JBACHS
Journal of Basic and Clinical Health Sciences

J Basic Clin Health Sci 2022; 6: 694-702
https://doi.org/10.30621/jbachs.1071136
RESEARCH ARTICLE

IS SCAPULAR DYSKINESIS EFFECTIVE ON SHOULDER STRENGTH PROFILES IN ASYMPTOMATIC YOUNG SWIMMERS?

Ferhat Ozturk[1], Aykut Ozcadirci[1], Sukru Alpan Cinemre[2], Gizem Irem Kinikli[1]

[1]Hacettepe University, Faculty of Physical Therapy and Rehabilitation, Ankara, Turkey
[2]Hacettepe University, Faculty of Sport Sciences, Ankara, Turkey

ORCID: F.O. 0000-0003-4070-8831; A.O. 0000-0002-0882-1298; S.A.C. 0000-0003-4955-2394; G.I.K. 0000-0003-1013-6393

Corresponding author: Ferhat Ozturk, **E-mail:** ferhat.ozturk012@gmail.com

Received: 10.02.2022; **Accepted:** 01.04.2022; **Available Online Date:** 29.09.2022

Cite this article as: Ozturk F, Ozcadirci A, Cinemre SA, Kinikli GI. Is Scapular Dyskinesis Effective on Shoulder Strength Profiles in Asymptomatic Young Swimmers? J Basic Clin Health Sci. 2022; 6: 694-702.

ABSTRACT

Purpose: The aim of this study was (a) to investigate whether presence of scapular dyskinesis (SD) differs by gender in asymptomatic young swimmers and (b) to compare shoulder muscle strength between asymptomatic young swimmers with and without SD.
Material and Methods: Fifty-six asymptomatic young swimmers (mean age: 10.35 years; 22 females; 34 males) were included in the study. The presence of SD was determined visually using SD test with dichotomous outcome (yes/no). The shoulder muscle strength was assessed via handheld dynamometer.
Results: There was statistically significant difference between swimmers with and without SD in shoulder flexion muscle strength in both females and males (respectively, $p<0.018$, $p<0.015$). There was statistically significant difference between swimmers with and without SD in shoulder internal and external rotation muscle strength in males (respectively, $p<0.048$, $p<0.041$). No significant prevalence was found between the presence of SD and gender ($p=0.167$).
Conclusion: The results of this study demonstrated that although SD prevalence was similar by gender, differences in shoulder muscle strength were present between asymptomatic young swimmers with and without SD. Thus, early identification of SD may be beneficial for asymptomatic young swimmers to avoid its possible transformation into symptomatic situation.

Keywords: Scapular dysfunction, muscular performance, gender, swimmers

INTRODUCTION

The normal scapular function is very important in overhead athletes as it transmits strength from the lower extremities to the upper extremities and maintains the ideal position of the glenohumeral joint (1). It may be impaired due to bone posture or injury, periscapular and rotator muscle imbalance, deterioration in soft tissue flexibility (2). Scapular dyskinesis (SD) has been defined as a pathology resulting in winging or arrhythmia in the scapula due to changes in the normal kinematics of the shoulder (3).

In swimmers, repetitive overhead activities at the glenohumeral joint can cause fatigue in the shoulder girdle muscle groups such as the rotator cuff (RC), scapula stabilizers and anterior-posterior shoulder muscles. Muscle fatigue may cause a decrease in muscle strength and deterioration in balance, which may disrupt the biomechanical balance of the RC and may create abnormal stress on the tendons and eventually result in SD (4,5). The prevalence of SD in swimmers has been reported to vary between 8.5% and 63.6% (1,6,7). Also, butterfly and backstroke swimming styles are the swimming styles that have different stresses in different swimming styles and the highest prevalence of injury according to stroke type (8).

Deterioration of scapula and shoulder biomechanics, fatigue, muscle imbalance, range of motion deficit and excessive training load are risk factors for shoulder injury in young swimmers (9). Looking at the 3-dimensional biomechanical analysis of swimming, it is seen that swimming with the right technique reduces shoulder compression and is associated with optimal strength. On the contrary, swimming with the wrong technique increased shoulder impingement and revealed differences in scapular biomechanics (10). Young swimmers may be more prone to shoulder and shoulder blade biomechanics changes and shoulder injury during training (11). However, it has been reported that strength training for the periscapular muscles (especially the rhomboids, serratus anterior and trapezius) and shoulder is beneficial in preventing injuries and improving performance in young swimmers (12, 13).

SD has been found to be associated with shoulder pain in swimmers as a result of muscle fatigue and muscle imbalance as a result of high training loads (7, 14). A recent study reported that athletes with SD are at a 43% higher risk of future shoulder pain than those with normal neuromuscular control (15). As a result, any deterioration in scapular stabilization may predispose the swimmer to shoulder injury and pain (2). Gender may be an issue that should be subject to in SD studies. Features of male and female anatomy, such as anthropometry (16), amount of skeletal muscle mass (17), and muscle activation patterns (18), may contribute to gender-specific different scapular movement patterns. Therefore, it may be important to identify possible differences by gender. Studies have reported that the prevalence of SD differs by gender (1, 7). However, there are no studies evaluating muscle strength according to gender in young swimmers with and without dyskinesis. The muscle strength profile between with and without SD by gender is unknown.

Despite the importance of SD in swimmers, it is noteworthy that there are few studies in the literature comparing strength measurements between groups with and without SD (19, 20). As far as we know, one of the studies was carried out on healthy individuals and the other on overhead athletes and none of them were analyzed by gender. Hannah et al. examined the strength profiles of healthy individuals with and without SD and found no difference in strength measurements between the groups (19). In the other study, Seitz et al found the significant weakness of the lower trapezius in the SD group in healthy overhead athletes, but the authors limited strength measurements to the lower trapezius and serratus anterior only (20). Therefore, the first aim of this study was to investigate whether the presence of SD differs by gender in asymptomatic young swimmers, secondly, was to compare shoulder muscle strength between asymptomatic young swimmers with and without SD by gender. We hypothesized that (a) the presence of SD in asymptomatic young swimmers would differ according to gender and (b) asymptomatic young swimmers with SD would demonstrate decreased strength when compared to asymptomatic young swimmers without SD.

MATERIAL AND METHODS

Study design

This study is a cross-sectional study examining shoulder muscle strength profiles in asymptomatic young swimmers with and without SD by gender.

Participants

Based on the shoulder flexion strength in the groups with and without SD, at least 34 people with a power ratio of 80% were predicted to be included. This cross-sectional study included 56 volunteer asymptomatic young swimmers (22 females; 34 males) with at least 3 years of experience in a professional swimming club. The training program includes swimming training 6 hours a week.

Inclusion criteria were no shoulder pain in the last 6 months, no discomfort in the shoulder joint during swimming, use of symmetrical breathing patterns in training and competitions.

Exclusion criteria were having a history of upper extremity injury (dislocation, fracture, muscle strain, etc.), current shoulder pain, current neck pain, feeling pain in clinical tests (Hawkins and Neer) and not participating in regular training (swimmers who do not attend 3 consecutive training sessions).

Procedures

All swimmers were directed to work by the team coaches of the ANKA sports swimming club. Informed consent was obtained from all swimmers and their

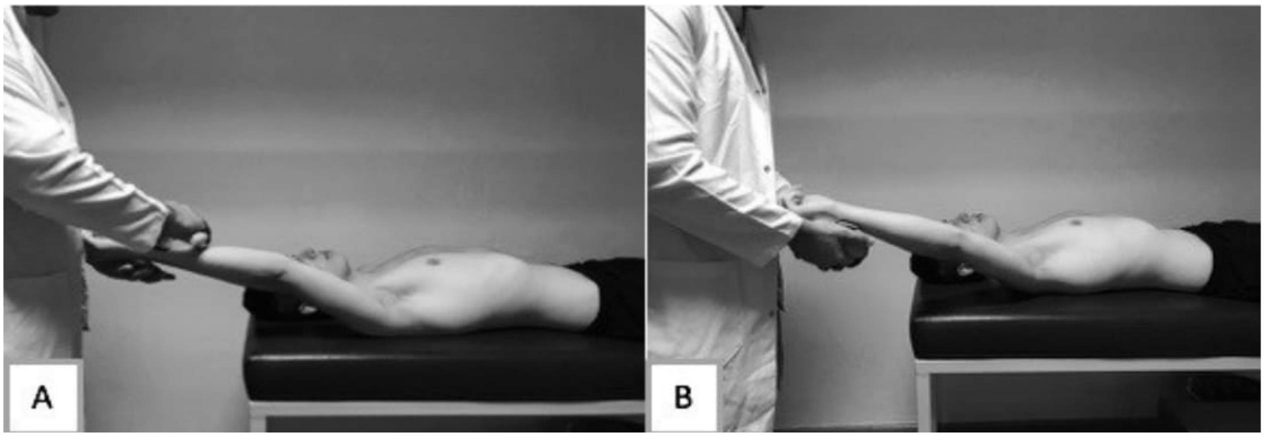

Figure 1. A) Flexion muscle strength assessment, B) Extension muscle strength assessment

parents before assessments. Measurements were made at the Beytepe Olympic Swimming Pool. The study was approved by the ethics committee of Hacettepe University under the number GO 19/876; 2019/22-05. Children and their parents were informed about the study and informed consent was obtained.

Shoulder Muscle Strength Assessment

Hand-held dynamometer (HHD) (Model-01165, Lafayette Instrument Company, Lafayette IN, USA) was used to measure shoulder muscle strength. HDD has been reported as a valid and reliable method in swimmers (21). All tests were performed in the supine position as described by Mclaine et al. (9). Before the measurement, the swimmers were given the necessary information and after a slight warm-up, the measurements were taken. It included warm-up, shoulder capsule stretching, 10 repetitions of resistance exercise with therabands (50% of maximal strength), 5 minutes of running, and 3 repetitions of handheld dynamometer at 50% of maximum effort. Measurements were made with physiotherapists with at least 4 years of experience in this field.

For flexion and extension measurement, the athletes positioned their shoulders in the scapular plane at 140º abduction with the elbow extended, because this position was defined as a functional position for hand entry and early pull-through phase in swimming (Figure 1) (22).

For internal rotation (IR) and external rotation (ER) measurement, athletes positioned the shoulders 90º abducted with the elbow at 90º flexion because this position was defined as a functional position for the mid-pull-through and recovery phases of the swim (Figure 2) (22). After the athletes were positioned properly, a hand dynamometer was placed, and the athletes were given verbal warnings for maximum isometric contraction (break test).

Each test was performed 3 times, lasted 5 seconds, and 1-minute break was given between the tests. After the trial tests were done, the average of the 3 values taken for measurement was recorded. Since there are swimmers of different body sizes, all strength measurements are standardized to body weight.

Scapular Dyskinesis Assessment

Scapular dysfunction of the dominant shoulder of the swimmers was evaluated with the scapular dyskinesis test (23). Abnormal motion patterns in SD were detected by determining the position of the scapula with the patient's arms at rest and then observing scapular motion in the sagittal plane. SD was observed when bilateral scapular motion during 5 repeated motions of arm elevation and lowering which is suggested as the preferred way to examine abnormalities in scapulohumeral rhythm (24). The presence of SD was determined as a dichotomous method (yes/no) as defined by Uhl et al. (25). SD was evaluated for winging or abnormal movement patterns. Scapula motion was recorded on camera and then evaluated separately by physiotherapists. If both physiotherapists indicated the presence of SD, SD was accepted as 'yes'. Asymptomatic young swimmers were divided into 2 groups as with and without SD.

Statistical Analysis

The data obtained from the study were evaluated with IBM SPSS 20.0 package program. Descriptive analyzes mean and standard deviation for numeric variables; frequency tables (n) proportions (%) for ordinal variables are shown. Kolmogorov - Smirnov,

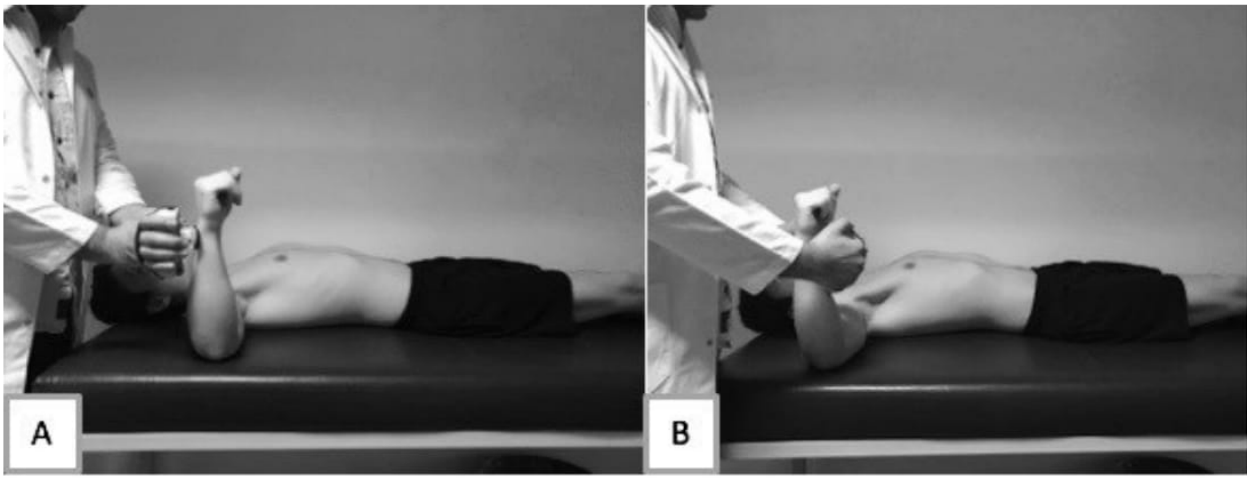

Figure 2. A) External rotation muscle strength assessment, B) Internal rotation muscle strength assessment

and histograms were used to determine whether the variables were normally distributed or not. Since all variables were normally distributed, the mean ± standard deviation was given and independent samples t-test was used for comparisons between the with and without SD in terms of muscle strength. In addition, the comparison of the presence of SD by gender was analyzed with the chi-square test. The p<0.05 value was accepted to be statistically significant.

RESULTS

The demographic information of the participants is summarized in Table 1. Except for body height and weight, other parameters were similar in swimmers with and without SD (Table 1). Also thirty-four males (mean age 10.4± 1.3 years, mean height 142.5 ± 8 cm and mean weight 26.11 ±7 kg) and 22 women (mean age 10.2 ±1 years, mean height 144.9 ± 5 cm and mean weight 34.5 ± 5.2 kg) were included in the study.

The 'yes' and 'no' method (intra tester k: 0.82, inter tester k: 0.80) reliability were high. The presence of SD by gender is shown in Table 2. SD was found in 59% of females and 76% of males. No significant prevalence was found between the presence of SD and gender (p=0.167) (Table 2).

Shoulder muscle strength (± SD) according to the presence of SD in basis gender are summarized in Table 3.

There was a statistically significant difference between swimmers with and without SD in shoulder flexion muscle strength in both females and males (respectively; p<0.018, p<0.015). While there was a statistically significant difference between swimmers with and without SD in shoulder internal and ER muscle strength in males (respectively; p<0.048, p<0.041), there was no statistically significant difference between groups in females (respectively; p> 0.329, p>0.413). In addition, shoulder extension and flexion/extension and ER/IR ratios were similar between groups.

Table 1. Demographic information for participant

Variable	With Dyskinesis (n=39)	Without Dyskinesis (n=17)	p*
Age (yrs)	10.26±1.36	10.56±0.66	0.272
Sport Age (yrs)	3.99±1.62	4.32±1.81	0.516
Body Mass Index (kg/m^2)	16.70±1.31	18.13±3.01	0.077
Weight (kg)	33.87±5.67	39.29±7.20	**0.011**
Height (cm)	141.92±8.77	147.11±6.16	**0.015**

* Independent sample t-test* Independent sample t-test

DISCUSSION

To the authors' knowledge, this is the first study to compare muscle strength in asymptomatic young swimmers with and without SD by gender. The first aim of this study was to investigate whether the presence of SD differs by gender. Secondly, was to compare shoulder muscle strength between asymptomatic young swimmers with and without SD by gender. The results of our study revealed that although the SD prevalence was similar by gender, some differences in shoulder muscle strength were present between asymptomatic young swimmers with and without SD by gender. In this case, we must reject our first hypothesis and must accept our second hypothesis.

Table 2. Profile of scapular dyskinesis in swimmers.

	Scapular Dyskinesis		
Gender	**Yes**	**No**	p†
Males n (%)	26 (76)	8 (24)	0.167
Females n (%)	13 (59)	9 (41)	

† Chi-Square test

It has been reported that SD is a common symptom in elite athletes. In the literature, SD has been reported 50-61% in healthy overhead athletes (20, 26, 27), 33% in non-overhead athletes (26), and in swimmers varies from 8.5% to 63.6% (1, 6, 7). The prevalence of SD in swimmers differs according to age, number, and symptoms and comes from inhomogeneous groups. Standoli et al. (1) found the prevalence of SD in swimmers to be 8.5% in their extensive study. Tate et al. found the prevalence of SD as 63.6% in the asymptomatic group in their study of swimmers with and without present shoulder pain (6). Madsen et al. (28) reported that the prevalence of SD increased after the training session in 78 swimmers. Similarly, Maor et al. (29) In their study in which they examined 20 swimmers, stated that the prevalence of SD increased from 30% to 80% after training. The prevalence of SD was 69% (39/56) in our study. Although, in our study, the athletes were evaluated on a day when they did not do intense physical activity and training for at least 2 days to eliminate the effect of fatigue; It is surprising that the prevalence of SD is high compared to the literature. This may be related to the age and sports experience of the swimmers participating in the study. The lack of adequate muscle balance due to the continuation of maturation may have caused the high rate of SD. Because the age range in the mentioned authors' study included adolescents and adults.

To our knowledge, the gender-related prevalence of SD in swimmers has been investigated in two studies (1, 7). Firstly, Bak et al.'s (7) study was performed on 49 painful shoulders in 36 athletes and failed to find any correlation between the gender. Secondly, Standoli et al (1) found that male swimmers (mean age 16 years) had a significantly higher prevalence of SD and an 8 times higher prevalence of SD than female participants. However, in the same study, no gender difference in terms of SD was found in swimmers under the age of 16. These results may indicate that there may be differences between the gender as the age of the swimmer increases. Similarly, in our study, although the prevalence of SD was found to be higher in male swimmers (76%) than in female swimmers (59%), there was no statistical difference between the genders.

Optimal scapula positioning is required for maximum strength generation of the RC muscles. Alteration in scapular motion and posture can affect rotator muscle strength. The ideal scapular position is the scapular retraction and ER position for the RC muscles to work efficiently. On the contrary, because the scapular protraction position reduces the strength-generating abilities of the internal and external rotators, there may be a decrease in RC strength (30, 31). Kebaetse et al (31) reported that the excessive scapular protraction posture seen in individuals with SD reduces the activation of the RC by 23%. In addition, Smith et al. (32) showed that maximum RC strength can be achieved with the scapular protraction/retraction balance. In our study, consistent with the literature, internal and external rotator muscle strength was less in swimmers with dyskinesis. This result showed that deterioration in scapula posture caused changes in shoulder rotator muscle strength. Although the swimmers in our study were asymptomatic, it can be said that conservative approaches should be applied to avoid its possible transformation into a symptomatic situation.

It is known that the shoulder ER to internal rotation (IR) strength ratio is reduced in swimmers due to dominant IR loading during the pull-through (propulsive) phase (33). This rotation strength imbalance then leads to changes in humeral head positioning resulting in shoulder pain due to impingement (33). Agonist and antagonist muscle strength balance is more important in terms of preventing injury, since not only a certain muscle

Table 3. Comparison of shoulder muscle strength (± SD) according to the presence of scapular dyskinesis in basis gender

Shoulder muscle strength		Without Dyskinesis (n=17)	With Dyskinesis (n=39)	p*
Flexion	**F**	13.90±2.86	10.99±2.37	**0.018**
	M	14.06±3.40	10.59±2.95	**0.015**
Extension	**F**	12.10±1.80	11.13±1.56	0.199
	M	11.83±1.77	10.42±1.58	0.052
Internal rotation	**F**	16.04±2.56	14.90±2.63	0.329
	M	16.81±2.81	14.29±2.95	**0.048**
External rotation	**F**	17.84±3.14	16.88±2.25	0.413
	M	16.54±2.81	14.24±2.42	**0.041**
Flexion/Extension	**F**	1.15±0.22	0.98±0.16	0.074
	M	1.19±0.22	1.01±0.26	0.122
External/Internal rotation	**F**	1.11±0.14	1.15±0.20	0.642
	M	0.99±0.16	1.00±0.11	0.826

*Independent sample t-test, **M:** male, **F:** female

group but also dynamic stabilizers are trusted for shoulder stability (9). Although there are different opinions about ER:IR muscle imbalance in the literature, it has been seen that the ER:IR ratio is 1:1 in recent studies (34). The results found in both genders in our study support the literature. In addition, the lower ER muscle strength in individuals with scapular dyskinesis in our study seems to be good for the balance of the ER:IR ratio, which may be a compensation pattern made to prevent structures in the subacromial space. The balance in these muscle strengths measured in functional positions can be a useful measure in monitoring the balance of power in shoulder stabilization in swimmers due to their functionality with sports.

Although rotator muscles in swimmers are frequently investigated, the muscles and muscle strength that provide extension and flexion have not been studied much (9, 35). Mclaine et al. (35) reported that low EX strength was associated with shoulder pain in swimmers. However, the authors stated that more studies are needed for a definite relationship. Flexion muscle strength was found to be lower in both genders in individuals with SD. This may be due to the biomechanical imbalance in the RC muscles and reduced ability to stabilize the scapula due to SD. Although flexion muscle strengths are different in individuals with scapular dyskinesis, it can be understood from the similarity of the FL:EX ratio in both groups that extensor muscles adapt in the pull-through phase to prevent shoulder compression and to help stabilize the scapula.

Although SD is associated with shoulder pain, it is difficult to say that the main cause of shoulder pain is SD (36). In studies conducted with symptomatic individuals, especially muscle strength, muscle performance and muscle balance stand out as causal factors for SD (36). Considering the differences in this study, the fact that different forces between with and without SD are seen in swimmers does not mean that they will be associated with injury. These data may indicate that SD in swimmers may be one of the variations of scapular normal movement. However, these results should not dispense with the assessment of scapular function and dyskinesis in asymptomatic swimmers.

This study had some limitations; In the current study, groups with and without SD were evaluated in terms of rotational muscle strength and flexion-extension muscle strength. However, the fact that the scapular stabilizer muscles and periscapular muscles were not evaluated in this study is an important limitation. Because, it was a known contribution of periscapular muscle weakness and imbalance to the development of SD (37). Scapular stabilizers have an important for rehabilitation programs in individuals with SD (2). Therefore, future studies should include swimmers of different age groups and focus on the evaluation of the scapula and shoulder girdle. Another limitation was that the data obtained was only from the dominant arm, with measurements from the non-dominant arm a much broader result may occur. Despite these limitations, it has shown important results for preventing injuries and programming training in individuals with SD in swimmers.

CONCLUSION

In this study, we aimed to reveal the shoulder muscle strength profiles in asymptomatic young swimmers with and without SD by gender. The results of this study demonstrated that differences in shoulder strength exist between asymptomatic young swimmers with and without SD by gender. Thus, gender may be a factor to be considered for evaluating SD in young swimmers. Also SD can occur as a result of swimming. Training programs should take these into account and the SD measurement should be taken into account throughout the season. Furthermore, this study improves to a growing body of evidence that SD is commonly found in healthy swimmers. Thus, early identification of SD may be beneficial for asymptomatic young swimmers to avoid its possible transformation into a symptomatic situation.

Acknowledgments: The authors would like to thank all the swimmers, parents and coach Efe Orhan of the ANKA sports club and thank the Hacettepe University for providing equipment assistance for this study.

Author contribution: Data Collection: F. Ozturk, A. Ozcadirci; Statistical Analyses: F. Ozturk, A. Cinemre, Gl. Kinikli; Data Interpretation: Gl. Kinikli, A. Cinemre; Manuscript Preparation: F. Ozturk, A. Ozcadirci, A. Cinemre, Gl. Kinikli, Literature Search: F. Ozturk, A. Ozcadirci.

Conflict of interests: No conflict of interest was declared by the authors.

Ethical approval: All swimmers and their parents provided written informed assent and consent, respectively, and the study was approved by the institutional and/or national research committee (Non-Interventional Research Ethics Committee; GO: 19/876 Decision No: 2019/22-05).

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Peer-review: Externally peer-reviewed.

REFERENCES

1. Preziosi Standoli J, Fratalocchi F, Candela V, Preziosi Standoli T, Giannicola G, Bonifazi M, et al. Scapular dyskinesis in young, asymptomatic elite swimmers. Orthopaedic journal of sports medicine. 2018;6(1):2325967117750814.
2. Kibler WB, Ludewig PM, McClure PW, Michener LA, Bak K, Sciascia AD. Clinical implications of scapular dyskinesis in shoulder injury: the 2013 consensus statement from the 'Scapular Summit'. British journal of sports medicine. 2013;47(14):877-85.
3. Kibler BW, McMullen J. Scapular dyskinesis and its relation to shoulder pain. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2003;11(2):142-51.
4. McQuade KJ, Dawson J, Smidt GL. Scapulothoracic muscle fatigue associated with alterations in scapulohumeral rhythm kinematics during maximum resistive shoulder elevation. Journal of Orthopaedic & Sports Physical Therapy. 1998;28(2):74-80.
5. Kibler WB, Sciascia A, Dome D. Evaluation of apparent and absolute supraspinatus strength in patients with shoulder injury using the scapular retraction test. The American journal of sports medicine. 2006;34(10):1643-7.
6. Tate A, Turner GN, Knab SE, Jorgensen C, Strittmatter A, Michener LA. Risk factors associated with shoulder pain and disability

across the lifespan of competitive swimmers. Journal of athletic training. 2012;47(2):149-58.
7. Bak K, Faunø P. Clinical findings in competitive swimmers with shoulder pain. The American Journal of Sports Medicine. 1997;25(2):254-60.
8. Trinidad A, González-Garcia H, López-Valenciano A. An updated review of the epidemiology of swimming injuries. PM&R. 2021;13(9):1005-20.
9. McLaine SJ, Ginn KA, Fell JW, Bird M-L. Isometric shoulder strength in young swimmers. Journal of science and medicine in sport. 2018;21(1):35-9.
10. Yanai T, Hay JG. Shoulder impingement in front-crawl swimming: II. Analysis of stroking technique. Medicine and science in sports and exercise. 2000;32(1):30-40.
11. Habechian FA, Lozana AL, Cools AM, Camargo PR. Swimming Practice and Scapular Kinematics, Scapulothoracic Muscle Activity, and the Pressure-Pain Threshold in Young Swimmers. Journal of athletic training. 2018;53(11):1056-62.
12. Wanivenhaus F, Fox AJ, Chaudhury S, Rodeo SA. Epidemiology of injuries and prevention strategies in competitive swimmers. Sports health. 2012;4(3):246-51.
13. Amaro NM, Marinho DA, Marques MC, Batalha NP, Morouço PG. Effects of dry-land strength and conditioning programs in age group swimmers. The Journal of Strength & Conditioning Research. 2017;31(9):2447-54.
14. Sein ML, Walton J, Linklater J, Appleyard R, Kirkbride B, Kuah D, et al. Shoulder pain in elite swimmers: primarily due to swim-volume-induced supraspinatus tendinopathy. British journal of sports medicine. 2010;44(2):105-13.
15. Hickey D, Solvig V, Cavalheri V, Harrold M, Mckenna L. Scapular dyskinesis increases the risk of future shoulder pain by 43% in asymptomatic athletes: a systematic review and meta-analysis. British journal of sports medicine. 2018;52(2):102-10.
16. Burkhart TA, Arthurs KL, Andrews DM. Reliability of upper and lower extremity anthropometric measurements and the effect on tissue mass predictions. Journal of Biomechanics. 2008;41(7):1604-10.
17. Janssen I, Heymsfield SB, Wang Z, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18–88 yr. Journal of applied physiology. 2000.
18. Anders C, Bretschneider S, Bernsdorf A, Erler K, Schneider W. Activation of shoulder muscles in healthy men and women under isometric conditions. Journal of Electromyography and Kinesiology. 2004;14(6):699-707.
19. Hannah DC, Scibek JS, Carcia CR. Strength profiles in healthy individuals with and without scapular dyskinesis. International journal of sports physical therapy. 2017;12(3):305.
20. Seitz AL, McClelland RI, Jones WJ, Jean RA, Kardouni JR. A comparison of change in 3D scapular kinematics with maximal contractions and force production with scapular muscle tests between asymptomatic overhead athletes with and without scapular dyskinesis. International journal of sports physical therapy. 2015;10(3):309.
21. Coinceicao A, Parraca J, Marinho D, Costa M, Louro H, Silva A, et al. Assessment of isometric strength of the shoulder rotators in swimmers using a handheld dynamometer: a reliability study. Acta of bioengineering and biomechanics. 2018;20(4).
22. McLaine SJ, Ginn KA, Kitic CM, Fell JW, Bird M-L. The reliability of strength tests performed in elevated shoulder positions using a handheld dynamometer. Journal of sport rehabilitation. 2016;25(2).
23. Tate AR, McClure P, Kareha S, Irwin D, Barbe MF. A clinical method for identifying scapular dyskinesis, part 2: validity. Journal of athletic training. 2009;44(2):165-73.
24. Giphart JE, Brunkhorst JP, Horn NH, Shelburne KB, Torry MR, Millett PJ. Effect of plane of arm elevation on glenohumeral kinematics: a normative biplane fluoroscopy study. JBJS. 2013;95(3):238-45.
25. Uhl TL, Kibler WB, Gecewich B, Tripp BL. Evaluation of clinical assessment methods for scapular dyskinesis. Arthroscopy: the journal of arthroscopic & related surgery. 2009;25(11):1240-8.
26. Burn MB, McCulloch PC, Lintner DM, Liberman SR, Harris JD. Prevalence of scapular dyskinesis in overhead and nonoverhead athletes: a systematic review. Orthopaedic journal of sports medicine. 2016;4(2):2325967115627608.
27. Struyf F, Nijs J, Meeus M, Roussel NA, Mottram S, Truijen S, et al. Does scapular positioning

predict shoulder pain in recreational overhead athletes? International journal of sports medicine. 2014;35(01):75-82.
28. Madsen PH, Bak K, Jensen S, Welter U. Training induces scapular dyskinesis in pain-free competitive swimmers: a reliability and observational study. Clinical journal of sport medicine. 2011;21(2):109-13.
29. Maor MB, Ronin T, Kalichman L. Scapular dyskinesis among competitive swimmers. Journal of bodywork and movement therapies. 2017;21(3):633-6.
30. Tate AR, McClure P, Kareha S, Irwin D. Effect of the scapula reposition test on shoulder impingement symptoms and elevation strength in overhead athletes. journal of orthopaedic & sports physical therapy. 2008;38(1):4-11.
31. Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. Archives of physical medicine and rehabilitation. 1999;80(8):945-50.
32. Smith J, Kotajarvi BR, Padgett DJ, Eischen JJ. Effect of scapular protraction and retraction on isometric shoulder elevation strength. Archives of physical medicine and rehabilitation. 2002;83(3):367-70.
33. Weldon III EJ, Richardson AB. Upper extremity overuse injuries in swimming: a discussion of swimmer's shoulder. Clinics in sports medicine. 2001;20(3):423-38.
34. Ramsi M, Swanik KA, Straub S, Mattacola C. Shoulder-rotator strength of high school swimmers over the course of a competitive season. Journal of sport rehabilitation. 2004;13(1):9-18.
35. McLaine SJ, Bird M-L, Ginn KA, Hartley T, Fell JW. Shoulder extension strength: a potential risk factor for shoulder pain in young swimmers? Journal of science and medicine in sport. 2019;22(5):516-20.
36. Cools AM, Struyf F, De Mey K, Maenhout A, Castelein B, Cagnie B. Rehabilitation of scapular dyskinesis: from the office worker to the elite overhead athlete. British journal of sports medicine. 2014;48(8):692-7.
37. Kibler WB, Kuhn JE, Wilk K, Sciascia A, Moore S, Laudner K, et al. The disabled throwing shoulder: spectrum of pathology—10-year update. Arthroscopy: the journal of arthroscopic & related surgery. 2013;29(1):141-61. e26.