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Human Kinetics
SCOPING REVIEW

The Effect of Exercise Therapy Interventions on Shoulder Pain and Musculoskeletal Risk Factors for Shoulder Pain in Competitive Swimmers: A Scoping Review

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Context: Shoulder pain is the main cause of missed or modified training in competitive swimmers. Exercise therapy can improve the outcomes, yet uncertainty exists regarding the characteristics of these interventions. ***Objectives:*** The primary aim was to describe the evidence base relating to the effectiveness of exercise therapy interventions on shoulder pain and shoulder musculoskeletal risk factors for shoulder pain in swimmers. The secondary aim was to identify gaps in the literature and provide recommendations for future research and practice. ***Evidence Acquisition:*** A scoping review methodology was applied through the search of MEDLINE, PubMed, Scopus, Web of Science, and CINAHL databases. The authors included any research studies (except clinical commentaries and conference papers) that assess the effect of exercise therapy on shoulder pain and musculoskeletal risk factors for shoulder pain in swimmers. The literature was critically appraised using the Modified Down and Black checklist. ***Evidence Synthesis:*** From 452 papers identified, 14 studies were included in this review. An exercise program of 6 to 8 weeks, including strengthening exercises (shoulder external rotator and scapula retractor muscles) and stretches (pectoral muscles), can decrease the incidence of shoulder pain in swimmers. Furthermore, a combination of exercises and stretches with manual therapy techniques can help to decrease shoulder pain in injured swimmers. Regarding risk factors, a strengthening program of more than 12 weeks increased shoulder external rotation peak force, endurance, and external rotation/internal rotation ratio; however, this was not associated to decreases in pain. Finally, open kinetic chain exercises and a dry-land program are superior to close kinetic exercises and water training for improving shoulder external rotation strength and endurance. ***Conclusions:*** Exercise therapy has positive effects on reducing the incidence of shoulder pain, the management of shoulder pain, and improving shoulder musculoskeletal risk factors in competitive swimmers. However, due to methodological limitations of the studies, caution must be used when applying these results in practice. Future research should focus on high-quality randomized controlled trials for prevention and management of shoulder pain in swimmers.

Keywords: swimming, shoulder injury, therapeutic exercises, injury prevention

Context

The shoulder is the most commonly injured joint in competitive swimmers and the main cause of missed or modified training.[1,2] The prevalence and incidence of shoulder pain in swimmers are high ranging between 23% and 91%[3–6] and 30% and 47%,[1,7–9] respectively. Importantly, the latest research has not shown a decline in prevalence[3,6] or incidence.[7,8]

Sports injuries are multifactorial, including the interaction between intrinsic (ie, athlete related) and extrinsic (ie, environmental) risk factors.[10,11] Regarding intrinsic factors, several modifiable (eg, training related, musculoskeletal physical qualities, etc) and nonmodifiable risk factors (level of competition, history of shoulder pain, etc) have been reported as potential contributors to shoulder pain in swimmers.[12,13] Modifiable risk factors have received much interest in the athletic population as they might help to identify athletes at risk of injury.[14] Importantly, they can also be changed through therapeutic interventions.[15,16] Within modifiable risk factors, shoulder musculoskeletal qualities have been extensively studied in swimmers. Studies have shown that alterations in shoulder range of motion,[9,17–19] flexibility,[19,20] strength,[8,19,21,22] endurance,[7,23,24] and scapula kinematics[25,26] are associated with shoulder pain.

Several reviews and clinical commentaries in swimmers suggest including some of these musculoskeletal factors in interventions to reduce the risk or manage shoulder pain.[2,27–33] These studies recommend incorporating shoulder stretches and strengthening exercises (targeting scapular, rotator cuff, and core muscles) to the interventions. Despite the number of studies, no one has yet systematically analyzed and summarized the evidence regarding the effects of exercise therapy on shoulder pain in swimmers. Furthermore, the effects of exercise therapy on musculoskeletal risk factors associated with shoulder pain have not been reviewed either.

It might prove that, this limited knowledge might explain why the incidence and prevalence of shoulder pain remain high, because of the lack of clarity around appropriate rehabilitation interventions. A comprehensive review of the literature could reveal the research's strengths and flaws, the quality of the evidence, and the exercise therapy interventions used (dosage, exercise progression, etc). This information can help practitioners working with swimmers to choose the most appropriate treatment to reduce the risk and manage shoulder pain. The primary aim of this review was to identify and describe the evidence base relating to the effectiveness of exercise therapy interventions on shoulder pain and shoulder musculoskeletal risk factors for shoulder pain in swimmers. The secondary aim was to identify gaps in the literature and provide

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recommendations for future research and practice. Our review question was: *What evidence is there on the benefits of exercise therapy interventions on shoulder pain and shoulder musculoskeletal risk factors for shoulder pain in competitive swimmers?*

Methods

Design

Scoping reviews examine the extent, variety, and nature of a topic, summarize the findings of a heterogeneous body of knowledge, and identify gaps in the literature to help the planning of future research.[34] In contrast, systematic reviews focus on answering a particular question.[35] Due to the broad research question and diverse evidence, a scoping review methodology was selected. The 5-stage scoping review process proposed by Arksey and O'Malley[36] with the subsequent adaptations by Levac et al[37] were used. This includes (1) identifying the research question, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing, and reporting the results. The extension for scoping reviews of the Preferred Reporting Items for Systematic Reviews and Meta-analysis checklist was followed to provide methodological transparency.[34]

Search and Selection of the Studies

MEDLINE, PubMed, Scopus, Web of Science, and CINAHL databases were searched using a combination of the following terms: competitive swimmers (swimming [Mesh] OR water sports [Mesh] OR swim), AND shoulder pain (shoulder injuries [Mesh] OR shoulder function OR painful shoulder), AND exercise therapy (exercise [Mesh] OR rehabilitation [Mesh] OR motion therapy [Mesh] OR resistance training [Mesh] OR therapeutic exercise [Mesh] OR physical therapy modalities [Mesh] OR muscle stretching exercises [Mesh]). The search was performed from earliest available to August 2021, and no limits were used for age and level of competition as a means to include a wider range of studies. The search of the literature was performed independently by 2 researchers (M.Y. and a nonauthor).

The definition of injury or pain was based on The International Olympic Committee consensus statement in injury and illness in sport.[38] It was defined as shoulder pain or injury that results in medical attention, time loss, or modification of training and competition (self-reported, symptom based, or performance based).[38] Exercise therapy was defined as "a regimen or plan of physical activities designed and prescribed for specific therapeutic goals, with the purpose to restore normal musculoskeletal function or to reduce pain caused by diseases or injuries."[39]

The eligibility criteria of the studies were based on the PICOS acronym (population, intervention, comparison, outcome, and study design). The studies needed to meet the following criteria: (1) competitive swimmers' population, (2) exercise therapy interventions, (3) outcome measures including shoulder pain and/or shoulder musculoskeletal risk factors, and (4) any study design were considered, except for conference papers and clinical commentaries. Other inclusion criteria included articles available in full text and published in English. Exclusion criteria included studies conducted on synchronized swimmers, water polo players, and triathletes. Studies investigating a specific shoulder diagnosis (eg, postoperative management, painful os acromiale, etc) or performing an intervention other than exercise therapy (eg, corticoid injections) were also excluded. Both M.Y. and L.H. screened the articles for eligibility independently, with T.A.M. acting as arbitrator for any disagreements.

Charting, Collating, and Summarizing Data

Data related to characteristics of the population and study design, exercise intervention protocol (duration, exercises, dosage, and progressions), and measures of shoulder pain or musculoskeletal risk factors were extracted from the included studies. When reporting the findings, *P* values, effect sizes, and confidence intervals were included as appropriate; one member of the project team (M.Y.) extracted all the data. Tables were used to organize and synthesize the data. Following the data extraction, a narrative synthesis of the studies was performed to describe the evidence available and identify the gaps in the current literature.

Quality Assessment

Although optional in scoping reviews, a critical appraisal of the literature was performed to analyze the quality of the evidence in order to help and guide future research. A risk of bias assessment was separately performed by 2 researchers (M.Y. and a nonauthor) using the Modified Down and Black checklist for both randomized controlled trial (RCT) and non-RCT.[40] Any disagreements were discussed and solved by the 2 researchers. If disagreements persisted, a third person (L.H.) was consulted. The Modified Down and Black tool[40] consists of a 27-item scale (maximum score of 28) assessing overall study quality, external validity, internal validity, and power of the study. Studies were categorized as high quality/low risk of bias (≥20), moderate quality/moderate risk of bias (17–19), and low quality/high risk of bias (≤17).[41] Case reports were not included in the risk of bias assessment.

Evidence Synthesis

Studies and Population Characteristics

Electronic databases and manual searches returned a total of 452 articles. Screening excluded 432 articles, because they were duplicates or did not meet the inclusion criteria. Finally, data were extracted from 14 studies (see Figure 1). A total of 354 swimmers from 11 to 24 years were included. The studies included 9 RCT, 2 interventional nonrandomized cohort studies, and 3 case reports (see Table 1).

Outcome Measures

Shoulder pain was reported as an outcome measure in 6 out of 14 studies.[16,43–47] Studies defined shoulder pain as pain that interfered with training and competition,[43] or using the visual analog pain scale,[16,44,46] the numerical pain rating scale,[47] the American Shoulder and Elbow Surgeons Assessment,[45] and the Quick Dash Questionnaire.[47]

Regarding shoulder risk factors, most studies assessed shoulder strength. Shoulder rotator and scapular protractor/retractor muscles were the most common muscle groups studied. They were measured using isokinetic,[15,43,49,53,54] hand-held dynamometer,[16,45,47,50,52] or manual testing.[44,46] Shoulder flexibility was assessed by 7 studies and was obtained by forward shoulder position,[45,48,51] pectoralis minor length,[52] and shoulder range of motion.[44,46,47,52]

Exercise Intervention Protocols

The exercise programs lasted between 2[51] and 16 weeks,[15] with 3 sessions per week being the most common frequency.

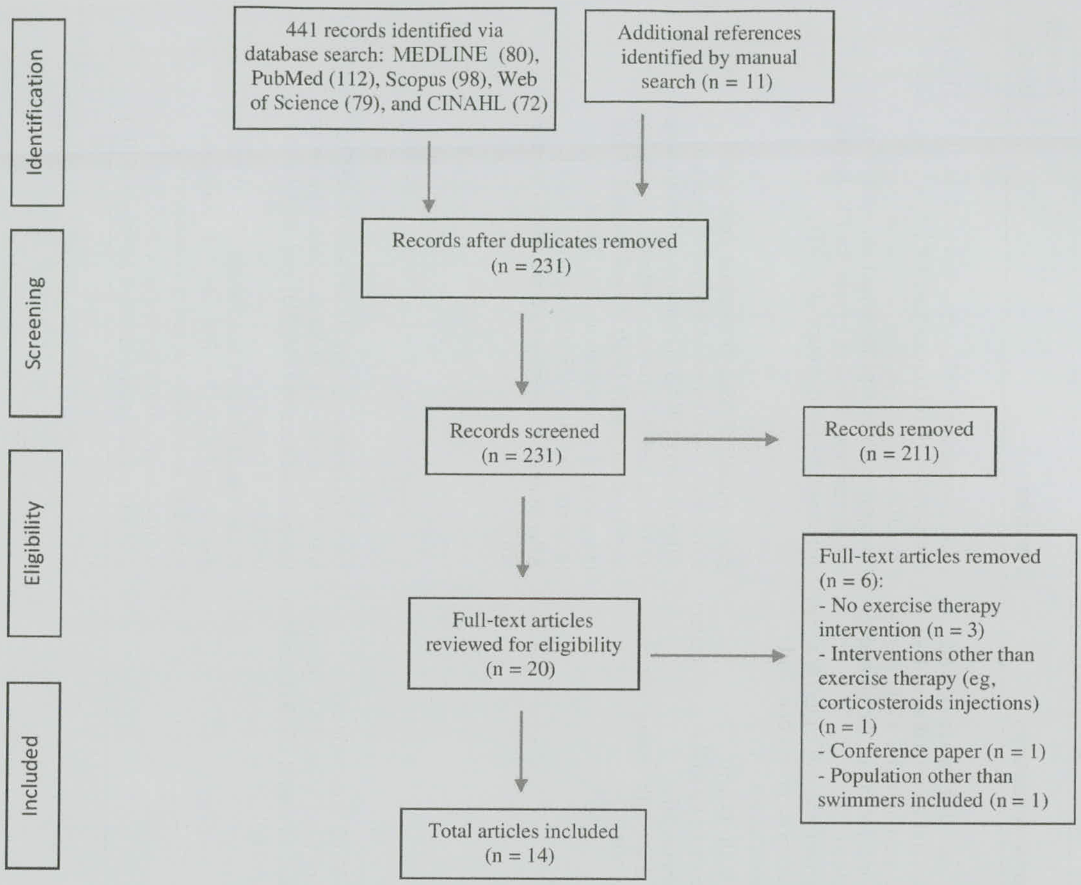

Figure 1 — Preferred reporting items for systematic reviews and meta-analysis flow diagram[42] of study selection and inclusion process.

Strengthening exercises, stretches, and manual treatment techniques were among the interventions.

With the exception of Laudner et al,[51] all studies incorporated strengthening exercises in the intervention. Although different exercises were used to target different muscle groups, shoulder external rotators and scapular retractors were prioritized. The progression of the exercises was performed by increasing the elastic band resistance, weight, or the number of repetitions. The criteria for progression was based on perceived difficulty,[15,16,43,53] time (eg, weeks),[47–49,53] examiners,[50,52] levels of pain,[46] or it was not reported.[44,45,54] All studies included open kinetic exercises in their programs, while 5 combined open and closed kinetic chain exercises.[43,46,49,52,54]

Studies using stretches as a therapeutic approach targeted anterior shoulder muscles (eg, pectoralis minor and major) to decrease FSP[45,48,51] or used a combination of anterior and posterior shoulder muscle stretches.[44,47,50,52] However, the applied technique and dose varied across studies: self-stretching (10×5 s),[45] self-stretching (2×30 s),[50] self-stretching (3×30 s),[52] peer-assisted (2×30 s),[48] muscle energy techniques (4×5 s),[51] or was not reported.[44,47]

Regarding manual therapy techniques, 3 case reports[44,46,47] included interventions along with strengthening exercises and stretches. These techniques included myofascial release, joint manipulations (thoracic spine and ribs), joint mobilizations (glenohumeral, cervical and thoracic spine), nerve mobilizations, neuromuscular electrical stimulation, and taping.

Exercise Protocol Effects on Shoulder Pain

The results showed that studies investigated the effects of exercise therapy to (1) reduce the risk of developing shoulder pain (ie, injury prevention) and (2) manage shoulder pain in injured swimmers (ie, treatment).

Regarding the prevention of shoulder pain, 2 out of 3 studies reported less incidence of shoulder pain in swimmers performing an exercise intervention compared to swimmers who did not.[43,45] Swanik et al[43] found a lower incidence of shoulder pain that interfered with training in the intervention group (IG) compared with the control group (CG) ($P = .02$) after a 6-week strengthening program. Similarly, Lynch et al[45] reported that the IG had less shoulder pain than the CG after 8 weeks of strengthening exercises and stretches. Although a difference in the total score of the American Shoulder and Elbow Surgeons Assessment was not found, a difference in the pain subsection of the questionnaire was reported. Using a minimal clinical important difference (MCID) of 2 points, the researchers found that 79% of the subjects in IG decreased 2 points (>MCID), whereas 50% in CG increased 2 points. On the contrary, a more recent study reported no between-group differences in shoulder pain measured by the numeric rating scale after a similar intervention program.[16] The different pain definitions might explain the inconsistencies in the results.

For the management of shoulder pain in injured swimmers, 3 case reports were included. Leao Almeida et al[46] found that a combination of strengthening, stretching, soft tissue management, manual therapy, and neural tissue techniques decreased shoulder

Table 1 Description of Included Studies: Exercise Therapy Intervention on Shoulder Pain and/or Musculoskeletal Risk Factors for Shoulder Pain in Swimmers

Study	Population and study design	Interventions	Outcome measures	Results	Risk of bias
Studies including shoulder pain and risk factors as an outcome measure					
Swanik et al[43]	Competitive swimmers IG: N = 13 (range = 18–22 y old) CG: N = 13 (range = 18–22 y old), 13 F:13 M Design: RCT	Period: 6 wk, 3 times a week *Strengthening*: 3 × 10 rep with resistance tubing and weights. Progression increasing loads when completing repetitions with ease. Exercises: shoulder flexion, extension, IR 90°, ER 90°, diagonal pattern (D2), prone exercises at 120° and 90° abduction, and push-up plus	Pain: "pain that interferes with practice and presented as a dull aching pain at night, while swimming or a feeling of the shoulder being tired" Isokinetic force and endurance: ER, IR, retraction, protraction, and diagonal pattern	Pain: >incidence in CG (episodes = 4.6 [4.7]) compared with IG (episodes = 1.8 [2.1]) ($P = .02$) Strength: both groups increased strength in all muscle groups ($P < .01$), except for ER. But no difference between groups ($P > .05$)	High (12/28)
Kurtz[44]	Competitive swimmer with left anterior shoulder pain N = 1 (20 y old) Gender = male Design: case report	Period: 4 wk, 3 times a week (first 2 wk), and 2 times a week (last 2 wk) *Myofascial release*: upper trapezius, pectoralis major and minor, and subscapularis muscles *Joint manipulation*: C7–T1, T4–T6, and left first and second ribs *Strengthening*: 3 × 12–15 rep with weights. Progression NR Exercises: Prone horizontal abduction (Y, T, and I) on a Swiss ball. Sitting rowing 0° shoulder ABD *Stretches*: Dosage NR. Posterior capsule and upper trapezius, pectoral major and minor, and subscapularis muscles	Pain: VAS (0–10) Active shoulder ROM (goniometer): movements NR Manual strength testing: muscle groups NR	Pain: initially VAS 5–6 constant during last 6 mo and 7–8/10 toward the end of practice. After treatment, VAS 0/10 at rest and swimming up to 1 h and 2–3/10 after swimming >1 h ROM: initially only IR ROM was limited. After treatment, it was within normal limits Strength initially +4/5 subscapularis muscle. After treatment was pain free and within normal limits	NA
Lynch et al[45]	Competitive swimmers IG: N = 14 (19.29 [1.2] y old) CG: N = 14 (19.29 [1.2] y old) Gender = NR Design: RCT	Period: 8 wk, 3 times a week *Strengthening*: 3 × 10 rep with an elastic band Progression NR Exercises: prone horizontal abduction (Ys to Ws, Ls to Ys) Swiss ball *Stretching*: pectoralis minor (1 × 5 s) and chin tucks	Pain: ASES questionnaire Forward head angle, FSP, scapular distance, isometric LT, MT, and SA force (HHD)	Pain: No between-group differences in ASSES. But 79% of subjects in IG decrease 2 points in the pain subsection (>MCID) and 50% in CG increase 2 points IG decreased forward head angle ($P = .005$; $d = 1.2$) and FSP ($P = .001$; $d = 1.4$) compared with CG strength: both groups increased strength in all muscle groups ($P < .005$; $d = 1.2$–2.4), but no difference between groups ($P > .05$)	High (16/28)

(continued)

Table 1 (continued)

Study	Population and study design	Interventions	Outcome measures	Results	Risk of bias
Leão Almeida et al[46]	Competitive swimmer with left anterior shoulder pain N = 1 (10 y old) Gender = female Design: case report	Period: 8 wk, 3 times a week The program was divided into 4 stages. Progression of the stage according to pain and ROM *Manual therapy techniques*: 3 × 30 s grade II anterior, posterior, and inferior mobilization of the glenohumeral joint and C5–C6–C7 3 × 1 min mobilization T2–T5 and neural mobilizations *Strengthening*: repetitions depend on the exercise and rehabilitation phase. The patient started with isometric exercises and progressed to isotonic and plyometric exercises. Pain-free exercise for progression Exercises: varied exercises including OKC and CKC in different shoulder elevations. Exercises targeting scapulothoracic, glenohumeral, and core muscles (shoulder IR and ER, push-ups, planks, rhythmic stabilization, etc)	Pain: Dash questionnaire and VAS (0–10) Active shoulder ROM (goniometer) for flexion, extension, abduction, and rotations with 90° of ABD Manual shoulder strength flexion, extension, abduction, adduction, and rotations	Pain: dash score decreased from 26.6 to 5 points. The Dash sport module decreased from 68.75 to 6.25 points. VAS decreased from 9.5/10 to 0/10 ROM: initially full but pain at the end range of each movement. Pain free after treatment Strength: initially 4/5 for flexion, extension, abduction, and ER. Normal after treatment	NA
Manske et al[16]	Competitive swimmers IG: N = 11 (11.20 [2.44] y old) CG: N = 10 (11.31 [2.24] y old) Gender = NR Design: RCT	Period: 12 wk, 3 times a week *Strengthening*: 3 × 15 rep with resistance bands. Progression changing band color when difficulty >6/10 Exercises: standing shoulder flexion, extension, IR, ER, and abduction	Pain: VAS (0–10) Isometric force (HHD) of shoulder flexion, abduction, ER, IR, and extension ER:IR ratios	Pain: no difference between groups Strength: IG increased ER force in the dominant side compared with CG (mean difference = 0.73 kg; 95% CI, 0.174–1.292; $P = .013$)	Moderate (18/28)
Smith et al[47]	Competitive swimmer with right superior shoulder pain N = 1 (15 y old) Gender = male Design: case report	Period: 8 wk, 2 times a week Program and swim training was progressed according to pain. *Manual therapy techniques*: dosage NR. Soft tissue techniques, joint mobilizations to target tight tissues (pectorals, latissimus, and posterior shoulder) or ROM deficits *Neuromuscular electrical stimulation:* Mid and low trapezius stimulation while doing exercises. *Taping*: Scapula reposition taping. *Stretches*: Dosage NR. Pectorals, latissimus dorsi, and posterior shoulder *Strengthening*: Resistance bands and cables. Repetitions NR. Progressions according to pain and time in weeks Exercises: shoulder rotations in neutral 45°, and 90° ABD, prone Ts and Ys, freestyle and breaststroke simulation exercises with bands and cables, and rhythmic stabilization drills	Pain: NPRS (0–10) and quick dash Active shoulder ROM (measurement instrument NR) for flexion and abduction. Passive shoulder ROM for flexion, abduction, and rotations Isometric force (HHD) for flexion 90°, abduction neutral, rotations, middle trapezius, lower trapezius, and PSET	Pain: quick dash score decreased from 29.5 to 0 points. The NPRS decreased from 4/10 at evaluation and 8/10, while swimming to 0/10 and 0/10, respectively ROM: symmetric and pain-free ROM of all movements after the intervention Force: pain-free force of all muscle groups after the intervention	NA

(continued)

Table 1 (continued)

Study	Population and study design	Interventions	Outcome measures	Results	Risk of bias
Studies only including risk factors as outcome measures					
Kluemper et al[48]	Competitive swimmers IG: N = 24 (16 [2.0] y old), 14 F:10 M CG: N = 15 (16 [2.0] y old), 11 F:4 M Design: RCT	Period: 6 wk, 3 times a week *Strengthening*: Elastic band: week 1 (3 × 10 rep), week 2 (3 × 15 rep), week 3 (3 × 20 rep) increase band resistance, week 4 (3 × 10 rep), week 5 (3 × 15 rep), and week 5 (3 × 20 rep) Exercises: standing scapular retraction at 90° ABD, standing ER at 90° ABD, and forward flexion in standing *Stretching:* peer-assisted pectoralis minor and major stretch (2 × 30 s hold)	FSP	IG decreased FSP compared with the CG (–9.6 [7.3] vs –2.0 [6.9] mm; $P < .01$)	Moderate (17/28)
Van de Velde et al[49]	Competitive swimmers N = 9 strength training group N = 9 endurance training group Age = 14.7 (1.3) y old, 11 F:7 M Design: interventional nonrandomized cohort	Period: 12 wk, 3 times a week *Strengthening*: 3 × 10 rep (strengthening group); 3 × 20 rep (endurance group), Examiner re-evaluates weights and band resistance after 6 wk for progression Exercises: dynamic hug variation, elbow push-up, side-lying ER 0°, bilateral prone horizontal abduction with 90° elbow flexion, and shoulder abduction	Isokinetic protraction–retraction peak force and endurance	Both groups increased protraction ($P < .05$) and retraction ($P < .01$) peak force but not endurance No difference in peak force and endurance between groups	High (16/27)
Hibberd et al[50]	Competitive swimmers IG: N = 20 (19.0 [1.2] y old), 10 F:10 M CG: N = 17 (19.4 [1.2] y old) 8:9 Design: RCT	Period: 6 wk, 3 times a week *Strengthening*: 2 × 15 rep with resistance tubing, Progression changing resistance assessed by examiners Exercises: Shoulder flexion, extension, IR 90°, ER 90°, throwing acceleration, throwing deceleration, low rows, scapular punches, Ys, Ts, and Ws *Stretches*: 2 × 30 s. Sleeper stretch and corner stretch	Isometric force (HHD): shoulder flexors, extensors, adductors, abductors, ER, IR, retraction, and retraction with upward and downward rotation	Shoulder extension and IR increased in both groups ($P < .005$). No significant differences between groups in strength	Low (20/28)
Batalha et al[15]	Competitive swimmers IG (exercise protocol): N = 20 (14.65 [0.49] y old) TG (only aquatic training): N = 20 (14.45 [0.51] y old) CG: N = 16 (14.69 [0.48] y old) Gender: males Design: RCT	Period: 16 wk, 3 times a week *Strengthening*: 2 sets of 20 reps and last set with an elastic band until fatigue (red band initially), changing band resistance when 30 reps achieved in the final set Exercises: standing abduction in ER below 90° and above 90°, and shoulder flexion above 90°	Isokinetic shoulder rotators peak force and endurance	IG increased ER force (dominant side: $P = .008$; $\eta_p^2 = .117$ nondominant side: $P = .015$; $\eta_p^2 = .247$) and ER/IR peak force ratio (dominant side: $P = .001$; $\eta_p^2 = .271$; nondominant side: $P = .036$; $\eta_p^2 = .222$) compared with TG. The IG increased ER endurance ($P = .007$; $\eta_p^2 = .116$) and ER/IR endurance ratio ($P = .020$; $\eta_p^2 = .235$) of the dominant side compared with TG	Low (20/28)

(continued)

Table 1 (continued)

Study	Population and study design	Interventions	Outcome measures	Results	Risk of bias
Laudner et al[51]	Competitive swimmers IG: N = 20 (19.6 [1.2] y old) CG: N = 20 (19.6 [2] y old) Gender: female Design: RCT	Period: 2 wk, 2 times per week *MET*: arm positioned in end range of horizontal abduction. Four cycles of 5 s of shoulder isometric adduction	Scapular upward rotation, PML, and FSP	IG increased PML (change = 0.9 [0.5] cm; $P = .01$: $d = 1.6$) and decreased forward scapular position (change = −1.5 [1.1] cm; $P = .01$: $d = 1.07$) but no changes were reported in the CG	Moderate (18/28)
Sawdon-Bea and Benson[52]	Competitive swimmers IG: N = 16 (15.0 y old) CG: N = 16 (15.0 y old), 16 F:16 M Design: RCT	Period: 6 wk, 3 times a week *Strengthening*: 3 × 30 s with resistance bands, progression increasing the resistance of the band approved by examiners or researchers Exercises: shoulder, ER 0° of ABD, squat with scaption, ER with trunk rotation in the 4-point kneeling position, serratus punch in supine, diagonal pulls, and planks *Stretches*: 3 × 30 s. Sleeper stretch and pectoralis minor stretch	Isometric force (HHD): lower trapezius, serratus anterior, latissimus dorsi, ER, and IR Pectoralis minor muscle length Posterior shoulder tightness (horizontal adduction ROM) Core strength (McGill Trunk Flexor Test)	No significant difference between groups in shoulder strength and flexibility The IG increased core strength compared with the CG ($P < .001$)	Moderate (19/28)
Batalha et al[53]	Competitive swimmers LG: N = 13 (13.52 [0.92] y old) WG: N = 12 (13.28 [0.96] y old) Gender: males Design: interventional nonrandomized cohort	Period: 10 wk, 3 times per week *Strengthening*: LG: 2 sets of 20 rep and last set with an elastic band until fatigue (red band initially), changing band resistance when achieved 30 reps in the final set Exercises: standing abduction in ER until 50°–60° and 160°, and shoulder ER 90° WG: progression every 2 wk: weeks 1–3 × 30 s; weeks 3–4 × 30 s; weeks 5–3 × 45 s; weeks 7–4 × 45 s; weeks 9–5 × 30 s Exercises: ER 0° with a band, paddles, and without implements	Isokinetic shoulder rotators peak force and endurance	WG increased bilateral IR peak torque and endurance for dominant ($P = .028–.023$; $\eta_p^2 = .157 - .147$) and nondominant side ($P = .013–.036$; $\eta_p^2 = .221 - .167$) compared with LG LG increased ER endurance ($P = .150$; $\eta_p^2 = .039$) and ER/IR endurance ratio ($P = .007$; $\eta_p^2 = .222$) in dominant side compared with the WG	Moderate (19/28)
Shahpar et al[54]	Competitive swimmers N = 45 OCG = 23.2 (3.3) y old CCG = 24.2 (4.2) y old CG (no dry-land workout, only aquatic training) = 23.4 (3.8) y old Gender: males Design: RCT	Period: 8 wk, 3 times per week *Strengthening*: CCG: 3 sets of 10–15 rep. Progression = NR Exercises: Push up, scapular push up, scapular dip, and crab walk OCG: 3 sets of 8 rep for ER and IR; 3 sets of 6 rep (80% 1 rm) for dumbbell fly and reverse dumbbell fly Progression = NR	Isokinetic shoulder rotators peak torque and endurance	OCG and CCG increased IR and ER peak torque and endurance ($P < .05$). But, the OCG increased more than the CCK ($P < .05$) OCG and CCG increased ER and IR peak torque and endurance compared with CG ($P < .05$)	Moderate (18/28)

Abbreviations: ABD, abduction; ASSES, American Association of Shoulder and Elbow Surgeons; CCG, closed-chain exercise group; CG, control group; ER, external rotation; F, female; FSP, forward shoulder position; HHD, hand-held dynamometer; IG, intervention group; IR, internal rotation; LG, land group; LT, lower trapezius; M, male; MCID, minimal clinical important difference; MET, muscle energy techniques; MT, middle trapezius; N, number of participants; NA, not applicable; NPRS, numerical pain rating scale; NR, not reported; OCG, open-chain exercise group; PML, pectoralis minor length; PSET, posterior shoulder endurance test; RCT, randomized controlled trial; rep, repetitions; ROM, range of motion; SA, serratus anterior; TG, training group; VAS, visual analog scale; WG, water group. Note: Risk of bias using the Modified Downs and Black quality checklist.

pain after 8 weeks in a 10-year-old swimmer. The pain was measured by the visual analog scale and was reduced from 9.5/10 points (at initial assessment) to 0/10 points (end of treatment). Using a similar treatment approach, Kurtz[44] also found reductions in shoulder pain after 4 weeks of treatment in a 20-year-old swimmer. Using the visual analog scale, the pain decreased from 5 to 6 at rest and 7 to 8/10 toward the end of the practice to 0/10 at rest and with swimming up to 1 hour and at 2 to 3/10 at the end of swimming practice. Finally, Smith et al[47] reported reductions in shoulder pain after 8 weeks of strengthening exercises, neuromuscular electrical stimulation, manual therapy techniques, and taping. Using the numerical pain rating scale, the pain decreased from 4/10 at evaluation and from 8/10 while swimming to 0/10. Furthermore, the Dash questionnaire decreased from 29.5 to 0 points after the intervention.

Exercise Protocol Effects on Risk Factors for Shoulder Pain

Regarding shoulder strength, all studies investigating uninjured swimmers reported an increase at follow-up regardless of the group assigned (IG or CG). However, for between-group comparisons, only studies performing interventions greater than 12 weeks reported increases in shoulder strength compared with the CG.[15,16] In contrast, studies with interventions <8 weeks did not find differences between groups.[43,45,50,52] After a 16-week strengthening program, Batalha et al[15] found that swimmers in the IG had an increase of shoulder external rotation (ER) peak force (both shoulders) and ER endurance (dominant side) compared with those who only did aquatic training, with a large effect size ($\eta_p^2 = .116 - .247$). The IG also improved shoulder ER/internal rotation (IR) ratio for peak force (both shoulders) and endurance (dominant side) with a large effect size ($\eta_p^2 = .222 - .271$).[15] Likewise, Manske et al[16] found greater increases in ER peak force of the dominant side in the IG after a similar 12-week strengthening program ($P = .013$). Although Manske et al[16] was the only study that investigated if the changes in shoulder strength were associated with decreases in shoulder pain, they did not find a relationship.

Some researchers have also investigated the change of shoulder strength after different interventions. Batalha et al[53] found that 10 weeks of dry-land strength training was superior to water strengthening exercises in increasing ER endurance ($P = .150$; $\eta_p^2 = .039$) and ER/IR endurance ratio ($P = .007$; $\eta_p^2 = .222$). They also found that open kinetic chain exercises provided greater increases in ER strength and endurance ($P < .05$) than closed kinetic chain exercises after 8 weeks.[54] Finally, a study failed to find differences in shoulder protraction and retraction strength after endurance or a strengthening program.[49]

Most studies assessing shoulder flexibility reported differences between the IG and CG. Kluemper et al[48] found that the IG decreased FSP compared with the CG ($P < .01$) after 6 weeks of strengthening exercises and stretches. Similarly, Lynch et al[45] found decreases in forward head angle and FSP in the IG compared with CG ($P < .05$; $d = 1.2$) after 8 weeks of a similar intervention. Finally, Laudner et al[51] reported that the IG increased PML ($P = .01$; $d = 1.6$) and decreased forward scapular position ($P = .01$; $d = 1.07$) after 2 weeks of muscle energy techniques. In contrast, Sawdon-Bea and Benson[52] did not find a difference in PML and posterior shoulder flexibility after 6 weeks of strengthening exercises and stretches. Despite this, Lynch et al[45] was the only study that investigated the relationship with shoulder pain, reporting that increases in PML and decreases in FSP were associated with reductions in shoulder pain.

Risk of Bias

Eleven of the 14 articles were eligible for analysis (RCT = 9; interventional nonrandomized cohort = 2). According to the Modified Down and Black risk of bias tool, studies had an average of 17.5 points, which corresponds to a moderate quality or risk of bias. The main methodological issues included not reporting confounding factors, allocation concealment, power calculation, and blinding of the study subjects or those measuring the outcome measures. Although confounding factors were partially described, most of the studies did not include important factors, such as history of shoulder injuries, level of competition, and training volume. These are important factors to consider in swimmers.[12] Not considering important demographic factors can introduce bias to the study and lead to misleading conclusions. Also, allocation concealment was not reported in any study, which is important to prevent selection bias. Furthermore, the sample size was not calculated. This could underpower the studies to identify changes. Overall, the studies have methodological limitations, so caution must be used when applying these results in practice.

Discussion

Understanding the evidence for the effectiveness of exercise interventions on shoulder pain and risk factors can help practitioners to choose the most appropriate treatment. The heterogeneity of the populations, outcome measures, and exercises protocols (eg, dose and progression) across studies make comparisons difficult. This supports the use of a scoping review instead of a systematic review with meta-analysis to gain some context-based insight.[34]

Effect of Exercise Therapy on Shoulder Pain

One finding of this review was that swimmers performing 6 to 8 weeks of shoulder and scapular strengthening exercises in combination with pectoralis minor stretches have less incidence of shoulder pain.[43,45] It is important to consider that the different pain definitions across these studies might have influenced the results. Swanik et al[43] was the only study including a pain definition based on training modification. Since most shoulder injuries in swimmers are caused by an overuse mechanism, and few stop training due to pain, International Olympic Committees in injury surveillance[38,55] recommend injury definitions that record sport participation, training modifications, performance reductions, and symptoms. Considering this, studies investigating the incidence of shoulder pain should include this type of definition using scales, such as the Oslo Sports Trauma Research Centre Questionnaire on Health Problems[56] to monitor shoulder pain.

Another finding was that the combination of strengthening exercises and stretches with other therapeutic modalities, such as manual therapy techniques can decrease shoulder pain in injured swimmers.[44,46,47] The most common interventions included were myofascial release and joint mobilizations, with the latest research incorporating novel approaches, such as neuromuscular electrical stimulation.[47] The evidence supports this, suggesting that combining manual therapy with exercises is better than exercise or manual therapy alone for the management of other musculoskeletal conditions.[57] However, since the studies investigating these interventions in swimmers are case reports, it is not possible to determine whether exercise alone or in combination with manual therapy is better or the superiority of one technique over the other (eg, joint mobilizations vs myofascial release). Despite this, our findings showed that performing a scoping review (ie, not excluding case reports) can provide important and valuable information about the management of shoulder pain in swimmers.

Effect of Exercise Therapy on Musculoskeletal Risk Factors

Another finding of our study was that strengthening programs of more than 12 weeks increased shoulder ER force, endurance, and ER/IR ratio in competitive swimmers when compared with interventions of less duration.[15,16] Regarding the duration of the intervention, studies[58,59] support these findings showing that athletes increase their strength after a similar period. Importantly, the changes were reported in shoulder ER endurance and force. These results might be relevant as several studies[7,23,24] have shown that reduced shoulder ER endurance is a modifiable risk factor for shoulder pain in swimmers. During a swimming stroke, the infraspinatus muscle controls the internal rotator forces of the subscapularis muscle during the midrecovery phase; whereas, the teres minor muscle controls the internal rotator forces of the pectoralis major muscle during the pull phase.[32] Investigators[60] have indicated that decreased infraspinatus activity can lead to glenohumeral instability, which may result in functional impingement. Although absolute shoulder strength is important in swimmers, muscle balance is also relevant.[22,61] In this review, we found that improvements in ER strength after an exercise program were reflected in an increase of the conventional ER/IR ratio (concentric ER: concentric IR).[15] Swimmers tend to develop lower conventional strength ratios as a result of the predominant internal rotation forces during swimming.[62] However, it is unclear whether this imbalance is associated with shoulder injury or is a common response to the demands of the sport.[61] Importantly, a recent 1-year prospective study[22] investigated this relationship using a functional ratio (eccentric ER:concentric IR). The authors found that swimmers with a ratio below 0.68 at preseason were 4.5 times at greater risk of developing a shoulder injury.[22] These findings suggest that while developing an injury prevention program, eccentric shoulder ER exercises may be required. Overall, studies[15,16] have demonstrated that a strengthening program of more than 12 weeks can improve ER force, endurance, and muscular balance. Although Manske et al[16] was the only study included in this review that investigated if the increases in shoulder ER strength were associated with decreases in shoulder pain, they did not find a relationship.

Findings of our study also highlight that a combination of pectoralis major and minor stretches with strengthening exercises increased PML and decreased FSP in uninjured competitive swimmers.[45,48] Lynch et al[45] was the only study that investigated this relationship with shoulder pain, reporting that improvements in these physical qualities were associated with reductions in shoulder pain. Importantly, reduced PML (ie, an indirect measure of FSP) has been reported as a potential modifiable risk factor for shoulder pain in swimmers.[19,20] Reductions of the PML can alter scapular position (eg, increase anterior tilt and internal rotation) decreasing the subacromial space and possibly increasing the risk of shoulder pain.[45] Interestingly, the 7 studies including flexibility exercises performed anterior shoulder stretches, and only 4 performed posterior shoulder stretches. This is supported by Matzkin et al[31] and Weldon and Richardson[2] suggesting that length to the posterior shoulder is often neglected. These investigators[2,31] highlight the importance of maintaining a balance between anterior and posterior muscle stretches to allow proper scapular motion and posture. Although stretching is an important part of dry-land programs in swimmers, overstretching of the noncontractile tissues (eg, anterior shoulder capsule) might increase the risk of instability and injury.[32] It is theorized that a reduction of passive stability provided by the ligaments needs a greater contribution of the muscles to stabilize the joint, leading to muscle fatigue and consequent secondary shoulder impingement.[2] Considering this, it is recommended to only stretch if range of motion deficits are identified.[27]

Another important finding was that open kinetic chain exercises and a dry-land program are superior to close kinetic exercises and water training for improving shoulder ER strength and endurance.[53,54] Open kinetic exercises incorporating overhead positions might be more relevant as they simulate the swimming stroke. Interestingly, the studies reporting pain reductions[43,45] included only open kinetic chain exercises in their interventions. Furthermore, dry land should be chosen over water strengthening training to improve shoulder ER endurance.[53] These findings may support the use of dry-land training in swimmers to reduce shoulder injury risk.[6] However, it seems more important to understand when to perform the dry-land training. In a recent study, Batalha et al[63] investigated the acute effects of a strengthening program on shoulder rotator strength and endurance in swimmers. The authors found that a single session of resistance band strengthening had no significant acute effect on shoulder rotator strength and endurance, suggesting that the implementation of strength exercises before an in-water swim session is appropriate. However, it may also be important to consider the intensity of the swim session associated to the dry-land training. Studies have shown that swimmers decrease their shoulder rotation force after a high-intensity session[64] but not after a low- to moderate-intensity session.[64,65] Thus, performing a low-intensity session along with a dry-land training might reduce the drops in strength, potentially decreasing the risk of injury.

Clinical Meaningfulness of the Results

We need to consider the clinical meaningfulness of these results. Clinical meaningfulness reflects the degree to which the study results are relevant to practice and can be determined by the effect size, confidence intervals, measurement error, and MCID.[66] For instance, only 4 studies[15,45,51,53] reported the effect size (ie, magnitude of change) of the results. Regarding measurement error (ie, reliability), only 2 studies reported whether the results exceeded the standard error of measurement[51] or minimal detectable change.[50] Reporting reliability of the results is important as it refers to the extent to which a test or instrument provides a measure that is free of error over repeated trials.[66] Furthermore, only Lynch et al[45] reported if the reductions of shoulder pain exceeded the MCID. When assessing the results of an intervention on pain, the MCID is an important parameter to report as it reflects the quantity of change that the patient perceives as worthwhile.[66] Finally, 4 studies (excluding case reports)[15,16,51,53] reported confidence intervals of the results. Confidence intervals are necessary as they provide a range of possible values obtained from samples to estimate the population.[66] Overall, these findings demonstrate a reduction in clinical meaningfulness in the results.

Review Strengths and Limitations

This review presents strengths and weaknesses. Although scoping reviews employ a rigorous and structured method consistent with a systematic review process, the inclusion and exclusion criteria are more flexible.[34] This allowed the identification of various study designs assessing the effects of exercise therapy interventions in shoulder pain in swimmers. We restricted our search to "exercise therapy" interventions. This was a strength as it showed the wide range of techniques used to prevent and manage shoulder pain in this population. However, this might be also a weakness as we excluded other treatments (eg, corticoid injections) or specific shoulder conditions (eg, postoperative management, painful os acromiale, etc) that were found in the literature. Another possible strength is that we performed a critical appraisal of the literature. Although this is optional for scoping reviews, we believe that this was appropriate to perform as most of the studies (11 out of 14) were eligible. Thus, along with a broader and more contextual overview of a scoping review, the methodological assessment of the literature might inform and guide future research.

The studies analyzed present limitations. First, all the studies present methodological limitations which inhibit generalizing results with confidence. Second, the studies' lack of efficacy in preventing shoulder pain could be explained by the fact that the intervention programs solely incorporated musculoskeletal components. According to injury models[10,11] in sport, other factors (eg, training loads, behavioral, and psychological) are equally important in the causation of injuries and should be included in injury prevention programs. Third, studies assessing the incidence of shoulder pain performed a single measurement of shoulder pain and musculoskeletal risk factors, without considering the dynamic interaction between factors over time.[11] A recent study showed that shoulder musculoskeletal risk factors in swimmers are dynamically changing according to the training load applied.[64] Fourth, the studies only included a primary prevention intervention (avoidance of injury through an intervention program). An important concept is secondary injury prevention, which involves the early detection and interventions addressing clinical signs which may result in injury (eg, decreases in strength after training or competition).[67,68] Recent research has suggested that in-season monitoring of physical qualities is a promising injury prevention strategy.[69] An example of this is a RCT[68] reporting that in-season monitoring of hamstring strength after football games during a season reduced the risk of injury.

More high-quality studies investigating primary injury prevention of shoulder pain in swimmers are necessary to confirm the findings of this review. Furthermore, future RCT should monitor shoulder pain using scales, such as the Oslo Sports Trauma Research Centre Questionnaire on Health Problems, and perform repeated measures of multidimensional risk factors when comparing groups to analyze the risk of developing shoulder pain (ie, secondary injury prevention). Although regular in-season monitoring seems to be the most appropriate approach, challenges of competitive athletes, such as training schedules, travel, competitions, among other issues, need to be considered.[69] Finally, comparing the efficacy of different protocols in injured swimmers is necessary to determine the most appropriate treatment to manage shoulder pain.

Conclusions

Through this scoping review, we have found that an exercise program including strengthening exercises and stretches can decrease the incidence of shoulder pain and improve shoulder musculoskeletal risk factors in swimmers. Also, combination of exercises and stretches with manual therapy techniques can help to decrease shoulder pain in injured swimmers. Due to the methodological limitations of the studies and the reduced clinical meaningfulness of the results, caution must be used when applying these results in practice. Future research in injury prevention should monitor shoulder pain and multiple risk factors more repeatedly. Finally, high-quality RCTs are needed to determine the best intervention to manage shoulder pain in swimmers.

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