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Original Article

Intra- and inter-rater reliability of isometric shoulder extensor and internal rotator strength measurements performed using a hand-held dynamometer

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Abstract. [Purpose] The purpose of the present study was to establish the intra- and inter-rater reliability of measurement of extensor strength in the maximum shoulder abducted position and internal rotator strength in the 90° abducted and the 90° external rotated position using a hand-held dynamometer. [Subjects and Methods] Twelve healthy volunteers (12 male; mean ± SD: age 19.0 ± 1.1 years) participated in the study. The examiners were two students who had nonclinical experience with a hand-held dynamometer measurement. The examiners and participants were blinded to measurement results by the recorder. Participants in the prone position were instructed to hold the contraction against the ground reaction force, and peak isometric force was recorded using the hand-held dynamometer on the floor. Reliability was determined using intraclass correlation coefficients. [Results] The intra- and inter-rater reliability data were found to be "almost perfect". [Conclusion] This study investigated intra- and inter-rater reliability and reveald high reliability. Thus, the measurement method used in the present study can evaluate muscle strength by a simple measurement technique.

Key words: Prone, Shoulder abduction, Measurement error

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INTRODUCTION

Shoulder muscle strength is often studied with a particular focus on the relationship between swimming performance and muscle strength in front crawl swimming. In a previous study on the relationship between swimming performance and muscle strength, Gola et al.[1)] reported a statistically significant correlation between the extensors of the shoulder joint and swimming velocity when swimming 25 meters. However, the starting angle of the shoulder joint in the Gola et al.[1)] report was 0°. This position does not consider the specificity of swim performance. Haycraft et al.[2)] reported that the need for swim-specific dry-land training was mentioned in several studies; however, their research did not find a significant relationship between the training protocol and swimming performance. Specific muscle strength measurement with swimming performance is important in order to find the relationship between swimming performance and muscle strength, and swim-specific dry-land training.

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The front crawl swimming strokes is classified in to the catch phase, pull phase, finish phase, and recovery phase. The catch and pull phases generate a propulsive force. The shoulder is extended from the maximum abducted position in the catch phase to internal rotation in the abducted position in the pull phase. Therefore, a reliability study of measurement is important to measure extensor strength in the maximum shoulder abducted position (MABP), similar to the catch phase, to measure internal rotator strength in the 90° abducted and the 90° external rotated position (ABERP), similar to the pull phase.

In the past, a limited number of reliability studies for extensor strength in the MABP and internal rotator strength in the ABERP have been published. Awatani et al.[3] reported high intra-rater reliability in the measurement of extensor strength in the MABP. However, thier study did not investigate inter-rater reliability in the measurement of extensor strength in the MABP. Additionally, measurement of internal rotator strength in the ABERP did not establish measurement methods for reliability[4].

The purpose of the present study was to establish the intra- and inter-rater reliability of measurement of extensor strength in the MABP and internal rotator strength in the ABERP using a hand-held dynamometer (HHD).

SUBJECTS AND METHODS

Twelve healthy volunteers (12 male; mean ± standard deviation [SD]: age 19.0 ± 1.1 years, height 173.5 ± 4.8 cm, body weight 65.8 ± 5.8 kg) participated in the study. Participants had experienced no shoulder pain in the past six months and had no history of shoulder surgery. They were also well informed both orally and in writing and gave written consent. This study was approved by the Research Ethics Committee of Kyushu Kyoritsu University (Approval No. 2015–04). The examiners were two students who had nonclinical experience with HHD measurement. The examiners observed the participants to ensure that they maintained the proper measurement position. Repeat measurement was made when the position was changed. The examiners and participants were blinded to measurement results by the recorder.

Muscle strength was measured as the peak isometric force using an HHD (Mobie MM100C, Minato Medical Science Co., Ltd., Japan). Measurements of extensor strength in the MABP and internal rotator strength in the ABERP were performed on the dominant and nondominant sides. In the case of both measurements, the participants lay in the prone position with their toes, abdomen, chest, and mentum touching the ground. The shoulder in which extensor strength was to be measured in the MABP was positioned with maximum shoulder abduction, with the elbow extended and the forearm in a neutral position[3]. The shoulder to be measured in internal rotator strength in ABERP was positioned with 90° shoulder abduction and 90° external rotation, with the elbow 90° flexion and the forearm in a neutral position. The opposite shoulder in the case of both measurements was positioned in contact with the side of the body. For both measurements, the HHD was placed on a firm carpet and against the heads of the metacarpal bones on the palm side, and it was held in place with a hand to prevent any improper movement during measurement[3]. Participants were instructed to hold the contraction against the ground reaction force, and the peak isometric force was recorded using the HHD on the floor. After warm-up shoulder movements, the trial was started. Measurements of maximum isometric contractions lasting three seconds were performed, with three trials per session; five minutes of rest was allowed between trials. The same protocols were utilized for in these participants in two sessions separated by a one-week interval. Participants and shoulders were assigned randomly by using a computer system.

Mean and SD values were calculated for descriptive data from each measurement. Same-session and between-day intra-rater reliability were determined using intraclass correlation coefficients ($ICC_{1,k}$) and associated 95% confidence intervals (95% CIs). Inter-rater reliability was determined using the $ICC_{2,k}$ and associated 95% CI ICC values were evaluated according to the criteria of Landis et al.[5]: 0.00 to 0.20 was slight, 0.21 to 0.40 was fair, 0.41 to 0.60 was moderate, 0.61 to 0.80 was substantial, and 0.81 to 1.00 was almost perfect. In the case of ‘substantial’, a decision study was performed with the obtained $ICC_{x,1}$ (p1) and 0.81 as the target $ICC_{x,k}$, and the number of required trials was calculated (k) [$k=\{0.81*(1-p1)\}/\{p1*(1-0.81)\}$]. The measurement error value was calculated using the standard error of measurement (SEM) [$SEM=SD*\sqrt{(1-ICC)}$], SEM% [SEM%=(SEM/mean)*100], the 95% CI of the minimal detectable change (MDC_{95}) [$MDC_{95}=SEM*\sqrt{2}*1.96$], MDC% [MDC%=($MDC_{95}$/mean)*100], and the limits of agreement (LOA) [$LOA=\bar{x} \pm 1.96*SD$]. Systematic errors were assessed using Bland-Altman (B-A) analysis[6,7] for between-day and inter-rater data. Statistical analysis was performed with R 2.8.1 and Excel for Windows 2010 (Microsoft Japan Co., Ltd.), and a p-value less than 0.05 was considered statistically significant.

RESULTS

The results for isometric shoulder extensor and internal rotator strength measurements are presented in Table 1. The results fot same-session intra-rater reliability and measurement error for extensor strength are presented in Table 2. The $ICC_{1,3}$ values for both examiners were ≥0.813 and were considered ‘almost perfect’. The SEM and SEM% for both examiners were ≤7.1 N and 8.8% respectively. The MDC_{95} and MDC% for both examiners were ≤19.5 N and 24.3% respectively.

The results for same-session intra-rater reliability and measurement error for internal rotator strength are presented in Table 2. The $ICC_{1,3}$ values for both examiners were ≥0.903 and were considered ‘almost perfect’. The SEM and SEM% for both examiners were ≤6.6 N and 8.6% respectively. The MDC_{95} and MDC% for both examiners were ≤18.4 N and 23.9% respectively.

Table 1. Isometric shoulder extensor and internal rotator strength

	Extensor				Internal rotator			
	Trial 1	Trial 2	Trial 3	Mean of 3 trials	Trial 1	Trial 2	Trial 3	Mean of 3 trials
Day 1								
Examiner 1								
Dominant	84.9 ± 22.0	86.9 ± 16.3	85.9 ± 19.1	85.7 ± 18.4	76.5 ± 31.4	80.9 ± 27.4	77.8 ± 25.4	78.4 ± 27.5
Non-dominant	71.0 ± 15.0	78.1 ± 16.1	76.9 ± 9.9	75.3 ± 12.7	62.3 ± 21.8	68.2 ± 18.9	71.0 ± 17.7	67.2 ± 18.5
Examiner 2								
Dominant	85.6 ± 19.4	83.5 ± 14.8	86.2 ± 15.1	85.1 ± 15.9	84.0 ± 28.1	83.3 ± 23.3	82.1 ± 25.9	83.1 ± 25.0
Non-dominant	78.3 ± 11.7	75.2 ± 16.8	78.2 ± 14.2	77.2 ± 12.8	72.6 ± 20.8	69.7 ± 18.5	68.4 ± 21.5	70.3 ± 19.8
Day 2								
Examiner 1								
Dominant	83.6 ± 13.9	80.9 ± 16.6	79.4 ± 21.6	81.3 ± 15.2	82.3 ± 22.8	80.8 ± 21.9	75.6 ± 20.7	79.6 ± 20.8
Non-dominant	75.1 ± 12.9	74.1 ± 13.3	78.3 ± 20.5	75.8 ± 14.2	70.3 ± 19.3	66.1 ± 17.4	68.9 ± 19.8	68.4 ± 17.3
Examiner 2								
Dominant	80.8 ± 18.8	77.7 ± 14.7	82.5 ± 16.2	80.3 ± 14.2	80.7 ± 28.0	75.1 ± 22.8	75.1 ± 21.1	77.0 ± 22.4
Non-dominant	76.6 ± 15.3	69.2 ± 18.9	69.7 ± 11.9	71.8 ± 14.0	70.3 ± 22.1	66.6 ± 21.2	61.5 ± 15.2	66.1 ± 18.3

Mean ± SD (N).
Measurements of maximum isometric contractions lasting three seconds were performed, with three trials in one session; and a five-minute rest was allowed between trials. The same protocols were performed in these participants in two sessions separated by a one-week interval.

The results for between-day intra-rater reliability and measurement error for extensor strength are presented in Table 3. The $ICC_{1, 2}$ values for examiner 1 were ≥0.884, and were considered 'almost perfect'. The SEM and SEM% for examiner 1 were ≤5.7 N and 6.8% respectively. The MDC_{95} and MDC% for examiner 1 were ≤15.7 N and 18.8% respectively. The $ICC_{1, 2}$ values for examiner 2 were considered 'substantial' for the dominant side at ≥0.772 and 'almost perfect' for the nondominant side at ≥0.847. The decision study for the dominant side revealed that the number of required trials in the case of examiner 2 is 2.5 times. The SEM and SEM% for examiner 2 were ≤7.1 N and 8.6% respectively. The MDC_{95} and MDC% for examiner 2 were ≤19.7 N and 23.9% respectively. Systematic errors did not exist and only random error existed by the B-A analysis (Table 3).

The results for between-day intra-rater reliability and measurement error for internal rotator strength are presented in Table 3. The $ICC_{1, 2}$ mean values for both examiners were ≥0.944 and were considered 'almost perfect'. The SEM and SEM% for both examiners were ≤5.6 N and 7.1% respectively. The MDC_{95} and MDC% for both examiners were ≤15.6 N and 19.8% respectively. The results of the B-A analysis are presented in Table 3. There was a proportional bias towards systematic errors on the dominant side for examiner 1 and a fixed bias on the dominant side for examiner 2. The error of the LOA was 22.8 N on the dominant side for examiner 1 and 14.5 N on the dominant side for examiner 2.

The results of inter-rater reliability and measurement error for extensor strength are presented in Table 4. The $ICC_{2, 2}$ mean values for both days were ≥0.869 and were considered 'almost perfect'. The SEM and SEM% for both days were ≤5.0 N and 6.8% respectively. The MDC_{95} and MDC% for both days were ≤14.0 N and 18.9% respectively. Systematic errors did not exist and only random error existed by the B-A analysis (Table 4).

The results for inter-rater reliability and measurement error for internal rotator strength are presented in Table 4. The $ICC_{2, 2}$ values for both days were≥0.952 and considered 'almost perfect'. The SEM and SEM% for both days were ≤4.5 N and 6.0% respectively. The MDC_{95} and MDC% for both days were ≤12.4 N and 16.6% respectively. Systematic errors did not exist and only random error existed by the B-A analysis (Table 4).

DISCUSSION

Regarding the intra-rater reliability for extensor strength, the ICC values were showed 'almost perfect' reliability except in the case of the dominant side for examiner 2. The $ICC_{1, 2}$ for the dominant side for examiner 2 was 0.77, revealing 'substantial' reliability. The results of the decision study revealed that the mean ICC for three trials ($ICC_{1, 3}$) for the dominant side was≥0.81 for examiner 2 and showed "almost perfect" reliability, as in the case of the other results. The results of the present study also showed high intra-rater reliability that was considered 'almost perfect'. Therefore, consistent with previous studies[3], use of the mean of 3 trials is recommended for this measurement method. Regarding the intra-rater measurement error for for extensor strength, Awatani et al.[3] reported that the $ICC_{1, 2}$ for between-day data was ≤6.2 N, and using data from the same study, the SEM% was calculated to be 6.7%. The coefficients of variation (CVs) of the SEM and SEM% were the

Table 2. Same-session intra-rater reliability for isometric shoulder strength measurement

	$ICC_{1, 3}$		
	Mean (95% CI)	SEM (SEM%)	MDC_{95} (MDC%)
Extensor			
Day 1			
Examiner 1			
Dominant	0.952 (0.876 to 0.985)	4.1 (4.8)	11.4 (13.3)
Non-dominant	0.881 (0.692 to 0.962)	4.8 (6.4)	13.3 (17.6)
Examiner 2			
Dominant	0.956 (0.887 to 0.986)	3.4 (4.0)	9.3 (11.0)
Non-dominant	0.869 (0.662 to 0.959)	5.1 (6.6)	14.1 (18.2)
Day 2			
Examiner 1			
Dominant	0.832 (0.566 to 0.947)	7.1 (8.7)	19.5 (24.1)
Non-dominant	0.870 (0.663 to 0.959)	5.6 (7.4)	15.6 (20.6)
Examiner 2			
Dominant	0.813 (0.517 to 0.941)	7.1 (8.8)	19.5 (24.3)
Non-dominant	0.857 (0.629 to 0.955)	5.9 (8.2)	16.3 (22.7)
Internal rotator			
Day 1			
Examiner 1			
Dominant	0.976 (0.938 to 0.992)	4.2 (5.4)	11.8 (15.0)
Non-dominant	0.926 (0.809 to 0.977)	5.2 (7.8)	14.5 (21.7)
Examiner 2			
Dominant	0.967 (0.915 to 0.990)	4.6 (5.5)	12.6 (15.2)
Non-dominant	0.972 (0.929 to 0.991)	4.3 (6.2)	12.0 (17.1)
Day 2			
Examiner 1			
Dominant	0.943 (0.851 to 0.982)	5.1 (6.4)	14.2 (17.9)
Non-dominant	0.906 (0.757 to 0.970)	5.6 (8.2)	15.6 (22.8)
Examiner 2			
Dominant	0.921 (0.796 to 0.975)	6.6 (8.6)	18.4 (23.9)
Non-dominant	0.903 (0.750 to 0.970)	4.3 (6.5)	11.9 (17.9)

ICC: intraclass correlation coefficient; CI: confidence interval; SEM: standard error of measurement; MDC_{95}: 95% confidence interval of minimal detectable change

same[8]), and the common analytical goal for the CV is ≤10%[9]). Therefore, the SEM% than 10% was considered to be a mild measurement error. In the present study, the intra-rater measurement errors also showed mild random error, consistent with previous studies[3]).

Regarding the intra-rater reliability for measurement of internal rotator strength, Cools et al.[10]) reported $ICC_{3, 3}$ values of 0.97. The results of the present study revealed high intra-rater reliability, consistent with previous studies[10]). Cools et al.[10]) also reported that the SEM of the $ICC_{3, 3}$ was ≤6.09 N for the intra-rater measurement error for internal rotator strength, and using data from the same study, the SEM% was calculated to be 5.0%. In the present study, intra-rater measurement errors were also mild. However, the presence of systematic error is means that the results must be interpreted carefully.

The inter-rater reliability for extensor strength showed high inter-rater reliability, and inter-rater measurement errors also showed mild random error, consistent with the intra-rater reliability. Regarding the inter-rater reliability for internal rotator strength, Cools et al.[10]) reported an $ICC_{2, 2}$ values of 0.97 and SEM of ≤9.6 N, and using data from the same study, the SEM% was calculated to be 7.8%. The results of the present study found high inter-rater reliability, and inter-rater measurement errors also showed mild random error, consistent with previous studies[10]).

Previous studies performed two different isometric shoulder extensor strength measurements, one with the shoulder 0° flexed and abducted with the participant in a sitting position[11]), and one with the shoulder 90° flexed with the participant in the supine position[12, 13]). In other studies[10, 14]), isometric shoulder internal rotator strength measurement was performed in all kinds of positions, e.g. prone, supine, and sitting, and against manual resistance provided by an examiner. A previous study has also been performed in which the participant was in the prone position with the shoulder abducted and 0° rotated[14]), and

Table 3. Between-day intra-rater reliability for isometric shoulder strength measurement

	$ICC_{1,2}$			Bland-Altman analysis					
	Mean (95% CI)	SEM (SEM%)	MDC_{95} (MDC%)	Mean (LOA) (N)	95% CI (N)	Fixed bias	Regres-sion	p value	Proportional bias
Extensor									
Examiner 1									
Dominant	0.884 (0.615 to 0.966)	5.7 (6.8)	15.7 (18.8)	4.4 (−16.0 to 24.8)	−2.2 to 11.1	No	0.322	0.307	No
Non-dominant	0.917 (0.725 to 0.976)	3.8 (5.0)	10.5 (13.9)	−0.5 (−15.7 to 14.7)	−5.4 to 4.4	No	−0.192	0.551	No
Examiner 2									
Dominant	0.772 (0.242 to 0.933)	7.1 (8.6)	19.7 (23.9)	4.7 (−20.1 to 29.5)	−3.3 to 12.8	No	0.149	0.644	No
Non-dominant	0.847 (0.491 to 0.955)	5.2 (7.0)	14.5 (19.5)	5.4 (−11.6 to 22.4)	−0.1 to 10.9	No	−0.147	0.647	No
Internal rotator									
Examiner 1									
Dominant	0.944 (0.814 to 0.984)	5.6 (7.1)	15.6 (19.8)	−1.2 (−24.0 to 21.6)	−8.6 to 6.2	No	0.59	0.043	Yes
Non-dominant	0.953 (0.843 to 0.986)	3.8 (5.6)	10.5 (15.6)	−1.3 (−16.6 to 14.0)	−6.2 to 3.7	No	0.156	0.628	No
Examiner 2									
Dominant	0.960 (0.868 to 0.988)	4.7 (5.8)	13.0 (16.2)	6.1 (−8.3 to 20.5)	1.5 to 10.8	Yes	0.345	0.273	No
Non-dominant	0.957 (0.858 to 0.988)	3.9 (5.7)	10.7 (15.8)	4.1 (−9.3 to 17.5)	−0.2 to 8.5	No	0.228	0.477	No

ICC: intraclass correlation coefficient; CI: confidence interval; SEM: standard error of measurement; MDC_{95}: 95% confidence interval of minimal detectable change

Table 4. Intrer-rater reliability for isometric shoulder strength measurement

	$ICC_{2,2}$			Bland-Altman analysis					
	Mean (95% CI)	SEM (SEM%)	MDC_{95} (MDC%)	Mean (LOA) (N)	95% CI (N)	Fixed bias	Regres-sion	p value	Proportional bias
Extensor									
Day 1									
Dominant	0.926 (0.753 to 0.978)	4.6 (5.4)	12.7 (14.9)	0.6 (−17.8 to 19.0)	−5.3 to 6.6	No	0.276	0.385	No
Non-dominant	0.964 (0.878 to 0.990)	2.4 (3.1)	6.6 (8.6)	−1.9 (−10.8 to 7.0)	−4.8 to 1.0	No	−0.001	0.998	No
Day 2									
Dominant	0.925 (0.741 to 0.979)	3.9 (4.9)	10.9 (13.4)	−0.9 (−14.7 to 16.5)	−4.1 to 6.0	No	0.131	0.684	No
Non-dominant	0.869 (0.565 to 0.962)	5.0 (6.8)	14.0 (18.9)	4.0 (−14.1 to 22.1)	−1.9 to 9.8	No	0.023	0.942	No
Internal rotator									
Day 1									
Dominant	0.969 (0.878 to 0.992)	4.5 (5.6)	12.4 (15.4)	−4.7 (−20.5 to 11.1)	−9.9 to 0.4	No	0.318	0.313	No
Non-dominant	0.952 (0.839 to 0.986)	4.1 (6.0)	11.4 (16.6)	−3.1 (−18.7 to 12.5)	−8.2 to 2.0	No	−0.173	0.591	No
Day 2									
Dominant	0.974 (0.913 to 0.993)	3.4 (4.3)	9.4 (12.0)	2.6 (−10.4 to 15.6)	−1.6 to 6.8	No	−0.256	0.422	No
Non-dominant	0.956 (0.854 to 0.987)	3.7 (5.4)	10.1 (15.1)	2.3 (−11.9 to 16.5)	−2.3 to 6.9	No	−0.142	0.660	No

ICC: intraclass correlation coefficient; CI: confidence interval; SEM: standard error of measurement; MDC_{95}: 95% confidence interval of minimal detectable change

another study performed measurements with the shoulder in the 90° abducted and 90° external rotated positions[10]. Thus, there is no consensus about measurement methods. Therefore, measurement methods should be selected that are appropriate to sports performance and easy to perform. The measurements used in the present study were performed in the MABP and ABERP which are similar to the catch phase and pull phase in front crawl swimming. Additionally, the measurements were easily performed because the examiners were not involved in holding the HHD.

The measurement error of the HHD has been reported to be due to lack of stabilization[15] and inadequate tester strength[16, 17]. Inconsistent participant effort levels contributed to the measurement error. Regarding a measurement method using an HHD, Awatani et al.[3] reported that lack of stabilization and inadequate tester strength did not affect the measurement error because the examiners was not involved in holding the HHD. Therefore, with respect to measurement error, inconsistent effort levels in the participants may have had a negative effect on the results.

In the present study, participants and shoulders were selected randomly, and the examiners and participants were blinded to the measurement results. Extensor strength in the MABP and internal rotator strength in the ABERP still showed high intra- and inter-rater reliability, and mild measurement errors by the randomized and blinded method. Therefore, this measurement method is easy, has high reliability, and is indicated to be unaffected by experience and examiner bias.

The present study has several limitations. The levels of experience of the examiners were not compared. In addition, the participants' postures during measurement may not have been completely consistent. This method is not appropriate for patients undergoing therapy for ADL improvement.

This study investigated the intra- and inter-rater reliability for extensor strength in the MABP and internal rotator strength in the ABERP revealed high reliability. Thus, the measurement method used in the present study can evaluate muscle strength by a simple measurement technique.

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