Isokinetic and isometric shoulder rotation strength in the protracted position: A reliability study

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Scapular position has been hypothesized to influence rotator cuff function, but no current methods exist to reliably measure shoulder rotation strength in different scapular positions. The purpose of this study was to develop a reliable technique to measure isokinetic (ISOK) and isometric (ISOM) shoulder rotation strength with the scapula protracted. Ten healthy volunteers (5 male, 5 female, ages 20–41) completed two to three ISOM and five ISOK (90 degrees/second) internal rotation (IR) and external rotation (ER) repetitions in a position of scapular protraction with the shoulder abducted 45 degrees in the scapular plane. Subjects returned 24–72 hours later to repeat testing. All torque measurements in the protracted position exhibited excellent intersession reliability (ICCs > 0.97). Shoulder rotational torque can be measured in the protracted scapula position with excellent reliability using the new technique described. Establishing the reliability of the protracted technique is a necessary prerequisite for the completion of future studies examining quantitative differences in rotational torque generation between the neutral and protracted scapula positions in the functional shoulder position of 45 degrees of scapular plane abduction.

Keywords: Rotator cuff, reliability, posture torque

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Isokinetics and Exercise Science 9 (2001) 119–127
ISSN 0959-3020 / $8.00

1. Introduction

Shoulder pain and dysfunction are common complaints among individuals of all ages seeking care with sports and occupational medicine clinicians. Most shoulder disorders result from cumulative, microtraumatic overload injuries to the rotator cuff and related soft tissues [21]. In recent years, clinicians have directed increased attention towards the potential role of the scapula in the pathogenesis of shoulder pain in general, and rotator cuff dysfunction specifically [26, 27]. It has been hypothesized that scapulothoracic dysfunction resulting from abnormal physiology or biomechanics may adversely affect rotator cuff and shoulder girdle function, and predispose to overload rotator cuff injury [26,27].

The position of scapular protraction may be particularly detrimental to shoulder function. Although some authors consider protraction as any advancement of the scapula to an anterior position on the thoracic cage, universally accepted definitions of the normal and protracted scapula positions do not exist [41,45]. Clinically, the protracted shoulder position is manifested as the "rounded shoulders posture". This posture has been associated with shoulder pain in athletes, workers, and in the elderly [2,4,8,15,22,26,35,37,50]. Research has indicated that the protracted, rounded shoulders posture may promote shoulder muscle fatigue in industrial workers, narrows the subacromial space, reduces the available impingement-free range of elevation, and increases strain on the anterior band of the inferior glenohumeral ligament during abduction-external rotation [2,24,26,42,49]. Kebaetse et al. [24] indirectly examined the effect of shoulder protraction on shoulder muscle strength by demonstrating that isometric shoulder abduction torque in the scapular plane was reduced 16% in normal individuals after assuming a "slouched" posture. Although it is assumed that scapular protraction commonly occurs in the setting of a "slouched posture", these investigators did not directly assess scapular position in their study. The authors of the current study have demonstrated significant reductions in peak shoulder elevation isometric torque production of up to 30% in the position of 90 degrees sagittal plane elevation when the scapula is maximally protracted [44]. Both studies measured strength in positions in which the deltoid muscle is a primary mover [23,25]. Given the hypothesized detrimental effects of shoulder protraction on rotator cuff function specifically, the authors of the current study decided that further examination of the effects of scapular protraction on rotator cuff strength was warranted.

Isokinetic dynamometers provide precise measurements of isokinetic and isometric shoulder rotational torque [5,7]. Rotational torque values represent a more valid measurement of rotator cuff function than isometric abduction or forward elevation [24,44]. Isokinetic dynamometers have been used extensively to study rotator cuff biomechanics, develop normative databases, and assist in rehabilitation [5,7]. Research has established the test-retest reliability of shoulder rotational strength measurements as used in these settings [7,14, 16,19,20]. Multiple investigations have documented position-dependent alterations in shoulder rotational strength measured in various planes of shoulder abduction and flexion, but none have addressed the effect of scapular protraction on these measurements [9,14,16, 46,48]. In fact, the authors of the current study found no mention of scapular positioning during isokinetic testing in the literature, and it assumed that the scapula has been allowed to assume the most comfortable position (i.e. neutral scapula) in these previous studies.

The purpose of this study is two-fold: (1) To develop a standardized technique to measure isokinetic and isometric shoulder internal and external rotational shoulder strength with the scapula protracted, and (2) To determine the test-retest reliability of the technique over time. For this study, we used normal individuals and tested the shoulder in 45 degrees of scapular plane abduction, a common position of function for daily and occupational activities [5,12,32–34,38,39]. We hypothesized that a standardized, reliable technique could be developed to measure isokinetic and isometric shoulder rotational strength in the protracted position (intraclass correlation coefficients $>$ 0.80) [3,13, 29]. Clinically, this study would provide a foundation for future quantitative research directly examining the relationship between scapular position and rotator cuff function. In addition, our findings may facilitate increased awareness of the importance of scapular positioning in the diagnosis and rehabilitation of shoulder disorders, especially in the setting of suspected scapulothoracic dysfunction.

2. Methods

2.1. Subjects

Ten normal males ($N = 5$) and females ($N = 5$) were recruited to participate. The mean age was 27.7 years ($SD = 6.39$ years) and the range was 20 to 41 years. Mean height was 172.7 cm ($SD = 9.57$ cm) and mean weight was 74.4 kg ($SD = 17.4$ kg). All subjects were right hand dominant. Subjects were volunteers recruited by advertisement from the biomechanics laboratory and physical therapy school at the authors' institution. All potential subjects were screened by the same co-investigator (DJP), an experienced orthopedic physical therapist. Subjects were eligible to participate in the study if they exhibited full, symmetric, pain-free, shoulder range of motion, and agreed to return for the second day of testing. Eligible subjects were accepted into the study if they did not fulfill any of the following exclusion criteria: (1) current shoulder or neck pain, or history of such within 1 year of study participation, (2) history of fracture, dislocation, or surgery to the thoracic spine, rib cage, neck, or shoulder girdle, (3) scoliosis, or thoracic kyphosis > 30 degrees, (4) known congenital or degenerative cervical spine disease, (5) congenital defect of the scapula, (6) known neuromuscular disease, (7) known or suspected shoulder instability, (8) scapular winging or subjectively excessive posterior protrusion of either the superior or inferior angles of the scapulae, (9) history of cardiopulmonary disease, or (10) currently pregnant or lactating.

2.2. Instrumentation

All tests were conducted on the KIN-COM125AP® robotic dynamometer (Chattanooga Group, Hixson, TN). The KIN-COM® uses a closed loop system to measure force via a load cell into which attachments insert for patient input. Torque is calculated by multiplying the force recorded at the attachment site by the length of the lever arm. Calculations are performed by internal software and graphically represented. For the purposes of the current study, the KIN-COM® recorded peak torque (PT) for both isokinetic and isometric contractions of the shoulder internal and external rotators (IR and ER). The mechanical reliability of the KIN-COM® has been previously documented [11, 17,47,51].

Fig. 1. Test subject immobilized in isokinetic testing device, upper limb in the test position of 45 degrees scapular plane abduction and the scapular neutral position.

Fig. 2. Subject positioned similar to Fig. 1, but with the scapula protracted into the test position.

2.3. *Testing positions*

Each subject was placed into the KIN-COM® chair and immobilized using double straps across the chest along with a pelvic strap (Figs 1 and 2). Pilot testing confirmed that the immobilization straps could be tightened to sufficiently restrain trunk motion while allowing unimpeded scapular protraction. The elbow was strapped with Velcro fixation into a custom brace designed for this study that maintained the elbow at 90 degrees flexion during testing (Figs 1 and 2).

Shoulder positions and testing velocities were chosen based on their potential clinical importance and safety [5,12,32–34,38,39]. For both isokinetic and isometric testing, the upper limb was oriented in the position of 45 degrees abduction in the scapular plane. This position was called the SC45 position. As described by Poppen and Walker, the true plane of shoulder joint movement occurs in the scapular plane at between 30 to 45 degrees anterior to the coronal plane [39]. For the current study, the scapular plane was chosen as 45 degrees anterior to the coronal plane because pilot testing revealed that scapular protraction was greater in amplitude and easier to obtain in this position as opposed to 30 degrees anterior to the coronal plane. However, the investigators realize that the SC45 position is only an approximation of the true scapular plane, which can only be reliably obtained with more invasive or sophisticated measures. To obtain the SC45 position, the KIN-COM® chair was rotated to orient the humerus in the scapular plane with respect to the trunk. Thereafter, the lever arm orientation was altered to abduct the upper limb to 45 degrees of abduction with respect to the trunk [39]. A standard plastic goniometer with one degree increments was used to confirm that the elbow was flexed to 90 degrees and that the humerus was in the scapular plane with respect to the trunk. A digital inclinometer (Saunders Group, Inc., Chaska, MN 55318) was utilized to confirm that the upper limb was abducted to 45 degrees with respect to the trunk. Since the KIN-COM® chair places the subject slightly reclined, the digital inclinometer was used to measure the difference between the trunk angle and the humeral angle with respect to gravity. The trunk angle was measured by placing the inclinometer on the sternum, and the humeral angle was measured by placing the inclinometer on the humeral mid-shaft. Using this method the amount of humeral abduction relative to the trunk was confirmed to be 45 degrees.

To minimize the efforts of the wrist flexors and extensors during test movements, a pad was used for isometric and isokinetic testing instead of the standard cylindrical handle [18]. The pad of the KIN-COM® was attached to the subject's distal forearm centered 1 cm proximal to the ulnar styloid process. The opposite upper limb was positioned in the subject's lap [16].

The primary position of interest for the current study was scapular protraction. Scapular protraction has been defined as the advancement of the scapula to an anterior position on the thoracic cage, also known as scapular abduction [4,36]. Pilot testing in the authors' institution indicated that the KIN-COM® device permitted a quantitative measure of scapular protraction. This measurement is achieved by moving the dynamometer away from the seated subject once the subject has been immobilized in the seat and the upper limb immobilized in the mobile arm piece. The KIN-COM® can record the number of centimeters the dynamometer arm has moved away from or towards the subject, serving as a measure of scapular protraction and retraction, respectively. Protraction and retraction could be performed until the subject reports a "most comfortable position". This position would function as the scapular neutral position for that subject. To achieve the scapular protracted position, the subject was placed in the neutral position and then the dynamometer head assembly was moved longitudinally away from the subject along the long axis of the humerus. For the purposes of this study, the end-range of protraction was defined as the maximum protraction motion comfortably attainable in which upper limb orientation is maintained in the SC45 position as re-verified with goniometry and inclinometry (Fig. 2). Pilot testing revealed that protraction of 7–8 cm, as measured by the KIN-COM® for the purposes of this study, was comfortably obtainable in normal subjects without altering the position of SC45 with 90 degrees of elbow flexion. This value is quantitatively similar to that reported by Schenkman and colleagues [48], who measured active protraction in a position of 90 degrees sagittal plane elevation, although the two studies are not directly comparable. As measured by the horizontal distance from the inferior angle of the scapula to the nearest thoracic spinous process, subjects typically achieve protraction of 3–4 cm using the Kin-Com® device as described herein [26, 44]. Greater amounts of protraction on the Kin-Com® in the SC45 position were not tolerated.

For the purposes of the current study, the position of protraction in the SC45 position was called the test position.

2.4. Testing protocol

Subjects refrained from upper body weight training and overhead sporting activities for 48 hours prior to each testing session. All testing was completed on the dominant right upper limb. Each subject was oriented to the apparatus and test design, but blinded to the study hypotheses.

Testing was completed by the same two examiners to optimize reliability (DJP, BRK). One examiner ensured the subject had not participated in weight training for the previous 48 hours, collected demographic data, and ensured subject positioning in the KIN-COM® apparatus. The second examiner operated the KIN-COM® software and provided verbal commands to the subject during testing, such as identifying the warm-up period, testing period, and when to start test motions.

Prior to testing an initial calibration procedure was performed by hanging certified standard weights from the KIN-COM® lever arm and verifying the accuracy of the recorded torque value using the system software. The subject then completed a 5 minute warm-up on an upper body ergometer at an intensity of 600 kg-m/min using 90 rpm setting, followed by passive range of motion into flexion, abduction, and 90 degrees of abduction with internal rotation, following the methods of Ellenbecker and Mattalino [9].

Each subject was seated into the KIN-COM® machine with the back supported and the hip angle at 80 degrees of flexion. Stabilization was obtained using straps placed diagonally across the chest and pelvis (Figs 1 and 2). The feet were supported during testing and the subject's eyes positioned straight ahead, with no visual feedback available from the computer monitor. The subject was then positioned in the SC45 position and the dynamometer input shaft aligned to the axis of rotation of the glenohumeral joint [9]. Positioning was confirmed with goniometry and inclinometry. The scapula was then protracted and retracted via KIN-COM® controls to obtain the neutral and protracted positions. Once the positions had been established and verified, the subject was placed into the test position. Shoulder and elbow positions were re-measured to confirm stable positioning.

All subjects completed isometric testing followed by isokinetic testing in the test position. During all testing, moderately loud verbal encouragement was given for both the isometric and isokinetic tests as recommended [9].

2.4.1. Isometric testing

The lever arm of the KIN-COM® was positioned horizontally, as verified by an inclinometer. This position was referenced as the neutral position by the software. The load cell force due to gravity was measured so that all torque values were gravity-corrected as recommended by Ellenbecker and Mattalino [9]. The lever arm was then externally rotated to 45 degrees, which served as the static testing position for all isometric tests.

Testing consisted of a warm-up of three 5 second submaximal isometric contractions, with 30 seconds rest between repetitions. The subject then rested for one minute, after which they completed two maximal voluntary isometric contractions in the direction of internal rotation. Each contraction lasted 5 seconds, with a 60-second rest interval between repetitions [9]. The results of these two repetitions were reviewed. If there was no torque increase from repetition one to two (i.e. the peak torques were within 5% of each other), the data were recorded and the isometric test stopped. Otherwise, a third repetition was completed to ensure that the peak torque value had been obtained. The procedure was then repeated to obtain isometric torque values for external rotation. A third repetition was necessary in 10% of the isometric tests and was equally necessary during internal and external rotation testing. Preload was set at 50 Newtons (N) for both internal and external rotation. The rest periods were chosen in concordance with previous studies to avoid fatigue effects [9,30,31].

2.4.2. Isokinetic testing

Following the isometric tests, the subject rested 2 minutes, after which isokinetic testing was completed. The lever arm was once again initially positioned in neutral-horizontal. Motion stops were set to test a 75 degree motion arc from +5 degrees to +80 degrees. Preload was set at 25 N for isokinetic testing because pilot testing revealed that some subjects, especially females moving into ER, were unable to reliably activate arm movement at a preload of 50 N as used for isometric testing. The subject completed 3 submaximal reciprocal isokinetic contractions at 90 degrees/second with the contraction mode being concentric/concentric. Each reciprocal contraction commenced with the arm in external rotation [9]. A one minute rest period was given, after which 5 maximal isokinetic internal-external reciprocal contractions were obtained in a similar manner. Peak torques were once again recorded for statistical analysis.

2.4.3. Test-retest reliability

Each subject returned between 24–72 hours after the initial testing to complete the same testing sequence. No subject reported significant post-exercise soreness at the time of re-testing. The testing sequence was completed in the same order as Day 1.

Table 1
ICCs* for shoulder rotation torque measurement in the protracted position

	Day 1[a]	Day 2[a]	Days 1 and 2[b]
Isom IR	0.99	0.99	0.97
Isom ER	0.99	0.98	0.97
Isok IR	–	–	0.98
Isok ER	–	–	0.99

*ICCs, Intraclass correlation coefficients.
[a]Intrasession correlations.
[b]Intersession correlations.

2.5. Informed consent

Prior to participation in the study, all subjects were verbally informed of the test procedures and risks by one of the co-investigators, and informed consent obtained. This investigation was approved by the Institutional Review Board at the authors' institution.

2.6. Data analysis

The Department of Biostatistics at the authors' institution provided statistical support. Descriptive statistics were used to calculate the mean peak torque values for isokinetic (ISOK) and isometric (ISOM) internal (IR) and external rotation (ER) in the test position on both test days. Intraclass correlation coefficients (ICCs) were calculated using the method of Fleiss (model 3,1) to determine the test-retest reliability of rotational torque measurements over time [43]. Due to the procedure used for isometric measurements (2 or 3 repetitions), ICCs were calculated for repetitions within each test day (intra-session), and also for peak torque values Days 1 vs. 2 (intersession) (Table 2). Since all subjects completed five isokinetic measurements, only intersession (Day 1 vs. 2) ICCs were calculated for isokinetic measurements (Table 1). Where applicable, the standard error of the mean was calculated using the ICC as previously described [13].

3. Results

Table 1 demonstrates that ISOM IR repetitions on each day exhibited a high degree of intrasession reliability (Day 1 ICC = 0.99 and Day 2 ICC = 0.99). In addition, intersession reliability between Days 1 and 2 was high (ICC = 0.97). The reliability of ISOM ER torque values was similar (Table 1, intrasession ICCs of 0.99 and 0.98, and intersession ICC = 0.97, respectively). Table 1 also demonstrates that ISOK IR and ISOK ER torque measurements in the test position ex-

Table 2
Isometric internal rotation mean peak torque (Nm*)

	Day 1	Day 2	Days 1 and 2
Males			
Mean	53.6	52.0	52.8
SD[a]	10.9	9.2	9.9
SEM[a]	1.9	1.6	3.6
Females			
Mean	26.4	25.3	25.9
SD	5.9	5.3	5.5
SEM	1.7	1.2	1.7

*Nm, Newton-meters.
[a]SD, standard deviation; SEM, standard error of the mean.

Table 3
Isometric external rotation mean peak torque (Nm*)

	Day 1	Day 2	Days 1 and 2
Males			
Mean	34.6	37.7	36.2
SD[a]	6.4	8.6	7.6
SEM[a]	0.6	2.1	2.5
Females			
Mean	17.1	18.0	17.5
SD	3.3	3.2	3.2
SEM	0.7	0.8	1.0

*Nm, Newton-meters.
[a]SD, standard deviation; SEM, standard error of the mean.

Table 4
Isokinetic internal rotation mean peak torque (Nm*)

	Day 1	Day 2	Days 1 and 2
Males			
Mean	46.5	49.1	47.5
SD[a]	7.9	7.5	7.3
SEM[a]	–	–	2.3
Females			
Mean	26.0	24.8	25.4
SD	4.0	4.0	3.8
SEM	–	–	0.9

*Nm, Newton-meters.
[a]SD, standard deviation; SEM, standard error of the mean.

Table 5
Isokinetic external rotation mean peak torque (Nm*)

	Day 1	Day 2	Days 1 and 2
Males			
Mean	29.7	30.7	30.2
SD[a]	5.1	5.8	5.2
SEM[a]	–	–	1.2
Females			
Mean	13.6	14.7	14.1
SD	1.9	2.2	2.0
SEM	–	–	0.8

*Nm, Newton-meters.
[a]SD, standard deviation; SEM, standard error of the mean.

hibited a high degree of intersession reliability between Days 1 and 2 (ICCs of 0.98 and 0.99, respectively).

For reference purposes, the mean peak torque, standard deviation (SD), and standard error of the mean (SEM) for each of the torque measurements in the protracted position are included in Tables 2–5. Tables 2 and 3 include the ISOM IR and ER torque values.

4. Discussion

This is the first investigation in which the position of the scapula with respect to the trunk was specifically regulated during shoulder rotation torque measurements. The test-retest (intersession) reliability for peak ISOK and ISOM IR and ER torque measurements in the protracted position was excellent. All ICCs for the test group were greater than 0.90 (Table 1). These results compare favorably with previous studies reporting ICCs ranging from 0.76 to 0.94 for concentric isokinetic contractions for shoulder internal and external rotation [9,14,16,18,20]. Intraclass correlation coefficients of > 0.90 are considered to have excellent reliability for clinical use [6,13]. Thus, the results of the current study support our primary hypothesis that a standardized and reliable technique to measure shoulder rotation strength in the protracted shoulder position could be developed. Establishing the reliability of a new technique as presented herein is a prerequisite for future investigations regarding the actual effect of scapular position on shoulder rotator cuff function.

Several points warrant discussion pertaining to the new technique. First, as previously discussed, a universally accepted quantitative definition of scapular protraction does not exist [41,45]. Consequently, a working definition of the test position (protraction in the SC45 position) was developed to standardize the technique for the purposes of the current study. Using this definition, all 10 subjects obtained a minimum of 7 cm of protraction when placed in the test position (range 7–8 cm) as measured by the KIN-COM125AP® robotic dynamometer. When measured as the horizontal distance between the inferior angle of the scapula and the nearest thoracic spinous process [26], each subject in the current study achieved between 3 cm and 4 cm of protraction when placed in the test position. There are no previously published values of scapular protraction in the SC45 to compare with our results. What we can conclude is that subjects did achieve some degree of scapular protraction, and that the amount of scapular protraction obtained using the current methodology represented the maximal amount of protraction subjects could tolerate in the SC45 position. The authors also recognize that the current protocol for obtaining scapular protraction is applicable only when either the seat or the dynamometer lever arm can be moved as described in the methods. Consequently, this testing design may not be applicable to all isokinetic testing machines.

Second, during the motion of scapular protraction, in which the scapula translates forward on the rib cage, it is assumed that coupled translational or rotational motions may be occurring. Researchers have documented three translational (anterior-posterior, superior-inferior, and medial-lateral) and three rotational (internal-external around a vertical axis, anterior-posterior around an axis through the scapular spine, and upward-downward in the plane of the scapula) scapular motions during voluntary shoulder motion [24–27,36]. Despite the assumed presence of coupled motions during protraction in our study, these motions would be expected to reliably occur under normal circumstances and therefore did not affect the reliability of our measurements. In addition, the same coupled motions should occur during sport or occupational activities in which the shoulder is protracted, supporting the clinical applicability of our testing model. The degree and importance of each of these potential coupled scapular motions was not investigated in the current study.

Third, the technique utilizes the SC45 position and an isokinetic speed of 90 degrees/second based upon the broad applicability of this position and speed to daily and occupational activities [5,12,52]. Pilot testing at our institution revealed poor reliability of torque measurements obtained in with the scapula protracted in a plane of 90 degrees sagittal elevation, and protraction was difficult to comfortably obtain and quantify in the position of 90 degrees coronal plane abduction. The SC45 position appeared to be well tolerated, simulated occupational positioning of the upper limb, and allowed quantitative protraction measurements. Wilk and Arrigo [52] have noted that 90 degrees/second is considered an intermediate velocity for isokinetic testing. Adaptation of the protracted technique for other positions and test speeds requires further investigation.

Fourth, the number of repetitions used in the testing protocol was 2–3 for the ISOM tests, and 5 for the ISOK tests. The choice of 5 ISOK repetitions was based upon previous work by Arrigo and colleagues [1] demonstrating that peak ISOK IR and ER torques occur between the second and fourth repetitions of a 15 repetition set. As shown in Table 1, peak ISOM torque values between repetitions on each day were highly consistent (intrasession ICCs = 0.98–0.99). This finding suggests that peak ISOM IR and ER torque values are obtainable with only two to three repetitions. Similar results have been reported by Mundale [31] with respect to repetitive maximal ISOM hand grip efforts. Increasing the number of ISOM repetitions would not be expected to increase peak torque values, and may result in fatigue, inconsistent inter-repetition performance, and exercise-related discomfort [10,31,40].

Fifth, the quantitative mean peak torques, standard deviations (SD), and standard errors of the mean (SEM) for the test position are shown in Tables 2–5 for reference only. The primary purpose of this study was to assess the feasibility and reliability of torque measurements obtained in the test position. The small number of subjects ($N = 10$) precludes a meaningful quantitative analysis, and direct comparison of the current results with previously published data would be problematic due to significant methodological differences [5,9,10,16,18,20,25,28,46,48]. Tables 2–5 do reveal the following noteworthy findings: (1) external rotation torque measurements are less than internal rotation torque measurements in the protracted position (Isokinetic ER/IR = 0.61 and Isometric ER/IR = 0.68), and (2) females generate approximately 50% of the ISOK and ISOM ER and IR torque generated by males. Similar findings have been reported by researchers measuring shoulder rotation torque in non-protracted (or scapular neutral) positions [9,10,16,18, 20,46,48,52]. It is also noteworthy that the SD and SEM values for the protracted position used in the current study are similar to values previously reported for more standard techniques [9,10,16,18,20,46,48,52]. Finally, the average peak torque values for the ISOM tests (Tables 2 and 3) and ISOK tests (Tables 4 and 5) appear to be quite similar. Post-hoc statistical analysis (Pearson Product Moment) revealed correlation coefficients of 0.87 for IR ISOM vs. ISOK, and 0.85 for ER ISOM vs. ISOK. This suggests that ISOM and ISOK peak torque generation is related in the test (protracted) position. Research has previously demonstrated correlations between isokinetic and isometric strength using other models [53]. Formal, larger scale investigations examining the quantitative differences in shoulder rotational torque generation in the neutral vs. protracted positions are being completed at the authors' institution.

5. Conclusion

Previous studies suggest that further research is warranted to investigate the interaction between scapular position and rotator cuff function [2,4,24,26,27,44,49]. This study describes a new technique of measuring isokinetic and isometric shoulder internal and external rotation strength in the protracted scapular position with the arm in the functional position of 45 degrees of scapular plane elevation. Test-retest (intersession) reliability was excellent (ICCs > 0.90). Future investigations will examine quantitative differences in shoulder rotation torque generation between the neutral and protracted scapular positions. The new technique may also be adaptable for other testing positions and speeds, although pilot testing suggests that data acquisition at higher degrees of elevation (e.g. 90 degrees sagittal plane elevation), or in the coronal plane, is problematic.

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