

APPLICATION OF ARTIFICIAL INTELLIGENCE IN THE TRAINING PROCESS OF COMPETITIVE SWIMMERS

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Abstract

The current stage of sports science is characterized by the intensive digital transformation of training systems and by the growing integration of artificial intelligence (AI) into the preparation of high-performance athletes. These technologies are especially relevant to competitive swimming, where performance depends not only on general physical fitness but also on precise technical execution, rational workload distribution, recovery quality, and timely correction of the training process. The purpose of this article is to analyze the main directions in which AI technologies are applied in the training process of competitive swimmers, to identify their methodological potential, and to determine the key limitations and prospects of their use. The study is based on analysis, synthesis, systematization, and comparative interpretation of contemporary scientific literature in sports science, digital technologies, biomechanics, machine learning, computer vision, and performance analytics. The results show that the most promising applications of AI in swimming include computer-vision-based biomechanical analysis, machine-learning models for performance prediction, intelligent personalization of training loads, wearable-sensor-based monitoring of functional state, and digital platforms that support coaching decisions. At the same time, AI implementation is associated with organizational, technical, methodological, and ethical challenges related to data quality, the need for expert interpretation, personal-data protection, and the high cost of advanced digital solutions. The article argues that AI should not be interpreted as a replacement for the coach but as an intelligent decision-support tool that can increase the objectivity, efficiency, and personalization of the training process.

Keywords: artificial intelligence, competitive swimming, training process, machine learning, computer vision, sports analytics, digital technologies, athlete preparation.

1. Introduction

The rapid development of information technologies is one of the defining characteristics of contemporary society. Digital transformation now affects almost every sphere of human activity, including industry, health care, education, transport, and professional sport. Within this process, artificial intelligence has acquired a particularly important role because its analytical capacity expands traditional approaches to data processing, prediction, and decision-making [6; 8; 12].

During the last decade, AI has developed from a prospective field of computer science into a practical tool for the analysis of complex biological, technical, and social systems. Modern machine-learning algorithms are capable of identifying hidden patterns that are difficult to detect through conventional statistical procedures. For this reason, AI technologies are increasingly applied in the preparation of high-performance athletes and in the optimization of sport performance [9; 14; 34].

Competitive swimming is among the most technically demanding Olympic sports. The final result depends on a combination of factors: stroke technique, starts and turns, special endurance, speed-strength qualities, pacing strategy, recovery effectiveness, and psychological stability. Even minimal technical errors may lead to the loss of hundredths of a second, which can determine medal distribution at major international competitions [17; 18; 21].

Traditional systems of swimmer preparation rely mainly on the professional experience of the coach, visual observation, manual interpretation of training results, and a limited number of physiological indicators. Although such approaches remain valuable, they have objective limitations related to human subjectivity, time-consuming data processing, and the inability to analyze many interdependent variables simultaneously [1; 5].

In this context, sports organizations increasingly introduce AI-based solutions that can automatically analyze video recordings, evaluate biomechanical characteristics, predict sport readiness, calculate optimal training loads, and identify injury risk. Recent studies show that the integration of computer vision, wearable sensors, and machine learning can improve the objectivity of technical assessment and support individualized training [4; 16; 31].

Despite this progress, the application of AI in swimming is still less developed than in sports such as football, basketball, cycling, and athletics. Most existing studies focus on separate tasks, such as stroke-style recognition, phase detection, fatigue monitoring, or isolated biomechanical analysis. Integrated intelligent systems that combine data collection, data processing, prediction, and automated recommendation for coaches remain at an early stage of development [15; 29].

Therefore, there is a clear need for a comprehensive analysis of the contemporary directions of AI use in competitive swimming, the identification of its potential advantages, and the evaluation of the conditions required for further integration into the system of sport preparation.

The purpose of the study is to analyze modern directions in the application of artificial intelligence to the training process of competitive swimmers and to determine the advantages, limitations, and prospects of intelligent technologies in sport preparation.

2. Literature Review

In recent years, AI in sport has become one of the fastest-growing areas of sports science. Initially, intelligent algorithms were used mainly for statistical processing of competition results. Today, however, they cover almost all stages of athlete preparation: technical movement analysis, tactical modeling, prediction of sport form, recovery monitoring, and injury prevention [27; 28; 30].

Researchers emphasize that the current stage of sports analytics is characterized by a shift from traditional descriptive statistics to machine learning, deep learning, computer vision, and explainable artificial intelligence. These methods make it possible to identify hidden regularities in large datasets and to generate individualized recommendations for athletes and coaches [8; 9; 36].

Although AI has already been actively introduced into elite sport, competitive swimming remains a relatively specific and technically complex environment for digital analysis. The aquatic medium creates unique obstacles for motion capture: light refraction, bubbles, unstable visibility, water resistance, and the need to synchronize underwater and above-water cameras [21; 24; 29].

Nevertheless, recent work demonstrates the increasing effectiveness of neural networks in automatic recognition of swimming movements. Current models can classify swimming styles, identify stroke phases, detect turn phases, and calculate kinematic characteristics. In some studies, recognition accuracy has reached a level that makes automated training analysis practically feasible [4; 15; 29].

Wearable sensors represent another important research direction. Integrated with machine-learning algorithms, such systems can register acceleration, angular velocity, body orientation, heart rate, and other physiological data directly during training. These data are used to construct individualized models of adaptation and to support timely correction of training loads [31].

One of the most promising areas is the prediction of sport performance using machine learning. Unlike classical regression analysis, AI models can simultaneously consider a large number of interconnected factors, including anthropometric characteristics, training volume, power indicators, stroke rate, swimming velocity, and physiological parameters [16; 30].

Explainable AI is particularly important in this context because it allows not only the generation of predictions but also the explanation of which variables have the strongest influence on performance. This transparency increases coaches' trust in intelligent systems and allows algorithmic conclusions to be interpreted from the perspective of sports physiology and biomechanics [4; 16].

The literature also highlights unresolved issues. There is still a lack of large, standardized databases containing biomechanical, physiological, and competitive indicators of swimmers across age groups and qualification levels. Existing AI models are often designed for one narrow task and are rarely integrated into a comprehensive digital support system for the athlete [15; 29; 37].

Overall, the literature shows that AI is gradually becoming a key factor in the digital transformation of sport preparation. The most actively developing areas are technical analysis, functional-state monitoring, performance prediction, and personalization of training. At the same time, integrated AI systems for swimmer preparation remain under development, which determines the scientific and practical relevance of further research.

3. Theoretical Foundations of AI Application in the Training Process of Competitive Swimmers

3.1. Artificial Intelligence as a Tool of Digital Transformation in Sport Preparation

The development of AI is one of the most significant factors in the modernization of contemporary sports science. Ten years ago, digital technologies were used mainly to register competition results and store statistical information. Today, they solve more complex tasks related to training analysis, prediction of sport form, competition modeling, and support for coaching decisions [6; 12; 35].

In contemporary literature, AI is understood as a set of computational methods, algorithms, and software tools capable of performing tasks that traditionally require human intelligence. These tasks include pattern recognition, natural-language processing, analysis of large datasets, prediction, decision-making, and self-learning based on accumulated experience [8; 11; 12].

Applied to swimmer preparation, AI can be interpreted as an intelligent information-processing system that unites different digital technologies into a single analytical environment. Unlike traditional sport-control methods, AI can simultaneously process numerous heterogeneous indicators, detect hidden relationships among them, and formulate recommendations for improving the training process [15; 31].

It is important to stress that AI does not replace the professional activity of the coach. Its main function is to increase the objectivity of analysis, reduce the time required for data processing, and support decision-making. Therefore, AI should be understood as an intelligent assistant to the coach rather than an autonomous system of sport management [12; 34].

3.2. Main AI Technologies Used in Competitive Swimming

Machine learning

Machine learning is a group of algorithms that identify patterns in accumulated data without the need to program every rule explicitly. In sport preparation, these algorithms are used to predict sport form, assess the effectiveness of training programs, analyze physiological indicators, and model performance dynamics. Regression methods, decision trees, random forests, gradient boosting, and artificial neural networks make it possible to consider many indicators that affect preparation effectiveness [7; 8; 30].

Deep learning

Deep learning is a modern branch of machine learning based on multilayer artificial neural networks. For swimming, this technology is especially important because it allows automatic recognition of complex motor actions without manual feature extraction. Neural networks can analyze stroke technique, body position, coordination, leg action, start effectiveness, turn execution, and finishing actions [6; 9; 28].

Computer vision

Computer vision is one of the fastest-developing areas of AI. Its main function is the automatic analysis of images and video. In swimming, computer vision can be used to detect stroke phases, analyze head position, assess elbow angle, measure joint angles, calculate stroke length and stroke rate, evaluate movement symmetry, and analyze starts and turns [5; 29].

Big data analytics

The contemporary training process generates large volumes of information, including data on training loads, split velocities, heart rate, heart-rate variability, lactate concentration, sleep quality, recovery state, strength indicators, and competition performance. Big data technologies make it possible to unite these indicators into a single analytical system and to identify patterns that cannot be found by traditional statistical methods [7; 30; 34].

3.3. Conceptual Model of AI Integration into the Training Process

On the basis of the literature analysis, this article proposes a conceptual model for integrating AI into the training process of competitive swimmers. The model is based on the principles of continuous data collection, intelligent information processing, and support for coaching decisions.

The model contains five interconnected components: (1) a data collection block, including video recordings, underwater cameras, wearable sensors, inertial devices, sports watches, medical examinations, laboratory tests, and competition results; (2) an analytical block, using machine learning, deep learning, computer vision, big data analytics, and predictive analytics; (3) an intelligent-analysis block, which identifies technical errors, fatigue level, sport form, injury risk, performance prognosis, and load effectiveness; (4) a decision-making block, where coaches use analytical outputs to correct plans, intensity, volume, recovery means, and competition preparation; and (5) a feedback block, where repeated data collection ensures continuous self-learning of the system.

The novelty of the model lies in its integrative character. Instead of considering AI technologies separately, it combines biomechanical analysis, monitoring of functional state, prediction of performance, personalization of training loads, decision support, and continuous self-learning. This makes it possible to regard AI not as an

isolated digital instrument but as an integrated support system for managing swimmer preparation.

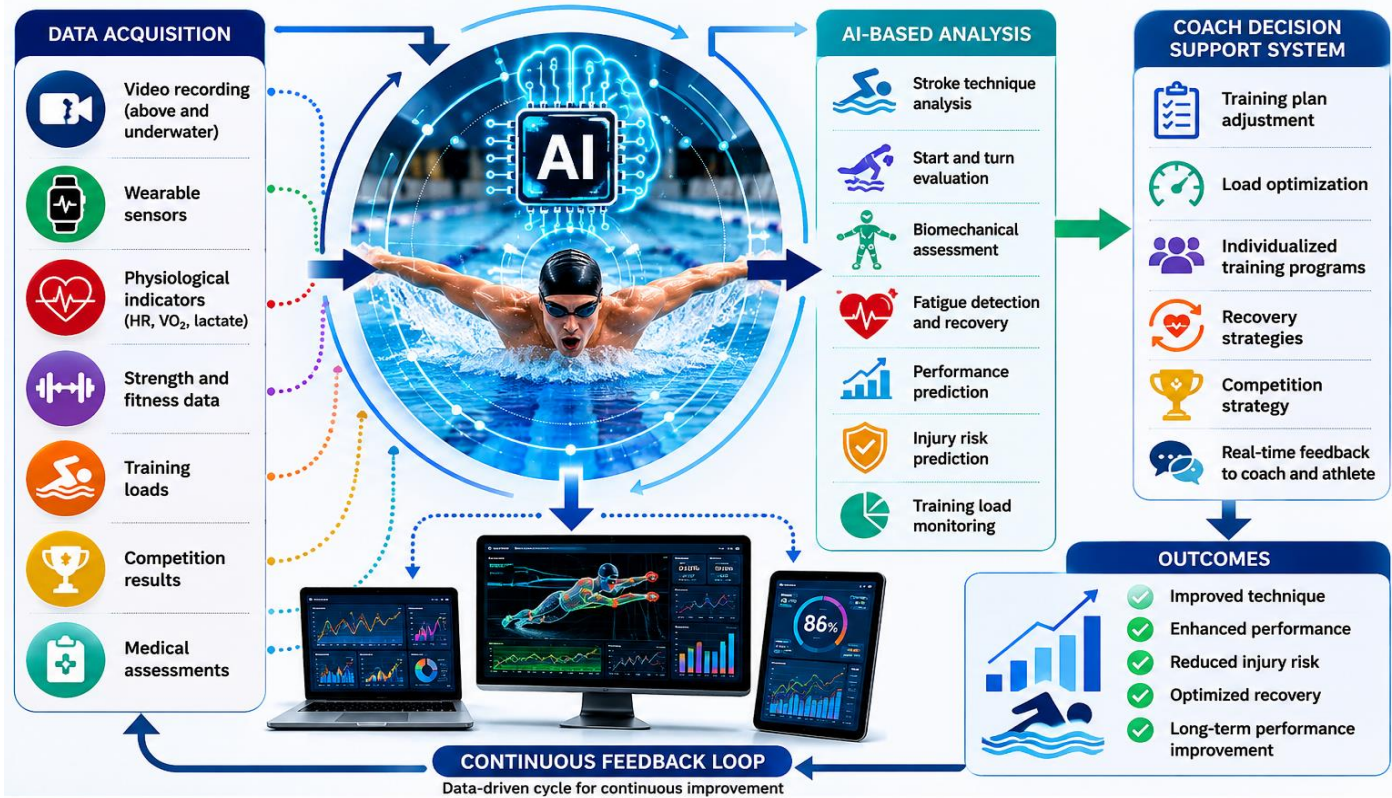


Figure 1 – Conceptual model of AI integration into the training process of competitive swimmers.

Source: developed by the author.

4. AI-Based Analysis of Swimming Technique and Optimization of the Training Process

4.1. Biomechanical Analysis of Swimming Technique Using Computer Vision

Technical mastery is one of the key factors determining performance in swimming. Even minor deviations in body position, hand trajectory, leg action, or execution of starts and turns can reduce swimming velocity and increase energy expenditure. For this reason, the improvement of technique occupies a central position in long-term swimmer preparation [17; 21; 24].

For a long time, technique assessment was based mainly on visual observation by the coach and subsequent video analysis. Although expert observation remains valuable, this approach is limited by subjectivity, the impossibility of simultaneously analyzing a large number of parameters, and the time required to process video materials [1; 5].

Computer vision significantly expands the possibilities of biomechanical analysis. Using deep-learning algorithms and motion-recognition methods, intelligent systems automatically identify key body points, track their spatial positions, and calculate kinematic characteristics of swimming technique [5; 29].

Compared with traditional observation, computer vision allows simultaneous evaluation of numerous parameters, including head position, hand-entry angle, shoulder-girdle amplitude, elbow trajectory, arm-leg synchronization, trunk alignment, stroke length, stroke rate, and temporal characteristics of each movement phase. Such complex assessment provides a more objective picture of technical preparedness [29; 31].

The possibility of analyzing technique directly during a training session is especially valuable. Modern software systems can process video streams almost in real time and automatically identify episodes that require the coach's attention. This makes it possible to correct technique immediately rather than after the training session has ended.

4.2. Automatic Detection of Technical Errors

Automatic recognition of technical errors is one of the most promising directions of AI application in swimming. Neural networks trained on large sets of videos of highly qualified swimmers can compare the movements of a particular athlete with reference biomechanical models and detect deviations that may be difficult to observe visually [4; 29].

The most common errors that can be identified by intelligent systems include excessive elbow flexion at the beginning of the pull, premature completion of the propulsive phase, disruption of arm-leg coordination, excessive vertical body oscillation, incorrect head position, movement asymmetry, insufficient stroke length, velocity loss after turns, and start-execution errors.

The automation of error detection reduces the time required for analysis and accelerates technical improvement. It is especially useful when the coach works with a group of swimmers and cannot continuously observe every technical detail of each athlete.

4.3. Analysis of Starts and Turns

Starts and turns are key components of competition performance. On sprint distances, their effectiveness can have a decisive influence on the final result. AI systems can conduct a detailed analysis of each start phase, including reaction time, take-off force, flight angle, flight distance, water-entry angle, depth of immersion, surfacing velocity, and the effectiveness of the first strokes [18; 24].

Turns can be analyzed in a similar way: approach velocity, contact time, push-off force, duration of the underwater phase, effectiveness of dolphin kicks, and the timing of the first stroke after surfacing. These indicators provide coaches with objective information for minimizing time loss in the most decisive parts of the race.

4.4. Integration of Video Analytics and Wearable Sensors

A highly promising direction is the integration of computer vision with wearable-sensor data. Modern sensors can register heart rate, heart-rate variability, acceleration, angular velocity, body orientation, force characteristics, muscle activity, and oxygen saturation [31].

The synchronous processing of video images and physiological indicators makes it possible to evaluate both technical and functional preparedness. For example, an intelligent system can determine how stroke length, stroke frequency, and body position change as fatigue increases, and can then recommend appropriate adjustments to training load.

This approach shifts training control from isolated analysis of separate indicators to complex management of the training process based on objective data.

4.5. Practical Value for Swimming Coaches

AI technologies significantly change the role of the coach. Instead of spending large amounts of time on collecting and processing information, the coach receives already processed analytical data and can focus on strategic training management, individualization, psychological preparation, and competition tactics [34; 35].

The effectiveness of AI is determined not only by the quality of algorithms but also by the professional competence of the coach. The coach interprets results, makes final decisions, and bears responsibility for their implementation. Therefore, the most promising model is cooperation between AI and the coach, where AI performs the function of intelligent support and the coach retains the leading role in sport preparation.

Table 1 – Main AI technologies and areas of application in competitive swimming

AI technology	Main functions	Practical application in swimming
Computer vision	Analysis of movement technique	Control of strokes, starts, and turns
Machine learning	Prediction of results	Individualization of training programs
Deep learning	Recognition of complex motor actions	Automatic detection of technical errors
Big data analytics	Complex data processing	Monitoring of preparation dynamics
Explainable AI (XAI)	Interpretation of predictions	Support for coaching decisions

5. Personalization of the Training Process Using Artificial Intelligence

5.1. Individualization of Preparation as a Contemporary Trend

One of the key trends in contemporary training theory is the transition from standardized programs to personalized models of training management. Athletes of the same age, qualification, and specialization may respond differently to identical training loads. These differences are determined by genetic factors, functional state, technical preparedness, recovery rate, psychological characteristics, and competition experience [19; 20; 31].

Traditional planning often relies on averaged indicators and therefore does not always allow full realization of the athlete's potential. AI opens new possibilities for constructing personalized programs based on continuous analysis of objective data. Intelligent algorithms can consider many variables simultaneously, identify hidden patterns in training dynamics, and generate recommendations adapted to the athlete's individual characteristics [30; 38].

As a result, the training process becomes more flexible, scientifically grounded, and oriented toward maximum sport effectiveness.

5.2. Machine Learning in Training-Load Planning

Optimization of training loads is one of the most important areas of AI use. Machine-learning algorithms analyze historical data, including training volume, intensity, physiological indicators, recovery speed, control-test results, and competition outcomes [7; 30].

Based on these data, an intelligent system predicts the organism's likely response to future training stimuli and suggests a more rational distribution of load. This approach helps to correct plans in a timely manner, avoiding both insufficient stimulation of adaptation and excessive loads that may lead to overtraining or injury [31].

The possibility of updating recommendations dynamically is especially valuable. As new data accumulate, algorithms can improve the accuracy of prediction and adapt to changes in the swimmer's functional state. Thus, planning becomes dynamic and more sensitive to individual differences.

5.3. Monitoring the Functional State of the Athlete

Wearable devices have expanded the possibilities of training control. Sensors integrated into sport watches, chest straps, and specialized devices allow the registration of a wide range of physiological parameters during training. Among the most informative variables are heart rate, heart-rate variability, oxygen saturation, sleep duration and quality, recovery indicators, daily activity level, and subjective well-being [31].

When these data are integrated with AI algorithms, the system can assess the current functional state of the swimmer and predict the probability of chronic fatigue,

reduced performance, or overtraining. If negative trends are detected, the system can recommend adjustment of training volume, increased recovery time, or changes in the orientation of training sessions [30; 38].

Such recommendations do not replace medical supervision but provide additional informational support to the coach and to specialists responsible for integrated scientific support.

5.4. AI and Prediction of Sport Performance

Prediction of future results is one of the most complex tasks in sports science. Traditional approaches rely on statistical analysis of selected indicators and expert judgment. However, they often fail to consider the complex interaction of multiple factors that determine competition success [16; 30].

AI makes it possible to create predictive models based on multidimensional data. These models can include technical, physiological, biomechanical, and competitive indicators and can evaluate their changes over time. The practical value of such models lies in estimating the probability of achieving planned results, assessing the effectiveness of a chosen program, and supporting timely correction of training [16].

Performance prediction also supports more rational planning of competition participation and tapering strategies before major events.

5.5. AI in Coaching Decision Support

The contemporary training process is accompanied by the processing of large volumes of information, which increases the demands placed on coaching analytics. AI automates data analysis and presents results in a form suitable for practical use [34].

Intelligent systems can generate reports on training-load dynamics, changes in technical characteristics, functional state, and predicted results. On the basis of these reports, the coach can make more informed decisions about the structure of the training process.

The final decision, however, must remain with the coach. AI functions as a consultative tool that provides objective analysis and scientifically grounded options, while professional experience determines the final practical solution.

Table 2 – Comparison of traditional and AI-oriented approaches to organizing the training process of swimmers

Criterion	Traditional approach	AI-oriented approach
Technique analysis	Visual observation by the coach	Automated biomechanical analysis
Load planning	Based mainly on coaching experience	Based on multidimensional data analysis
Functional-state control	Periodic testing	Continuous real-time

		monitoring
Error detection	Expert assessment	Automatic recognition and classification
Performance prediction	Expert opinion	Machine-learning algorithms
Training individualization	Limited	High level of personalization
Speed of data processing	Low	High
Decision support	Predominantly subjective	Combination of objective data and expert judgment

The analysis shows that AI substantially expands the possibilities of personalizing swimmer preparation. Machine learning, intelligent data analysis, and continuous monitoring increase the objectivity of training assessment, support timely load correction, and improve performance prediction. The greatest effectiveness is achieved when digital technologies are integrated with coaching expertise.

6. AI for Functional-State Monitoring, Injury Prevention, and Performance Prediction

6.1. AI-Based Monitoring of Functional State

The effectiveness of swimmer preparation depends largely on the coach's ability to evaluate the current functional state of the organism and to adjust training stimuli in time. Insufficient monitoring of adaptation may lead to chronic fatigue, reduced performance, impaired recovery, and increased injury risk [30; 31].

AI-based systems integrate data from wearable sensors, sport watches, heart-rate monitors, inertial devices, force platforms, and mobile applications that record subjective well-being. Complex processing of this information provides an objective picture of adaptation dynamics and allows early detection of unfavorable changes [31].

Unlike traditional control based on periodic testing, AI enables continuous analysis of the athlete's state. Algorithms compare current indicators with individual baseline values, identify unusual changes, and predict possible decreases in readiness. This allows the coach to correct volume and intensity before negative states develop.

6.2. Prediction of Overtraining Risk

Overtraining remains one of the most serious problems in modern sport. It is associated with decreased performance, impaired recovery, immune dysfunction, emotional instability, and increased injury probability. Traditional diagnosis often relies on subjective complaints or periodic medical testing, which may not detect early warning signs [30].

AI supports a preventive model of control by predicting risk before pronounced symptoms appear. Machine-learning algorithms analyze physiological, biomechanical, and training data and determine individual patterns of adaptation. When signs of excessive fatigue are detected, the system can issue a warning and suggest changes in intensity, recovery duration, or microcycle structure [31; 38].

This approach contributes to the preservation of high performance and more rational management of training loads throughout the preparation period.

6.3. AI in Injury Prevention

Injury prevention is one of the main tasks in high-performance sport. Although swimming is less traumatic than many contact sports, the repeated execution of similar motor actions may cause chronic overloads, particularly in the shoulder joint, spine, and knees [21; 24].

AI can improve prevention by analyzing technique, load distribution, physiological dynamics, and injury history. Computer vision is especially important because it can automatically detect biomechanical deviations that increase stress on specific anatomical structures. For example, incorrect elbow position during the stroke or asymmetry of movement may be interpreted as a risk factor for shoulder overload [5; 29].

The obtained information can be used to design individual prevention measures, including technique correction, training-load modification, special exercises, and optimization of recovery procedures.

6.4. Prediction of Competitive Results

Prediction of sport performance is one of the most promising applications of AI in contemporary sport. Unlike traditional methods based mainly on expert judgment, intelligent algorithms can consider numerous interrelated factors and identify complex nonlinear relationships among them [16; 30].

Predictive models may include anthropometric characteristics, special physical-preparedness indicators, biomechanical parameters, training volume and intensity, functional state, control-start results, competition experience, and recovery characteristics. Complex analysis of these variables makes it possible to estimate the likelihood of achieving a planned result, identify strengths and weaknesses, and correct training in time [16].

AI models should not be interpreted as tools for exact prediction of the future. Their main purpose is to estimate probable scenarios of sport-form development and to provide coaches with objective analytical information for making rational decisions.

6.5. Practical Implementation in Sport Organizations

Despite the significant potential of AI, its effective use requires appropriate organizational and technical infrastructure. Sport centers need modern video-registration tools, wearable sensors, analytical software, and reliable data-storage systems [34; 35].

Equally important is the improvement of coaches' digital competence. Even the most advanced algorithm cannot produce a high-quality result without competent interpretation by specialists. Training programs for coaches should therefore include the basics of data analysis, machine learning, biomechanics, and digital technologies in sport [34].

A promising direction is the creation of integrated digital platforms that combine training, medical, physiological, and competition data. Such systems can support the long-term development of swimmers at all stages of their sport specialization.

Table 3 – Advantages and limitations of AI use in the training process of competitive swimmers

Advantages	Limitations
High objectivity of analysis	High cost of equipment
Fast processing of large datasets	Need for technical support
Personalization of training	Dependence on data completeness and quality
More accurate biomechanical assessment	Lack of standardized databases
Prediction of sport form	Limited interpretability of some models
Reduced risk of overtraining	Need for specialist training
Support for coaching decisions	Personal-data protection issues

7. Problems, Limitations, and Prospects of AI Application in Competitive Swimming

7.1. Main Problems of AI Implementation

Despite the rapid development of AI and its growing role in sport preparation, practical implementation in sport organizations is associated with objective difficulties. Most limitations are not caused only by the algorithms themselves but by organizational, technical, and methodological conditions [15; 34].

One of the most serious problems is the limited availability of high-quality datasets. The effectiveness of machine learning directly depends on the quantity and quality of data used for model training. In swimming, standardized collection of

biomechanical, physiological, and competitive data is difficult because it requires specialized equipment, unified testing protocols, and long-term observation [29; 31].

Another problem is the heterogeneity of input data. Athletes differ by age, sex, qualification, specialization, preparedness level, and training history. This makes it difficult to create universal AI models that are equally effective for all categories of swimmers.

The high cost of digital technologies also remains a significant limitation. Computer-vision systems, three-dimensional biomechanical analysis tools, high-resolution underwater cameras, wearable sensors, and specialized software require considerable financial investment. Therefore, the most advanced technologies are often available mainly to national teams, major sport centers, and professional clubs.

7.2. Ethical and Legal Aspects

The development of AI creates new ethical and legal questions. Modern systems collect and analyze a large amount of personal information, including physiological indicators, medical data, video recordings, functional-test results, and other confidential information [34; 35].

Therefore, the protection of athletes' personal data is essential. All processes of collection, storage, processing, and transfer of information must comply with legal requirements and international standards in information security.

Transparency of AI algorithms is also important. The use of complex neural networks may produce a prediction without clear explanation of the logic behind it. Explainable AI is therefore becoming increasingly relevant because it makes analytical results more interpretable and clarifies the contribution of separate variables [4; 16].

The final responsibility for organizing the training process must remain with the coach. AI is a decision-support instrument, but it cannot fully account for psychological, motivational, and social factors that determine athlete preparation.

7.3. Future Prospects

Current trends suggest that the role of AI in athlete preparation will continue to increase. One promising direction is the development of integrated platforms that unite video data, wearable-sensor indicators, medical control, biochemical analysis, and competition results in a single information-analytical system [34; 35].

The development of digital twins is also significant. Such systems can create a virtual model of the swimmer that reflects individual morphological, physiological, and biomechanical characteristics. Digital twins could make it possible to model different training programs, predict adaptation processes, and estimate potential results without additional physical load [34].

Generative AI also has potential in coaching practice. It can help prepare draft training plans, analyze opponents' competition activity, develop individual recommendations, and generate analytical reports. However, the outputs of generative

models must always be checked by experts because final decisions require professional judgment and contextual understanding.

Future progress requires interdisciplinary cooperation among specialists in sports science, biomechanics, physiology, medicine, computer science, and data analytics. The integration of these fields will allow the development of new-generation intelligent systems adapted to the specific demands of competitive swimming.

Table 4 – Practical recommendations for implementing AI in the training process of competitive swimmers

Area	Practical recommendations
Technique analysis	Use computer-vision systems for regular assessment of starts, turns, and stroke technique
Training planning	Apply machine-learning algorithms to correct training volume and intensity
Functional-state control	Integrate wearable-sensor data with analytics software
Injury prevention	Use predictive models for early detection of risk factors
Coach education	Develop digital literacy and data-analysis competence among coaches
Organization of work	Create integrated databases of training and competition data
Information security	Ensure protection of personal data and compliance with ethical standards

Conclusion

The analysis of contemporary scientific research shows that artificial intelligence is becoming one of the most promising directions in the digital transformation of swimmer preparation. Intelligent technologies expand the possibilities of objective analysis, provide complex assessment of technical, functional, and competitive preparedness, and improve the quality of managerial decisions.

The most actively developing technologies in competitive swimming are computer vision, machine learning, big data analytics, and intelligent systems for monitoring functional state. Their application makes it possible to automate biomechanical analysis of technique, identify technical errors, predict performance, assess the risk of overtraining, and develop personalized training programs.

The literature indicates that AI provides a higher level of objectivity compared with traditional observation methods. At the same time, it enables comprehensive

processing of heterogeneous data and therefore improves the quality of scientific support for the training process.

Effective AI implementation requires the solution of organizational, technical, and methodological problems, including the creation of standardized databases, development of digital infrastructure, improvement of coaches' qualifications, and reliable protection of athletes' personal information.

The most promising model is one in which AI acts as an intelligent decision-support system while the coach retains the leading role in managing athlete preparation. The combination of digital technologies and professional expertise can increase the effectiveness of training and create conditions for further improvement of competitive results.

Future research should focus on developing integrated platforms that combine computer vision, machine learning, digital twins, and generative AI into a unified system of scientific support for swimmer preparation. Such solutions can support a transition to a new level of personalized training management and can become an important factor in the international competitiveness of athletes.

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