Scale

The Fugl-Meyer scale, used to measure motor and sensory impairment of post-stroke individuals, presents a total score of 226 points, in which six aspects are analyzed. In this study, only the motor function aspect was evaluated, including measurement of movement, coordination, and reflex activity. For the normal motor function aspect, the scale presents a total of 100 points, with a maximum score of 34 points for lower limbs and 66 for upper limbs. The score was used according to the level of motor impairment: 50 points indicates a severe motor impairment (small or no voluntary movement of the limbs); 50 to 84 points, marked impairment; 85 to 95, moderate (specifically the function of the hand that may be compromised); and 96 to 99, mild motor impairment[8].

Statistical analysis

Data analysis included descriptive statistics for the characterization of groups expressed as mean and standard deviation. Data normality was verified by the Shapiro-Wilk test and the homogeneity of variances by the Levene test. To compare groups, the two-tailed independent t-test was used. For effect size (ES) Cohen's *d* was used for homogeneous variances and Glass delta (Δ) for heterogeneous variances. Classified as magnitude (0.01)=very small, d (0.2)=small, d (0.5)=medium, d (0.8)=large, d (1.2)=very large, and d (2.0)=huge[16]. To verify a possible correlation between the sit-to-stand test and walking speed, Spearman's rank correlation coefficient (ρ) was performed[17]. All tests were applied considering a 0.05 significance level. The data were processed in the R programming language.

RESULTS

In total, 28 individuals with hemiplegia (14 women and 14 men) were recruited for HG. The CG had 22 individuals (14 women and 8 men) paired for age, gender, and body mass variables. Table 1 shows the characteristics of the individuals.

Table 1. Anthropometric characteristics of participants

	HG	CG
Gender (men)	50%	36%
Age (years)	56.2±6.6	53.8±5.9
Body mass (kg)	77.9±12.8	74.2±13.2
Height (m)	1.63±0.1	1.60±0.1
Stroke time (years)	6.43±4.68	-

Data presented in mean±standard deviation (SD). CG: control group; HG: hemiplegia group; kg: kilograms; m: meters.

There is an effect of the group on the number of repetitions in the sit-to-stand test ($p<0.001$) [ES (d): 1.77; 95% CI 1.11–2.43]. Thus, the resistance of lower limbs was lower in HG, presenting a mean of 15.07±5.72 repetitions per minute, while in the CG about 25.14±5.62 repetitions were performed (Figure 2). Furthermore, HG presented lower walking speed 0.21±0.09m/s than CG, which had higher speed around 0.38±0.04m/s (Figure 2). There was also an effect of the group ($p<0.001$) [ES (Δ): 1.96; 95% CI 1.29–2.61], showing that the CG presented a mean walking speed higher than HG.

We also found a positive and moderate association[17] between lower limbs resistance and walking speed [Spearman rho (ρ)=0.773; $p<0.001$] (Figure 3).

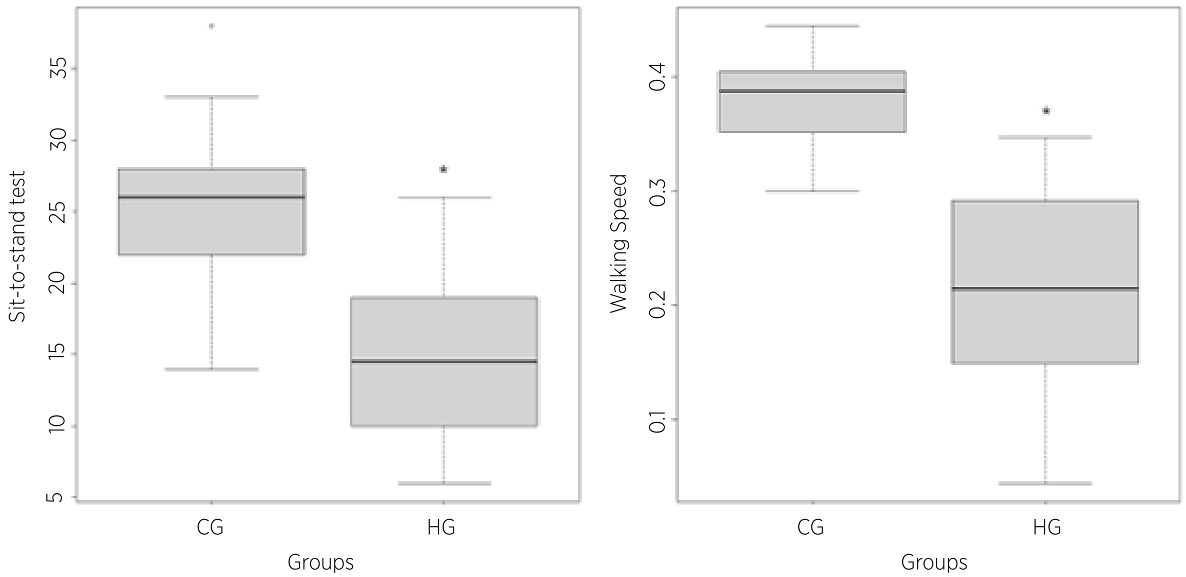

Figure 2. Mean values observed in the evaluations of the control group and hemiplegia group in the sit-to-stand test and walking speed

Statistically significant differences were found for the differences between the groups in both tests. *p<0.001.

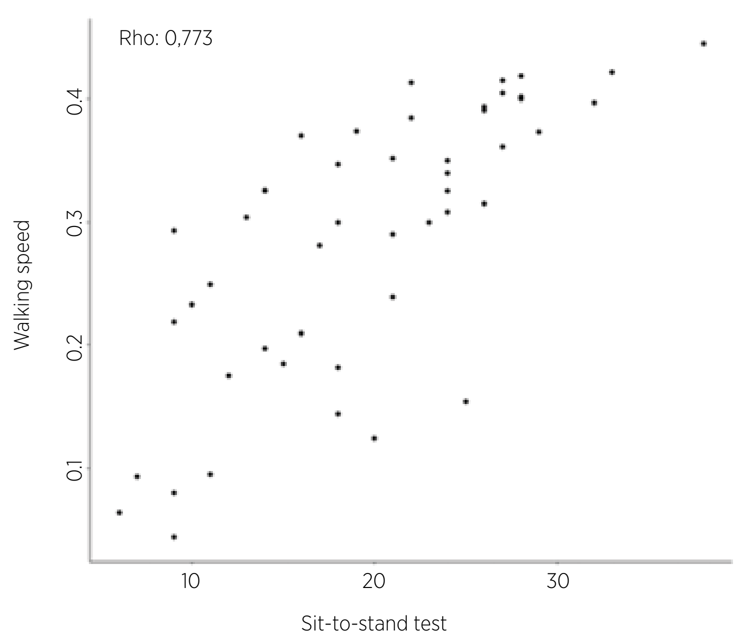

Figure 3. Correlation between walking speed and lower limbs resistance

$\rho=0.773$; $p<0.001$.

By analyzing the HG with the functional performance scores using the Fugl-Meyer scale, 25% of the participants had a mild motor impairment, 28% a marked impairment, 28% moderate impairment, and 18% of the sample presented severe motor impairment. Figure 4 shows mean performance values in the tests when dividing HG, according to the classification of the Fugl-Meyer scale, into two groups: mild and moderate hemiplegic group (MMHG) (n=15) and marked and severe hemiplegic group (MSHG) (n=13). In the sit-to-stand test, MMHG presented 16.93±5.79 mean repetitions and MSHG 12.92±5.01 mean repetitions. For walking speed, MMHG presented a mean value of 0.23±0.08m/s and MSHG 0.19±0.09m/s. There was no effect of the group on the sit-to-stand test (p=0.062) or on walking speed (p=0.2404).

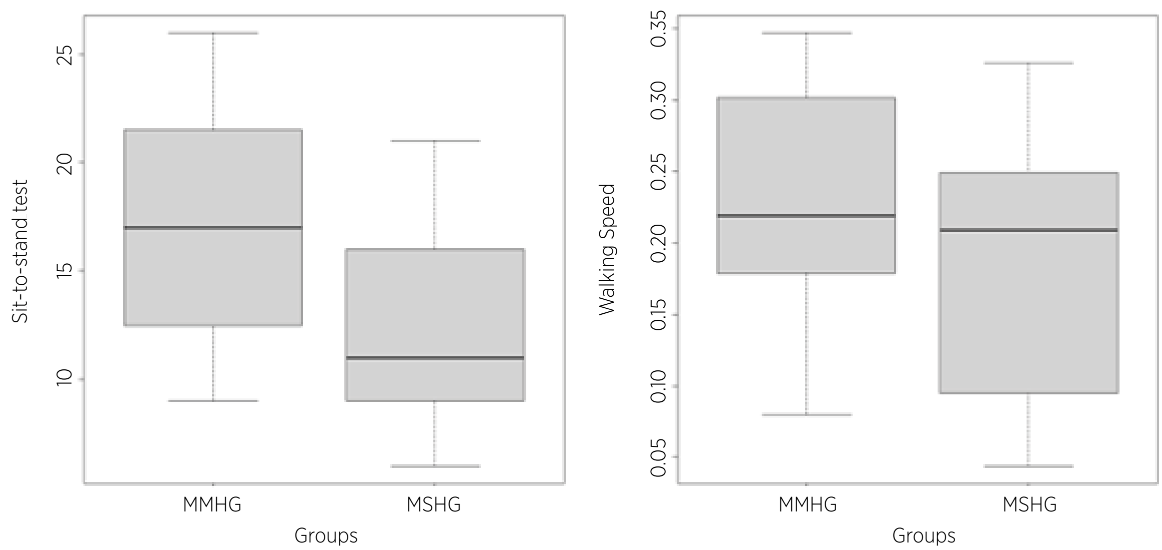

Figure 4. Mean HG values observed in the evaluations, according to the classification of the Fugl-Meyer scale, in the sit-to-stand test and walking speed

MMHG: mild and moderate hemiplegic group; MSHG: marked and severe hemiplegic group

By separating the HG according to the Fugl-Meyer scale, we also verified that the difference between groups was maintained when analyzing only the MMHG versus the CG. Thus, MMHG presented lower functional performance in the sit-to-stand test ($p<0.000$) [ES (d): 1.44; 95% CI 0.70–2.17] and in walking speed ($p<0.000$) [ES (Δ): 1.93; 95% CI: 1.02–2.80]. Figure 5 shows the mean performance values in the MMHG and CG tests.

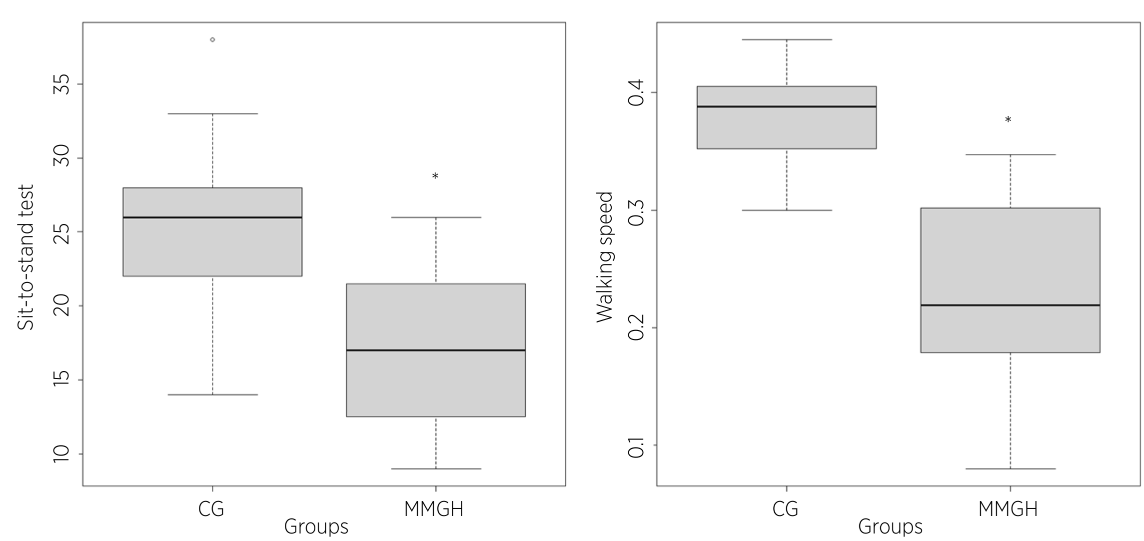

Figure 5. Mean values observed in the evaluations of the control group and hemiplegia group in the sit-to-stand test and walking speed

We found statistically significant differences when comparing the groups in both tests. *$p<0.000$.

DISCUSSION

Individuals with hemiplegia post-stroke presented lower resistance of the lower limbs in the sit-to-stand test (40.06%), compared with the control group paired by gender, body mass, and height. Similarly, HG had 44.76% lower walking speed when compared to CG. Furthermore, the sit-to-stand test was strongly related to the walking speed test, suggesting that the former may present a satisfactory concurrent validity. By classifying and dividing the HG into subgroups, according to the Fugl-Meyer scale, in mild/moderate and marked/severe, we found no difference in the performance of the sit-to-stand test and walking speed for individuals with greater motor and sensory impairment post-stroke. In the sit-to-stand test, the MSHG presented 23.69% fewer repetitions than the MMHG. Regarding walking speed, the MSHG was 17.4% slower than the MMHG. By comparing only the MMHG with the CG, we observed the maintenance of the differences between the groups, demonstrating the lowest functional performance in both tests.

The decrease in resistance, especially of the lower limbs, in individuals with chronic hemiplegia may be due to muscle weakness, especially in the dorsiflexor muscles of the ankle, which predicts walking speed reflected in tests of walking speed and distance[10]. Muscle weakness[18] of the lower limbs can be explained by the decrease in the average time of onset of muscle activity and failure to recruit motor units[19], preventing a better performance in tasks such as sitting and standing up when compared to healthy individuals[20]. A systematic review[21] reported that lower limbs of individuals post-stroke presented muscle weakness compared to healthy individuals paired by age. Moreover, the study showed that, as individuals post-stroke age, the muscle function of the limbs continues to decrease more rapidly than in individuals without stroke. Thus, interventions that increase and maintain muscle function in this population are essential.

This study demonstrated that individuals with hemiplegia post-stroke have lower muscle resistance and reduced walking speed. In this way, rehabilitation programs should aim to recover and improve the locomotor capacity of these patients. Interventions focused on strength gain are essential for individuals with hemiplegia sequelae. Cardoso et al.[22] demonstrated that, with a resistance training program, it is possible to increase muscle strength, improve dynamic balance, and decrease the time of a walking test and a sit-to-stand test, contributing to the daily activities of these individuals. Patients with chronic hemiplegia present a higher risk for the occurrence of falls, resulting from the decrease of sensory information and strength of the affected hemibody, generating intense postural instability[23]. Harris et al.[24] reported that most falls occur during walking activity; however, the walking speed test used by these authors could not determine the risk of falls in the group.

The sit-to-stand test can be a valid and reliable indicator of lower limbs muscle strength[25]. In a recent systematic review[12], the average number of repetitions in one minute ranged from 8.1 repetitions in post-stroke patients to 50 in young men. Our findings present a significant difference, but in smaller proportions compared to those found in the studied mentioned. The highest number of repetitions for HG in our study may be due to the inclusion criteria—individuals who present preserved and independent gait, that is, we included individuals with better motor function than those who use walking aids. Regarding the CG, we believe that the lower values than those mentioned are due to the advanced age of many individuals (53.8±5.9 years).

Mong et al.[26] verified that the five-times sit-to-stand test is associated with the muscular strength of knee flexors, similarly to walking speed being a variable strongly associated with muscle strength of knee flexors and extensors[27]. Therefore, in our study, the group of individuals with hemiplegia, who demonstrated worse performance of lower limb muscle resistance in the sit-to-stand test and lower walking speed, may present muscle alterations, such as weakness and spasticity of the side affected by hemiplegia. Muscle alterations on the side affected by the stroke are added to changes in the life routine due to the injury, such as decreased/impossibility of performing ADLs and physical activities. These factors show the importance of monitoring this population by physical therapy professionals in rehabilitation and adaptation for performing ADLs. Hemiplegia post-stroke presents a complex clinical picture, associated with different degrees of motor disorders, cardiorespiratory, sensory, and psychological deficits, which can hinder mobility, increase the risk of falls, and decrease the quality of life of individuals[28,29].

In this study, we found no differences when dividing HG into two subgroups (mild/moderate and marked/severe) according to the Fugl-Meyer scale. This may be a limitation of the study, since this scale classifies the general motor function, covering different scoring ratios for the upper and lower limbs. However, the motor function tests evaluated in this study (sit-to-stand and walking speed) prioritize functional performance of the lower limbs. Therefore, we considered that the tests chosen were not sensitive to capture the differences between the HG subgroups. Moreover, the sit-to-stand test presents an aerobic component, but the Fugl-Meyer assessment excludes this component, which possibly contributed to the similar outcomes between subgroups.

Clinical applications

To understand the changes in motor function of individuals with chronic hemiplegia post-stroke is increasingly necessary to improve clinical interventions in this population. The use of functional tests such as sit-to-stand and walking speed, evaluated by this study, can contribute to quantify the motor function of individuals with hemiplegia. The results show that individuals with hemiplegia have altered motor function when compared to healthy individuals. Therefore, these tests can be used in clinical practice to quantify and identify changes in lower limbs resistance and walking speed.

CONCLUSION

Individuals with chronic hemiplegia post-stroke present decreased performance in the sit-to-stand test and walking speed, when compared to the control group. The sit-to-stand and walking speed test are associated with and quantify changes in lower limbs motor function. Despite the higher or lower degree of motor impairment classified according to the Fugl-Meyer scale, participants presented a poor lower limbs resistance, as well as low walking speed. The improvement of performance in these tests, which presented a strong relationship, seems to be a valid and very important assessment and rehabilitation strategy, since these functional activities are essential for the independence and quality of life of this population.

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