■ **ORIGINAL ARTICLE**

Reliability of a hand-held dynamometer in muscle strength measurement in stroke patients

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ABSTRACT: The purpose of this study was to investigate the reliability of a hand-held dynamometer (HHD) with a belt in the measurement of paretic and non-paretic limb muscle strength of hemiplegic patients. Forty-six stroke patients (men: 25, women: 21; mean age: 68.6 years [SD 11.4]) participated in this study. Of the 46 patients, 34 were hemiparetic on the right side, and 12, on the left side. The mean time since onset of hemiplegia was 100.9 days. The paretic and non-paretic limb muscle strength and the lower limb Brunnstrom stage were determined. The quadriceps muscle strength, which was measured using a HHD with a belt, was used an estimate of the lower limb muscle strength. The test and retest values of paretic limb muscle strength were 13.6 kgf and 15.1 kgf, respectively, and the interclass correlation coefficient (ICC) was 0.955 ($p < 0.05$). The test and retest values of non-paretic limb muscle strength were 24.6 kgf and 25.9 kgf, respectively, and the ICC was 0.925 ($p < 0.05$). Therefore, in the present study, we found that using a belt with the HHD improved the reliability of the measurement of paretic and non-paretic limb muscle strength.

Key words: stroke, muscle strength of the paretic limb, Hand-held dynamometer

INTRODUCTION

A stroke is accompanied by decrease in the muscle strength of the paretic and non-paretic limbs, motor paralysis, and sensory disturbance. Many studies [1,2] have shown that knee muscle strength in the paretic limb is significantly associated with gait performance and the ability to climb up and down stairs; thus, lower limbs muscle strength is important for independence in activities of daily living.

The use of isokinetic dynamometry for muscle strength measurement in stroke patients has been reported in many studies [3-5]; it is considered an effective and reliable method for assessing the outcome of rehabilitation and relief of problems in stroke patients. However, the expense and inconvenience involved have limited the use of the heavy dynamometer in hospitals and other institutions. On the other hand, a hand-held dynamometer (HHD) is cheap and convenient to use, but the level of muscle strength that can be measured depends on the measurer who uses his strength to hold the sensor completely still against the force applied by the subjects [6]. Therefore, accurate muscular strength measurement in subjects with high muscular strength is difficult when using an HHD.

The Katoh et al. [7] reported that when a belt was used for fixing the HHD provided highly reliable measures of lower limb muscle strength in healthy subjects. Reliable muscle strength-measurement methods would be useful for assessing the outcome of rehabilitation and relief of problems in stroke patients.

The purpose of this study was to investigate the reliability of an HHD with a belt in the measurement paretic and non-paretic limb muscle strength in hemiplegic patients.

MATERIALS AND METHODS

SUBJECTS

Forty-six individuals who suffered a stroke following their first known cerebrovascular accident were enrolled in this study; informed consent was acquired from each subject. Of the 46 patients (men: 25, women: 21; mean age: 68.6 years [SD 11.4]), 34 were hemiparetic on the right side, and 12, on the left. The mean time since onset of hemiplegia was 100.9 days (81.0). Thirty-two patients developed hemiparesis after cerebral infarction, and 14, after cerebral hemorrhage. The mean weight was 55.5 (10.3) kg and the mean height was 156.9 (8.8) cm.

Patients with pain in the lower extremities, unstable medical conditions, high cortical function disorder, or other diagnosed neurologic or musculoskeletal diseases were excluded. Patients in Brunnstrom stage I-II were also excluded because they were unable extended their knees from the position of 90 degrees flexion.

METHODS

Paretic and non-paretic limb muscle strength and the lower limb Brunnstrom stage were determined. Subjects who on examination were found to be in poor physical condition were examined by a doctor.

The quadriceps muscle strength was measured according to the method of Katoh et al [7]. Quadriceps muscle strength, which was measured using an HHD (ANIMA, μ-Tas MF-01), was used as an estimate of the lower limb muscle strength. The HHD had a measuring range of 0.0–80.0 kgf with a precision of 0.1 kgf. The patients were asked to sit upright on a mat platform, with their upper limbs crossed in front of the chest, without back support, and knees flexed at 90°. The dynamometer was attached to the front of the distal crus (Fig 1). A physical therapist was always kept present when taking measurement in subjects with poor balance. We ensured that help was provided should the subjects lose their

Fig. 1 Subject's position for testing the muscle strength of limb

balance. The patients were then asked to perform 2 maximal isometric contractions of the quadriceps (test and retest) for 5 seconds, with a time interval of >30 seconds between recordings. The lower limb muscle strength (kgf/kg) was determined by dividing the higher of the 2 values (kgf) by body weight (kg).

Motor paralysis was evaluated using Brunnstrom 6 recovery stages [8, 9], which are defined as follows: stage I, flaccid paralysis; stage II, increased muscle tone without active movement; stage III, increased muscle tone with active movements, mainly in rigid extension synergy; stage IV, increased muscle tone with alternating gross movements in extension and flexion synergies; stage V, normal muscle tone with some degree of selective muscle control; and stage VI, normal muscle tone and control.

Spearman's rank-order correlation was used to determine whether a significant relation existed between paretic limb muscle strength and the lower limb Brunnstrom stage. In order to determine the reliability of the measurements, the intra-class correlation coefficient (ICC) between the mean test and retest values of paretic and non-paretic limb muscle strength was determined. The results were considered statistically significant when $P < 0.05$.

RESULTS

The mean test and retest values of paretic limb muscle strength were 13.6 (9.6) kgf (range, 1.0-36.3) and 15.1 (11.1) kgf (range, 0.9-47.1), respectively, and the mean test and retest values of non-paretic limb muscle strength were 24.6 (12.6) kgf (range, 2.9-55.8) and 25.9 (12.2) kgf (range, 3.7-49.0), respectively. In the male patients, the mean test and retest values of paretic limb muscle strength were 17.6 (10.3) kgf (range, 1.3–36.3) and 19.3 (12.3) kgf (range, 1.0–47.1), respectively, and the mean test and retest values of non-paretic limb muscle strength were 30.0 (13.2) kgf (range, 11.3–55.8) and 31.6 (12.1) kgf (range, 11.4–49.0), respectively. In the female patients, the mean test and retest values of paretic limb muscle strength were 9.0 (6.2) kgf (range, 1.0–24.7) and 10.2 (6.9) kgf (range, 0.9–26.9), respectively, and the mean test and retest values of non-paretic limb muscle strength were 18.2 (8.2) kgf (range, 2.9–30.9) and 19.2 (8.5) kgf (range, 3.7–34.3), respectively.

The ICC between the test and retest values of paretic limb muscle strength was 0.96 (ICC range, 0.92–0.98; $P < 0.05$), and the ICC between the test and retest values of non-paretic limb muscle strength was 0.93 (ICC range, 0.87–0.96; $P < 0.05$).

The paretic limb muscle strength of the subjects were as follows: 0–10 kgf = 16, 11–20 kgf = 18, 21–30 kgf = 8, >31 kgf = 4. The non-paretic limbs muscle strength of the subjects were as follows: 0–10 kgf = 3, 11–20 kgf = 12, 21–30 kgf = 14, >31 kgf = 17.

The relationship between paretic limb muscle strength and lower limb Brunnstrom stage is reported in Fig 2. The results indicate that paretic limb muscle strength is correlated with lower limb Brunnstrom stage ($r = 0.49$, $P < 0.05$). The lower limb Brunnstrom stages of

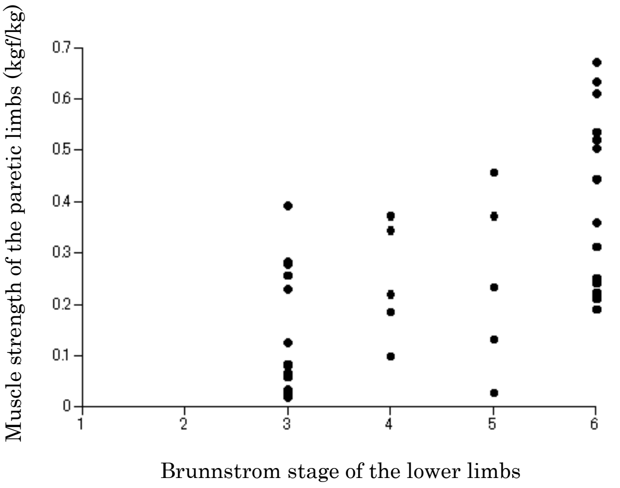

Fig.2 Scatterplot demonstrates the relationship between muscle strength of the paretic limbs and Brunnstrom stage of the lower among 46 stroke patients.

the subjects were as follows: stage III = 14, stage IV = 6, stage V = 8, and stage VI = 18. The range of the lower limb muscular strength for each lower limb Brunnstrom stage was as follows: stage III = 1.0–23.8 kgf, stage IV = 4.6–25.2 kgf, stage V = 1.8–28.2 kgf, and stage VI = 7.0–47.1 kgf.

DISCUSSION

The purpose of this study was to investigate the reliability of the HHD with a belt in the measurement of the paretic and non-paretic limb muscle strength of hemiplegic patients. In the present study, the obtained measures of paretic and non-paretic limbs muscle strength of hemiplegic patients were highly reliable.

Bohannon [10] reported ICC of 0.981 for knee extension torque measurements of the paretic and non-paretic limb obtained with a Cybex. Hsu [11] found that the ICCs for the muscle strength for non-paralytic-side knee extension of a 30° peak torque level, paralytic-side knee extension of a 30° peak torque level, non-paralytic-side knee extension of a 90° peak torque level, and paralytic-side knee extension of 90° peak torque level were 0.86, 0.91, 0.94, and 0.91, respectively. Thus, the heavier and more expensive dynamometer provides highly reliable measures of muscle strength. Katoh et al. [7] examined the intrarater reliability of an HDD with a belt in healthy subjects and found that the ICC was 0.937; they suggested that a cheap, simple, and easy-to-use HDD with a belt could also provide reliable measurement of muscle strength. In the present study, the ICC of both, the paretic and non-paretic limb muscle strength in hemiplegic patients, was 0.96 and 0.93, respectively. Therefore, as reported in the preliminary research with healthy subjects, an HHD with a belt provides highly reliable measurements of the muscle strength. The reliability of the HHD with a belt was similar to that of isokinetic dynamometer.

Hyde et al. [6] found that most physiotherapists were able to offer a maximum resistance force of only up to 30 kgf. Clark [12] and Wiles et al. [13] reported that manual fixation of the HDD is difficult at muscle strengths of approximately 27 kgf and >30 kgf, respectively. Yamazaki et al. [14] reported that the mean maximal fixed force against a knee extension force was 27.6 kgf and 19.0 kgf in men and women, respectively; the lower limit of the minimal fixed force (11.0 kgf) in women was lower than that reported in other studies. In the present study, paretic limb and non-paretic limb muscle strength of >11 kgf was found in 30/47 subjects and 43/47 subjects, respectively, and the subjects that fixation was difficult in measurers of women were included a lot. The muscular strength of the paralytic-side lower limb was lower than that in the non-paralytic-side lower limb in stroke patients; however, manual fixation was difficult in some patients. If the subjects have high muscular strength, manual fixation may lower the reliability of the measurement. In the present study, we found that using a belt increased the reliability of the measurement of paretic and non-paretic limb muscle strength.

Because knee extension was restricted in patients of lower limbs Brunnstrom stage I and II, we were unable to include them in this study. We believe this is a limitation of our study. Therefore, patients with Brunnstrom stage I and II in the lower limbs should use alternative methods for measurement of muscle strength such as measure of the leg press force when performing a knee extension of 60 degrees in the supine position [15].

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