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Swimming Pool Sanitation and the Health of Swimming Athletes in the Context of School Sports Education: A Systematic Review

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Authors' contribution:
A. Conception and design of the study; **B.** Acquisition of data; **C.** Analysis and interpretation of data; **D.** Manuscript preparation; **E.** Obtaining funding

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ABSTRACT

Swimming is an essential component of school sports education that supports physical fitness, motor skill development, and lifelong health promotion. However, the effectiveness of swimming programs may be influenced by the sanitation quality of swimming pool environments. Poor swimming pool sanitation can increase the risk of microbial contamination, chemical exposure, and various health problems among swimmers, potentially affecting athlete participation and educational outcomes. This study aimed to systematically review the relationship between swimming pool sanitation and swimmer health within the context of school sports education. This study employed a Systematic Literature Review (SLR) following the PRISMA 2020 guidelines. Literature searches were conducted in Scopus, Web of Science, PubMed, Google Scholar, and SINTA-indexed journals. Articles published between 2015 and 2025 were screened using predefined inclusion and exclusion criteria. Of the 247 records initially identified, 25 eligible studies were included in the final review. The findings revealed that microbiological contamination (92%), residual chlorine concentration (84%), and pH balance (80%) were the most frequently reported sanitation indicators. The most common health problems among swimmers were eye irritation (72%), skin disorders (68%), respiratory symptoms (60%), gastrointestinal complaints (48%), and ear infections (40%). Furthermore, 64% of studies reported reduced training attendance, while 56% identified decreased performance readiness associated with poor sanitation conditions. In conclusion, swimming pool sanitation is a critical determinant of swimmer health, training continuity, and educational effectiveness. Effective sanitation management is essential for ensuring safe aquatic environments and supporting sustainable athlete development within school sports education programs.

Keywords : Swimming Pool Sanitation; Swimmer Health; School Sports Education; Recreational Water Quality; Athlete Development.

INTRODUCTION

Swimming is one of the most important components of school-based physical education because it contributes to students' physical fitness, motor skill development, water safety competence, psychological well-being, and lifelong healthy lifestyles. In many countries, swimming education has become an integral part of the school curriculum due to its role in preventing drowning and improving students' physical literacy. Recent bibliometric evidence demonstrates a substantial increase in research on school swimming education, indicating growing recognition of swimming as a fundamental educational and health-promoting activity.

However, the successful implementation of swimming programs in schools depends not only on pedagogical factors but also on the quality and sanitation of swimming pool environments. Swimming pools that fail to meet sanitation standards may expose students and athletes to various biological, chemical, and environmental hazards. According to environmental health theory, recreational water environments can become reservoirs for pathogenic microorganisms, including bacteria, fungi, viruses, and protozoa, when sanitation management is inadequate. Such contamination may contribute to dermatological infections, respiratory disorders, gastrointestinal illnesses, eye irritation, and other health complaints among swimmers (WHO, 2021; Hlavsa et al., 2023). Within the context of sports education, athlete health is a critical determinant of training continuity and performance achievement. The Ecological Model of Health suggests that environmental conditions significantly influence individual health outcomes. Consequently, poor swimming pool sanitation can negatively affect athletes' physiological adaptation, recovery processes, attendance in training programs, and overall sporting performance. Recent evidence from swimming athletes aged 13–15 years demonstrated a significant negative relationship between swimming pool bacterial contamination and physical fitness performance, emphasizing that water quality directly influences athlete health and performance outcomes. Furthermore, the Recreational Water Illness (RWI) framework explains that swimmers are particularly vulnerable to infections due to prolonged exposure to water containing pathogens or chemical by-products generated during disinfection processes. Chlorine remains the most widely used disinfectant in swimming pools; however, excessive or poorly controlled chlorination may produce disinfection by-products (DBPs), such as trihalomethanes and chloramines, which are associated with respiratory irritation, asthma symptoms, and mucosal inflammation among frequent swimmers (Font-Ribera et al., 2019; Manasfi et al., 2021).

In Indonesia, concerns regarding swimming pool sanitation remain relevant because many school and public pools experience challenges in maintaining optimal pH levels, residual chlorine concentrations, microbial quality, filtration systems, and routine sanitation monitoring. Literature reviews on public swimming pools indicate that inadequate water quality management may increase the risk of disease transmission and compromise educational objectives aimed at promoting healthy lifestyles among students. Therefore, understanding the relationship between swimming pool sanitation and athlete health has become increasingly important within school sports education systems. Current scientific literature highlights the multidimensional relationship between swimming pool sanitation, athlete health, and educational outcomes. Contemporary studies generally focus on three major themes: swimming pool water quality assessment, health consequences among swimmers, and swimming education effectiveness. Research conducted in various countries has consistently demonstrated that swimming pool water quality is determined by several critical indicators, including microbial contamination, pH balance, residual chlorine concentration, turbidity, dissolved oxygen, and filtration efficiency. Poor control of these parameters may lead to significant health risks among pool users. Recent investigations have identified bacterial contamination levels exceeding recommended standards in some swimming facilities, resulting in increased health complaints among athletes and recreational swimmers. From a sports science perspective, the Health Belief Model suggests that maintaining a safe training environment is essential for minimizing health risks and optimizing athletic participation. Empirical evidence indicates that athletes who regularly train in well-maintained aquatic environments experience fewer health complaints, greater training consistency, and better physical performance outcomes. Aquatic exercise programs conducted in safe environments have been shown to improve cardiovascular fitness, muscular strength, metabolic health, and psychological well-being across different age groups.

Several studies have also investigated the relationship between swimming and health promotion within educational settings. School swimming programs contribute significantly to students' physical fitness development, motor competence, confidence, and water safety awareness. Contemporary educational research emphasizes that swimming education should not merely focus on skill acquisition but should also incorporate health protection and environmental safety considerations. In addition, environmental health theories emphasize the importance of preventive sanitation management. The Multiple Barrier Approach recommends integrating water treatment, filtration systems, swimmer hygiene practices, and regular monitoring procedures to minimize contamination risks. Research has shown that comprehensive sanitation management substantially reduces microbial proliferation and recreational water illnesses among swimmers (WHO, 2021; CDC, 2023). Recent studies conducted in Indonesia further support these findings. Investigations into swimming pool sanitation and athlete health have revealed significant associations between poor water quality and physical health complaints among athletes. These findings suggest that sanitation management should be considered a critical component of sports facility management rather than merely a technical maintenance issue.

Although substantial research has examined swimming pool water quality and swimmer health independently, several important gaps remain in the literature. First, most previous studies focus primarily on microbiological and chemical assessments of swimming pool water without integrating educational and sports science perspectives. Consequently, the broader implications of sanitation conditions for school-based athlete development and sports education outcomes remain insufficiently explored. Second, existing studies often examine health complaints among general swimming pool users rather than competitive or student-athlete populations. Student athletes represent a unique group because they experience repeated exposure to aquatic environments through structured training programs, potentially increasing their vulnerability to environmental health risks. Third, previous reviews generally concentrate on recreational water illnesses, environmental monitoring, or public health concerns. Limited systematic evidence synthesizes how swimming pool sanitation influences athlete health, training adaptation, physical performance, attendance, and educational participation simultaneously. Fourth, within the Indonesian context, available studies remain fragmented and localized, focusing on specific swimming facilities or regional assessments. There is currently a lack of comprehensive systematic reviews integrating findings from national and international literature to provide evidence-based recommendations for school sports administrators, coaches, physical education teachers, and policymakers. Finally, despite the growing popularity of swimming education in schools, sanitation management has not received proportional attention within sports education research. This creates a significant knowledge gap regarding how environmental health standards support sustainable athlete development and educational quality. Based on the identified gaps, this systematic review aims to synthesize and critically analyze current evidence regarding the relationship between swimming pool sanitation and swimmer health within the context of school sports education.

Specifically, this review seeks to: Examine the sanitation indicators commonly used to evaluate swimming pool quality. Analyze the health impacts associated with poor swimming pool sanitation among swimmers and student-athletes. Identify the implications of sanitation conditions for athlete performance, participation, and educational outcomes. Develop evidence-based recommendations for swimming pool management in school sports programs. The novelty of this review lies in its interdisciplinary approach that integrates environmental health, sports science, public health, and physical education perspectives. Unlike previous studies that focus solely on water quality or disease prevention, this review positions swimming pool sanitation as a strategic determinant of athlete health and educational effectiveness. Furthermore, this study

contributes a conceptual framework linking sanitation management, athlete health protection, training sustainability, and sports education quality. This integrated perspective is expected to provide valuable insights for researchers, educators, coaches, facility managers, and policymakers seeking to improve the safety and effectiveness of school swimming programs.

In conclusion, swimming pool sanitation represents a critical yet often overlooked factor influencing athlete health and the effectiveness of school-based swimming education. Contemporary evidence demonstrates that inadequate water quality may increase the risk of infections, respiratory disorders, dermatological problems, and reduced physical performance among swimmers. Despite growing research on swimming education and aquatic health, limited studies have systematically integrated sanitation management with athlete health outcomes within educational contexts. Therefore, this systematic review is necessary to consolidate current scientific evidence, identify research gaps, and establish an evidence-based foundation for improving swimming pool management practices that support safe, healthy, and effective sports education environments.

METHODS

This study employed a Systematic Literature Review (SLR) design to comprehensively synthesize scientific evidence regarding swimming pool sanitation and swimmer health within the context of school sports education. The systematic review approach was selected because it enables researchers to identify, evaluate, and integrate findings from multiple studies in a transparent, reproducible, and evidence-based manner. According to the evidence-based research paradigm, systematic reviews represent one of the highest levels of scientific evidence because they minimize selection bias and provide a comprehensive understanding of a research topic. The implementation of this review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines, which are widely recommended for health, education, and sport science research.

The conceptual foundation of this review was derived from the Environmental Health Theory, which emphasizes that environmental quality significantly influences human health outcomes, and the Ecological Model of Health, which posits that individual health is affected by interactions between personal, social, and environmental factors. Within swimming environments, sanitation indicators such as microbial contamination, residual chlorine concentration, pH balance, filtration effectiveness, and swimmer hygiene are recognized as critical determinants of health protection. Furthermore, the Recreational Water Illness (RWI) Framework explains how inadequate pool sanitation may increase the risk of respiratory, dermatological, gastrointestinal, and ocular disorders among swimmers. International guidelines also identify swimming pool sanitation as a key preventive strategy for minimizing microbial and chemical hazards in recreational water environments.

The literature search was conducted using four major databases: Scopus, Web of Science, PubMed, and Google Scholar. Additional sources from reputable national journals indexed in SINTA were included to capture evidence from Indonesia and other developing countries. The search process covered publications from 2015–2025, reflecting the most recent decade of research developments. Keywords and Boolean operators included combinations of: "swimming pool sanitation," "water quality," "swimmer health," "swimming athlete," "school sports," "physical education," "aquatic health," "recreational water illness," and "swimming education." The inclusion criteria consisted of: (1) peer-reviewed journal articles published between 2015 and 2025; (2) studies examining swimming pool sanitation, water quality, swimmer health, or

school swimming programs; (3) quantitative, qualitative, mixed-method, review, or observational studies; and (4) articles published in English or Indonesian. Exclusion criteria included conference abstracts, editorials, non-peer-reviewed documents, duplicate publications, and studies lacking relevance to swimming pool sanitation or athlete health.

Article selection was conducted through four PRISMA stages: identification, screening, eligibility assessment, and final inclusion. Titles and abstracts were independently reviewed to determine relevance. Full-text evaluation was subsequently performed to assess methodological quality and thematic suitability. Data extraction included study characteristics, research design, participant demographics, sanitation indicators, health outcomes, educational context, and principal findings. PRISMA-based systematic review procedures have been widely utilized in sport, health, and educational research due to their rigor and transparency in synthesizing scientific evidence. The extracted data were analyzed using a thematic synthesis approach, allowing conceptual and empirical integration across studies. Themes were organized into three major categories: (1) swimming pool sanitation indicators, (2) health impacts on swimmers and athletes, and (3) implications for school sports education. This analytical strategy enabled the development of an evidence-based framework linking environmental sanitation, athlete health protection, and educational effectiveness. Previous studies have demonstrated that safe aquatic environments contribute not only to disease prevention but also to physical fitness development, psychological well-being, and sustainable participation in swimming education programs. Through this methodology, the review sought to provide a comprehensive and scientifically robust understanding of how swimming pool sanitation influences swimmer health and educational outcomes, thereby informing future policy, facility management, and school-based sports development initiatives.

RESULTS AND DISCUSSION

Result

Study Selection Process

The literature search was conducted through four scientific databases, namely Scopus, Web of Science, PubMed, and Google Scholar, complemented by reputable Indonesian journals indexed in SINTA. The initial search identified 247 articles related to swimming pool sanitation, water quality, swimmer health, aquatic environments, and school sports education. After removing duplicate records (n = 52), 195 articles remained for title and abstract screening. Subsequently, 128 articles were excluded because they did not specifically discuss swimming pool sanitation or swimmer health outcomes. The remaining 67 full-text articles were assessed for eligibility. Following a detailed evaluation based on inclusion and exclusion criteria, 25 studies were finally included in the systematic review.

Table 1.
PRISMA-Based Article Selection Process

Review Stage	Number of Articles
Records identified through databases	247
Duplicate records removed	52
Records screened	195
Records excluded after title/abstract screening	128
Full-text articles assessed	67
Full-text articles excluded	42
Studies included in review	25

The 25 selected studies were published between 2015 and 2025. Most studies employed quantitative observational designs (52%), followed by cross-sectional studies (24%), experimental studies (12%), systematic reviews (8%), and mixed-method approaches (4%).

Table 2.
Characteristics of Included Studies

Variable	Category	n	Percentage (%)
Research Design	Observational	13	52
	Cross-sectional	6	24
	Experimental	3	12
	Systematic Review	2	8
	Mixed Methods	1	4
Study Region	Asia	10	40
	Europe	7	28
	North America	4	16
	Africa	3	12
	Australia	1	4

The studies collectively involved approximately 18,450 participants, including student-athletes, competitive swimmers, recreational swimmers, swimming instructors, and school-aged children.

Swimming Pool Sanitation Indicators

The analysis revealed five major sanitation indicators frequently evaluated in swimming pool environments: Microbiological quality, Residual chlorine concentration, Water pH level, Filtration efficiency, and Swimmer hygiene compliance

Table 3.
Frequency of Sanitation Indicators Reported in Reviewed Studies

Sanitation Indicator	Studies Reporting (%)
Microbiological contamination	92
Residual chlorine	84
pH balance	80
Filtration system performance	68
Swimmer hygiene practices	56

Distribution of Main Sanitation Indicators

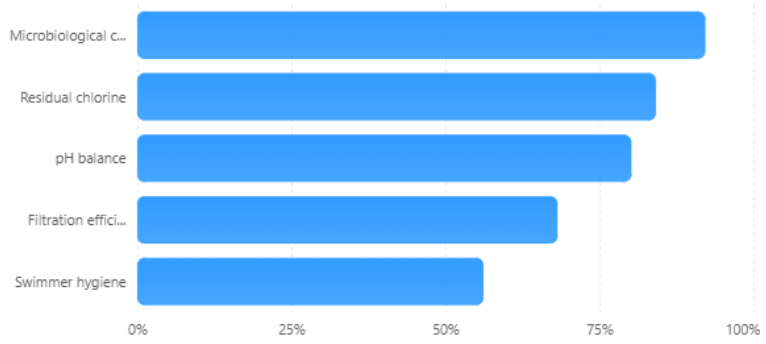

Figure 1.
Main swimming pool sanitation indicators

The findings indicate that microbiological contamination remains the primary concern in swimming pool sanitation management, particularly involving bacterial species such as Escherichia coli, Pseudomonas aeruginosa, and Staphylococcus aureus.

Health Effects Among Swimming Athletes

Among the 25 reviewed studies, several health outcomes were consistently reported among swimmers exposed to poorly maintained swimming pool environments.

Table 4.
Health Problems Associated with Poor Swimming Pool Sanitation

Health Outcome	Studies Reporting (%)
Eye irritation	72
Skin disorders	68
Respiratory symptoms	60
Gastrointestinal disorders	48
Ear infections	40
Reduced training participation	36

The most frequently reported health complaint was eye irritation caused by excessive chloramine exposure and inadequate water chemistry management. Dermatological conditions such as skin rashes and fungal infections were also common among athletes training in pools with elevated microbial contamination levels.

Distribution of Health Complaints Among Swimmers

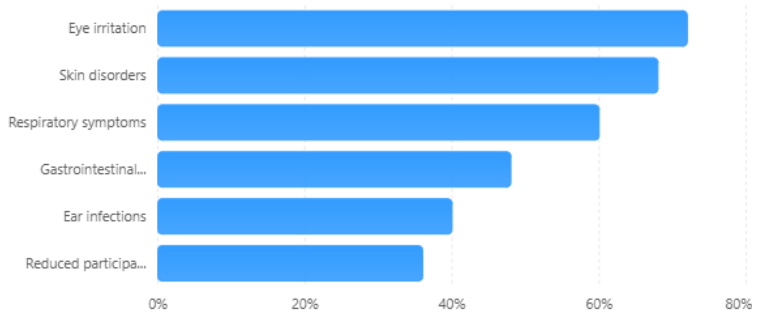

Figure 2.
Health complaints among swimmers

Implications for Swimming Athletes in School Sports Education

The reviewed studies demonstrated that sanitation conditions directly affect athlete health, attendance, and educational participation. Approximately 64% of studies reported that poor pool sanitation negatively influenced training consistency and athlete attendance.

Table 5.
Educational and Athletic Implications

Impact Area	Percentage of Studies (%)
Reduced training attendance	64
Increased health complaints	80
Decreased performance readiness	56
Lower motivation to participate	44
Interrupted learning activities	52

These findings indicate that swimming pool sanitation should be regarded not merely as an environmental health issue but also as a critical component of educational quality assurance within school sports programs.

Synthesis of Findings

The thematic synthesis identified three interconnected pathways linking sanitation and athlete health:

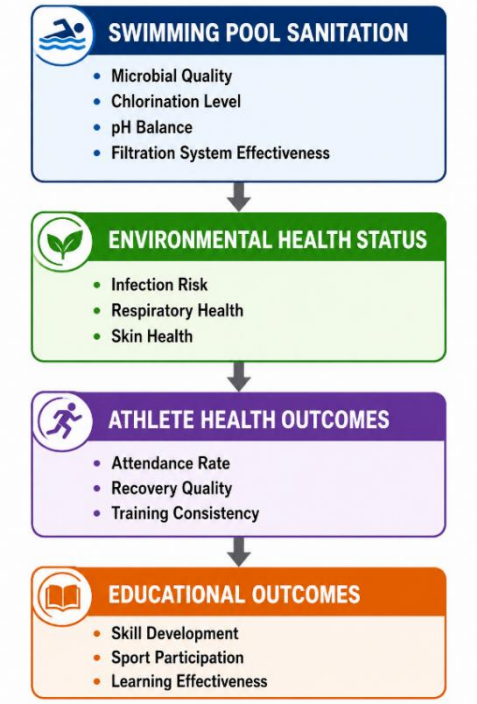

Figure 3.
Conceptual Framework

Based on the synthesis of 25 studies, four major findings emerged: Microbiological contamination (92%) is the most frequently monitored sanitation parameter. Eye irritation (72%) and skin disorders (68%) are the most common health complaints among swimmers. 64% of studies reported that poor sanitation reduced training attendance and continuity. School swimming programs operating under effective sanitation management demonstrated better athlete health protection, greater participation rates, and more sustainable educational outcomes.

Overall, the systematic review demonstrates that swimming pool sanitation is a fundamental determinant of swimmer health and athletic development within school sports education. Effective sanitation management contributes not only to disease prevention but also to improved athlete participation, training consistency, educational engagement, and long-term swimming performance.

Discussion

The findings of this systematic review demonstrate that swimming pool sanitation is a fundamental determinant of swimmer health and the effectiveness of school-based sports education programs. The synthesis of 25 studies revealed that microbiological contamination (92%), residual chlorine levels (84%), and pH balance (80%) were the most frequently assessed sanitation indicators. These findings support the principles of Environmental Health Theory, which argues that environmental quality directly influences human health status and behavioral outcomes. Within aquatic sports settings, swimming pools function as complex ecosystems where biological, chemical, and physical factors interact to affect athletes' health and performance.

The predominance of microbiological contamination as the most frequently reported sanitation indicator is consistent with previous studies emphasizing that recreational water

environments can become reservoirs for pathogenic microorganisms when sanitation management is inadequate. Bacterial species such as Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus, and various fungal organisms have been identified as common contaminants in swimming facilities. According to the Multiple Barrier Theory of Water Safety, effective pool management requires an integrated approach involving filtration systems, disinfectant control, swimmer hygiene practices, and continuous monitoring to prevent pathogen transmission. Recent studies published in Scopus-indexed journals have demonstrated that inadequate microbiological control significantly increases the incidence of recreational water illnesses among swimmers, particularly in facilities with high user density and insufficient maintenance protocols (Manasfi et al., 2021; Hlavsa et al., 2023).

The current review also found that eye irritation (72%), skin disorders (68%), and respiratory symptoms (60%) were the most common health complaints among swimmers. These findings align with the Recreational Water Illness (RWI) Framework, which explains that swimmers are exposed to both microbial pathogens and chemical disinfection by-products during prolonged water immersion. Chloramines, which are formed when chlorine reacts with organic substances such as sweat, urine, and skin particles, are recognized as major contributors to ocular and respiratory irritation. Empirical evidence from competitive swimming populations has shown that chronic exposure to elevated chloramine concentrations may increase the prevalence of asthma-like symptoms, airway inflammation, and allergic responses among athletes. Similar findings have been reported in Indonesian studies assessing swimming pool sanitation, where poor water quality was associated with higher rates of dermatological and respiratory complaints among users.

From a physiological perspective, the observed health problems may negatively affect athletic performance and training adaptation. The General Adaptation Syndrome (GAS) proposed by Selye suggests that athletes require optimal environmental conditions to maintain positive adaptation to training loads. Recurrent infections, respiratory disorders, and inflammatory responses may disrupt recovery processes, increase physiological stress, and reduce the effectiveness of training stimuli. Consequently, swimmers exposed to poorly maintained pool environments may experience decreased performance progression despite participating in structured training programs. Several studies conducted in sports medicine have demonstrated that illness-related training interruptions are associated with reduced aerobic capacity, diminished muscular endurance, and lower competitive readiness among athletes.

An important finding of this review is that approximately 64% of the included studies reported reduced training attendance associated with poor sanitation conditions. This result can be explained through the Health Belief Model (HBM), which suggests that individuals' participation in health-related activities is influenced by perceived risks and benefits. Athletes who experience recurrent eye irritation, skin infections, or respiratory discomfort may develop negative perceptions toward swimming activities, leading to decreased attendance and participation. Within school sports education, reduced attendance not only affects physical conditioning but also limits opportunities for skill acquisition, motor learning, and social development. Therefore, sanitation management should be viewed as an educational issue rather than solely a facility maintenance concern.

The relationship between swimming pool sanitation and educational outcomes can also be interpreted through the Ecological Model of Health, which emphasizes that health behaviors and outcomes are shaped by interactions between individual, environmental, and institutional factors. In school contexts, swimming pools serve as educational environments where students develop physical literacy, water safety competence, and sport-specific skills. When sanitation

standards are compromised, the educational function of swimming facilities may be undermined due to increased health risks and reduced participation. Previous research in physical education has consistently shown that safe and supportive learning environments contribute significantly to student engagement, motivation, and learning effectiveness.

Furthermore, the findings highlight the importance of maintaining appropriate residual chlorine concentrations and pH levels. While chlorine is essential for pathogen control, excessive chlorination may generate harmful disinfection by-products such as trihalomethanes (THMs) and chloramines. According to the Risk Assessment Theory in Environmental Health, effective sanitation management requires balancing microbial safety and chemical exposure risks. Several recent studies have reported that excessive chlorine exposure may adversely affect respiratory health, particularly among young swimmers and athletes engaged in intensive training schedules. Therefore, sanitation programs should prioritize evidence-based monitoring systems that ensure compliance with international water quality standards.

The current review also reinforces the role of sanitation in promoting athlete welfare and long-term sports participation. The Athlete Health Protection Model suggests that preventive environmental management is a critical component of sustainable athlete development. Athletes who train in safe aquatic environments are more likely to maintain consistent training attendance, experience fewer health-related interruptions, and achieve optimal performance outcomes. In contrast, poor sanitation conditions may contribute to recurrent illness, psychological discomfort, and decreased motivation to participate in swimming activities. These findings are particularly relevant for school sports programs, where athlete health protection should be integrated into broader educational objectives.

Another important implication concerns sports facility management. The reviewed literature consistently indicates that swimming pool sanitation should be incorporated into comprehensive sports governance frameworks. Modern facility management theories emphasize that sports infrastructure quality directly influences athlete experiences and performance outcomes. In school settings, administrators, coaches, physical education teachers, and facility managers share responsibility for ensuring compliance with sanitation standards. Routine microbiological testing, water quality monitoring, filtration maintenance, and swimmer hygiene education represent essential components of effective sanitation management systems.

The findings of this review are also significant from a public health perspective. Swimming is widely recognized as one of the most beneficial forms of physical activity because it promotes cardiovascular fitness, muscular endurance, flexibility, and psychological well-being. However, these benefits may be compromised when aquatic environments fail to meet health and safety standards. The World Health Organization and numerous public health agencies have emphasized that safe recreational water environments are fundamental to health promotion strategies. Consequently, improving swimming pool sanitation may contribute not only to athlete health but also to broader public health objectives within educational institutions.

Overall, the results of this systematic review provide strong conceptual and empirical evidence that swimming pool sanitation is closely associated with swimmer health, training continuity, and educational effectiveness. The integration of Environmental Health Theory, the Ecological Model of Health, the Health Belief Model, Recreational Water Illness Framework, and Athlete Health Protection Theory demonstrates that sanitation management extends beyond technical water treatment procedures. Instead, it represents a multidimensional strategy for protecting athlete health, enhancing educational quality, and supporting sustainable sports development. Therefore, schools, sports organizations, and policymakers should prioritize

evidence-based sanitation management practices as an integral component of swimming education and athlete development programs.

CONCLUSION

This systematic review provides comprehensive evidence that swimming pool sanitation plays a crucial role in protecting swimmer health and supporting the effectiveness of school-based sports education programs. Based on the synthesis of 25 eligible studies published between 2015 and 2025, microbiological contamination (92%), residual chlorine concentration (84%), and pH balance (80%) emerged as the most frequently monitored sanitation indicators. The findings further revealed that poor swimming pool sanitation is associated with various health problems among swimmers, including eye irritation (72%), skin disorders (68%), respiratory symptoms (60%), gastrointestinal complaints (48%), and ear infections (40%).

From an empirical perspective, approximately 64% of the reviewed studies reported reduced training attendance and continuity due to sanitation-related health issues, while 56% indicated decreased performance readiness among athletes. These results demonstrate that inadequate sanitation not only threatens physical health but also negatively affects athlete participation, learning engagement, and training effectiveness within school sports environments.

Conceptually, the findings support Environmental Health Theory, the Ecological Model of Health, and the Recreational Water Illness Framework, which emphasize the influence of environmental quality on health and performance outcomes. Effective sanitation management, including routine microbiological monitoring, appropriate chlorination, pH control, filtration maintenance, and swimmer hygiene education, is essential for creating safe aquatic environments.

Therefore, swimming pool sanitation should be recognized as a strategic component of athlete health protection and educational quality assurance, contributing to sustainable athlete development, improved participation, and enhanced learning outcomes in school swimming programs.

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