DOI: 10.7860/JCDR/2025/76944.21219

Screening Tests to Identify Injury Risk in Competitive Swimmers: A Scoping Review

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ABSTRACT

Introduction: Swimming places unique demands on athletes, encompassing repetitive, high-intensity movements in a challenging aquatic environment, which predisposes them to a higher risk of injuries. Early identification through screening tests is essential for injury prevention in swimmers. Several screening tests are available to assess injury risk in swimmers, highlighting the need to identify effective, clinically relevant tools.

Aim: To review existing literature on screening tools that identify the risk of injury in competitive swimmers.

Materials and Methods: An electronic search of the PubMed database, as well as secondary sources like Google Scholar, was conducted for relevant studies from the earliest available date until February 2024. This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines. A population, concept, and context framework was used to select and collect data. Peer-reviewed full-text studies involving competitive swimmers across different age categories were included, while studies that were reviews or in non English languages were excluded. Data were extracted using Excel, and the following factors were summarised: study design, population, screening tools, and major findings. A quality rating for the selected studies was conducted using the National Institutes of Health (NIH) study-quality assessment tool.

Results: A total of 7,255 articles were identified, from which 16 full-text studies reported the use of various screening tools to assess injury risk. The majority of the studies (n=12) were rated as fair quality according to NIH standards. Shoulder horizontal abduction Range of Motion (ROM), posterior shoulder endurance, and the isokinetic functional strength ratio (EccER: ConIR) were most effective in identifying shoulder injuries. However, limited evidence exists regarding the identification of injury risk in other body regions, such as the knee and spine.

Conclusion: Screening tools identified decreased shoulder rotation strength ratio, Posterior Shoulder muscle Endurance (PSE), and shoulder horizontal abduction ROM as causative risks for swimming injuries. However, it is also evident that screening needs to be comprehensive and should include robust outcomes to effectively determine injury risk.

Keywords: Injuries, Isokinetic functional strength, Range of motion, Risk assessment, Swimming

INTRODUCTION

Competitive swimming is a physically demanding sport that requires athletes to perform repetitive and high-intensity movements in a non-weight-bearing environment, which predisposes them to various injuries [1]. Overuse injuries are more likely to occur in swimmers due to the repetitive nature of the sport, faulty stroke mechanics, and high training intensity [2-5]. The most common injuries are shoulder injuries, commonly known as "swimmer's shoulder," which result from the cumulative load on muscles and tendons over time [2,4,6]. Other frequent injuries include low back injuries and knee injuries, often caused by repetitive microtrauma, improper technique, and muscular imbalances [6,7]. The incidence of injuries among elite swimmers has been reported to be as high as 4.00 injuries per 1,000 hours of training for men and 3.78 injuries per 1,000 hours for women [8].

Screening tests for injury risk have emerged as critical tools for injury prevention, providing a systematic approach to identifying athletes who are at risk [9]. Considering the high injury rates and the potential impact on the careers of competitive swimmers, effective screening enables clinicians and coaches to identify potential injuries, facilitating timely interventions, enhancing performance, and ensuring the longevity of the athlete's career [10,11]. Various generic screening tools, such as the Functional Movement Screen (FMS) and the Movement System Screening tool, have been studied across different sports to identify injury risk [12-14]. While injury risk assessment in competitive swimmers is crucial, it is also challenging due to the limited availability of standardised screening tests. A previous systematic review highlighted significant limitations in identifying a single standalone test for injury prediction in elite swimmers due to a lack of predictive validity in the included studies [15]. Additionally, another review reported a lack of strong evidence linking shoulder pain with injury risk, with considerable variation in findings [16]. Given that the shoulder is the most commonly injured region in swimmers, the limited and conflicting evidence on key shoulder variables further complicates injury risk identification and prevention strategies. These gaps underscore the need for a comprehensive synthesis of existing screening tools to map the available evidence, identify key assessment domains, and highlight areas requiring further research in injury risk assessment across different age groups and competition levels.

Therefore, this scoping review aimed to explore the available literature on screening tests used to identify injury risk in competitive swimmers of different age groups, body regions, and levels of competition, without restrictions on geographical location or study settings. The objective was to identify and categorise the screening tests based on common key elements, facilitating a clearer understanding of their scope, application, and relevance in injury risk assessment for competitive swimmers.

MATERIALS AND METHODS

The PRISMA-ScR guidelines were followed in this scoping review [17]. This review was conducted according to the Population, Concept, and Context (PCC) framework to define the eligibility criteria [18]. The operational definitions for each component of PCC are illustrated in [Table/Fig-1].

PCC	Definition
Population	Competitive swimmers of all age groups and competitive levels (both male and female)
Concept	Injury Screening tools used to identify injury risk in competitive swimmers
Context	No geographical limitations; studies conducted in any clinical or field setting

[Table/Fig-1]: Operational definitions for the Population, Content and Context (PCC) considered in scoping review.

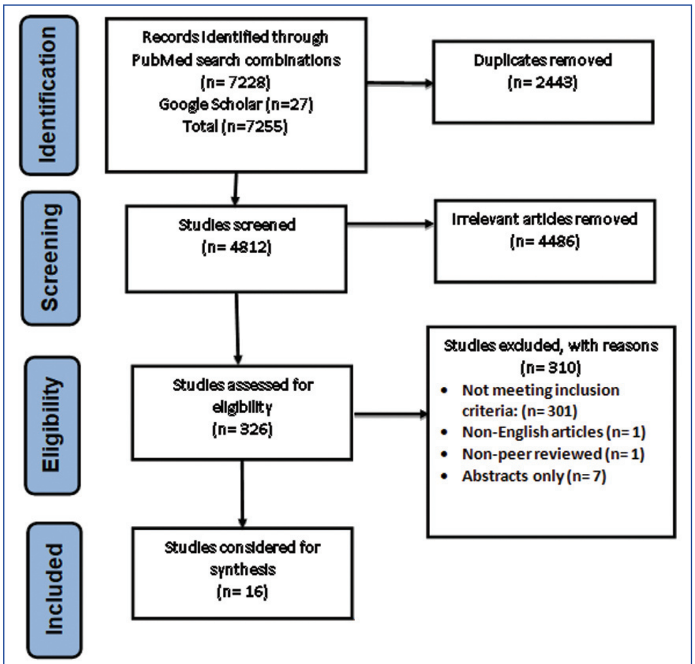
Inclusion criteria: Studies focused on professional swimmers, specifically within competitive categories across various age groups; and studies using cohort or cross-sectional designs; and original, peer-reviewed articles published in English were included in present study.

Exclusion criteria: Systematic reviews, commentaries, editorials, books, etc., and studies involving triathletes, water polo players, or recreational athletes; and magazine articles or articles without full-text availability were excluded from the study.

A literature search was conducted using the PubMed database, supplemented by secondary sources like Google Scholar, to identify relevant studies published from the inception of the databases until February 2024. The exact search strategy, with specific search terms used, included: swim* AND screening; swim* AND screen*; swim* AND screen* AND injury; swimming AND musculoskeletal injury AND screening; swim* AND injury assess*; movement screen AND swimmers; injury risk AND swimmers; and injury risk AND swim*.

Study Procedure

The systematic search of the PubMed database and secondary sources, along with the study selection criteria, is depicted in the PRISMA Flowchart [Table/Fig-2]. Initially, the titles and abstracts were screened by the first author (DP) using Microsoft Excel to identify studies that met the pre-defined eligibility criteria. Full-text articles of the potentially eligible studies were then retrieved and independently reviewed by two raters (DP and AD) to determine final inclusion based on the previously described eligibility criteria. The included studies consisted of cross-sectional and cohort studies. Any disagreements between the raters regarding study eligibility were resolved through discussion to reach a consensus.



[Table/Fig-2]: PRISMA flowchart depicting the process of selection of studies.

A custom data extraction sheet was developed by both authors using Microsoft Excel (MSO version 2019). The extracted data included study design, population characteristics (sex, age), outcome measures, and major findings. Data extraction was performed by the first author (DP) and independently reviewed by the second author (AD). The extracted data were then categorised into the following domains: Strength and Endurance, Range of Motion, Muscle Length, Joint Laxity, Balance, and other adjunct assessments that included training-related measures, posture assessment, 3D motion capture, Penn Shoulder Score, DASH, and SF-36. The quality of the included studies was assessed using the NIH Study Quality Assessment Tools, with each study independently rated as poor, fair, or good by both authors [19]. Any discrepancies in quality ratings were reviewed and resolved through mutual discussion between the authors until an agreement was reached. Studies that were rated as fair or good were included in the qualitative synthesis, while the inclusion of studies rated as poor was determined through further discussion based on the content and relevance of the studies.

RESULTS

The systematic search of the PubMed database and secondary sources yielded a total of 7,255 studies. After removing 2,443 duplicates, 4,812 studies were screened by their titles and abstracts. From these, 4,486 studies were excluded as they did not fulfill the inclusion criteria. The full texts of 326 studies were then reviewed for eligibility, resulting in 16 studies being included in the final scoping review [Table/Fig-2].

Study characteristics: The 16 studies included in this review varied in design, population, and outcome measures. The studies primarily focused on competitive swimmers, with ages ranging from youth to adult (8-77 years), across different levels of competition. One study with the fewest participants included 18 swimmers [20], while the study with the most participants involved 661 swimmers [21]. This wide range in sample sizes reflects the diversity of study designs and populations within the reviewed literature [Table/Fig-3] [10,20-34].

Quality assessment: Out of the 16 studies assessed according to NIH study quality assessment tools, three were rated as good [24,28,32], twelve as fair [10,20-22,25-27,29-31,33,34], and one as poor [23]. The findings from the included studies were categorised into six main domains: strength and endurance, range of motion, muscle length, joint laxity, balance, and other adjunct assessments.

Strength and endurance: Nine studies assessed strength and endurance, focusing primarily on shoulder internal and external rotator strength [10,24,25,27,28,30,31,33,34]. Isokinetic dynamometers were commonly used to measure strength at varied speeds (e.g., 60°/s, 80°/s, 180°/s) [10,28,30]. The internal rotation strength ratio was frequently identified as a key indicator of shoulder injury risk [28,33]. One high-quality study found that an isokinetic functional external rotator strength ratio below 0.68 was a significant predictor of shoulder pain [28]. However, results were mixed, with some studies showing that strength improved over a competitive season without correlating with injury risk [27,33]. Conflicting results also indicated that strength ratios were normal in swimmers with shoulder pain [30].

Range of Motion (ROM): Five studies examined range of motion, with particular attention to shoulder external and internal rotation [22,24,25,32,34]. Additionally, shoulder flexion was identified as a significant predictor of shoulder pain, with decreased shoulder abduction (less than 39°) being associated with a 3.6 times higher injury risk [32].

Muscle length: Three studies focused on muscle length, particularly the pectoralis minor [24,25,34]. Tight pectoralis minor was associated with an increased risk of shoulder pain, with proposed cutoff values being 9.8 cm at rest and 11.9 cm in a stretched position [25].

Joint laxity: Joint laxity was investigated in two studies, with findings indicating that competitive swimmers had greater laxity compared to controls. The anterior drawer and apprehension tests, as well as the Sulcus sign, were commonly used to assess laxity, with

S. No.	Author name	Study design	Population	Age	Outcome measures	Major findings	Quality rating
1	Evershed J et al., [10]	Cross-sectional	Nationally ranked junior swimmers in the 100 m freestyle	Under 18 years	1. Clinical strength: Isokinetic shoulder Internal Rotation/External Rotation (IR/ER), shoulder abduction/adduction (conc: conc) at 80°/sec 2. Shoulder horizontal adduction (isometric) 3. Bilateral hand force with swim ergometer and motion capture 4. 3D kinematic swimming movement	Asymmetry of strength found in 85% of swimmers presented with strength asymmetry Approximately 50% of swimmers with asymmetrical still produced symmetrical hand force by compensation	Fair
2	Staker JL et al., [20]	Cross-sectional	Competitive swimmers (n=18)	18-55 both gender	1) Anterior Drawer test; 2) posterior drawer test; 3) Sulcus sign	Mean composite scores 1.77 mm greater than controls (moderate association r=0.40), greater translations for posterior drawer (-2.4 mm) and sulcus test (-0.27 mm) in swimmers with multi directional instability than controls	Fair
3	Preziosi Standoli J et al., [21]	Cross-sectional	Elite swimmers (n=661) Club to international level elite swimmers, both gender	12-25 years	Examination of the shoulder blades throughout synchronous forward flexion motion in the sagittal plane	Swimmers with preferred breathing side were more prone to develop scapular dyskinesia in opposite shoulder, long distance swimmers were at greatest risk of developing scapular dyskinesia	Fair
4	Riemann BL et al., [22]	Cohort	National Association of Intercollegiate Athletes, high school, US Masters and USA Swimming teams (n=144)	12-61 years	Shoulder external rotation, isolated internal rotation, composite internal rotation and total arc of motion range of motion	1) Dominant external rotation range of motion when compared to non dominant limb 2) Isolated Internal rotation, composite Internal rotation, Total arc of motion (ER+IR) of non dominant limb was greater than dominant limb	Fair
5	Zemek MJ and Magee DJ, [23]	Cohort	Elite swimmers (n=30), Recreational swimmers (n=30), both gender	15-25 years	1) Anterior drawer test; 2) Anterior apprehension test; 3) Inferior drawer at 0 degrees abduction; 4) Inferior drawer at 45 degrees Abduction; 5) General joint hypermobility	Greater Laxity in anterior drawer test, anterior apprehension test, Inferior drawer at 45 deg abduction in elite swimmers	Poor
6	Feijen S et al., [24]	Cohort	Elite swimmers (n=201) both gender	10-40 years	SF-36, Disabilities of the Arm, Shoulder, and Hand (DASH), Scapular dyskinesis, Thoracic rotation, shoulder ROM, pectoralis minor length, shoulder internal and external rotation strength, Posterior Shoulder Muscle Endurance (PSE), core endurance and pain threshold, swimmers' freestyle stroke pattern, Acute: Chronic Workload Ratio (ACWR)	Strongest predictors to shoulder pain 1) acute:chronic workload ratio ((OR=4.31) 2) competitive level (OR=0.19), 3) shoulder flexion range of motion, Posterior Shoulder Endurance (PSE) (OR=0.96) and 4) hand entry position error (OR=0.37)	Good
7	Harrington S, et al., [25]	Cross-sectional	National Collegiate Athletic Association Division I (NCAA D1) female swimmers (n=37)	Age: 19.5±1.19 years	1. Penn Shoulder Score (PSS)-pain subscale 2. Sports module-DASH 3. Passive shoulder IR and ER ROM at 90° abduction and 4. Shoulder strength- IR, ER, scapular depression, and adduction 5. Core endurance- Side and prone bridge 6. Pectoralis minor muscle length	Decrease in pectoralis minor muscle length at dominant side at rest (9.8 cm) and at stretch positions (11.9 cm)	Fair
8	Butler R et al., [26]	Cohort	NCAA D1 collegiate swimmers (n=97)	Age: 19.1±0.7 years (43 males) Age: 19.3±1.2 years	1. Y-balance test-upper Quarter	Females scored lower in medial, inferolateral and composite score Y-Balance Test – Upper Quarter (YBT UQ)	Fair
9	Batalha N et al., [27]	Cohort	20 national-level male Portuguese swimmers	Age: 14.45±0.50 years 16 sedentary male students Age: 14.69±0.48 years	1. Isokinetic IR and ER shoulder strength at 3 reps at 60°/sec and 20 reps at 180°/sec	ER: IR muscle imbalance as a result of increased shoulder IR strength during training season	Fair
10	Drigny J et al., [28]	Cohort	Adolescent elite swimmers (n=18), both gender	Adolescent Age group total 16.1±2.3, follow-up 16.3±1.7	Isokinetic Shoulder Internal and External rotation strength Conventional (con ER: con IR) 60 deg/sec, Eccentric ER: Eccentric IR), Functional Ratio (eccentric Er:con IR), Ecc Ir: con ER) at 60 deg/sec	Functional strength ratio Eccentric External Rotation to Concentric Internal Rotation Ratio (ECC ER: CON IR) below 0.68 showed 4.5 times increase of shoulder injury	Good
11	Hibberd EE et al., [29]	Cross-sectional	Adolescent swimmer (N)=44, and Non-overhead athletes (n)=31	Age: 13-18 years	1. Posture Assessment A) Forward head angle B) Forward shoulder angle; 2. Subacromial space distance via ultrasound measurement	No difference in subacromial space distance and forward shoulder posture when compare with non overhead athletes Swimmers had less horizontal adduction in comparison with non overhead athletes but not significant differences observed	Fair
12	Boettcher C et al., [30]	Cohort	Elite 68 swimmers (40 men and 28 women)	Above 16	Shoulder External rotator and Internal Rotator strength	No difference between dominant and non-dominant shoulder and with pain. Normal strength ratios. No association between strength and pain	Fair

13	Abdelmohsen et al., [31]	Cohort	Adolescent competitive swimmers (n=30), both gender	Above 12	Isokinetic Trunk flexion and Extension at 60°/s, 180°/s, 2) Side bridge endurance test 3) Static back endurance test 4) Ball bridge test 5) Unilateral bridge test	Trunk extension at 60 and 180 had greater endurance time than shoulder pain group. Peak torque 110.92+- 31.43 (60), 67.48 (180)	Fair
14	Cejudo A et al., [32]	Cohort	Young competitive swimmers (n=24), both gender	12-20 years	Passive ROM: 1) shoulder extension; 2) shoulder flexion; 3) Horizontal abduction; 4) Abduction; 5) Horizontal adduction; 6) External rotation; 7) Internal rotation	Shoulder pain risk was 3.6 times associated with reduced Abduction ROM. Cut-off ≤39°	Good
15	Ramsi M et al., [33]	Cohort	Competitive high school swimmers (n=27), both gender	14-18 years	Isometric strength 1) Shoulder ER:IR ratio	ER: IR strength ratio increased from pre-season to post season. Increase in ER strength through the season	Fair
16	Tate A et al., [34]	Cross-sectional	Youth, high school, US masters Competitive swimmers (n=236), female	8-77 years	1) Passive ROM- Shoulder flexion, Long head triceps tightness length, Latissimus dorsi length, Internal and external rotation ROM; 2) Strength- isometric shoulder elevation, External rotation, internal rotation, horizontal abduction;3) Pectoralis minor length; 4) Core endurance- side bridge test, prone bridge test, Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST); 5) Scapular dyskinesis test; 6) Penn Shoulder score	Swimmers under 12 years of age had reduced shoulder flexibility, middle trapezius and shoulder IR weakness and Latissimus Dorsi tightness. Swimmers aged 12 years and above showed pectoralis minor tightness and decrease core endurance	Fair

[Table/Fig-3]: Characteristics of studies selected for analysis [10,20-34].

greater translations observed in swimmers with multidirectional instability [20,23].

Balance: One study examined balance using the Upper Quarter Y-Balance Test (UQ-YBT). Female swimmers were found to have lesser medial and inferolateral reach compared to males; however, the evidence linking balance to injury risk was weak [26].

Other adjunct assessments: Several studies explored additional assessment methods, including posture scales, questionnaires, and 3D assessments of scapular dyskinesis [10,21,24,29,34]. The Acute Workload Ratio (ACWR) has been identified as a significant predictor of shoulder pain, with an odds ratio of 4.31. This indicates that a higher acute workload in relation to chronic training loads considerably increases the risk of injury [24].

DISCUSSION

Even though there may be an association between a screening test and a subsequent injury, such tests may not always predict injury or identify athletes at risk. To predict injury risk, it is essential to establish a link between screening markers, validate diagnostic properties across cohorts, and demonstrate that targeted interventions are more effective than generalised ones [9].

In this scoping review, existing screening tools were mapped for injury risk in competitive swimmers, identifying key assessment elements. The most commonly reported tests primarily focused on the shoulder joint, with limited evidence regarding the lower extremities and spine [9,20-30,32-34]. Among the 16 included studies, isokinetic strength testing of shoulder internal and external rotators was the most commonly used outcome, followed by measurements of shoulder internal and external rotation range of motion. Isokinetic strength was measured at varied speeds, while other studies assessed isometric strength [10,28,31,33].

Passive external and internal rotation range of motion was evaluated in certain studies, whereas others focused on active external and internal rotation range of motion [22,24,25,32,34]. This scoping review primarily identified studies with cohort and cross-sectional designs but lacked prospective longitudinal studies with predictive validity.

This review contributes to the understanding of injury risk assessment in competitive swimmers by identifying and categorising key screening domains. Building on previous research [15], the main findings of this review focus on additional factors such as joint laxity, balance, muscle strength and endurance, as well as other adjunct assessments, including training-related measures and 3D kinematic movements that are available for injury risk screening approaches.

A low External Rotation to Internal Rotation (ER:IR) strength ratio contributes to shoulder pain and injury risk, although research findings are not consistent across some studies [27,28,30,33]. The scapular and rotator cuff muscles stabilise the shoulder by keeping the humeral head centered at the glenoid fossa and generating translational, compressive, and rotational forces that enable the arms to move smoothly. During the propulsive phase of swimming, there is an increase in the work of internal rotators, thereby altering the strength ratio and contributing to shoulder pain [35]. Therefore, there is inconclusive evidence that shoulder rotation strength imbalance predicts injury risk in competitive swimmers, and strength alone may not determine injury risk.

Considering the complexity of shoulder function, muscle endurance may also contribute to these inconsistent findings. Decreased PSE has been reported as the best predictor of shoulder injury, with high odds, but its validity has not been determined [24]. Maintaining PSE is essential for preventing injuries from repetitive overhead movements.

Four studies examined core endurance [24,25,31,34], with one finding that swimmers over 12 years of age with reduced endurance had a higher risk of shoulder pain, emphasising core stability for injury prevention [34]. The complexities of muscle function, including the role of endurance alongside strength, may contribute to these mixed findings. This inconsistency suggests that shoulder strength and endurance are essential, but they may not serve as independent predictors of shoulder injury. There is a need for further longitudinal research to establish these relationships. Therefore, a more comprehensive assessment of injury risk can be obtained by considering both strength and endurance assessments.

Based on five studies included in this review, shoulder internal and external rotation was the most frequently assessed parameter, followed by shoulder horizontal abduction, shoulder abduction, and shoulder flexion [20,24,25,32,34]. In a study that reported a low range of shoulder horizontal abduction being associated with shoulder pain, this limited abduction in swimmers can be indicative of muscular imbalance or tightness, which compromises their ability to perform optimally [32].

Shoulder external and internal rotation range of motion was assessed in isolation and as part of composite motion but did not predict any risk for injury. Decrease in shoulder flexion is associated with increase odds of shoulder injury or pain. Thoracic rotation is not identified as potential predictor of shoulder pain [24]. One study identified that shortness of the pectoralis minor muscle is associated with an increased risk of injury [25]. The repetitive nature of swimming places continuous stress on the anterior shoulder structures, contributing to pectoralis minor tightness. This tightness can alter scapular positioning, leading to scapular dyskinesis and increasing the likelihood of shoulder pain [25]. The need for more comprehensive, high-quality research is evident to fully understand how pectoralis minor tightness, along with other potential muscle length deficits, contributes to injury risk in competitive swimmers.

Increased joint laxity has been consistently reported in swimmers, particularly in those with multidirectional instability. Competitive swimmers, especially those engaged in high volumes of training, frequently perform repetitive shoulder rotations that place significant stress on the shoulder joint, potentially contributing to multidirectional instability [20,23].

Moreover, repetitive shoulder motion, coupled with the large range of motion required in swimming, may exacerbate joint laxity and increase susceptibility to future injury. This finding suggests that joint laxity assessments, when combined with other screening tools, may provide valuable insights into identifying swimmers at risk for shoulder injuries. However, joint laxity alone may not be sufficient to predict injury, given the high prevalence of laxity in swimmers in general.

One study reported that the UQ-YBT in female swimmers had less medial and inferolateral reach compared to males; however, there is still a lack of evidence linking balance deficits to injury risk, and further research is needed to determine if balance deficits contribute to injury risk [26].

Several studies explored additional assessment methods, such as posture scales, questionnaires, and 3D assessments of scapular dyskinesis [10,21,24,29,34]. Given the multifactorial nature of injury risk, this scoping review provides a comprehensive framework for identifying risk factors in competitive swimmers by mapping key screening domains. Furthermore, by synthesising existing screening tools, this review provides valuable insights for sports physiotherapists, athletic trainers, coaches, and swimmers to utilise one or more screening tools within the identified domains to assess injury risk and identify athletes who may be more susceptible to injuries. Based on these findings, they can offer targeted recommendations to tailor individual training programs, ultimately enhancing injury prevention strategies and optimising performance in competitive swimming. Clinicians should consider using a comprehensive battery of assessments that includes strength and endurance testing, ROM assessments, muscle length evaluations, and workload monitoring to more effectively identify swimmers at risk of injury. Future research should focus on conducting larger, more rigorous cohort studies and developing standardised screening protocols that can be widely adopted in clinical practice.

Limitation(s)

A few limitations were identified in present scoping review. The sample size in many studies was small, affecting the generalisability of the results. Moreover, population heterogeneity and variability in study designs further contribute to inconsistent results. Additionally, the search was limited to the PubMed database and Google Scholar, which primarily identified tools for assessing shoulder injury risk. Consequently, insufficient literature on injury risk in the lower extremities and spine was identified. Furthermore, there is a paucity of long-term cohort studies that could provide more definitive evidence on the predictive validity of these screening tools over time. Most of the studies included in this review are cross-sectional, with only one utilising predictive analysis, which limits the ability to draw strong conclusions about the likelihood of range of motion as a predictor of shoulder injury. Finally, age variability among participants was notably broad, with some studies including age groups ranging from 12 to 77 years, which may contribute to inconsistencies in findings across different age groups and limit the generalisability of these results.

CONCLUSION(S)

The existing literature on screening tools for identifying injury risks in competitive swimmers was comprehensively analysed in this scoping review. Significant predictors of shoulder injuries include a lower shoulder ER: IR strength ratio and reduced shoulder horizontal abduction ROM. Furthermore, joint laxity, muscle length, and workload ratios were also noted as risk factors but lacked supporting evidence. This scoping review highlights the lack of robust screening tools for identifying injury risk in swimmers, emphasising the need for a comprehensive assessment tool. Developing a screening tool through the Delphi method would offer a structured approach to address this gap, thereby providing a specific screening tool for swimmers.

Acknowledgement

The authors express their sincere gratitude to Dr. Summaiya Zareen Shaikh (PT, PhD), Associate Professor at The SIA College of Health Sciences, College of Physiotherapy, Dombivli, Thane, for her expert guidance in planning and conducting this scoping review.

Authors' contribution: A significant contribution was made by both authors, including conceptualisation, study design, data collection, data analysis, and interpretation. The authors have drafted, revised, and critically reviewed the manuscript, approved the final version for publication, and mutually agreed upon the journal for publication. They accept responsibility for all aspects of the work.

REFERENCES

[1] Hill L, Collins M, Posthumus M. Risk factors for shoulder pain and injury in swimmers: A critical systematic review. Phys Sportsmed. 2015;43(4):412-20.
[2] Wanivenhaus F, Fox AJS, Chaudhury S, Rodeo SA. Epidemiology of injuries and prevention strategies in competitive swimmers. Sports Health. 2012;4(3):246-51.
[3] Hsu C, Krabak B, Cunningham B, Borg-Stein J. Swimming anatomy and lower back injuries in competitive swimmers: Narrative review. Sports Health. 2024;16(6):971-81. Available from: https://doi.org/10.1177/19417381231225213.
[4] Johnston TR, Abrams GD. Shoulder injuries and conditions in swimmers. Endurance Sports Medicine. 2016;127-38.
[5] Struyf F, Tate A, Kuppens K, Feijen S, Michener LA. Musculoskeletal dysfunctions associated with swimmers' shoulder. Br J Sports Med. 2017;51(10):775-80.
[6] Chrenkó M, Mayer ÁA, Szendrő G, Várnagy A. Investigation of the effectiveness of a complex injury prevention programme among young swimmers. Developments in Health Sciences [Internet]. 2024;7(1):01-07. [cited 2024 Mar 30]. Available from: https://akjournals.com/view/journals/2066/aop/article-10.1556-2066.2024.00053/article-10.1556-2066.2024.00053.
[7] Trinidad A, González-Garcia H, López-Valenciano A. An updated review of the epidemiology of swimming injuries. PM&R. 2020;13(9):1005-20.
[8] Wolf BR, Ebinger AE, Lawler MP, Britton CL. Injury patterns in Division I Collegiate swimming. Am J Sports Med. 2009;37(10):2037-42. Available from: https://doi.org/10.1177/0363546509339364.
[9] Bahr R. Why screening tests to predict injury do not work- and probably never will…: A critical review. Br J Sports Med. 2016;50(13):776-80.
[10] Evershed J, Burkett B, Mellifont R. Musculoskeletal screening to detect asymmetry in swimming. Phys Ther Sport. 2014;15(1):33-38.
[11] Schweizer N, Strutzenberger G, Franchi MV, Farshad M, Scherr J, Spörri J. Screening tests for assessing athletes at risk of ACL injury or reinjury-a scoping review. Int J Environ Res Public Health. 2022;19(5):2864.
[12] Chimera NJ, Warren M. Use of clinical movement screening tests to predict injury in sport. World J Orthop. 2016;7(4):202.
[13] Bullock GS, Brookreson N, Knab AM, Butler RJ. Examining fundamental movement competency and closed-chain upper-extremity dynamic balance in swimmers. J Strength Cond Res. 2017;31(6):1544-51. [Cited 2019 Nov 17].
[14] Pollen TR, Warren M, Ebaugh D, Taylor JA, Silfies SP. Intrinsic risk factors for noncontact musculoskeletal injury in collegiate swimmers: A prospective cohort study. J Athl Train. 2023;58 (2):185-92. Available from: https://doi.org/10.4085/1062-6050-0658.21.
[15] Schlueter KR, Pintar JA, Wayman KJ, Hartel LJ, Briggs MS. Clinical evaluation techniques for injury risk assessment in elite swimmers: A systematic review. Sports Health a Multidisciplinary Approach. 2020;13(1):57-64. Available from: https://doi.org/10.1177/1941738120920518.
[16] McKenzie A, Larequi S, Hams A, Headrick J, Whiteley R, Duhig S. Shoulder pain and injury risk factors in competitive swimmers: A systematic review. Scand J Med Sci Sports. 2023;33(12):2396-412. Available from: https://doi.org/10.1111/sms.14454.
[17] PRISMA Extension for Scoping Reviews (PRISMA-SCR): Checklist and explanation. EQUATOR Network [Internet]. Available from: https://www.equator-network.org/reporting-guidelines/prisma-scr/.
[18] The Joanna Briggs Institute. Joanna Briggs Institute Reviewers' Manual: 2015 edition/supplement Adelaide: The Joanna Briggs Institute, 2015.
[19] National Institute of Health. Study Quality Assessment Tools. National Heart, Lung, and Blood Institute (NHLBI) [Internet]. Nih.gov. 2021. Available from: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools.

[20] Staker JL, Braman JP, Ludewig PM. Kinematics and biomechanical validity of shoulder joint laxity tests as diagnostic criteria in multidirectional instability. Braz J Phys Ther. 2021;25(6):883-90.
[21] Preziosi Standoli J, Fratalocchi F, Candela V, Preziosi Standoli T, Giannicola G, Bonifazi M, et al. Scapular dyskinesis in young, asymptomatic elite swimmers. Orthop J Sports Med. 2018;6(1):232596711775081.
[22] Riemann BL, Witt J, Davies GJ. Glenohumeral joint rotation range of motion in competitive swimmers. J Sports Sci. 2011;29(11):1191-99.
[23] Zemek MJ, Magee DJ. Comparison of glenohumeral joint laxity in elite and recreational swimmers. Clin J Sport Med. 1996;6(1):40-47.
[24] Feijen S, Struyf T, Kuppens K, Tate A, Struyf F. Prediction of shoulder pain in youth competitive swimmers: The development and internal validation of a prognostic prediction model. Am J Sports Med. 2020;49(1):154-61.
[25] Harrington S, Meisel C, Tate A. A cross-sectional study examining shoulder pain and disability in division I female swimmers. J Sport Rehabil. 2014;23(1):65-75.
[26] Butler R, Arms J, Reiman M, Plisky P, Kiesel K, Taylor D, et al. Sex differences in dynamic closed kinetic chain upper quarter function in collegiate swimmers. J Athl Train. 2014;49(4):442-46.
[27] Batalha N, Paixão C, Silva AJ, Costa MJ, Mullen J, Barbosa TM. The effectiveness of a dry-land shoulder rotators strength training program in injury prevention in competitive swimmers. J Hum Kinet. 2020;71(1):11-20.
[28] Drigny J, Gauthier A, Reboursière E, Guermont H, Gremeaux V, Edouard P. Shoulder muscle imbalance as a risk for shoulder injury in elite adolescent swimmers: A prospective study. J Hum Kinet. 2020;75(1):103-13.
[29] Hibberd EE, Laudner K, Berkoff DJ, Kucera KL, Yu B, Myers JB. Comparison of upper extremity physical characteristics between adolescent competitive swimmers and nonoverhead athletes. J Athl Train. 2016;51(1):65-69.
[30] Boettcher C, Halaki M, Holt K, Ginn KA. Is the normal shoulder rotation strength ratio altered in elite swimmers? Med Sci Sports Exerc. 2020;52(3):680-84.
[31] Abdelmohsen A, Elhafez S, Nabil B. Core stability in adolescent swimmers with swimmer's shoulder syndrome. Physiother Quart. 2021;29(4):33-41.
[32] Cejudo A, Sánchez-Castillo S, Sainz de Baranda P, Gámez JC, Santonja-Medina F. Low range of shoulders horizontal abduction predisposes for shoulder pain in competitive young swimmers. Front Psychol. 2019;10:478.
[33] Ramsi M, Swanik KA, "Buz" Swanik C, 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):09-18.
[34] 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. J Athl Train. 2012;47(2):149-58.
[35] Jain K, McLaughlin P. Shoulder Strength in Amateur Swimmers [master's thesis]. Melbourne (Australia): Victoria University; 2005.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Nov 23, 2024
- Manual Googling: Jan 16, 2025
- iThenticate Software: Mar 24, 2025 (14%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? No
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: Nov 22, 2024
Date of Peer Review: Jan 28, 2025
Date of Acceptance: Mar 26, 2025
Date of Publishing: Jul 01, 2025