



The Role of AI in Sport and Health

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Abstract

Artificial Intelligence (AI) is increasingly transforming the fields of sports and health, offering novel approaches to performance enhancement, injury prevention, and personalized healthcare. This paper explores the multifaceted role of AI in these domains, highlighting its contributions to athlete training, real-time monitoring, and rehabilitation processes. In sports, AI-powered systems analyze vast datasets to optimize training regimens, improve decision-making, and predict injury risks. In healthcare, AI aids in early diagnosis, treatment customization, and patient management, particularly in sports-related injuries and conditions. By integrating AI technologies, both fields are experiencing significant advancements, leading to more effective strategies for enhancing athletic performance and overall health outcomes. This review also addresses the ethical considerations and challenges associated with AI adoption in these areas, emphasizing the need for transparent, fair, and accountable AI systems. The paper concludes by discussing future directions, including the potential of AI to revolutionize sports and health further through innovations in wearable technology, predictive analytics, and personalized medicine.

Keywords: Artificial Intelligence; Sport; Health

Background

Sport is a highly versatile aspect of life, serving as an indicator of social status, psycho-physical skills, and the ability to cope with unexpected situations since ancient times, often translating into non-sporting life. In Ancient Greece, the cradle of civilization and athletic competition epitomized by the Olympic Games, sport was considered a crucial element of education and character building [1]. A more dramatic role of sport involved preparation for warfare and direct combat with enemies. Only subsequently did measurable results or appearance gain importance. Sporting events were invariably accompanied by religious ceremonies, emphasizing the significance of both psyche and soma, or mind and body. This approach is echoed in the modern definition of health by the World Health Organization (WHO), which views health not merely as the absence of disease but as a state of physical, mental, and social well-being. Competitive sports have always been a part of societies worldwide over thousands of years, varying in forms and events, but the goal remained consistent: achieving the best results. Since the dawn of civilization, results have been the driving force behind progress. With technological advancements and globalization, a race began to find elements that could enhance performance, analyze athletes' stances, and refine them based on gathered experiences. This also led to

numerous negative phenomena, including the use of prohibited substances to enhance physical capabilities, known as doping. During the Cold War, countries like East Germany, the Soviet Union, and China excelled in laboratory achievements to improve their athletes' results, often at the expense of their health, both mental and physical. Such practices led to distortions, exemplified by East German shot-putter Heidi Krieger, whose hormonal doping altered her appearance so significantly that she decided to undergo a sex change and become Andreas Krieger after her career ended. In cycling, the era of doping spanned the late 20th and early 21st centuries, with top titles won by athletes who regularly used doping (e.g., Lance Armstrong), arguing that competing at the highest level would have been impossible otherwise as others also used these substances. Sometimes, doping indirectly caused deaths, as in the case of Italian cyclist Marco Pantani. However, a significant part of sports remains within permissible competition, and technological advancement, prosperity, and financial support enable athletes to dedicate almost their entire lives to self-improvement. The influence of sports on society is evidenced by its billion-strong audience and the global industry's value estimated at 1.3 trillion dollars. It is essential to remember that the professionalization of sports involves not only the professional

level but also the youth level, where the number of regularly training athletes far exceeds that of professionals [2].

For decades, athletes and coaches have agreed that motor skills alone do not guarantee success. Knowledge, the ability to anticipate opponents' moves, learning from one's mistakes, and making accurate decisions are crucial. Increasingly recognized is the value of analyzing one's and opponents' stances, identifying strengths and weaknesses. This includes intelligence in spotting opportunities or spaces to maximize one's potential. Psychological aspects are also vital for development, as everyone needs room to progress. The greatest champions have had moves that opponents couldn't counter, deciding the outcomes of competitions. Michael Jordan was famous for his fadeaway shot, which was nearly impossible to block. Muhammad Ali's punches were so fast that opponents couldn't react, using speed and distance control for defense, avoiding many blows. Tiger Woods mastered not only golf ball striking but also concentration, minimizing strokes needed to sink the ball. Mike Tyson fought in heavyweight boxing despite his relatively short height (178 cm), but his first trainer, Cus D'Amato, developed a system of dodges and punches that allowed him to evade attacks and deliver deadly counters. Adam Małysz had an exceptional ability to maintain concentration, crucial in the precise discipline of ski jumping, combined with leg strength, producing stunning results. All great champions agree that details distinguish success from mediocrity. Recognizing and improving these details requires thorough self-analysis and awareness of necessary elements for improvement. To ensure every aspect, from psyche and soma to the smallest details, supports the quest for "gold," more than one person's effort is often needed.

With the dynamic development and practical application of artificial intelligence as a key tool supporting sports activities, this review aims to analyze available functions and potential directions for AI use in sports.

Components of Sports Competition Subject to AI Analysis

In today's world, conducting a sports campaign has become a logistical endeavor. Organizers must adequately prepare the venue, ensure the safety of spectators and athletes, provide conditions for broadcasting, appropriate sponsor exposure, and adhere to schedules. Athletes prepare for optimal performance with the support of a coaching team, often involving multiple specialists responsible for various aspects affecting results, including sport-specific skills, tactical analysis and selection, psychology, dietetics, fitness preparation, and biological recovery. Additionally, there is the individual analysis of physiological performance to tailor all these factors to natural predispositions. During the work of an entire team and the performance of an athlete or group of athletes, a vast amount of information arises about when goals were achieved and when they were not. Proper analysis and conclusions can help not only avoid future mistakes but primarily indicate the direction for development and identify the "space" where results

will be most tangible. However, gathering the maximum amount of information can benefit training but should not overwhelm the athlete. It is crucial to select data that can be implemented at a given moment without disrupting the existing "spine" of skills.

In this regard, artificial intelligence can play an increasingly significant role. The virtually unlimited ability to store data and use it for specific purposes with algorithmic selection of potentially best solutions appears to be the future of computer involvement in training and sports competitions.

The application of AI can start with video analysis of competitions, training sessions, individual movements of athletes or opponents. One pioneer of this approach, based on collecting opponent data, comparing it with data on one's team, and seeking ways to increase the chances of victory in direct confrontation, was football coach Jacek Gmoch, a former coach of the Polish national team. His analyses conducted in the 1960s and 70s were ahead of global approaches by nearly three decades in terms of comprehensiveness and quality. The Polish coach analyzed, among other things, how to move in a selected area of the field relative to the opponent's stance, the skill level of opponents, their strengths and weaknesses, what moves they most often choose in specific situations, and how to conduct pre-match briefings for optimal information transfer. Coach Gmoch also defined the components of a team's victory, serving as a universal indicator not only for team sports. He identified the following components: a) potential psycho-physical values, b) knowledge level and training methods, c) players' mental attitude, d) biological rhythms. This approach correlates positively with today's use of AI and the concept of pushing the boundaries of inference. In a word—what more can we do to be even better?

Conducting Individual and Team Analysis and Results

Monitoring the players' or team's posture can indicate under what circumstances, with which personnel combination, and why a chosen tactic is desirable or not [3]. Identifying strengths and weaknesses, as well as drawing conclusions based on opportunities or threats, resembles the adaptation of the well-known SWOT analysis from economics and is based on hard data [4]. The mechanism for selecting the best solutions by AI depends on programmed algorithms, but it is still not fully understood. It remains a puzzle almost like the human mind and suggests treating AI as an excellent aid, but the final choice should be critical and depend primarily on the level of knowledge and experience of the decision-maker. At the same time, it should be noted that the human mind is based on information created by its own receptors. The external source can be a human (e.g., a coach), but the advantage of AI may lie in its ability to process a vast amount of data at once and select the most important ones. Furthermore, AI can significantly enhance and specify the so-called feedback loop, which originates from an external source, which is important in the technical, tactical, and motor learning process. By using AI, a so-called sports cloud is created, where all information about the

athlete, their behaviors, and possible corrections are gathered [5]. Especially in recent times, analyzed data include player movement, health-related statistics, performance, and tactical issues mentioned. Additionally, a key question arises, especially in team sports, which plays a fundamental role. Which lineup to designate for the match day? In football, assuming that the team squad consists of 25 players and 11 must appear on the field, there are 4,457,400 ways to set up the starting lineup, which somewhat illustrates the multifaceted nature of the choices coaches face [2]. More detailed observations concern selected game fragments, such as the effectiveness of applied pressing, counterattacks, and ways of creating goal-scoring opportunities [6]. According to researchers, proper recognition of the situation and timely reaction multiply the chance of successfully completing the action [7]. Other analyzes concern the expected, or rather anticipated, values, such as ball possession in football (Fernandez, Bornn 2019) or points scored in basketball along with player decision evaluation [8]. Another model created for basketball proposes the analysis of short-term behaviors, long-term goals achievement, and behavior towards defenders [9]. Additionally, analyses of body positioning in shooting situations and the correlation of this element with effectiveness can be found. The analysis itself focused on movement habits, which, in relation to a given player, can translate into a successful shot and the compilation of those that most guaranteed success [10-13]. Precisely based on basketball, it was defined that victory in the case of a balanced rivalry is determined by elements such as shot efficiency, steals, and committed fouls [14]. On the other hand, the impact on the result in a general context includes shot efficiency, defensive rebounds, turnovers, and steals [15]. In other analyzes using the three-dimensionality of image measurement, the best forms of cooperation between basketball players in various configurations were selected. This allowed for the selection of the most optimal ways of conducting actions in terms of their effectiveness [16]. Not isolated are the analyzes related to predicting match outcomes, which achieve accuracy levels of 60-70%, and even close to 80% regarding the analyzed number of matches [17]. Such analyses, conducted based on parameters such as the number of points scored, assists, rebounds, steals, or turnovers, prove to be very effective. This shows that with the introduction of additional data and further reasoning combinations, this percentage may increase [18,19].

An interesting issue seems to be the simulation of competition based on the introduced data. Such a solution on a mass scale in sports also took place back in the 1970s, when a simulated boxing match was held between Muhammad Ali and Rocky Marciano. Nowadays, it can be an excellent way to indicate solutions that will lead to victory.

Artificial Intelligence in Sports and Health

Artificial intelligence can also be applied to personalize training programs. Among the analyzed player data are often

fatigue markers, blood lactate levels, heart rate, maximum oxygen consumption VO₂ max, as well as achieved results in the range of speed or strength efforts in selected training phases. Monitoring and indicating subthreshold, normative, and suprathreshold levels provide guidance on the player's current condition and direct what training loads should be applied to optimally prepare for competitions [20]. Additionally, reacting at the right time to training loads can help prevent injuries, which are a temporary factor excluding further competition. These solutions are used in many professional leagues and are subject to continuous improvement [21-25]. Some researchers have presented variables that may be relevant in the context of injury occurrence. These include gender, body mass, current physical fitness, tendon condition, flexibility, and especially knee joint flexibility [26]. Player assessment can occur as a result of motor actions taken, as well as skills specific to a given discipline presented. This simultaneously allows for differentiating players and indicating those with a greater skill set and development potential [27]. Additionally, there is an option to indicate players with the highest potential and the greatest significance for achieving a favorable outcome, and the obtained data do not necessarily have to be based on the number of goals scored or points scored [28]. Another area subject to monitoring appears to be the process of children's and youth training. The goal of every professional club is to prepare a player for appearances in the first team or, in the case of individual disciplines, for appearances at the senior level. The training process often begins when the player is 7-10 years old. This means that approximately a decade should be allocated to the entire shaping process. Areas of technical skills, team play, intellectual skills related to the intelligence characteristic of a given discipline, or anticipation, social skills, and the level of coping with life situations may be subject to assessment. Considering the still low percentage of individuals becoming professionals compared to the number of individuals undergoing training, the process of selection is naturally suggested again, and the role of AI. Which players, based on the available data, are most likely to succeed among professionals? [2,29,30]. Among others, such an analysis was subjected to the characteristics a player should possess to succeed in the NBA basketball league [31].

The application of AI can also be related

Artificial Intelligence in Sports and Jurisdiction

A separate aspect is the analysis conducted in terms of jurisdiction. Again, the most transparent example is football, as the most popular sport globally, accounting for 43% of the market industry according to statistical data [2]. The increased pace of the game, dynamics, and the almost instantaneous need for a referee's reaction to events have drastically increased the risk of error. Sometimes, one mistake can determine the future of a player, a team, and decide who will win the world championship and who will end up as the loser. In an effort to minimize the risk of human error, the "AI assistant" has been introduced on a

massive scale, namely VAR - Video Assistant Referee. Thanks to this, selected actions can be subjected to video analysis using additional tools, such as determining the offside position line. This allows for a precise determination of whether someone was actually in an offside position or whether the play was conducted correctly. Many other disciplines, admired daily on the world's arenas, have followed this path, such as tennis, basketball, and volleyball. The possibility of using replays exists there not only in relation to referees but also players or judges. The assistant role in relation to supervisory personnel may occur in the case of anti-doping controls, the way they are conducted, and the speed and quality of laboratory analysis. The effectiveness of control lies in the detectability of prohibited substances, and recognition should cover the largest possible area, which requires the collection of a database and its proper use [32].

Organizational Processes in Sports Utilizing AI

AI plays an increasingly important role from an organizational perspective. It demonstrates the scope of using individual facilities, their workload, facilitates the creation of schedules, or indicates the efficiency or lack thereof in organizing sports activities in a selected complex. In relation to users, especially at the level of mass events, it allows for the creation of a database and participant identification. Sometimes, in situations of security threats, it ensures the rapid detection of undesirable behaviors, helps identify the perpetrator, and enables a rapid response by security services. And since we're talking about monitoring, AI has a great impact on the way image and sound transmission is carried out, combining devices generating images, even from multiple locations simultaneously, match results, sound, while also creating the possibility of creating instant replays [33]. In addition to this, similar to all sales networks, customer preferences regarding purchased goods and services are analyzed, which allows for optimizing the product offer and acquiring new buyers. It is also possible to monitor the level of satisfaction or verify how many customers consistently use the offer or how many resign. The ticket sales process, season tickets, loyalty packages, and all interactions related to customer participation in the sales system create relationships between the sports enterprise and the customer. In many professional sports leagues, applications that are directly in contact with the customer play a key role in information dissemination. Managing a database, potential reminders, informing about new offers, establishing balances of acquired and lost customers are further tools offered by AI. It aims not only to streamline operations but also clearly informs about the current position of the business. Based on choice preferences, AI can even create groups of fans with similar views and preferences, which, considering the quantitative aspect, provides an excellent opportunity to create new products dedicated precisely to these recipients who guarantee a purchase [34,35]. Improper use of information or fragmentary data collection can result in an ineffective operating strategy [36]. In addition to data collection and analysis, AI can also support enterprise operations

by conducting risk analysis, which simultaneously translates into human safety, optimal enterprise functioning, and finances [32,37]. Already, contact with the enterprise, in many cases not only in sports, is made through chat with artificial intelligence (AI). Thanks to the collected data, AI can logically and helpfully answer the queries of the interested party, and only in the next phase does direct contact with a human become possible [32]. Another issue is controlling the data stored in the AI database and detecting errors, which is necessary regarding the correctness of inference [38].

The use of AI at the level of professional sports is increasing, and it even constitutes an auxiliary management tool, as exemplified by the Wisła Kraków football club. The distinguished football club, currently managed by one of the pioneers of Artificial Intelligence in Poland, Jarosław Królewski, has a wide range of data regarding revenue monitoring, the impact of the club product on GDP, and also uses AI, among other things, for personnel selection, i.e., selecting players or coaches for the planned concept. AI allows for the analysis of such a large number of variables that it increases the likelihood of optimizing choices compared to choices made by humans. Variables such as body parameters, playing style, number of player interactions with the ball, preferred plays, behaviors depending on the opponent's defense, endurance level in different phases of the match, number of sprints performed, how the team's result changed when a player was on the field, and what trends these variables created in relation to the selected time frame, e.g., one season, five years, the period since the beginning of the career, can be analyzed simultaneously. The obtained information clearly shows whether a player is at a stage of improving game efficiency and thus skills, or whether there are difficulties in selected circumstances [39,40].

Summary

Using artificial intelligence assistance primarily means access to a multidimensional tool that enables data integration, drawing conclusions, and applying multiple functions simultaneously in a short time, which will affect the quality of conducted activities. The AI domain seems to be inexhaustible, just like its capabilities [41-50]. The assistance it offers concerns employees at almost every level in the sports world, and in some cases, it can even replace human activity. Obtaining information directly from AI can serve player personal development, improve team functioning, and also constitute a tangible tool in predicting results [51-55].

It is also of great importance for the health sector, where methods applied in professional sports can be equally useful for people who do not engage in sports regularly. This makes the development of medicine with the participation of AI likely to bring benefits to the entire society [56-60].

Further development of artificial intelligence will undoubtedly bring new solutions and facilitate human work, provided that one knows how to utilize the obtained data [61-62].

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