Grip strength is a representative measure of muscle weakness in the upper extremity after stroke

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Introduction

Stroke is a major cause of long term disability in the adult population worldwide [1]. About half of the individuals who suffer a stroke have remaining upper extremity impairments,[2, 3] such as muscle weakness, reduced somatosensation, spasticity and synergistic movements which can affect the motor control.[4] Muscle weakness is the most common impairment in the upper extremity after stroke and thereby an important contributing factor to the reduced ability to use the arm and hand in daily activities.[5, 6]

To be able to assess muscle strength in the upper extremity, valid and reliable outcome measures are important. In a previous study, we have showed that isometric and isokinetic muscle strength measurements in the upper extremity can be reliably measured in persons with chronic stroke.[7] Isometric grip strength was measured with a modern computerized grip dynamometer and arm strength (isometric shoulder abduction, elbow flexion and isokinetic elbow extension/flexion) was measured with a gold standard isokinetic dynamometer.[8, 9] However, as isokinetic equipment is expensive, stationary, and the measurement procedure time-consuming, it is less practical in the clinical setting. Modern computerized grip strength dynamometers are, on the other hand, precise, portable and easy to use and therefore more time-efficient.

As grip strength is easy to measure it would be advantageous if grip strength could be used as a proxy for muscle strength in the entire upper extremity after stroke. However, very few studies have investigated the association between grip strength and arm strength after stroke. One small study (n=12) showed strong correlations between grip strength and isokinetic muscle strength in the shoulder stabilizers.[10] Another study found strong correlations between grip strength and isometric arm strength, measured by a hand-held dynamometer in the acute phase after stroke.[11] To the best of our knowledge, no study has thoroughly investigated the association between grip strength and isometric and isokinetic shoulder and elbow muscle strength in a stable phase after stroke.

The aim of this study was therefore to investigate the association between grip strength and arm muscle strength in persons with chronic stroke.

Methods

This study is a secondary analysis of data from our previous methodological study of upper extremity muscle strength measurements after stroke.[7] In that study the test-retest reliability of isometric arm strength (shoulder abduction and elbow flexion) and isokinetic arm strength (elbow extension/flexion) and isometric grip strength were evaluated in 45 persons with mild to moderate impairments in upper extremity. The participants were measured twice (on two occasions), one week apart. In the present study, data from the second test occasion were used, as the performance was slightly better during the second test occasions than the first, indicating a small learning effect.

Participants

Forty-five persons with a clinically and neuroradiologically verified ischemic or hemorrhagic stroke were recruited from Skåne University Hospital in southern Sweden from April to December 2013. Inclusion criteria were: i) at least six months post stroke; ii) mild to moderate paresis in the more affected upper extremity (i.e., preserved ability to take the hand to the forehead and to grasp and release a small object); iii) ability to understand and follow test instructions, and iv) no other disorder or disease affecting muscle strength in the upper extremity.

Before inclusion each person was informed about the study and gave his/her written consent to participate. The principles of the Declaration of Helsinki were followed and approval was attained from the Regional Ethical Review Board, Lund, Sweden (Dnr 2012/591).

Procedures

To characterize the participants' upper extremity function, the following assessments were performed: (i) light touch (arm and hand) and proprioception (wrist and thumb) by the Fugl-Meyer Assessment of Sensorimotor Recovery After Stroke (FM-UE) [12] and (ii) spasticity (elbow, wrist or fingers) by the Modified Ashworth Scale (MAS) [13] (classified as present if the MAS score was ≥1).

Grip strength and arm muscle strength were measured in a quiet adjoining room by an experienced physiotherapist (first author). Prior to testing, the dynamometers were calibrated according to the manufacturer's instructions and the test positions were standardized according to the test protocol.[7] The less affected upper extremity was measured first, and then the more affected.

Grip strength measurements

Grip strength was measured with the computerized dynamometer Grippit (Catell AB, http://www.catell.se, Hägersten, Sweden). Grippit consists of a vertical cylinder on a foot, and has a wireless computer connection (Figure 1). Grip strength was measured with the participants seated with the forearm resting in a semi-pronated position on a foam cushion on a table with the shoulder at 30° abduction, the elbow at 90° flexion and the wrist at 0° to 15° dorsiflexion. The grip strength measurements were repeated three times (each contraction lasting 3 seconds with 60 seconds rest interval). The highest voluntary contraction was recorded as the maximal grip strength (isometric) in Newtons (N). In our previous test-retest reliability study,[7] high Intra-class Correlation Coefficients ($ICC_{2,1}$) were found for both the less affected and the more affected hand (0.95 to 0.96) with acceptable measurement errors (Standard Error of Measurement, SEM%, 7.2% to 9.2%).

Figure 1: The grip-strength dynamometer Grippit.

Arm strength measurements

Arm strength (isometric shoulder abduction and elbow flexion and isokinetic elbow extension/flexion) was measured using a Biodex System 3 PRO dynamometer (Biodex Medical Systems Inc., NY, USA; http://www.biodex.com) (Figure 2). The arm strength was tested with the participants seated in the Biodex chair (hip flexion 85°) with foot support and trunk stabilization with straps across the shoulders and waist. The Biodex chair and dynamometer were adjusted (for height, rotation and tilt) so the joint axis of the participants were aligned with the dynamometer's movement axis. For measurement of the abductor strength the shoulder was positioned in 15° abduction in the scapular plane, the elbow was extended and the forearm in a neutral position. For isokinetic elbow extensor and flexor strength the shoulder was positioned in 30° flexion and slight abduction, the elbow supported and the forearm supinated (see Figure 2). The isometric elbow flexor strength was measured in 90° elbow flexion with the same position for the shoulder and forearm as during the isokinetic measurement.

Prior to each measurement the participants practiced the movement about 5 times and then performed 1 or 2 submaximal contractions to warm-up and to become familiar with the procedures. The isometric strength measurements were performed twice (each contraction lasting 3 to 5 seconds with 60 seconds rest interval) and the isokinetic strength measurements included three trials (reciprocal extension and flexion at 60°/s). The highest maximal voluntary contraction (isometric and isokinetic) from the Biodex measurements was recorded as the highest peak torque in Newton meters (Nm). In our test-retest reliability study,[7] high ICCs were found for both upper extremities (isometric shoulder abduction 0.97; isometric elbow flexion 0.97; isokinetic elbow extension 0.92; isokinetic elbow flexion 0.95) together with acceptable measurement errors (SEM% 5.6% to 12.6%).

Figure 2: The isokinetic dynamometer Biodex System 3 PRO.

Statistical methods

The characteristics of the sample are presented as frequencies, means and standard deviations (SD). All muscle strength measurements are presented as means and SD as they were symmetrically distributed, as well as ratios between the more affected and the less affected upper extremity. The associations between grip strength and arm muscle strength measurements were evaluated with the Pearson's correlation coefficient (*r*) and interpreted as < 0.3 = poor, 0.3 to 0.6 = fair, > 0.61 to 0.8 = moderately strong, and > 0.8 = very strong.[14] IBM SPSS Statistics version 22 (IBM Corporation, Armonk, New York, United States) was used to analyze the data. P-values less than 0.05 were considered statistically significant.

Results

In Table 1, the demographic and clinical characteristics of the 45 participants (82% men) are presented. Their mean age was 65 years (SD 7) and the mean time since stroke onset was 44 months (SD 28). Seventy-one percent had suffered an ischemic stroke. Most participants were right handed (93%) and the dominant hand was affected in 58% of the participants. Somatosensory impairments in the more affected upper extremity were present in 38% (assessed by the Fugl-Meyer Assessment of Sensorimotor Recovery After Stroke[12]) and spasticity in 33% (assessed by the Modified Ashworth Scale[13]) of the participants.

The strength measurements were completed by all participants (n=45) except for one who could not perform the isometric shoulder abduction and another participant who could not perform the isokinetic elbow extension and flexion in the more affected upper extremity (n=44).

Table 1. Characteristics of the participants with chronic stroke (n=45)

Gender, n (%)	
Male	37 (82)
Female	8 (18)
Age, mean years (SD; min - max)	65 (7; 44 to 76)
Type of stroke, n (%)	
Ischemic	32 (71)
Hemorrhagic	13 (29)
Months from stroke onset to first test occasion, mean (SD; min-max)	44 (28; 10 to 116)
Paretic side, n (%)	
Right	25 (56)
Left	20 (44)
Handedness, n (%)	
Right handedness	42 (93)
Left handedness	3 (7)
Spasticity in the more affected UE ≥ 1, n (%)[a]	15 (33)
Light touch absent or diminished in the more affected UE, n (%)[b]	17 (38)
Proprioception absent or diminished in the more affected UE, n (%)[b]	9 (20)

n: number of participants; SD: standard deviation; UE: upper extremity; [a]Modified Ashworth Scale; [b]Fugl-Meyer Assessment of Sensorimotor Recovery After Stroke.

The mean values (SD) and ratios (more affected/less affected) for the grip and arm strength measurements are presented in Table 2. The ratios ranged from 0.70 to 0.78 for all strength measurements.

Table 2. Maximal isometric and isokinetic muscle strength measurements of the upper extremity in the participants with chronic stroke (n=45)

Strength Measures	Mean (SD)
Grip strength (N)	
Less affected hand	351.5 (122.0)
More affected hand	244.3 (113.9)
Ratio (more affected/less affected)	0.71 (0.28)
Isometric shoulder abduction (Nm)	
Less affected arm	46.5 (15.7)
More affected arm[a]	32.0 (17.5)
Ratio (more affected/less affected) [a]	0.70 (0.32)
Isometric elbow flexion (Nm)	
Less affected arm	51.9 (17.3)
More affected arm	40.1 (17.2)
Ratio (more affected/less affected)	0.78 (0.24)
Isokinetic elbow extension at 60°/s (Nm)	
Less affected arm	31.9 (10.7)
More affected arm[a]	22.9 (10.7)
Ratio (more affected/less affected) [a]	0.72 (0.25)
Isokinetic elbow flexion at 60°/s (Nm)	
Less affected arm	37.3 (12.9)
More affected arm[a]	28.5 (12.1)
Ratio (more affected/less affected) [a]	0.76 (0.22)

SD: standard deviation; Nm: Newton meter; N: Newton; [a]number of participants=44.

The correlations between the grip strength and the arm strength measurements were significant ($P < .0001$) for both the more affected upper extremity ($r = 0.77$ to 0.82) and the less affected upper extremity ($r = 0.65$ to 0.82) (Table 3).

Table 3. Pearson correlations (*r*) (95% CI) between grip strength and arm strength measures in the more and less affected arm (n=45)

Arm strength	Grip strength	
	More affected hand	Less affected hand
	Pearson's r (95% CI)	*Pearson's r (95% CI)*
Isometric shoulder abduction	0.80[**] (0.66 to 0.89)[a]	0.82[**] (0.69 to 0.90)
Isometric elbow flexion	0.82[**] (0.69 to 0.90)	0.77[**] (0.62 to 0.87)
Isokinetic elbow extension	0.77[**] (0.61 to 0.87)[a]	0.65[**] (0.44 to 0.79)
Isokinetic elbow flexion	0.81[**] (0.68 to 0.89)[a]	0.76[**] (0.60 to 0.86)

[a]number of participants=44; CI: confidence interval; [**]correlation is significant at the 0.01 level

Discussion

In this secondary analysis of data from our previous test-retest reliability study[7], we investigated the association between grip strength and isometric and isokinetic arm strength in the shoulder and elbow muscles in persons with mild to moderate paresis in the chronic phase after stroke. There were moderately strong to very strong correlations between the grip strength and the arm strength measurements for both the more affected and the less affected upper extremity.

The ratios between the more affected and the less affected upper extremity were similar for the shoulder, elbow and hand muscles (0.70 to 0.78). This underscores that the participants in our study were mildly to moderately affected in their upper extremity and that the weakness was approximately equally distributed in the muscles measured between the upper extremities. Our findings are thereby in agreement with other studies that have reported similar strength ratios and distribution of weakness in the shoulder, elbow and hand in the upper extremity after stroke.[5, 15, 16]

Among our participants, grip strength was strongly correlated (*r*) with arm strength (0.65 to 0.82). To the best of our knowledge only two studies have previously investigated the association between grip strength and arm muscle strength after stroke. Nascimento et al.[10] evaluated the association between grip strength and isokinetic muscle strength in the shoulder stabilizers (shoulder rotation, protraction and retraction). They found correlations (*r*) from 0.60 to 0.82, but their sample was very small (12 persons). Bohannon et al.[11] evaluated the association between grip strength and isometric arm strength measured by hand-held dynamometry in 26 persons with stroke in the acute phase. They reported correlations (*r)* from 0.74 to 0.86. Our results are in agreement with these results even if they differ with regard to which muscle groups that have been measured, the mode (isometric versus isokinetic) the sample size and time after stroke.

Measures of muscle strength in the upper extremity after stroke can be influenced by other common impairments, for example reduced somatosensory function, spasticity and synergistic movements, which can affect motor control. In particular, this applies to the isokinetic measurements as they are often more demanding to perform. In our previous test-retest reliability study we found that isokinetic arm strength measurements had somewhat larger measurement errors than the isometric strength measurements.[7] This suggests that it might be preferable to measure isometric strength as such measurements are more stable and easier to perform. Moreover, isometric grip strength measurements have the advantage of being simpler to obtain and less time consuming compared to arm strength measurements. In this study, we used a modern, wireless computerized dynamometer that has been found to be reliable when measuring isometric grip strength in persons with chronic stroke.[7] Hydraulic dynamometers have also been reported to be reliable, but computerized dynamometers give more stable measurements for persons with weak hands.[7, 17, 18]

Grip strength has been suggested as an important variable to measure after stroke. Boissy et al.[19] investigated grip strength in 15 persons with chronic stroke and demonstrated that the strength in the more affected hand was significantly associated with the degree of disability of the upper extremity. They also showed that persons with equal grip strength in the more affected hand had almost normal upper extremity function. Moreover, in longitudinal studies grip strength has been show to predict motor function in the upper extremity, in a short-term as well as a long-term perspective. [20, 21]

Taken together, as isometric grip strength is a stable measure, easy to perform and strongly associated with the arm strength, this indicates that grip strength could be a proxy for muscle weakness of the entire upper extremity in the chronic phase after stroke. However, future studies are needed to investigate the association between grip strength and arm strength in different phases after stroke and over time in order to establish if grip strength can be used to follow recovery and changes of upper extremity muscle strength after stroke.

A limitation of the present study was that only individuals with mild to moderate paresis in the upper extremity after stroke were included. In addition, we did not include persons with major cognitive impairments or difficulties to communicate, and more men than women volunteered to participate. Therefore, the results cannot be generalized to the entire stroke population. On the other hand, measurements of grip strength may not be applicable to all persons after stroke, for example those with excessive spasticity or severe paresis of the hand. One of the strengths of this study is that we measured 45 participants who were in a stable phase after stroke and that care was taken to standardize the entire test situation.

Conclusions

This cross sectional study showed that grip strength is strongly associated with muscle strength in the arm in persons in the chronic phase after stroke. As grip strength is easy to measure and less time consuming than arm muscle strength measurements, this implies that grip strength can be a representative measure of muscle weakness of the entire upper extremity in the chronic phase after stroke. However, future studies are needed to investigate the association between grip strength and arm strength in different phases and over time to determine if grip strength can be used as a proxy to follow upper extremity muscle strength after stroke.

Conflict of interest

No part of this work has been published elsewhere and is not under consideration for publication in any other journal. No conflict of interest exists. All authors approved the manuscript and its submission to the journal.

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