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Differences in Strength and Fatigue Resistance of Scapular Protractors and Retractors Between Symptomatic and Asymptomatic Dyskinesis

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Context: Scapular dyskinesis is a shoulder dysfunction that can be asymptomatic or associated with pain or weakness. Reduced strength and fatigue resistance of the scapular protractor and retractor muscles that stabilize the scapula might contribute to dyskinesis.

Objectives: To determine the strength and fatigue resistance profiles of participants with symptomatic or asymptomatic scapular dyskinesis and compare them with healthy control (HC) individuals using isokinetic assessment.

Design: Cross-sectional study.

Setting: University hospital.

Patients or Other Participants: Twenty HC individuals and 21 overhead athletes with symptomatic (n = 10) or asymptomatic (n = 11) scapular dyskinesis.

Main Outcome Measure(s): Strength (peak torque, maximum work), fatigue resistance (total work), and protraction:retraction ratios measured during a closed chain isokinetic protocol (40 repetitions in concentric mode at 24.4 cm/s).

Results: The scapular protractors' strength and fatigue resistance were higher ($P < .01$) in HC individuals (peak torque = 5.0 ± 0.9 N/kg, maximum work = 2.4 ± 0.5 J/kg, total work = 72.4 ± 0.6 J/kg) than in asymptomatic (peak torque = 3.4 ± 0.7 N/kg, maximum work = 1.7 ± 0.4 J/kg, total work = 50.0 ± 13.7 J/kg) or symptomatic (peak torque = 3.8 ± 0.6 N/kg, maximum work = 1.8 ± 0.3 J/kg, total work = 58.1 ± 12.9 J/kg) dyskinetic participants. The symptomatic dyskinetic group presented the highest retractor strength and fatigue resistance ($P < .01$) values (peak torque = 5.2 ± 0.6 N/kg, maximum work = 2.9 ± 0.8 J/kg, total work = 87.7 ± 22.7 J/kg), followed by the HC individuals (peak torque = 4.7 ± 1.0 N/kg, maximum work = 2.1 ± 0.5 J/kg, total work = 65.3 ± 17.9 J/kg) and the asymptomatic dyskinetic participants (peak torque = 3.9 ± 1.0 N/kg, maximum work = 1.9 ± 0.6 J/kg, total work = 58.6 ± 18.5 J/kg). The protraction:retraction ratios showed a gradual decrease ($P < .001$) from the HC individuals (1.1) to the asymptomatic (0.9) and symptomatic (0.7) dyskinetic participants.

Conclusions: Scapular dyskinesis is characterized by weaker scapular protractors and reduced agonist:antagonist ratios, especially when patients are symptomatic. Targeting the scapular protractors to achieve a better balance of scapular musculature in rehabilitation and strengthening programs may improve shoulder symptoms and function, but more interventional studies are required.

Key Words: shoulder injuries, scapular dyskinesis, isokinetic exercise, closed chain exercise

Key Points

- Scapular dyskinesis affects shoulder motion in overhead athletes and can be symptomatic (ie, painful) or not.
- As assessed by a specific isokinetic protocol, scapular muscle strength and fatigue resistance differed among symptomatic patients, asymptomatic patients, and healthy control individuals.
- Weaker shoulder protractors and a reduced agonist:antagonist ratio characterize symptomatic dyskinesis and should be considered in developing strengthening and rehabilitation strategies.

Overhead athletes place specific constraints on their shoulder joint, given the demanding nature of movements such as throwing, hitting, or swimming. The important ranges and amplitudes of these scapulohumeral movements require precise positioning and smooth motion of the scapula. When these motion patterns are altered, a condition known as *scapular dyskinesis* occurs. This phenomenon, initially defined by Kibler et al as "an alteration in the normal position or motion of the scapula during coupled scapulohumeral movements,"[1,2] is particularly prevalent among overhead athletes, with a reported rate of 61% compared with 33% in nonoverhead athletes.[3] Past researchers have indicated that scapular dyskinesis increased the risk of shoulder pain and injuries.[4,5]

Biomechanically, the upper, middle, and lower trapezius muscle along with the serratus anterior muscle play key roles in scapular positioning.[6] The serratus anterior facilitates protraction, whereas the middle trapezius enables retraction, ensuring scapular stability during both movement and rest.[6] For overhead athletes, who continually stress their shoulders, these stabilizing muscles are pivotal. Strength deficits in these muscles may contribute to the pathophysiology of dyskinesis.[7,8] For instance, decreased strength in the lower trapezius and the serratus anterior is associated with reduced scapular upward rotation during maximal contraction.[9] Consequently, athletic performance can be impaired due to insufficient mobility, and the altered biomechanics increase the risk of injury.[10]

Fatigue resistance of the scapular protractors and retractors also plays a role in scapular dyskinesis. Scapular muscles lose their stabilizing capacity when fatigued by an intense training session or a specific exhausting fatigue protocol, which is deleterious for scapular kinematics.[11–14] For example, decreased posterior tilting and increased internal rotation of the scapula were observed after a fatigue protocol (ie, a modified push-up plus task) for the serratus anterior.[14]

Strength and fatigue deficits of scapular protractors and retractors can be measured using isokinetic testing, which is considered the criterion standard for scapular strength measurements.[15,16] A closed chain isokinetic protocol for protraction and retraction movements developed by Cools et al has demonstrated excellent test-retest reliability (intraclass correlation coefficient = 0.82–0.96).[17] The original protocol consisted of 10 repetitions focusing on maximal strength assessment.[17–19] Later iterations involved 40 repetitions to evaluate muscle endurance.[20–22] This protocol focuses on the assessment of fatigue by increasing the number of repetitions, and the prolonged muscle effort indeed engages the anaerobic lactic pathway.[23] This pathway accurately reflects scapular muscle demands on the field, where overhead athletes perform multiple prolonged efforts that can induce scapular fatigue.

To date, the isokinetic assessment of scapular protractors and retractors has concentrated on either providing sport-specific normative values[20–22] or evaluating the relationship between muscle dysfunction (ie, reduced strength and imbalanced protraction:retraction ratios) and subacromial impingement symptoms in athletes.[18,19] The strength and fatigue resistance profiles of the scapular protractors and retractors in scapular dyskinesis remain largely unexplored. This assessment could enhance the early detection and diagnosis of scapular dyskinesis, which currently relies on clinical evaluation. Despite ongoing debates, scapular dyskinesis appears to be a risk factor for shoulder injury in overhead athletes.[24,25] Early detection and refinement of the diagnosis with quantitative measures would allow for proactive management of this risk.

Additionally, scapular dyskinesis can be asymptomatic, with individuals not experiencing pain or discomfort even when their scapular kinematics are altered.[26] It remains unclear whether these asymptomatic cases exhibit similar muscle profiles to symptomatic cases or should be treated differently.

Therefore, our aim was to compare the isokinetic strength and fatigue resistance profiles of the scapular protractors and retractors in overhead athletes with symptomatic or asymptomatic scapular dyskinesis and healthy control participants (HCs), unaffected by their sport practice. A second aim was to determine whether the profiles of the asymptomatic cases were more like those of the HCs or symptomatic cases. We hypothesized that we would observe significant differences among the 3 groups, with symptomatic cases demonstrating less strength and fatigue resistance than asymptomatic cases and HCs. We further hypothesized that asymptomatic cases would present similar profiles as symptomatic cases.

METHODS

Study Design, Ethical Approval, and Participant Selection

This was a cross-sectional study complying with the ethical standards of the Declaration of Helsinki, and the protocol was reviewed by the institutional ethics committee. The participants were recruited through the faculty and university hospital databases. Using convenience sampling, we invited recruits potentially meeting the inclusion criteria to join the study. Each participant gave signed informed consent. Inclusion criteria for the participants with dyskinesis were as follows: males between 18 and 35 years old; practicing overhead sports (eg, handball, tennis, rugby) for 3 to 5 hours per week; currently able to practice; no history of musculoskeletal lesions of the upper limbs; no spine scoliosis, thoracic kyphosis beyond the norm, or cervical hyperlordosis; and no lower limb length differences, which could affect the assessment and the homogeneity of the group. They were also required to have no other condition affecting their dyskinetic shoulder, and the contralateral shoulder had to be free of injury (ie, only unilateral dyskinesis present). For the HCs, the same criteria were applied except that they either could not practice overhead sports or only practiced them for <2 hours per week. Participants were allocated to 1 of 3 groups (ie, HC, asymptomatic dyskinesis, or symptomatic dyskinesis) depending on the clinical assessment (see following section and Figure 1). Participants were required to not perform any upper limb training on the day before and the day of the assessments.

Clinical Assessment

Based on clinical evaluation by a physical therapist who specialized in shoulder injuries, participants were classified into 3 groups: HCs, symptomatic unilateral dyskinesis (DS-S), or asymptomatic unilateral dyskinesis (DS-A). The same physical therapist performed all evaluations. The clinical assessment consisted of 2 parts; the first part focused on identifying the presence or absence of dyskinesis, and the second part focused on determining whether the participant was symptomatic (ie, with a painful or weak shoulder or both) or not. We chose these evaluations based on the existing literature and clinical practice. Reliability data and illustrative examples can be found in the Supplemental Material (available online at http://dx.doi.org/10.4085/1062-6050-0092.23.S1).

For the first part, the examiner assessed dyskinesis using 4 steps:

(1) Visual observation at rest and during arm elevation to determine the presence (ie, abnormal floating of the scapula or abnormal scapular movement or both) or absence of dyskinesis.
(2) Kibler lateral scapular slide test (LSST), which consists of measuring the distance between the lower angle of the scapula and the corresponding vertebral spinal process. This measurement is performed in 3 positions: the arm alongside the body, hands on hips,

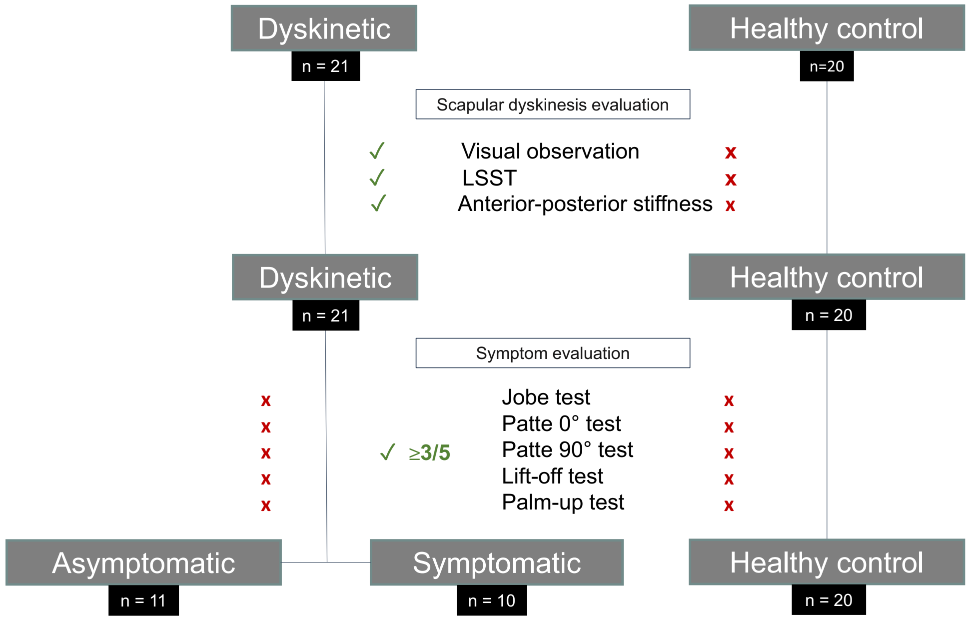

Figure 1. Categorization of the study participants based on the clinical assessment of dyskinesis and on symptoms. Abbreviation: LSST, lateral scapular slide test.

and the arm at 90° of abduction in maximal internal rotation. The test is considered positive for an asymmetry ≥1.5 cm in 2 of the 3 positions.[27]

(3) Stiffness of the pectoralis minor[28]: while the participant lies supine, arms relaxed alongside the body and palms facing downward, the distance (cm) between the posterior edge of the acromion and the table is measured. The test is positive if the distance is >4 cm.[29]

(4) Stiffness of the posterior shoulder structures[28,30]: while the participant is in the sleeper stretch position (lateral decubitus, shoulder and elbow flexed to 90°), the investigator applies maximum internal rotation and measures the distance between the radial styloid and the table.[31] The test is positive if the distance is >19 cm.[32]

For the shoulder to be considered *dyskinetic*, the participant had to meet the following criteria: criterion 1 (observation) positive and criterion 2 (LSST) positive and either criterion 3 (pectoralis minor stiffness) or criterion 4 (posterior structures stiffness) positive.

Once identified as having a dyskinetic shoulder, the participants were included in the symptomatic group if pain or weakness was present on ≥3 of the following 5 isometric tests (reliability data and illustrations provided in the Supplemental Material):

(1) Jobe test (supraspinatus)[33,34]: shoulder elevation and internal rotation with the arm extended at 90° of abduction in the scapular plane.
(2) Patte test 0° (infraspinatus)[35,36]: shoulder external rotation at 0° of abduction with the elbow flexed.
(3) Patte test 90° (teres minor)[35,36]: shoulder external rotation at 90° of abduction with the elbow flexed.
(4) Lift-off test (subscapularis)[36,37]: shoulder internal rotation starting with the hand behind the back.
(5) Palm-up test (long head biceps)[36,38]: shoulder elevation with the arm extended to 90° and externally rotated.

An individual who was previously thought to have a dyskinetic shoulder but was not positive for any of these isometric tests was considered asymptomatic. The HCs all had negative dyskinetic and isometric tests (Figure 1).

Isokinetic Assessment

The isokinetic assessment protocol was adapted from the one described and used by Cools et al in several scapular assessment studies of overhead athletes.[17–22] In the present context of dyskinesis, in which the fatigue component is important, we opted for the 40-repetition protocol. Arm dominance was recorded for each participant. The *dominant arm* corresponded to the primary limb the participant used in his sport. We assessed the dyskinetic side of those individuals with dyskinesis (DS groups) and the dominant side of the HCs. The isokinetic assessment of scapular protractors and retractors was performed in the concentric mode using the Biodex System 4 (Biodex Medical Systems Inc). The warmup consisted of 2 × 20 push-ups and 2 × 20 rowing exercises using elastic bands while standing. The isokinetic evaluation occurred in a closed chain setting. The chair was rotated to 15° from the sagittal plane while the engine base was rotated to 45°, and the shoulder was elevated to 90° in the scapular plane. The participant had to keep his elbow actively extended in neutral position throughout the tests. Compensation was limited by a belt, as shown in Figure 2. The seat height was adjusted so that the participant's arm was horizontal, and the individual was instructed to perform a maximal protraction and retraction movement (Figure 2). The total range of motion was set at 8 cm. The protocol consisted of (1) familiarization at 18.3 cm/s (10 trials) followed by a 1-minute rest and (2) 3 submaximal trials followed by a 10-second rest and 40 maximal trials at 24.4 cm/s in concentric mode. The Biodex software was used to calculate *peak torque* (Newton), the maximum force developed by the participant over the 40 trials; *maximum work* (Joule), the maximum amount of work performed on 1 trial; and *total work* (Joule),

Figure 2. Participant positioning on the isokinetic dynamometer (Biodex System 4).

the total amount of work performed over the 40 trials. These values were calculated for the protractors and retractors in the concentric mode at 24.4 cm/s. For each variable, we computed agonist:antagonist (ie, protractor:retractor) ratios as well. These variables were normalized by body weight (kg). Strength measurements consisted of peak force and maximum work. Fatigue resistance was measured by total work.

Statistical Analysis

No a priori statistical estimation was made for this convenience sample. Statistical analyses were conducted using R (version 3.6.2; R Core Team 2008). Data normality was determined using Shapiro-Wilk tests. The demographic and isokinetic variables among the 3 groups (ie, DS-A, DS-S, and HCs) were compared via 1-way analyses of variance after the homogeneity of variances was verified using Levene tests. The effect sizes for each variable were established with partial η^2 and 95% CIs. We interpreted the magnitude of the effect as *small*, >0.01; *medium*, >0.06; or *large*, >0.14. Post hoc pairwise comparisons were performed using a Tukey HSD test. Results were considered significant at the $P < .05$ level.

RESULTS

Population

Forty-one male participants (age = 22 ± 2 years, height = 181 ± 10 cm, mass = 80 ± 13 kg) were prospectively included in the study based on convenience sampling. After the first part of the clinical assessment (Figure 1), 21 participants were classified as having dyskinesis, and 20 were classified as HCs with no clinical feature of dyskinesis (ie, scapular dyskinesis evaluation negative for dyskinesis). After the second part of the clinical assessment, 11 participants were classified as DS-A and 10 as DS-S. The DS-A group had no positive isometric test on the second symptom evaluation, the DS-S group had $\geq$3 positive isometric tests, and the HCs had none. Five participants in the DS-A or DS-S group presented with dyskinesis on their nondominant side. Demographic and clinical characteristics of the sample are shown in Table 1. No differences were found among the 3 subgroups in age ($P = .26$), height ($P = .18$), or weight ($P = .18$). All participants underwent isokinetic testing according to the protocol, and none complained of discomfort or pain during or immediately after testing. The isokinetic data were normally distributed as assessed by Shapiro-Wilk tests (P values $> .05$), and the group variances were assumed equal as assessed by Levene tests (P values $> .05$).

Strength Assessment

Peak torque and maximum work values for the protraction: retraction 24.4 cm/s concentric movement are presented in Table 2. The peak torques of the protractors were different ($P < .001$) among the DS-S, DS-A, and HC groups, with a large effect size ($\eta^2 = 0.49$). The HCs showed the highest values (5.0 ± 0.9 N/kg), followed by the DS-S (3.8 ± 0.6 N/kg) and DS-A (3.4 ± 0.7 N/kg) groups. Post hoc pairwise comparisons showed differences between the HC and DS-A groups and

Table 1. Demographic and Anthropometric Characteristics of the Dyskinetic-Symptomatic, Dyskinetic-Asymptomatic, and Control Groups

Variable	Dyskinetic-Asymptomatic (n = 11)	Dyskinetic-Symptomatic (n = 10)	Control (n = 20)	*P* Value[a]
	Mean ± SD (Range)			
Age, y	22.4 ± 2.4 (19–26)	24.6 ± 4.7 (18–33)	23.0 ± 2.6 (20–30)	.26
Height, cm	180.5 ± 9.6 (168–203)	182.4 ± 4.9 (176–190)	177.6 ± 6.0 (163–190)	.18
Mass, kg	80.2 ± 13.3 (60–105)	81.2 ± 12.4 (68–108)	73.8 ± 10.5 (60–102)	.18
Sport practice, h	4.2 ± 0.9 (3–5)	4.0 ± 0.8 (3–5)		
	n			
Dominance	Right = 10 Left = 1	Right = 10	Right = 15 Left = 5	
Dyskinetic side	Dominant = 9 Nondominant = 2	Dominant = 7 Nondominant = 3		
Practiced sport	Tennis = 4 Rugby = 2 Swimming = 2 Climbing = 1 Decathlon = 1 Volleyball = 1	Handball = 6 Rugby = 1 Swimming = 1 Tennis = 1 Weightlifting = 1		

[a] One-way analysis of variance.

Table 2. Isokinetic Strength (Peak Torque, Maximum Work) and Fatigue Resistance (Total Work) Values Over a 40-Repetitions Protraction:Retraction Protocol for Healthy Control Individuals (HCs), Participants With Asymptomatic Dyskinesis (DS-A), and Participants With Symptomatic Dyskinesis (DS-S)[a]

Concentric Movement, 24.4 cm/s	Variable	Group			Analysis of Variance Values[b]			*P* Values[c]		
		HC (n = 20)	DS-A (n = 21)	DS-S (n = 20)	*F*	*P*	η^2	HC/DS-A	HC/DS-S	DS-A/DS-S
Protractors	Peak torque, N/kg	5.0 ± 0.9	3.4 ± 0.7	3.8 ± 0.6	18.19	**<.001**	0.49 (0.28, 1.0)	**<.001**	**<.001**	.53
	Maximum work, J/kg	2.4 ± 0.5	1.7 ± 0.4	1.8 ± 0.3	9.77	**<.001**	0.34 (0.13, 1.0)	**<.001**	**.01**	.69
	Total work, J/kg	72.4 ± 19.7	50.0 ± 13.7	58.1 ± 12.9	6.83	**.003**	0.26 (0.07, 1.0)	**.003**	**.09**	.52
Retractors	Peak torque, N/kg	4.7 ± 1.0	3.9 ± 1.0	5.2 ± 0.6	6.50	**.004**	0.25 (0.06, 1.0)	**.02**	.48	**.004**
	Maximum work, J/kg	2.1 ± 0.5	1.9 ± 0.6	2.9 ± 0.8	7.54	**.002**	0.28 (0.08, 1.0)	.62	**.007**	**.002**
	Total work, J/kg	65.3 ± 17.9	58.6 ± 18.5	87.7 ± 22.7	6.65	**.003**	0.26 (0.07, 1.0)	.63	**.01**	**.004**
Protractors: retractors	Peak torque, N/kg	1.1 ± 0.2	0.9 ± 0.1	0.7 ± 0.1	15.13	**<.001**	0.44 (0.23, 1.0)	.10	**<.001**	**.01**
	Maximum work, J/kg	1.1 ± 0.2	0.9 ± 0.2	0.7 ± 0.2	18.50	**<.001**	0.49 (0.29, 1.0)	**.01**	**<.001**	**.03**
	Total work, J/kg	1.1 ± 0.2	0.9 ± 0.2	0.7 ± 0.3	10.49	**<.001**	0.36 (0.15, 1.0)	**.03**	**<.001**	.22

[a] Body weight normalized.
[b] One-way analysis of variance, *F* value, *P* value, η^2 effect size, and 95% CI.
[c] Tukey Honestly Significant Difference post hoc test pairwise comparisons. Significant *P* values are depicted in bold.

the HC and DS-S groups. Regarding maximum work for the protractors, the 3 groups demonstrated different values ($P < .001$) with a large effect size ($\eta^2 = 0.34$). Again, the HCs had the highest value (2.4 ± 0.5 J/kg), followed by the DS-S (1.8 ± 0.3 J/kg) and DS-A (1.7 ± 0.4 J/kg) groups. Post hoc pairwise comparisons indicated differences between the HC and DS-A groups and the HC and DS-S groups.

The retractors displayed a different profile. The peak torques were different ($P = .004$) among the 3 groups, with a large effect size ($\eta^2 = 0.25$). However, the DS-S group had the highest value (5.2 ± 0.6 N/kg), followed by the HC (4.7 ± 1.0 N/kg) and DS-A (3.9 ± 1.0 N/kg) groups. Post hoc pairwise comparisons showed differences between the DS-A and HC groups and the DS-A and DS-S groups. Similarly, for the maximum work, the DS-S group had the largest value (2.9 ± 0.8 J/kg), followed by the HC (2.1 ± 0.5 J/kg) and DS-A (1.9 ± 0.6 J/kg) groups, with a difference among the 3 ($P = .002$) and a large effect size ($\eta^2 = 0.28$). Post hoc pairwise comparisons revealed differences between the DS-S and HC groups and the DS-S and DS-A groups.

These results are reflected in the protractor:retractor ratios, which were different among the 3 groups ($P < .001$) with a large effect size ($\eta^2 = 0.44$). The highest ratio was for the HCs (1.1 ± 0.2), followed by the DS-A (0.9 ± 0.1) and DS-S (0.7 ± 0.1) groups. Post hoc pairwise comparisons showed differences between the DS-S and HC groups and the DS-S and DS-A groups. Similarly, for the maximum work, the HCs had the highest ratio (1.1 ± 0.2), followed by the DS-A (0.9 ± 0.2) and DS-S (0.7 ± 0.2) groups, with a difference among the 3 groups ($P < .001$) and a large effect size ($\eta^2 = 0.49$). Post hoc pairwise comparisons indicated differences among all pairs (Figure 3).

Fatigue Resistance Assessment

Total work values for the protraction:retraction 24.4-cm/s concentric movement are provided in Table 2. The total work of the protractors was different ($P = .003$) among the DS-S, DS-A, and HC groups, with a large effect size ($\eta^2 = 0.26$). The HCs had the highest value (72.4 ± 19.7 J/kg), followed by the DS-S (58.1 ± 12.9 J/kg) and DS-A (50.0 ± 13.7 J/kg) groups. Post hoc pairwise comparisons demonstrated differences between the HC and DS-A groups and the HC and DS-S groups. As for the strength values, the retractors exhibited a different profile. The total work was different ($P = .003$) among the 3 groups, with a large effect size ($\eta^2 = 0.26$). However, the DS-S group displayed the highest value (87.7 ±

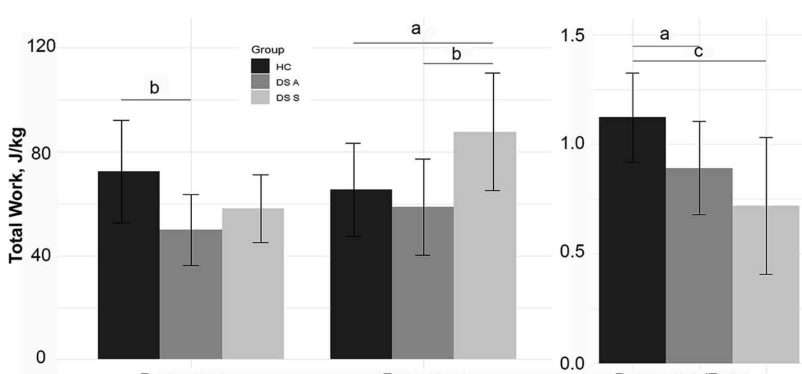

Figure 3. Barplot of the mean total work (body weight normalized) during the fatigue resistance protocol (40 repetitions) for the scapular protractors (Pro) and retractors (Ret) and for the ratio Pro:Ret. Error bars represent the SD from the mean. Abbreviations: DS-A, dyskinetic asymptomatic (n = 11); DS-S, dyskinetic symptomatic (n = 10); HC, healthy control (n = 20). [a] *P* < .05. [b] *P* < .01. [c] *P* < .001.

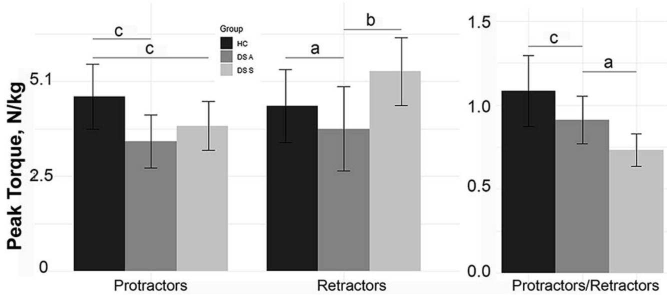

Figure 4. Barplot of the mean peak torque values during the fatigue resistance protocol (40 repetitions) for the scapular protractors and retractors and for the ratio protractors/retractors. Error bars represent the SD from the mean. Abbreviations: DS-A, dyskinetic asymptomatic (n = 11); DS-S, dyskinetic symptomatic (n = 10); HC, healthy control (n = 20). [a] *P* < .05. [b] *P* < .01. [c] *P* < .001.

22.7 J/kg), followed by the HC (65.3 ± 17.9 J/kg) and DS-A (58.6 ± 18.5 J/kg) groups. Post hoc pairwise comparisons revealed differences between the DS-S and HC groups and the DS-S and DS-A groups.

The protractor:retractor ratios were different ($P < .001$) among the 3 groups with a large effect size ($\eta^2 = 0.36$). The HCs presented the highest ratio (1.1 ± 0.2), followed by the DS-A (0.9 ± 0.2) and DS-S (0.7 ± 0.3) groups. Post hoc pairwise comparisons reflected differences between the HC and DS-A groups and the HC and DS-S groups (Figure 4).

In summary, the protractors of the participants with dyskinesis (symptomatic and asymptomatic) were weaker and had less fatigue resistance than those of the HCs. Conversely, the retractors of the participants with DS-S were stronger and had better fatigue resistance than those of the HCs and the participants with DS-A. The protractor:retractor ratios showed a gradual decrease from HC individuals to participants with DS-A to participants with DS-S.

DISCUSSION

Main Findings

We investigated the isokinetic strength (peak torque, maximum work) and fatigue resistance (total work) of the scapular protractors and retractors using a 40-repetition, 24.4-cm/s protocol for symptomatic and asymptomatic scapular dyskinesis, with a healthy group for comparison. This extended protocol was designed to engage the anaerobic lactic pathway while maintaining optimal movement speed.[23] We aimed to identify strength and fatigue resistance imbalances associated with symptomatic scapular dyskinesis and assess whether asymptomatic cases aligned more with HC or symptomatic profiles.

Although prior authors often focused on the shoulder rotators, research on the scapular protractors and retractors is limited. Nonetheless, it is crucial to assess these muscles and identify imbalances specific to these groups. For instance, certain athletes (eg, elite field hockey players) may exhibit a symmetric rotational strength profile but an asymmetric strength protraction:retraction profile.[22] If not addressed, such patterns can lead to injuries.

Individuals with symptomatic or asymptomatic dyskinesis presented abnormal strength and fatigue resistance compared with those of HCs, with the discrepancy being more pronounced in symptomatic participants. This was evident in the gradual decrease in scapular protractor:retractor ratios from around 1.1 in HCs to 0.9 in participants with DS-A and 0.7 in those with DS-S. Although normative values are lacking, earlier authors have suggested values ranging from 1 to 1.18 in a healthy nonathletic population.[16,17] For overhead athletes with impingement symptoms, this ratio was lower for injured shoulders (0.97) than healthy shoulders (1.05),[19] indicating weaker scapular protractors relative to retractors. Thus, a continuous decrease in ratios appears along with symptoms.

Surprisingly, when we considered protraction and retraction separately, participants who were symptomatic had stronger scapular retractors than did participants who were asymptomatic. Several explanations could account for this unexpected finding. Firstly, this imbalance in favor of the retractors could result from a kinematic adaptation to dyskinesis, in which the retractor muscles adapt to misaligned scapula positioning, potentially exacerbating the problem. Conversely, strong retractors that lack balance with the protractors might contribute to DS-S by pulling the scapula away from the rib cage.[7] This hypothesis of altered kinematics due to muscle imbalances requires confirmation through larger prospective studies.

Secondly, conventional training and rehabilitation programs often focus on retractor strengthening, potentially neglecting scapular protractors such as the serratus anterior, which tends to be weaker.[7] Prioritizing retractor over protractor strengthening or not addressing the protractors sufficiently could result in the unbalanced ratio observed in this study.

Thirdly, the composition of the DS-S sample, primarily consisting of handball players (6 out of 10), could explain their stronger retractors. Handball players often experience pain and dyskinesis[24,39] due to the sport's unique kinematic demands, characterized by high-velocity, large-amplitude overhead movements that heavily engage the shoulder retractors, unlike athletes in other sports in the study (eg, tennis, swimming).

We did not explore these hypotheses in depth, and they require further investigation. Other researchers who evaluated normative values in elite field hockey and gymnastics athletes have found stronger retractors in the dominant shoulder than in the nondominant shoulder and in control nonathletes.[21,22] However, we are the first to observe stronger retractors in participants who were symptomatic versus nonsymptomatic and HCs.

Clinical Implications

Scapular dyskinesis is prevalent among overhead athletes (61% according to a systematic review[3]) and may be underestimated due to its potential asymptomatic nature.[26] Ongoing debate questions whether dyskinesis represents an adaptation to sport practice or even a performance-enhancing adaptation.[40] Our results challenge this premise, as both the DS-S and DS-A groups showed altered protractor:retractor ratios, suggesting compromised scapular function. Despite having stronger retractors, the symptomatic group reported pain, dispelling the notion of a positive adaptation.

The DS-A group might represent an intermediate stage before transitioning into the symptomatic category, though this requires further investigation. It could pave the way for primary injury-prevention programs to counterbalance low protraction:retraction ratios. Such strengthening programs should aim at achieving a proportionate protractor:retractor ratio (about 1.1 in our HCs). Clinicians and staff should adapt rehabilitation and conditioning to focus on both retractors and protractors, specifically the weaker serratus anterior, using tailored exercises (eg, supine exercises using dumbbells). Both the strength and fatigue resistance modalities should be targeted. This involves short exercises with heavy loads (eg, 3 × 4–5 repetitions at 85%–90% of the 1-repetition maximum for strength) and long exercises with medium loads (eg, 3 × 15–20 high-intensity repetitions at 50%–60% of the 1-repetition maximum for fatigue resistance). This dual approach has been effective in rebalancing supraspinatus and infraspinatus strength in participants with dyskinesis.[41]

Benefits and Limitations of a Quantitative Assessment

Traditional assessment of scapular dyskinesis relies on subjective visual observation. A quantitative evaluation of muscle strength and fatigue through isokinetic testing offers personalized rehabilitation goals and customized strengthening programs, moving beyond the 1-size-fits-all approach. Additionally, follow-up evaluations can gauge intervention effectiveness. However, this assessment approach has limitations. Apart from cost and expertise requirements, the closed chain isokinetic protocol is highly analytical and does not capture the complete function of the shoulder, only some specific aspects. To tackle this concern, it might be interesting to complement the evaluation with field tests that are more accessible and versatile.

To fully capture fatigue resistance performance, we considered total work >40 repetitions, instead of solely the first and last trials, to avoid overreliance on the first trial performance. Although we assumed participants maintained maximal effort throughout, mental fatigue could have led to suboptimal performance toward the end. Therefore, investigators must offer proper encouragement and visually inspect strength curves to ensure maximal effort throughout the evaluation.

Methodologic Strength and Limitations

Several limitations of this study should be considered before generalizing the results. First, strict inclusion criteria for sport practice compromised the study's external validity for other sport participation levels (eg, leisure or professional). The control group consisted of participants not heavily engaged in overhead sports to isolate the effect of sport practice on scapular dynamics. Second, this was a prospective convenience sample without an a priori sample size estimation. However, differences were observed among the 3 groups of interest, which refines the understanding of scapular dyskinesis and underscores the value of a combined clinical and isokinetic approach.

Future Directions

Future researchers could explore the multimodal assessment of scapular dyskinesis by integrating the data from assessments such as electromyography to distinguish activation patterns during fatigue resistance tests or sport-specific movements. Authors of prospective studies could also evaluate the effect of interventions aimed at rebalancing low protraction:retraction ratios on symptoms. Additionally, comparing dyskinesis classification accuracy between clinical experts and machines, such as isokinetic devices or others, could further refine diagnostic approaches.

CONCLUSIONS

In this research, we presented an innovative approach to assessing symptomatic and asymptomatic scapular dyskinesis by combining qualitative (clinical) and quantitative (isokinetic) assessments of scapular protractors and retractors. This comprehensive evaluation of muscle function appears capable of distinguishing DS-S and DS-A based on the muscle imbalance in favor of the retractors. Addressing such imbalances, even in asymptomatic cases, is crucial to prevent the development of DS-S. Consequently, tailored training regimens that restore the balance between protractors and retractors, focusing on both strength and fatigue resistance, should be considered, particularly because participants who were asymptomatic already displayed altered profiles compared with those of HCs.

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SUPPLEMENTAL MATERIAL

Supplemental Material. Differences in strength and fatigue resistance of scapular protractors and retractors between symptomatic and asymptomatic dyskinesis.

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