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Original Article

Handgrip strength deficits best explain limitations in performing bimanual activities after stroke

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Abstract. [Purpose] To evaluate the relationships between residual strength deficits (RSD) of the upper limb muscles and the performance in bimanual activities and to determine which muscular group would best explain the performance in bimanual activities of chronic stroke individuals. [Subjects and Methods] Strength measures of handgrip, wrist extensor, elbow flexor/extensor, and shoulder flexor muscles of 107 subjects were obtained and expressed as RSD. The performance in bimanual activities was assessed by the ABILHAND questionnaire. [Results] The correlations between the RSD of handgrip and wrist extensor muscles with the ABILHAND scores were negative and moderate, whereas those with the elbow flexor/extensor and shoulder flexor muscles were negative and low. Regression analysis showed that the RSD of handgrip and wrist extensor muscles explained 38% of the variance in the ABILHAND scores. Handgrip RSD alone explained 33% of the variance. [Conclusion] The RSD of the upper limb muscles were negatively associated with the performance in bimanual activities and the RSD of handgrip muscles were the most relevant variable. It is possible that stroke subjects would benefit from interventions aiming at improving handgrip strength, when the goal is to increase the performance in bimanual activities.

Key words: Stroke, Upper limb strength, Manual ability

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INTRODUCTION

Upper limb (UL) impairments may negatively impact the everyday life of stroke individuals, because they limit the execution of essential activities, which are necessary for an independent living[1, 2)]. However, the interactions between impairments and activity limitations are specific and do not always occur in an unequivocal and predictable way[3)]. Thus, understanding the impact of impairments on activity limitations could provide insights into the mechanisms of recovery, as well as guide clinical decision-making[4)].

Previous studies, which examined the associations between measures of impairments and activity limitations of the UL of individuals with stroke, found that weakness of the UL muscles was identified as the major determinant of activity limitations[4–6)]. However, these studies included measures of UL capacity, such as the action research arm test[4)], motor assessment scale[5)], *test d'évaluation des membres supérieurs des persones âgées*[6)], box and block test[6)], and nine-hole peg test[6)]. According to the International Classification of Functioning, Disability, and Health, capacity refers to the highest level of functioning within standardized environments[3)]. Although measures of capacity provide very useful clinical information, capacity does not reveal valid information regarding the individuals' functioning in daily life situations[2)]. Capacity and performance refer to different constructs and a large difference may exist between them[2, 7)]. However, the assessment of activities in the individuals' actual environment is often not feasible within clinical contexts. Thus, self-reported measures, such as questionnaires, are good options for performance evaluation[2, 8)].

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Only one study[1] has investigated factors that could explain UL performance of individuals with stroke using the motor activity log (MAL). The results showed that the sum of the strength measures of the paretic wrist and elbow flexor/extensor, and shoulder flexor/abductor muscles best explained the MAL scores[1]. However, the MAL only assesses the performance of the paretic UL in unimanual activities, which may not reflect the actual performance of individuals with stroke, because it exclude bimanual tasks and the non-paretic UL, which is, in fact, mostly used for the execution of everyday activities[7]. Therefore, the associations between measures of UL strength and performance in bimanual activities of stroke individuals still remain unclear. This knowledge would help rehabilitation professionals plan interventions focused on functional improvements within subjects' real life contexts. Therefore, the research questions of this study were:

1) Are there significant relationships between strength deficits of the UL muscles and the performance in bimanual activities of individuals with chronic stroke?

2) Which muscular groups would best explain the performance in bimanual activities of individuals with chronic stroke?

SUBJECTS AND METHODS

The participants were recruited from the general community of the city of Belo Horizonte, Brazil, by screening outpatients at public rehabilitation centers and research contact lists, from March, 2013 to August, 2014. People with stroke were included if they were above 20 years of age; had a mean time since the onset of the stroke of at least six months; had a diagnosis of unilateral stroke, and were living in the community. They were excluded if they had any other non-stroke disabling conditions or cognitive impairments, as determined by the education-adjusted cut-off scores of the mini-mental state examination[9]. This study was approved by the institutional ethical review board (113.846/326.216) and all participants provided written consent, prior to data collection.

All measures were collected by well-trained physical therapists, who had at least five years of clinical and/or research experience with stroke subjects. Demographic, anthropometric, and clinical characteristics of the participants, such as age, sex, paretic side, time since the onset of the stroke, and motor recovery of the UL, as determined by the Fugl-Meyer UL sub-scale scores[10], were collected for characterization purposes. The outcome measures were randomly collected over one day in a laboratory setting.

The performance in bimanual activities was assessed by the Brazilian version of the ABILHAND, which is a questionnaire that has shown adequate construct validity[11] and test-retest reliability[12]. The ABILHAND, specific for stroke individuals, contains 23 bimanual activities, which are rated as: 0=Impossible, 1=Difficult or 2=Easy[11]. It was administered by interviews, in which the individuals were asked to estimate their abilities to perform the activities without help, irrespective of the limb(s) actually used to perform them and the strategy they used[11], following the standardized instructions of the application manual[13]. The activities, which were not attempted within the last three months, were not scored, i.e., not applicable. Because the ABILHAND was built according to the Rasch measurement model, the subjects' responses were submitted to www.rehab-scales.org, for analysis[13]. This on-line analysis converted the raw scores into linear measures of manual ability, according to the calibration established for chronic stroke patients.

Isometric strength measures, in kgf, of the wrist extensor, elbow flexor/extensor, and shoulder flexor muscles were bilaterally obtained with a digital hand-held dynamometer (Microfet2®, Hoggan Health Industries, UT, USA), which provides reliable strength measures of individuals with stroke[14]. All measurements followed the standardized positions proposed by Bohanonn[15] and the non-paretic UL was always tested first. Before testing, the examiner demonstrated the procedures to the participants and instructed them to exert maximal force against the device for five seconds. All muscular groups were tested once, after a familiarization trial, and a 30-second rest interval was allowed between the tests[16].

Handgrip strength, in kgf, was evaluated using a hydraulic handgrip dynamometer (SAEHAN®, SAEHAN Corporation, Korea, Model SH5001), which has demonstrated high levels of reliability for individuals with chronic stroke[17]. The participants' adopted positions recommended by the American Society of Hand Therapists[18] and they were instructed to squeeze the dynamometer, as hard as they could, for three seconds. The test was executed once, after familiarization, and the non-paretic UL was always tested first[17].

All strength measures were expressed as percentages of the residual strength deficits (RSD), which were calculated as the deficits in strength of the paretic UL normalized to the non-paretic one, using the following formula: $RSD=100 - (paretic/non\text{-}paretic \times 100)$[19].

Descriptive statistics and tests for normality and equality of variance were calculated for all outcomes, using SPSS (version 19.0) for Windows. Pearson's correlation coefficients (r) were calculated to examine the relationships (magnitude, direction, and significance) between the strength variables and the ABILHAND scores. The strength of the relationships was based upon Munro's correlation descriptors[20]: very low=0.15–0.24, low=0.25–0.49, moderate= 0.50–0.69, high=0.70–0.89, and very high=0.90–1.00. Step-wise multiple regression analysis was used to determine which muscular group best explained the performance in bimanual activities, as determined by the ABILHAND scores. Variable entry for the regression analysis was set at 0.05 and removal at 0.10. A significance level of 5% was adopted in all analyses. A sample size of 109 participants was required to include the five selected independent variables in the regression analysis, based upon the formula proposed by Tabachnick and Fidell[21].

RESULTS

As shown in Fig. 1, 485 individuals with stroke were screened by telephone and 152 were scheduled for the assessments. However, 32 did not show up for the tests and 13 were excluded due to cognitive deficits, other disabling health conditions, or bilateral stroke. Therefore, 107 participants (59% men, with a mean age 58±12 years), were evaluated. Their characteristics are reported in Table 1.

Significant and negative correlations of low to moderate magnitudes were found between the ABILHAND scores and the RSD of the following muscular groups: handgrip (r=−0.58, p<0.0001), wrist extensors (r=−0.55, p=0<0.0001), elbow flexors (r=−0.40, p<0.0001), shoulder flexors (r=−0.31, p=0.001), and elbow extensors (r=−0.30, p=0.001).

The regression analysis resulted in only the RSD of handgrip and wrist extensor muscles being retained in the model (Table 2). Handgrip RSD alone explained 33% (p<0.0001) of the variance of the ABILHAND scores. When the RSD of the wrist extensor muscles was included in the model, the explained variance increased to 38% (p=0.005).

DISCUSSION

To the best of our knowledge, this is the first study to investigate the relationships and the contributions of strength deficits of the UL to the performance of bimanual activities, as determined by ABILHAND scores. The results showed that the

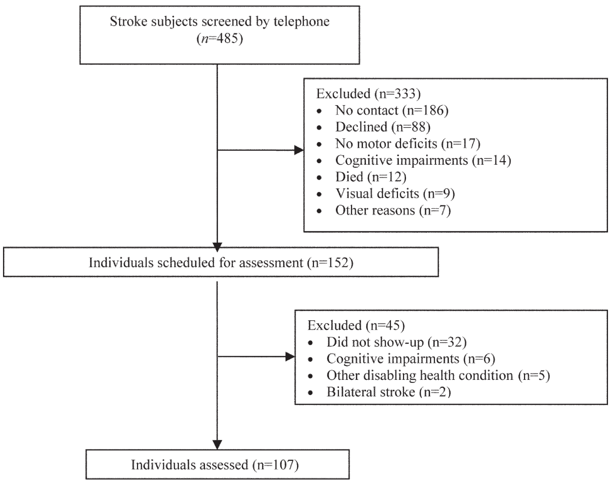

Fig. 1. Flow of the participants throughout the study

Table 1. Characteristics of the participants

Characteristic	(n=107)
Age (years), mean (SD)	58 (12)
Gender, number men (%)	63 (59)
Time since stroke (years), mean (SD)	5 (5)
MMSE (scores:0–30), mean (SD)	25 (4)
Paretic side, number right (%)	56 (52)
UL motor recovery – FMS (0–66), mean SD	44 (19)
Normal, n (%)	5 (5)
Mild motor impairments, n (%)	50 (47)
Moderate motor impairments, n (%)	24 (22)
Severe motor impairments, n (%)	28 (26)
Outcomes	
Residual strength deficits	
Handgrip (kgf), mean (SD)	50 (34)
Wrist extensors (kgf), mean (SD)	45 (39)
Elbow extensors (kgf), mean (SD)	38 (35)
Elbow flexors (kgf), mean (SD)	42 (27)
Shouder flexors (kgf), mean (SD)	41 (46)
ABILHAND (logits), mean (SD)	1 (1.6)

SD: standard deviation; MMSE: Mini-mental state examination; UL: upper limb; FMS: Fugl-Meyer scale

Table 2. Results of the regression analysis for the performance in bimanual activities, as assessed by the ABILHAND scores, using the residual strength deficits of the upper limb muscles (n=107)

ABILHAND	B	95% CI for B	β	R^2	SEE
Step 1					
Constant	2.371 ± 0.230	1.915 to 2.826	-	-	-
Handgrip RSD	−0.028 ± 0.004	−0.035 to −0.020	−0.58	0.33	1.34
Step 2					
Constant	2.454 ± 0.224	2.010 to 2.898	-	-	-
Handgrip RSD	−0.018 ± 0.005	−0.028 to −0.008	−0.38	-	-
Wrist extensor RSD	−0.012 ± 0.004	−0.021 to −0.004	−0.30	0.38	1.29

RSD: residual strength deficit; B: regression coefficients, followed by the respective standard error; CI: confidence interval; β: standardized regression coefficient; R^2: coefficient of determination; SEE: standard error of the estimate

ABILHAND scores were negatively associated with the RSD of all the assessed muscular groups: handgrip, wrist extensors, shoulder flexors, and elbow flexors/extensors. In addition, the ABILHAND scores were explained by the RSD of handgrip and wrist extensor muscles. These two variables together explained over one third of the variance in the ABILHAND scores of individuals with chronic stroke.

Although previous studies have reported significant relationships between the strength of the UL muscles and activity limitations involving the UL[6, 22, 23], they used measures of capacity, which cannot be extrapolated to the individuals' real life situations. The significant and negative correlations found in the present study, indicated that greater strength deficits were associated with lower ABILHAND scores, suggesting that the strength of the UL muscles is important, to some degree, for the performance of bimanual activities. These results are in agreement with those reported by Harris and Eng[1], who found significant correlations between the sum of the strength of the UL muscles and the performance of the paretic UL in unimanual activities, as determined by MAL scores, after stroke. These findings are not surprising, since the recovery of the strength of the paretic UL muscles and, consequently, the reduction of the strength deficits between the paretic and non-paretic UL, may improve the performance of individuals with stroke in both unilateral and bilateral activities. Although unilateral and bilateral training protocols for the rehabilitation of the UL of individuals with stroke conceptually represent contrasting approaches, no protocol has been found to be superior, when the ultimate goal is to improve the accomplishment of UL activities[24].

The present results demonstrated that handgrip RSD alone explained 33% of the variance of the ABILHAND scores. The RSD of the wrist extensor muscles contributed with an additional 5% of the explained variance. These findings can be explained by the roles of the UL muscles. Indeed, it is the hand that performs the manipulation of objects by the action of the intrinsic and extrinsic finger muscles. However, the wrist extensor muscles play a critical role, since the position of the wrist joint is critical in setting the optimum length-tension relationship of the extrinsic muscles of the fingers[25]. Thus, handgrip and wrist extensor muscles appear to have more direct actions on the manipulation of objects, a conclusion that supports the present findings, since handgrip strength includes both the intrinsic and extrinsic muscles of the fingers.

Surprisingly, the RSD of the shoulder flexor and elbow flexor/extensor muscles were not retained in the model. These findings may be partially explained by the fact that these muscular groups act to position the hand in space. However, compensatory strategies, such as displacement of the trunk (flexion, lateral inclination, and rotation) are often used to achieve the target, in order to compensate for the reduced range of motion and/or weakness of the elbow or/and shoulder joints[26].

The present findings corroborate those of previous studies, which demonstrated that handgrip strength greatly contributes to measures of UL capacity of chronic stroke individuals[6, 22]. However, Harris and Eng[1] reported that handgrip strength did not explain the paretic UL performance in unimanual activities and did not substantially contributed to UL capacity, since it only explained 2% of the variance of the Chedock Arm and Hand Activity Inventory[1]. It is important to point-out that the present study only included measures of strength as potential predictors of performance in bimanual activities. Both Harris and Eng[1] and Faria-Fortini et al.[6] included other impairment variables, besides strength, in their regression analyses, while Boissy et al.[22] included only handgrip strength. Other impairment measures, which were not evaluated in the present study, such as sensation and motor coordination, may also contribute to UL performance. Future studies should examine whether the contribution of handgrip strength remains significant, when other impairment variables are included.

It is possible to argue that concentric or eccentric measures should have been assessed, rather than isometric strength. However, the assessment of isometric strength was chosen, because it can be easily reproduced within clinical contexts. A sample size of 109 participants was not achieved, due to difficulties with the recruitment process. It is well known that sample size depends upon financial support, time, and the availability of the volunteers. However, the number of 107 participants was close enough to the required sample size. In addition, all the participants were community-dwelling individuals at the chronic stage of recovery after stroke. Therefore, the present findings should not be generalized to individuals with other characteristics.

In conclusion, strength deficits of the UL muscles were negatively associated with limitations in performing bimanual activities in individuals with chronic stroke and handgrip strength deficits were the most relevant measures in this category. Thus, it is possible that stroke subjects would benefit from interventions aiming at improving handgrip strength, when the goal is to increase performance in bimanual activities.

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