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Original Article

Reliability of isometric knee extension muscle strength measurements made by a hand-held dynamometer and a belt: a comparison of two types of device

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Abstract. [Purpose] The purpose of the present study was to compare the reliability of 2 hand-held dynamometers (HHD-1, 2) with different designs, by performing isometric knee muscle extension measurements two times each. [Subjects] The subjects were 40 young healthy adults. [Methods] The reliability of the measurements was examined using Bland-Altman analysis. [Results] Bland-Altman analysis found a fixed bias in measurements made by HHD-1 with an average limits of agreement (LOA) value of −2.1 kgf. For HHD-2, only random errors were detected, and the minimal detectable change (MDC) was 11.4 kgf. Fixed biases were observed between the two devices with an average LOA value of 2.2 kgf. When the bodyweight ratio was used, fixed biases were observed in measurements made by both devices, and the average value of LOA was −0.03 kgf/kg. The comparison of the two devices revealed only random errors, and MDC was 0.22 kgf/kg. [Conclusion] For HHD measurements using these two devices, the appropriate number of measurements is two times, and comparison of measurement values between the two devices should be avoided.

Key words: Hand-held dynamometer, Muscle strength, Reliability

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INTRODUCTION

Decreased muscle strength is a major area of intervention in physiotherapy. Physiotherapists perform muscle strength measurements of individuals for the purpose of evaluating muscle strength training. While there are a large number of methods of muscle measurement, quantitative muscle strength measurement is indispensible in the evaluation of subjects, for setting target values and for determining appropriate exercise loads. Moreover, quantitative muscle strength measurement is also useful for evaluating the progress and effects of training in detail, and it is considered that evaluating can motivate patients in training.

Quantitative muscle strength tests include methods which use spindles, those which use large devices, such as isokinetic muscle strength measurement devices, and methods using small devices such as a hand-held dynamometer (HHD). Among these methods, measurement using a HHD is the simplest. However, the prevailing opinion in the literature is that the limit of HHD measurement is approximately 30 kg (300N) because the assessor fixes the HHD using his own strength[1, 2)]. If the maximum muscle strength which can be measured by an assessor when holding a HHD is smaller than that of the subject, the muscle strength value obtained will be less than the subject's actual strength. Measurement values may vary depending on the strength of the assessor, resulting in reliability issues for measurements made by different assessors[3–5)]. In a study of three assessors measuring the muscle strength of healthy subjects, Wikholm et al.[3)] reported that elbow flexor and shoulder external rotator muscles which have low muscle strength, had intraclass correlation coefficients (ICC) of 0.768 and 0.932, respectively whereas the ICC of knee extensor muscles, which have high muscle strength, was 0.226. In a study of three assessors measuring healthy subjects, Agre et al.[4)] reported that the Pearson correlation coefficient for inter-rater measurements ranged from −0.19 to 0.96 for the lower extremity, whereas the range was from 0.88 to 0.94 for the upper extremity. In a study of two assessors measuring healthy subjects, Katoh et al.[5)] reported that ICC of lower extremity muscle strength (10 types of exercise) ranged from 0.21 to 0.88.

Previous studies have addressed the reliability issue, by devising method which use metal frames[5, 6)] and belts[7, 8)] to fix HHD sensors. Katoh et al. invented a method of fixing a sensor using a belt, and investigated the reliability and the validity of the method using healthy subjects[8–10)]. They also investigated knee muscle extension strength. In terms of the reliability of measurements made by two assessors, the ICC

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(2, 1) of a method which does not use a belt was 0.04, and the ICC (2, 1) of a method which uses a belt was 0.98[8]. Test-retest reliability of three sections was 0.94, 0.96 and 0.96, respectively[9]. A comparison with an isokinetic muscle strength measurement device in terms of validity found that Pearson's product moment correlation coefficient was 0.75[10]. The HHD (HHD-1) used in the study of Katoh et al. was a type which measures the force when the sensor is pushed. However, in addition to HHD-1, there are many types of HHD which can perform measurement using belts. One such HHD is a device which measures the pull force. Moreover, there are HHDs which measure push force which have designs different from that of HHD-1. Four sensors are used in HHD-1: the four corners of the measuring surface which contacts the measurement object have sensors. However, certain HHDs which measure push force measure the force at the center of the measuring surface which contacts the measurement object using a single sensor. Therefore, when HHDs with different designs are used, it is likely that there will be issues of measurement reliability. Thus, the present study investigated the test-retest reliability of measurements made by HHDs with different designs using healthy subjects. Moreover, isometric knee muscle strength measurement values were compared using the HHD (HHD-1) used by Katoh et al., and a HHD (HHD-2) which measures pull force.

SUBJECTS AND METHODS

The subjects were 40 healthy adults with no pain in their knee joints or femurs. The number of male subjects was 20, and that of female subjects was 20. The subjects had an average age of 20.6 years old (20–23 years old), average body height of 165.7 cm (SD = 9.2 cm), and average body weight of 58.5 kg (SD = 12.4 kg). The study was conducted in accordance with the principles of the Declaration of Helsinki (1975, revised 1983). Explanations of the methods and the purpose of the study were provided by the assessor to the subjects in writing, and consent to participation was obtained with the subjects' signature. Moreover, the present study was approved by the Ethics Committee of Ryotokuji University.

Two types of hand-held dynamometers were used to measure isometric knee extension muscle strength. HHD-1 was a μTas F-1 (Anima Corp., Tokyo, Japan), and HHD-2 was a Mobie (Sakai Medical Corp., Tokyo, Japan). HHD-2 can be used to measure both pull and push forces; however, in the present study, we used the option of using a belt and a sensor measuring pull force.

Subjects sat on a training bench and adjusted the position of their gluteal region so that a bench leg was behind the lower extremity of the measurement side. Measurement was performed on the leg used when kicking a ball. The training bench was adjusted to a height at which both feet of the subject were just off the floor. Subjects kept their trunk straight and perpendicular with both hands on the bench beside the body. The assessor placed a large folded towel at the popliteal fossa of the subject on the measurement side to keep the femurs parallel, and the knee joint was maintained at 90 degrees of flexion while the lower extremities were hanging perpendicularly downwards. The HHD and a belt were used to measure isometric knee muscle extension strength while the knee joint was at a flexion angle of 90 degrees.

Table 1. Values of isometric knee extension muscle strength

		Value		Body weight ratio	
		kgf		kgf/kg	
HHD-1	1st	44.1	(17.7)	0.737	(0.205)
	2nd	46.1	(17.3)	0.774	(0.195)
	large	46.9	(17.4)	0.712	(0.192)
HHD-2	1st	42.5	(16.5)	0.712	(0.192)
	2nd	44.4	(17.7)	0.744	(0.207)
	large	45.4	(18.0)	0.787	(0.194)

Mean (SD), HHD-1: μTas F-1; HHD-2: Mobie; 1st: The 1st value; 2nd: The 2nd value; large: The value of the larger of two measurements

In measurements using HHD-1, the sensor of the dynamometer was placed over the front surface of the distal part of the lower extremity, and the lower edge of the sensor was fixed using Velcro at the height of the upper edge of the medial malleolus. Then, the measurement leg to which the sensor was applied and the bench leg that was directly behind the measurement leg were tied and fixed using a belt. In measurements using HHD-2, the belt pad was placed over the front surface of the distal part of the lower extremity, and the lower edge of the pad was fixed using Velcro at the height of the upper edge of the medial malleolus. Then, the measurement leg and the bench leg behind and furthest from the measurement leg were tied and fixed using a belt. The sensor of the HHD-2 was placed near the middle of the bed leg and the measurement leg was tied using the belt.

HHD-1 and HHD-2 were used to measure isometric knee extension strength at maximal effort for 5 seconds, twice, with intervals of at least 30 seconds between measurements. One practice session was performed for measurement by each of HHD-1 and HHD-2 before conducting the measurements. HHD-1 and HHD-2 were used in a random order. The assessor was a female researcher (body height 156 cm, body weight 44 kg) with sufficient experience of the present measurement methods. An assistant who was blind to the present study read and recorded the numerical values. Neither the assessor nor the subjects were informed of the measurement values during the measurements.

Knee extension strength and knee extension strength body weight ratios were used to investigate the relative reliability and absolute reliability of the measurements. To investigate relative reliability, the intraclass correlation coefficient (ICC) was used. To investigate absolute reliability, Bland-Altman analysis was used. R2.8.1 was used for statistical analysis. For the analysis, the largest value of the two measurements was adopted.

RESULTS

The average values (SD) of isometric knee extension muscle strength and isometric knee extension muscle strength body weight ratio are shown in Table 1. Average values of isometric knee extension muscle strength (body

Table 2. Isometric knee extension strength measurement reliabilities of two hand-held dynamometers

Group	n	ICC (1,1)		Bland-Altman analysis							
		Point estimation	(95% CI)	LOA	SEM	Fixed bias		Proportional bias			Random error
						95% CI	bias*	slope**		bias*	MDC
HHD-1[a)]	40	0.958	0.923 to 0.978	−8.80–4.60	0.70	−3.70 to −0.60	exist	0.016	p=0.711	n-exi	
		0.909	0.835 to 0.953	−0.15–0.07	0.01	−0.06 to −0.01	exist	−0.076	p=0.138	n-exi	
HHD-2[a)]	40	0.953	0.913 to 0.975	−9.40–7.00	0.90	−3.00 to 0.70	n−exi	−0.028	p=0.630	n-exi	11.4
		0.913	0.843 to 0.953	−0.14–0.08	0.01	−0.06 to −0.01	exist	0.026	p=0.586	n-exi	
HHD1-2[b)]	40	0.928	0.868 to 0.961	−5.60–10.00	0.90	0.40 to 3.90	exist	0.013	p=0.808	n-exi	
		0.846	0.729 to 0.915	−0.18–0.13	0.02	−0.06 to 0.01	n−exi	−0.095	p=0.198	n-exi	0.22

Top: Measured value; Lower; Body weight ratio. HHD-1: μ tas; HHD-2: Mobie. [a)] Reliability of the 1st value and the 2nd value. [b)] Reliability of the value of the larger of two measurements by both devices. ICC: intraclass correlation coefficient; 95% CI: 95% confidence interval; LOA: limits of agreement; SEM: standard error of measurements; *: presence of bias, exist: present; n-exi: not-present; **: Slope of regression line; MDC: minimal detectable change

weight ratio) in the first measurement, the second measurement, and the larger value out of the two measurement values were respectively 44.1 kgf (0.737 kgf/kg), 46.1 kgf (0.774 kgf/kg) and 46.9 kgf (0.712 kgf/kg) in measurements made by HHD-1, and 42.5 kgf (0.712 kgf/kg), 44.4 kgf (0.744 kgf) and 45.4 kgf (0.787 kgf/kg) in measurements made by HHD-2.

The results of ICC (1, 1) in isometric knee extension muscle strength are shown in Table 2. It was 0.958 for HHD-1, 0.953 for HHD-2, and between HHD-1 and HHD-2, it was 0.928. The results of a Bland-Altman analysis are also shown in Table 2. In measurements made by HHD-1, fixed biases were found: values in the first measurement were smaller, and the average value of limits of agreement (LOA) was −2.1 kgf. In measurements made by HHD-2, only random errors were found, and the minimal detectable change (MDC) was 11.4 kgf. Fixed biases were found between HHD-1 and HHD-2, with larger values in measurements made by with HHD-1, and the average value of LOA being 2.2 kgf.

The results of ICC (1, 1) for isometric knee muscle strength body weight ratios are shown in Table 2. It was 0.909 for HHD-1, 0.913 for HHD-2, and between HHD-1 and HHD-2, it was 0.846. The results of a Bland-Altman analysis are also shown in Table 2. Fixed biases were found in measurements made by both HHD-1 and HHD-2, with smaller values in the first measurement, and the average value of limits of agreement (LOA) was −0.03 kgf/kg. Only random errors were found between HHD-1 and HHD-2, and MDC was 0.22 kgf/kg.

DISCUSSION

Landis et al.[11)] were the determination of reliability by Kappa coefficient, 0.81–1.00 almost perfect, 0.61–0.80 is a substantial. The ICC (1, 1) in measurement values of the two devices was 0.9 or greater, indicating the reliability of measurements made by the same assessor is high. When the higher value of the two measurements was adopted, the ICC between HHD-1 or HHD-2 was 0.9 or greater, and the reliability between measurement values by both devices was also high. Therefore, based on the ICC results, it appears that one measurement is sufficient. However the results of a Bland-Altman analysis, which investigated the absolute reliability, found fixed biases HHD-1, suggesting there is an average increase of 2.1 kgf in the second measurement. Therefore, the second measurement of HHD-1 is the more appropriate value. In measurements made by HHD-2, only a random error of 11.4 kgf was observed. It is necessary to consider the possibility that there will be an error of 11.4 kgf in a HHD-2 if measurements are performed two times. Therefore, performing two measurements with a HHD is appropriate. A comparison of measurements made by HHD-1 and HHD-2 found fixed biases, suggesting that measurements made by HHD-2 are smaller than those of HHD-1 by 2.2 kgf on average. Based on LOA, the values measured by HHD-2 varied from an increase of 5.6 kgf to a decrease of 10.0 kgf from those of HHD-1. Looked at the other way, the values measured by HHD-1 varied from a decrease of 5.6 kgf to an increase of 10.0 kgf from those of HHD-2. Therefore, it is not highly appropriate to compare measurement values of HHD-1 and HHD-2, because it would result in significantly large errors.

Measurement values expressed as body weight ratios exhibited fixed biases in measurements made by both HHD-1 and HHD-2. Based on LOA, there was an average increase of 0.03 kgf/kg in values in the second measurement. A comparison of HHD-1 and HHD-2 found only a random error of 0.22 kgf/kg. Therefore, when using the body weight ratio, an increase in the second measurement of both HHD-1 and HHD-2 of approximately 0.03 kgf/kg (3 points) on average should be expected. When comparing measurement values of the two devices, there is a possibility that there is an error of 0.20 kgf/kg (20 points). This error makes it difficult to compare the measured value and the standard value. Also, the error is difficult to associate the measured value and motions. Therefore, when the body weight ratio is used, the measurement error is large, and the compatibility of the measurement values is low. Thus, when the body weight ratio is used, comparisons of measurement values between HHD-1 and HHD-2 should be avoided.

Since the present study was conducted using healthy

young subjects, there is a possibility that results would be different if the subjects were healthy elderly or patients suffering from diseases. The accuracy of the sensors used in both HHD-1 and HHD-2 is high; therefore it is likely that the discrepancies in their measurement values are caused by the measurement method. Possible causes are the length and thickness of the belt, and the softness of the pad. However, in the present study it was not possible to identify the causes. It will be necessary to investigate the causes of the differences between HHD-1 and HHD-2 in a future study.

Based on the results and the discussion above, the performance of two measurements following one practice session is appropriate for making measurements with both HHD-1 and HHD-2. When comparing the measurement values of HHD-1 and HHD-2, it should be noted that the measurement values of HHD-1 are larger than those of HHD-2 by 2.2 kgf on average, and that there is an error of approximately 20 points between values expressed as body weight ratios.

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