

# Test-retest Reliability of Isometric Knee Extension Muscle Strength Measurement using a Hand-held Dynamometer and a Belt: Study of Hemiplegic Patients

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**Abstract.** [Purpose] The purpose of this research was to study the test-retest reliability of three continuous sets of measurements of isometric knee extension muscle strength of hemiplegic patients, using a handheld dynamometer (HHD) and a belt. [Subjects] The subjects were 26 hospitalized hemiplegic patients (12 men, 14 women) with an average age of 62.4 years. [Method] The subjects sat on a mat table, and three sets of measurements were taken, at intervals of 30 seconds, of isometric knee extension muscle strength with the knee joint at a flexion angle of 90 degrees using an HHD and a belt. The measurements were also taken in a second session on a different day. Reliability was examined using the intraclass correlation coefficient (ICC (1,1)) and multiple comparison as a post-hoc test of one-way variance through repeated measurement. [Results] The ICC of the measurement values taken on the same day on the paralyzed side was 0.98, while in Session 2 it was 0.99; on the non-paralyzed side, it was 0.98 in Session 1 and in Session 2 it was 0.99. On the paralyzed side, main effect was seen in Session 2; the values of the first measurement were significantly smaller than the values of the second and third measurements. And, the highest values were obtained from the third measurement. [Conclusion] The ICC results show the test-retest reliability was high in both sessions. We thought it would be sufficient for measurements to be conducted three times, taking the highest values of those three.

**Key words:** Hand-held dynamometer, Isometric knee joint extension muscle strength, Reliability

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## INTRODUCTION

The hand-held dynamometer (HHD) is a small tool that enables relatively simple quantitative muscle strength measurement. However, research into the reliability of measurement using a HHD has not produced consistent results<sup>1–10)</sup>. Katoh et al. investigated isometric lower limb muscle strength measurement (hip flexion and extension, abduction, adduction, external rotation, internal rotation, knee flexion and extension, and ankle plantar and dorsal flexion) of young healthy male and female subjects (average age: 20 years). They examined the test-retest reliability of two examiners (one man and one woman) who made measurements with the HHD fixed in the hand of the examiners, and measurements with the HHD fixed by a belt. The intraclass correlation coefficients (ICC) among the examiners ranged from 0.88 to 0.21 for manual measurement, and from 0.99 to 0.97 when fixed with a belt, showing a high degree of reliability among examiners when using the belt for fixation<sup>11)</sup>. Katoh et al. also measured in measurement of isometric lower limb muscle strength using

a belt and a HHD, and examined the test-retest reliability with young healthy male and female subjects, average age of 21.9. They found a wide range of ICC, from 0.75 to 0.97, in the first and second measurements, but for knee extension a high reliability of 0.94–0.96 was found<sup>12)</sup>. Katoh et al. also measured isometric knee muscle strength using an HHD in conjunction with a belt, and examined the test-retest reliability with 183 healthy elderly male and female subjects, average age of 70.5 years. They reported ICCs ranging from 0.85 to 0.92 for the 1<sup>st</sup> and 2<sup>nd</sup> measurements, a comparatively high reliability for the elderly<sup>13)</sup>. However, in the studies conducted by Katoh et al., all of the subjects were healthy persons, and the reliability for subjects with health problems was not investigated.

In the present research, we examined the test-retest reliability in the three continuous sets of measurements of isometric knee extension muscle strength, using a belt in conjunction with an HHD. Measurement sets were made on two separate occasions, and the subjects were hemiplegic patients.

**Table 1.** BRS of the subjects in each session

BRS	Session 1 (each)	Session 2 (each)
I	5	0
II	7	3
III	5	8
IV	6	4
V	3	9
VI	0	2

BRS: Brunnstrom-recovery-stage.

## SUBJECTS AND METHODS

The subjects were 26 hospitalized hemiplegic patients (12 men, 14 women) who had no impairment of consciousness or other higher cerebral dysfunction such as aphasia. For all subjects it was the first time for the onset of symptoms, and the diagnosis was cerebral hemorrhage (15 patients) or cerebral infarction (11 patients). The paralyzed side was the left side for 13 subjects and the right side for 13 subjects, and subjects' average age was 62.4 years (SD = 8.1 years). Subjects' Brunnstrom-recovery-stage (BRS)<sup>(14)</sup> on the day of measurement ranged from I to V in Session 1, and from II to VI in Session 2 (Table 1). There were no subjects with arthralgia or orthopedic problems in any joint of their lower limbs. Measurements were conducted after explaining the objective and contents of this research to the subjects and receiving their consent.

The HHD used for the isometric muscle strength measurement was a  $\mu$ Tas MF-01 (Anima Co., Tokyo). The surfaces of the metal sensors on the HHD were covered with rubber pads. The surface fasteners attached to the sensor part were used to fix the sensors to the measurement areas. A buckle was attached to the belt that fixes the sensors, enabling the length of the belt to be adjusted. Also, there was a plate holding the sensors in place. The range of measurement of the device was 0.0–80.0 kgf and the device was adjusted so that the margin of error was 0.1 kgf or less.

The subjects sat on a mat table, and the position of their buttocks was adjusted so that their leg on the bed was in a position behind the lower limb that was to be measured. The

mat table had a height such that when the subjects sat on it both their feet were slightly off the floor. The subjects kept their trunks vertical and placed both their hands on top of the mat table, at the sides of their trunks. The examiners laid out the bath towels that had been folded under the subjects' popliteal fossa to keep the subjects' thighs horizontal and with the lower limbs vertical. In this position the subjects' knee joints were flexed at an angle of 90 degrees. The HHD sensor was placed on the anterior surface of the distal portion of the lower thigh anterior surface, and the lower edge of the sensor was fixed with a surface fastener at the height of the upper edge of the malleolus medialis. Then, the limb to be measured, on which the sensor had been put, and the leg of the bed were linked and fixed. Isometric exercise comprising knee joint extension for a period of about five seconds using maximum possible effort was conducted three times, with an interval of at least 30 seconds between each measurement. To ensure that at the time of measurement the sensor surface was aligned in the opposite direction to the direction of the exercise, the examiner held both sides of the sensor and maintained the direction of the sensor. For patients who could not maintain a stable sitting position, measurement was conducted by having an assistant stabilize the patient's trunk. No practices were conducted, and after explaining the method, three sets of measurements were taken.

After an interval of about a month, the second session took place. The average number of days since the onset of symptoms was 12.4 (SD=9.4) in Session 1, and 43.5 (SD=11.6) in Session 2. Measurement for each test was conducted by the examiner, who was not fully informed of the details of the research. The examiner was a female physiotherapist who had mastered this measurement method (experience of using it: 6 years, height: 160.0 cm, weight: 45.0 kg).

When the measurement value on the paralyzed side was 0 kgf it was omitted from the analysis. The test-retest reliability of the three measurements taken on the same day was investigated, using the intraclass correlation coefficient [ICC (1, 1)] and analysis by multiple comparison (Bonferroni) as a post-hoc test of one-way variance through repeated measurement (paired factors). For statistics, SPSS ver. 15.0J for Windows (SPSS Japan Inc., Tokyo) was used.

**Table 2.** Isometric lower limb muscle strengths of hemiplegic patients as measured by a hand-held dynamometer fixed with a belt

	Session	n	Average values of knee extension muscle strength*			ICC(1,1)
			1st time	2nd time	3rd time	
Paralyzed side	Session 1	17	10.7 (10.5)	11.1 (11.9)	11.5 (12.6)	0.98 [0.96–0.99]
	Session 2	25	10.7 (9.7)	11.6 (10.1)	11.8 (10.1)	0.99 [0.98–0.99]
Non-paralyzed side	Session 1	26	20.6 (13.6)	20.9 (12.8)	21.0 (12.9)	0.98 [0.97–0.99]
	Session 2	26	25.5 (12.7)	26.3 (12.6)	25.5 (12.2)	0.99 [0.97–0.99]

\*: mean(SD); kgf. ICC: interclass correlation coefficient. [–] : 95%CI.

P values of less than 5% were considered significant.

## RESULTS

In Session 1 nine subjects (BRS I: five subjects, BRS II: four subjects) and in Session 2 one subject (BRS II) had a measurement value of 0 kgf on the paralyzed side. These values were omitted from the analysis. The subjects' average isometric knee extension muscle strength measurement values were, in the order of their 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> measurements on the paralyzed side, 10.7 kgf, 11.1 kgf, and 11.5 kgf in Session 1, and 10.7 kgf, 11.6 kgf, and 11.8 kgf in Session 2, while on the non-paralyzed side they were 20.6 kgf, 20.9 kgf, and 21.0 kgf in Session 1, and 25.5 kgf, 26.3 kgf, and 25.5 kgf in Session 2 (Table 2). For the three sets of measurement values on the same day, the ICC was 0.98 on the paralyzed side in Session 1, and 0.99 in Session 2, and 0.98 on the non-paralyzed side in Session 1, and 0.99 in Session 2.

The one-way variance analysis through repeated measurement (paired factors) gave results on the paralyzed side of  $F(2,32)=0.960$ ,  $p=0.394$  in Session 1 and  $F(2,48)=10.835$ ,  $p=0.000$  in Session 2, and on the non-paralyzed side of  $F(1,385,34.662)=0.413$ ,  $p=0.591$  in Session 1, and  $F(1,322,33.042)=2.832$ ,  $p=0.092$  in Session 2. They showed a significant result in Session 2 on the paralyzed side. In multiple comparison of Session 2 of the paralyzed side, significant differences ( $p<0.01$ ) were found between the first and second measurements, and between the first and third measurements, and the values of the first measurement were small.

## DISCUSSION

We found that in the three same-day measurements, for both the paralyzed and the non-paralyzed sides, the ICC was 0.98 or above, showing a high test-retest reliability. Katoh et al. investigated the test-retest reliability of isometric knee extension muscle strength measurement using the same measurement method. They found that the ICC of two measurements with an interval of 30 seconds between them was 0.94–0.96 (three sessions) for healthy subjects with an average age of 21.9 years, while for healthy elderly subjects with an average age of 70.5 years it was 0.85–0.92 (with eight gender and age analysis divisions)<sup>12,13</sup>. In this research, isometric knee extension muscle strength measurement using an HHD with a belt is seen to also have high test-retest reliability in hemiplegic patients, in the same way as for healthy subjects.

Bohannon et al. studied 17 hemiplegic patients with an average age of 59 years and an average number of days since the onset of symptoms of 51. They measured isometric knee extension muscle strength twice, two days in succession, with the knee at a 90-degree flexion angle, using an isokinetic muscle strength measuring device (CYBEX II) at an interval of one minute. They found an ICC of 0.970 on the first day, and one of 0.989 on the second day<sup>15</sup>. Accordingly, isometric knee extension muscle strength measurement using an HHD with a belt has about the same

level of test-retest reliability as that of the isokinetic muscle strength measuring device; that is, they both have a high test-retest reliability.

In Session 2, on the paralyzed side, the values of the first measurement were relatively small compared to the values the second and third measurements. It is possible that, since no practice was done after the explanation of the measurement method had been given, there was insufficient learning of the exercise or warming-up. In the present study, the highest values were obtained from the third measurement. We thought it would be sufficient for measurements to be conducted three times, taking the highest values of those three.

In this research, the average number of days from the onset of symptoms was 12.4 in Session 1 and 43.5 in Session 2. Therefore, high test-retest reliability of the isometric knee extension muscle strength measurement using an HHD with a belt on both the paralyzed and the non-paralyzed sides was obtained at a relatively short time after the onset of symptoms, when some recovery from paralysis could be seen. In the present study, measurement values of 0 kgf were omitted from the analysis. However, by treating them as values of 0 kgf in clinical practice, it would become relatively easy to compare the process and would be a useful means of evaluating the movement function of the lower limb on the paralyzed side. However, the result of obtaining should consider the influence of associated movement and synergy, because BRS of the subjects in the present study were from I to VI; therefore, the obtained muscle strength might not have been voluntary, and not the pure knee extension muscle strength.

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