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Original Article

Validity and reliability of isometric knee extension muscle strength measurements using a belt-stabilized hand-held dynamometer: a comparison with the measurement using an isokinetic dynamometer in a sitting posture

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Abstract. [Purpose] This study aimed to determine the validity and reliability of isometric knee extension muscle strength measurements using a belt-stabilized hand-held dynamometer compared to that using an isokinetic dynamometer with the participant in a sitting posture. [Participants and Methods] Forty-two university students participated. The isometric knee extension muscle strength was measured using a hand-held dynamometer and an isokinetic dynamometer. For both measurements, the participants were in the similar sitting posture. The sitting posture maintained trunk stability, with the hands on the bed, and the non-measurement-side toe touching the floor or table. The intra-class correlation coefficient and the relevance were verified. [Results] Intra-rater correlation coefficient (1, 1) of the two measurements was ≥0.75. A significant difference was found in the measurement value between males and females. No significant difference was found between the measurements value of the two devices. A significant positive correlation was found in the measurement value of two devices in the male participants. [Conclusion] When compared to the standard method of isometric knee extension muscle strength measurements using an isokinetic dynamometer with the participant in the sitting posture, measurements using the belt-stabilized hand-held dynamometer were considered valid and highly reliable in the male participants.

Key words: Isometric knee extension muscle strength, Hand-Held dynamometer, Validity

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INTRODUCTION

Findings about the measurement of isometric knee extension muscle strength using a hand-held dynamometer (HHD) are helpful for skeletal muscle function and dysfunction assessment[1–20)]. The gold standard measuring equipment for objective muscle strength assessment is isokinetic dynamometer (IKD)[1)], IKD has been recommended for use in the measurement of muscle strength in the lower extremities[11)]. The IKD is regarded as an indicator of the validity of the new device[21)], thus, IKD is used a reference for assessing the validity and reliability of HHD in measuring muscle strength[1, 2–11)]. With respect to knee extension strength, the measurement value of IKD is often higher than that of HHD[3–10)]. However, a previous study on validity was conducted using different measurement postures or different sitting conditions. In the same postural setting with the participant in the sitting position fixed with straps, Hirano et al.[22)] reported that the measurement values between the measuring equipment was not significantly different and that the HHD and IKD were correlated (r=0.96 to 0.98, p<0.01).

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Thus, it was assumed that there was little influence of instrument accuracy and that the trunk fixation status caused the difference in the measured values of the HHD and IKD.

In the manual muscle testing (MMT), knee extension strength measurement is performed with the participant in the sitting position[23)]. In clinical setting, isometric knee extension muscle strength using belt-stabilized HHD is often measured in the sitting posture, and the stability of the sitting position may be secured in consideration of falls by touching the non-measuring side leg to the floor or placing the upper limbs on the bed. In many of the studies on HHD and IKD, the position of the upper limbs may be placed in front of chest or on the knee, and the measurement conditions of knee extension are not standardized uniformly, there are no studies comparing HHD and IKD in the same sitting position with bilateral upper and lower limbs to support the body. The method of measuring isometric knee extension muscle strength using belt-stabilized HHD needs to be studied in the same measurement posture for standardization. Therefore, this study aimed to investigate IKD as a reference standard to assess and compare the reliability and validity of belt-stabilized HHD that referred to posture of the MMT method for measuring muscle strength. The authors hypothesized that unifying the measurement posture without fixing the trunk using straps for performing measurements using HHD and IKD would eliminate the influence of trunk fixation on the measurement value.

The objective of the present study was to determine the validity and reliability of isometric knee extension muscle strength measurement using belt-stabilized HHD and compare it with the measurement using IKD with the participant in the sitting position; the sitting posture maintained the trunk stability with the upper limbs supporting the body and the non-measurement side toe touching the floor/table.

PARTICIPANTS AND METHODS

Total 42 university students were enrolled in this study (Table 1). Participants who were experiencing symptoms were excluded. Two females who had a past medical history of anterior cruciate ligament injury were included in this study. The study protocol was approved by the ethics committee of the Ryotokuji University (approval number: 2709) and was as per the principles of the Declaration of Helsinki. Informed consent was obtained from each participant before participation.

Knee extension muscle strength measurement was performed on the right leg using the HHD and IKD. The examiners were physical therapists. The HHD was performed by a single examiner. The IKD was performed by two examiners with each type of equipment. The measurement values were recorded by allocated assistants.

The measurement equipment used for assessing the muscle strength were IKD (BIODEX, Biodex system 3, Biodex Medical System Corp., NY, USA) and HHD (μTas F-1, Anima Corp., Tokyo, Japan). The bed tables for the measurements using IKD and HHD were the same type of liftable beds (manual high-low bed, Takada Bed Corp., Osaka, Japan). Measurement was conducted with the participant in the sitting position. In the sitting position, the upper limb was placed on the bed and supported the body to prevent a fall. The lower limb of the measurement side was maintained horizontal by inserting a towel under the thigh, and the knee joint was at 90° flexion position, not touching the floor/table. The toe of the non-measurement side lower limb touched the floor or the platform of the 40-cm table.

The sensor of the HHD was fastened using Velcro tape on the distal front portion of the lower leg, with the lower end of the sensor fastened using Velcro where it was placed just above the malleolus. The bed support pillar and the measurement leg were connected using an anchor belt[13, 14)]. The sensor pad of the HHD was a thick pad. The examiner held the sensor to maintain the orientation.

The IKD was measured using a knee attachment, with the dynamometer axis at a line drawn through the lateral femoral condyle on the sagittal plane, with the lower leg cuff located on the distal front side.

Measurements of HHD and IKD were performed with isometric knee extension exercise at 90° of knee flexion (Fig. 1). Two measurements were conducted after orientation and one exercise practice. The rest time between measurements was >30 s. Each measurement was performed for 5 s in order to maintain and reach the maximal contractions in 3 s. The examiner verbally instructed the participants to put in their best effort during the exercise. The highest value obtained during measurement was recorded. In order to compare the measured values of HHD and IKD, the value of HHD calculated the torque value (Nm) after measuring the distance from the knee joint lateral space to the height of the central part of the sensor.

Statistical analyses were performed using statistical software (R2.8.1). The reliability of the two measurements was confirmed with the intra-class correlation coefficient (ICC). Gender differences were examined by unpaired t-test or Mann-Whitney test after confirming Shapiro-Wilk test for normality and equal variance. The validity of the measurement values

Table 1. Participant's characteristic

	All (n=42)	Male (n=22)	Female (n=20)
Age (years)	19 to 22	19 to 22	19 to 22
Height (cm)	163.5 ± 9.1	170.6 ± 5.5*	155.8 ± 5.1
Body weight (kg)	57.6 ± 8.7	63.1 ± 6.3*	51.6 ± 6.8

Mean ± SD, *: vs. female, $p<0.01$.

Fig. 1. Measurement method for isometric knee extension muscle strength measurement with the participant in the sitting position. In the sitting position, the knee joint was flexed at 90°, with the toe of the non-measurement side lower limb touching the floor/table, and the upper limbs supporting the trunk on the body side.
a. HHD: Handheld dynamometer, b. IKD: Isokinetic dynamometer.

Table 2. Isometric knee joint extension muscle strength, intraclass correlation coefficients and correlation coefficient

			All (n=42)	Male (n=22)	Female (n=20)
Measurement values	HHD (Nm)	1st	114.1 ± 45.0	141.4 ± 45.1*	84.1 ± 18.3
		2nd	124.4 ± 48.6	154.6 ± 47.2*	91.2 ± 20.7
		maximum value	125.7 ± 47.4	154.9 ± 46.9*	93.7 ± 18.9
	IKD (Nm)	1st	120.3 ± 52.1	152.7 ± 51.6*	84.9 ± 20.0
		2nd	121.6 ± 49.7	154.9 ± 43.7*	84.9 ± 22.8
		maximum value	127.4 ± 53.3	161.6 ± 50.5*	89.9 ± 22.0
ICC (1,1) (95%CI)	HHD		0.94 (0.89 to 0.97)	0.93 (0.83 to 0.97)	0.75 (0.48 to 0.89)
	IKD		0.93 (0.87 to 0.96)	0.88 (0.73 to 0.95)	0.83 (0.62 to 0.93)
Coefficient of correlation			0.78†	0.71†	0.39

Mean ± SD, *: vs. female, $p<0.01$, †: $p<0.01$, HHD: belt-stabilized Handheld dynamometer; IKD: Isokinetic dynamometer; 1st: first measurement; 2nd: second measurement; maximum value: the muximum obtained during the 1st and 2nd measurments; ICC (1, 1): Intra-rater reliability; 95% CI: 95% confidence interval; ICC (1, 1) examied reproducibility of 1st and 2nd measurements in the device; Coefficient of correlation used Spearman ('s) rank-correlation coefficient (ρ) in the male, and Pearson's correlation coefficient (r) in the female, Adpted values are the muximum obtained during the 1st and 2nd measurments each equipment.

obtained using HHD was examined with the test of difference (paired-t-test or Wilcoxon signed-rank sum test) and correlation analysis (Pearson's product moment correlation or Spearman's rank correlation coefficient) after using the Shapiro-Wilk test for normality. A probability (p) value <0.01 was considered statistically significant.

RESULTS

The gender differences in the characteristics of the participants are shown in Table 1. The measured values of HHD and IKD, ICC and correlation coefficient are shown in Table 2. In order of overall, male, female, the intra-rater correlation coefficient (ICC [1,1]) of the two measurements was observed to be 0.94, 0.93, 0.75 in the HHD group, 0.93, 0.88, 0.83 in the IKD group. Significant difference was observed the high measurement value in male than in female ($p<0.01$). No significant difference was observed between the measured values of HHD and IKD. A significant positive correlation was observed between HHD and IKD in the overall and male ($\rho=0.78, 0.71, p<0.01$). No significant correlation was observed in the female.

DISCUSSION

The criteria for ICC were 0.61–0.80 for substantial and 0.81–1.00 for almost perfect[24]. For measuring the isometric knee extension strength with the participant in the sitting position with upper limbs supporting the trunk and the non-measurement side toe touching the floor, the measurement of HHD and IKD determined substantial from that the ICC of two measurements after practice were more than 0.75 each HHD and IKD. Based on the above, HHD and IKD were compared using the maximum values of the first and second measurement as the adopted values. No significant difference was observed between HHD and IKD. A significant positive correlation was observed in the male (ρ=0.71). From the consequence, the intra-rater reliability of the measurement method using HHD was acceptable, and it was suggested that it has validity and reliability with IKD in male.

The relationship between the measured values obtained using HHD and IKD are reported as the relativity of the values at the 35° knee flexion in the supine position[3)], sitting position[4–6, 8–10)], and 35° knee flexion in the sitting position[7)]. These previous studies have suggested that measurement value of IKD is higher than that of HHD, and HHD and IKD are related although the conditions of measurement position for comparing are not similar. In contrast, in the same sitting condition with trunk fixation, no significant difference was reported between the measurements obtained using HHD and IKD[22)]. The difference between the measurement values of HHD and IKD was considered to be attributed to the different measurement conditions with respect to the presence or absence of trunk fixation. In general, in the measurements using IKD, straps are used to fix the trunk. Measurement value obtained using IKD appeared to increase because of the effect of trunk fixation. In the present study, in order to determine the validity of the measurement using HHD, the measurement posture using IKD unified with the posture of measurement using HHD. The measurement posture defined the sitting position as one with trunk stability achieved by touching the toe to the floor/table and supporting the body with the upper limbs. The correlation between the measured values of HHD and IKD in the male was similar to that in previous studies. Moreover, no significant difference was observed between the measured values of HHD and IKD. As an opinion to support this result, the measurement using IKD was considered to be affected by the fact that the trunk was not fixed using a strap. The reason is assumed when the trunk is not fixed using the strap, the knee extension action at the distal part is difficult to be obtained because the fixation of the pelvis and the thigh at proximal part becomes low. Thus, it is necessary to consider that the interpretation of the measurement value includes a component other than knee extension muscle. On the other hand, from results of no significant difference and no correlation in the female was inferred that the difference with male of the maintenance capability of trunk stability to the material of peripheral fixation part of HHD and IKD (sensor pad or lower leg cuff) during measurement influenced the measurement value. Katoh et al.[25)] reported that knee extension strength value is high the belt-stabilized HHD than the modified IKD; not fixing the trunk etc. no touching floor, and by sitting on the mat table IKD. In present study condition, the toe of non-measurement side was in contact the floor/table, in addition to not fixing the trunk and pelvis with belt. The present results suggest that non-measurement side to touching the floor/table is important in order to compare the measurement values of HHD and IKD, that the measurements of HHD and IKD in the sitting posture are compatibility and exhibit validity of the measurement method in the male. Thus, in the measurement of knee extension muscle strength, although it is difficult to directly compare the measurement values of the different measurement postures using HHD and IKD, unifying the conditions of sitting position provides a measurement that can withstand comparison between HHD and IKD.

The strengths of this study were that the measurements using HHD and IKD were performed using a unified measurement posture and that the measurement posture or position was different from that in previous studies that compared HHD and IKD. Heretofore, the measured value using IKD was higher than that using HHD. The main factor for the high measurement value with IKD was experimentally inferred to be trunk fixation, not the difference in the equipment.

In conclusion, the present study has demonstrated that the measurement using HHD with the participant in the sitting posture is highly reliable, has criterion-related validity with IKD in the male, and has acceptable reproducibility within the examiner.

The limitations include the combination of measurement position with or without the toe touching the floor and the upper limbs supporting the body, investigation for female; further research is needed to clarify these issues.

Conflict of interest

There is no conflict of interest.

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