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Reproducibility of the Isokinetic Joint Torque as a Rotator Cuff Weakness Test Protocol in Patients With Rotator Cuff Tendinitis

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Abstract

Background: The measurement of the strength of the shoulder muscles is an important element of the overall assessment of patients with various shoulder disorders. However, the clinical utilization of this measurement is dependent on its reproducibility.

Objects: To explore the reproducibility of the measurements derived from testing of the isokinetic strength of shoulder muscles in patients with tendinitis of the rotator cuff.

Methods: A total of 20 patients with tendinitis of the rotator cuff participated in this study and were assessed twice in 1 week. Isokinetic testing was performed concentrically for shoulder flexors, abductors, and external rotators and eccentrically for the shoulder extensors, adductors, and internal rotators. The relative and absolute reproducibility of the peak torque (PT) and ratios were assessed using intra-class correlation coefficients (ICC), standard error of measurement (SEM), and minimal clinically important difference (MCID), respectively.

Results: Overall, high to excellent ICC, clinically acceptable SEM and MCID values were obtained for the PT (ICC: .83-.95, SEM: 1.2%-9%, MCID: 3.4%-25%) and ratios (ICC: .85-.93, SEM: 5.1%-10%, MCID: 14.2%-27.6%).

Conclusion: These findings suggest that isokinetic tests may be effectively utilized for the determination of shoulder strength profiles and appropriate position are recommended to perform test without pain in patients with tendinitis of the rotator cuff.

Key Words: Isokinetic dynamometer, reproducibility, shoulder muscle strength.

Introduction

Patients with tendinitis of the rotator cuff present with shoulder pain, limited range of motion (ROM), and weakness of the shoulder muscles (McCabe et al, 2005; Miller et al, 2015). Previous studies have indicated that patients with tears of the rotator cuff are impaired, with weakness of the shoulder abductors, flexors, and external rotators (Kirschenbaum et al, 1993; Miller et al, 2015) and that the size of the tear is associated with abductors weakness (McCabe et al, 2005). Weakness of external rotator is factor involved in the existence of symptoms related to rotator cuff tears (Yamamoto et al, 2010). The weakness of shoulder muscle strength in patients with rotator cuff tendinitis is related to pain (Miller et al, 2015). In addition, functionally, shoulder muscles control movement by concentric and eccentric contraction during daily life, so muscle strength testing is necessary for patients with rotator cuff tendinitis (Adusar et al, 2013). Therefore, evaluation of weakness in shoulder muscle strength with pain free position has the potential to help clinical examination in patients with tendinitis of rotator cuff (Miller et al, 2015).

Isokinetic dynamometry is the gold standard in muscle testing, including testing muscles in patients with tendinitis of the rotator cuff (Anderson et al, 2006). Previous studies have reported that shoulder

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muscle strength is damaged with rotator cuff pathology or improves with surgery (Cofield et al, 2001; Itoi et al, 1997; Kirschenbaum et al, 1993). However, for these measurements to be clinically interpretable they must be reproducible. For this reason, reproducibility studies of isokinetic strength testing in patients with tendinitis of the rotator cuff have been performed (Anderson et al, 2006; MacDermid et al, 2004). Anderson et al (2006) reported Intraclass orrelation coefficient (ICC) values that ranged from .90 to .96 for concentric internal rotators and external rotators of the affected side and .75 to .86 for the unaffected side, based on testing at 60°/s in the scapula plane. In another study, the values were moderate to high (.76 to .86) based on the peak torque (PT) in concentric, isometric, and eccentric contractions of internal rotators and external rotators of the affected side at 75°/s in the scapula plane (MacDermid et al, 2004).

However, these studies are limited by two factor. First, correlation coefficients (e.g. ICC, Pearson's r) do not enable an operative decision regarding change (progression or regression) in a patient's strength status. Indeed, the modern approach to reproducibility focuses on the error of measurement and its derivative-the minimal clinically important difference (MCID), where the latter sets the cutoff beyond which clinicians may confidently (95%) proclaim that a change has indeed taken place (Copay et al, 2007). Second, most studies have focused on internal and external rotators function and neglected other important muscle groups in the shoulder, such as the flexors and abductors. Also, the shoulder flexor and abductor are recommended to be examined below 120 to avoid impingement, but there is no study that investigates whether the patient with rotator cuff tendinitis has a reliable posture. In addition, two studies did not measured reproducibility of concentric/eccentric ratios. Muscle strength ratios, especially the concentric/eccentric ratios are associated with the grade of impairment in many disease states(Adsuar et al, 2013; Marshall et al, 2010).

Therefore, the first purpose of this study was to determine if a single external rotators test was sufficient for representative shoulder strength tests, for this purpose, the relative and absolute reproducibility of PT and ratios were analyzed during isokinetic test of shoulder muscles such as external rotators, abductors, and flexors in patients with tendinitis of the rotator cuff. The second purpose was to investigate reliable method such as pain free position of flexors and abductors as well as external rotators during isokinetic muscle stregth test. We hypothesized that ICC, standard error of measurement (SEM), and MCID of not only external rotators but also flexors and abductors would be excellent, and excellent reproducibility would be presented in scapula plane for external rotators strength tests and below of elevation 120° for flexors and abductors strength test using isokinetic dynamometer.

Methods

Participants

A total of 20 male patients presented with rotator cuff tendinitis at least 1 month prior to tests performed in this study. All patients were seen by a physician at P hospital. The general characteristics of the subjects are presented in Table 1. The inclusion criteria consisted of positive ultrasonographic findings and a positive drop arm test, Neer's test, empty can test, and lift off test by physicians. Exclusion criteria included a pain produced during below 100° flexion and/or abduction and below 30° external and internal rotation on the symptomatic side, history of shoulder surgery, inflammation, glenohumeral (GH) joint arthritis, and shoulder trauma. Participants were requested not to take medications or perform strenuous exercise for the 2 days preceding each testing day. Prior to the study, all participants read and signed an informed consent document approved by the Inje University Ethics Committee for Human Investigations.

Physical examination

Shoulder ROM: Shoulder ROM was measured us-

Table 1. Demographics characteristics of participants (N=20)

Parameters	
Age (years)	49.90±12.21[a]
Height (㎝)	165.25±12.28
Weight (㎏)	62.25±9.32
[b]VAS (㎝)	6.45±0.82
Duration of symptoms (mon)	12.14±2.91
Grade of rotator cuff tear	Grade II
Range of motion	
Flexion (°)	144.23±10.25
Abduction (°)	132.17±6.21
external rotation (°)	33.23±4.07
Internal rotation (°)	31.75±4.25

[a]mean±standard deviation, [b]visual analogue scale.

ing a goniometer. To measure ROM of shoulder flexion, the patient was asked to stand position with the arms at the side with neutral rotation. Then the patient was asked for performing of active shoulder flexion as far as possible under pain-free conditions. At this point, the examiner measured the shoulder flexion ROM. To measure ROM of shoulder abduction, the patient was asked to stand position with the arms at the side and shoulder externally rotated. Then the subject was asked to performing of active shoulder abduction while still not experiencing pain. At this point, the examiner measured the shoulder abduction ROM. To measure external and internal rotation, the patient was asked to lie in a supine position with the shoulder abducted to 90°, the elbow flexed to 90°, and in a neutral rotation (Senursa et al, 2007). Then the patient was asked for performing of active external and internal rotation until pain-free condition. At this point, the examiner measured the shoulder external and internal rotation ROM.

Neer's test: The patients shoulder was passively elevated until end range with shoulder medially rotated by the examiner. The test is considered positive if the maneuver produces pain (Jain et al, 2013).

Empty can test: The patients shoulder was abducted to 90° with internally rotated and angled forward 30°; patients thumbs point toward the floor. The examiner applied resistance to abduction at the distal forearm. The test is considered positive if the maneuver produces weakness or pain (Jain et al, 2013).

Drop arm test: In the drop arm test, patients were placed in a standing and shoulder-neutral position and the examiner stood beside the subjects. In this position, the examiner performed passive abduction of the shoulder of patients to 180°. Then the patients were asked to slowly lower their arms to the waist. The test is considered positive if the arm drops to the side before it is lowered to the waist (Jain et al, 2013).

Lift-off test: The examiner helps the patients place the dorsum of hand on the lower back with fully extended and internally rotated. Then the patients were asked lifting hand off lower back. The test is considered positive if patients were unable to lift the hand away from the lower back (Jain et al, 2013).

Neer's test, empty can test, drop arm test, and lift-off test were presented positive sign in all patients.

Isokinetic strength tests

Shoulder muscle strength was evaluated using a Biodex dynamometer system 4 (Biodex Corp., Shirley, NY). The tests were performed in a seated position with proximal stabilization using straps, which were placed on the chest and pelvis. All tests were performed in a randomized order, which was concluded by choosing a single card, randomly from among three card marked 1, 2, and 3.

GH flexion and extension were evaluated in the sagittal plane with the arm at the side and in a neutral rotation. The frontal axis of the shoulder, that is, the acromial process in the sagittal plane, was aligned with the rotational axis of the dynamometer. Patients were evaluated through 100° of ROM (flexion 100°, extension 0°) to avoid shoulder impingement syndrome (Ellenbecker and Davies, 2000; Hellwig et al, 1991). The test consisted of maximal concentric of flexion (FLcon) and maximal eccentric of extension (EXecc) (shoulder is generating an extension movement, while participants are

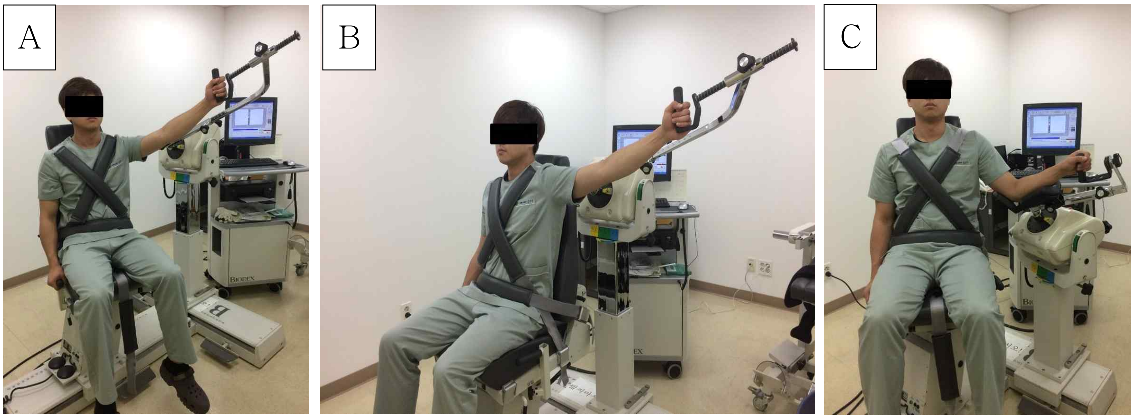

Figure 1. A: FLcon and EXecc, B: ABcon and ADecc, C: ERcon and IRecc (ABcon: concentric abduction, ADecc: eccentric adduction, ERcon: concentric external rotation, EXecc: eccentric extension, FLcon: concentric flexion, IRecc: eccentric internal rotation).

generating an eccentric flexion) (Figure 1A).

GH abduction and adduction were evaluated in the frontal plane with the arm at the side and the shoulder rotated externally. The sagittal axis of the shoulder, namely, the acromioclavicular joint, was aligned with the rotational axis of the dynamometer. Patients were evaluated through 100˚ ROM (abduction 100˚, adduction 0˚) to avoid shoulder impingement syndrome (Ellenbecker and Davies, 2000; Hellwig et al, 1991). The test consisted of maximal concentric of abduction (ABcon) and maximal eccentric of adduction (ADecc) (shoulder is generating an adduction movement, while participants are generating an eccentric abduction) (Figure 1B).

To evaluate shoulder external and internal rotation, patients were requested to flex the elbow at 90° and abduct the shoulder at 45˚ in the scapula plane (Edouard et al, 2013). This position is associated with the least stress on the rotator cuff and minimizes possible pain provocation (Edouard et al, 2011; Edouard et al, 2013). The longitudinal axis of the humerus was aligned with the axis of the dynamometer, as marked by the olecranon. Patients were evaluated through 60˚ (with symmetrical 30˚ of internal and external rotations). The test consisted of maximal concentric of external rotation (ERcon) and maximal eccentric of internal rotation (IRecc) (shoulder is generating an internal rotation movement, while participants are generating an eccentric external rotation) (Figure 1C).

All tests were performed with five repetitions at 60˚/s (Adsuar et al, 2013; Anerson et al, 2006). Only the affected side was tested, and no participants complained of pain during the test. Before the tests, patients performed three trials at submaximal concentric or eccentric action of the shoulder muscles at 60˚/s for familiarization with the tests (Itoi et al, 1997). A rest of 30s was permitted between each set and a 5 min rest was permitted between each test. To prevent bias, the investigator did not provide verbal cues or visual feedback from the monitor screen. The patients were evaluated twice within 1 week at the same time of day. All tests were performed by the same examiner.

Data analysis

The PT and ratios (FLcon/EXecc, ABcon/ADecc, and ERcon/IRecc) were obtained for each angular velocity of the affected shoulder. PT is defined as one torque value which appears to be the largest during the five repetitions within the test range and this mean strength (Adsuar et al, 2013).

Statistical analysis

Statistical analyses were performed using SPSS for Windows, and p values of $<.05$ indicated statistical significance. The relative reproducibility was estimated using ICC 3.1. We considered an ICC over .90 as excellent, one between .70 and .89 as high, and one between .50 and .69 as moderate (Munro et al, 1986). Absolute reproducibility was presented by the standard error of measurement ($SEM = SD \times \sqrt{(1-ICC)}$); the 95% confidence intervals for the determination of the MCID was calculated using the following formation: $1.96 \times SEM \times \sqrt{2}$. Bland-Altman plots with a 95% limit of agreement were used to compare measurements between test and retest.

Results

Table 2 indicated the ICC, SEM, and MCID for PT and ratios obtained in the tests. ICC of the PT values was excellent in FLcon, ABcon, ERcon, and ADecc at angular velocity 60°/s (.91-.95). ICC of the PT values were high in EXecc 60°/s (.83) and IRecc 60°/s (.88). Absolute reproducibility for shoulder muscles PT ranged from 1.2% to 9% and from 3.4% to 25% for SEM and MCID, respectively. ICC of FLcon/EXecc, ABcon/ADecc at 60°/s ratios values was excellent (.90-.93) and ICC of the ERcon/IRecc at 60°/s was high (.85). Absolute reproducibility for shoulder muscles ratios ranged from 5.1% to 10% and from 14.2% to 27.6% for SEM and MCID, respectively.

Figure 2 display Bland-Altman plots for shoulder muscles PT and ratios. The plots show a commonly bias-less homoscedastic distribution for both normalized PT and ratios. For PT findings, for the FLcon and EXecc, the 95% limit of agreement between test 1 and test 2 ranged from -5.47 to 4.84 Nm and from -26.47 to 22.47 Nm, respectively. For PT findings, for ABcon and ADecc were from -4.78 to 4.60 Nm and from -13.75 to 11.43 Nm, respectively. For PT findings, for ERcon and IRecc were from -2.97 to 2.84 Nm and from -10.30 to 9.85 Nm, respectively. For ratios findings, for FLcon/EXecc, ABcon/ADecc, and ERcon/IRecc were ranged from -22.39 to 21.41 %, from -26.88 to 29.90%, and from -16.29 to 12.02%, respectively.

Discussion

We investigated the reproducibility of isokinetic findings related to the PT and ratios values of several shoulder muscles in patients with tendinitis of the rotator cuff. PT (FLcon, ABcon, ADecc, and

Table 2. Reproducibility of shoulder muscle strength during isokinetic tests (N=20)

Parameter	Mean±SD[a]		ICC[b]	95%CI[c] lower-upper	SEM[d]	MCID[e]
	Session 1	Session 2				
FLcon[f] (Nm)	12.94±9.06	13.25±9.04	.94	.901-.984	2.1	5.7
EXecc[g] (Nm)	30.16±20.41	32.26±18.25	.83	.644-.933	9.0	25.0
ABcon[h] (Nm)	14.62±10.03	14.71±10.67	.95	.917-.990	2.2	6.0
ADecc[i] (Nm)	28.77±16.93	29.93±18.63	.93	.848-.974	6.6	18.3
ERcon[j] (Nm)	8.02±4.28	8.09±4.44	.91	.867-.978	1.2	3.4
IRecc[k](Nm)	15.87±10.70	16.10±10.30	.88	.733-.953	3.2	8.8
FLcon/EXecc (%)	49.12±25.29	49.61±24	.90	.780-.962	7.8	21.7
ABcon/ADecc (%)	50.37±38.17	48.86±38.02	.93	.834-.972	10.0	27.6
ERcon/IRecc (%)	46.99±15.56	49.13±16.47	.85	.758-.957	5.1	14.2

[a]means±standard deviation, [b]intraclass correlation coefficient, [c]confidence interval, [d]standard error of measurement, [e]minimal clinically important difference, [f]concentric flexion, [g]eccentric extension, [h]concentric abduction, [i]eccentric adduction, [j]concentric external rotation, [k]eccentric internal rotation.

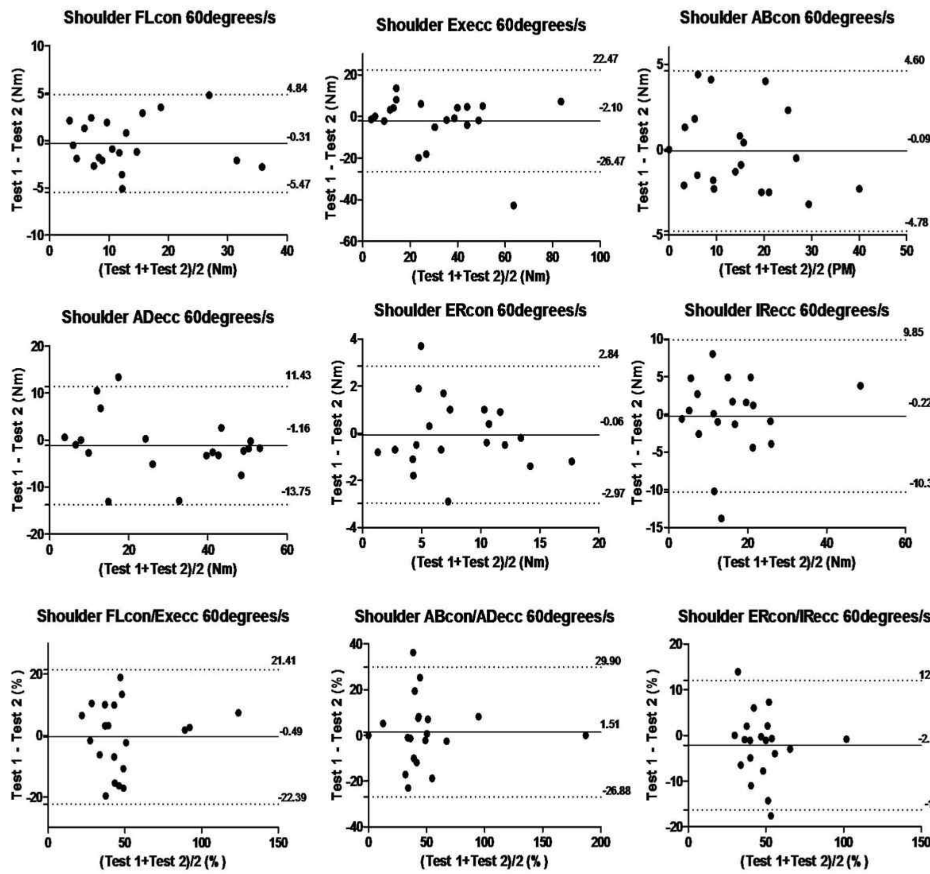

Figure 2. The Bland-Altman plots for shoulder muscles peak torque and ratios (ABcon: concentric abduction, ADecc: eccentric adduction, ERcon: concentric external rotation, EXecc: eccentric extension, FLcon: concentric flexion, IRecc: eccentric internal rotation).

ERcon) and ratios (FLcon/EXecc and ABcon/ADecc) were showed excellent ICC.

Our study showed high to excellent ICC for PT (.83-.95). These results may be associated with the test positions and protocol. External rotators and internal rotators were tested in the sitting position at the scapular plane with a 45° elevation of the arm. This position elicits the least load for the rotator cuff and provides a risk-free, comfortable setup (Edouard et al, 2011). It induces optimal moment and shows high to excellent reproducibility of external rotators/internal rotators. In addition, the abduction test must be limited to within 120° to avoid subacromial impingement syndrome (Ellenbecker and Davies, 2000; Hellwig et al, 1991). In this study, we measured flexion and abduction from adduction 0° to abduction 100°. Measurements under this condition may be safe and comfortable, leading to high to excellent reproducibility. The test angular velocities were 60°/s for fleoxors, extensors, adductors, abductors, external rotators, and internal rotator. External rotators and internal rotaors velocities were assessed by Anderson et al (2006), who report similar inter-rater (.75-.96) reproducibility for external rotators/internal rotators muscle groups using a Biodex dynamometer in patients with rotator cuff pathology. The present findings also support other reports (Adsuar et al, 2013; Edouard et al, 2013; Meeteren et al, 2002). Thus, PT is a reliable outcome measure for evaluating muscle strength in this patient cohort.

Our study showed high to excellent ICC for ratios (from .85 to .93). These findings are consistent with previous studies. Edouard et al (2013) determined unilateral dominant, unilateral non-dominant, and bilateral non-dominant/dominant external rotators and intern rotators ratios, and reported low relative reproducibility for external rotators/internal rotators ratios (from .25 to .81). Although, general reproducibility was showed lower, ERcon/IRecc ratios of unilateral dominant ICC was .81. All participants in present study performed concentrically/eccentrically mode and this mode evaluate same muscle in both concentric and eccentric phase, and thus the flexors, abductor, and external rotators muscles in eccentrically phase were already contracted before finishing of the concentrically phase. This may have contributed to the high reproducibility (Adsuar et al, 2013).

The concentric mode showed better ICC, SEM, and MCID than the eccentric mode. These results could explain the difficulty of the eccentric test mode and patient anxiety (Codine et al, 2005,). In addition, participants become more accustomed to concentric contraction than eccentric contraction (Frisiello et al, 1994). These results suggest that concentric muscle assessments are more reliable than eccentric shoulder muscle assessments.

Although ICC is useful for reliable comparisons between devices (Edouard et al, 2011) because this value is a proportional index of reproducibility and the error variance is lopsided against the between-subject variance, the ICC value is not informative (Meeteren et al, 2002). On the other hand, SEM (as absolute reproducibility) appears more appropriate in clinical settings. The SEM represents the amount of variation that could be caused by chance; that is, inaccuracies in the measurement or noise (Hopkins, 2000). It is not influenced by between-participant variability and allows for the calculation of the MCID (Impellizzeri et al, 2008). In clinical settings, to interpret a sole measurement or to identify a true change between two measurements for one subject, the SEM and MCID are more meaningful and interesting. The change in the PT, and ratios should be compared with the SEM following the smallest important change to identify whether the change is real (Hopkins, 2000). Based on the absolute MCID, change in an individual patient with rotator cuff tendinitis close or higher than 3.4% to 25% for PT and 14.2% to 27.6 for the ratios are required to identify a real change.

To date, the reproducibility of shoulder strength test using isokinetic equipment was reported to be excellent (Anderson et al, 2006; Edouard et al, 2013; Frisiello et al, 1994; Greenfield et al, 1990; MacDermid et al, 2004; Magnusson et al, 1990). These results were influenced by methodological factors as well as isokinetic devices. In previous studies, it has been reported that external rotators is best performed at 45° on the scapula plane (Anderson et al, 2006; MacDermid et al, 2004), which is consistent with our results. In patients with tendinitis of the rotator cuff, a range of high reproducibility for flexors and abductors was reported below ROM of 120°. However, this is the theoretical content, and the actual roll measurement results in this study showed from high to excellent reproducibility. Therefore, in order to perform accurate muscle strength test without pain in patients with tendinitis of rotator cuff, it is necessary to be in the proper position and range.

Our study has several limitations. First, the sample size was small; 20 patients with rotator cuff tendinitis participated in this study, all of whom were male. The alignment of the dynamometer axis to the shoulder was set manually, and the arrangement of the chair relative to the dynamometer was set based on visual inspection. Therefore, the arrangement may have differed least between days 1 and 2. Three, only affected side was measured.

Conclusion

We investigated the reproducibility of the shoulder flexors, abductors, and external rotators muscle strength test using isokinetic dynamometer in patients with rotator tendinitis. High to excellent relative reproducibility was reported when assessing FLcon, Execc, ABcon, ADecc, ERcon, IRecc PT and FLcon/Execc, ABcon/ADecc, and ERcon/IRecc ratios. These results are due to the position of isokinetic strength test as a safe way to minimize symptoms. Thus, we recommend performing isokinetic strength test at 100° for shoulder flexors or shoulder abductors and at 45° in the scapular plane for shoulder external rotators in patients with rotator cuff tendinitis. Our study applied SEM and MCID data, and can be used by a therapist or clinician to identify a real change in strength and/or ratios during assessment and post-intervention.

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