Test-retest reliability of isometric shoulder muscle strength measurement with a handheld dynamometer and belt

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Abstract. [Purpose] The aim of this study was to develop a method of measuring isometric shoulder joint muscle strength using a handheld dynamometer with a belt and investigate its test-retest reliability. [Subjects] The subjects comprised 40 healthy adults. [Methods] Six types of isometric shoulder muscle strength were measured twice, and reliability was assessed. [Results] The intraclass correlation coefficient (1, 1) values ranged from 0.976 to 0.902. The result of a Bland-Altman analysis showed differences in the types of errors between measurement items. [Conclusion] The relative reliability of isometric shoulder muscle measurement using a handheld dynamometer with a belt was high. However, analysis of absolute reliability revealed errors that may affect interpretation of values; therefore, it was considered that adapting the greater of two measurement values is appropriate.

Key words: Handheld dynamometer, Reliability, Shoulder muscle strength

INTRODUCTION

Previous studies of test-retest reliability of muscle strength measurement using a handheld dynamometer (HHD) have shown low reliability in measuring the lower limbs and high reliability in measuring the upper limbs1, 2). Wikholm et al.1) conducted an investigation with 3 examiners and healthy subjects and reported that, while the intraclass correlation coefficient (ICC) values for measurements of elbow flexor and shoulder external rotator muscles, which have low muscle strength, were 0.768 and 0.932, respectively, that of measurements of knee extensor muscles, which have high muscle strength, was 0.226. Agre et al.2) conducted an investigation with three examiners and healthy subjects and reported that Pearson’s product-moment correlation values ranged from −0.19 to 0.96 for the lower extremities, but from 0.88 to 0.94 for the upper extremities.

Katoh et al.3) developed a method of measurement with an HHD and a belt in order to increase the reliability of lower extremity muscle strength measurement. The ICC (2, 1) values for measurements of hip adduction, external rotation, and internal rotation, the average strength of which was less than 20 kgf, ranged from 0.70 to 0.83 without a belt and from 0.97 to 0.99 with a belt, suggesting that using a belt increases reliability even if muscle strength is lower than 30 kgf3) (300 N3)), which was believed to be the HHD measurement limit.

The purpose of this study was to develop a method of measuring shoulder joint muscle strength with an HHD and a belt and to investigate its test-retest reliability.

SUBJECTS AND METHODS

The subjects comprised 40 right-handed healthy adults (20 male, 20 female) with an average, height, and weight of 20 (range 20 to 22) years, 164.5 cm (SD=7.8 cm), and 60.8 kg (SD=13.4 kg), respectively, and no history of or-thopedic disease or shoulder injury, from whom informed consent was obtained. The study was conducted in accordance with the principles of the Declaration of Helsinki (1975, revised 1983). Explanations of the methods and the purpose of the study were provided by the assessor to the subjects in writing, and consent to participation was obtained in the form of signed consent forms. The study was approved by the Institutional Review Board of Ryotokuji University (approval number 2376).

Isometric shoulder joint muscle strengths (flexion, extension, abduction, external rotation, internal rotation, horizontal extension) were measured twice with an HHD (μTas F-1, Anima Corp., Tokyo, Japan) fixed in place with a belt. Prior to measurement, subjects performed exercises using 50%, 75%, and 100% of maximum muscle strength to both warm-up and practice. Measurements were taken as subjects performed isometric exercises with 3 seconds of maximum effort, once before and once after a 30-second break. Subjects were instructed not to strongly contract muscle groups of the elbow, hand joints, or digits when performing exercises. Measurement conditions are described in...
Table 1. Conditions for measuring shoulder joint muscle strength using a handheld dynanometer with a belt

| Exertion task          | Posture     | Limb positions                                         | Dynamometer position | Belt fixation       |
|-----------------------|-------------|-------------------------------------------------------|-----------------------|---------------------|
| Flexion               | Supine      | 0° shoulder flexion, 0° abduction, elbow slightly bent, forearm in pronation | Humerus lateral supracondylar ridge | Bed leg below arm   |
| Extension             | Seated (a)  | 0° shoulder flexion, 0° abduction, 0° elbow flexion, forearm in pronation | Olecranon              | Stairs baluster parallel to arm |
| Abduction             | Seated (a)  | 90° shoulder abduction, elbow slightly bent, forearm in pronation | Humerus lateral supracondylar ridge | Bed leg below arm   |
| External rotation     | Seated (b)  | 45° shoulder flexion, 135° elbow flexion               | Styloid process of the ulna   | Stairs baluster parallel to forearm |
| Internal rotation     | Seated (b)  | 45° shoulder flexion, 135° elbow flexion               | Styloid process of the ulna   | Stairs baluster parallel to forearm |
| Horizontal extension  | Prone       | 90° shoulder abduction, 90° elbow flexion              | Styloid process of the ulna   | Bed leg below arm   |

(a) The examiner held the subject’s shoulder on the measured side.
(b) To prevent abduction-adduction, a 5 kg bag of sand was fixed between the elbow and the baluster.
used to assess absolute reliability. When a proportional bias was observed, regression analysis was used to obtain the primary regression equation. R 2.8.0 was used for statistical analysis. P values less than 0.05 were deemed significant.

RESULTS

Table 2 shows the results of isometric shoulder joint muscle strength measurements. The average values for the first and second measurements of shoulder joint muscle strength were as follows: flexion, 16.2 and 16.1 kgf; extension, 14.6 and 14.9 kgf; abduction, 13.9 and 13.3 kgf; external rotation, 8.4 and 7.9 kgf; internal rotation, 15.3 and 15.0 kgf, and horizontal extension, 11.0 and 10.7 kgf.

Table 3 shows the reliability of measures of isometric shoulder joint muscle strength measurements. In terms of relative reliability, the ICC (1, 1) values ranged from 0.976 to 0.902 (p<0.05). In terms of absolute reliability, fixed biases were observed for abduction and external rotation, and proportional biases were observed for extension and horizontal extension. The limit of agreement (LOA) for extension ranged from −16.0% to 10.6%. The LOA for horizontal extension ranged from −18.6% to 20.6%. No systematic biases were observed for flexion and internal rotation, and only random errors were observed.

DISCUSSION

Since the ICC values for all six types of exercise were > 0.9, relative test-retest reliability was considered high. However, absolute reliability by Bland-Altman analysis revealed random errors at 4.5 kgf for flexion and 3.0 kgf for internal rotation. The average value of flexion and internal rotation was 15 kgf, whereas the random errors relative to the average value were 28% in flexion and 37% in internal rotation, which may impact patient performance. Therefore, it was considered appropriate to adopt the larger of two measurements rather than assuming errors within the random error range when performing measurement once.

Proportional biases were observed for extension and horizontal rotation. Based on the LOA, biases from −16.0% to 10.6% for extension and from −18.6% to 20.6% for horizontal extension were expected. Since the range of bias was wide, we considered it appropriate to adopt the larger of two measurements rather than assuming biases within the LOA range.

Since fixed biases observed in abduction and external rotation mostly showed smaller values in the second measurement for both muscle strengths, we considered it appropriate to adopt the first measurement. However, as some subjects showed larger values in the second measurement, we considered it acceptable to adopt the larger value of two measurements in line with the other exercise items.

In lower extremity muscle strength measurement with an HHD with a belt in 40 young healthy subjects, Katoh et al. reported that measurement values when a belt was used were higher than measurement values when the HHD was held by the examiner. The present study measured the strength of shoulder joint muscles which included many items considered to be below the limit of value that can be measured to have to hand the HHD. It is necessary to compare measurements obtained with an HHD and a belt with those obtained with an HHD but without a belt, i.e., with the HHD held by the examiner, when measuring should joint muscle strength in the future.

Since the present study measured young adult healthy subjects, the results may differ from those of elderly subjects.

Table 2. Isometric shoulder muscle strength measurements of young healthy adults made by one tester using a handheld dynamometer with a belt

| Shoulder exertion task | 1st time | 2nd time |
|------------------------|----------|----------|
| Flexion                | 16.2 (7.9) | 16.1 (7.5) |
| Extension              | 14.6 (5.2) | 14.9 (4.7) |
| Abduction              | 13.9 (5.7) | 13.3 (5.5) |
| External rotation      | 8.4 (3.4)  | 7.9 (3.0)  |
| Internal rotation      | 15.3 (5.8) | 15.0 (5.6) |
| Horizontal extension   | 11.0 (5.1) | 10.7 (4.2) |

Values are shown as the mean (SD). Unit: kgf

Table 3. Reliability of isometric shoulder muscle strength measurements of young healthy adults made by one tester using a handheld dynamometer with a belt

| Shoulder exertion task | ICC (1,1) | Bland-Altman analysis |
|------------------------|-----------|-----------------------|
|                        | Point estimation (95% CI) | LOA | SEM | Fixed bias | Proportional bias | Random error |
|                        |                        |     |     | 95% CI | Bias | Slope** | Bias | MDC |
| Flexion                | 0.957 (0.921–0.977)    | −0.6–0.8 | 0.062 | p=0.202 | n-exi | exist | exist | 4.5 |
| Extension              | 0.951 (0.910–0.974)    | −0.8–0.2 | 0.102 | p=0.042 | n-exi | exist | exist | 1.5 |
| Abduction              | 0.976 (0.956–0.987)    | −0.9–2.1 | 0.040 | p=0.207 | n-exi | exist | exist | 3.0 |
| External rotation      | 0.902 (0.823–0.947)    | 0.1–0.9 | 0.111 | p=0.107 | n-exi | exist | exist | 4.0 |
| Internal rotation      | 0.963 (0.932–0.981)    | −0.2–0.8 | 0.044 | p=0.318 | n-exi | exist | exist | 3.0 |
| Horizontal extension   | 0.967 (0.850–0.955)    | −0.3–0.9 | 0.191 | p=0.002 | n-exi | exist | exist | 3.0 |

Reliability: reliability of the 1st value and the 2nd value; ICC, intraclass correlation coefficient; 95% CI, 95% coefficient interval; LOA, limit of agreement; SEM, standard error of measurements. *Presence of bias: exist, present; n-exi, not present. **Slope of regression: MDC, line minimal detectable change.
and those suffering from a disease. Moreover, while the present study performed two measurements taking into account the time required for measurements in the clinic, the results may be different in an investigation in which measurements are performed three times or more.

The relative reliability of isometric shoulder joint muscle strength measurements with an HHD and a belt in young healthy adults was high; however, as absolute reliability analysis revealed random errors, it was considered appropriate to perform two measurements of isometric shoulder muscle strength and to adopt the larger value of the two.

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