J. Phys. Ther. Sci.
27: 2125–2127, 2015

Original Article

# Absolute reliability of shoulder joint horizontal adductor muscle strength measurements using a handheld dynamometer

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**Abstract.** [Purpose] The aim of this study was to verify the absolute reliability of shoulder joint horizontal adductor muscle strength measurements using a handheld dynamometer (HHD). [Subjects and Methods] The subjects were 33 healthy college students. The measurements were made three times with the HHD fixed using a belt (BFHHD) or with the examiner's hand (conventional method; HFHHD). The absolute reliability of measurements was verified using Bland-Altman analysis, both in the all subjects group and a group of subjects showing measurements less than a fixed limit of 30 kgf. [Results] In the <30 kgf group, a systematic bias was not observed, and BFHHD values were greater than HFHHD values. BFHHD values in the all subjects group showed a systematic bias; the 3rd measurement value was less than the maximum value obtained during the 1st and 2nd measurements. [Conclusion] For obtaining an acceptable value during clinical measurements of horizontal adductor muscle strength, single measurements obtained using an HFHHD in the case of a <30 kgf group and the maximum value of two measurements obtained using a BFHHD are reliable.

**Key words:** Absolute reliability, Handheld dynamometer, Shoulder joint horizontal adduction strength

*(This article was submitted Jan. 26, 2015, and was accepted Apr. 1, 2015)*

## INTRODUCTION

The portability of a handheld dynamometer (HHD) is excellent, and its clinical application for measurements is simple. The relative intra-class and inter-class reliabilities of an HHD are 0.84–0.99[1)] and 0.84–0.94[2)], respectively. Conventionally, the sensor unit of an HHD is fixed during the measurement of muscle strength. Although HHDs are usually fixed by examiners using their hands, there are fixed limits for the strength values than can be accurately measured[3, 4)]. Considering this, previous studies have examined the reliability of using belt fixation[5–9)]. A previous study reported 30 kgf as the fixed limit of shoulder horizontal adductor muscle strength measurements using an HHD fixed with the examiner's hand (hand-fixed HHD; HFHHD)[10)]. Although the HFHHD method has measurement limits, it is simple. Therefore, measurements made by the same examiner in accordance with the fixed limits of the sensor are considered clinically reliable. Katoh et al. reported that in the measurement of lower limb muscle strength, the inter-class reliability was higher when using a belt-fixed HHD (BFHHD) than when using the conventional HFHHD method, even for muscle strength values less than the fixed limits of measurements[6)]. However, there have been no previous studies on the absolute reliability in measurements upper limb muscle strength. This study examined shoulder joint horizontal adduction muscle strength measured using an HFHHD and BFHHD. The purpose of this study was to examine the absolute reliability of measurements in the all subjects group as well as a group with less than a fixed limit of muscle strength.

## SUBJECTS AND METHODS

A total of 33 healthy college students (20 males and 13 females; age, 21–22 years; height, 168.4 ± 7.6 cm; body weight, 62.4 ± 9.6 kg) were recruited in this study. The examiner, a 21-year-old college student (male; height, 174 cm; body weight, 63 kg), received sufficient training on measurement techniques before the experiment. Measurements of the strength of the shoulder joint horizontal adductor muscles were made using an HHD. All measurements were made on the dominant side. A μTAS F-1 HHD (Anima Corp., Tokyo, Japan) was used. The sensor was fixed using a belt or with the examiner's hand. All measurements were made in the supine position on an examination table. The shoulder joint was abducted to 90°, with 0° internal rotation and 0° external rotation, and the elbow joint was flexed to 90°. The elbow on the measurement side was positioned on the edge of the examination table. Two beds were placed in tandem with the examination table. The subject was positioned such that the shoulder joint position was aligned with the bedpost. For the BFHHD measurements, a belt was inserted between the bedpost and the floor to fix the HHD. The sensor was

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**Table 1.** Subject characteristics and shoulder joint horizontal adduction muscle strength

| | All subjects | | <30 kgf group | | >30 kgf group | |
|---|---|---|---|---|---|---|
| | HFHHD | BFHHD | HFHHD | BFHHD | HFHHD | BFHHD |
| Number of subjects (male, female) | 33 (20,13) | | 13 (1,12) | | 20 (19,1) | |
| Age (years) | 21.8 ± 8.4 | | 21.5 ± 0.5 | | 21.9 ± 0.3 | |
| Height (cm) | 168.4 ± 0.4 | | 161.2 ± 4.3 | | 173.0 ± 5.4 | |
| Body weight (kg) | 62.4 ± 9.6 | | 53.8 ± 3.7 | | 68.0 ± 3.7 | |
| 1st (kgf) | 21.0 ± 6.2 | 32.0 ± 15.2 | 14.8 ± 3.7 | 16.7 ± 4.9 | 25.0 ± 3.7 | 41.9 ± 10.6 |
| 2nd (kgf) | 21.6 ± 6.8 | 31.0 ± 13.1 | 14.3 ± 3.9 | 17.8 ± 4.7 | 26.4 ± 2.8 | 39.6 ± 8.7 |
| 3rd (kgf) | 20.6 ± 6.8 | 30.3 ± 12.3 | 13.9 ± 4.2 | 17.9 ± 5.4 | 24.9 ± 4.1 | 38.4 ± 7.8 |
| The maximum value obtained during the 1st and 2nd (kgf) | 22.3 ± 6.8 | 33.6 ± 14.5 | 15.0 ± 3.7 | 18.9 ± 4.7 | 27.0 ± 3.0 | 43.1 ± 9.8 |

Mean±SD
HFHHD: conventional method of an examiner manipulating the HHD by hand (hand-fixed HHD)
BFHHD: HHD fixed with a belt (belt-fixed HHD)

placed on a thin rubber pad on the distal upper arm. The examiner controlled his hand in such a way that he did not move the sensor of the HHD and suppressed compensatory movements by placing his other hand on the anterior aspect of the opposite shoulder joint.

Subjects were asked to perform isometric contractions in a manner similar to the "make test". Maximum contractions were attained within 3 s and were maintained for 5 s. The maximum values of the horizontal adduction muscle strength of the shoulder joint were recorded. Three measurements each were made using a BFHHD and HFHHD. Measurements were made on the same day at intervals of ≥30 s. Repetitions of HFHHD and BFHHD measurements were made at intervals of ≥1 week. An assistant recorded the measured values, and the examiner was blinded to these values.

For obtaining representative values from the results obtained, the differences in the values were measured, along with an analysis of absolute reliability in HFHHD and BFHHD measurements for both all subjects and the <30 kgf group. Because the fixed limit of the HFHHD for shoulder horizontal adduction muscle strength measurements was 30 kgf[10], we examined subjects with <30 kgf measurement values as a single group. The absolute reliability was verified using Bland-Altman analysis (BAA)[11]. BAA was performed using statistical software (R2.8.1) between the 1st and 2nd measurements as well as between the maximum value obtained during the 1st and 2nd measurements and the 3rd measurement. A probability (p) value of <0.05 was considered statistically significant.

The study protocol was approved by the ethics committee of Ryotokuji University (approval number: 2528) and was in accordance with the Declaration of Helsinki. Informed consent was obtained from each subject before participation.

## RESULTS

The mean and standard deviation of the measurements of the shoulder joint horizontal adduction muscle strength are shown in Table 1. The results of BAA and the standard error of measurement (SEM) are shown in Table 2. The <30 kgf HFHHD group had no systematic bias between the 1st and 2nd measurements, and the SEM was 0.8 kgf. A fixed bias was observed between the maximum value obtained during the 1st and 2nd measurements and the 3rd measurement. The 3rd measurement was smaller than the maximum value obtained during the 1st and 2nd measurements. The <30 kgf BFHHD group had no systematic bias between the 1st and 2nd measurements, and the SEM was 2.8 kgf. In addition, no systematic bias between the maximum value obtained during the 1st and 2nd measurements and the 3rd measurement was observed, and the SEM was 1.3 kgf. In the <30 kgf group, a fixed bias existed between the maximum value obtained during 1st and 2nd measurements with the HFHHD and BFHHD. In addition, the values measured using the BFHHD were greater than those measured using the HFHHD.

In the all subjects group, a proportional bias between the 1st and 2nd measurements was observed. Moreover, proportional and fixed biases between the maximum value obtained during the 1st and 2nd measurements and the 3rd measurement were observed. The 3rd measurement was smaller than the maximum value obtained during the 1st and 2nd measurements.

## DISCUSSION

In the present study, by using 30 kgf as the fixed limit for measurement of the shoulder joint horizontal adduction muscle strength by HFHHD in accordance with previous research, we verified the absolute reliability of the test-retest method in measurements less than the fixed limit. In addition, we investigated the absolute reliability between the HFHHD and BFHHD for measurements less than the fixed limit. Flansbjer et al.[12] reported good sensitivity of a test in the analysis of reliability of the gait performance criteria, and the SEM of measurement values was reported to be 10% or less. Therefore, in this study, no systematic bias for absolute reliability was observed; an SEM of <10% was regarded to be the bias allowed for clinical settings.

The HFHHD results in the <30 kgf group had no systematic bias, and the SEM was <10% of the means of the 1st and 2nd measurements. In addition, the 3rd measurement was less than the maximum value from the 1st and 2nd measurements. Therefore, in the <30 kgf HFHHD group, a single

**Table 2.** Bland-Altman analysis of shoulder joint horizontal adduction muscle strength measurements

| | | Fixed bias | | Proportional bias | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 95% CI | Bias* | Slope of the regression line | Bias* | SEM (kgf) | LOA | $MDC_{95}$ (kgf) |
| <30 kgf group (n=13) | HFHHD (the 1st and 2nd measurements) | −0.22 to 1.08 | n-ex | −0.055 | n-ex | 0.8 | −0.6 to 1.4 | 2.1 |
| | HFHHD (the maximum obtained during the 1st and 2nd measurements and the 3rd measurrment) | 0.30 to 1.76 | Exist | −0.143 | n-ex | 0.9 | −0.1 to 2.1 | 2.3 |
| | BFHHD (the 1st and 2nd measurements) | −3.47 to 1.38 | n-ex | 0.051 | n-ex | 2.8 | −4.7 to 2.6 | 7.8 |
| | BFHHD (the maximum obtained during the 1st and 2nd measurements and the 3rd measurement) | −0.10 to 2.08 | n-ex | −0.142 | n-ex | 1.3 | −0.7 to 2.6 | 3.5 |
| | BFHHD and HFHHD (the maximum obtained during the 1st and 2nd measurements) | 1.83 to 6.10 | Exist | 0.293 | n-ex | 2.5 | 0.7 to 7.2 | 6.9 |
| All subjects (n=33) | BFHHD (the 1st and the 2nd measurements) | −0.82 to 2.99 | n-ex | 0.158 | Exist | 3.7 | −6.0 to 8.0 | 10.2 |
| | BFHHD (the maximum obtained during the 1st and 2nd measurements and the 3rd measurement) | 1.62 to 4.87 | Exist | 0.167 | Exist | 3.2 | −2.9 to 9.4 | 9.0 |

HFHHD: conventional method of an examiner manipulating the HHD by hand (hand-fixed HHD); BFHHD: HHD fixed with a belt (belt-fixed HHD). *Presence of bias: exist, present; n-ex: not present.
95% CI: 95% confidence interval; SEM: standard error of measurement; LOA: limits of agreement; $MDC_{95}$: minimal detectable change in the 95% confidence interval.

measurement was considered to be reliable in the clinical setting.

The BFHHD results in the <30 kgf group had no systematic bias, and the SEM was <10% of the mean of the 1st and 2nd measurements. In addition, the 3rd measurement value was less than the maximum of the 1st and 2nd measurement values. Therefore, the maximum value of two measurements in the <30 kgf BFHHD group was considered to be reliable. Although 30 kgf is within the manipulative fixed limit, a fixed bias was observed between the maximum value obtained during the 1st and 2nd measurements using the HFHHD and BFHHD, and BFHHD values were higher than HFHHD values. The magnitude of the bias was estimated to be 0.73–7.19 from the limits of agreement. Consequently, caution should be exercised when comparing measurements made using an HFHHD and BFHHD because of the different measurement methods.

In all subjects, a proportional bias between the 1st and 2nd measurements was observed, and the SEM was >10% of the mean. Fixed bias and proportional bias were observed between the maximum value obtained during 1st and 2nd measurements and the 3rd measurement. The 3rd measurement was smaller than the maximum value obtained during the 1st and 2nd measurements. The SEM was <10% of the mean. Therefore, the adopted value was considered to be the maximum value of two measurements.

According to the results of the present study, for measurement of the shoulder joint horizontal adduction muscle strength using an HFHHD, a single measurement was considered adequate in the <30 kgf group. However, HFHHD values may not accurately represent actual strength, because they are smaller than BFHHD values; thus, the measurement method should be considered in the comparison of the measured values. For a BFHHD, the adopted values were considered to be the maximum value of two measurements.

In the present study, intra-class reliability was observed; however, we were not able to ensure face validity. In addition, the subjects were healthy young adults. Therefore, future research must consider inter-class reliability and the reliability of measurements in elderly subjects and those with diseases.

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