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REVIEW

Swimmer's Shoulder: An Update on Pathogenesis, Risk Factors, Clinical Assessment, and Management

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Abstract

Purpose of Review Shoulder pain is the most common cause of pain in competitive swimmers. This review will cover the current available literature on the pathogenesis, assessment, management, and gaps in knowledge of swimmer's shoulder; and provide insight into the practical clinical evaluation, treatment, and future directions from a multi-disciplinary group of authors with extensive clinical experience treating swimmers.

Recent Findings Good thoracic mobility and extension is vitally important in the scapula's success maintaining dynamic stability of the glenohumeral joint in swimmers. Both the front squat and overhead squat are good functional movement assessments for shoulder mobility and stability. Three evidence-based risk factors for shoulder pain in swimmers have been identified by experts and supported with evidence in the literature: low posterior shoulder strength-endurance, inconsistent training load, and poor stroke technique. Additionally, twenty-two other risk factors have been proposed by swimming experts, though these have not been investigated adequately in the literature.

Summary Overdevelopment of the anterior shoulder muscles combined with tightness in the pectoralis minor and posterior shoulder capsule, imbalanced scapular stabilizers, and decreased thoracic mobility can lead to fatigue, dysfunctional swim stroke, and shoulder pain. Evaluation should focus on known risk factors and utilize functional movements. Treatment should be interdisciplinary and include relative rest, anti-inflammatories, stretches of the posterior capsule and pectoralis minor, and a progressive exercise program of shoulder and scapular strengthening.

Keywords Swimmer · Shoulder · Rehabilitation · Rotator cuff · Impingement · Scapular dyskinesia

Introduction

Shoulder pain is the most common musculoskeletal complaint in competitive swimmers [1] and appears to be associated with swim-training volume [2]. In one study of 80 young elite swimmers, 91% reported shoulder pain [3]. Women's [4] and Men's [5] collegiate data also reports shoulder injuries as the most common injury reported, with most in both sexes attributed to overuse mechanisms. Swimmer's shoulder is a non-specific term encompassing multiple pathologies that can be the source of pain in a swimming athlete. The term "swimmer's shoulder" was first described in 1974 by Kennedy and Hawkins [6] and was described as a syndrome of painful repeated shoulder impingement in swimmers. Unfortunately, despite being recognized for 50 years, there is a paucity of high-quality research into the pathology and most effective treatments for "swimmer's shoulder." The authors will explore the most up to date research and supplement their clinical input from decades of working with competitive swimmers in this review.

Pathogenesis

The pathogenesis of swimmer's shoulder is usually multifactorial but can be influenced by the number of training hours per week, weekly mileage, and poor technique [2, 3,

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7, 8]. To best understand the underlying technique and biomechanics that might be contributing to the pain, it is first important to get familiar with the different swim strokes and phases. The four competitive strokes include the breaststroke, butterfly, backstroke, and freestyle [9, 10]. Independent of the swimmer's specialty, most of the training takes place in freestyle [6, 9]. The freestyle stroke can be further broken down into six phases consisting of hand entry, forward reach, pull-through, middle pull-through, hand exit, and middle recovery [7, 9] (Figure 1). During hand entry, the shoulder is typically forwardly flexed, adducted, and internally rotated, which is the classic subacromial impingement position and to a lesser extent may also cause subcoracoid impingement [7]. The pull-through and middle pull-through generate the most force and propulsion via the latissimus dorsi and pectoralis major by adducting and internally rotating the shoulder. During these two phases, the humerus reaches its maximum internal rotation which accounts for the majority of pain within the six phases [7, 11, 12].

In symptomatic painful shoulders, an alteration of muscle activity has been demonstrated, likely to minimize the painful positions. Serratus anterior activation is reduced during the middle pull- through, which increases the space between the glenoid and the humerus, leading to instability [1, 7, 13]. The rhomboids typically overcompensate; and by retracting the scapula, increase the clearance beneath the coracoacromial space to minimize impingement, but this can lead to scapular dysfunction by its disruption of normal firing patterns [11–13]. The subscapularis is predisposed to fatigue during freestyle swimming due to its high levels of active engagement throughout the entire stroke cycle, whereas the other rotator cuff muscles demonstrate significant levels of activation only during certain phases of the swim cycle [11–13]. When the subscapularis fatigues, this leaves the infraspinatus to work unopposed and overcompensate during hand exit (middle recovery), also leading to glenohumeral instability [12, 13]. This can sometimes be appreciated by a dropped elbow during the recovery phase [7, 12]. There is maximum humeral external rotation during the middle recovery phase, which is aided by optimal body roll [7]. An insufficient body roll will lead to abnormal tension and stress on the scapula while excessive roll leads to arm crossing during the entry or pull-through [1, 14].

Common Etiologies of Swimmer's Shoulder

Subacromial Impingement

Kennedy and Hawkins [6] originally described this condition as supraspinatus tendon impingement within the coracohumeral arch from repeated shoulder abduction and forward flexion. This action is most prominent during freestyle and butterfly strokes [6, 9]. Morphologically, the acromion type (Bigliani classification) can predispose swimmers to increased subacromial impingement. Bigliani originally described a type 1 acromion as flat, a type 2 as curved, and a type 3 as hooked [15]. Vanarthos later described a fourth convex variation [16]. The impingement can be further exacerbated by altered shoulder kinematics such as fatigue and laxity [9]. Shoulder stability is dependent on static stabilizers (glenoid labrum and capsular ligaments) and dynamic stabilizers (rotator cuff and scapular muscles) [9]. Some laxity can be advantageous by improving stroke length and increasing speed [7, 9, 11]. Due to the biomechanics of swim training, swimmers tend to have disproportionately increased anterior shoulder strength (adductors and internal rotators) and a tight posterior capsule. Overdevelopment of these muscle groups and anterior capsule laxity can lead to joint instability by displacing the humeral head anteriorly [7, 17, 18]. Anterior head displacement will predispose swimmers to impingement. The rotator cuff muscles help depress the humeral head to minimize impingement [9, 18, 19]. Supraspinatus tendinopathy is the leading cause of shoulder pain in swimmers [3, 7]. During the hand entry phase, there is increased contact between the greater tuberosity and the posterosuperior glenoid [7]. Humeral internal rotation prevents the clearance of the greater tuberosity from under the acromion during humeral elevation [9, 18–20]. In addition to the aforementioned soft tissue adaptations, consideration of hyperactivity and adaptive shortening of the triceps at its insertion on the humerus can cause internal rotation and increase the abutment on the undersurface of the AC joint.

Scapular Dyskinesis

With high volume swim training or improper technique, the serratus anterior and subscapularis can become fatigued during the pull-through and middle pull-through phases. This

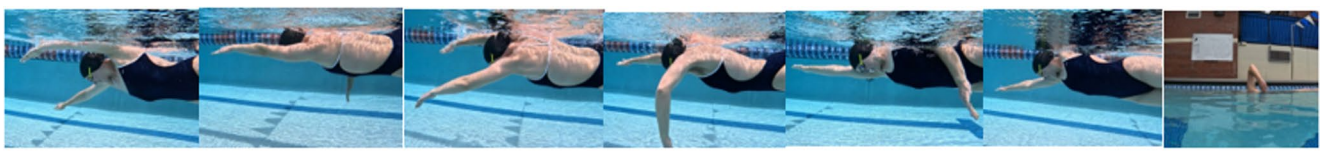

Fig. 1 Phases of the freestyle stroke

will then lead to pectoralis major dominance which can contribute to anterior glenohumeral (GH) joint laxity. An anteriorly tilted scapular position may lead to a shortened pectoralis minor muscle [1, 9, 12, 18, 20, 21]. Scapular protraction and GH laxity increases the stress over the anterior capsule and labrum leading to anterior labral deformities, impingement, and suprascapular nerve entrapment [7, 9, 12, 18]. Scapular dyskinesis can contribute to suprascapular nerve entrapment through traction from abnormal scapular positioning. During completion of the pull-through, scapular winging can impinge the nerve under the suprascapular ligament [7].

Glenohumeral Internal Rotation Deficit (GIRD)

Similar to land based overhead athletes, swimmers tend to develop adaptive features consisting of limited internal rotation and excessive external rotation. The capsule and cuff are tighter posteriorly with a mean internal rotation in competitive swimmers of 12 degrees +/- 6.8 degrees [22]. Swimmers tend to have an additional 10 degrees of external and 40 fewer degrees of internal rotation compared to non-swimmers [23]. Pain will typically manifest after a GIRD greater than 25 degrees [17]. This complicates the ability to center the humeral head within the glenoid fossa leading to excessive anterior humeral head translation, capsular instability, and impingement [7, 9, 12, 17, 22, 24, 25]. GIRD often presents unilaterally which is likely secondary to the increased external rotation required for breathing on the dominant side [7, 22, 26]. Internal impingement is usually from the humeral head contacting the posteroinferior portion of the glenoid [7, 9, 11, 17, 18].

Os Acromiale

This is a rare cause of swimmer's shoulder only affecting about 1–15% of the population. This is caused by an embryological ossication center failure of the acromion [7, 27]. Although uncommon, this should remain on the differential.

Suprascapular Neuropathy

The entrapment of the suprascapular nerve will typically occur over the medial wall of the suprascapular notch at completion of an arm rotation due to scapular dyskinesis, hyperelasticity, or infraspinatus hypercontraction. This can be further exacerbated by a narrowed subacromial space, inflamed bursa, and thickened supraspinatus tendon [7, 9]. A dropped elbow during the pull-through and a reduced body roll may lead to a traction neuropathy [7, 28].

Labral Injury

Labral injury may occur from increased humeral laxity and subluxation from internal rotation and adduction [7]. Swimmers are at an increased susceptibility of labral pathology due to the circular motion and hand position during the dive entry [7].

Clinical Evaluation

History

When evaluating shoulder pain in swimmers, it is essential to consider both the history of previous shoulder injuries and the associated risk factors.

Despite the recognized prevalence of shoulder pain in swimmers, high-quality evidence identifying the key risk factors contributing to this condition remains limited. McKenzie et al. [29] surveyed 27 Swimming experts and juxtaposed systematic review findings for shoulder injury risk factors in competitive swimmers. They found only 3 proposed risk factors (inconsistent training load, poor stroke technique, and low posterior shoulder strength-endurance) with high perceived importance by the experts also had supporting evidence in the literature; and they identified 22 highly important proposed risk factors that had not been adequately studied [29]. Several studies have provided moderate evidence suggesting that factors such as competition level, previous shoulder injury, training errors, training volume, low posterior shoulder strength-endurance, and the acute-to-chronic workload ratio may contribute to shoulder pain in swimmers [1, 26, 29, 30]. Interestingly, swimmers with a history of shoulder pain are 4.1–11.3 times more likely to sustain a future shoulder injury [24, 26]. However, other variables, including swimming experience, stroke distance, stroke specialty, breathing side, and the use of training equipment, have not been consistently identified as predictors of shoulder pain.

Therefore, the first step in assessing shoulder pain in a swimmer is obtaining a comprehensive history with a focus on the known risk factors. Key aspects of the history include understanding the onset of pain, its location, the intensity of symptoms, and any specific swimming strokes in addition to phase of the stroke, activities, or equipment (i.e., off the block entries, pull sets, dryland, and strength training) that exacerbate the pain. It is important to ask the swimmer if they have had any changes to their stroke mechanics or use of new equipment (ex: paddles, drag socks, power towers, parachutes, other). It is also important to assess if they have received coaching feedback about any technique errors and, if possible, speak to the coach about it. In many settings, access to specialized swimming biomechanists and

high-quality underwater video analysis remains limited. However; advancements in wearable technology and imaging tools are increasingly enabling more objective assessment of stroke technique and the identification of modifiable risk factors.

Physical Exam

Despite our advances in sports science, high-quality evidence identifying the key physical exam risk factors contributing to shoulder pain remains limited. Several systematic reviews suggest there is moderate evidence that deficits in posterior shoulder endurance-strength, and low confidence evidence that alterations in scapular kinematics, may contribute to shoulder pain in swimmers [1, 26, 30, 31], making these important assessments to include in the shoulder evaluation. There is conflicting evidence relating to joint laxity and no evidence to suggest shoulder range of motion or rotational shoulder strength contributes to shoulder pain [26].

Ideally, the examination should include the spine and lower extremity given their linkage to swimming mechanics.

Shoulder

An evaluation of the shoulder should include an assessment of range of motion (ROM), joint stability, flexibility, muscle strength, and specific tests designed to isolate the potential cause of pain. Swimmers frequently present with a rounded shoulder posture and asymmetric muscle bulk in the pectoral and latissimus muscle regions. Asymmetries including scapular dyskinesis, limitations in motion, and hypermobility should be documented.

Feijen et al. [31] noted that low posterior shoulder endurance-strength was predictive of shoulder pain (OR, 0.96; 95% CI, 0.92–0.99) such that for every one additional repetition, the risk of shoulder pain decreased by 5%. Posterior shoulder endurance-strength (Figure 2) can be assessed by having the swimmer lay prone on a table with their arm hanging vertically off the side. They then raise their arm to 90 degrees of horizontal abduction with a weight (2% of body weight), repeating until exhaustion. This exercise exhibits high levels of activation of the supraspinatus, infraspinatus, and trapezius muscles of the posterior shoulder. Increased endurance of the posterior shoulder may contribute to the stability of the humeral head in the glenoid, subsequently lessening impingement during prolonged swim training [26].

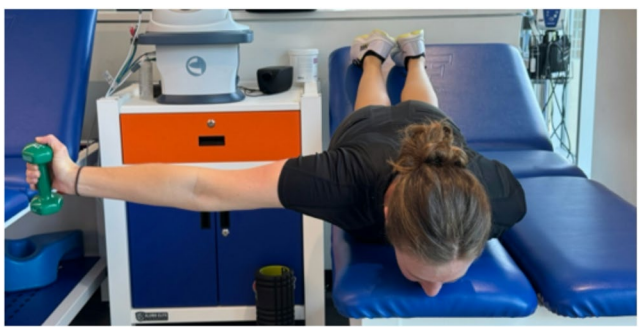

Fig. 2 Posterior shoulder endurance-strength: Lie prone on a table with arm hanging vertically off the side. Raise arm to 90 degrees of horizontal abduction with a weight

Other assessments can include supine latissimus dorsi length measurement, with the clinician stabilizing the scapula against the exam table. Triceps length can be assessed in a similar fashion, this time with the elbow flexed. However, these measurements have moderate evidence against association with injury risk [26]. Supine pectoralis length measurement can also be conducted with the distance from the exam table to the athlete's anterior clavicle, however; this has conflicting evidence of low strength [26].

Finally, several tests shoulder be considered when assessing specific shoulder pathologies. Subacromial / shoulder impingement can be assessed with the Neer Test or Hawkins-Kennedy Test, which would suggest pathology to the rotator cuff or bursa. O'Brien's Test or Modified Labral Sheer Test should be utilized to assess for a labral tear. Shoulder mobility / laxity can be assessed with an Anterior/ Posterior Load-Shift or Sulcus Sign.

Spine

In evaluating swimmers for shoulder pain, it is crucial to assess the integrity of the spine, as spinal imbalances can often contribute to shoulder issues [32, 33]. When assessing the spine, particular attention should be paid to both posture and strength. The clinician may observe poor posture, largely due to the overdevelopment of the chest, arms, and upper back muscles from swimming and underdevelopment of the deeper postural muscles of the hips and trunk. Robust core muscles are crucial for maintaining spinal balance, particularly in butterfly, breaststroke, and during the underwater dolphin kick. Additionally, assessing spinal mobility can help identify restrictions or areas of tightness, especially in the thoracic spine, which can further impact shoulder movement and flexibility.

While performing the physical exam, it is also helpful to observe the relationship between spine and shoulder movement. If the spine is misaligned or restricted, the swimmer may have difficulty achieving full shoulder range of motion, as the shoulders rely on a stable spine to function properly. Proper cervical rotation, in conjunction with sufficient deep cervical flexor endurance, is necessary for proper acromioclavicular joint and scapular kinematics

[34]. The levator scapulae, cervical extensors, flexors, and trapezius all connect the shoulder girdle to the spine and swimmers frequently rotate their neck to breathe, especially in the freestyle stroke. Additionally, the swimmer's thoracic spine should be assessed for mobility, as limited movement in this area can lead to compensation in the shoulders, causing additional overuse and potentially leading to injury. A functional assessment of the spine and shoulder is crucial to developing an effective rehabilitative program.

Functional Movements

When evaluating shoulder pain in a swimmer, it is critical to assess not just the spine but also the swimmer's functional movements. The ability to perform fundamental movements, such as those involving shoulder mobility/stability, core stability, and balance directly impacts shoulder function. By observing these movements, the clinician can assess the swimmer's overall movement patterns and identify any compensations or imbalances that may be contributing to shoulder pain.

One effective approach is to assess the swimmer in the quadruped position. The quadruped position requires the athlete to engage their core and stabilize their trunk while also demanding shoulder stability and mobility [32]. Evaluating the swimmer in this position can highlight any deficiencies in core strength or shoulder control that might be contributing to shoulder discomfort. For example, if the swimmer struggles to maintain a neutral spine or experiences shoulder instability during movement in this position, it may indicate a weak trunk or poor shoulder stabilization, both of which could lead to overuse injuries in the shoulder.

Another key functional movement to assess is jumping, which can be reflective of power during starts and turns [35]. The ability to perform vertical jumps with proper technique relies heavily on the coordination between the core and shoulders. Poor technique, such as excessive forward lean or a lack of shoulder coordination, can create compensations that overload the shoulders, potentially leading to pain or injury. By observing the swimmer's ability to jump effectively and land with control, the clinician can gain insight into their overall movement efficiency, core strength, and shoulder mechanics.

Analysis of both a swimmer's overhead squat and front squat can be used to assess thoracic extension, stabilization of the humerus and scapula, and spinal positioning. The erector spinae act as a thoracic extensor in both squat variations. Adequate thoracic extension during these squats allows the swimmer's scapula to rotate appropriately. During the overhead squat, the scapular stabilizers (middle trapezius, serratus anterior, among others) must activate to maintain dynamic stability of the glenohumeral joint while allowing for controlled mobility in those athletes who tend to have anterior shoulder instability. Protraction of the scapula is necessary during the front squat in order to keep the barbell in its correct placement. Proper spinal alignment during the overhead squat and front squat leads to appropriate positioning throughout the kinetic chain in the neck, shoulders, trunk, and hips [36]. Due to the scapula's position at the thoracic spine and in shoulder stability, good thoracic mobility is important in both the prevention and treatment of shoulder pain.

Incorporating these functional movement assessments—quadruped position, jumping mechanics, overhead squat, and front squat—into the evaluation process allows for a holistic view of the swimmer's movement patterns which can potentially identify deficits and allow targeted interventions to reduce the incidence of injury.

Diagnostic Imaging

Diagnostic imaging should be considered when physical examination findings are inconclusive or there are concerns for a significant injury that may impact training or competition. The selection of specific imaging modalities will depend upon the suspected etiology of the shoulder pain. The most common imaging modalities include radiographs, ultrasound, and magnetic resonance imaging (MRI).

Radiographs (X-rays) Radiographs of the shoulder are typically the first imaging modality when evaluating the shoulder region. They provide a relatively inexpensive, accessible, and quick method to assess bony alignment and integrity.

Ultrasound Ultrasound is a valuable imaging tool for evaluating shoulder pain in the swimmer due to its cost-effectiveness, dynamic evaluation capabilities, and ability to assess soft tissue structures in real-time. Unlike radiographs, which primarily focus on bony structures, ultrasound allows for visualization of tendons, muscles, and bursae; making it particularly useful in diagnosing conditions such as rotator cuff injuries, subacromial bursitis, and biceps tenosynovitis. It does not visualize the labrum well. One of the key benefits of ultrasound is its dynamic evaluation, which enables the clinician to observe the shoulder in motion, assessing for shoulder impingement. Ultrasound can be utilized as part of the in-office clinical examination, allowing for real-time diagnosis and can also be useful in treatments involving guided injections.

MRI MRI plays a crucial role in evaluating shoulder pain in swimmers by providing detailed high-resolution images of both soft tissue and osseous structures, which is essential for diagnosing complex injuries (i.e., rotator cuff tears,

labral tears). MR Arthrogram of the Shoulder or 3T MRI will allow visualization of the labrum and should be the primary modality when evaluating for a tear of the labrum. The primary limitations of MRI are its higher cost compared to other modalities, such as radiographs or ultrasound, and its relatively limited accessibility in certain clinical settings.

Management

It is important to address all the contributing factors of shoulder pain in the swimmer, which is often multifactorial. Weekly swim volume, training hours, and years of competitive swimming have been associated with supraspinatus tendon thickening, which has been linked to shoulder pain [2, 3]; thus it is important to decrease swim volume and time spent training in the initial stage of management. It is common to have an athlete substitute kicking for swimming to decrease the repetitive shoulder rotations but still spend time training. Using a kickboard places the shoulders in a constant impingement position, so kicking without a board, starting with hands at sides and progressing to board-free streamlined overhead position, may be necessary. Any possible technique contributors to the pain should be addressed with coaching staff and corrected. If the athlete has been using paddles or other equipment increasing the load on the shoulder, this is discontinued. When pain is improved and the athlete is returning to full swimming training, a gradual and progressive load to the shoulder is imperitive to prevent recurrent pain. This can be accomplished by utilizing increased drill work and also using equipment which might offload shoulder stress (fins).

A scoping review found that an exercise program of 6–8 weeks; which included shoulder strengthening exercises of the scapular retractors and external rotators, in addition to pectoralis minor stretching; decreased the incidence of swimmers with shoulder pain [37]. The same review further found that the addition of manual therapy techniques; such as myofascial release, joint mobilizations of the glenohumeral, cervical and thoracic spines, and neuromuscular stimulation, to a shoulder strengthening and stretching program can decrease shoulder pain in injured swimmers [37].

It is encouraged that some form of isometric shoulder activity is included in all swimmers' post training weekly routine [38]. Eccentricly-loaded rotator cuff exercises specific to the irritated tendon should be included in the acute and subacute phases [39].

Tavares et al. recommends that the frequency of therapeutic strengthening exercises should be 2–3 times/week and include progression over 6 weeks [40]. Stretching the posterior capsule (sleeper stretch) and pectoralis minor stretches are very important for swimmers in preventing and treating impingement [7]. Strengthening exercises of the scapular stabilizers and external rotators are critical to balance the overdevelopment of the anterior shoulder musculature and include exercises such as the push-up with a plus (to engage the serratus anterior), horizontal rows with a band, and the scapular Y and T exercises [7]. Specific strengthening exercises favored by our authors include shoulder taps (Figure 3), scapular push-ups (Figure 4), side-lying weighted external rotatation (Figure 5), and serratus anterior wall slides (Figure 6).

Fig. 3 Shoulder Taps: In plank position, lift right palm and tap left shoulder and hold for a beat. Repeat with opposite side.

Fig. 4 Scapular Push-Ups: In a push-up position, focus on squeezing and releasing the scapulae, not bending the elbows

In the initial phase of pain, treating acute inflammation with a 1–2 week course of NSAIDs can help prevent worsening, and decrease pain to allow for a more effective rehabilitation program. If the cause of pain is determined to be a subacromial bursitis or impingement, a subacromial or glenohumeral corticosteroid injection may be used but there is currently no evidence for the effectiveness of corticosteroid injections over oral NSAIDs in shoulder pain due to rotator cuff tendonitis [41–44]. To our knowledge, no studies have examined image-guided injections in this context. Rest is

Fig. 5 Side-Lying Weighted External Rotation: Lie on side with one hand supporting the head and the other holding a dumbbell, keeping your elbow bent at 90 degrees against the torso. Abduct the arm holding the dumbbell to maximum external rotation without rotating body and keeping elbow close to torso. Pause and return to initial position

also important but can be difficult to implement, especially depending on the timing within the competitive season. At minimum, decreasing swim-pull yardage is important.

Surgical treatment of swimmer's shoulder should almost always only be considered after all other conservative measures have failed. The return to pre-injury level of competition has the best prognosis if glenohumeral instability is the primary pathology [8]. The return rates to pre-injury level after arthroscopic debridement of labral tears or bursectomy are low with only up to 56% return to pre-injury level after arthroscopy for therapy-resistent shoulder pain in one study of eighteen competitive swimmers [45].

Gaps in Knowledge/Future Directions

This review highlights the significant gap in high-quality research investigating shoulder injury risk factors in competitive swimmers [26]. While studies suggest that deficits in posterior shoulder endurance-strength may contribute to shoulder injury, there are conflicting findings regarding other factors, such as the external rotation: internal rotation strength ratio and scapular stability, across different levels of swimmers. Glenohumeral laxity has been shown to correlate with shoulder pain but not with the level of competition or training hours, indicating that laxity is likely a contributing factor to pain, though not the sole determinant of injury risk [3]. Core endurance also appears to play a role in shoulder pain [20], though studies examining focused treatments to prevent shoulder injury are limited.

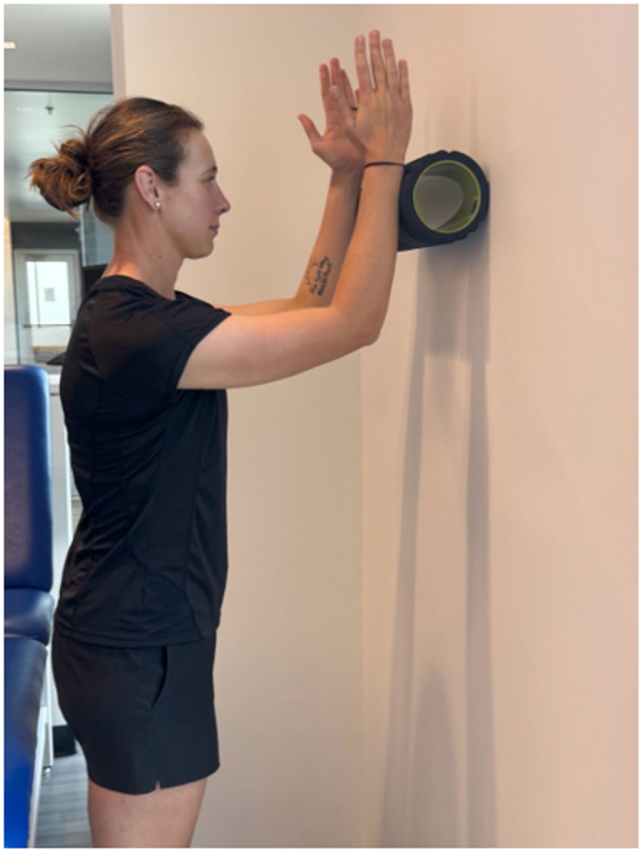

Fig. 6 Serratus Anterior Wall Slides: Stand facing wall with feet shoulder width apart. Place forearms directly on the wall at shoulder height, or onto foam roller at shoulder height, with thumbs facing you. Protract shoulder blades (press forearms into wall/roller and push upper back away from wall) and maintaining this protraction, slowly slide arms up as far as possible with shoulder blades protracted, then return to starting position

Moving forward, it is essential for prospective studies to identify and regularly monitor modifiable intrinsic and extrinsic risk factors that may contribute to shoulder injury. Research on injury prevention and treatment should continue to focus on muscle imbalances, joint laxity, core strength, and training load variations throughout a swimmer's season at all levels of experience. Adopting a standardized classification system for shoulder injury in swimmers will improve inter-study consistency and facilitate meta-analyses. Additionally, emerging technologies, such as wearable devices like inertial measurement units (IMUs) [19], can provide valuable insights into training loads, while psychological factors like sleep quality and perceived exertion (RPE) should be further explored for their potential role in performance and injury risk. By addressing these gaps, future research will be better positioned to develop more effective injury prevention strategies and improve swimmer care.

Conclusion

Swimmer's shoulder is a complex condition encompassing multiple pathologies with a very high prevalence causing disability in competitive swimmers. More high-quality research is needed investigating the risk factors and effectiveness of treatment options. An imbalance of posterior shoulder strength-endurance to anterior shoulder strength and laxity, training errors, and large training load variations have evidence of their contribution to shoulder pain in swimmers and should be evaluated and appropriately addressed in the treatment. A period of at least relative rest is important. An exercise program of 6–8 weeks focusing on strengthening of the scapular stabilizers and external rotators, along with posterior capusule stretching and pectoralis minor stretching has found to be effective in decreasing shoulder pain.

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  This review discusses in depth the role of the trunk and spine in the kinetic chain in swimming.

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  This study identified evidence levels for proposed risk factors for shoulder pain in swimmers, identifying areas that had supporting evidence, those that had evidence which showed no association with injury, and the majority of proposed risk factors which have not been investigated yet and deserve study.

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  This review demonstrated that a shoulder strenthening and stretching exercise program can decrease shoulder pain in swimmers.

Author Contributions Author Qualifications: Conception and design: KME, JO, CG, BKAnalysis and interpretation of data: KME, JO, CG, BKDrafting/Revising manuscript for important intellectual content: KME, JO, CG, KR, BKFinal approval of submitted manuscript: KME, JO, CG, KR, BK.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Ethical Approval The authors declare no conflicts of interest.

Competing interests The authors declare no competing interests.

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