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Systematic Review

Injury Patterns and Frequency in Swimming: A Systematic Review

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Abstract: Swimming is a widely practiced sport with significant physical demands, placing athletes at a considerable risk of injury, particularly in the shoulder, due to repetitive high-intensity movements. The aim of this systematic review was to analyze the patterns and frequency of injuries associated with swimming. Methods: A systematic search of the Web of Science, PubMed, Scopus, and SportDiscus databases identified nine relevant studies. Results: The findings revealed a higher incidence of injuries in female swimmers compared to males, with the shoulder being the most frequently affected joint. This disparity is partially attributed to the Female Athlete Triad, a syndrome characterized by low energy availability, menstrual dysfunction, and poor bone health, which increases injury susceptibility. Other commonly affected regions include the knee, often associated with the biomechanical demands of breaststroke, and the lumbar spine, which is impacted by degenerative changes resulting from high training volumes. However, variability in the injury measurement protocols across studies limits their comparability and highlights the need for standardized methods. Conclusions: Based on these findings, professionals in the field can identify injury patterns to enhance diagnosis and treatment, design personalized prevention programs, implement early interventions, and innovate equipment and training methods to improve swimmer safety and performance.

Keywords: injury prevention; rehabilitation; epidemiological study; risk factors

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1. Introduction

According to the 2022 Sports Habits Survey conducted by the Higher Sports Council [1], swimming ranked as the second most popular sport in Spain based on federative licenses, with 66,774 registered athletes. Its widespread practice across all age groups is attributed to its numerous health benefits, including its minimal stress on bones and joints, which make it a highly accessible activity for individuals of all ages [2]. Additionally, the survey reported that 57.35% of individuals over the age of 15 had participated in swimming during the last year.

Competitive swimming involved consistently high training volumes and intensities, with some swimmers covering up to 110 km per week and performing thousands of shoulder revolutions per session, typically across 10–12 sessions per week [3]. Consequently, swimming was not exempt from injury risks, particularly overuse injuries affecting the shoulder, elbow, knee, ankle, and back [4,5]. Among these, shoulder injuries were the most prevalent. A study by the National Collegiate Athletic Association (NCAA) revealed that 34.7% of injuries in collegiate male swimmers and 36.8% in female swimmers involved the shoulder [6]. Reported rates of shoulder injuries among competitive swimmers ranged from 40% to 91%, primarily due to repetitive overhead motions and the biomechanical demands of swimming [7]. Furthermore, overuse and non-contact injuries were more frequent in women, with 63.7% of injuries reported compared to 44.4% in men [6]. This difference was attributed to biomechanical factors, as female swimmers performed more arm revolutions per lap, thereby increasing their exposure to repetitive stress [8]. At the elite level, swimmers trained up to 14.5 km per day, completing more than 2500 shoulder revolutions daily, which significantly elevated their risk of musculoskeletal injuries [3].

Freestyle (commonly known as “crawl”) and butterfly strokes pose the highest injury risks among swimming styles, primarily due to the repetitive arm abduction and the elevation above the head required by these techniques [9,10]. The repetitive nature of these strokes places significant stress on the rotator cuff and scapular stabilizers, often leading to fatigue, reduced dynamic stability, and impingement syndromes [11]. The shoulder joint, which plays a crucial role in swimming, is characterized by its extensive range of motion and is supported by ligaments such as the glenohumeral and coracohumeral [12]. Despite this support, muscular coordination is essential to maintaining joint stability. Research highlights the importance of shoulder range of motion (ROM), along with a balance between strength and flexibility, as deficits in these areas increase the risk of conditions such as scapular dyskinesis and “swimmer’s shoulder” [13].

In contrast, breaststroke swimmers are more prone to knee injuries due to the valgus and rotational forces generated during the whip kick, commonly referred to as “breaststroker’s knee” [14]. Both butterfly and breaststroke styles are also associated with an increased risk of lumbar spine injuries, as the hyperextension required to maintain a streamlined position places considerable load on the posterior structures of the lower back [15]. The cyclical nature of swimming, combined with high training loads, technical precision, and strength demands, further increase the risk of injury, particularly to the shoulder, knee, and lumbar spine [16,17].

McKenzie et al. [18] synthesized the findings from 22 studies on shoulder pain in competitive swimmers, highlighting the moderate evidence that associated competitive level training and altered muscle recruitment with pain, while factors such as range of motion and training frequency showed no significant association. Similarly, Hill et al. [19] reviewed 29 studies to assess the risk factors for shoulder pain and injury, identifying clinical joint laxity, internal/external rotation, previous pain history, and competitive level training as moderately certain contributors, though no factors were deemed highly certain. These findings aligned with Barry et al. [20], who found no direct link between training load and pain, but suggested a potential connection to injuries and illnesses, while also emphasizing the methodological limitations. Additionally, Trinidad et al. [17] reported a higher injury incidence in female swimmers due to anatomical, biomechanical, physiological, and psychological factors, while Tate et al. [21] observed improvements in posterior shoulder endurance alongside reductions in disability with increased training load, albeit with decreases in internal rotation and horizontal adduction, which predisposed swimmers to overuse injuries.

Despite extensive research on swimming injuries, systematic analyses of injury patterns and frequencies in regions beyond the shoulder, such as the knee and lumbar spine, remain scarce. Moreover, variability across swimming styles, competitive levels, and populations, along with the impact of specific training practices and equipment use, still require further investigation. Addressing these gaps could provide critical insights to improve injury prevention and management in swimming. The aim of this systematic review was to analyze the patterns and frequency of injuries associated with swimming. The findings could provide valuable insights to support injury prevention strategies and improve the overall health and performance of swimmers.

2. Materials and Methods

2.1. Protocol and Registration

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [22]. The protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) on 14 September 2024, under the registration number CRD42024586463. The registration ensured transparency and methodological rigor throughout the review process. The PRISMA checklist guided the design, implementation, and reporting of this review, ensuring compliance with the established best practices for systematic reviews.

2.2. Eligibility Criteria

This review followed the Population, Intervention, Comparison, Outcomes, and Study Design (PICOS) framework to establish the eligibility criteria. Studies were included if they focused on swimming-related sports injuries and provided detailed descriptions of the types of injuries, including participant demographics such as age, sex, and competitive level (e.g., amateur, collegiate, elite). Eligible studies were observational or experimental, with outcomes reporting the injury characteristics, prevalence, or associated risk factors. Only peer-reviewed primary research articles published in scientific journals were considered for inclusion.

Studies were excluded if they combined interventions from multiple sports, did not specifically address swimming injuries, or were reviews (e.g., systematic or narrative) or non-research articles such as books, theses, or conference abstracts. Animal studies or biomechanical analyses not involving human participants were also excluded. These criteria ensured the selection of studies with a clear focus and methodological rigor, allowing for a comprehensive synthesis of the evidence.

2.3. Search Strategies

A systematic search was conducted across four electronic databases—WoS, PubMed, Scopus, and SportDiscus—from their inception dates up to 4 March 2024. Boolean operators and Medical Subject Heading (MeSH) terms were utilized to optimize the search queries, combining terms such as "swimming [title]" and "injur* [title]". Search strings were tailored to each database's specific syntax and indexing system to ensure a comprehensive retrieval of relevant studies. No restrictions regarding language or publication date were applied.

In addition to the database searches, the reference lists of the included studies and relevant reviews were manually screened to identify additional articles that might meet the eligibility criteria. All records retrieved were independently assessed by two reviewers, who screened titles, abstracts, and full texts for relevance and eligibility. Disagreements between the reviewers were resolved through consultation with a third reviewer. A standardized form was used to document eligibility decisions, ensuring consistency and transparency throughout the selection process.

The search and screening process is summarized in Figure 1, which details the number of records identified, screened, and included at each stage. Full search strategies for each database, including specific search terms and filters, are available upon request.

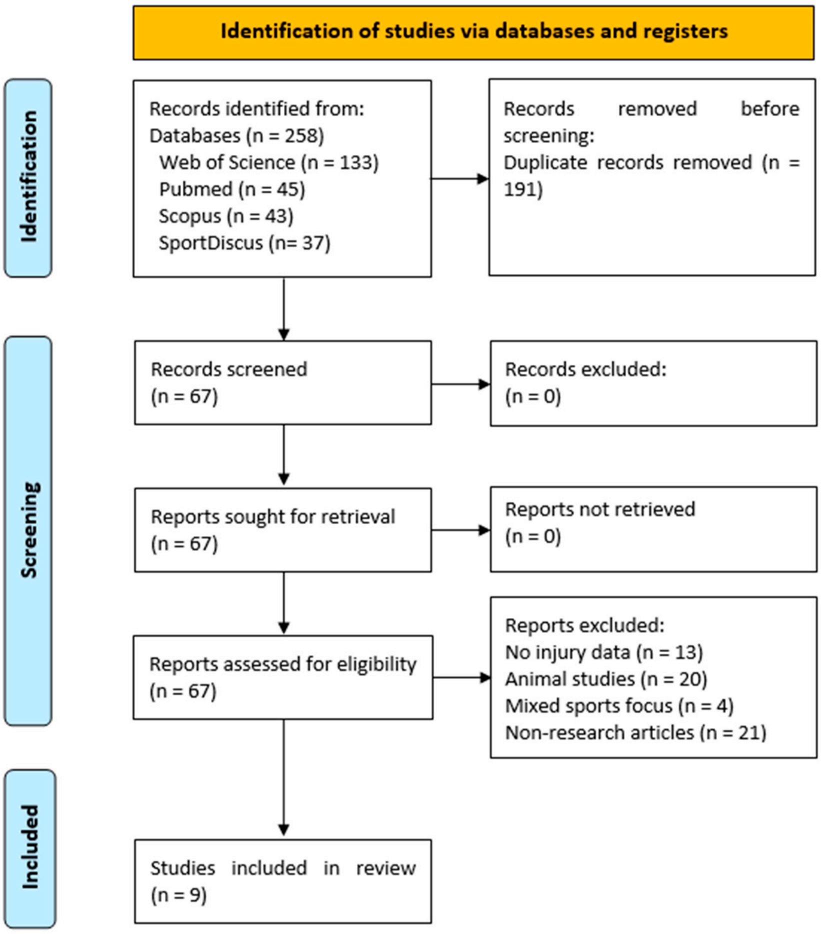

Figure 1. Flowchart of the study selection process.

2.4. Study Selection

The study selection process was conducted independently by two reviewers who evaluated all retrieved records for their relevance and eligibility based on the predefined inclusion and exclusion criteria. Titles, abstracts, and keywords were initially screened. In cases where the abstract did not provide sufficient information or if there was a disagreement between the reviewers, the full text was retrieved for further evaluation.

Full-text articles were carefully assessed against the eligibility criteria, with decisions documented in a standardized form to ensure consistency and transparency. Any disagreements between the reviewers were resolved through discussion, and when necessary, a third reviewer was consulted to reach consensus.

To streamline and organize the selection process, EndNote x9 (Clarivate Analytics, Philadelphia, PA, USA) reference management software was used to handle citations and track inclusion decisions systematically. The outcomes of the study selection process are summarized in Figure 1, providing a detailed overview of the number of records screened, excluded, and included at each stage.

2.5. Data Extraction

Data extraction was independently conducted by two reviewers using a standardized form specifically designed for this review. The extracted data included details on study characteristics (e.g., authors, year of publication, study design), population information (e.g., number of participants, age, sex, swimmer level), and injury-related data (e.g., prevalence, types of injuries, predominant injuries, and associated risk factors). In cases of disagreement, a third reviewer was consulted to reach a consensus.

To ensure consistency and accuracy, the references were managed using EndNote EndNote x9 (Clarivate Analytics, Philadelphia, PA, USA). Regular discussions were held between reviewers to address and resolve any discrepancies during the extraction process. Additionally, missing or unclear information was clarified by contacting the corresponding authors of the included studies when necessary.

The extracted data were organized and coded in Microsoft Excel (Microsoft Corp. Redmond, WA, USA) for further analysis and synthesis, providing a systematic approach to collating and interpreting the results.

2.6. Quality Assessment

The methodological quality of the included studies was assessed using the Physiotherapy Evidence Database (PEDro) scale, a widely recognized tool for evaluating the internal validity and methodological rigor of randomized controlled trials (RCTs). The PEDro scale consists of 11 items (Table 1), each assessing the critical aspects of trial design and execution. The first item was not included in the final score, and each remaining item was rated as "yes" (1 point) or "no" (0 points), resulting in a maximum possible score of 10 points. For this review, a score of 6 or higher was considered indicative of moderate to good quality.

Table 1. Item scores and final PEDro scale rating for studies included in the systematic review.

Study	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	PT
de Almeida et al. (2015) [2]	1	0	0	1	0	0	0	1	1	1	1	6/10
Knobloch et al. (2008) [9]	1	1	0	1	0	0	0	1	1	1	1	7/10
Aguiar et al. (2010) [10]	1	0	0	1	0	0	0	1	1	1	1	6/10
Witkoś et al. (2022) [16]	1	1	0	1	0	0	0	1	1	1	1	7/10
Wolf et al. (2009) [23]	1	0	0	0	0	0	0	1	1	1	1	5/10
Salerno et. (2022) [24]	1	1	0	1	0	0	0	1	1	1	1	6/10
Chase et al. (2013) [25]	1	0	0	1	0	0	0	1	1	1	1	6/10
Mountjoy et al. (2010) [26]	1	1	0	0	0	0	0	1	1	1	1	6/10
Atilla et al. (2020) [27]	1	1	0	1	0	0	0	1	1	1	1	7/10

P1. eligibility criteria; P2. random allocation; P3. concealed allocation; P4. similar groups at baseline; P5. blinding of subjects; P6. blinding of therapists; P7. blinding of assessors; P8. adequate follow-up; P9. intention-to-treat analysis; P10. between-group comparisons; P11. point measures and variability; and PT. total PEDro Scale score.

Two independent reviewers performed quality assessments. Discrepancies were resolved through consensus, and when necessary, a third reviewer was consulted. To ensure reliability, Cohen's kappa index was calculated, resulting in a value of 0.918 (95% CI: 0.852–0.984), which indicated an almost perfect level of agreement. This approach ensured a consistent and highly reliable evaluation process.

3. Results

3.1. Included Studies

A total of 258 studies were initially identified from four databases: WoS (n = 133), PubMed (n = 45), Scopus (n = 43), and SportDiscus (n = 37). After the removal of 191 duplicates, 67 records remained for screening. No studies were excluded based on their titles and abstracts, and all 67 full-text articles were retrieved for further assessment. Out of these, fifty-eight studies were excluded for not meeting the eligibility criteria: thirteen studies did not report injury data, twenty were animal-based studies, four had a mixed sports focus, and twenty-one were non-research articles (e.g., abstracts, books, theses). Ultimately, nine studies met the inclusion criteria and were included in this systematic review. The study selection process is outlined in Figure 1.

3.2. Methodological Quality

The results of the methodological quality assessment of the included studies (Table 1) showed that most studies achieved an average score of 6 to 7 points. This moderate score reflected the inherent challenges of blinding both participants and evaluators to the measured variables. Nevertheless, the studies met most of the other criteria on the PEDro scale.

Among the analyzed studies, four achieved the highest score of 7/10 [9,16,24,27], five obtained a score of 6/10 [10,24–26], and one had the lowest score of 5/10 [2]. According to the criteria proposed by Maher et al. [28], a score of 5/10 or higher was indicative of a high methodological quality, which applied to all of the reviewed studies.

3.3. Participants, Age, and Gender

A total of 2550 participants were analyzed across the included studies, with 1114 women (42.33%) [2,9,10,16,23,25,26], 1436 men (57.85%) [2,9,10,23,25–27], and 21 participants from a mixed-gender group (0.82%) [24].

Regarding sample size, six studies (n = 6, 66.66%) included more than 60 swimmers [2,9,10,16,26,27], while three studies (n = 3, 33.33%) analyzed smaller cohorts with fewer than 60 participants [23–25].

Most of the studies focused on participants aged between 19 and 25 years (n = 7, 77.77%) [2,9,10,16,24–26]. However, one study (n = 1, 11.11%) reported a mean participant age of 47.1 $\pm$ 13.2 years [27]. In another study by Wolf et al. [23], the participant age was not provided as specific numerical values but categorized into academic levels as follows: "freshman", "sophomore", "junior", and "senior" (Table 2). These levels are part of the recreationally active group, representing the progression and growing commitment of those who engage in physical activity casually and for recreational purposes.

3.4. Swimmer Level

The majority of the studies analyzed focused on elite-level swimmers (n = 6, 66.66%) [2,9,10,25–27], while two studies (n = 2, 22.22%) included trained swimmers who did not compete at the elite level [16,24]. Additionally, one study (n = 1, 11.11%) analyzed swimmers at the recreationally active level, which in this case aligns with the academic courses corresponding to the levels 'freshman', 'sophomore', 'junior', and 'senior' in the American education system [23].

3.5. Injury Prevalence

The injury prevalence in most of the analyzed studies was reported either as incidence per 1000 h of exposure (n = 4, 44.44%) [9,23,25,26] or as the number of injuries occurring over a 12-month period (n = 4, 44.44%) [2,10,16,24]. Among the studies reporting injury prevalence over 12 months, the injury rate was consistent across three studies at 53% (n = 3, 75%) [2,10,24]. However, one study (n = 1, 25%) reported a higher prevalence, with 76.69% of swimmers experiencing at least one injury in the previous 12 months [16]. One study did not specify the prevalence of injuries among swimmers, limiting its comparability with other findings (n = 1, 11,11%) [27].

Table 2. Study characteristics.

Study	S (n)/ Gender	Participant Age	Level	Prevalence of Injury	Anatomical Location	Type of Injury	Injury Measure	Training Load (Meters per Day)
de Almeida et al. (2015) [2]	140 M 117 F	20.6 ± 3.7	Elite and NT	12 months 56% ≥ 1 I	Ankle (4.9%) Elbow (4.2%) Knee (16%) L. back (6.2%) Shoulder (46.5%)	Ligamentous rupture (6.7%) Meniscus tear (6.7%) Muscle strain (7.7%) Tendinitis (58.7%)	Author Devel—Q	12,000 ± 2000 m 4–6 days
Knobloch et al. (2008) [9]	141 M 155 F	19 ± 10 18.3 ± 9.6	Elite and NT	UL (0.106 I/1000 h)	Hip (3.2%) Knee (30.8%) Shoulder (49.9%) Trunk (13.4%)	Knee tear (27.6%) Muscle strain (49%) Overuse injuries (71.7%)	Author Devel—Q	12,000 ± 2000 m 4–6 days
Aguiar et al. (2010) [10]	135 M 80 F	19.76 ± 2.79	Elite and NT	12 months 56.3% ≥ 1 I	Knee (13.56%) L. back (15.25%) Shoulder (47.46%) Upper arm [1] (5.08%)	Tendinitis (no data) Muscle or tendon strain (no data)	Author Devel—Q	12,000 ± 2000 m 4–6 days
Witkoś et al. (2022) [16]	64 F	24.69 ± 2.15	Trained	12 months 76.69% ≥ 1 I	Ankle (6.45%) Elbow (4.30%) Knee (27.96%) Shoulder (36.56%)	Joint inflammation (31.58%) Knee contusion (12.63%) Ligamentous injury (5.26%) Meniscus tear (15.79%) Muscle strain (27.37%) Overuse injuries (52.1%)	Author Devel—Q Questionnaire LEAF-Q	5000 ± 2000 m 3 days
Wolf et al. (2009) [23]	44 M 50 F	"freshman" [2] "sophomore" [2] "junior" [2] "senior" [2]	Recreationally active	M (3.78 I/1000 h) F (4 I/1000 h)	Shoulder (36%) Upper arm [1] (31%)	Impingement (no data) Overuse injuries (no data) Tendinitis (no data)	SIMS-Med Sport Systems	No data
Salerno et. (2022) [24]	21 both	19.4 (range 14–30)	Trained	12 months 52.4% ≥ 1 I	Ankle (4.8%) Knee (4.8%) Shoulder (23.8%) Upper arm [1] (9.5%)	Muscle or tendon strain (no data) Tendinitis (no data)	Author Devel—Q Skype interview	4100 ± 2000 m 3 days
Chase et al. (2013) [25]	16 M 18 F	19.5	Elite and NT	M (2.74 I/1000 h) F (3.32 I/1000 h)	Ankle (12.9%) Knee (12.9%) L. back (16.1%) Shoulder (38.7%)	Knee tear (25.8%) Knee sprain (ACL y LCL) (6.5%) Tendinitis/impingement (58%)	Author Devel—Q	12,000 ± 2000 m 4–6 days

Table 2. *Cont.*

Study	S (n)/ Gender	Participant Age	Level	Prevalence of Injury	Anatomical Location	Type of Injury	Injury Measure	Training Load (Meters per Day)
Mountjoy et al. (2010) [26]	872 M 630 F	19.5 ± 1.4	Elite and NT	M (52.1 I/1000 S) F (65.6 I/1000 S)	Knee/hip (27.5%) Shoulder (36.8%) Trunk (16.4%)	Tendinitis and shoulder impingement (24%)	Author Devel—Q	12,000 ± 2000 m 4–6 days
Atilla et al. (2020) [27]	88 M	47.1 ± 13.2	Elite and NT	No data	Ankle (2.3%) Elbow (9.1%) Hip (5.7%) Knee (19.8%) L. back (26.7%) Shoulder (35.6%)	ACL rupture (6.6%) Ankle sprain (2.2%) Lumbar disc injury (18.3%) Meniscus injury (2.2%) Tendinitis and shoulder impingement (22.7%)	Author Devel—Q	10,081 ± 7601.8 m 4–6 days

S = sample; M = male; F = female; NT = national team; NCAA = National Collegiate Athletic Association; L/h = injury per hour; L/S = injury per swimmer; I = injury; L.back = lower back; UL = upper limb; ACL = anterior cruciate ligament; LCL = lateral collateral ligament; LEAF-Q = Low Energy Availability in Females Questionnaire; Author Devel—Q = Author Development Questionnaire; SIMS-Med: Integrated Monitoring and Tracking System for Sport Medicine; [1] Upper arm = biceps brachii, brachialis, and triceps brachii; [2] the levels ‘freshman’, ‘sophomore’, ‘junior’, and ‘senior’ correspond to the academic years in the American education system and form part of the recreationally active group, representing progression and engagement in physical activity at a casual level; m = meters.

3.6. Injury Region

All studies included in this review consistently identified the shoulder as the joint with the highest incidence of injuries among swimmers (n = 9, 100%) [2,9,10,16,23–27]. The knee was reported as the second most affected region in four studies (n = 4, 44.44%) [2,9,16,26], followed by the lower back (lumbar region) in three studies (n = 3, 33.33%) [10,25,27]. Additionally, two studies (n = 2, 22.22%) highlighted the upper arm, including the biceps brachii, brachialis, and triceps brachii, as the second most affected region [23,24].

3.7. Injury Type

There was considerable variability in the types of injuries reported across studies. Tendinitis and shoulder impingement were identified as the most common injuries in six studies (n = 7, 77.77%) [2,10,23–27], while overuse injuries were highlighted in three studies (n = 3, 33.33%) [9,16,23]. Additionally, shoulder muscle strain was frequently noted as the second most common type of injury, appearing in four studies (n = 5, 55.55%) [2,9,10,16,24].

For the knee joint, the second most affected region, the reported injuries included meniscal tears [2], knee tears [9,25], anterior cruciate ligament (ACL) and lateral collateral ligament (LCL) sprains [25], and ACL ruptures [27].

3.8. Injury Measurement

The primary tool used to measure injuries in the majority of the analyzed studies was the questionnaire (n = 8, 88.88%) [2,9,10,16,24–27]. One study employed the SIMS-Med Sport Systems (SIMS; FlanTech, Iowa City, IA, USA) software program (n = 1, 11.11%) [23], which provided an alternative approach to data collection. Additionally, Witkoś et al. [16] utilized the Low Energy Availability in Females Questionnaire (LEAF-Q) to analyze injury prevalence specifically in female swimmers.

3.9. Training Load

Elite-level swimmers train an average of 12,000 ± 2000 m, with a frequency of 4 to 6 days a week, depending on the phase of the training cycle they are in (n = 6–66.66%) [2,9,10,25–27]. The trained level of swimmer trains an average of 5000 ± 2000 m, with a frequency of 3 days per week (n = 2–22.22%) [16,24]. No specific data on training load was found for the recreationally active level (n = 1–11.11%) [23].

4. Discussion

4.1. Main Findings

The primary finding of this review is the higher incidence of injuries in female swimmers compared to male swimmers, with the shoulder being the most affected joint. This aligns with the findings of De Almeida et al. [2], who reported shoulder injuries in 48% of female swimmers compared to 41.4% of males. Several factors, including physiological and hormonal differences, contribute to this discrepancy. The prevalence of the Female Athlete Triad (FAT), which is characterized by low energy availability, menstrual dysfunction, and poor bone health, is a significant risk factor [29]. Up to 47% of female swimmers exhibit all three components of FAT [29,30], which triples their risk of stress fractures compared to athletes without this condition [31,32]. Hormonal fluctuations during the menstrual cycle further exacerbate this risk by temporarily affecting muscle strength, joint stability, and neuromuscular control [33,34].

4.2. Factors Contributing to Injury Risk

The increased injury risk in female swimmers is influenced by multiple factors, including biomechanics, training load, and competition level. Shorter limb lengths in female swimmers result in a higher stroke count per distance, increasing joint stress and the likelihood of overuse injuries [17,20]. Additionally, lower muscular strength and altered movement patterns place greater strain on the shoulder, which endures continuous cyclical loading during swimming [17,20].

The level of competition significantly influences the injury prevalence and anatomical distribution. Elite swimmers exhibit the highest injury rates, particularly shoulder tendinitis, impingement, and knee injuries, primarily due to higher training volumes and repetitive overhead motions [2,9,10,25–27]. Trained (non-elite) swimmers also experience frequent shoulder and knee injuries; however, their injuries are more often related to joint inflammation and cumulative overuse rather than acute damage [16,24]. In contrast, recreational swimmers present a lower overall injury prevalence, though shoulder impingement and tendinitis remain common [23]. Additionally, elite swimmers show a higher prevalence of degenerative changes in the lumbar spine compared to recreational athletes, reinforcing the long-term impact of high training loads [24].

Improper training load management—both excessive and insufficient—can increase the injury risk by disrupting the balance between stress and recovery [17,20]. High-intensity periods, particularly during competitions, may expose female swimmers to greater risks due to cumulative fatigue and hormonal fluctuations, which can compromise joint stability and neuromuscular control [17,20]. Additionally, repetitive movements, including shoulder rotations, turns, and push-offs, contribute to progressive tissue strain.

Preventive Strategies

Given these risk factors, structured injury prevention approaches are essential. Individualized training load management can mitigate cumulative stress, while stroke technique optimization may reduce joint strain. Targeted strength programs focusing on the shoulder, knee, and lumbar spine can enhance stability, and structured recovery protocols, including periodized rest and mobility exercises, may help to counteract fatigue and repetitive stress effects. To specifically address the FAT, training programs should integrate nutritional strategies to ensure adequate energy availability, menstrual health monitoring, and bone health assessments. Female swimmers at risk of FAT may benefit from adjusting their training loads during periods of low energy availability and implementing strength-based interventions to enhance bone mineral density and joint stability. Additionally, educational programs for athletes and coaches on the early detection of FAT symptoms could help to prevent long-term health consequences.

4.3. Shoulder Injuries

This review confirms that the shoulder is the joint most frequently affected in swimmers, accounting for 39.04 ± 1.95% of injuries across the analyzed studies [3,7]. This aligns with findings by Sein et al. [7], where 91% of elite swimmers reported shoulder pain, and 69% of those undergoing imaging exhibited supraspinatus tendinopathy. The shoulder's biomechanical role in swimming, contributing to approximately 90% of forward propulsion [25], predisposes it to overuse injuries such as rotator cuff impingement, tendinitis, and instability [2,7]. Repetitive overhead motions in swimming, combined with high training volumes, increase the injury risk [25,26].

Moreover, factors such as muscular imbalances, excessive joint laxity, and poor technique further exacerbate the risk of shoulder injuries [17,20]. Specific styles of swimming, such as freestyle and butterfly, involve extensive internal rotation and adduction of the shoulder, which increase strain on the rotator cuff [25]. Differences in stroke mechanics, such as unilateral versus bilateral breathing, may create asymmetrical loading, increasing injury risk [17,20].

These findings underscore the necessity of tailored preventive strategies. Effective interventions should focus on managing training loads, correcting stroke mechanics, and implementing shoulder-specific strength and mobility exercises. Such approaches are critical for minimizing overuse injuries and optimizing performance in competitive swimmers.

4.4. Other Regions Affected

While the shoulder remains the most injured region among swimmers, this review also underscores the knee and lumbar spine as prevalent sites of injury. Degenerative meniscal tears were the most frequently reported knee injury, accounting for 16.50 $\pm$ 0.83% of cases [24,29]. These injuries are often linked to the biomechanical demands of the breaststroke, which impose rotational and valgus stresses on the knee joint [35]. Such findings align with the work of Salerno et al. [24], who emphasized that the repetitive nature of the breaststroke kick, particularly when performed with improper technique or high intensity, amplifies knee joint stress and predisposes swimmers to overuse injuries.

Regarding the lumbar spine, this review identified a high prevalence of disc degeneration, being reported in 68% of elite swimmers compared to 29% of recreational swimmers [24]. This disparity reinforces the influence of training intensity, duration, and cumulative load on spinal health. Previous studies attributed lumbar spine degeneration to the hyperextension and rotation required to maintain a streamlined body position, particularly in strokes such as butterfly and freestyle [35]. Butterfly and freestyle strokes place high stress on the lumbar spine because of the required hyperextension and rotation. Additionally, repeated flip turns and wall push-offs contribute to cumulative spinal load, increasing the risk of chronic pain and degenerative changes [24,35].

These findings underscore the necessity of targeted injury prevention strategies. For the knee, emphasis should be placed on optimizing breaststroke technique, improving lower limb strength, and reducing valgus stress through specific conditioning programs. For the lumbar spine, incorporating core stabilization exercises, monitoring training volume, and ensuring adequate recovery are critical to mitigating injury risks in competitive swimmers, especially those exposed to prolonged and intense training loads.

4.5. Injury Prevalence and Measurement

Injury prevalence was reported inconsistently across the analyzed studies, employing diverse metrics such as injuries per 1000 h of exposure or the percentage of athletes injured over a 12-month period. This inconsistency aligns with findings from previous systematic reviews [17], where the lack of standardized reporting frameworks complicates direct comparisons across studies. This variability underscores the need for standardized injury surveillance methods to improve data comparability in swimming research.

Injury rates were consistently reported to be higher during competitions than training, likely due to the increased intensity, physical demands, and cumulative overload associated with competitive events [36,37]. These findings emphasize the need for load management strategies during competitive periods to mitigate the heightened injury risk.

The primary tools for injury measurement across the reviewed studies were questionnaires, which, although widely used for their feasibility and standardization, may not capture the multifactorial nature of injuries or subclinical issues effectively [25,38]. For example, while the LEAF-Q offers a targeted approach to assessing risks related to the FAT [29], it lacks sensitivity for identifying broader biomechanical or overuse injuries. Conversely, technological tools such as SIMS-Med Sport Systems provide a more dynamic approach, enabling real-time injury monitoring and the longitudinal tracking of athletes' health [23]. Despite their potential, such tools remain underutilized in swimming research.

Future studies should focus on integrating wearable sensors, digital tracking systems, and validated questionnaires for a more accurate injury assessment. These innovations can significantly enhance the accuracy, comparability, and depth of injury data, facilitating the development of tailored preventive strategies and contributing to evidence-based interventions.

4.6. Limitations and Future Directions

This review has several limitations. One major challenge is the variability in injury prevalence reporting due to differences in study designs, injury definitions, and data collection protocols, which complicate direct comparisons. Additionally, the limited number of epidemiological studies on swimming injuries restricts the ability to estimate incidence and risk factors, with most research focusing on elite swimmers, reducing the generalizability of the findings to other populations.

To improve comparability, future studies should adopt standardized injury surveillance protocols, defining clear criteria for injury diagnosis, severity classification, and exposure metrics (e.g., injuries per 1000 training hours). The use of validated injury-specific questionnaires, real-time monitoring tools (e.g., SIMS-Med Sport Systems), and international guidelines such as the Oslo Sports Trauma Research Center (OSTRC) questionnaire would enhance data reliability. Additionally, integrating wearable sensors could facilitate long-term injury tracking and improve cross-study comparability.

Future research should also expand to include recreational-, youth-, and master-level swimmers to improve generalizability. Longitudinal studies tracking swimmers over time would provide better insights into training load, injury progression, and rehabilitation effectiveness. Lastly, investigating how technological advancements in swimwear and training equipment impact injury prevention could offer practical applications for reducing overuse injuries.

By addressing these gaps and standardizing reporting methods, future research can improve injury surveillance, prevention strategies, and long-term athlete health.

5. Conclusions

This review underscores the high prevalence of injuries in swimmers, with the shoulder being the most frequently affected joint due to the biomechanical and physiological demands of the sport. Female swimmers show a disproportionately higher injury incidence, likely influenced by hormonal and biomechanical factors, as well as the FAT, which exacerbates injury risks. Additionally, the knee and lumbar spine emerge as critical injury sites, particularly in specialized strokes like breaststroke, which impose unique mechanical stresses.

Despite these findings, the lack of standardized injury measurement protocols and the variability in data reporting across studies hinder the comparability and generalizability of results. Future research should prioritize the implementation of unified injury surveillance frameworks and explore the integration of advanced technologies, such as wearable sensors and real-time tracking systems. These steps will provide deeper insights into injury mechanisms, facilitate the development of tailored preventive strategies, and ultimately contribute to enhancing the health, safety, and performance of swimmers across all levels.

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