

Strength of the respiratory and lower limb muscles and functional capacity in chronic stroke survivors with different physical activity levels

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ABSTRACT | Background: The assessment of strength and its relationships with functional capacity could contribute to more specific and effective disability management of stroke survivors. **Objective:** To compare and investigate associations between measures of strength and functional capacity of 98 chronic stroke survivors, stratified into three groups, according to their physical activity levels. **Method:** The physical activity levels were classified as impaired, moderately active, and active, based on their Human Activity Profile (HAP) scores. Strength was assessed by the maximal inspiratory (MIP) and expiratory (MEP) pressures and by the residual deficits (RDs) of work of the lower limb and trunk muscles, whereas functional capacity was evaluated by the distance covered during the six-minute walking test (6MWT). **Results:** One-way analyses of variance revealed significant differences between the groups, except between the active and moderately active groups regarding the RDS of the hip and knee flexors/extensors and ankle dorsiflexors ($2.91 < F < 8.62$; $0.001 < p < 0.01$). Differences between the groups were found for the 6MWT ($F=10.75$; $p < 0.001$), but no differences were found for the MIP and MEP measures ($0.92 < F < 2.13$; $0.13 < p < 0.40$). Significant, negative, and fair correlations were observed between the RDS of the hip and knee muscles and the 6MWT ($0.30 < r < -0.43$; $p < 0.01$) and the HAP ($-0.28 < r < -0.41$; $p < 0.01$). Moderate to good correlations were found between the 6MWT and the HAP ($r=0.50$; $p < 0.0001$). There were no significant correlations between measures of respiratory strength and any of the investigated variables ($-0.11 < r < 0.12$; $0.26 < p < 0.56$). **Conclusions:** Lower strength deficits and higher functional capacity were associated with higher physical activity levels. However, the moderately active and active groups demonstrated similar strength deficits.

Keywords: stroke; respiratory muscles; muscular weakness; exercise capacity; physical activity levels; rehabilitation.

HOW TO CITE THIS ARTICLE

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● Introduction

The physical consequences of stroke are variable and may include impairments in the motor, emotional, and sensory systems, language, perception, and cognitive functions¹. Hemiparesis, the most frequently observed motor deficit, affects more than 80% of these individuals² and is related to decreased exercise capacities and physical function³. Clinically, muscular weakness has been recognized as a limiting factor in the motor rehabilitation of stroke patients and as the most contributing factor to post-stroke disabilities⁴. Therefore, strengthening exercises have been widely employed to increase functional capacity in individuals with hemiparesis⁵⁻⁸. However, further studies are required to investigate other variables, which could interfere with functional capacities with this population.

Previous studies have reported decreased respiratory strength in individuals during both the

acute and chronic post-stroke stages⁹⁻¹². Within this context, weaknesses of the respiratory muscles and changes in the thoraco-abdominal motion could be related to decreased tidal volumes, and consequently, lower exercise tolerance, as observed in healthy individuals¹³. Additionally, in accordance with Patterson et al.¹⁴, the ability to generate force with the paretic lower limb is the major determinant of the ability to perform short or long walks.

The preventive and rehabilitative approaches of individuals with hemiparesis are of utmost relevance due to the increased survival rates of this population¹⁵. Thus, to assess muscular parameters of individuals with chronic hemiparesis and its relationships with functional capacities could contribute to a more specific management of this condition. Therefore, the aim of this study was to compare motor performance measures (strength of the respiratory and lower limb

muscles) and functional capacity, as assessed by the distance walked during the six-minute walk test (6MWT), between individuals with hemiparesis with various levels of physical activity. In addition, it investigated possible associations between motor parameters and functional capacities in individuals with chronic hemiparesis. It was hypothesized that subjects with chronic stroke who had higher levels of physical activity would demonstrate higher levels of functional capacity and lower strength deficits of the respiratory and lower limb muscles.

● Method

Participants

Ninety-eight subjects with unilateral stroke, who had residual weakness and/or spasticity of the affected lower extremity, were recruited on a volunteer basis from the general community of Belo Horizonte, MG, Brazil. All participants were screened to ensure that their mean time since the onset of the stroke was at least nine months; were above 20 years of age; were able to walk with or without assistive devices; had no facial palsy which could prevent proper labial occlusion during tests; and had no cognitive impairments, as assessed by the Mini Mental State Examination¹⁶, according to the cut-off scores recommended by Brucki et al.¹⁷. They should also be able to understand and perform all of the test procedures. Those individuals with non-stroke-related disabilities and who had respiratory diseases were excluded. All participants provided consent based upon approval by the Ethical Review Board of Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, MG, Brazil (protocol 172/02).

Instruments and procedures

Initially, the participants underwent a physical examination and an interview for the collection of anthropometric, demographic, and clinical data, such as age, gender, body mass, height, time since the onset of stroke, paretic side, and the use of medications. The participants were stratified into three groups based upon their physical activity levels, which were determined by the self-reported activity scores on the Brazilian version of the Human Activity Profile (HAP), which is considered a valid and reliable tool¹⁸. The participants' physical activity levels were classified according to their adjusted activity scores (AAS) either as impaired (<53), moderately active (53-74) or active (>74)¹⁹.

Lower limb muscular strength

Bilateral measures of strength of the major muscular groups of the ankle, knee, and hip joints were obtained with the Biodex System 3Pro[®] isokinetic dynamometer (Biodex Medical System Inc., Shirley, NY) in the concentric-concentric mode at angular speeds of 60°/s. Isokinetic measures have shown to be reliable for evaluating the strength of individuals with hemiparesis^{20,21} and all procedures were carried out following previously described protocols^{8,21}. The residual deficits (RDs) of the normalized work measures, in Joules, were used for analyses and were calculated according to the following formula: $100 - (\text{paretic/non-paretic lower limb} * 100)$.

Six-minute walk test

The distances covered during the 6MWT, which appropriately reflect the physical capacity to perform daily tasks, were registered for analyses²²⁻²⁴. The test was carried out, following the procedures and recommendations of the American Thoracic Society²⁵, which were adapted to the Brazilian Portuguese language²⁶.

Respiratory muscular strength

Respiratory strength was evaluated by measures of maximal inspiratory (MIP) and expiratory (MEP) pressures, which were obtained by a previously calibrated manovacuometer with operating intervals of ± 300 cmH₂O (GeRar[®], São Paulo, Brazil). All of the test procedures were conducted according to previous recommendations^{27,28}. These measures have shown adequate psychometric properties in previous studies^{29,30}.

Statistical analysis

Descriptive statistics, tests for normality (Kolmogorov-Smirnov), and equality of variances (Levene) were carried out for all outcome variables. One-way analyses of variance (ANOVAs) followed by LSD *post-hoc* tests were employed to investigate differences between the groups (impaired, moderately active, and active) regarding the RDs of the paretic lower limb muscles, the distances covered during the 6MWT, and the respiratory pressures. Pearson correlation coefficients were calculated to explore the relationships between these selected variables and were classified as low or none ($0.00 < r < 0.25$), fair ($0.25 < r < 0.50$), moderate to good ($0.50 < r < 0.75$), and good to excellent ($r > 0.75$)³¹. All analyses were carried out with the SPSS software package (Version 17.0) with a significance level of 5%.

● Results

Participants' characteristics

Ninety-eight individuals, 54 men and 44 women, participated in this study. They had a mean age of 56.4 ± 12.5 years and a time since the onset of stroke ranging from six to 240 months. No significant differences between the three physical activity level groups were observed regarding the participants' ages and the time since the onset of stroke ($p=0.84$ and $p=0.68$, respectively). Their clinical, demographic, and anthropometric data are described in Table 1.

Six individuals were unable to perform the respiratory pressure procedures (four of the impaired and two of the moderately active group) and the isokinetic work data of eight individuals were

excluded due to technical problems (two of the impaired, six of the moderately active, and one from the active group). Strength data for the ankle plantar and dorsal flexor muscles were obtained for only 40 individuals (four from the impaired, 25 from the moderately active, and 11 from the active group), since 58 participants were unable to generate enough torque to perform the tests.

Comparisons between the groups

Table 2 provides the results of the between-group comparisons for all of the variables. No significant differences between the groups were observed for the RDs of the ankle plantar flexor muscles [$F(2, 37)=0.67$; $p=0.52$]. However, for all the other muscular groups, significant differences between the groups were found, except between the moderately

Table 1. Demographic and anthropometric characteristics of the participants.

Characteristic	n=98
Age (years), mean±SD, (range: min-max)	56.4±12.5 (24-86)
Gender, male, n (%)	54 (55)
Paretic side, right, n (%)	58 (59)
Time since the onset of stroke (months), mean±SD, (range: min-max)	64.8±53.6 (6-240)
Use of medications (number), mean±SD	3±2
BMI (Kg/m ²), mean±SD, (range: min-max)	25.9±4 (15.24-36.51)

SD=Standard deviation; BMI= Body Mass Index.

Table 2. Demographic and clinical data (means±standard deviations and range [minimum-maximum] of the participants, according to their physical activity levels and comparisons between the groups.

Variable	Impaired (n=26)	Moderately active (n=55)	Active (n=17)	Total (n=98)
Time since the onset of stroke (months)	74.4±69.8 ^a (6-240)	60.9±46.4 ^a (6-228)	63.5±51.1 ^a (15-180)	64.8±53.6 (6-240)
Age (years)	56.4±12.5 ^a (29-86)	55.7±12.0 ^a (24-79)	57.8±14.2 ^a (26-82)	56.4±12.5 (24-86)
MIP (cmH ₂ O)	65.1±33.4 ^a (20-150)	73.6±24.3 ^a (30-130)	84.7±35.6 ^a (30-150)	73.5±29.2 (20-150)
MEP (cmH ₂ O)	73.9±35.4 ^a (20-140)	82.1±34.1 ^a (30-200)	90.3±49.9 ^a (25-190)	81.6±37.7 (20-200)
RD hip flexion (%)	34.6±23.8 ^a (-25-71)	21.3±24.6 ^b (-23-100)	10.6±24.9 ^b (-56-46)	22.6±25.3 (-56-100)
RD hip extension (%)	55.2±50.1 ^a (-101-100)	20.4±70.9 ^b (-322-100)	13.5±35.9 ^b (-26-100)	27.7±62.1 (-322-100)
RD knee flexion (%)	72.4±39.5 ^a (-48-100)	52.5±40.8 ^b (-47-100)	32.9±24.1 ^b (-13-74)	53.6±40.4 (-48-100)
RD knee extension (%)	53.5±23.1 ^a (-12-87)	33.4±28.6 ^b (-30-90)	19.4±27.5 ^b (-25-77)	36.0±29.6 (-30-90)
RD plantar flexion (%)	51.8±49.7 ^a (-7-95)	29.0±73.1 ^a (-159-100)	52.2±15.8 ^a (28-72)	36.9±60.0 (-159-100)
RD dorsiflexion (%)	-190.0±216.8 ^a (-433-18)	0.1±68.5 ^b (-209-100)	10.3±21.4 ^b (-26-35)	-11.3±91.1 (-433-100)
6MWT (m)	267.7±118.3 ^a (40-454)	368.4±124.4 ^b (61-674)	440.7±107.0 ^c (220-650)	356.6±132.2 (40-674)

BMI=Body Mass Index; MIP= maximal inspiratory pressure; MEP= maximal expiratory pressure; RD= residual deficit; 6MWT= distance covered during the six-minute walk test. For each row, different letters represent statistically significant differences between groups ($p<0.05$).

active and active groups ($4.91 < F(2, 89) < 8.62$; $0.01 < p < 0.001$). As illustrated in Figure 1, the RDS of the hip flexor muscles demonstrated a tendency for lower values with higher physical activity levels, although no significant differences between the moderately active and the active groups were observed. Similar patterns were found for the RD values for all of the other muscular groups.

Significant between-group differences were observed for the distance covered during the 6MWT [$F(2, 95) = 10.75$; $p < 0.001$]. However, no significant differences between the groups were found for the MIP [$F(2, 91) = 2.13$; $p = 0.13$] and MEP [$F(2, 91) = 0.92$; $p = 0.40$] measures.

Associations between the variables

Significant, negative, and fair correlations were found between the RDs of all the lower limb muscles, except for the ankle plantar and dorsal flexors, with the distance covered during the 6MWT ($-0.30 < r < -0.43$; $p < 0.01$) and the AAS scores ($-0.28 < r < -0.41$; $p < 0.01$). These associations indicated that the higher the work differences between the paretic and non-paretic lower limbs, as expressed by the RDs, the lower were the AAS score and the distances covered during the 6MWT. In addition, moderate to good correlations between the distances covered during the 6MWT and the AAS scores were also found ($r = 0.51$; $p < 0.0001$). It is important to note that no significant correlations were found between the respiratory strength measures and any of the other investigated variables ($-0.11 < r < 0.12$; $0.26 < p < 0.56$).

muscles. However, regarding the RD, no significant differences were found between the moderately active and active groups. No significant between-group differences were found for the respiratory strength measures. Significant correlations were found between the RDs of the hip and knee muscles, the functional capacity, and the physical activity levels. Interestingly, no significant correlations were found between the measures of respiratory strength and any of the investigated variables.

To the best of our knowledge, this was the first study to examine the relationships between the strength of the respiratory and the lower limb muscles and the distances covered during the 6MWT in individuals with chronic hemiparesis based upon their physical activity levels. It is reported that little attention is given to the pulmonary system during the evaluation and treatment of individuals with hemiparesis, although it is known that these individuals demonstrate deficits in this system³². Interestingly, there were no significant correlations between the respiratory strength measures and any of the other studied variables, nor differences in respiratory strength between the impaired, moderately active, and active groups.

Differences between the impaired, moderately active, and active groups were found for all work measures, except for the ankle plantarflexor muscles, demonstrating that individuals with higher levels of physical activity showed fewer strength discrepancies between their paretic and non-paretic lower limbs. Interestingly, the work measures were not different between the moderately active and active groups. These findings could be partially explained by the high levels of inter-subject variability, as evidenced by the high standard deviation values found for all groups. The RDs of the work measures were used for analyses, since their calculations are based upon the principle that the performance of the non-paretic lower limb of each individual was the reference for the performance of the paretic one. Thus, the use of this variable allows objective comparisons between groups and reduces the typical variability of the results in this population, which facilitates the interpretation of the findings³³. However, the variability of the results still remained high, but this finding seems common with this population, when motor and functional parameters are investigated^{8,11,34,35}.

Although previous studies have reported that the variable which best explained physical activity levels was walking speed³⁶, and that plantar flexor strength has been identified as an important component of speed³⁷, the work produced by the ankle plantar flexor

Discussion

The present study found significant differences between the groups regarding the functional capacities and the RDs of the paretic lower limb

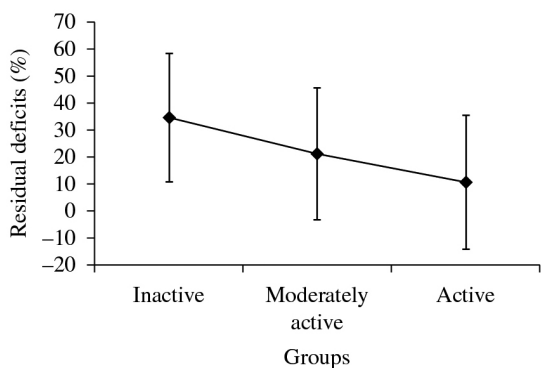


Figure 1. Residual deficits of the hip flexor muscles (means and standard deviations) for the impaired, moderately active, and active groups.

muscles was the only variable which did not show differences between the groups. However, only 40 individuals were able to perform the ankle tests and this may have influenced the results, in addition to the high inter-subject variability.

Most of the RD values did not show regular distribution patterns since some individuals showed positive values and others negative ones, which meant that in these cases, the paretic side was able to produce higher levels of work than the non-paretic one. Stabilization has been reported to be an important factor influencing the amount of muscular force produced during testing³⁸⁻⁴⁰. Although stabilization was performed following the manufacturer's recommendations, perhaps the paretic limbs received greater stabilization from the non-paretic side, which could have contributed to the higher values found in the same muscles on the paretic side, compared to the non-paretic one, and could partially explain the negative values.

The RD levels of the isokinetic work generated by the lower limb muscles were selected to demonstrate muscular performance. Despite the fact that peak torque is considered an excellent indicator of maximum levels of forces that an individual is able to generate, this variable alone does not take into account the ability of maintaining this force over a certain range of motion. Work, on the other hand, demonstrates the ability of individuals to generate and sustain forces over a certain range of motion⁴¹. This fact might explain the fair correlations found between the isokinetic work and the distance covered during the 6MWT.

Despite reports that individuals with hemiparesis show significant respiratory dysfunctions and reduced exercise tolerance⁴², the present findings do not support the idea that individuals with various exercise capacities show differences in strength in their respiratory muscles. These findings could be partially explained by the fact that the included individuals had chronic hemiparesis and were probably already functionally adapted and did not demonstrate major respiratory strength deficits¹¹. However, Sutbeyaz et al.³² showed that a six-week strengthening program of the inspiratory muscles was able to increase exercise capacity, decrease dyspnea, and improve the quality of life in individuals with hemiparesis who demonstrated greater respiratory strength deficits.

The absence of significant relationships between measures of respiratory strength and the distance covered during the 6MWT, could be related to the distinct demands required for the measurement of

these variables. The manovacuometry, for instance, requires maximum effort over a short period of time, whose demands are not equivalent to those required for the execution of the 6MWT, in which the individual should maintain efforts throughout the test.

The significant differences between the groups regarding the distance covered during the 6MWT suggested that active individuals had higher physical capacities, corroborating previous reported findings with the elderly²⁶. From the functional point of view, the 6MWT is widely used for the evaluation of physical fitness and exercise capacity with various populations⁴³ and consists of a simple and practical test, that can be widely used within clinical contexts. Moderate correlations were observed between the distances covered during the 6MWT and the AAS, which demonstrated that they assessed similar aspects.

It was observed that individuals with higher activity levels, as determined by their AAS scores, also had higher levels of functional capacity, as demonstrated by the greater distances covered during the 6MWT. Previous studies reported that individuals with hemiparesis have reduced abilities to exercise and showed a 40% reduction in their exercise capacities, compared to sedentary healthy individuals, matched by age and sex³². These findings show the importance of maintaining high physical activity levels for this population.

It should be noted that due to the design of the study, causal relationships cannot be determined. In addition, the fact that the sample size was also not uniformly distributed between the groups may have influenced the results. It is important to point out that only individuals with chronic hemiparesis who demonstrated the ability to independently walk were included. Thus, the present findings cannot be generalized to subjects with different characteristics, such as being in the acute or sub-acute stages or being unable to walk. Furthermore, parameters related to the cardiovascular system were not taken into consideration and they may have influenced the assessments, especially the 6MWT. This aspect should be investigated in future studies.

● Conclusions

The findings of this study demonstrated that individuals with hemiparesis with different physical activity levels showed differences in the distance walked during the 6MWT and work deficits of the paretic lower limb muscles. However, differences in strength were not found only between the moderately

active and active groups. Measures of respiratory strength were similar between the groups, and these variables were not related to any of the other functional variables. Lower strength deficits and higher functional capacities were associated with higher physical activity levels.

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