ORIGINAL ARTICLE

Association between walking and strength of lower limbs after chronic stroke

Associação entre velocidade de marcha e força de membros inferiores após acidente vascular encefálico crônico

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ABSTRACT
Certain muscle groups strength directly influence walking speed (WS), and the lower strength of the paretic side is significantly associated with lower WS of individuals after stroke. Studies that have investigated the association between the average of lower limb strength and the WS in individuals are scarce. Therefore, it is important to determine whether the strength could explain walking performance due to some muscle weakness could be compensated by the strength of others, mainly because all muscles act in group, not isolated. **Objective:** To investigate the association between WS and lower limbs muscle strength, and to identify whether an individual muscle group or the average strength of lower limb would best predict WS and walking speed reserve (WSR) in individuals with stroke. **Methods:** Sixty-four community-dwelling individuals with chronic stroke have their maximum isometric strength (hip flexors/extensors/abductors, knee flexors/extensors, and ankle dorsiflexors/plantarflexors) and self-selected and fast WS (10m walk test) measured. WSR was considered as the difference between the fast and self-selected speed. **Results:** Average strength of the paretic limb accounted for 19% and 20% of the variance in self-selected and fast WS, respectively. Plantarflexor strength of the paretic, knee and hip flexors of the non-paretic side explained alone 27% of the WSR scores and plantarflexor strength of the paretic side alone explained 15%. **Conclusion:** Average muscle strength of the paretic side contributed to self-selected and fast WS. Plantarflexor strength of the paretic side, knee and hip flexors of the non-paretic side contributed with the WSR of chronic stroke individuals.

Keywords: Stroke, Muscle Strength, Gait, Walking Speed

RESUMO
Estudos que investigam a associação entre a força média de membro inferior e a velocidade de marcha em indivíduos pós AVE são escassos. Logo, é importante determinar se a força muscular média pode explicar o desempenho na marcha, visto que os músculos agem em grupo. **Objetivo:** Investigar a associação entre velocidade de marcha e força muscular de membros inferiores, e identificar se um grupo muscular individual ou a força média de membros inferiores poderia predizer a velocidade de marcha e a velocidade de reserva (VR) em indivíduos pós AVE crônico. **Métodos:** 64 indivíduos deambuladores comunitários pós AVE crônico passaram por avaliação de força isométrica máxima (flexor/extensor/abdutor de quadril, flexor/extensor de joelho e flexor plantar/dorsoflexor de tornozelo) e velocidade de marcha habitual e máxima (Teste de Caminhada de 10 metros). A VR foi considerada a diferença entre velocidade de marcha máxima e habitual. **Resultados:** A força média do lado parético foi responsável por 19% e 20% da variância na velocidade de marcha habitual e máxima respectivamente. A força de flexor plantar do lado parético e flexor de quadril e joelho do lado não parético explicaram 27% da VR e força de flexor plantar do lado parético explicou 15%. **Conclusão:** A força média do lado parético contribuiu para a velocidade de marcha habitual e máxima. A força de flexor plantar do lado parético, flexor de quadril e joelho do lado não parético contribuíram para a VR de indivíduos pós AVE crônico.

Palavras-chave: Acidente Vascular Cerebral, Força Muscular, Marcha, Velocidade de Caminhada

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INTRODUCTION

It is well established in the literature that muscle strength is a crucial variable and directly influence several outcomes, such as static and dynamic balance,[1] cardiorespiratory fitness,[1] and walking speed,[1-4] when referring to individuals after stroke. It is reported that walking speed is the sixth functional vital sign, that is, powerful predictor of health-related outcomes.[5,6]

Community ambulation is a pre-requisite to a social participation for individuals after stroke since mobility ability is essential for carrying out daily activities and social roles, such community life, and recreational activities, directly or indirectly.[7,8] Besides that, the return of community ambulation is the most important goal reported by individuals after stroke.[9]

Walking after stroke is usually marked by asymmetry that reduces the moment of plantarflexion, knee extension and hip flexion.[10] In addition, these individuals produce lower torque of plantarflexors and high torque of hip flexors, when compared to healthy controls, which explains in part the reduced walking speed of this population.[11] Muscle weakness is associated with gait performance in individuals after stroke, since the lower strength of the paretic side is significantly associated with lower walking speed of individuals.[4,12]

During clinical practice, assessment of muscle strength of the lower limbs is routinely performed. However, previous studies have only investigated the association between the strength of some specific muscle groups, mainly knee extensors, dorsiflexors, and plantarflexors, with walking speed.[1,2,4,5,11,13-17]

Studies in the literature that have investigated the association between average lower limb strength and the walking speed in individuals after stroke are scarce. Therefore, it would be also important to determine whether the average strength could explain walking performance due to some muscle weakness could be compensated by the strength of others, mainly because all muscles act in group, not isolated.

In addition, the literature is scarce about the association between muscle strength an individual's ability to increase their walking speed under specific demands of everyday activities and the environment, such as crossing a street safely and take public transport, for example.

This is an important issue, since individuals could increase their ability to walking speed and this fact allows individual to improve their social participation in activities that requires ambulation in the community. The ability to increase the walking speed according to the demand is described as walking speed reserve, which is calculated by the difference between fast and self-selected walking speed.[18]

OBJECTIVE

To investigate the association between walking speed and walking speed reserve and muscle strength of lower limbs, and to identify whether an individual muscle group or average limb strength would best predict self-selected and fast speed and walking speed reserve in individuals after stroke.

METHODS

This is an exploratory cross-sectional study, where the individuals were recruited in public rehabilitation centers and research contact lists. The outcome measures were randomly collected over one day in a laboratory setting.

Participants

The participants were included according the inclusion criteria: clinical diagnosis of primary or recurring stroke (at least 6 months since the onset after stroke);[19] ≥18 years of age; and able to walk, with or without walking aids. Individuals were excluded if they had other clinical disabling conditions, and had cognitive impairments, which were screened by minimum score of 18 in the Mini Mental State Examination.[20]

Procedures

This study was approved by the institutional ethical review board and all participants provided written consent, prior to data collection. Before data collection, eligible participants were informed about the aims of the study and provided consent, based on previous approval from the ethics review board (CAAE: 58866416.0.0000.5134). Then, the participants underwent an interview and physical examination to characterize the sample. All data were collected in one day session (one hour and thirty minutes of duration) by trained personnel who had research experience in the area of stroke rehabilitation. The vital signs were monitored during all data collection.

After the initial procedures, demographic, clinical data, balance (Berg Balance Scale), and mobility (Timed Up and Go Test) were collected for sample characterization purposes. Berg Balance Scale is an objective measure that were composed by 14 items. Timed Up and Go Test start with the individual seated in a chair with his/her back at the chair back, and, with the command “go”, the individual rises from the chair, walk 3 meters at fast speed without run, turn, walk back to the chair and sit. The time were measured by a chronometer.

Outcome measures

Walking speed measurement

The self-selected and fast walking speed (in m/s) was evaluated by means of the 10 meters Walk Test (10MWT) in which it was carried out in 14 meters, with two initial meters of acceleration and two final meters of deceleration.[21]

The time used to perform the 10MWT was timed once[22] by using a cell phone timer, after verbal command for self-selected speed: "You will walk at the usual speed as if you are walking day by day", and for fast speed: “Walk as fast as possible and safely, but without running, to reach a bus which was about to pull out”.[23]

At the end of the aisle a chair was placed where the individual could sit down after the test. Throughout the test one researcher walked alongside the individual to monitor their performance and minimize the risk of falling. The individual was allowed to use the usual assistive device during the test, including ankle stabilization devices (ankle foot orthosis – AFO), as they wish. The test present excellent test-retest reliability (ICC=0.94)[24] for individuals after stroke. Walking speed reserve was determined as the difference between the fast walking speed and self-selected walking speed.[18]

Muscle strength measurements

Muscle strength (in mmHg) was assessed by the Modified Sphygmomanometer Test (MST), in an isometric contraction.[25] A previous studies investigated the intra and inter-rater reliability, which presented adequate values[25] and showed adequate reliability and validity, when compared against the hand-held dynamometer, for muscle strength measurements of individuals after stroke.[26]

Prior to the start of the test, the cuff was inflated to 100 mmHg and all the folds are removed and, then emptied to 20 mmHg. The direction of the strength to be executed by the individual was demonstrated previously. The individual was also informed to maintain the maximum force strength for five seconds and the strength peak was recorded.

All tests were performed with the following verbal stimulus: "strength, strength, strength..." The measured muscle groups were hip flexors and extensors, hip abductors, knee flexors and extensors, and ankle dorsiflexors and plantarflexors. The positioning was standardized according to previous recommendations.[27]

The interval of one minute between each muscle group measurement was obeyed. Measurement was done once on both sides, always started measuring the non-paretic side. The manometer reading was done by a third researcher.[27]

The average strength of lower limbs was obtained by the sum of the muscle groups of each limb divided by the number of evaluated muscle groups.

Statistical analyses

The sample size of at least 60 participants was estimated, based upon formula proposed by Dohoo et al.[28] For this calculation, five independent variables can be included in the multiple regression analyses.

Descriptive statistics (mean, SDs, ranges, and proportions), tests for normality (Kolmogorov-Smirnov), and equality of variances (Levene) were calculated for all outcomes. Pearson's correlation was used to evaluate the relationships (magnitude, direction, and significance) between walking speed (self-selected, fast, and ability to increase walking speed) and muscle strength (individual muscle group and average limb strength) variables.

Correlations are classified as very weak (0.25), weak (0.26-0.49), moderate (0.50-0.69), strong (0.70-0.89) and very strong (0.90-1.00).[29] Stepwise multiple regression analysis was performed to identify which independent variables (muscle strength variables) would significantly predict three proposed models (self-selected, fast walking speed, and walking speed reserve). Variable entry for the regression was set at 0.05, and removal was set at 0.10.[30,31]

Prior to perform regression, the data were evaluated, to determine whether they fulfill all requirements for regression analyses, such as linearity, homoscedasticity, independence and normality of the residuals, as well as multicollinearity and outliers.[32]

All analyses were carried-out with the SPSS software (version 17.0) with a significance level of 5%. All analysis was performed by a researcher who was not involved in the data collection.

RESULTS

Eighty-five potential individuals were recruited by telephone, and nine did not meet the inclusion criteria (were not able to walk). Out of the 76 individuals, who agreed to participate, 12 did not show up, despite prior confirmation. Thus, the sample consisted of 64 individuals after stroke, 34 males, mean age of 59 (±16) years. Their mean self-select walking speed was 0.8 (±0.34) m/s, whereas their fast walking speed was 1.00 (±0.42) m/s, and walking speed reserve was 0.21 (±0.15) m/s. The clinical and demographic characteristics of the participants are reported in Table 1.

Table 1. Clinical and demographic characteristics of the participants

Characteristics	n= 64
Age (years), mean (SD)	59 (16)
Sex, n males (%)	34 (57)
Time since the onset of the stroke (months), mean (SD)	62 (48)
Paretic side, right n (%)	51 (80)
Type of stroke, n ischemic (%)	41 (64)
Cognition (MMSE, 0-30), mean (SD)	25 (5)
Balance (BBS, 0-56), mean (SD)	46 (11)
Mobility (TUG, seconds), mean (SD)	17 (9)

SD: Standard deviation; MMSE: Mini-mental state examination; BBS: Berg Balance Scale; TUG: Timed Up and Go Test

As shown in table 2, on the paretic lower limb there was a reduction in muscle strength, when compared to the non-paretic lower limb, varying between 13.6% and 35.8%.

Table 2. Descriptive statistics of measures of strength of the lower limb in individuals with chronic stroke (n= 64)

Variable	Mean (SD)
Hip extensors	
paretic side (MST, mmHg), mean (SD)	199.1 (62.2)
non-paretic side (MST, mmHg), mean(SD)	236.5 (52.8)
Hip flexors	
paretic side (MST, mmHg), mean (SD)	149.8 (48.2)
non-paretic side (MST, mmHg), mean (SD)	186.7 (56.7)
Hip abductors	
paretic side (MST, mmHg), mean (SD)	117.8 (43.5)
non-paretic side (MST, mmHg), mean (SD)	145.9 (34.9)
Knee extensors	
paretic side (MST, mmHg), mean (SD)	217.5 (58.8)
non-paretic side (MST, mmHg), mean (SD)	251.8 (47.2)
Knee flexors	
paretic side (MST, mmHg), mean (SD)	137.5 (70.4)
non-paretic side (MST, mmHg), mean (SD)	214.2 (56.6)
Ankle dorsiflexors	
paretic side (MST, mmHg), mean (SD)	121.0 (67.7)
non-paretic side (MST, mmHg), mean (SD)	182.5 (54.1)
Ankle plantarflexors	
paretic side (MST, mmHg), mean (SD)	131.8 (72.2)
non-paretic side (MST, mmHg), mean (SD)	191.2 (62.7)
Average strength	
paretic side (MST, mmHg), mean (SD)	153.5 (45.4)
non-paretic side (MST, mmHg), mean (SD)	201.2 (38.7)

SD: Standard Deviation; MST: Modified Sphygmomanometer Test

Statistically significant and positive relationship of weak magnitudes (0.32<r<0.43) were found between self-selected walking speed scores and all muscle groups and average strength of the paretic side, except between the hip extensors and ankle dorsiflexors, which was not statistic significant (p= 0.05).

In addition, positive correlations of weak magnitudes were found between muscle strength of the non-paretic side, on following muscle groups: hip flexors (r= 0.36, p<0.0001) and abductors (r= 0.30, p= 0.02), knee flexors (r= 0.30, p= 0.02) and average strength (r= 0.32, p= 0.01) and self-selected walking speed values (Table 3).

Within the fast walking speed, weak relationships (r=0.27-0.45) were found between fast walking speed scores and all muscle groups and average strength of the paretic side, except between the fast walking speed and hip extensors, which was not statistically significant (r= 0.26;p= 0.05). In turn, positive correlations of weak magnitudes were found between muscle strength of the non-paretic side, only hip flexors (r= 0.33; p= 0.01) and abductors (r= 0.27; p= 0.04) (Table 3).

The walking speed reserve showed weak relationships only with ankle dorsiflexors (r= 0.30; p= 0.02) and plantarflexors (r= 0.38; p<0.0001) of the paretic side (Table 3).

Table 3. Pearson correlation coefficients between self-selected, fast walking speed, walking speed reserve, and muscle strength in individuals with chronic stroke (n= 64)

	Self-selected walking speed	Fast walking speed	Walking speed reserve
Hip extensors, paretic side	0.25	0.26	0.15
Hip extensors, non-paretic side	0.13	0.10	0.05
Hip flexors, paretic side	0.35*	0.32***	0.04
Hip flexors, non-paretic side	0.36*	0.33**	0.10
Hip abductors, paretic side	0.42*	0.44*	0.20
Hip abductors, non-paretic side	0.30***	0.27****	0.09
Knee extensors, paretic side	0.34*	0.27****	0.02
Knee extensors, non-paretic side	0.14	0.09	0.13
Knee flexors, paretic side	0.32**	0.35*	0.19
Knee flexors, non-paretic side	0.30***	0.16	0.24
Ankle dorsiflexors, paretic side	0.25	0.31***	0.30***
Ankle dorsiflexors, non-paretic side	0.19	0.17	0.06
Ankle plantarflexors, paretic side	0.36*	0.43*	0.38*
Ankle plantarflexors, non-paretic side	0.22	0.20	0.04
Average strength, paretic side	0.43*	0.45*	0.25
Average strength, non-paretic side	0.32**	0.26	-0.03

**p<0.0001; **p= 0.01; ***p= 0.02; ****p= 0.04*

For the self-select walking speed model, the regression analysis revealed that the average muscle strength of the paretic side alone explained 19% (F= 13.16; p<0.01) of the variance. This variable was positively correlated with self-select walking speed, indicating that individuals who had higher average muscle strength to have higher self-select walking speed (Table 4).

For the fast walking speed model, the regression analysis revealed that the average muscle strength of the paretic side alone explained 20% (F= 13.35; p<0.01) of the variance. This variable was positively correlated with fast walking speed, indicating that individuals who had higher average muscle strength to have higher fast walking speed (Table 4). For walking speed reserve model the regression analysis revealed that the three predictors (ankle plantaflexor of the paretic side, knee flexor of the non-paretic side and hip flexor of the non-paretic side) were retained (Table 4).

The ankle plantarflexor of the paretic side alone explained 15% (F= 9.28, p<0.01) of the variance in the walking speed reserve scores. When knee flexor of the non-paretic side was included in the model, the explained variance increased to 21% (F= 7.03, p<0.01). By adding hip flexor of the non-paretic side, the variance increased to 27% (F= 6.33, p<0.01).

All variables were positively correlated with walking speed reserve, indicating that individuals who had higher muscle strength to have higher ability to increase walking speed (Table 4).

DISCUSSION

The results of the present study indicate muscle strength of some lower limb muscle groups have association with self-selected, fast and walking speed reserve in individuals after stroke. In addition, average muscle strength of the paretic side explained 19% of variance for self-selected speed, and 20% of variance for fast speed. Ankle plantarflexor muscle strength of the paretic side explained alone 15% of the walking speed reserve of individuals after stroke. Knee and hip flexors of the non-paretic each added 6% on the model.

Measures of walking speed are recognized as indicators of functional performance, independence, quality of life, and social participation.[3,33-36]

The relationship between muscle strength of paretic lower limb and walking speed in individuals with stroke was previously investigated.[1,4,12] A previous systematic review[12] investigated the association between isometric strength with self-select and fast walking speed after stroke. The study found that all investigated muscle groups have association (poor to strong) with walking speed: paretic hip flexors (r= 0.25–0.82), hip extensors (r= 0.29–0.78), hip abductors (r= 0.24–0.80), knee extensors (r= 0.18–0.81), knee flexors (r= 0.30–0.83), ankle plantarflexors (r= 0.11–0.83), ankle dorsiflexors (r= 0.50–0.77), hip adductors (r= 0.29), hip internal rotators (r= 0.30), hip external rotators (r= 0.22), ankle invertors (r= 0.25) and ankle evertors (r= 0.33). The non-paretic limb showed poor to moderate correlations for each muscle group (r= 0.05–0.70).[12]

When compared to previous studies, it is observed similar results to those reported by Dorsch et al.[4] These authors analyzed this association in a sample of individuals with chronic stroke (>1 year after stroke).

The results showed maximum isometric strength of various muscle groups were positively associated (0.27<r<0.50) with self-selected walking speed, with weak magnitude correlation values. This fact can be explained by a greater number of factors that influence in the walking speed, such as lower limb coordination,[37] balance[38] and cardiorespiratory fitness.[22]

However, divergent results were found to those reported by Aguiar et al.[1] These authors investigated the association between muscle strength of trunk and lower limbs with self-selected and fast walking speed in individuals after sub-acute stroke (3-6 months after stroke).

They found positively association between self-selected (0.29-0.43) and fast (0.37-0.59) walking speed and all 12 investigated group muscles, except for knee flexors of non-paretic side (r= 0.29; p= 0.06).[1]

Table 4. Results of regression analysis for self-select, fast and walking speed reserve in individuals with chronic stroke (n= 64)

Variable	B (95% CI)	β	R2	SEE
Self-selected walking speed				
Step 1				
Constant	0.31±0.14 (0.02 to 0.59)	-	-	-
Average muscle strength of the paretic side	0.01±0.02 (0.01 to 0.05)	0.43	0.19	0.35
Fast walking speed				
Step 1				
Constant	0.38±0.19 (0.02 to 0.74)	-	-	-
Average muscle strength of the paretic side	0.04±0.01 (0.02 to 0.61)	0.45	0.20	0.38
Walking speed reserve				
Step 1				
Constant	0.10±0.04 (0.03 to 0.18)	-	-	-
Ankle plantarflexor of the paretic side	0.01±0.01 (0.01 to 0.02)	0.39	0.15	0.13
Step 2				
Constant	0.24±0.08 (0.09 to 0.39)	-	-	-
Ankle plantarflexor of the paretic side	0.01±0.01 (0.01 to 0.02)	0.39	-	-
Knee flexor of the non-paretic side	-0.01±0.01 (0.01 to 0.02)	-0.25	0.21	0.13
Step 3				
Constant	0.19±0.08 (0.04 to 0.35)	-	-	-
Ankle plantarflexor of the paretic side	0.01±0.01 (0.01 to 0.02)	0.36	-	-
Knee flexor of the non-paretic side	-0.01±0.01 (0.01 to 0.02)	-0.41	-	-
Hip flexor of the non-paretic side	0.01±0.01 (0.01 to 0.03)	0.29	0.27	0.12

B: Regression coefficients, followed by the respective standard error; CI: Confidence interval; β: Standardized regression coefficient; R2: Coefficient of determination; SEE: Standard error of the estimate

In the present study, it was observed that only approximately 50% of the evaluated muscle groups were correlated with self-selected and fast walking speed, while Aguiar et al.[1] reported a correlation among almost all muscle groups evaluated and the usual and fast gait speed.

The difference between these findings could be related to the phase after stroke, since during chronic phase the pattern of walking is well stablished and presents compensation features, reducing the contribution of some muscular groups during the walking.

The regression model showed average strength of the paretic side explains 19% and 20% of the variance of the self-selected and fast walking speed, respectively. In addition, it was also observed the walking speed reserve can be explained by the strength of paretic plantarflexors (15%), knee (6%), and hip flexors of the non-paretic side (6%). In the previous studies that performed regression analyses to identify the lower limb muscle group that would predict walking speed after stroke, the paretic ankle dorsiflexors appeared as the main explanatory variable.[1,4]

Dorsch et al.[4] demonstrated that ankle dorsiflexors of the paretic side accounted for 31% of the variance in self-selected walking speed ($p<0.001$),[4] while Aguiar et al.[1] demonstrated that 29% ($p= 0.002$) of fast speed can be explained by the strength of dorsiflexors of the non-paretic side.

These results are not in agreement with the findings of the present study, which found that average strength of the paretic side predict self-selected and fast walking speed in individuals with chronic stroke.

The differences could be explained by the fact that previous studies that performed regression analyses assessed only the contribution of isolated muscle groups, without concomitantly considering the combined contribution of all paretic and non-paretic lower limb muscle groups to the ability of the individual to walking.

Additionally, it is necessary to consider the phase of evolution after the occurrence of stroke. The time after stroke allows compensatory adaptation for movements and activities.[39,40] Possibly the individuals in the sub-acute phase are re-adjusting their gait pattern in order to achieve a state of optimal metabolic efficiency, for example. On the other hand, during chronic phase the individuals are already adapted to the physical demands, so they used the expected muscle group to produce the major power during gait, i.e., plantarflexors.[41-43]

The literature is scarce about the factors related to ability to increase walking speed. In our study the walking speed reserve was 20%, which is slightly lower than previous studies,[44,45] described between 25 to 50% in ambulatory after stroke with similar walking speed, and age (mean self-selected walking speed between 0.74m/ and 0.84m/s, and mean fast walking speed between 0.93m/s to 1.05m/s; mean age ranged 60 to 61 years).[44,45]

One previous study found a significant association between balance (assessed by Berg Balance Scale) and walking speed reserve ($r= 0.74$) in individuals after stroke, demonstrating that besides muscle strength other variables may be related to ability to increase gait speed. As best of our knowledge, this is the first study to found plantarflexor muscle strength of the paretic side is the major responsible of the walking speed reserve. This result is in line with the literature reporting the role of plantarflexors power during push-off as the main predictor of walking speed.[41-43]

The results of present study have important clinical implications. Previous studies have investigated the individual role of muscles groups in predicting the walking speed.[4,44,46-48] However, the relation between average strength of paretic side on walking speed and walking speed reserve was not well reported so far. Individuals after stroke show different strategies to activate the lower limb muscles to walk during self-selected, fast and, to increase walking speed. Thus, the evaluating, and possibly strengthening, should be addressed for the total paretic side, not only to specific muscle groups, since the residual deficits of the lower limbs were the physical variable impairment that best predict participation in daily activity (r^2= 22%; p<0.0001) and social role domains (r^2= 16%; p<0.0001) of the social participation in individuals after stroke.[8]

Thus, the average lower limb strength training can be an strategy to in order to increase speed, and consequently, enhance social participation within home and community environment, when the ability to manage complex environmental demands is required, for example to crossing the street before traffic light changes and getting on and off buses and subways.

Limitations of the study

Although it was observed previously that trunk and upper limb strength of individuals after stroke could influence on force transmission during the walking, we did not address these issues. Therefore, the interaction between upper limbs and trunk with lower limb strength was not accessed in this study.

Our results are valid for chronic, ambulators, mild/moderate physical limitations, preserved cognitive, and capable to communicate, limiting the external validity of the findings. The statistical analyses used do not allow interpretation related to causality between variables.

Although it is well established in the literature that each muscle group contributes differently during daily activities performance, it is not possible to transfer this level of contribution to this population, since each individual use a different strategy of movement, for example. Also, the use of ankle foot orthosis was not controlled.

Finally, factors as balance, coordination, cardiorespiratory fitness, and other outcomes could explain the remaining variance of the independent variables. Future studies should include other variables in the model beyond the muscle strength.

CONCLUSION

The results of the present study indicated muscle strength of the lower limbs have significant association with self-selected, fast walking speed and, walking speed reserve. It was observed average muscle strength of the paretic side explained 19-20% of the variance of self-selected and fast walking speed, respectively. It was found plantarflexor muscle strength of the paretic side explained alone 15% of ability to increase walking speed of individuals after chronic stroke. When knee and hip flexors of the non-paretic side were included in the model, the explained variance increased to 27%.

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