Limits of the manipulative-fixed method for measurement of shoulder joint horizontal adduction muscle strength using a handheld dynamometer

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Abstract: [Purpose] The aim of this study was to verify the limit of isometric muscle strength of shoulder joint horizontal adduction using handheld dynamometer (HHD) manipulated by hand (referred to as the manipulative-fixed method). [Subjects and Methods] The subjects were 33 healthy college students. The examiner was a healthy college student. Shoulder joint horizontal adductor muscle strength was measured using HHD with the subject in the supine position. The belt-fixed and manipulative-fixed methods were used to secure the HHD sensor unit. The limitations of the manipulative-fixed method were assessed by simple regression analysis, in which the participants were divided into 2 groups according to a branch point. The slope of the straight line of the graph was visualized. [Results] Single regression analysis of the <30 kgf group revealed significant results. The results of single regression of the >30 kgf group were not significant. [Conclusion] The manipulative-fixed method is simple to perform. However, there exists the possibility that the actual muscle strength is not measurable by this method. The measurement limit of the shoulder horizontal adduction strength with the manipulative-fixed method was 30 kgf in the case of the examiner in the present study. The fixed limit was also found to influence in the muscle strength of the upper limbs.
Key words: Handheld dynamometer, Shoulder joint horizontal adduction strength, Manipulative-fixed limit

INTRODUCTION

Previous studies have shown that the inter-class reliability of muscle strength measurements using a handheld dynamometer (HHD) varies according to tester strength, which appears to be a major determinant of the magnitude and reliability of the measured forces[1–9]. An HHD is used to measure the force that gives rise to isometric contraction by inhibiting movement in the articulation performed by the subject. Thus, the magnitude of the force exerted by the examiner to suppress the movement of the subject affects the measured value. The limit of measurement using an HHD is reported to be 30 kgf (300 N)[10, 11]. Muscle strength varies depending on the age of the subject, type of articulation, gender, and disease. In general, muscle strength is greater in young adults than in the elderly, a healthy person can produce more force than patients with motor dysfunction, and muscles of the lower limbs generate greater force than those of the upper limbs. The reliability of muscle strength measurement using an HHD is influenced by various factors of both the subject and the examiner. As a result, in addition to the type of articulation, it is necessary to control for factors associated with both the subject and the examiner when comparing reliability. Studies comparing the inter-class reliability of muscles of the lower and upper limbs reported less reliability with the lower limbs[2, 4]. However, the intra-class correlation coefficients of the flexors of the elbow and external rotators of the shoulder were 0.768 and 0.932, respectively, indicating a greater trend in reliability of measurements of the upper limb muscles[4]. The pectoralis major muscles can affect respiratory function and have been implicated in rib cage compliance. Strength training of the upper limbs demonstrated several benefits for patients with respiratory disease[12]. Development of a quantitative method to evaluate strength of the upper limb muscles is also necessary to determine the intervention effects on the chest wall. Muscle strength is high in the upper limb muscles, and the pectoralis major muscle may be influenced by the fixed limit of an HHD. For measurement of lower limb muscle strength, Katoh et al. devised a method using a belt to compensate for the limitations of a fixed HHD[13–15]. We hypothesized that if there is influence by the fixed limit of HHD, then the branch point changing correlation may be exist. In this study, compensatory movements of the subjects were suppressed, and two methods of fixation of an HHD were used: an HHD fixed with a belt (belt-fixed HHD, BFHHD) and the conventional method of an examiner manipulating the HHD by hand (manipulative-fixed HHD, MFHHD). The limit of isometric strength measurement of shoulder joint horizontal adduction with a manipulative-fixed HHD was investigated.

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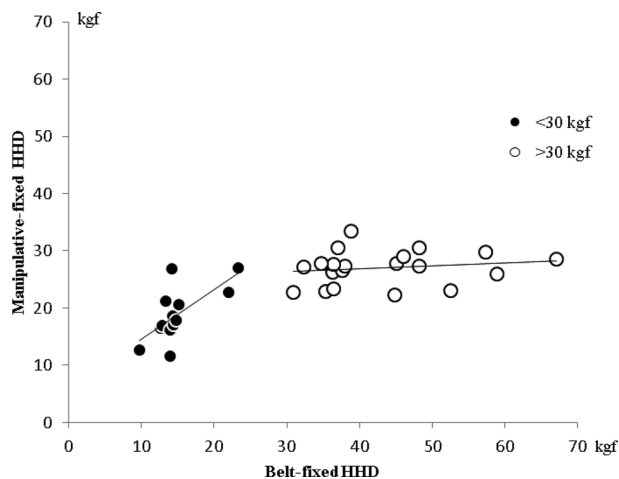
Fig. 1. Relationship of the measured values for the belt-fixed and manipulative-fixed methods

Table 1. Shoulder joint horizontal adduction strength

Group	Manipulative-fixed HHD	Belt-fixed HHD
<30 kgf (n=13)	15.0±3.7	18.9±4.7
>30 kgf (n=20)	27.0±3.0	43.1±9.8

Mean±SD (kgf)

Table 2. Simple linear regression analysis for the belt-fixed HHD and manipulative-fixed HHD

Group	Constant term	Standard partial regression coefficient	Standard error	Adjusted R^2
<30 kgf (n=13)	6.0447	0.86	4.40	0.40
>30 kgf (n=20)	28.3029	0.55	20.62	−0.03

SUBJECTS AND METHODS

A total of 33 healthy university students (20 males and 13 females; age, 21–22 years; mean height, 168.4 ± 7.6 cm; and mean body weight, 62.4 ± 9.6 kg) were recruited for this study. The examiner, a 21 year-old male (174 cm, 63 kg), received sufficient training on measurement techniques prior to the experiment. Strength measurements 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 in this study. The sensor was fixed using a belt or was manipulated by hand. All measurements were made in the supine position on a bed. The shoulder joint was abducted to 90° with an internal rotation of 0°, external rotation of 0°, and flexion of the elbow joint of 90°. The elbow on the measurement side was positioned to be on the outside of the bed. At this time, was measured by placing a tandem two beds. The subject was aligned such that the shoulder joint was aligned with a bedpost. In the BFHHD, a belt was fixed by inserting between the bedpost and the floor. The sensor was placed on a thin rubber pad on the distal upper arm. The sensor grip was positioned so that it would not shift with use by one hand, and the examiner suppressed compensatory movements by placing the shoulder joint on the unmeasured side at the front using his other hand. The horizontal adduction muscle strength of the shoulder joint was measured 3 times each using the BFHHD or MFHHD. Muscle strength was measured on the same day during a period of ≥30 s. Measurements with the MFHHD and BFHHD were performed at intervals of 1 week or more. The examiner was a college student who was blinded to the measured values, and assistants recorded the measured values. The maximum values of the first and second measurements, respectively, were selected as representative values for the belt-fixed and manipulative-fixed methods. Scatterplots were created from the obtained values. Fixed limits were divided into 2 branch points as straight lines with flat slopes on the graph. This study utilized regression equations before and after the branch point.

Regression analysis was performed using the R statistical software (version 2.8.1). A 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 consent was obtained from each subject before participation.

RESULTS

Measured values for the shoulder joint horizontal adduction muscle strength by isometric contraction were greater when using the BFHHD than when using the MFHHD (Table 1). The relationship between the measured values obtained using the BFHHD and MFHHD is shown in the scatterplot presented in Fig. 1. Visual analysis revealed that the relationship between the measured values obtained using the MFHHD and BFHHD changed to the boundary of 30 kgf the value of BFHHD. Single regression analysis of the <30 kgf group revealed significant results. The results of single regression for the >30 kgf group were not significant. The regression equation for the manipulative-fixed values of the <30 kgf group was as follows: y = 6.0447 + 0.8607 × x (adjusted R^2 = 0.4015, F = 9.051, p = 0.0119), where y was the manipulative-fixed value and x was the belt-fixed value. The regression equation for the manipulative-fixed values of the >30 kgf group was as follows: y = 28.3029 + 0.5481 × x (adjusted R^2 = −0.02588, F = 0.5206, p = 0.4798), where y was the manipulative-fixed value and x was the belt-fixed value (Table 2).

DISCUSSION

The slope of the regression equation was the result of significant differences between the >30 and <30 kgf groups. The graph of the >30 kgf group shows that measurement with the MFHHD created a state close to the horizon. Therefore, a fixed limit of 30 kgf for shoulder horizontal adduction muscle strength was adopted in this study. In addition,

the limit for the manipulative-fixed method was considered to be 30 kgf for the examiner in this study. As a result of eccentric and concentric contractions, it was not possible to maintain the joint angle during measurement, and when the strength values were near 30 kgf, the possibility of an error in muscle strength was slightly increased in the MFHHD measurements. In such cases, measurement with a BFHHD is required. Because the examiner was a young adult male, there is a possibility that the lower body size of the female participants may have influenced the results. In future studies, fixed limits are required for examiner. In addition, Katoh et al.[13], in a discussion on lower limb muscle strength measurement using a BFHHD, showed significantly greater values for measurements using a BFHHD even in the case of internal and external rotation of the hip compared with those obtained using an MFHHD. Even cases in which the fixed limit was less than the conventional values suggested insufficient values in the manipulative-fixed model. In future research, results obtained using an MFHHD in the measurement of shoulder horizontal adduction movement with a limit of <30 kgf should be assessed. The measurement limit for shoulder horizontal adduction muscle strength with the MFHHD was 30 kgf in this study. As a result, the fixed limit was also found to influence the muscle strength of the upper limbs.

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