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Original Article

Test-retest reliability of isometric ankle plantar flexion strength measurement performed by a hand-held dynamometer considering fixation: examination of healthy young participants

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Abstract. [Purpose] This study aimed to investigate the test-retest reliability of isometric ankle plantar flexion strength measurements performed by a hand-held dynamometer (HHD) using two belts and a newly devised fixation plate. [Participants and Methods] The participants were 83 healthy individuals (female, n=31; male, n=52) with an average age of 20 years. An HHD (μTas F-1) sensor was fixed using two belts and a newly developed metal device to the measurement site on the dominant foot of a participant who was in a sitting position. Measurements were performed twice for each participant. [Results] The average value was 65.6 kgf (bodyweight ratio, 127.3%) for female and 88.0 kgf (136.9%) for male participants. The intraclass correlation coefficients of the two measurements were 0.915 for female and 0.938 for male participants. The minimum detectable change at 95% was 10.1 kgf (12.1% of the average value) for female and 12.1 kgf (15.4%) for male participants. [Conclusion] The test-retest reliability of measuring the ankle plantar flexion strength performed by an HHD using a belt and plate is high. Therefore, the increase or decrease in muscle strength should be judged based on the minimal detectable change with 95% confidence.
Key words: Muscle strength, Ankle plantar flexion, Hand-held dynamometer

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INTRODUCTION

A hand-held dynamometer (HHD) is a small device that enables easy, quantitative muscle strength measurement. However, since an HHD is used by the examiner by manually fixing the sensor, there may be a limit to the value that can be measured[1–3)].

To improve the reliability of muscle strength measurement using an HHD, Katoh and Yamasaki[4)] developed a method for measuring lower limb muscle strength that supplements fixation by attaching a fixing belt to the HHD with a thin sensor. The inter-rater reliability study involved young healthy individuals with an average age of 20 years. From these results, the inter-rater reliability of using a belt was high; however, that of not using a belt was low. Furthermore, Katoh and Yamasaki[5)] examined the intra-rater reliability of lower limb muscle strength measurement using a belt and an HHD in the morning, afternoon, and 1 week later. From these results, the intra-rater reliability of using a belt was high. With this background, it is necessary to improve the method of fixing the sensor and maintaining the joint angle. Thus, this study aimed to investigate the test–retest reliability of isometric ankle plantar flexion strength measurements performed by HHD using two belts and a newly developed fixing device.

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PARTICIPANTS AND METHODS

The participants were 83 healthy young individuals (female, n=31; male, n=52) with an average age of 20.1 (SD=0.4) years, average height of 166.6 (SD=8.4) cm, and average weight of 60.1 (SD=9.9) kg. The details of gender division are shown in Table 1. The ankle plantar flexion muscle strength of the participants' dominant foot (the foot kicking the ball) was measured. The participants had no orthopedic disease of the lower extremity joints or arthralgia.

This study was approved by the Bioethics Review Committee (No. 3008) of Ryotokuji University. The purpose and content of this study were explained to the participants, and measurements were taken after obtaining their consent.

The HHD used was an isometric muscle strength measuring instrument μTas F-1 (Anima Corp., Tokyo, Japan). The maximum value that the instrument can measure was 100.0 kgf, and the HHD was used with the error range calibrated to 0.1 kgf or less. In this study, kgf was used as the unit of muscle strength. One kgf is approximately 9.8 N.

Ankle plantar flexion muscle strength was measured with the participants sitting on a chair. An HHD sensor was fixed using two belts and a newly developed device. In this study, a fixing device for processing metal plates (fixing plate), two belts with buckles, and a shin pad (thin support) were used to improve the fixation of the sensor. The fixing plate was made by processing and welding two metal plates (Fig. 1). One was processed with a metal plate with a thickness of 2 mm to form the base part of the fixing plate. The other was processed with a metal plate with a thickness of 3 mm to form the belt loop part of the fixing plate. A rubber sheet was attached to the surface of the fixing plate on which the legs of the chair were placed to prevent slipping, and a hook-and-loop fastener was attached to the surface of the fixing plate on which the forefoot was placed. To prevent pain from the pressure on the belts, the two belts were attached to the thighs from above the pads. The pad was a commercially available shin pad for sports.

The participants sat in a chair and placed their heel on the belt-passing part of the fixing plate, with the knee in the 115° flexion position, and two belts secured the lower limb on the measuring side (Fig. 2). The participant's lateral malleolus was aligned with the center of the front–back width of the part through which the belt was passed. The surface of the HHD sensor was covered with a silicone pad. The HHD sensor adjusted the distance so that it was placed under the metacarpophalangeal joint of the participant's thumb. Two belts were passed through the space for passing the belts of the fixing plate, the thigh pad and fixing plate were connected by two belts, and the lower limbs were fixed at a predetermined joint angle. The angle of the lower limb joint on the measurement side was fixed by fastening with a buckle while adjusting the length of the two belts. During measurements, the participants were instructed to grab the chair legs by hands and pressed the chair legs downward to prevent the fixing plate from floating.

The participants performed an isometric ankle plantar flexion contraction, which reached the maximum effort in approximately 3 s, and then maintained a steady state until approximately 5 s. The maximum value during that period was adopted

Table 1. Demographics, participant characteristics

Gender	n	Age: years	Height: cm	Weight: kg
Females	31	20.1 (0.4)	158.3 (4.9)	51.9 (5.3)
Males	52	20.0 (0.3)	171.5 (5.8)	65.0 (8,8)

Continuous data is presented as mean (SD).

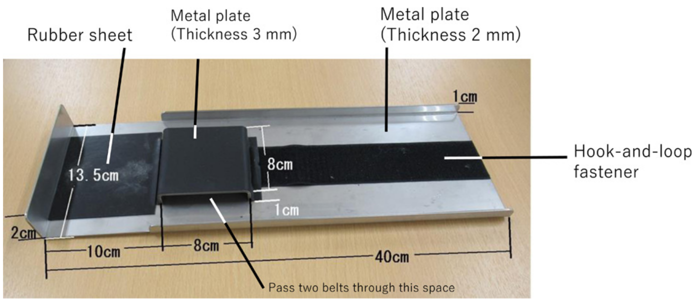

Fig. 1. Fixing plate.

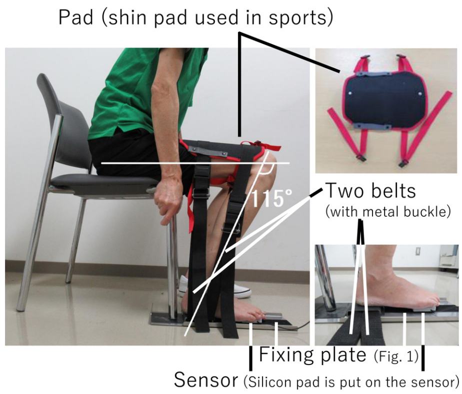

Fig. 2. Settings at the time of measurement.
Two belts (with metal buckle), Fixing plate (Fig. 1), Sensor (Silicon pad is put on the sensor).

as the measured value. The measurement was performed twice with a 30-s interval. The examiner was a physiotherapist who has >20 years of experience using an HHD and familiarized the measurement method before the study.

As warm-up before the measurements, the participants performed a stand-on-tiptoe exercise with both feet, a stand-on-tiptoe exercise with one foot on the measurement side, and a light jump with one foot on the measurement side. Warming up exercises were performed 10 times each. Furthermore, in the measured limb position, 50%, 75%, and 90% plantaris flexion muscle strength was exerted twice, and 100% muscle strength was exerted once with respect to the maximum muscle strength.

As an analysis method, the test–retest reliability was examined using intraclass correlation (ICC (1,1), hereinafter ICC) and the Bland–Altman analysis (BAA). If a random error was found in the BAA, minimum detectable change at the 95% (MDC95) was calculated. Furthermore, the bodyweight ratio (BWR) was calculated by dividing the measured value by the bodyweight (BWR=measured value/ bodyweight×100).

RESULTS

The results are summarized in Table 2. The average value of isometric plantar flexion muscle strength in the knee flexion position was 62.2 kgf and 64.7 kgf for female and 85.6 kgf and 85.6 kgf for male participants in the order of the first and second times. When the BWR of 34.9% of ankle plantar flexion muscle strength was calculated by selecting the larger value from the two measurements, the average value was 127.3% (SD=37.8%) for female and 136.9% (SD=27.2%) for male participants. Regarding the test–retest relative reliability, the ICC value was 0.915 for female and 0.938 for male participants. Regarding absolute reliability, a random error was found in the BAA, and the MDC95 was 10.1 kgf (15.4% of the average value) for female and 12.1 kgf (15.4% of the average value) for male participants (Table 2).

DISCUSSION

In this study, the average plantar flexion strength was 65.6 kgf (BWR=127.3%) for female and 88.0 kgf (BWR=136.9%) for male participants. According to Katoh and Yamasaki[5)], the reliability of plantar flexion muscle strength in young healthy participants of nearly the same age, as in this study, was 56.0 kgf (BWR=91.2%) for male and 41.5 kgf (BWR=76.6%) for female participants (the measurement results were divided by gender and recounted). The results of the present study were clearly larger than those reported by Katoh and Yamasaki[5)]. Therefore, in ankle plantar flexion muscle strength measurement (knee flexion position), the present method may exert higher force than previous methods. The values measured in this study were larger than those of previous studies, which was perhaps attributed to the difference in the measurement posture (prone position in previous studies versus sitting position in the present study) and fixation method that suppresses the joint movement (one belt versus two belts and fixing plate). To clarify the difference between the values measured in previous studies and in the present study, a comparison among the same participants is necessary.

Regarding relative reliability, the ICC within the examiner exceeded 0.9 for both male and female participants. According to Landis and Koch[6)], 0.81–1.00 is the nearly perfect index of Kappa coefficient. When the standard by Landis and Koch was applied to the ICC value, the test–retest reliability of the devised ankle plantar flexion strength measurements can be extremely high. Regarding absolute reliability (error), a random error was found in the two measurements, and the MDC95 was 10.1 kgf (12.1% of the mean) for female and 12.1 kgf (15.4% of the mean) for male participants. Therefore, the increase or decrease in muscle strength should be judged based on MDC95.

This study has three limitations. First, regarding the measurement method, the thigh on the measurement side could not be set horizontally, and the leg side of the chair of the fixing plate could be lifted during the measurement. Thus, the measurements should be performed in a heavy treatment bed with adjustable height. Second, regarding the measuring equipment, there were multiple measurements that exceeded the equipment limit of 100.0 kgf for both female and male participants. The measured values exceeded 100 kgf in more than a quarter of male participants. For measurement, it is necessary to use equipment with a measurement limit of ≥200 kgf. Third, this study targeted healthy individuals around 20 years old; thus, it is necessary to examine older individuals and individuals with diseases.

Table 2. Isometric plantar flexor strength measurements performed by a handheld dynamometer using a belt and metal plate

Gender	n	1st : kgf	2nd : kgf	larger† : kgf	ICC(1,1)			BAA	BWR : % (kgf/kg*100)
					Estimate	95% CI		MDC95	
		Mean (SD)	Mean (SD)	Mean (SD)		Lower	Upper		Mean (SD)
Females	31	62.2 (19.0)	64.7 (19.7)	65.6 (19.1)	0.915	0.915	0.979	10.1	127.3 (37.8)
Males	52	85.6 (17.4)	85.6 (17.2)	88.0 (16.7)	0.938	0.894	0.963	12.1	136.9 (27.2)

ICC: intraclass correlation coefficients; CI: confidence interval; BAA: Bland-Altman analysis; MDC: minimal detectable change; BWR: bodyweigh ratio, †: The larger of the two measurements.

Conflict of interest

There are no conflicts of interest to be declared in this study.

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