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Risk factors Associated with Shoulder Injuries in Swimmers: A Systematic Review

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Authors' Contribution: A: Study design, B: Data collection, C: Data analysis, D: Manuscript preparation, E: Discussion and conclusion

ABSTRACT

Study aim(s): This literature review aims to comprehensively analyze the key risk factors associated with shoulder injuries in swimmers, synthesizing existing research to provide valuable insights for injury prevention strategies and the overall enhancement of swimmers' performance and well-being.
Methods: Systematic searches on the Web of Science and Scopus databases were conducted using the following phrase: shoulder injury risks in swimmers. Studies included in this review address, the main risk factors that are associated with shoulder injuries in swimmers. This study is a systematic review model, which is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards.
Results: This review identified the main risk factors associated with shoulder injuries in swimmers. These insights provide valuable guidance for coaches, athletes, and sports medicine professionals on improving the performance of each swimmer while minimizing shoulder injuries.
Conclusion: In conclusion, this literature review has provided a comprehensive understanding of the multifaceted nature of shoulder injuries in swimmers and the associated risk factors. Through an in-depth discussion of various studies, we have highlighted the critical aspects that contribute to these injuries. These include the importance of monitoring training loads, maintaining optimal shoulder mobility, considering psychological factors and swimming techniques, and implementing effective injury prevention strategies.

Keywords: Swimming, Strokes, Injuries, Shoulders, Prevention

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INTRODUCTION

Swimming is a popular sport admired for its grace and endurance, which place a significant load on the shoulder joint. Shoulder pain/injury is the most common musculoskeletal problem experienced by competitive swimmers [1]. While it offers a range of health benefits, it also presents a unique set of challenges, particularly concerning shoulder injuries.

Swimming strokes involve repetitive and forceful movements that put a lot of stress on the shoulder joint, making it prone to injuries. These injuries often disrupt training routines and compromise an athlete's overall physical and mental well-being. Factors like poor swimming technique, overtraining, and lack of proper rest worsen the issue. Also, deformities in shoulder anatomy, muscle asymmetry, and external factors like environmental conditions and equipment use contribute to the higher risk of injuries. Biomechanical three-dimensional analysis of freestyle swimming supports the notion that adequate rotational shoulder range of motion is required to swim with the correct technique and avoid shoulder impingement [1]. Given its prevalence, numerous risk factors for a shoulder injury in swimmers are proposed in the literature, including a glenohumeral joint range of motion and laxity, scapular dyskinesis, rotator cuff strength imbalances, gender, competitive swimming level, stroke, swim distance, and hand paddle usage during swim training [1]. However, these have received limited prospective investigation [2].

This literature review seeks to investigate and synthesize existing studies to establish a comprehensive understanding of the key risk factors responsible for shoulder injuries in swimmers. By examining the available literature, we aim to provide a clear and substantiated overview of these risk factors, ultimately contributing to injury prevention strategies and the overall enhancement of swimmers' performance and well-being.

Based on the National Collegiate Athletic Association (NCAA) study, the 5-year study found that the overall injury rate of professional swimmers was 4.00 injuries per 1000 training hours for men and 3.78 injuries per 1000 training hours for women. Of all injuries, shoulder injuries are the most common, with a prevalence between 40% and 91% [3]. Unlike most other sports, where in most sports the legs are the ones that initiate the propulsive force, swimmers primarily use their arms to generate forward propulsion. Well-trained swimmers can swim up to 9 miles a day. (more than 2500 shoulder rotations). For this reason, fatigue of the muscles of the rotator cuff, upper back, and chest muscles caused by repetitive movements can result in microtrauma due to the decrease in dynamic stabilization of the humeral head [4,5]. In recent studies, 91% of 80 young elite swimmers (13-25 years old) complained of shoulder pain. Eighty-four percent demonstrated a positive stroke sign, and 69% of 52 swimmers examined with magnetic resonance imaging demonstrated signs of supraspinatus tendinopathy. Interestingly, the level of competition has been associated with supraspinatus tendinopathy, with a higher percentage of swimmers at the highest level of competition having radiographic signs of tendinopathy [5].

The characteristic position of the subacromial impingement is forward flexion and then internal rotation of the glenohumeral joint during the recovery phase (above water) of the stroke. As the hand enters the water, the hydrodynamic force applied to the hand produces a large thrust at the shoulder joint, causing elevation of the humeral head and subsequent impact. Then, hyperextension of the upper extremity in the final phase of retraction of the impingement pushes the humeral head forward and internally rotates, producing impingement when muscle fatigue is present [6,7].

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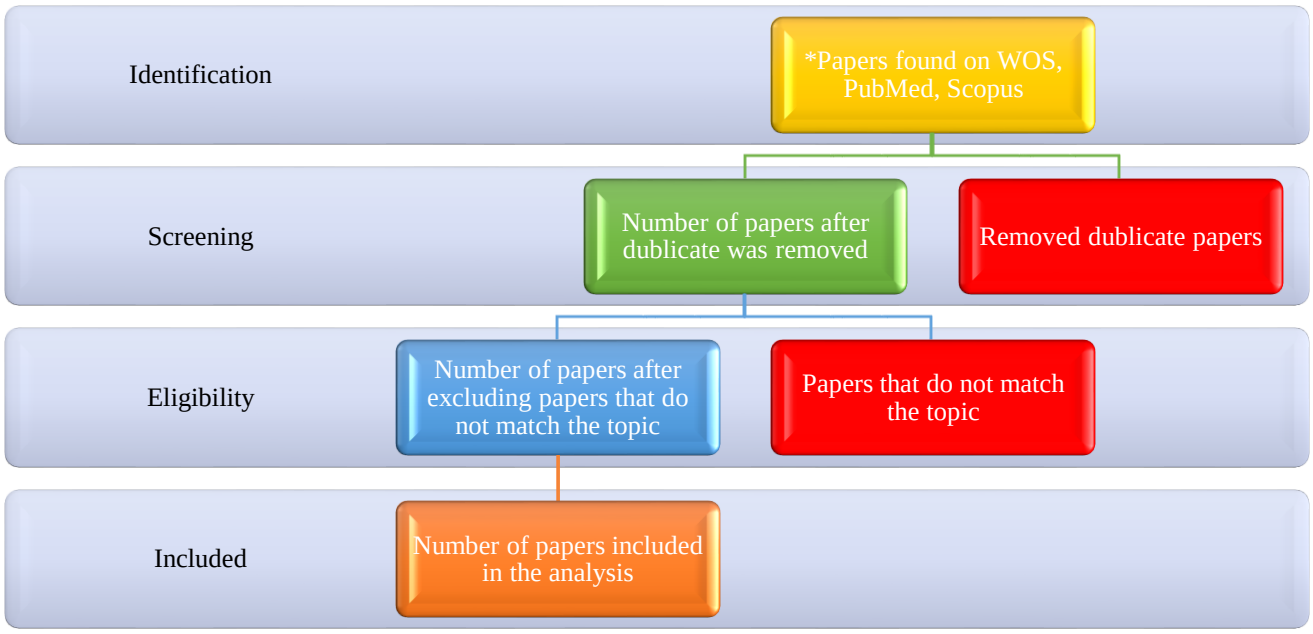
Moreover, it's important to emphasize the broader implications of shoulder injuries in swimmers. These injuries not only hinder an athlete's performance but can also have long-term consequences on their overall quality of life. Chronic shoulder pain and discomfort can affect everyday activities, potentially leading to the development of other musculoskeletal issues. Additionally, the economic burden of treating shoulder injuries and the potential loss of talented swimmers due to these injuries are areas of concern that underline the significance of this research. Therefore, understanding and addressing the risk factors for shoulder injuries in swimmers is not only a matter of sporting performance but also a matter of public health and financial significance.

METHODS

Research design

This study is a systematic review model, which is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards and aims to deduce a new conclusion about the current literature about the risk factors associated with shoulder injuries in swimmers [8].

Scheme of the reduction of papers found in the current literature:



**There were no exclusion criteria for quality because the search criteria were limited to WOS, PubMed, and Scopus.*

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Table 1. Papers related to risk factors associated with shoulder injuries in swimmers found in the current literature

Papers	Web of Science	Scopus	Total
Found papers	72	64	136
Matching topics	7	6	13
Topics that have conclusions about the risk factors associated with shoulder injuries in swimmers	7	6	13

While the total number of found papers is 136, just 13 papers cover the topic, and just 13 papers have a conclusion about the risk factors associated with shoulder injuries in swimmers. This means a lack of research related to risk factors associated with shoulder injuries in swimmers.

RESULTS

Table 2. Papers related to risk factors associated with shoulder injuries in swimmers found in Web of Science (WOS)

Source (authors, year, country, index)	Model and methods	Analyzed topic	Conclusion
Tavares N, Dias G, Carvalho P, Vilas-Boas JP, Castro MA (2022), Portugal, WOS [16]	Literature review	The objective of this review was to identify, evaluate, and compare exercise programs used to minimize musculoskeletal risk factors related to a swimmer's shoulder.	There is high heterogeneity and little methodological quality evidence about the theme. However, strength programs with five or fewer OKC exercises performed out of the water seem to lead to better results in the swimmer's shoulder prevention.
Wymore, Lucas, Reeve Robert E Chaput, CD, Christopher D (2012), USA, WOS [17]	All members of the top 25 NCAA men's swim teams were invited to complete the survey. Eleven teams with a total of 187 participants completed the study survey	The teams were mailed surveys that included multiple choice questions regarding their primary stroke and their incidence of shoulder pain. Additionally, the survey included questions about risk factors including distance training, type of equipment, weight training, and stretching.	This study found no significant correlation between stroke specialty and shoulder pain in male collegiate swimmers.
Yoma, Matias., Herrington, Lee., Mackenzie, Tanya A. (2023), England, WOS [18]	Literature 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 injured swimmers. Regarding risk factors, a strengthening program of more than 12 weeks increased shoulder external rotation peak force,	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 the methodological limitations of the studies, caution must be used when applying these results in practice.

		endurance, and external rotation/internal rotation ratio; however, this was not associated with a decrease in pain	
Tate,Angela.,Turner,Gregory N., Knab,Sarah E., Jorgensen,Colbie., Strittmatter,Andrew.,Michener,Lori A. (2012), USA, WOS [14]	A total of 236 competitive female swimmers aged 8 to 77. Swimmers were grouped by age for analysis: age 8 to 11 years, 12 to 14 years, 15 to 19 years, and 23 to 77 years.	Participants completed the Penn Shoulder Score and underwent testing of core endurance, range of motion, muscle force production, pectoralis minor muscle length, and the Scapular Dyskinesis Test.	Female competitive swimmers have shoulder pain and disability throughout their lives. Given the exposure and physical examination findings varied between athletes with and without substantial pain and disability, a program to prevent shoulder injury that might lead to pain and dysfunction appears warranted and might include exposure reduction, cross–training, pectoral and posterior shoulder stretching, strengthening, and core endurance training.
Mise,Takao., Mitomi, Yosuke., Mouri,Saki., Takayama,Hiroki.,Inoue,Yoshitomo., Inoue,Mamoru., Akuzawa,Hiroshi., Kaneoka, Koji.(2021), Japan, WOS [11]	The participants were competitive swimmers (n=76;37 males and 39 females) with a mean age of 14 years in Japan.	The shoulder rotation width, which was the index of shoulder complex mobility, shoulder internal and external rotation range, and middle finger distance of the back-scratch test were measured. An examiner regularly visited the swimming clubs to evaluate the development of shoulder pain in both female and male swimmers.	Hypomobility and hypermobility of the shoulder complex were identified as risk factors for shoulder pain in male and female swimmers, respectively.
Moeda,Frederico., Melo,Xavier., Hatia., Madjer.,Pinho,Sergio., Calado,Duarte., de Andrade,Miguel Rovisco., Tomas,Nuno., Barbosa,Jorge. (2023), Portugal, WOS [10]	This cross-sectional study was conducted at the Portuguese Open and Youth Swimming National Championships between 27 and 30th July 2022. A total of 102 swimmers out of 662 Portuguese athletes were included in the study.	Each athlete entered details regarding personal and training history into a questionnaire and underwent a physical and ultrasound shoulder examination.	A high prevalence of shoulder morphological changes was found in surveyed swimmers and there were several associations with training load, regardless of the individual characteristics of each athlete. It is essential to understand the true impact of current injury prevention programs and to develop effective measures to protect swimmers' health.
Feijen,Stef., Tate,Angela., Kuppens,Kevin., Claes,Anke., Struyf,Filip (2021), Belgium, WOS [9]	Literature review	Twelve studies (N=1460 participants) met the criteria. Swimmers were grouped by age for analysis: young (<15 years), adolescent (15-17 years), adult (18-22 years) and masters (23-27 years).	Evidence suggests that swim-training volume was associated with shoulder pain in adolescent competitive swimmers (level II conclusion). Year-round monitoring of the athlete's swim training is encouraged to maintain a well-balanced program. Developing athletes should be aware of and avoid a sudden and large increase in swimming

	volume. However, additional high-quality studies are needed to determine cutoff values to make data-based decisions regarding the influence of swim training.

Table 2, presents a collection of papers extracted from Web of Science underscoring their significant conclusions.

Table 3. Papers related to risk factors associated with shoulder injuries in swimmers found in WOS

Authors	Sample	Analyzed topic	Conclusion
Pollen, T.R., Warren, M., Ebaugh, D., Taylor, JA., Silfies, S.P. (2023), Philadelphia, Scopus [12]	Thirty-seven National College Athletic Association Division III swimmers (21 females, 16 males; median age = 19 years [interquartile range = 3 years], height = 175 ± 10 cm; mass = 70.0 ± 10.9 kg).	Participants completed preseason questionnaires on their previous injuries and perceived susceptibility to sports injury. At the beginning of the season, they completed the Movement System Screening Tool and the Freestyle Swimming Technique Assessment. Logistic regression was used to calculate odds ratios (ORs) with 95% CIs for the association between each risk factor and injury.	Previous injury, a crossover hand-entry position in freestyle, and a low perceived percentage chance of injury were associated with increased injury odds. Ascertaining injury histories and assessing for crossover positions may help identify swimmers with elevated injury risk and inform injury-prevention strategies.
Abdelmohsen , Salam Mohamed Elhafez, Bassam Ahmed Nabil (2021), Egypt, Scopus [15]	The study involved 30 swimmers, assigned to 2 equal groups. The experimental group (A) suffered from SSS; the control group (B) included healthy swimmers with no history of shoulder pain or instability. The mean values of age, body mass, and height were 12.86 ± 1.59 years, 41.73 ± 3.99 kg, and 142.0 ± 3.96 cm, respectively, in group A and 13.2 ± 1.56 years, 42.66 ± 3.9 kg, and 142.26 ± 4.39 cm, respectively, in group B.	Isokinetic peak torque (PT) for trunk flexors and extensors was measured with a Biodex isokinetic dynamometer. Four functional tests assessed core endurance: side bridge endurance test, static back endurance test, ball bridge test, and unilateral bridge test.	A weak core inhibits shoulder muscles, which is a major risk factor for shoulder instability and SSS. It is crucial to incorporate core stability training into the rehabilitation plan to provide proximal stability for obtaining safe and proper distal mobility across the shoulder joint.
Matias Yoma, Lee Herrington, Tanya Anne Mackenzie, Timothy Alejandro Almond	Sixteen asymptomatic national- and regional-level swimmers (7 females, 9 males; age = 14.6 ± 3.9 years, height = 160.5 ± 12.7 cm, mass = 55.3 ± 12.5 kg).	Bilateral active shoulder-rotation range of motion (ROM), joint position sense, latissimus dorsi length, combined elevation test, and shoulder-rotation isometric peak torque and handgrip peak force normalized to body weight were measured before and immediately after low- and high-intensity swim-	Shoulder active external-rotation ROM and rotation isometric peak torque were decreased immediately after a high-intensity training session, possibly increasing the risk of injury during subsequent training. Monitoring these variables may help

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(2023), England, Scopus [18]		training sessions. The intensity of the sessions was determined by the distance swum over or at the pace threshold and confirmed by the swimmer's rating of perceived exertion.	practitioners adjust and manage training loads to decrease the risk of shoulder injury.
Yuta Suzuki, Noriaki Maeda, Junpei Sasadai, Kazuki Kaneda, Taizan Shirakawa, Yukoi Urabe. (2020), Japan, Scopus [19]	A total of 60 subjects participated in this study, with 20 master swimmers with shoulder pain, 20 asymptomatic master swimmers, and 20 sex- and age-matched controls.	All swimmers completed a self-reported questionnaire for shoulder pain, their history of competition, and training volume. Each subject underwent ultrasonographic examination of both shoulders for pathologic findings in the LHB tendon, rotator cuff (supraspinatus (SSP) and subscapularis (SSC)) tendons, and subacromial bursa (SAB) of both shoulders and had thickness measured.	A high prevalence of structural changes in the rotator cuff and biceps tendons in master swimmers reflects the effect of shoulder symptoms, aging, and swim training.
Stef Feijen, Thomas Struyf, Kevin Kuppens, Angela Tate, Filip Struyf (2021), Belgium, Scopus [7]	A total of 201 pain-free club-to international-level competitive swimmers were followed for 2 consecutive seasons. The cohort consisted of 96 male (mean ± SD age, 13.9 ± 2.2 years) and 105 female (13.9 ± 2.2 years) swimmers	Demographic, sport-specific, and musculoskeletal characteristics were assessed every 6 months. Swim-training exposure was observed prospectively. Shoulder pain interfering with training was the primary outcome. Multiple imputation was used to cope with missing data. The final model was estimated using multivariable logistic regression. We applied to bootstrap to internally validate the model and correct for over-optimism.	Our model consists of parameters that are readily measurable in a swimming setting, allowing the identification of swimmers at risk for shoulder pain. Multivariable logistic regression showed the strongest predictors for shoulder pain were regional competitive swimming level, acute: chronic workload ratio, posterior shoulder muscle endurance, and hand entry error.
Hibberd, E.E., Myers, J.B (2013), USA, Scopus [13]	One hundred two swimmers, aged 13-18 years, at the top training level of their club team, were included in the study.	Participants were given a survey with questions regarding swimming practice and attitudes and behaviors concerning shoulder pain.	Club swimmers have a high frequency of practices, comparable to collegiate and professional swimmers. They believe that shoulder pain is normal and should be tolerated to complete practice. The association between the swimmers' attitudes and behaviors indicates that the interventions that educate the swimmers, coaches, and parents may be effective in changing their attitudes and ultimately their behaviors, decreasing the number of athletes who train with shoulder pain.

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Table 3 presents a collection of papers extracted from Scopus, underscoring their significant conclusions.

DISCUSSION

Through a comprehensive review of the literature and a primary search, a deeper understanding of the factors contributing to shoulder injuries in swimmers is elucidated. Each group of authors contributes with unique perspectives and insights, collectively forming a comprehensive approach to injury prevention.

From injury prevention strategies and training load management to shoulder mobility, swim technique, and psychological factors, these findings collectively reinforce the multifaced nature of shoulder injury prevention in the world of competitive swimming.

Firstly, Feijen et al. and Moeda et al. both discuss the impact of training load and the need for careful monitoring [9,10]. Considering Feijen et al.'s and Moeda et al.'s findings, it's evident that managing training loads is not just a formality but a critical aspect of injury prevention. Keeping a close eye on training volume and intensity is essential, especially for young athletes. On the other hand, Mise et al. and Moeda et al. both touch upon the significance of shoulder mobility and its relationship with shoulder injuries [10,11]. Based on Mise et al.'s and Moeda et al.'s research, maintaining good shoulder mobility is like armor against shoulder injuries. Swimmers should pay close attention to this aspect of their physical fitness to stay injury-free. Moreover, Pollen et al. and Hibberd and Myers discuss factors related to swim technique and psychological factors in injury prevention [12,13]. Considering Pollen et al., Hibberd and Myers's insights, it's not just about the physical aspects but also the mental ones. A swimmer's attitude towards pain and their past injury history can greatly impact their risk of future injuries. Education and psychological support are key components of an injury prevention strategy.

Lastly, researchers Tate et al. and Azza et al. both highlight the importance of injury prevention strategies in reducing shoulder injuries among swimmers [14,15]. Based on what Tate et al. and Azza et al. are saying, it's clear that a proactive approach to injury prevention is crucial for swimmers. Incorporating strategies like stretching, cross-training, strengthening, and core stability exercises can go a long way in safeguarding swimmers against shoulder injuries.

CONCLUSION

In conclusion, this literature review has provided a comprehensive overview of the main risk factors associated with shoulder injuries in swimmers. While we discussed various aspects in detail within the discussion section, the following points summarize the critical takeaways:

To begin with, training load and monitoring**,** swimmers must carefully manage their training loads, as evidenced by studies from Feijen et al. and Moeda et al. Monitoring training volume and intensity, especially in young athletes, is essential to reduce the risk of shoulder injuries. Additionally, mobility and morphological factors in Shoulder mobility play a pivotal role in injury prevention, according to research by Mise et al. and Moeda et al. Maintaining optimal shoulder mobility is vital for injury prevention among swimmers. Furthermore, swim technique and injury history**,** psychological factors, swim technique, and past injury history have a substantial impact on injury prevention, as highlighted in studies by Pollen et al. and Hibberd and Myers. Swimmers' attitudes towards

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pain and their mental well-being are as important as their physical condition.

Last but not least, Injury Prevention Strategies by Tate et al. and Azza et al. stress the significance of proactive injury prevention strategies. Incorporating stretching, cross-training, strengthening exercises, and core stability training is crucial for safeguarding swimmers against shoulder injuries.

In essence, shoulder injury prevention in swimmers demands a holistic approach that encompasses both the physical and mental aspects of the sport. This multifaceted approach involves managing training loads, maintaining training loads, shoulder mobility, considering stroke and psychological factors, and implementing effective injury prevention strategies. Further research and ongoing education in these areas will contribute to the continual refinement of injury prevention measures in competitive swimming, ultimately benefiting swimmers at all levels of the sport.

CONFLICT OF INTERESTS

No potential conflict of interest was reported by the authors.

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