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Original Article

Reliability of belt-stabilized handheld or isokinetic dynamometer-based isometric knee-extensor strength-testing when seated with the toes of the contralateral nonexamined side off the floor

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Abstract. [Purpose] To determine the intra-rater and inter-devices reliability of isometric knee-extensor muscle-strength-measurement. [Participants and Methods] The participants were 77 university students (50 males; 27 females) who underwent isometric knee-extension muscle-strength measurement twice with a belt-stabilized handheld dynamometer and isokinetic dynamometer. The intra-rater and inter-devices reliability was ascertained from measurements that were performed with the participant seated on the edge of the bed, the toes of the contralateral nonexamined side off the floor, and the trunk supported by the upper limb. [Results] In the overall, male, and female cohorts, the 95% confidence intervals of intra-rater reliabilities (1,1) in the belt-stabilized handheld and isokinetic dynamometers were 0.96–0.98, 0.92–0.97, and 0.81–0.96, 0.82–0.92, 0.73–0.90, and 0.78–0.95, respectively, and the inter-device 95% confidence intervals were 0.52–0.77, 0.28–0.69, and −0.03 to 0.63, respectively. Compared to the belt-stabilized handheld dynamometer group, the isokinetic dynamometer group had higher knee-extension muscle strength. [Conclusion] The intra-rater reliability was rated good-to-excellent and moderate-to-excellent for the belt-stabilized handheld and isokinetic dynamometers, respectively. The inter-devices reliability was poor, and isometric knee-extension muscle strength in the isokinetic dynamometer group was higher than that in the belt-stabilized handheld dynamometer group.

Key words: Isometric knee extension muscle strength, Handheld dynamometer, Reliability

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INTRODUCTION

The assessment of isometric knee extension muscle strength using an objectively quantifiable handheld dynamometer (HHD) is highly applicable to a wide range of age groups, from 3 years to over 65 years, as well as to patients with illnesses[1–4)]. Two methods are used to measure muscle strength using HHD, handheld, or belt-stabilized sensors. The belt-stabilized handheld dynamometer (Belt-HHD) method is more reliable than the handheld method for high muscle strength measurement[5)].

The prominent posture for measuring knee extension muscle strength is the sitting posture. The procedure of measurement, conditions of the participant's attitude and position, and methods of ensuring the examiner's stability are varied. The toe or sole of the nonexamined side of the leg may not touch the floor because of the high height of the bed used as the measurement environment in clinical practice. Hence, the assessor should be familiar with the examination characteristics.

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Influence factors of muscle strength measurement include the examiner, participants, measurement sensor, and measurement environment, such as the seating surface, bed type and bedpost, and surrounding walls. Factors that influence the participant's measured knee extension strength include measurement posture and attitude, trunk and pelvis stabilization, upper limb position, and toe or sole floor contact status. The gold standard for measuring knee extension muscle strength with the isokinetic dynamometer (IKD) is a stable seated posture with the nonexamined toes off the floor and the trunk and pelvis securely in place by straps (conventional-IKD: con-IKD). The common measurement setting for knee extension muscle strength using manual muscle testing or HHD is with the upper limb placed on the bed at the body side and the toes of the nonexamined side on the floor, with no stabilized trunk and pelvis using the strap. Previous studies have reported on the agreement and validity of knee extension muscle strength measurements using Belt-HHD and IKD[5–8]. However, no studies have reported the relationship between Belt-HHD and IKD knee extension muscle strength in the measurement posture with the trunk and pelvis not stabilized, the upper limb placed on the bed of the body side, the knee joint in 90° flexion, the thigh horizontal, and the toe of the nonexamined side not touching the floor. In the knee extension muscle strength measurement, touching the toes of the nonexamined side to the floor when the trunk and pelvis are not strapped down is presumed to help increase postural stability and reduce the risk of falls and tumbles. However, depending on the type of bed used for measurement and the length of the participant lower leg, the toes do not touch the floor. Therefore, in clinical practice, knee extension muscle strength measurement using Belt-HHD may involve measuring the toe of the nonexamined side without touching the floor. Thus, the present study was designed to investigate the reliability of Belt-HHD and IKD measurements in a sitting position in which the upper limb is placed on the body side without trunk, pelvis, and thigh fixation, and the toes not touching the floor.

This study aimed to determine the intra-rater and inter-devices reliability of isometric knee-extensor muscle-strength-measurement when seated with the upper limb placed on the bed at the body side and the toes of the contralateral nonexamined side off the floor. The hypothesis is that Belt-HHD and IKD have high repeatability and that Belt-HHD and IKD measurements are comparable when the measurement attitude conditions are similar.

PARTICIPANTS AND METHODS

The participants were 77 university students (Table 1). Symptomatic participants were excluded from the study. The ethics committee of SBC Tokyo Medical University (former Ryotokuji University, approval number: 3008) approved this study, which was conducted under the Declaration of Helsinki and the Ethical Guidelines for Medical and Health Research Involving Human Subjects. Written informed consent was fully explained to the participants orally and signed.

Knee extension muscle strength was measured in the right lower extremity using HHD and IKD.

A physical therapist (male, 41 years old, 168 cm, 72 kg, 19 years) examined the measurements using HHD and IKD. A separate recorder was used to record the measurements.

Muscle strength measurements were performed using HHD (μTas F-1, Anima Corp., Tokyo, Japan) and IKD (BOIDEX, Biodex system 3, Biodex Medical Systems, Shirley, NY, USA) devices. Liftable beds (manual high–low bed, Takada Bed Corp., Osaka, Japan) were used as sitting platforms.

The measurement posture was the sitting position in which the upper limbs were placed on the bed at the body side, the thigh of the measurement side was kept horizontal with a towel inserted between the thigh and the bed, the knee joint was flexed 90 degrees, and the toes of the measurement and nonexamined lower limbs were kept off the floor.

The HHD was placed on the distal anterior lower leg with the sensor positioned at a height just above the lateral malleolus and fixed with hook and loop fasteners. In addition, the bedpost and the lower limb to be measured are connected with a belt (Belt-HHD)[5]. A thin sensor pad (Standard type) was used. The examiner grasped the sensor so that its orientation did not change during measurement.

The IKD was set at a height where the dynamometer axis coincided with the lateral condyle of the femur using a knee attachment, and the pad, which is a lower leg cuff attachment, was placed on the distal anterior leg.

Isometric knee extension muscle strength was measured during knee extension movement, and "make test" was conducted with the knee joint in a 90-degree flexed position using the Belt-HHD and IKD (Fig. 1). Preorientation and measurements were performed to reach maximal contraction in 3 s and maintain the knee extension movement for 5 s. Measurements were conducted twice after the movement practice. The rest period between measurements was at least 30 s. The examiner encouraged the participants to exert maximal effort during the exercise. The recorded value was the highest during the exercise. The

Table 1. Participant's characteristic

	All (n=77)	Male (n=50)	Female (n=27)
Age (years)	19–20	19–20	19–20
Height (cm)	166.7 (8.3)	171.1 (6.1)	158.6 (4.9)
Body weight (kg)	58.2 (9.8)	62.5 (9.0)	50.2 (5.0)

Mean (standard deviation).

Belt-HHD value was calculated as the torque value (Nm) after measuring the distance from the lateral space of the knee joint to the height of the center of the sensor to compare the Belt-HHD and IKD measurements.

Statistical analyses were conducted using the statistical software R (version 4.0.2). The reliability of two measurements with the same device and the reliability between Belt-HHD and IKD devices were evaluated using intrarater reliability (ICC [1, 1]) of intraclass correlation coefficients. The maximum value of the first and second was used as the adopted value for the comparison between devices. The Wilcoxon signed-rank test was performed after confirming normality using the Shapiro–Wilk test. A probability (p) value of <0.01 was considered statistically significant.

RESULTS

Table 2 shows the measured values of Belt-HHD and IKD, ICC (1, 1), and the test results for the difference in maximum values between devices. The 95% confidence interval (CI) of overall, male, and female participants were 0.96–0.98, 0.92–0.97, and 0.81–0.96 in Belt-HHD in the ICC (1, 1), 0.82–0.92, 0.73–0.90, and 0.78–0.95 in IKD, and 0.52–0.77, 0.28–0.69, and −0.03–0.63 between devices, respectively. The knee extension muscle strength was higher in IKD than in Belt-HHD in the overall and female participants.

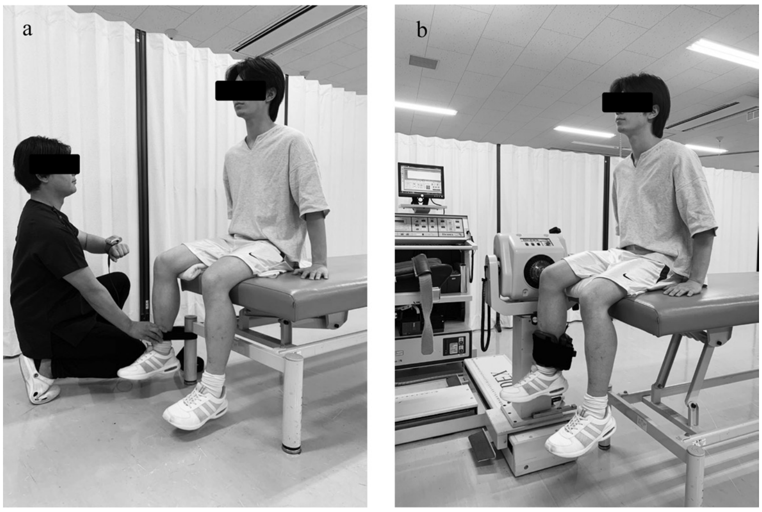

Fig. 1. Measurement method for isometric knee extension muscle strength measurement with the participant in the sitting position. The knee joint, in the sitting position, was flexed at 90°, with the toe of the lower limb of the nonexamined side not touching the floor, and the upper limbs supporting the trunk on the body side.
a. Belt-handheld dynamometer (HHD): belt-stabilized handheld dynamometer, b. IKD: isokinetic dynamometer.

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

			All (n=77)	Male (n=50)	Female (n=27)
Measurement values	Belt-HHD (Nm)	1st	130.7 (49.5)	156.7 (38.8)	82.7 (25.5)
		2nd	129.3 (46.1)	153.3 (36.4)	84.8 (23.6)
		Maximum value	134.1 (47.7)	159.3 (37.0)	87.7 (24.9)
	IKD (Nm)	1st	137.4 (40.6)	152.5 (37.4)	109.5 (30.6)
		2nd	138.0 (43.1)	151.9 (43.6)	112.4 (28.2)
		Maximum value	144.6 (43.7)*	159.8 (42.8)	116.1 (28.8)*
ICC (1,1) (95% CI),	Belt-HHD	1st and 2nd	0.97 (0.96–0.98), 7.8	0.95 (0.92–0.97), 7.7	0.91 (0.81–0.96), 7.5
SEM (Nm)	IKD	1st and 2nd	0.88 (0.82–0.92), 14.4	0.84 (0.73–0.90), 16.5	0.89 (0.78–0.95), 9.6
	Belt-HHD and IKD	Maximum value	0.66 (0.52–0.77), 25.8	0.51 (0.28–0.69), 28.0	0.34 (−0.03–0.63), 14.6

Mean (standard deviation), *: vs. maximum value with HHD, $p<0.01$, Belt-HHD: belt-stabilized handheld dynamometer; IKD: Isokinetic dynamometer; 1st: first measurement; 2nd: second measurement; maximum value: the maximum obtained during the 1st and 2nd measurements; ICC (1,1): Intra-rater reliability; 95% CI: 95% confidence interval; SEM: standard error of the mean.

DISCUSSION

This study complements previous results on measurement procedures for knee extension muscle strength measurement methods. Reliability of isometric knee extensor strength using Belt-HHD and IKD was verified. The measurement conditions were set as in a sitting posture with the upper limb on the bed at the body side and the toe of the nonexamined side not touching the floor. The reliability criteria was based on the 95% CI of the ICC estimate[9].

The results demonstrated excellent, excellent, and good 95% CI of the twice-measured ICC (1, 1) for Belt-HHD and good, moderate, and good for IKD, in overall, male, and female participants, respectively. The results between the devices were moderate, poor, and poor. A comparison of the maximum knee extension muscle strength on each device revealed that the IKD demonstrated higher values than the Belt-HHD.

Con-IKD has higher knee joint extension muscle strength than Belt-HHD with the toes touching the floor. In addition, the Belt-HHD measurements in the toe-ground condition were higher than the IKD in the toe-unground condition under the same conditions with the upper limb placed on the bed at the body side and the trunk unfastened with straps. Moreover, con-IKD and IKD with the upper limb on the body side and the trunk unfixed with a strap and toes ungrounded had higher Con-IKD[6]. Few studies comparing the validity of HHD and IKD have unified conditions such as joint angles of measurement limbs and the use of straps for trunk immobilization. Among the few, Belt-HHD and IKD were validated in a study in which the upper limbs were placed on the bed at the body side, and the toes at the nonexamined side touching the floor/table, with the trunk and pelvis fixed by straps[7]. A study in which the trunk and pelvis were fixed by straps and only the measuring device was changed revealed no difference in measurements[8]. That is, the measurements will be similar for different lower leg attachments or sensors, considering that the straps provide trunk stability. The value of IKD was higher than that of Belt-HHD for the overall and female participants in the toe-unground measurement condition of this study. The difference between the Belt-HHD and IKD measurement conditions is the lower leg attachment. The HHD is small and thin (The pad covering the sensor is made of silicone rubber with a hardness of 50 degrees. The thickness on the sensor is 6 mm, with R39.3 applied at the center 6 mm, thickening from the center outward to form an indentation. The external dimensions are 55.5 × 55.5 mm.), whereas the IKD has cushioning and is large, as a cuff for the lower leg attachment. The reasons for the greater occurrence of IKD values in females in cases where the trunk is not fixed by a strap include relevant differences in the way the body responds to lower leg attachment, postural stability due to touching the floor on the nonexamined side, hip extension, and trunk muscle strength. Female data influenced the higher value of IKD than Belt-HHD in all participants. Based on previous studies[5–8] and the results of the present study, the toes of the nonexamined side not touching the floor/table, when the trunk was not strapped, affected trunk stability of the, resulting in lower measured values. From these results, the measurement procedure combination of the toe of nonexamined side touching/not touching the floor/table and trunk fixation with/without a strap indicated that they influence each other in the knee extension muscle strength measured using Belt-HHD.

The limitations and issues of this study include the use of thick pads instead of thin pads, which is the standard type of sensor attachment. In addition, the extent of trunk fixation or stability using straps that influences the results remains unclear.

This study revealed that the intrarater reliability was good to excellent in the measurement procedure when seated with the upper limb placed on the bed at the body side for trunk support and the toes of the contralateral nonexamined side off the floor using Belt-HHD and IKD. The values of IKD were higher than those of Belt-HHD, indicating poor reliability between devices using Belt-HHD and IKD in this measurement procedure from the 95% CI of ICC (1, 1). These results reveal that Belt-HHD and IKD are useful in capturing changes in knee extension muscle strength over time under the same measurement procedure conditions. The measurement posture depends on the environment of the sitting equipment, such as the height of the bed and the length of the bedpost. Measurement of the same person using Belt-HHD requires the same measurement procedure, limb position, and environment.

Conflict of interest

There are no conflicts of interest.

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