Measuring seated hip extensor strength using a handheld dynamometer: an examination of the reliability and validity of the protocol

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Abstract. [Purpose] The purpose of this study was to examine the reliability and validity of measurements of hip extensor muscle strength using a handheld dynamometer (HHD) with subjects in a sitting position. In doing so, we also aimed to establish a modified method of measurement for patients with flexion contractures in the trunk and lower extremities. [Subjects and Methods] In 20 healthy males, hip extensor muscle strength was measured using a handheld dynamometer in sitting, prone, and standing positions by contracting the hip extensor muscle isometrically with the knee flexed at 90 degrees. For each position, we investigated the relative and absolute reliability and validity of the measurements, and compared muscle strength between the different positions. [Results] The reliability and validity of measurements were highest in the sitting position and higher in both the sitting and standing positions as compared with those in the prone position. [Conclusion] Our findings suggest that measurements taken in a sitting position are accurate in assessing hip extensor muscle strength and would be applicable to patients with flexion contractures in the trunk and lower extremities.

Key words: Hip extensor strength, Reliability, Bland-Altman analysis

INTRODUCTION

Muscle strength measurement is widely known to be an important method of evaluation in rehabilitation medicine1). Manual muscle testing (MMT), which has long been used to evaluate muscle strength, is used by approximately 80% of physical therapists2). However, MMT is strongly affected by the subjectivity of the tester. MMT offers particularly low reliability when measuring level 4 (fair) or above with a difference in resistance and has difficulty representing changes in muscle strength3). Therefore, in recent years, the handheld dynamometer (HHD), which enables objective, simple, and quantitative evaluation, has been widely used for measurement of muscle strength3, 4). In general, muscle strength measurements with an HHD are often performed in accordance with MMT. However, several issues related to muscle strength measurement with an HHD have been indicated. It has been reported that the reliability and validity were insufficient, that compensatory motion strongly affected results, and that the requirement that subjects be in the prone position made measurement difficult5). In actual clinical practice, for some patients, commonly elderly individuals, undergoing muscle strength measurement in the prone position is difficult because of pain or flexion contracture of the spine or lower limbs. The subjects of MMT include hip extensor, knee flexior, neck extensor, trunk extensor, and shoulder extensor strength. Of these, hip extensor strength is often used for muscle strength evaluation because it plays an important role in pelvic stability when rising into a standing position, walking, and standing6, 7). Therefore, if a patient cannot assume the prone position for MMT, other possible measurement positions include standing up with the front of the trunk against an examination table and lying in the supine position while the tester lifts the leg for measurement and the patient holds the pelvis and trunk in a straight line8). However, because the presence of marked flexion contracture of the spine or lower limbs of the hip can make discerning criteria for measurement in the supine position difficult, the muscle strength of the leg not being measured may affect the measurement results in the standing
position. Thus, certain requirements are required to establish the measurement environment.

A simple and safe method for measuring hip extensor strength in individuals in a seated position that can be used for elderly patients, who cannot assume the prone position, could contribute to the formulation of treatment programs in clinical practice and aid in the measurement of treatment effects. Therefore, the aim of this study was to investigate the reliability and validity of a method for measuring hip extensor strength in a seated position using an HHD and to investigate its usefulness.

SUBJECTS AND METHODS

Subjects

Subjects received an explanation of the purpose and methods of this study in addition to a sufficient explanation of the protection of personal information policy in advance, and all subjects consented to participate in the study. The subjects included 20 young, healthy individuals (all male; mean age, 24.5 ± 5.7 years; mean height; 167.1 ± 5.1 cm; mean weight, 61.5 ± 6.6 kg) with no history of motor disorders or central nervous system disease. In accordance with the Declaration of Helsinki, measurements were performed with the utmost care while considering subject safety. Also the institutional review board of Aizen Hospital approved this study.

Methods

The measurement task was isometric hip extension with maximum effort. For all three measurement positions of seated, prone position, and standing (hereinafter, seated measurement, prone measurement, standing measurement), the knee joint was flexed at 90°. An HHD (Mobie MT-100, SAKAI Medical Co., Ltd., Tokyo, Japan) for which reliability was confirmed by the Japan Quality Assurance Organization was used for muscle strength measurement. Based on a previous study, seated measurements were performed with a posteriorly tilted pelvis so that the angle of the line joining the pelvis anterior superior iliac spine and posterior superior iliac spine and the floor was at a retroversion angle of 10°. We also had subjects place both of their hands behind their trunk on the examining table to increase stability, with the soles of both feet raised from the floor. During measurement, the popliteal region was moved two to three fingerbreadths away from the edge of the examining table before the HHD was placed on the distal third of the thigh. Then, to minimize the influence of the subject’s own weight, zero correction was performed with the measurement device’s offset switch. The tester held both hands at the pelvic iliac crest site from in front of the subject and verbally instructed the subject to push their thigh down (Fig. 1). Prone measurements and standing measurements were conducted at level 5 (normal), according to MMT version 9. With one hand, the tester used the HHD to apply resistance to the distal third of the thigh, and the other hand was used to hold the pelvis still. For standing measurements, the examining table was adjusted to the height of the lower margin of the subject’s anterior superior iliac spine on both sides, and the hip joint was then bent on both sides so that the front of the subject’s trunk was on the examining table. Muscle strength values measured in each measurement position were divided by body weight to calculate newtons per kilogram for use in our analysis. Measurements were performed twice for each measurement position by two physiotherapists (one male and one female). The measurements for each position were performed in a random order with a break between each measurement, adequately considering subject fatigue.

Statistical investigation was performed by confirming the normality of the acquired data with the Shapiro-Wilks test, and the intratester and intertester reliability for muscle strength values in each measurement position were examined using intraclass correlation coefficients [ICC (1,1) and (2,1)] as the relative reliability index. Absolute reliability was investigated using Bland-Altman analysis to confirm the presence or absence of systematic error in the form of fixed error and proportional error. If systematic error was found, the limit of agreement (LOA) of the error was calculated, and if no systematic error was found, the 95% confidence interval of the minimal detectable change (MDC), referred to as MDC95, was calculated as an index for absolute reliability. Spearman’s rank correlation coefficient was used to investigate criterion-related validity for seated measurements and standing measurements with conventional prone measurements as a standard. The Holm method was used for muscle strength comparisons between measurement positions because it is a multiple comparison method that offers high detectability and can be used for parametric or nonparametric tests. All statistical analyses were performed using free statistical analysis software, R version 2.12.0, with a level of significance of 5%.

RESULTS

The results of intratester reliability testing indicated an ICC (1,1) of 0.89 for seated measurement, with no systematic error and an MDC95 of 0.80 N/kg. For prone measurement, the ICC (1,1) was 0.93, no systematic error was found, and the MDC95 was 0.51 N/kg. For standing measurement, the ICC (1,1) was 0.84, no systematic error was found, and the MDC95 was 0.94 N/kg (Table 1). The results of intertester reliability testing indicated an ICC (2,1) of 0.88 for seated measurement, with no systematic error and an MDC95 of 0.86 N/kg. For prone measurement, the ICC (2,1) was 0.80,
no systematic error was found, and the MDC₀.₉₅ was 1.06 N/kg. For standing measurement, the ICC (2,1) was 0.76, and no proportional error was observed, but a marked fixed error was found. The LOA for this error was −0.96 to 0.37 N/kg (Table 2).

With muscle strength values measured in the prone measurement position as the standard, the criterion-related validity of the seated and standing measurements exhibited strong correlations with prone measurements. The correlation coefficient was 0.81 for seated measurement and 0.53 for standing measurement (Table 3).

Muscle strength values of seated and standing measurements were significantly higher than those of prone measurements (Table 4).

### DISCUSSION

The results of this study indicated that for seated, prone, and standing measurements, the ICC (1,1) values were 0.89, 0.93, and 0.84, respectively, whereas the ICC (2,1) values were 0.88, 0.80, and 0.76, respectively. Although there are no unified ICC standards, those suggested by Landis indicate that an ICC of ≥0.81 is almost perfect and, according to Kuwabara, an ICC of ≥0.80 is good. This suggests good reliability for the seated measurement proposed in this study and shows that there may be even higher intertester reliability and therefore reproducibility for the seated measurement than for the prone measurement compared with conventional MMT and standing measurements. In general, HHD muscle strength measurement is highly influenced by compensatory motion, and while performing measurement in the seated position, maintaining the pelvis and trunk in a fixed position is difficult, leading to decreased reproducibility. However, because the posteriorly tilted pelvis position used here for seated measurement created a wide support base by having both hands placed behind the trunk and because both hands of the tester were used for pelvic fixation, measurement with a stable trunk and pelvis was possible.

The results of Bland-Altman analysis used to investigate absolute reliability did not indicate any systematic error for any of the measurement positions in terms of intratester reliability. Meanwhile, although no systematic error was observed for intertester reliability for seated or prone measurement, fixed error was observed for the standing measurement. The results of criterion-related validity testing also revealed a strong correlation between prone and seated measurements ($r = 0.81$) and a moderate correlation between standing and prone measurements ($r = 0.53$). The systematic error calculated via Bland-Altman analysis demonstrated structural and systematic deviation from true values. It includes fixed error that occurs in a specific direction for a fixed extent and proportional error that increases or decreases in proportion with

### Table 1. ICC(1,1) and Bland-Altman analysis results

| Measurement        | ICC(1,1) | 95% CI      | Fixed Error | Proportional Error | MDC₀.₉₅ |
|--------------------|----------|-------------|-------------|--------------------|---------|
| Seated measurement | 0.89     | 0.74 to 0.95| −0.10 to 0.28| 0.35               | 0.80    |
| Prone measurement  | 0.93     | 0.84 to 0.97| −0.14 to 0.30| −0.29              | 0.51    |
| Standing measurement| 0.84    | 0.65 to 0.93| −0.33 to 0.11| 0.01               | 0.94    |

ICC: intraclass correlation coefficients; CI: confidence interval; MDC: minimal detectable change

### Table 2. The ICC(2,1) and Bland-Altman analysis results

| Measurement        | ICC(2,1) | 95% CI      | Fixed Error | Proportional Error | MDC₀.₉₅, LOA |
|--------------------|----------|-------------|-------------|--------------------|--------------|
| Seated measurement | 0.88     | 0.73 to 0.95| −0.16 to 0.24| −0.43              | 0.86         |
| Prone measurement  | 0.80     | 0.57 to 0.91| −0.25 to 0.25| −0.33              | 1.06         |
| Standing measurement| 0.76    | 0.47 to 0.90| −0.13 to −0.86| −0.19 (−0.96 to 0.37) |             |

ICC: intraclass correlation coefficients; CI: confidence interval; MDC: minimal detectable change; LOA: limits of agreement. †: p < 0.05

### Table 3. Criterion-related validity

| Measurement        | r        | Spearman’s rank correlation coefficient |
|--------------------|----------|----------------------------------------|
| Seated measurement | 0.81 †   | †: p < 0.05                             |
| Standing measurement| 0.53 †  |                          |

### Table 4. Muscle strength comparisons between measurement positions

| Measurement | Seated | Standing | Prone | Judgement |
|-------------|--------|----------|-------|-----------|
| N/kg        | 4.90 ± 0.19 | 4.48 ± 0.19 | 3.64 ± 0.16 | †, §      |

Values are expressed as the mean ±SD unless otherwise indicated.
†: Seated > Prone, §: Standing > Prone, p < 0.05
values. The presence or absence of systematic error is highly important for the clinical applicability of a measurement method. If a systematic error occurs in the measurement testing stage, then that method of measurement is considered ineffective, and evaluation validity is affected. However, seated measurement, similar to prone measurement, did not include any intratester or intertester systematic errors during repeated measurement, suggesting that seated measurement could be a highly valid type of measurement. Meanwhile, a fixed error was found for intertester reliability for standing measurement. For standing measurements, the HHD measurements made by the male and female testers were 298.5 ± 62.3 N and 270.4 ± 48.3 N, respectively. For seated measurements, measurements the measurements made by the male and female tester were 297.6 ± 53.7 N and 294.5 ± 50.5 N, respectively. Hyde et al. and Hirano et al. reported that the HHD resistance applied by the tester is limited to approximately 300 N. Bohannon et al. indicated that for a strong male subject, fixation can be difficult to achieve for a female tester. Thus, the high muscle strength values obtained in the present study for seated measurements may have been due to the tester using both hands to fix the pelvis. However, because pelvic fixation must be performed with one hand (non-resistance side) during standing measurements, maximum muscle strength values may not have been properly measured by the female tester.

After confirming that measurement values did not include any systematic error, the MDC95 was calculated to clarify measurement error range. With the MDC95 changes within values depend on measurement error; in addition, if changes greater than the MDC95 values are observed, they can be considered to be true changes. Furthermore, the MDC95 values for intratester and intertester reliability were 0.80 N/kg and 0.86 N/kg, respectively, for seated measurement and 0.51 N/kg and 1.06 N/kg, respectively, for prone measurement. The intratester reliability MDC95 for standing measurement, which did not include systematic error, was 0.94 N/kg. This information could contribute to increasing the precision of determining the effects of treatment clinically and result in scientifically based developments in physical therapy.

However, a comparison of hip extensor strength values indicated that values of seated and standing measurements were higher than those of prone measurements. This suggests that whether the measurement position was a gravity-eliminated position or anti-gravity position affected the measurements. Therefore, measurements must be unified if used for evaluation.

Here we clarified that hip extensor strength measurement in seated individuals using an HHD has both relative and absolute reliability and high validity, indicating a correlation with the conventional prone measurement. Furthermore, because measurement in a seated position can be used for patients, who cannot assume the prone position because of a condition such as flexion contracture of the spine or lower limbs, this could be a useful method of measuring muscle strength in elderly individuals during rehabilitation.

Because this study employed healthy individuals as subjects, the utility of seated measurement for elderly individuals requires further investigation in the future. If the relationship of hip extensor strength with the ability to perform basic movements and perform activities of daily living could be clarified, then this measurement technique could provide even more valuable data.

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