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Dynamometry for the Assessment of Grip, Pinch, and Trunk Strength in Subjects with Chronic Stroke: Reliability and Various Sources of Outcome Values

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Abstract

Background: Muscular weakness, commonly observed in individuals with stroke, is usually assessed with portable dynamometers. However, no studies were found which investigated the reliability of the dynamometry for the assessment of grip, pinch, and trunk strength in subjects with chronic stroke, nor which evaluated the best source of outcome values.

Objectives: To investigate the test-retest and inter-rater reliabilities of the portable dynamometer for the assessment of grip, pinch, and trunk strength in subjects with chronic stroke and to verify whether the use of various sources of outcomes (first trial, the means of two and three trials) affected the obtained values, as well as their reliabilities.

Methods: A methodological study with 47 (58.67 ± 14.79 years) and 38 (57.05 ± 16.23 years) subjects with chronic stroke was carried out to investigate test-retest and inter-rater reliabilities, respectively. Grip and pinch (pulp-to-pulp, palmar, and lateral) strength were bilaterally assessed, as well as the strength of the trunk flexors/extensors, lateral flexors, and rotators, with portable dynamometry by two independent examiners over two sessions, 1-4 weeks apart. One-way ANOVAs were employed to compare the values between the various sources of outcome values. Intra-class correlation coefficients (*ICCs*) were calculated to investigate the test-retest and inter-rater reliabilities for all sources of outcome values (α=0.05).

Results: For all muscular groups, similar results were found for all sources of outcome values ($0.01<F\leq0.15$; $0.85 \leq p \leq 0.99$), with significant and adequate values of test-retest ($0.58 \leq ICC \leq 0.97$) and inter-rater ($0.60 \leq ICC \leq 0.98$) reliabilities.

Conclusions: Only one trial, after familiarization, demonstrated adequate test-retest and inter-rater reliabilities to be clinically employed for the assessment of grip, and trunk strength in subjects with chronic stroke.

Keywords: Stroke; Dynamometer; Grip; Pinch; Trunk; Muscular strength assessment; Reliability

Abbreviations: UE: Upper Extremity; PTs: Physical Therapists; *ICC*: Intra-class Correlation Coefficient

Introduction

Stroke is a leading cause of chronic disability in adults [1]. Muscular weakness, which is a common motor impairment in subjects with stroke, is associated with limitations in activity performances of the upper extremity (UE) and trunk [2-5]. Therefore, the assessment of strength in individuals with stroke should be considered during rehabilitation [2].

Two devices commonly used to objectively assess muscular strength are the isokinetic and portable dynamometers [6]. Although the isokinetic dynamometer is the gold standard for measuring strength, its high costs and time to obtain the measures, make its use difficult within clinical settings [6]. For the stroke population, the applicability of isokinetic dynamometry becomes more restricted, since it sometimes requires adaptations of the test positioning to avoid compensatory movements [7]. Within this context, the portable dynamometer is the device mostly commonly used within clinical and research contexts to measure strength of subjects with stroke [8].

The portable dynamometer is very simple, easy to use, portable, and requires little time to apply [6]. It is also sensitive to detect important changes in strength [9] with adequate values of validity [6] and reliability [6,8,10] for the assessment of the following muscular groups in subjects with stroke: wrist, elbow, shoulder, hip, knee and ankle flexor/extensors; shoulder adductor/abductor and internal/external rotators; hip abductors; anterior and lateral trunk flexors; and grip strength [11].

Reliability is the first important pre-requisite of an assessment tool [12]. But, despite the large use of dynamometers, there were not found any studies which evaluated their measurement properties for the assessment of pinch and trunk extensor and rotator muscular groups in subjects with stroke [11].

Only four studies were found which investigated the reliability of the dynamometer for the measurement of grip and anterior or lateral trunk flexor strength in subjects with stroke [11], but these studies only evaluated test-retest reliability. In addition, three of these studies included subjects with stroke in the acute phase [11]. It is well recognized that subjects in the acute phase of the stroke may differ from those in the chronic stages [13] and that reliability is directly related to population characteristics [12]. Only one study was found which

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investigated the reliability of portable dynamometers for the assessment of grip strength in subjects with chronic stroke [14]. However, different types of devices were used (mechanical versus hydraulic devices) and it is well known that the dynamometric results are not interchangeable, particularly if their mechanisms are not similar [15].

The majority of the studies which assessed UE and trunk strength with portable dynamometry in subjects with stroke usually used the means of three trials [11]. However, no studies were found which investigated the effects of various sources of outcome values for the assessment of strength of the UE and trunk muscular groups and their measurement properties in subjects with stroke [11]. Furthermore, variations regarding the number of trials have been reported in the literature [16-19]. For example, if only one assessment trial proved to be reliable, this would rapidly improve the applicability and feasibility of dynamometry for the assessment of strength, considering that valuable time would be saved, besides avoiding muscular and general fatigue [16,17].

Therefore, the aims of this study were to evaluate the test-retest and inter-rater reliabilities of the portable dynamometry for the assessment of grip, pinch (pulp-to-pulp, palmar, and lateral), and trunk strength in subjects with chronic stroke and to investigate whether the use of various sources of outcomes (first trial, the means of two, and three trials) affected the values obtained with the portable dynamometry, as well as their reliabilities.

Methods

Subjects

To participate in this methodological study [12], subjects with stroke were recruited from the general community by screening out-patient clinics in university hospitals, based upon the following criteria: Had a time since the onset of the stroke of at least six months; were ≥ 20 years of age; demonstrated the ability to perform all of the tests; had no cognitive impairments, as determined by the cut-off scores on the Mini-Mental State Examination [20]; and demonstrated the ability to respond to the following commands: "lift your good arm and open your good hand" [21]. Subjects were excluded if they had pain complaints before or during the strength assessments, had bilateral hemiparesis, or other health conditions that could affect the strength of the hand and trunk.

Before data collection, eligible subjects were informed about the objectives of the study and provided consent, based upon approval from the university ethical review board. Demographic and clinical data were collected by trained physical therapists (PTs) for characterization purposes, which included: age, gender, type and time since the onset of stroke; paretic side; motor recovery, as determined by the scores on the Fugl-Meyer (UE section) [22,23]; and trunk performance, evaluated by the Trunk Impairment Scale [24]. The paretic UE was determined by scores above zero on the modified Ashworth scale of the elbow, wrist, and finger flexors [25] and/or decreased strength, compared to the non-paretic side. Some studies have established that trunk musculature has innervations from both cerebral hemispheres, although they are predominantly on the contralateral side [26]. Others suggested that motor impairments of the trunk in individuals with hemiparesis could occur on both sides and could be compensated by bilateral innervations [27]. Therefore, in the present study, for the trunk, the muscular groups were not named as paretic and non-paretic, but as right and left sides.

For all included subjects, it was planned to bilaterally evaluate the strength of the following muscular groups: Grip and pinch (pulp-to-pulp, palmar, and lateral); anterior trunk flexors/extensors, lateral flexors, and rotators. If the subject was not able to perform the test with a particular muscular group, this was not assessed. Therefore, the sample size could be different across the various assessed muscular groups.

Instrumentation

Strength measures were obtained with three portable dynamometers: Microfet2® digital hand-held dynamometer (Hoggan Health Industries, UT, USA), SAEHAN® hydraulic handgrip dynamometer (SAEHAN Corporation, Korea, Model SH5001), and the SAEHAN® hydraulic pinch dynamometer (SAEHAN Corporation, Korea, Model SH5005). All dynamometers were new and were calibrated according to the manufacturers' manual.

Procedures

All the strength assessments were independently performed by two previously trained PTs (examiners 1 and 2), who adopted the same procedures. The measures obtained at the first day by examiners 1 and 2, were used to investigate the inter-rater reliability. Re-assessments were carried out one to four weeks apart by the examiner 1, to investigate the test-retest reliability. A third examiner was responsible for reading and recording all data, so that both examiners 1 and 2 were blinded regarding the obtained values [12]. No feedback nor further discussions were allowed between the examiners. Proper positioning and stabilization was provided to avoid compensatory movements, and all verbal encouragements were standardized.

Prior to data collection, demonstration and familiarization trials of all procedures were allowed [28]. Then, the subjects were asked to perform a maximal isometric force against the dynamometer during five seconds and the peak values were recorded. Three trials were performed for each assessed muscular group with 15 to 20 second rest intervals to avoid fatigue [11]. The trials were alternated performed and always started with the non-paretic side, whereas for the trunk muscles, the trials were alternately between the right and left sides.

To obtain the grip and pinch strength measurements, the subjects were positioned following recommendations provided by the American Society of Hand Therapists [29]: They sat on a chair, upright, with their feet flat and hips and knees flexed to approximately 90°, shoulders adducted, elbows flexed to 90°, forearms in a neutral position and wrists in 0 to 30° of extension. The dynamometer and the tested UE were sustained by the examiner and the untested hand rested over the ipsilateral thigh.

The strength of the following trunk muscles was bilaterally assessed: Anterior flexor/extensors, lateral flexors, and rotators using the Microfet2® hand-held dynamometer. For the assessments, the subjects' positioning, stabilization, and resistance application followed procedures described by Bohannon et al. [30], except for the trunk extensor and rotator muscles. To perform the assessment of the lateral trunk flexors and rotators, the subjects' feet and back were supported. For the anterior trunk flexor/extensors, only the feet were supported. For the lateral trunk flexors, the resistance was applied below the acromion of the scapula. The trunk rotators were assessed in the same position used for the lateral flexors, and the resistance was applied over the coracoid process of the scapula on the contralateral side. To evaluate the anterior trunk flexors, the resistance was applied on the body of the sternum, whereas for the trunk extensors, over the spinal process of the 1st thoracic vertebra.

Statistical analyses

Descriptive statistics and tests for normality (Shapiro-Wilk) were

carried out for all outcomes. *One-way* ANOVAs were used to compare the values obtained using the various sources of outcome values (first trial and means of two and three trials), considering the values obtained by the first examiner. Intra-class correlation coefficients (*ICCs*) were calculated to investigate the test-retest and inter-rater reliabilities, which were classified as follows: very low=0-0.25; low=0.26-0.49; moderate=0.50-0.69; high=0.70-0.89; and very high=0.90-1.00 [31]. All analyses were performed with the SPSS® for Windows, release 15.0 (SPSS Inc., Chicago, IL) with a significance level of 5%.

Results

Forty-seven subjects with chronic stroke (24 men and 23 women) with a mean age of 58.67 ± 14.79 years (ranging between 30 to 86) and a mean time since the onset of the stroke of 96.20 ± 74.30 months (ranging between six and 371), were assessed for the test-retest reliability. Thirty-eight subjects (19 men and 19 women) with a mean age of 57.05 ± 16.23 years (ranging between 25 to 86) and a mean time since the onset of the stroke of 93.47 ± 75.42 months (ranging between six and 371) were assessed for the inter-rater reliability. Their demographic and clinical characteristics are reported in Table 1.

Table 2 provides the descriptive statistics, as well as the ANOVA results of the comparisons between the various sources of outcome values for all of the assessed muscular groups. As given in Table 2, the values provided by all sources of outcome values were similar for all assessed muscular groups ($0.01<F\leq 0.15$; $0.85\leq p\leq 0.99$).

Table 3 provides the *ICC* values for the test-retest and inter-rater reliabilities for all assessed muscular groups, considering the various sources of outcome values. Regarding the test-retest reliability, all measures showed significant and high to very high *ICC* values for both the non-paretic ($0.71\leq ICC\leq 0.95$; $p\leq 0.001$) and paretic ($0.72\leq ICC\leq 0.97$; $p\leq 0.001$) UE and trunk muscles ($0.72\leq ICC\leq 0.91$; $p\leq 0.001$), except for the first trial of the pinch strength (pulp-to-pulp, palmar, and lateral) ($0.58\leq ICC\leq 0.65$; $p\leq 0.003$), which showed moderate values of reliability (Table 3). For the inter-rater reliability, all sources of outcomes significant and high to very high *ICC* values for both the non-

Variables	Test-retest reliability *(n=47)*	Inter-rater reliability *(n=38)*
Age (years): mean (SD); range [min-max]	58.67 (14.79); [30-86]	57.05 (16,23); [25-86]
Time since the onset of stroke (months): mean; range [min-max]	96.20 (74.30); [6-371]	93.47 (75.42); [6-371]
Body mass index (kg/m2): mean (SD); range [min-max]	28.84 (4.43); [17.29-38.39]	27.19 (4.78); [17.29-38.00]
Gender		
Men: number (percentage)	24 (51.1%)	20 (52.6%)
Women: number (percentage)	23 (48.9%)	18 (47.4%)
Paretic Side		
Right: number (percentage)	26 (55.32%)	19 (50%)
Left: number (percentage)	21 (44.68%)	19 (50%)
Type of stroke		
Ischaemic: number (percentage)	37 (78.72%)	30 (79%)
Haemorrhagic: number (percentage)	6 (12.77%)	4 (10.5%)
Ischaemic and Haemorrhagic: number (percentage)	4 (8.51%)	4 (10.5%)
Upper limb motor impairment (Fugl-Meyer Scale), score (0-66)	-	-
Mild motor impairments: number (percentage)	33 (70.20%)	21 (55.30%)
Moderate motor impairments: number (percentage)	7 (14.90%)	8 (21.10%)
Severe motor impairments: number (percentage)	7 (14.90%)	9 (23.70%)
Trunk impairment scale: median (IQR), score (0-23)	16.5 (11)	17.5 (13)

SD: Standard Deviation; IQR: Interquartile Range

Table 1: Subjects' demographic and clinical characteristics regarding the test-retest and inter-rater reliabilities.

Muscular groups (n)	First trial	Means of two trials	Means of three trials	ANOVA (F; p)
Non-paretic upper extremity				
Hand grip (29)	26.41 ± 8.67	27.07 ± 8.57	26.99 ± 8.42	0.05; 0.95
Pulp-to-pulp pinch (29)	5.36 ± 1.76	5.40 ± 1.63	5.39 ± 1.56	<0.001; 1.00
Palmar pinch (29)	5.55 ± 1.77	5.59 ± 1.67	5.56 ± 1.59	0.01; 0.99
Lateral pinch (29)	6.66 ± 2.02	6.64 ± 1.92	6.54 ± 1.90	0.03; 0.97
Paretic upper extremity				
Hand grip (25)	18.08 ± 7.45	17.80 ± 7.27	17.46 ± 7.02	0.05; 0.96
Pulp-to-pulp pinch (21)	3.21 ± 1,45	3.19 ± 1.24	3.17 ± 1.23	0.01; 1.00
Palmar pinch (19)	3.53 ± 1.38	3.46 ± 1.20	3.46 ± 1.17	0.02; 0.98
Lateral pinch (23)	4.54 ± 1.68	4.57 ± 1.68	4.54 ± 1.68	<0.001; 1.00
Trunk				
Anterior trunk flexors (33)	11.58 ± 4.47	11.38 ± 4.46	11.38 ± 4.49	0.02; 0.98
Trunk extensors (34)	14.69 ± 5.54	14.80 ± 5.58	14.75 ± 5.61	<0.001; 0.99
Right lateral trunk flexors (34)	9.77 ± 3.71	9.69 ± 3.70	9.67 ± 3.77	<0.001; 0.99
Left lateral trunk flexors (34)	10.24 ± 3.87	10.18 ± 3.90	10.10 ± 3.85	0.01; 0.99
Right trunk rotators (33)	8.59 ± 3.32	8.60 ± 3.43	8.61 ± 3.40	<0.001; 0.99
Left trunk rotators (33)	7.83 ± 3.25	8.18 ± 3.35	8.25 ± 3.37	0.15; 0.85

SD: Standard deviation

Table 2: Descriptive data (means ± SD) and ANOVA results regarding the comparisons between the various sources of outcome values for strength assessment of both the non-paretic and paretic upper extremities and trunk with portable dynamometry (kgf).

Muscular Groups	Test-retest reliability				Inter-rater reliability			
	n	First trial	Means of two trials	Means of three trials	*n*	First trial	Means of two trials	Means of three trials
Non-paretic upper extremity								
Hand grip	29	0.92*	0.95*	0.95*	30	0.92*	0.97*	0.97*
Pulp-to-pulp pinch	29	0.84*	0.89*	0.91*	30	0.91*	0.94*	0.94*
Palmar pinch	29	0.71*	0.89*	0.90*	30	0.74*	0.88*	0.91*
Lateral pinch	29	0.79*	0.90*	0.89*	30	0.88*	0.92*	0.93*
Paretic upper extremity								
Hand grip	25	0.88*	0.96*	0.97*	25	0.90*	0.97*	0.98*
Pulp-to-pulp pinch	21	0.58***	0.84*	0.84*	20	0.62**	0.83*	0.84*
Palmar pinch	19	0.64*	0.76*	0.79*	15	0.87*	0.93*	0.91*
Lateral pinch	23	0.65*	0.84*	0.86*	23	0.84*	0.94*	0.96*
Trunk								
Anterior trunk flexors	33	0.74*	0.83*	0.86*	22	0.71*	0.85*	0.86*
Trunk extensors	34	0.80*	0.88*	0.88*	22	0.69*	0.85*	0.85*
Right lateral trunk flexors	34	0.78*	0.88*	0.89*	22	0.77*	0.89*	0.90*
Left lateral trunk flexors	34	0.72*	0.86*	0.85*	22	0.80*	0.89*	0.89*
Right trunk rotators	33	0.80*	0.91*	0.91*	21	0.73*	0.85*	0,85*
Left trunk rotators	33	0.75*	0.89*	0.89*	22	0.60**	0.73***	0.75**

*$p \leq 0.001$; **$p=0.002$;***$p=0.003$

Table 3: Intra-class correlation coefficients for the test-retest and inter-rater reliabilities for the strength assessment of both the non-paretic and paretic upper extremities and trunk with portable dynamometers (Kgf) considering various sources of outcome values.

paretic ($0.74 \leq ICC \leq 0.97$; $p \leq 0.001$) and paretic ($0.70 \leq ICC \leq 0.98$; $p \leq 0.001$) UE and trunk muscles ($0.71 \leq ICC \leq 0.90$; $0.001 \leq p \leq 0.003$), except for the first trial of the trunk extensors, left trunk rotators, and pulp-to-pulp pinch ($0.60 \leq ICC \leq 0.69$; $p=0.002$), which demonstrated moderate values of reliability (Table 3).

Discussion

This was the first study to report the reliability of the portable dynamometry for the assessment of strength of the trunk extensors/rotators and pinch in subjects with chronic stroke. Furthermore, this study was also the first to investigate if the various sources of outcome values affected the values obtained with the dynamometers, as well as their reliability. The results of the present study showed that the portable dynamometers provided adequate values of test-retest and inter-rater reliabilities for the bilateral assessment of grip, pinch, and trunk strength of subjects with chronic stroke. The values obtained with various sources of outcomes, i.e., the first trial and the means of two or three trials, were similar for all assessed muscular groups. Therefore, the present results supported the use of only one dynamometric trial, after familiarization for the assessment of grip, pinch, and trunk strength in subjects with chronic stroke.

Considering that *ICC* is most recommended for reliability analyses, since it reflects both the correlations and agreements between the ratings, the present results were compared only with those of prior studies which provided *ICC* values to report reliability. Boissy et al. [14] investigated the test-retest reliability of a portable dynamometer for the assessment of grip strength in subjects with chronic stroke. High to very high reliability coefficients were found for the non-paretic (*ICC*=0.86) and paretic (*ICC*=0.91) sides, which were similar to the present results ($0.88 \leq ICC \leq 0.97$). However, no studies were found regarding the investigation of the test-retest reliability of the portable dynamometers for the pinch and trunk strength with stroke subjects [11]. Abizanda et al. [19] investigated the test-retest reliability of the dynamometer for the assessment of pinch strength of the dominant UE of 281 independent community-dwelling elderly and found *ICC* of 0.98, whose value was similar to that found in the present study for both the paretic and non-paretic UE ($0.79 \leq ICC \leq 0.97$).

According to a previous literature review, there were not found any studies which investigated the inter-rater reliability of the portable dynamometry for the assessment of grip or pinch strength in subjects with chronic stroke [11]. Bohannon et al. investigated the inter-rater reliability of the portable dynamometers for the assessment of the strength of the anterior and lateral trunk flexors with subjects in the acute phase of stroke and reported high values of reliability ($0.80 \leq ICC \leq 0.82$) [30]. In the present study, similar *ICC* values ($0.71 \leq ICC \leq 0.90$) were found for the inter-rater reliability for all measures of the anterior and lateral trunk flexor muscles.

Other studies investigated the reliability of portable dynamometry for the assessment of trunk strength with other populations. Larson et al. [32] investigated the inter-rater reliability of the portable dynamometer to assess the anterior trunk flexors, extensors and lateral flexors of 29 individuals with spinal cord injuries and reported very high inter-rater reliability coefficients ($0.96 \leq ICC \leq 0.99$) [32]. The present results also demonstrated high to very high values of inter-rater reliability for the same muscle groups for all sources of outcome values ($0.71 \leq ICC \leq 0.90$), except for the first trial of the trunk extensors, which demonstrated a moderate reliability coefficient (*ICC*=0.69). Another study, which investigated the inter-rater reliability of portable dynamometry for the assessment of the lateral trunk flexors of 12 healthy athletes, found high reliability coefficients ($0.79 \leq ICC \leq 0.88$) [33], which were similar to those found in the present study for all sources of outcome values ($0.77 \leq ICC \leq 0.89$), except for the mean of the three trials of the right lateral trunk flexors (*ICC*=0.90).

Coldham et al. [16] showed that only one trial of maximal grip strength was as reliable as the mean of three trials, and had also the advantage of being less tiring, when measuring strength of subjects following carpal tunnel decompression, flexor tendon repair, and even in asymptomatic subjects. Kennedy et al. [17] investigated the test-retest reliability of grip strength in subjects with rheumatoid arthritis, and also reported that the use of only one trial provided similar values and it was as reliable as the mean of three trials. Abizanda et al. [19] compared the first, second, and third trials of grip and pinch strength in elderly subjects, and concluded that when muscular strength is measured with

the dynamometer, only one trial was sufficient. The test-retest reliability of various sources of grip strength trials in a group of older adults was assessed by Wang and Chen [18], who found acceptable results when the best, the mean, or the first of two trials were used.

The findings of the present study also demonstrated that one trial of grip, pinch, or trunk strength was as reliable as the means of two or three trials and the obtained values were similar. The fact that only one trial demonstrated to be sufficiently accurate and consistent for the measurement of maximum grip, pinch, and trunk strength, increases the clinical applicability of the dynamometric measurements, since less time is required to be performed and moreover, the subjects will be exposed to less discomfort. In addition, fatigue, boredom, loss of attention, and frustration may become problems with the use of multiple measures for subjects with stroke [34]. By requiring that subjects perform multiple trials, it might exclude the least able subjects, who may be able to perform a test just once, but could not do it multiple times [34].

Conclusions

The dynamometric measures showed adequate values of test-retest and inter-rater reliabilities for the assessment of grip, pulp-to-pulp, palmar, and lateral pinch, as well as trunk strength, when applied to individuals during the chronic phase of stroke, regardless of the sources of the outcome values. Only one trial, after familiarization, was sufficient to produce reliable results.

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