The reliability of strength tests performed in elevated shoulder positions using a hand-held dynamometer

Journal:	*Journal of Sport Rehabilitation*
Manuscript ID:	JSR.2015-0034.R2
Manuscript Type:	Technical Report
Keywords:	dynamometry, shoulder, sports-physiotherapist, strength, swimming, testing-and-measurement

Context: The reliable measurement of shoulder strength is important when assessing the athlete involved in overhead activities. Swimmers' shoulders are subject to repetitive humeral elevation and consequently have a high risk of developing movement control issues and pain. Shoulder strength tests performed in positions of elevation assist with the detection of strength deficits that may impact on injury and performance. The reliability of isometric strength tests performed in positions of humeral elevation without manual stabilisation, which is a typical clinical scenario, has not been established.

Objective: To establish the relative and absolute intra-rater reliability of shoulder strength tests functional to swimming in three body positions commonly used in the clinical setting.

Design: Repeated measures, reliability study.

Setting: Research laboratory

Subjects: Fifteen university students and staff (mean ± SD age 24 ± 8.2 y) volunteered for the study.

Intervention: Isometric shoulder strength tests were performed in positions of humeral elevation (flexion and extension in 140° abduction in the scapular plane; internal and external rotation in 90° abduction) on subjects without shoulder pain in supine, prone and sitting. Subjects were tested by one examiner with a hand-held dynamometer and retested after 48 hours.

Main Outcome Measures: Relative reliability ($ICC_{3,1}$) values with 95% CI. Absolute reliability was reported by minimal detectable change (MDC).

Results: Good to excellent intra-rater reliability was found for all shoulder strength tests (ICC 0.87-0.99). Intra-rater reliability was not affected by body position. MDC%

was less than 16% for every test and less than or equal to 11% for tests performed in supine.

Conclusions: Shoulder flexion, extension, internal and external rotation strength tests performed in humeral elevation demonstrated excellent to good intra-rater reliability regardless of body position. A strength change of more than 15% in any position can be considered meaningful.

Keywords: *isometric contraction, muscle strength dynamometer, shoulder joint*

The reliable measurement of an athlete's shoulder strength is an important part of clinical assessment. Accurate shoulder strength assessment and measurement of strength change over time is necessary when making clinical decisions concerning diagnosis, treatment, exercise progression, training loads and in sport specific screening. In order to determine specific shoulder strength deficits related to an athlete's overhead function, assessment should include tests in elevated positions of the humerus at and above 90° shoulder abduction.

In the early pull-through phase of the freestyle swimming stroke may reach end range abduction and shoulder pain is commonly reported[1, 2] hence the reliable investigation of possible contributing factors, such as shoulder muscle weakness,[3, 4] is paramount. Flexion (FL) and extension (EX) strength tests in 140° abduction are functionally relevant to this part of the stroke and the hand-entry phase. Another vulnerable part of the stroke is recovery when the arm is out of the water and the shoulder is moving into abduction and external rotation (ER), where pain and impingement has been reported to occur.[1, 2]

Previous research has demonstrated that shoulder ER, internal rotation (IR), abduction, adduction, FL and EX strength testing using a hand-held dynamometer

(HHD) is reliable in ranges at or below shoulder height,[5-7] however, no studies have investigated shoulder FL and EX in ranges above 90° abduction. Body position has been shown to influence the reliability of strength testing. Cools et al.[6] demonstrated good to excellent reliability for shoulder rotation strength tests regardless of patient position with stabilisation provided to the trunk or limb, which is not always possible for the sole clinician.

This study aimed to establish the relative and absolute intra-rater reliability for testing shoulder (FL and EX in 140° abduction; ER and IR at 90° abduction) strength in different body positions without manual stabilisation.

Methods

Design

A repeated-measures reliability study design was used. Independent variables were examiner, tests and body position. The dependent variable was muscle strength (Newtons).

Subjects

Volunteers between the ages of 18-30 years were recruited from the university community. Exclusion criteria were a history of: shoulder dislocation or surgery and shoulder pain within the previous two months. Potential subjects were excluded if shoulder pain was experienced during the testing procedure. Permission to conduct this research was granted by the university's ethical committee.

Procedures

One experienced female physiotherapist (weight, 56kg) performed the measurements. The tester was blinded during testing. Tests were performed using the self-calibrating JTech PowerTrack™ Commander Muscle Tester (JTECH Medical, Salt Lake City, Utah, USA).

Shoulder FL, EX, ER and IR strength tests were performed bilaterally in prone, supine and sitting positions on two occasions, 48 hours apart. The order of testing was block randomised. Within each test position (prone, supine and sitting), shoulder strength tests (ER, IR, FL and EX) and side of testing were randomised for each subject. The same order for shoulder FL and EX (FIGURE 1A) and ER and IR (FIGURE1B) strength tests was used for both sessions. No manual stabilisation was provided to the participant's body or upper limb.

Subjects completed a questionnaire which included questions on hand dominance, shoulder injury, pain and exercise frequency. A three minute shoulder warm-up was performed with resistance tubing in the same directions used for testing.

A 'make' strength test was performed for each of the test positions. Two repetitions of each strength test were performed in each test position with a rest period of five seconds between each repetition and 30 seconds between each strength test. The subject was asked to gradually build up to a maximum force and maintain the effort, then relax after five seconds.

Statistical Analyses

The maximum value recorded from the two repetitions of each test session was used for analysis. The overall mean (M) and standard deviation (SD) in Newtons (N) were calculated for each strength test in each body position. Test-retest intraclass correlation coefficients (two-way mixed with absolute agreement) $ICC_{3,1}$[8] and associated 95% confidence intervals (CI) were calculated after normality of data were determined using the Kolmogorov-Smirnov test. Reliability was reported as excellent (ICC ≥0.90), good (ICC between 0.80 and 0.89), moderate (ICC between 0.70 and 0.79) and low (ICC<0.70).[9]

To determine absolute reliability i.e. the extent to which the measurement varied for subjects between the two testing sessions, the standard error of measurement (SEM) was calculated. The SEM value was used to calculate the minimal detectable change (MDC) at the 90% CI. To enable more meaningful comparison between different individuals and tests, %MDC was then calculated. All data analyses were performed with SPSS (Version 20, IBM Corp, Armonk, NY, USA).

Results

Fifteen subjects: age 24 (± 8.2) years; height 169 (± 3.4) cm; weight 66 (± 10.4) kg completed all tests with no reports of shoulder pain during testing. Ten subjects were female, two were left-handed, three had a history of previous injury (more than 12 months before testing) and 13 participated in structured physical activity at least three times per week.

Good reliability was demonstrated for all FL and EX tests (ICC 0.87-0.99) (Table 1). All rotation tests demonstrated excellent reliability (ICC 0.90-0.97) (Table 2). The MDC_{90} ranged from an absolute 1.81 to 13.41 N for all strength tests with %MDC consistently below 16% (Tables 1 and 2).

Discussion

This is the first investigation to report the reliability of shoulder FL and EX strength tests above 90° shoulder abduction in three different positions. Intra-rater reliability for FL and EX tests was good in all positions. (ICC 0.87-0.99) (Table 1). These more than acceptable intra-rater reliability results were achieved without the application of any external stabilisation to the upper limb or trunk and with tests performed on different days, replicating a typical clinical scenario.

Excellent intra-rater reliability was also demonstrated for ER and IR strength tests performed in 90° shoulder abduction in all three body positions, without external or manual stabilisation and MDC results remained below 14% for all tests (Table 2). These results are comparable to previously described intra-rater ICC values (0.93-0.99) for ER and IR strength tested at 90º abduction[6] and indicate that ER and IR shoulder strength can be measured in elevated ranges as reliably as reported in lower ranges[5, 10] when external stabilisation was provided. [5, 6, 10] Although %MDC values have not been previously reported for shoulder rotation strength tests, the MDC values for ER and IR strength measured in this study are comparable to those previously reported at 90° abduction (10.7 to 16.8)[6] and 0° abduction (8.7-10.6N)[5] (Table 2). Previous studies performed retesting on the same day, while the current study protocol retested after 48 hours, a more common clinical situation.

These results indicate that for shoulder FL, EX and rotation strength tests performed in an elevated position in any of the three body positions, a change of more than 15% is likely to be a true change in strength, rather than a difference due to measurement error. The supine position is recommended if performing all tests as a group as the %MDC values remained below 12% and it is ergonomically better for the tester. The MDC remained below 6% for all rotation tests performed in prone hence this position is preferable for the rotation tests.

The good to excellent intra-rater reliability and %MDC results demonstrated in this study have significant implications for the clinician assessing and treating athletes. As many overhead athletes, including swimmers, experience shoulder pain when the arm is above shoulder height,[1, 2] a reliable functional strength assessment in this range is required. To assess the effectiveness of strengthening exercises to restore function, optimise performance and prevent injury, changes need to be measured over time often by a single clinician. The results of this study have demonstrated that such a strength assessment can be performed reliably without external stabilisation, benefiting the sole clinician, and thus is an accurate and efficient method that can be easily translated into busy clinical schedules. Furthermore, establishing the %MDC which represents meaningful change in shoulder strength enables clinicians to accurately evaluate the effectiveness of strengthening programs.

The intra-rater reliability achieved in this study was aided by a number of factors. It has been established that the strength of the tester affects his/her ability to stabilise a HHD, and therefore, influences the reliability of measurements.[7, 10] Consequently, the strength testing protocols without manual stabilisation were designed for the sole clinician by employing optimal tester positioning and maximising the length of the lever arm giving a mechanical advantage to the tester. In addition, careful and consistent HHD and subject positioning, clear instructions to subjects and familiarisation with the tests by incorporating these as the warm-up movements are likely to have contributed to the reliability results achieved.

The results of this study only apply to a single tester and the inter-tester reliability of shoulder strength tests in elevated shoulder positions remains to be established. However, the encouraging intra-rater reliability results achieved show promise that a reliable, functionally relevant shoulder strength testing protocol for the swimming population and other overhead athletes is achievable. Future research will determine if this predication is accurate.

References

1. Fowler P. Upper extremity swimming injuries. In: Nicholas JA, ed. *The Upper Extremity in Sports Medicine*. St. Louis, MO: C.V.Mosby 1990:891-902.

2. Yanai T, Hay JG, Miller GF. Shoulder impingement in front-crawl swimming: I. A method to identify impingement. *Med Sci Sport Exer.* 2000;32(1):21-29.

3. Bak K, Magnusson SP. Shoulder strength and range of motion in symptomatic and pain-free elite swimmers. *Am. J. Sports Med.* 1997;25(4):454-459.

4. Scovazzo ML, Browne A, Pink M, Jobe FW, Kerrigan J. The painful shoulder during freestyle swimming - An electromyographic cinematographic analysis of twelve muscles. *Am. J. Sports Med.* 1991;19(6):577-582.

5. Dollings H, Sandford F, O'Conaire E, Lewis JS. Shoulder strength testing: the intra- and inter-tester reliability of routine clinical tests, using the PowerTrack™ II Commander. *Shoulder Elbow.* 2012;4(2):131-140.

6. Cools AM, De Wilde L, Van Tongel A, Ceyssens C, Ryckewaert R, Cambier DC. Measuring shoulder external and internal rotation strength and range of motion: comprehensive intra-rater and inter-rater reliability study of several testing protocols. *J. Shoulder Elbow Surg.* 2014;23(10):1454-1461.

7. Stark T, Walker B, Phillips JK, Fejer R, Beck R. Hand-held dynamometry correlation with the gold standard isokinetic dynamometry: A systematic review. *PM&R.* 2011;3(5):472-479.

8. Hopkins WG. Measures of reliability in sports medicine and science. *Sports Med.* 2000;30(1):1-15.

9. Portney LG WM. *Foundations of Clinical Research: Applications to Practice.* 3rd ed. Upper Saddle River, NJ: Prentice Hall 2009.

10. Sullivan SJ, Chesley A, Hebert G, McFaull S, Scullion D. The validity and reliability of hand-held dynamometry in assessing isometric external rotator performance. *J. Orthop. Sports Phys. Ther.* 1988;10(6):213-217.

Table 1 Intra-rater reliability of flexion and extension shoulder strength tests for sitting, supine and prone positions.

Test	Position	Test1 (N)	Test2 (N)	ICC (95% CI)	SEM (N)	MDC_{90}(N)	%MDC
FL DOM	Sitting	46.6 (18.6)	48.4 (16.9)	0.94 (0.82-0.98)	2.15	5.02	10.57
	Supine	64.4 (24.6)	60.5 (22.3)	0.94 (0.82-0.98)	2.76	6.43	10.30
	Prone	36.7 (8.6)	35.8 (10.6)	0.87 (0.62-0.96)	2.38	5.54	15.30
FL NON	Sitting	45.3 (15.1)	45.3 (18.7)	0.93 (0.78-0.98)	2.70	6.30	13.90
	Supine	61.3 (21.8)	60.7 (21.0)	0.94 (0.81-0.98)	2.67	6.21	10.19
	Prone	35.5 (10.7)	35.9 (11.1)	0.93 (0.79-0.98)	1.51	3.53	9.87
EX DOM	Sitting	59.2 (25.4)	62.0 (22.5)	0.96 (0.88-0.99)	1.86	4.34	7.15
	Supine	73.2 (42.5)	71.7 (41.3)	0.98 (0.94-0.99)	1.74	4.05	5.59
	Prone	79.1 (41.1)	79.7 (36.9)	0.98 (0.95-0.99)	1.51	3.52	4.43
EX NON	Sitting	60.8 (32.2)	60.6 (28.6)	0.97 (0.90-0.99)	1.91	4.45	7.34
	Supine	74.9 (40.7)	74.7 (39.8)	0.96 (0.87-0.99)	3.53	8.25	11.02
	Prone	77.0 (35.1)	78.1 (37.5)	0.99 (0.97-0.99)	0.78	1.82	2.34

Abbreviations: CI, confidence interval; DOM, dominant side; EX, extension; FL, flexion; ICC, intraclass correlation coefficient; MDC, minimal detectable change; N, newtons; NON, non-dominant side; SEM, standard error of measurement.

Table 2 Intra-rater reliability of external and internal rotation shoulder strength tests for sitting, supine and prone positions.

Test	Position	Test1 (N)	Test2 (N)	ICC (95% CI)	SEM (N)	MDC_{90}(N)	%MDC
ER DOM	Sitting	93.7 (37.2)	87.1 (33.7)	0.97 (0.88-0.99)	1.79	4.17	4.61
	Supine	109.3 (43.6)	103.9 (35.2)	0.96 (0.87-0.99)	3.15	7.36	6.90
	Prone	103.8 (36.0)	96.7 (39.0)	0.95 (0.81-0.99)	3.31	7.73	3.54
ER NON	Sitting	94.2 (40.8)	90.9 (36.4)	0.97 (0.91-0.99)	2.36	5.51	5.96
	Supine	110.7 (38.7)	99.2 (33.5)	0.92 (0.68-0.97)	4.97	11.60	10.41
	Prone	103.8 (45.7)	97.4 (37.7)	0.96 (0.89-0.99)	2.99	6.98	3.26
IR DOM	Sitting	103.2 (34.8)	105.6 (39.7)	0.97 (0.90-0.96)	2.41	5.63	5.39
	Supine	100.1 (36.4)	100.6 (35.9)	0.93 (0.80-0.98)	4.90	11.42	10.28
	Prone	106.7 (50.3)	104.3 (41.9)	0.97 (0.90-0.99)	2.89	6.74	2.90
IR NON	Sitting	101.3 (38.6)	97.3 (28.2)	0.90 (0.70-0.97)	5.75	13.41	13.51
	Supine	101.8 (35.0)	102.1 (33.3)	0.97 (0.91-0.99)	2.13	4.97	4.88
	Prone	99.7 (43.7)	100.9 (39.5)	0.94 (0.82-0.98)	4.96	11.57	11.45

Abbreviations: CI, confidence interval; DOM, dominant side; EX, extension; FL, flexion; ICC, intraclass correlation coefficient; MDC,minimal detectable change; N, newtons; NON, non-dominant side; SEM, standard error of measurement.

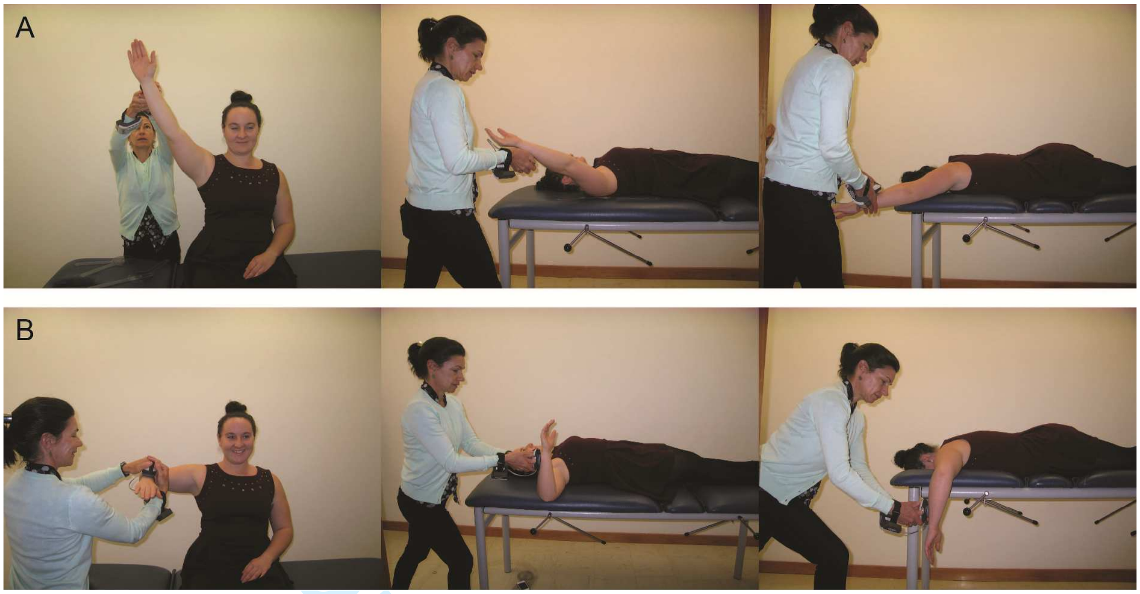

Figure 1 Measurement of shoulder strength. (A) Flexion test performed in sitting, supine and prone (B) External rotation test performed in sitting, supine and prone.