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SPINAL DEFORMITIES AND INJURIES IN COMPETITIVE SWIMMING: A SYSTEMATIC REVIEW

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Abstract

Competitive swimming is traditionally considered a low-impact sport; however, repetitive stroke mechanics, high training volumes, and stroke-specific lumbar loading patterns may contribute to spinal malalignment, lumbar intervertebral disc degeneration (LDD), and low back pain (LBP). Emerging evidence suggests that these risks may be particularly relevant for adolescent and young adult swimmers who undergo early and intensive training. Our study systematically reviewed the literature on spinal posture, lumbar disc degeneration, and low back pain in competitive swimmers aged 6–25 years, and identified key risk factors and preventive strategies.

A systematic search of Google Scholar, Scopus, and PubMed was conducted in accordance with PRISMA guidelines. Eligible studies included cross-sectional, case-control, and cohort designs published between 2005 and 2024 that involved competitive swimmers with ≥2–3 years of training and ≥3 weekly sessions. Outcomes of interest were spinal posture abnormalities, MRI-confirmed LDD, and LBP prevalence. Eight studies met the inclusion criteria. Methodological quality was assessed using the Mixed Methods Appraisal Tool (MMAT).

Across studies, swimmers exhibited a higher prevalence of postural deviations—including hyperkyphosis, hyperlordosis, trunk asymmetry, and anterior pelvic tilt—compared with non-athletes. MRI-based studies consistently report elevated rates of LDD among swimmers, particularly at L4–L5 and L5–S1, with degeneration present in up to 68% of elite swimmers, compared with 29–31% of controls. LBP was identified as the second most common musculoskeletal complaint among swimmers, with an increased risk associated with greater training exposure and strokes that involve repetitive lumbar flexion–extension (e.g., butterfly, breaststroke). Contributing factors included early specialization, muscular imbalances, and technical inefficiencies. Methodological limitations included small sample sizes and predominantly cross-sectional designs.

Competitive swimming is associated with increased rates of spinal postural abnormalities, lumbar disc degeneration, and low back pain in youth and young adult athletes. Early screening, core stabilization, stroke technique optimization, and training load management are essential to mitigate spinal stress. Longitudinal research is needed to clarify causal pathways and inform evidence-based prevention strategies.

Keywords: *competitive swimming, spinal deformities, injuries*

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INTRODUCTION

Swimming, a globally popular sport practiced by millions at recreational and competitive levels, is widely recognized as a highly beneficial activity for overall health. Its unique benefits stem from the distinctive nature of aquatic movement, the buoyant and resistive properties of water, and the biomechanical and physiological responses it elicits, which differ markedly from those of land-based activities (BÍRÓ et al., 2007). As a low-impact, endurance-driven sport, swimming is frequently recommended in clinical rehabilitation settings, particularly for managing lumbar spine conditions, such as chronic low back pain and degenerative disorders (SHI et al., 2018). Sport's ability to support the body while engaging multiple muscle groups makes it an ideal therapeutic exercise, promoting cardiovascular fitness and muscular strength without excessive joint stress.

Competitive swimming demands sustained moderate-to-high-intensity effort in a fluid medium, requiring distinct adaptive movement patterns from those in terrestrial sports. Swimmers must coordinate muscular activity to maintain a streamlined body position throughout the stroke cycle, optimizing efficiency and reducing drag (TÓVÁRI - PRISZTÓKA, 2015). Effective propulsion relies on a synchronized kinetic chain, where a strong, stable core is critical for maintaining lumbar spine alignment and facilitating efficient force transfer across the trunk, shoulders, and hips (MCLEOD, 2010). The absence of a fixed base in water necessitates continuous activation of core and stabilizing muscles, placing unique biomechanical demands on the lumbar spine and surrounding musculature, which may contribute to injury risk over time.

Although water's buoyancy reduces axial loading on joints, competitive swimming is associated with a high incidence of overuse injuries due to repetitive stroke cycles, intense training volumes, suboptimal technique, and muscular imbalances, challenging its low-impact reputation (MCLEOD, 2010; POLLARD - FERNANDEZ, 2004). The shoulder, lumbar spine, and knees are the most frequently affected areas, with repetitive motions and sustained muscular demands contributing to tissue stress. Historically, shoulder injuries have dominated injury prevention efforts, but recent research highlights lumbar spine injuries as a significant and growing concern among competitive swimmers (HILL - MOUNTJOY, 2021).

Spinal injuries are the second most common musculoskeletal complaint in swimmers, following shoulder injuries (HSU et al., 2024a; HILL - MOUNTJOY, 2021). In a Division I collegiate cohort, back and neck injuries accounted for approximately 21–24% of all reported injuries, and 37% of injuries led to missed time from training or competition (WOLF et al., 2009). Low back pain (LBP) is particularly prevalent in butterfly and breaststroke swimmers, likely due to the repetitive lumbar extension and flexion inherent in these strokes (HSU et al., 2024a). This elevated risk underscores the significant biomechanical strain on the lumbar spine and underscores the need for targeted injury-prevention strategies to mitigate long-term spinal health risks.

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Competitive swimming dynamically engages the lumbar spine, with each stroke imposing distinct biomechanical demands. Freestyle and backstroke rely on extensive body roll, driven by coordinated paraspinal and abdominal muscle activation, to optimize stroke efficiency and minimize segmental torque (HSU et al., 2024b; PERSSON - ZETARUK, 2014). Conversely, butterfly and breaststroke involve repetitive lumbar flexion and hyperextension, elevating the risk of lower back injuries, particularly when poor biomechanics or muscular imbalances are present. Suboptimal techniques, such as excessive lumbar extension during pull-through phases or misaligned starts and flip turns, amplify stress on intervertebral discs and facet joints, contributing to chronic spinal strain.

Recent systematic reviews indicate that competitive swimmers have an elevated risk of developing lumbar degenerative disc disease (DDD), with prevalence varying by training intensity (HSU et al., 2024a). Three of four major studies report DDD in 15–20% of low-load recreational swimmers and up to 68% in elite swimmers. Kaneoka et al. (2007) found DDD in 68% of elite swimmers versus 29% of controls, while Hangai et al. (2009) reported a 57% prevalence in swimmers compared to 31% in controls, highlighting the significant spinal stress associated with high-volume training.

Competitive swimmers commonly exhibit postural abnormalities, such as hyperlordosis, scoliosis, and anterior pelvic tilt, which exacerbate lumbar strain and injury risk. These deviations often stem from muscular imbalances between the hip flexors and extensors, coupled with hamstring tightness, which disrupt pelvic alignment and lumbar mechanics (GAUNT - MAFFULLI, 2012; SAHAI - DARJEE, 2023). Francavilla et al. (2024) found that breaststroke and butterfly swimmers showed greater improvements in postural balance over 12 months compared to freestyle and backstroke swimmers, underscoring how stroke-specific biomechanical demands influence spinal adaptations.

Dryland training, a critical component of competitive swimming programs, significantly increases the risk of lumbar spine injury. Up to 38% of swimming-related injuries may originate in dryland sessions, particularly those involving repetitive spinal flexion or extension or heavy loading (HSU et al., 2024a). When performed with poor technique, these exercises can accelerate lumbar disc degeneration, especially in adolescent swimmers whose developing spines are vulnerable to cumulative stress, highlighting the need for careful exercise design and supervision.

A scoping review by Wareham et al. (2024) highlighted the scarcity of high-quality evidence directly linking competitive swimming to LBP. However, consistent trends suggest elevated risks, particularly for butterfly and breaststroke swimmers due to intense lumbar loading. Despite methodological limitations, such as variability in study designs and incomplete exposure data, the repeated identification of swimming as a risk factor for spinal pathology reinforces the need for further research and targeted interventions.

While preventive strategies aim to reduce injury risk, aquatic exercise also plays a therapeutic role in managing existing spinal conditions. A meta-analysis of eight randomized controlled trials by Shi et al. (2018) demonstrated that aquatic therapy significantly alleviated LBP symptoms (standard mean difference [SMD] = −0.65) and enhanced physical function (SMD = 0.63), highlighting its therapeutic value while underscoring the paradox of swimming's dual role as both a risk factor and a rehabilitative tool.

Preventative and rehabilitative strategies for competitive swimmers increasingly emphasize core stabilization, stroke technique correction, training load management, and early musculoskeletal screening to safeguard spinal health (POLLARD - FERNANDEZ, 2004; HILL-MOUNTJOY, 2021). When effectively implemented, these approaches can reduce the risk of lumbar DDD and LBP prevalence, particularly in young athletes vulnerable to repetitive spinal stress, promoting long-term musculoskeletal resilience.

Given these spinal health challenges, it is essential to examine these issues within the unique biomechanical context of competitive swimming, where repetitive motions and high training volumes exert distinct stresses on the lumbar spine. This systematic review evaluates the evidence on spinal postural abnormalities, degenerative disc changes, and LBP prevalence among adolescent and young adult competitive swimmers. It proposes evidence-based strategies to prevent injuries and optimize spinal health.

METHODS

LITERATURE SEARCH

We limited our literature search to three openly available electronic databases: Google Scholar, Scopus, and PubMed. Google Scholar was included due to its high coverage of academic literature, with studies showing it can identify over 90% of peer-reviewed articles across a wide range of disciplines (MARTÍN-MARTÍN et al., 2018), making it a valuable tool for comprehensive literature retrieval.

We searched according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (PAGE et al., 2021) and completed on 28 February 2025. The search was restricted to English-language, peer-reviewed journal articles. Materials such as book chapters, abstracts, dissertations, conference proceedings, and non-English publications were excluded.

The search strategy employed a combination of keywords and Boolean operators to fine-tune the retrieval of relevant studies. Core search terms included: “swimming” OR “swimmers” OR “competitive swimming,” combined with outcome-related terms such as “low back pain” OR “degenerative disc disease” OR “posture” OR “postural abnormalities,” and population filters such as “adolescent” OR “youth” OR “young adult.” Boolean operators (AND/OR) were applied to link concepts across domains, ensuring comprehensive coverage of the literature while excluding irrelevant results (HIGGINS et al., 2022).

The inclusion criteria for this review were as follows: studies involving adolescents or young adults aged 6–25 years engaged in competitive swimming or elite-level training. Eligible participants had at least 2–3 years of training experience and attended at least 3 training sessions per week. Studies were required to assess outcomes related to spinal postural abnormalities (such as kyphosis, lordosis, scoliosis, or flat back), lumbar intervertebral disc degeneration confirmed by MRI or clinical diagnosis, or the prevalence of low back pain through self-reported or clinical assessment. Comparators could include non-athletes, athletes from other sports, or swimmers with different training intensities (e.g., elite vs. recreational). We included only original research articles (cross-sectional, cohort, or case-control studies) published in English between 2005 and 2024. Studies needed to be conducted within a competitive or organized swimming setting, such as swimming clubs or national training centers.

The exclusion criteria were studies involving recreational swimmers without competitive training, general adolescent populations not specified as swimmers, or studies focusing on leisure swimming or aquatic rehabilitation. We excluded studies without appropriate comparator groups or irrelevant comparisons (e.g., surgical interventions). Research concentrating solely on non-spinal musculoskeletal injuries (e.g., shoulder or knee) was omitted, as were narrative reviews, systematic reviews, meta-analyses, and case reports. Non-English studies without available translations and studies published before 2000 were also excluded, unless deemed highly relevant (none met this condition). Additionally, studies conducted in rehabilitation hospitals or therapeutic centers without a competitive sports focus were excluded.

Vol 9, No 1 (2026): Stadium – Hungarian Journal of Sport Sciences
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Table 1: Delimitations of the Study: Inclusion and Exclusion Criteria for the Eligible Articles

Category	Inclusion	Exclusion
Population	Competitive swimmers (6–25 yrs)	Recreational swimmers, general adolescents
Exposure	≥2–3 years training, ≥3 sessions/week	Leisure swimming, rehabilitation swimming
Comparator	Non-athletes, other sports, intensity levels	No comparator or irrelevant comparator
Outcomes	Spine posture, DDD, low back pain	Focus on the shoulder, knee, or other joints
Study Design	Cross-sectional, Cohort, Case-control	Reviews, meta-analyses, case reports, letters
Language	English only	Non-English without translation
Publication Year	2005–2024	Before 2005 (unless highly relevant)
Setting	Clubs, teams, training centers	Rehabilitation hospitals, therapy centers

SEARCH OUTCOME

The initial database search yielded **182 records**. After removing **45 duplicate entries**, **137 unique articles** remained for screening. Titles and abstracts were then evaluated, resulting in the exclusion of **123 articles** that did not meet the predefined inclusion criteria. Subsequently, **14 full-text articles** were retrieved and assessed in detail for eligibility. Of these, **6 articles** were excluded following full-text review, primarily due to deviations from the target population, study design, or outcome measures of interest. Ultimately, **8 studies** met all inclusion criteria and were included in the final systematic review.

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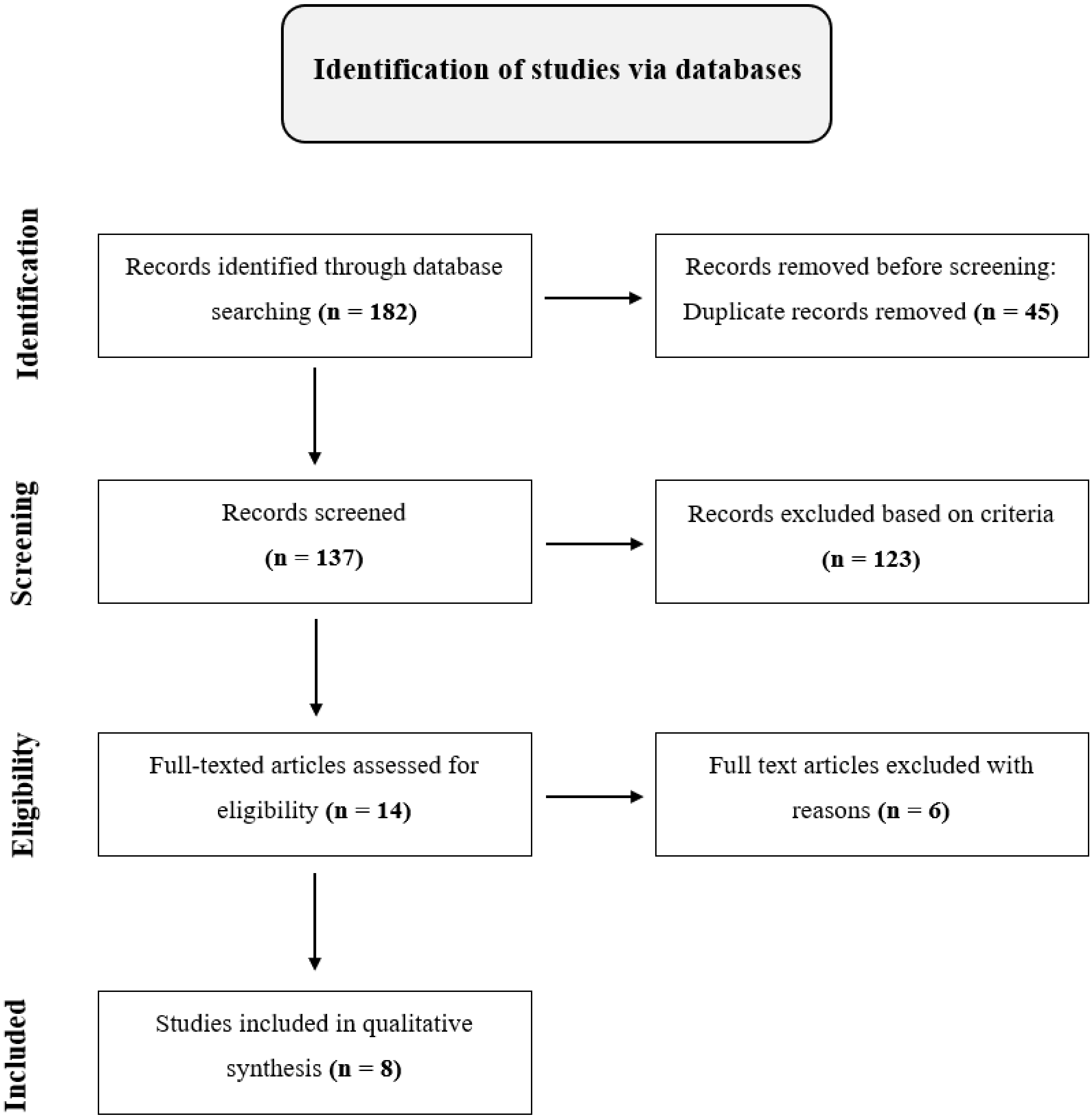

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram of the search strategy.

DATA EXTRACTION

The data extraction table synthesizes findings from eight peer-reviewed studies examining various aspects of **spinal health in swimmers**, encompassing a combined sample of approximately **6,345 participants**. These studies include **cross-sectional**, **comparative**, and **epidemiological cohort designs**, with sample sizes ranging from **38 elite youth athletes** (SOLOVJOVA et al., 2023) to **4,667 university students** from an extensive Japanese epidemiological survey (HANGAI et al., 2010). Most studies targeted **adolescent to young adult competitive swimmers**, with age ranges spanning **6 to 25 years**, and reported exposure durations **of 2 to over 10 years** of structured swim training, often defined as ≥3 sessions per week.

Vol 9, No 1 (2026): Stadium – Hungarian Journal of Sport Sciences
https://doi.org/10.36439/shjs/2026/1/16814

LDD was evaluated by **MRI** in five studies (KANEOKA et al., 2007; HANGAI et al., 2009; HANGAI et al., 2010; FOLKVARDSEN et al., 2021; TAKATALO et al., 2017), all of which reported **greater disc degeneration in swimmers than in sedentary controls**. Notably:

- **Kaneoka et al. (2007)** reported LDD at L5-S1 in **68% of swimmers, compared with 29% in controls**, highlighting the terminal lumbar segment's vulnerability.
- **Hangai et al. (2009)** found that male collegiate swimmers had significantly higher Pfirrmann scores and disc height loss than age-matched controls.
- **Takatalo et al. (2017)** demonstrated in a birth cohort study that **adolescents who were highly active in swimming (≥2×/week)** had increased cumulative odds ratios (COR = 5.0, 95% CI: 1.7–15.2) for disc degeneration in young adulthood.
- **Folkvardsen et al. (2021)** extended these findings by linking LDD not only to sport exposure but also to increased lumbar lordosis and sacral slope in young swimmers, suggesting a morpho-functional predisposition.

LBP prevalence and risk were assessed through **self-reported questionnaires** in three studies (HANGAi et al., 2010; ZAINA et al., 2015; DJORDJEVIC et al., 2022). Findings show:

- **Hangai et al. (2010)** reported that **lifetime LBP prevalence** was significantly higher in athletes with **greater cumulative years and frequency of sports participation**, including swimmers.
- **Zaina et al. (2015)** found that **female adolescent swimmers** had **2.1 times higher odds of reporting LBP** than their non-athletic peers.
- **Djordjevic et al. (2022)** documented early back pain complaints and spinal discomfort among **youth swimmers aged 6–14**, raising concerns about spinal stress in pre-adolescent athletes.

Four studies (Zaina et al., 2015; Djordjevic et al., 2022; Solovjova et al., 2023; Folkvardsen et al., 2021) examined **spinal posture and asymmetry** using tools such as **scoliometer screening**, **plumb line analysis**, and **radiographic measures**.

- **Zaina et al. (2015)** reported significantly higher rates of **trunk asymmetry (OR: 1.86)**, **hyperkyphosis (OR: 2.26)**, and **hyperlordosis (OR: 2.24)** in swimmers compared with controls.
- **Djordjevic et al. (2022)** observed that nearly **half of young swimmers (6–14 years)** exhibited postural anomalies, including **anterior pelvic tilt** and **increased lumbar curvature**, suggesting early, **sport-specific spinal adaptation**.
- **Solovjova et al. (2023)** compared elite youth swimmers with cyclists and reported a **greater incidence of thoracic asymmetry and lordotic spinal curves** in the swim group, suggesting stroke-specific biomechanical influence.
- **Folkvardsen et al. (2021)** quantified increased **lumbar lordosis** and **pelvic tilt angles** in swimmers, correlating them with both training volume and the presence of disc pathology on imaging.

The majority of studies used **objective imaging (MRI, radiographs)** or **validated clinical tools (scoliometer, postural grid, questionnaires)**. While most are **observational and cross-sectional**, they offer important **associative insights**. The **sample represent**ed elite athletes and general school cohorts. All included studies were published in peer-reviewed journals and scored moderate to high on the **Mixed Methods Appraisal Tool (MMAT)**.

Collectively, the studies reveal a **consistent association between competitive swimming and structural or symptomatic spinal changes**, particularly **lumbar disc degeneration**, **low back pain**, and **postural adaptations**. These effects are most pronounced **in early, high-frequency sport participation**, especially among **butterfly and breaststroke swimmers**, who exhibit greater **lumbar flexion-extension cycles**. The findings emphasize the need for **longitudinal monitoring, load management**, and **postural screening protocols** in youth swim programs.

https://doi.org/10.36439/shjs/2026/1/16814

Table 2: Summary of Included Studies

Study	Study Design	Population	Intervention/Exposure	Comparator (if any)	Outcome Measures	Main Findings	Risk of Bias/Limitations
Kaneoka et al. (2007)	Case-control	56 elite swimmers vs 38 recreational swimmers, ~19-21 years	High-load competitive swimming	Recreational swimmers	MRI lumbar degeneration and swimming history	Elite swimmers had significantly more lumbar degeneration, especially at L5-S1	Different MRI machines used; cross-sectional data
Hangai et al. (2009)	Cross-sectional	308 athletes (various sports) vs 71 non-athletes, university students	Participation in different competitive sports, including swimming	Non-athletes	MRI disc degeneration, LBP history	Swimmers and baseball players showed higher disc degeneration rates	Self-reported questionnaires; potential recall bias
Hangai et al. (2010)	Cross-sectional	4667 university students, 18–19 years	Competitive sports (various types, including swimming)	No vs medium vs high competitive sport load	Lifetime low back pain, school absence, lower extremity pain	Higher LBP prevalence with increased sport participation; sports-specific LBP risks vary	Potential selection bias; training loads not fully controlled
Zaina et al. (2015)	Cross-sectional	112 swimmers vs 217 controls, mean age 12.5 years	Competitive swimming vs the general population	Regular students (non-competitive athletes)	Scoliosis, kyphosis, lordosis (plumbline & scoliometer), LBP questionnaire	Swimming is associated with increased trunk asymmetry, hyperkyphosis, and hyperlordosis; LBP is higher in females	Cross-sectional design: unclear whether spinal issues predated swimming onset

Folkvardsen et al. (2016)	Cross-sectional (case-control)	100 elite swimmers vs 96 controls, mean age ~19-21 years	Elite swimming training	No-sport control group	MRI lumbar disc degeneration, disc herniations, LBP questionnaire	Swimmers showed different DD patterns, but overall similar DD and LBP rates compared to controls	Cross-sectional design; cannot infer causality
Takatalo et al. (2017)	Cohort	558 participants from Northern Finland Birth Cohort 1986, ~21 years	Participation in swimming during adolescence	Inactive or low-activity adolescents	MRI lumbar DD, activity questionnaire	Highly active swimmers showed higher odds of lumbar DD	Self-reported exposure data; observational design
Djordjevic et al. (2022)	Cross-sectional	53 swimmers, 6–14 years	Competitive swimming training	Juvenile vs adolescent swimmers	Spinal posture with Spinal Mouse	High prevalence of spinal postural disorders; no significant age-group difference	Small sample size; single-center study
Solovjova et al. (2023)	Cross-sectional	38 athletes (19 swimmers, 19 cyclists), aged 14–15 years	Comparison between swimming and cycling	Swimmers vs cyclists	Posture markers and muscle function tests	Cyclists showed worse postural markers; swimmers had significant muscle weaknesses.	Small sample size; few swimmers; limited generalizability

METHODOLOGICAL QUALITY AND RISK OF BIAS

Risk of bias was common across the included studies, primarily due to small sample sizes (≤100 participants in 5 studies), cross-sectional designs (7 studies), and frequent reliance on self-reported measures, which are inherently susceptible to recall errors and subjective bias. These limitations affect the internal validity and generalizability of the findings. For instance, several studies did not account for potential confounding variables such as training intensity, duration, or pre-existing spinal conditions, which may influence outcomes related to lumbar disc degeneration and posture.

To systematically assess study quality, the Mixed Methods Appraisal Tool (MMAT) version 2018 was employed (HONG et al., 2018). The MMAT is a validated and widely accepted instrument designed to appraise the methodological quality of qualitative, quantitative, and mixed-methods studies, enabling a unified approach to evaluating heterogeneous research designs. It builds upon the foundational work of Pluye et al. (2009), who developed an integrative framework for assessing mixed studies in systematic reviews. The MMAT considers critical domains, including the appropriateness of sampling strategies, measurement tools, completeness of outcome data, and adjustment for confounding variables. Application of the MMAT revealed variability in methodological quality across the eight included studies. Three studies—Hangai et al. (2009), Hangai et al. (2010), and Takatalo et al. (2017)—met all five MMAT criteria, indicating low risk of bias. Another three studies met four of five criteria, reflecting a moderate risk, while the remaining two studies (Djordjevic et al., 2022; Solovjova et al., 2023) met only three criteria, suggesting a high risk of bias. **Full MMAT domain ratings for each study are provided in Tables 3 and 4.** The most commonly unmet criteria are related to insufficient control of confounding variables, unrepresentative or poorly justified sampling strategies, and limited statistical analysis. These findings underscore the need for more rigorously designed studies in this field.

Application of the MMAT revealed variability in methodological quality across the eight included studies (e.g., clear research questions, valid outcome measures); others exhibited moderate to high risk of bias due to incomplete reporting, descriptive-only designs, or limited comparability with the control group. Notably, two small cross-sectional studies lacked robust statistical analysis and employed sampling frames that limited generalizability. Despite these methodological shortcomings, the synthesis of evidence—particularly from higher-quality studies—demonstrates a consistent pattern linking competitive swimming with an increased risk of lumbar spine degeneration, postural abnormalities, and low back pain in adolescent and young adult athletes.

https://doi.org/10.36439/shjs/2026/1/16814

Table 3: MMAT Quality Appraisal of Quantitative Descriptive Studies in Alphabetical Order (Cross-Sectional and Case Series)

	Screening questions		Methodological quality criteria				
Study	**S1. Are there clear research questions?**	**S2. Do the collected data allow addressing the research questions?**	**Q4.1. Is the sampling strategy relevant to address the research question?**	**Q4.2. Is the sample representative of the target population?**	**Q4.3. Are the measurement s appropriate?**	**Q4.4. Is the risk of nonresponse bias low?**	**Q4.5. Is the statistical analysis appropriate to answer the research question?**
Djordjevic et al. (2022)	Yes	Yes	Yes	No	Yes	Unclear	Yes
Hangai et al. (2009)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hangai et al. (2010)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Solovjova et al. (2023)	Yes	Yes	Yes	No	Yes	Unclear	Yes
Zaina et al. (2015)	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Vol 9, No 1 (2026): Stadium – Hungarian Journal of Sport Sciences
https://doi.org/10.36439/shjs/2026/1/16814

Table 4: MMAT Quality Appraisal of Quantitative Non-Randomized Studies in Alphabetical Order (Case-Control and Cohort Designs)

	Screening questions		**Methodological quality criteria**				
Study	**S1. Are there clear research questions?**	**S2. Do the collected data allow addressing the research questions?**	**Q3.1. Are the participants representative of the target population?**	**Q3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?**	**Q3.3. Are there complete outcome data??**	**Q3.4. Are the confounders accounted for in the design and analysis?**	**Q3.5. During the study period, was the intervention administered (or exposure occurred) as intended?**
Folkvardsen et al. (2016)	Yes	Yes	Yes	Yes	Yes	No	Yes
Kaneoka et al. (2007)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Takatalo et al. (2017)	Yes	Yes	Yes	Yes	Yes	Yes	Yes

RESULTS

To present a clear and structured synthesis of findings, the results of this systematic review are organized into three thematic domains:

- **Spinal Posture and Alignment in Swimmers**
- **Lumbar Intervertebral Disc Degeneration in Swimmers**
- **Low Back Pain and Symptom Burden in Swimmers**

This categorization reflects the primary outcomes examined across the included studies and captures the multifactorial nature of spinal health in aquatic athletes. Changes in spinal curvature and alignment—such as lumbar hyperlordosis, thoracic asymmetry, and anterior pelvic tilt—are considered early postural adaptations to the biomechanical demands of swimming. In contrast, intervertebral disc degeneration represents more advanced structural alterations, typically confirmed by imaging modalities. The low back pain domain centers on clinical symptoms, severity, and associations with training exposure and stroke technique. Grouping the results in this manner allows for a nuanced interpretation of how swimming impacts spinal morphology, function, and pain experience across different age groups and competitive levels.

This structure is consistent with recent literature. Hsu et al. (2024a), in a systematic review, reported elevated odds of multilevel disc degeneration and greater low back pain severity among elite swimmers compared with non-athletes. In a related narrative review, the same authors (HSU et al., 2024b) discussed the stroke-specific spinal mechanics of swimming, emphasizing that repetitive lumbar extension and flexion—particularly in butterfly and breaststroke—may contribute to chronic loading. Similarly, Hill and Mountjoy (2021) highlighted low back pain as one of the most prevalent and under-recognized complaints in swimmers, especially in relation to training volume and stroke mechanics.

SPINAL POSTURE AND ALIGNMENT IN SWIMMERS

Several studies in this review examined the relationship between competitive swimming and spinal posture. Djordjevic et al. (2022) assessed juvenile (ages 6–10) and adolescent (ages 11–14) swimmers (n = 53) and found a high prevalence of postural asymmetries in both frontal and sagittal planes, particularly increased thoracic kyphosis and lumbar lordosis. No significant differences in posture were observed between age groups, suggesting an early onset of adaptive spinal deviations.

Zaina et al. (2015) investigated postural abnormalities in competitive swimmers (n = 112) aged 11–16 compared to non-athletic controls (n = 217). Swimmers had significantly higher odds of hyperkyphosis (OR = 2.26), hyperlordosis (OR = 2.24), and trunk asymmetry (OR = 1.86). In addition, female swimmers were 2.1 times more likely to report low back pain.

https://doi.org/10.36439/shjs/2026/1/16814

In contrast, Solovjova et al. (2023) compared swimmers and cyclists (n = 38 per group) and found that swimmers exhibited greater thoracic asymmetry and increased lumbar lordotic curvature, suggesting that repetitive stroke mechanics may contribute to altered spinal alignment. No assessment of muscle strength was reported.

Swimming appears to be associated with specific postural adaptations, including increased thoracic kyphosis, lumbar lordosis, and trunk asymmetry. While swimming may offer general musculoskeletal conditioning, stroke-specific movement patterns and insufficient core stabilization may contribute to asymmetrical spinal loading and early morphological deviations.

LUMBAR INTERVERTEBRAL DISC DEGENERATION IN SWIMMERS

Five studies assessed the prevalence and severity of lumbar intervertebral disc degeneration (LDD) in swimmers using magnetic resonance imaging (MRI). Kaneoka et al. (2007) compared 56 elite swimmers with 38 recreational-level controls and reported that 68% of elite swimmers had LDD, compared to 29% of controls (OR = 5.18, $p < .01$). degeneration was most frequently observed at the L4–L5 and L5–S1 levels.

Hangai et al. (2009) examined 47 collegiate swimmers and 71 sedentary participants, reporting LDD in 57% of swimmers versus 31% of controls (OR = 2.95, $p < .01$). Similarly, Folkvardsen et al. (2021) compared 48 elite swimmers with 48 age-matched controls and found significantly greater rates of disc degeneration and disc height loss among swimmers, especially at lower lumbar levels.

In a population-based MRI study, Takatalo et al. (2017) analyzed 558 young adults from the Northern Finland Birth Cohort. Among the 19 participants who identified as swimmers, 68% showed lumbar LDD, compared with 52% among non-swimmers. After adjustment for severity, swimmers had 5 times the odds of severe degeneration (OR = 5.0, 95% CI: 1.7–15.2).

Competitive swimming—especially at high training volumes or elite levels—is associated with increased prevalence and severity of lumbar disc degeneration, most commonly at L4–L5 and L5–S1. While effect sizes vary, most studies show significantly more advanced or multilevel degeneration in swimmers than in controls.

LOW BACK PAIN AND SYMPTOM BURDEN IN SWIMMERS

Low back pain (LBP) was assessed in 4 of the included studies, revealing mixed but important patterns in symptom prevalence and severity. Hangai et al. (2010) examined a large university cohort. They found that athletes, including swimmers, had significantly higher odds of lifetime LBP (OR = 2.76) and moderate-to-severe LBP (OR = 2.71) compared to non-athletes.

Kaneoka et al. (2007) reported that 76.8% of elite swimmers experienced LBP, compared to 29.7% of recreational-level controls. Moreover, severe symptoms were more frequent

https://doi.org/10.36439/shjs/2026/1/16814

in swimmers (48.2%) than in controls (36.8%), indicating not only higher prevalence but also increased pain burden.

Folkvardsen et al. (2021) found no statistically significant difference in overall LBP prevalence between swimmers (52%) and controls (66.7%). However, swimmers who also presented with MRI-confirmed disc degeneration reported more LBP symptoms, suggesting an interaction between structural degeneration and pain.

Zaina et al. (2015) identified significantly higher odds of LBP in female swimmers, particularly those with postural abnormalities such as hyperlordosis and asymmetry, reinforcing the link between spinal alignment and symptom development.

Although not all studies reported higher rates of LBP in swimmers, those who did report symptoms tended to experience greater severity and chronicity, particularly when associated with spinal degeneration or misalignment. These findings support a multifactorial model of LBP in swimmers, where both biomechanical and structural factors contribute to increased pain risk.

Table 5. Summary of Outcomes by Study, Ordered by Appearance in the Results Section

Study	Postural Abnormalities	Degenerative Disc Disease (DDD)	Low Back Pain (LBP)
Djordjevic et al. (2022)	High prevalence of thoracic kyphosis and lumbar lordosis	Not assessed	Not assessed
Solovjova et al. (2023)	Postural asymmetry; weakness in core stabilizing muscles	Not assessed	Not assessed
Zaina et al. (2015)	Greater odds of hyperkyphosis, hyperlordosis, and trunk asymmetry	Not assessed	Higher LBP prevalence in females with poor posture
Kaneoka et al. (2007)	Not assessed	Significantly higher DDD in elite swimmers (68% vs 29%, OR = 5.18)	Swimmers reported more severe LBP symptoms
Hangai et al. (2009)	Not assessed	Higher prevalence of DDD in swimmers (57% vs 31%, OR = 2.95)	LBP prevalence and severity assessed
Hangai et al. (2010)	Not assessed	Not assessed	Significantly higher LBP in swimmers compared to non-athletes

Folkvardsen et al. (2016)	Not assessed	No overall difference in DDD; more multilevel degeneration and disc bulging	No significant difference; LBP symptoms related to DDD presence
Takatalo et al. (2017)	Not assessed	Higher odds of severe DDD in swimmers (OR = 5.0)	Not assessed

DISCUSSION

Hsu et al. (2024a) and Hill & Mountjoy (2021) both emphasize the spine as the second-most-commonly affected region in swimmers, after the shoulder. Zaina et al. (2015) and Solovjova et al. (2023) highlight the early emergence of spinal asymmetry and curvature deviations during adolescence. Although Folkvardsen et al. (2021) did not find a significant difference in overall DDD prevalence, their study revealed more multilevel degeneration among swimmers, suggesting that stroke mechanics or cumulative loading may play a role. This review extends prior work by incorporating imaging-confirmed pathology and by thematically categorizing findings across posture, structure, and symptoms.

Across the included studies, there is moderate-to-strong evidence that competitive swimming is associated with an increased risk of spinal health issues in adolescent and young adult athletes. The most consistently observed findings were a higher prevalence of **postural deviations—**including **hyperkyphosis**, **lumbar hyperlordosis**, and **trunk asymmetry—**and elevated rates of **lumbar intervertebral disc degeneration (LDD)**, particularly at the L4–L5 and L5–S1 levels. Several studies also noted a higher incidence and severity of **low back pain (LBP)** among swimmers, especially in those with confirmed postural or structural abnormalities.

Although swimming is often considered a low-impact activity due to water's buoyancy, the demands of high-volume, stroke-specific training can introduce substantial, repetitive mechanical stress. The combination of **lumbar extension, flexion, axial rotation**, and **undulatory movements—**particularly during **starts, turns, and dolphin kicking—**can lead to cumulative loading of the lumbar spine. This mechanism is supported by external reviews (Hsu et al., 2024a; Hsu et al., 2024b), which highlight how the **biomechanics of butterfly and breaststroke** may contribute to lumbar stress, and by Hill and Mountjoy (2021), who identified the spine as the second most commonly injured region in swimmers after the shoulder.

While methodological limitations such as small sample sizes and cross-sectional designs temper the strength of conclusions, the **directional consistency** of findings across multiple studies supports the interpretation that **elite-level swimming may pose elevated spinal health risks**. Risk factors are present in athletes who specialize early, engage in high training volumes, or display compensatory postural patterns. Although not all swimmers develop symptoms, those with LBP often report **greater intensity and chronicity**, frequently linked to **disc degeneration** or **alignment abnormalities**.

Preventive strategies may include **routine postural screening**, **stroke technique optimization**, and **individualized dryland programs** that target **core strength**, **pelvic alignment**, and **hip mobility**. A multidisciplinary approach—integrating sports medicine, physiotherapy, and coaching expertise—offers the most comprehensive strategy for protecting spinal health in competitive swimmers and supporting sustainable athletic development.

CLINICAL AND PRACTICAL IMPLICATIONS

The findings support the need for proactive spinal health strategies in competitive swimming. Postural screening during early developmental stages may enable timely intervention. Coaches and clinicians should monitor athletes for compensatory movement patterns, particularly during strokes that involve repeated lumbar hyperextension (e.g., butterfly and breaststroke). Individualized dryland training programs focused on core stability, pelvic alignment, and thoracolumbar control may help mitigate cumulative spinal stress. Evidence from Zaina et al. (2015) and Djordjevic et al. (2022) further supports the value of early biomechanical monitoring.

CONCLUSIONS

This systematic review provides a comprehensive synthesis of evidence linking competitive swimming—particularly at the adolescent and young adult levels—to alterations in spinal health. Across the eight included studies, swimmers consistently demonstrated higher rates of **spinal postural abnormalities**, including **hyperkyphosis**, **lumbar hyperlordosis**, and **trunk asymmetry**, as well as a greater prevalence of **lumbar intervertebral disc degeneration (LDD)** and **moderate-to-severe low back pain (LBP)** compared to non-athletes or athletes from other sports. These findings were particularly pronounced in MRI-based studies (Kaneoka et al., 2007; Hangai et al., 2009; Takatalo et al., 2017), which objectively confirmed multilevel degeneration in competitive swimmers.

Postural deviations appeared early in youth swimmers (Djordjevic et al., 2022; Zaina et al., 2015), suggesting that spinal adaptations may begin during key developmental periods. These deviations may be subtle and asymptomatic initially, yet they contribute to biomechanical imbalances that increase an athlete's vulnerability to symptomatic LBP later in their career. Indeed, multiple studies found that swimmers reporting LBP experienced more **severe and chronic symptoms**, notably when imaging also revealed disc pathology (HANGAI et al., 2010; KANEOKA et al., 2007). While one study (Folkvardsen et al., 2021) found no statistically significant difference in LBP prevalence, it still reported more multilevel LDD and pain in swimmers with disc changes—underscoring the complexity of pain-pathology relationships.

Despite being frequently promoted as a low-impact sport, swimming imposes **unique spinal loading patterns**. The repetitive cycles of **lumbar flexion, extension, and axial rotation**, especially in **butterfly and breaststroke**, create cumulative stresses on intervertebral discs and facet joints. Starts, flip turns, and underwater dolphin kicks further intensify this strain. Although these mechanical demands are essential to competitive performance, they may also contribute to long-term structural adaptations and pain syndromes if unaddressed. As highlighted by Hsu et al. (2024b), the biomechanics of specific strokes may predispose swimmers to spinal overuse injuries, particularly when pre-existing alignment issues or insufficient core stabilization are present.

From a clinical and coaching perspective, this review supports the implementation of **preventive measures** to reduce the risk of spinal injury in swimmers. These include **early and periodic postural assessments**, **targeted dryland programs** focusing on **core strength**, **pelvic control**, and **hip mobility**, and **stroke technique modification** to reduce unnecessary lumbar loading. Collaboration between **sports medicine providers, physiotherapists, strength coaches, and swim coaches** is essential to building a sustainable framework for spinal health throughout a swimmer's developmental trajectory.

Future research should prioritize **longitudinal designs** to clarify causality, investigate the **stroke-specific effects** on spinal loading through kinematic and biomechanical analyses, and examine **sex-based differences** in spinal adaptation. Intervention trials testing the impact of **postural correction**, **dryland protocols**, and **stroke refinements** on spinal outcomes are also needed. Finally, the role of **dryland training itself** deserves greater scrutiny, as up to 38% of injuries in swimmers may originate outside the pool (HSU et al., 2024a). Understanding how land-based activities interact with in-water biomechanics could unlock more holistic injury prevention strategies for this high-risk athletic population.

SUMMARY OF KEY FINDINGS

This systematic review synthesizes evidence from eight studies investigating the effects of competitive swimming on spinal health in youth and young adults. The results indicate a clear pattern: swimmers—particularly at elite levels—demonstrate higher prevalence of postural abnormalities (e.g., hyperkyphosis, lumbar hyperlordosis, and trunk asymmetry), lumbar intervertebral disc degeneration (LDD), and moderate-to-severe low back pain (LBP). MRI-based studies confirmed structural degeneration, while others linked symptoms to biomechanical loading, training intensity, and early postural adaptation (KANEOKA et al., 2007; HANGAI et al., 2010; DJORDJEVIC et al., 2022; ZAINA et al., 2015).

STRENGTHS AND LIMITATIONS

We conducted the review following the PRISMA 2020 guidelines (Page et al., 2021) and included a broad range of study designs, which were evaluated using the MMAT tool (HONG et al., 2018). MMAT findings, detailed in Tables 3 and 4, revealed variability in methodological quality and highlighted several high-quality studies that used validated outcomes and imaging. The use of MRI-confirmed degeneration in five studies adds objective weight to the synthesis. Nonetheless, several limitations must be acknowledged. Most studies were cross-sectional, limiting causal inference—especially regarding outcome heterogeneity—and reliance on self-report measures introduced bias. Additionally, small sample sizes in studies such as Solovjova et al. (2023) restrict external generalizability.

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should prioritize longitudinal designs and use standardized MRI grading systems and validated pain questionnaires. Stroke-specific spinal mechanics should be investigated using motion capture and EMG to isolate biomechanical risk factors better. Sex differences in adaptation and the impact of early sport specialization remain underexplored. Finally, intervention trials assessing the efficacy of dryland programming, postural screening protocols, and technique modification are needed to establish evidence-based spinal injury prevention. As noted by Hsu et al. (2024a), up to 38% of injuries among swimmers may originate from dryland training, further underscoring the need for integrated monitoring across aquatic and land-based activities.

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