Test-Retest Reliability of Isometric Leg Muscle Strength Measurements Made Using a Hand-Held Dynamometer Restrained by a Belt: Comparisons during and between Sessions

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Abstract. [Purpose] The aim of this study was to evaluate the test-retest reliability of isometric muscle strength measurements made using a hand-held dynamometer restrained by a belt. [Subjects] The subjects were 37 healthy adults (18 men and 19 women) with a mean age of 21.9 years. [Methods] Measurements were made on the dominant leg using a hand-held dynamometer (μ Tas MF-01 or F-1, Anima Corp., Tokyo) and a belt to fix the position of the body part under test. The strengths of the following 10 muscle groups were evaluated: flexors, extensors, abductors, adductors, internal rotators and external rotators of the hip; flexors and extensors of the knee; and dorsiflexors and plantar flexors of the ankle. Each measurement was repeated after at least 30 seconds of rest in three sessions: in the morning, in the afternoon on the same day, and one week later. [Results] The intraclass correlation coefficient (ICC) for the first and second sets of measurements made in each session ranged from 0.75 to 0.97. ICC for the highest measurements of each muscle group in each of the three sessions ranged from 0.56 to 0.91. [Conclusions] The test-retest reliability of isometric muscle strength measurements of the lower limb made using a hand-held dynamometer equipped with a stabilizing belt varies widely, depending on the muscle action tested, and it would be better to repeat the measurements on different occasions.

Key words: Muscle strength, Hand-held dynamometer, Test-retest reliability

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INTRODUCTION

Hand-held dynamometers are small devices that are relatively simple to use for quantitatively measuring muscle strength. However, the level of muscle strength that can be measured depends on the users because they must use their own strength to hold the sensor completely still against the forces applied by the examinee. This also makes interrater reliability poor^{1–5)}.

In a study by Wikholm et al.⁷⁾ in which muscle

strengths of healthy subjects were evaluated by 3 raters, ICC was 0.226 for strength measurements of knee extensor muscles, which are strong, and 0.768 and 0.932, respectively, for measurements of elbow flexor and shoulder external rotator muscles, which are weaker. In a study by Agre et al.⁸⁾ using 4 healthy subjects and 3 raters, Pearson correlation coefficients for interrater measurements ranged from –0.19 to 0.96 for the lower extremity, and from 0.88 to 0.94 for the upper extremity. Regarding the limitations of measurements using a

Table 1. Subjects' posture, dynamometer position and belt fixation method during isometric muscle strength measurements made using a hand-held dynamometer with belt

Exertion Task	Posture	Joint Position	Dynamometer Position*	Belt Fixation Method
Hip flexion	Sitting upright(1)	Hip flexed 90°, popliteal fossa floating	Femur head	Under table leg
Hip extension	Prone (2)	Hip at 0°, distal femur floating	Femur head	Under table leg
Hip abduction	Supine(3)	Hip at 0°, opposite pelvic side on pillow, touching bed rail	Femur head	Around bed rail
Hip adduction	Supine(4)	Hip at 0°, pelvis held by tester's hand	Femur head	Around tester's lower leg
Hip external rotation	Sitting upright(1)	Hip at 0°, thigh horizontal	Medial maleolus	Around table leg
Hip internal rotation	Sitting upright(1)	Hip at 0°, thigh horizontal	Lateral maleolus	Around table leg
Knee flexion	Sitting upright(1)	Knee flexed 90°, thigh horizontal	Medial maleolus	Around tester's lower leg
Knee extension	Sitting upright(1)	Knee flexed 90°, thigh horizontal	Medial maleolus	Around table leg
Ankle plantar flexion	Prone(5)	Knee at 115°, ankle dorsiflexed 15°	1st metatarsal head	Around subject's thigh
Ankle dorsiflexion	Sitting on chair (6)	Heel on 10 cm block touching bed rail, ankle dorsiflexed 20°	1st metatarsal head	Around bed rail

(1) On edge of a table (2) On table, more proximal than sensor (3) On bed (4) On mat (5) On table (6) Lower leg on bed

*lower part of sensor placed on top of part of body under test in opposite direction to movement.

hand-held dynamometer(HHD), Hyde et al.¹⁰⁾ claimed that, regardless of the tester's experience or power of resistance, 30 kg is the limit, while Wiles et al.¹¹⁾ and Roebeck et al.¹²⁾, claimed respectively that it is difficult to maintain the position of the HHD at forces of 300 N and 85 Nm or higher.

We have tackled this problem by using a thin sensor and stabilizing it with a belt⁶⁾. Using this technique, the interrater reliability of two testers, a man and a woman, was very good for various muscle strength measurements of the lower limb, with the intraclass correlation coefficient (ICC) ranging from 0.97 to 0.999.

The aim of the present study was to assess the test-retest reliability of our methods. We compared measurements of lower limb muscle strength taken in the morning, and repeated in the afternoon and one week later.

SUBJECTS AND METHODS

The subjects were 37 healthy adults (18 men and 19 women) with a mean age of 21.9 (SD 1.5) years, and mean body weight of 57.6 (SD 6.7) kg. They all had a right dominant leg, as determined by kicking a ball. None of the subjects had any joint pain or other orthopedic problems of the joints used in this study. All the subjects gave their informed consent to participate.

The HHD was a μ Tas MF-01 or F-1 (Anima Corp., Tokyo). Its metal sensor was covered by a rubber pad. When the belt was used to secure the

device, the sensor's Velcro fastener was used to secure the sensor to the part of the body under investigation, but when the belt was not used to secure the device, the sensor's Velcro fastener was used as a grip for the tester to hold when applying resistance. The belt length could be adjusted using a sliding bar buckle and a plate was used to fix the position of the sensor. The HHD had a measuring range from 0.0 to 80.0 kgf with a precision of 0.1 kgf.

The strengths of each of the following 10 isometric muscle actions were evaluated during three sessions, in the morning, in the afternoon of the same day and one week later: flexion, extension, abduction, adduction, internal rotation and external rotation of the hip, flexion and extension of the knee, and dorsiflexion and plantar flexion of the ankle. The HHD was fixed to the subjects using the sensor's Velcro fastener. The HHD was equipped with a belt that could be secured to something immovable such as a bed leg (Table 1). The subjects ramped up to maximum the force of the 10 muscle actions over 3 s, and then maintained a static state for about 5 seconds during which the peak force was noted. The exertions were repeated after a rest of at least 30 seconds. Measurements were made by a total of 5 male testers, each responsible for two muscle groups as indicted in Table 2. Before starting the actual measurements, the testers practiced using the same type of HHD to make the same type of measurements until familiar with the technique.

Table 2. Characteristics of the testers who took isometric muscle strength measurements using a hand-held dynamometer fixed in position by a belt

Muscle action	Tester	Sex	Age	Height(cm)	Weight(kg)
Hip flexion	A	M	22	174.0	75.0
Hip extension	A	M	22	174.0	75.0
Hip abduction	B	M	26	175.0	70.0
Hip adduction	B	M	26	175.0	70.0
Hip external rotation	C	M	23	172.0	72.0
Hip internal rotation	C	M	23	172.0	72.0
Knee flexion	D	M	23	172.0	68.0
Knee extension	E	M	22	183.0	70.0
Ankle plantar flexion	D	M	23	172.0	68.0
Ankle dorsiflexion	E	M	22	183.0	70.0

The statistical analyses were performed using SPSS for Windows (version 10.0, SPSS Japan Inc., Tokyo). Test-retest reliability was evaluated by ICC (1,1) for data from the first and second sets of measurements in each session, the average measurements from each session, and the highest measurements from each session. When ICC was less than 0.9, the Spearman-Brown formula was used to calculate the number of measurements required to arrive at the standard coefficient of 0.9.

RESULTS

The measurements and statistical analytical results for each muscle action are shown in Tables 3–5. The largest and smallest of the averages of each of the 3 pairs of measurements, one pair per session, were: hip flexion 23.1 and 26.3 kgf, hip extension 33.4 and 35.3 kgf, hip abduction 28.7 and 33.1 kgf, hip adduction 20.3 and 26.2 kgf, hip external rotation 15.0 and 16.3 kgf, hip internal rotation 19.1 and 21.8 kgf; knee flexion 20.5 and 22.9 kgf, knee extension 46.1 and 50.2 kgf; and ankle plantar flexion 66.3 and 73.4 kgf, and ankle dorsiflexion 16.3 and 17.1 kg (Table 3). ICC for the first and second sets of measurements in each session ranged from 0.75 to 0.97. In cases where ICC was less than 0.9, the number of required sets of measurements to reach 0.9 as predicted by the Spearman-Brown formula was 2–4 (Table 4). ICC for average and peak measurements of each session ranged from 0.56 to 0.92 and 0.56 to 0.91, respectively. In cases where ICC was less than 0.9, the number of required sets of measurements to reach 0.9 as predicted by the Spearman-Brown formula was 2–8 (Table 5).

DISCUSSION

Bohannon et al.⁷⁾ assessed the test-retest reliability of an isokinetic dynamometer (Cybex II) in the evaluation of 20 healthy women with a mean age of 29.2 years for the isometric muscle strength of unilateral knee flexion repeated after 30 seconds of rest in a single session, and reported an ICC of 0.932. In the present study, in which measurements of muscle action strengths were also repeated after 30 seconds of rest, the 30 calculated ICCs ranged from 0.75–0.95, of which 21 (70%) were 0.9 or higher. This suggests that the reliability of our measurements is about as high as those made using an isokinetic dynamometer. In the cases of the 9 ICCs below 0.9, from the Spearman-Brown formula, the required number of measurements necessary to reach a coefficient of 0.9 was 4 for knee flexions in the afternoon, 3 for knee flexions in the morning, and 2 for the other muscle actions. This suggests that 2 measurements will likely produce good reliability.

In previous studies, even when limited to healthy subjects, test-retest reliability of measurements repeated in different sessions were found to be poor, with widely scattered ICC values. Emery et al.⁸⁾ used an isokinetic dynamometer (Cybex Norm) to measure the strength of hip adduction and flexion at 60 degrees/second on both the dominant side (determined by preferred leg to kick a ball) and the non-dominant side of 19 healthy men aged 21–43 years. They repeated the measurements within 1 week and found that ICC ranged from 0.37 to 0.85 for the dominant leg and from 0.04 to 0.84 for the other leg. Kea et al.⁹⁾ used an isokinetic dynamometer (Kin-Com) to measure the strength of hip adduction and abduction at 60 degrees/second (concentric and eccentric contraction) on the dominant side (also determined by preferred leg to kick a ball) of 27 male athletes with an average age of 20.2 years. They repeated the measurements 72 hours to 1 week later and found that ICC ranged from 0.59 to 0.74. Lund et al.¹⁰⁾ used an isokinetic dynamometer (BIODEX) to measure the strength of extension and flexion of the knee and elbow of 13 healthy men and women with an average age of 32 years. They repeated the measurements after intervals of 20 h and 1 week and reported that ICC ranged from 0.96 to 0.98 for the 3rd and 4th measurements taken 20 minutes apart and ranged from 0.89 to 0.97 for measurements taken 1 week

Table 3. Isometric muscle strength measurements of young healthy adults made using a hand-held dynamometer fixed in position by a belt(n=37)

		Hip flexion	Hip extension	Hip abduction	Hip adduction	Hip external rotation
Morning	1st	23.1 ± 7.1	34.4 ± 10.1	30.2 ± 8.5	20.3 ± 6.3	15.9 ± 4.7
	2nd	24.6 ± 7.4	33.6 ± 9.6	29.5 ± 8.3	20.3 ± 6.1	15.0 ± 4.3
Afternoon	1st	25.8 ± 6.5	34.3 ± 9.4	33.1 ± 8.8	26.2 ± 6.9	16.1 ± 4.9
	2nd	26.3 ± 6.5	33.4 ± 9.1	33.0 ± 8.2	25.8 ± 6.3	15.5 ± 4.5
1 week later	1st	26.0 ± 6.5	35.3 ± 9.0	29.2 ± 6.7	22.8 ± 6.2	16.3 ± 5.1
	2nd	25.3 ± 5.7	34.6 ± 8.8	28.7 ± 6.6	22.9 ± 6.1	16.0 ± 4.8
		Hip internal rotation	Knee flexion	Knee extension	Ankle plantar flexion	Ankle dorsiflexion
Morning	1st	20.4 ± 5.8	20.5 ± 5.6	46.1 ± 15.0	66.3 ± 19.0	16.4 ± 4.1
	2nd	20.2 ± 5.6	21.7 ± 5.1	46.7 ± 14.5	66.4 ± 19.9	16.3 ± 4.4
Afternoon	1st	21.8 ± 4.7	22.7 ± 5.7	50.2 ± 16.8	73.4 ± 22.2	17.0 ± 4.4
	2nd	21.5 ± 4.7	22.9 ± 6.2	50.1 ± 16.9	72.2 ± 23.5	16.8 ± 4.2
1 week later	1st	20.1 ± 5.1	21.0 ± 4.2	46.7 ± 14.9	71.8 ± 19.8	17.1 ± 3.5
	2nd	19.1 ± 4.7	20.9 ± 4.6	46.2 ± 14.0	69.0 ± 22.0	16.7 ± 3.3

mean ± SD : kgf

Table 4. Test-retest reliability within each session for isometric muscle strength measurements of healthy young adults made using a hand-held dynamometer fixed in position by a belt

Muscle action	Session	ICC(1,1)	95%CI	k*
Hip flexion	Morning	0.78	(0.62–0.88)	3
	Afternoon	0.89	(0.80–0.94)	2
	1 week later	0.84	(0.71–0.91)	2
Hip extension	Morning	0.93	(0.86–0.96)	–
	Afternoon	0.96	(0.92–0.98)	–
	1 week later	0.92	(0.85–0.96)	–
Hip abduction	Morning	0.95	(0.91–0.98)	–
	Afternoon	0.94	(0.88–0.97)	–
	1 week later	0.93	(0.87–0.97)	–
Hip adduction	Morning	0.95	(0.90–0.97)	–
	Afternoon	0.95	(0.91–0.98)	–
	1 week later	0.91	(0.84–0.95)	–
Hip external rotation	Morning	0.89	(0.80–0.94)	2
	Afternoon	0.94	(0.90–0.97)	–
	1 week later	0.96	(0.93–0.98)	–
Hip internal rotation	Morning	0.93	(0.87–0.97)	–
	Afternoon	0.83	(0.70–0.91)	2
	1 week later	0.85	(0.74–0.92)	2
Knee flexion	Morning	0.73	(0.54–0.85)	4
	Afternoon	0.85	(0.73–0.92)	2
	1 week later	0.90	(0.81–0.95)	2
Knee extension	Morning	0.94	(0.89–0.97)	–
	Afternoon	0.96	(0.92–0.98)	–
	1 week later	0.96	(0.92–0.98)	–
Ankle plantar flexion	Morning	0.90	(0.81–0.95)	–
	Afternoon	0.95	(0.91–0.98)	–
	1 week later	0.93	(0.86–0.96)	–
Ankle dorsiflexion	Morning	0.96	(0.93–0.98)	–
	Afternoon	0.96	(0.93–0.98)	–
	1 week later	0.93	(0.87–0.96)	–

ICC: intraclass correlation coefficient. 95% CI: 95% confidence interval. *Number of measurements required to obtain a coefficient of 0.9 as predicted by the Spearman-Brown formula.

Table 5. Test-retest reliability of isometric muscle strength measurements of healthy young adults made using a hand-held dynamometer fixed in position by a belt during 3 sessions

Muscle action	Value	ICC(1,1)	95%CI	k*
Hip flexion	Large ¹⁾	0.75	(0.62–0.85)	3
	Mean ²⁾	0.75	(0.61–0.85)	4
Hip extension	Large	0.89	(0.82–0.94)	2
	Mean	0.89	(0.82–0.94)	2
Hip abduction	Large	0.80	(0.68–0.88)	3
	Mean	0.78	(0.65–0.88)	3
Hip adduction	Large	0.62	(0.44–0.76)	6
	Mean	0.60	(0.42–0.75)	7
Hip external rotation	Large	0.86	(0.77–0.92)	2
	Mean	0.88	(0.80–0.93)	2
Hip internal rotation	Large	0.54	(0.36–0.71)	8
	Mean	0.54	(0.35–0.71)	8
Knee flexion	Large	0.76	(0.63–0.86)	3
	Mean	0.77	(0.64–0.86)	3
Knee extension	Large	0.89	(0.82–0.94)	2
	Mean	0.91	(0.84–0.95)	–
Ankle plantar flexion	Large	0.81	(0.70–0.89)	3
	Mean	0.82	(0.72–0.90)	2
Ankle dorsiflexion	Large	0.76	(0.63–0.86)	3
	Mean	0.71	(0.57–0.83)	4

ICC: intraclass correlation coefficient.

95% CI: 95% confidence interval.

*Number of measurements required to obtain a coefficient of 0.9 as predicted by the Spearman-Brown formula.

¹⁾Highest value of second trial in session.²⁾Mean value of the two measurements sessions.

apart. Möller et al.¹¹⁾ used an isokinetic dynamometer (Kin-Com) for bilateral measurements of dorsiflexion and plantar flexion (concentric and eccentric contraction) of the ankle at 30 and 180 degrees/second in 10 healthy men with an average age of 37 years, and repeated the measurements 7 days later. ICC ranged from 0.34 to 0.96 when the subjects were in a sitting position, and from 0.00 to 0.85 when they were in a supine position. In the present study, ICC also varied widely, ranging from 0.56 to 0.91 when the highest measurements in each session were used. When ICC was less than 0.9, as calculated using the Spearman-Brown formula, the number of measurements required to obtain a coefficient of 0.9 for the highest measurements within sessions was 6 for adduction of the hip and 8 for internal rotation of the hip, and 2 or 3 for the other muscle actions. Therefore, for most muscle actions, 3 measurements may give high test-retest reliability, but for adduction and internal rotation of the hip, measurements should probably be made in more sessions.

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