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Utilizing artificial intelligence in sports research, coaching, and enhancing sports performance: SWOT analysis

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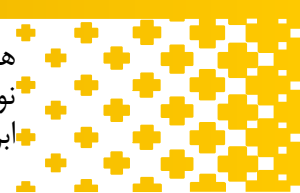
Abstract

Artificial intelligence (AI) offers immense potential to revolutionize sports research, coaching, and performance optimization. This article provides a SWOT (strengths, weaknesses, opportunities, threats) analysis evaluating the integration of AI in these areas. Key strengths of AI include efficient data processing, pattern recognition, prediction capabilities, talent identification, and automated decision-making support. However, weaknesses exist regarding data quality dependencies, interpretability, cost barriers, and ethical risks surrounding privacy. Opportunities highlighted involve leveraging AI for evidence-based decisions, customized training insights, fan engagement innovations, comprehensive performance analytics, and collaboration platforms. Concerning threats, considerations include legal/regulatory challenges, overreliance on technology, negative psychological impacts on athletes, and resistance to change. Overall, while AI integration offers tremendous benefits, it is critical to address associated weaknesses and threats appropriately. Maintaining human expertise alongside AI-driven insights is vital for holistic analysis inclusive of both quantitative metrics and qualitative factors. As the sports domain rapidly adopts AI, a nuanced, ethical approach focused on maximizing strengths while mitigating risks is essential.

Keywords: Artificial Intelligence, Coaching, Sports Performance, SWOT

Introduction

Artificial intelligence (AI) is the “theory and development of computer systems able to perform tasks that normally require human intelligence” and “makes it possible for machines to learn from experience, adjust to new inputs, and perform human-like tasks” (1). AI encompasses all forms of classical machine learning and modern artificial neural networks and through the processing of large amounts of available data (2) develop more and more human-like capabilities for decision-making and planning. The various applications of artificial intelligence (AI) are revolutionizing numerous aspects of our society (3–5), including the academic community (5) focusing on applied research relevant to sports. This community is still in the early stages of utilizing the potential of AI (6) to maintain and improve athletic performance, prevent injuries, optimize training and assist in overall decision-making (7). However, as has already been carried out with other novel technologies being applied to the practice of and research on sports (10, 11), an ongoing and comprehensive understanding of the potential strengths, weaknesses, opportunities, and threats (SWOT) of AI in this context is required (8). To evaluate the application of artificial intelligence (AI) in sports, we executed a SWOT analysis, we performed a non-systematic review of academic papers, case studies, and reports by actors in the sports industry. The broad perspective on this subject presented here is meant



primarily as an aid in strategic planning, risk assessment, and resource allocation in connection with sport science research, coaching, and optimization of athletic performance (9).

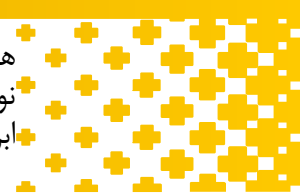
In recent years, the field of sports has witnessed a significant influx of artificial intelligence (AI) technologies (11). AI has been increasingly utilized in various aspects related to sports research, coaching, and sports performance optimization (7-9). In conclusion, the utilization of artificial intelligence in sports research, coaching, and performance optimization offers numerous strengths including efficient data processing and real-time feedback capabilities (5). Recognizing opportunities for innovation and improvement in injury prevention strategies allows coaches to effectively leverage AI systems within their training programs (9, 11). Additionally, ethical considerations regarding privacy protection along with maintaining the importance of human expertise should be prioritized throughout the integration process. (10). This article aims to provide a brief analysis using the popular SWOT framework to evaluate the strengths, weaknesses, opportunities, and threats associated with the use of artificial intelligence in these areas. However, it is essential to address the weaknesses and threats associated with AI usage carefully to maximize its potential benefits while minimizing risks. The integration of artificial intelligence (AI) technologies in sports research and coaching has brought about significant advancements in recent years. This article organizations might pose a challenge for smaller clubs or institutions with limited financial resources.

Strengths

A growing number of repetitive and time-consuming tasks, such as processing, and analysis of medical data, as well as reporting of findings can be performed by AI (12, 13). For example, language-based AI such as Chat GPT (Open AI, CA, USA) has already demonstrated its potential to assist healthcare professionals in writing medical reports (14), although its applicability with respect to various types of sports writing remains to be established. AI systems can process large sets of data and perform complex calculations, thereby enabling accurate and efficient analysis of (longitudinal) data on numerous athletes (9). For example, certain types of AI can already analyze the spatiotemporal behavior of soccer players in a manner that allows, among other things, automatic identification of dynamic attack formations, information which might be of value in connection with tactical training (15). In connection with its rapid processing and analysis of large amounts of data, AI may reveal patterns, trends, relationships, and other insights not immediately apparent to human observers (16).

One of the primary strengths of integrating AI into sports research is its ability to process vast amounts of data quickly and efficiently. Traditional methods often struggle with handling large datasets effectively; however, AI algorithms can analyze complex patterns within seconds or minutes (17). This speed allows researchers to extract meaningful insights from extensive databases that would otherwise be time-consuming or even impossible without AI assistance. By identifying correlations between different variables such as player performance metrics and environmental conditions during games or training sessions, researchers can develop more accurate models for predicting future outcomes (18).

The application of artificial intelligence also provides significant advantages when it comes to coaching athletes. Coaches can utilize AI-powered tools that analyze players' movements during training sessions or matches. These tools offer real-time feedback on technique improvements and highlight areas for development based on comprehensive biomechanical analyses. The article provides an analysis of the strengths, weaknesses, opportunities, and threats associated with the integration of artificial intelligence (AI) in sports research and coaching (16-18). AI technologies have been increasingly utilized in various aspects related to sports performance optimization. One notable strength of incorporating AI into sports research is its ability to process vast amounts of data quickly and efficiently. This enables researchers to extract meaningful insights from extensive databases that would otherwise be time-consuming or even impossible without AI assistance.



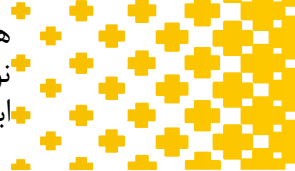
Additionally, coaches can utilize AI-powered tools that analyze players' movements during training sessions or matches, providing real-time feedback on technique improvements and highlighting areas for development based on comprehensive biomechanical analyses (19). However, there are limitations associated with integrating artificial intelligence into sports-related fields. One significant weakness is the potential bias in AI algorithms' results if the training data used lacks diversity or contains inherent biases. This may lead to inaccurate conclusions or perpetuate existing inequalities within sports populations (20). Moreover, while AI can process large volumes of data effectively, it may face challenges concerning contextual understanding as qualitative aspects may not be easily quantifiable using traditional data sources alone. Nevertheless, integrating artificial intelligence presents exciting opportunities for innovation and improvement in various areas such as injury prevention strategies. By analyzing players' movement patterns during practice sessions or games, coaches can identify potential risk factors associated with specific movements that could lead to injuries over time. Personalized recommendations based on each player's unique biomechanics and injury history enable the design of more effective individualized training programs aimed at reducing the likelihood of injuries (15-17).

Weaknesses

Despite its numerous benefits, there are some limitations associated with integrating artificial intelligence into sports research, coaching, and performance optimization. One significant weakness is the potential for AI algorithms to produce biased results (21, 22). If the training data used to develop these algorithms contains inherent biases or lacks diversity, it can lead to inaccurate conclusions or perpetuate existing inequalities within sports (8-10).

Moreover, while AI can process large volumes of data effectively, it may struggle with contextual understanding. Sports encompass a wide range of variables and subjective elements that may not be easily quantifiable or captured by traditional data sources (22). Therefore, relying solely on AI-generated insights without considering qualitative aspects might overlook critical factors necessary for comprehensive analysis. The article discusses the strengths, weaknesses, opportunities, and threats associated with the integration of artificial intelligence (AI) in sports research and coaching. AI technologies have been increasingly utilized in various aspects related to sports performance optimization. One notable strength is the ability of AI to process vast amounts of data quickly and efficiently. This enables researchers to extract meaningful insights from extensive databases that would otherwise be time-consuming or even impossible without AI assistance. Additionally, coaches can leverage AI-powered tools that analyze players' movements during training sessions or matches. These tools offer real-time feedback on technique improvements and highlight areas for development based on comprehensive biomechanical analyses (20). However, there are limitations associated with integrating artificial intelligence into sports-related fields. One significant weakness is the potential bias in AI algorithms' results if the training data used lacks diversity or contains inherent biases. This may lead to inaccurate conclusions or perpetuate existing inequalities within sports populations. Moreover, while AI can process large volumes of data effectively, it may face challenges concerning contextual understanding as qualitative aspects may not be easily quantifiable using traditional data sources alone (16-18).

Some AI systems, such as artificial neural networks, can be considered “black boxes” which perform data analysis and decision-making that is un- or even counterintuitive to human brains (6). This absence of transparency in AI models can raise concerns among athletes, coaches, and other stakeholders. For instance, when an AI model is initially trained using data regarding elite athletes, but subsequently applied to non-elite or sub-elite athletes, it may introduce biases that could result in erroneous decisions and pose potential risks to athletes which would not be apparent to the humans involved, due to the opaque nature of the decision-making process (9).



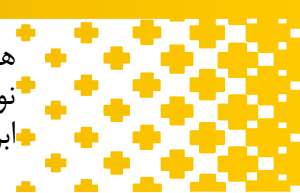
While AI can provide valuable insights, it should not replace human judgment entirely. Athletes and coaches should not abandon their own critical evaluations, but make the final decisions, relying on AI for support. Unfortunately, in this context recent research findings indicate the presence of a tendency towards excessive reliance on AI for decision-making, with an associated potential risk of making the wrong decision (22). Reliable application of AI technology to sport science may require a considerable level of expertise, significant financial investment, specialized infrastructure, and individuals who can accurately interpret the output (6). This could give teams with more resources a considerable advantage. As AI becomes more prevalent, humans may have to do more and more “cleaning” up and otherwise preparing data for usage by AI. This may necessitate hiring additional personnel or require regular staff members to allocate more of their time to such duties, potentially reducing the time they have available for interaction with their athletes (12, 18-21).

Opportunities

The integration of artificial intelligence (AI) in sports research and coaching offers numerous opportunities. Coaches can leverage advanced analytics provided by AI systems to make well-informed decisions based on objective evidence, moving away from subjective evaluations (23). Additionally, AI's ability to analyze player performance metrics facilitates the development of innovative training techniques tailored to individual needs, thereby enhancing overall performance improvements (24). AI can also be used to create interactive applications or virtual platforms that promote fan engagement, leading to increased fan participation and revenue generation. Furthermore, AI enables coaches to conduct a detailed analysis of player movements, match tactics, and other performance-related aspects for enhanced performance analysis (23, 24).

The integration of AI in sports research and coaching provides various opportunities for advancements in the field. AI systems can efficiently process vast amounts of data, offering valuable insights into player behavior, training techniques, and team strategies. These strengths empower coaches and researchers to make well-informed decisions based on objective evidence rather than relying solely on instinct or experience. AI algorithms can create accurate prediction models by analyzing historical data from previous matches or seasons, allowing coaches to anticipate future outcomes with statistical probabilities and enhance their strategizing abilities. Moreover, AI, coupled with wearable technologies, can assist in injury prevention by identifying early signs of fatigue or potential risks, allowing coaches to adjust training regimes accordingly and minimize injuries among players. Additionally, AI systems provide valuable tactical insights through the analysis of various factors, such as opponent playing styles and individual player strengths/weaknesses, enabling coaches to devise more effective game plans tailored specifically for each match scenario.

AI allows overall individual athletic performance and relevant individual physiological variables to be analyzed both in real-time and long-term. Such feedback enables short- and long-term adjustments (23) in training load and other interventions that can help individualize and optimize both training and competitive performance. Sufficiently comprehensive data, combining video recordings with a wide variety of measurements (24), also promises to predict future performance and aid in early diagnosis of injury, followed by design, monitoring and assessment of appropriate rehabilitation (22). On the basis of their analyses of individual athletes, including their health and history of injuries, AI-based systems may aid coaches and medical staff in preventing injuries before they occur (17). In this context, artificial neural networks, decision trees and support vectors are already being used to assess risk for injury in connection with different team sports (17). By analyzing large amounts of data concerning the determinants of performance, including physical attributes, and other potential indicators of success for individual athletes, AI can potentially help identify new talent (19-20). In addition to simplifying the monitoring of indicators of performance which have been previously difficult to measure, the correct comprehensive analysis and interpretation of data on both individual and groups of athletes by AI could help reveal novel indicators of performance (25). The massive

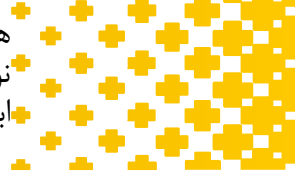


amounts of objective data that can be collected and analyzed by AI allow coaches and athletes to more easily make data- and, ideally, evidence-based decisions about training, competition, and coaching strategies concerning, e.g., training intensities, recovery protocols, and tactical adjustments. For instance, training plans for kickboxers generated automatically can be tailored to each individual athlete's current level of performance, period of development, and performance goals, thereby not only reducing the time required for planning, but also providing plans that were more comprehensive and personalized than those designed by an expert coach (26). Increased automatization of repetitive tasks, helping to improve the coach-athlete relationship. The performance of repetitive and time-consuming tasks by AI could free up more time for personal activities that improve the relationship between a coach and his athletes, which is often regarded as a key factor in the effectiveness of training (27). AI-powered platforms and systems have the potential to facilitate collaboration and other types of interactions between sport scientists, coaches, and athletes, enabling easy sharing of data, insights, and guidelines for best practices (28).

Threats

While the integration of artificial intelligence (AI) in sports research and coaching offers significant potential benefits, it also raises certain threats that must be considered. Ethical considerations emerge concerning players' privacy, data collection methods, and the potential for teams with greater financial resources to gain an unfair advantage. Additionally, relying solely on AI's automated analysis may lead to a decline in human expertise within the field (29). Therefore, it is crucial for human coaches to maintain strategic oversight while incorporating AI-driven insights into decision-making processes. The complexity of sports dynamics makes them susceptible to misinterpretation when relying solely on quantitative data analysis provided by AI systems. Coaches must exercise caution and consider qualitative factors as well. Moreover, rapid technological advancements require coaches to continuously update their knowledge and skills; failure to adapt may result in an inability to fully leverage the benefits offered by integrating artificial intelligence into coaching strategies (30). In summary, while there are immense opportunities presented by integrating AI into sports research and coaching methodologies, it is essential to address potential threats such as ethical concerns regarding player privacy and unfair advantages based on financial resources (28, 29). Maintaining human expertise alongside AI-driven insights is crucial for accurate decision-making processes considering both quantitative and qualitative factors in sports dynamics analysis. Furthermore, coaches should stay updated with rapid technological advancements to fully exploit the benefits offered by artificial intelligence integration effectively (26).

However, implementing AI technology also entails certain weaknesses that need consideration. The reliability and accuracy of AI analysis heavily depend on the quality and integrity of the data fed into the system; incomplete or inaccurate data may lead to flawed conclusions that could misguide coaches or researchers. Additionally, although AI systems excel at processing quantitative data efficiently; they lack contextual understanding possessed by human coaches who can read emotions perceive team dynamics beyond quantitative metrics alone. Moreover, deploying an effective AI system requires substantial initial investments in hardware and software which may present financial barriers for smaller teams with limited resources. Safeguarding sensitive player information against hacking threats or security breaches is also a concern that needs to be addressed adequately. However, it is crucial to address the weaknesses associated with AI technology while considering ethical implications regarding data privacy. Maintaining human expertise alongside AI-driven insights is important for accurate decision-making processes that encompass both quantitative and qualitative factors in sports dynamics analysis. Coaches must stay updated with rapid technological advancements to fully exploit the benefits offered by integrating artificial intelligence effectively (31).



The collection, storage and analysis of sensitive data on individual athletes by AI can expose organizations to privacy breaches, cyber-attacks, or other forms of unauthorized access. Thus, robust data protection is required. In addition, there is the possibility that the company managing the AI system may utilize personal data for the purpose of enhancing their models, which may lead to unintentional exposure of this data to third-party users (30). The incorporation of AI into sport science raises a number of legal and regulatory concerns, such as ownership of data and copyrights, liability for deleterious consequences of AI-based decisions, and compliance with prevailing regulations concerning data protection. To address such challenges, the European Parliament recently issued a resolution aimed at legislative regulation of AI (28).

For a variety of reasons, malicious actors may attempt to manipulate the data employed by AI systems, even introducing false information, actions commonly referred to as adversarial attacks and which can alter the decisions arrived at. One such example would be manipulating the camera of a self-driving car so that it overlooks red traffic lights (29). In a similar manner, sports data could be altered by competitors to cause the opposing team to, for example, adopt suboptimal tactics (30). Usage of AI in sport science may impair the psychological well-being of athletes, leading, for example, to performance anxiety, pressure to conform to AI-generated recommendations, and less trust in the coach. Communication and psychological aspects of the relationships between athletes, coaches and the support staff may be damaged (29, 30). As with any new technology, integration of AI into sports science may face resistance (6). There can be many reasons for such resistance and these need to be assessed employing, e.g., the technology acceptance framework (30) to survey coaches, athletes and other stakeholders (31).

Limitations and future research

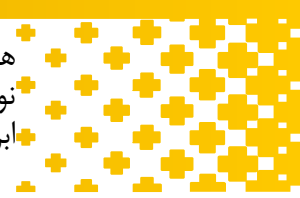
One limitation of the present study lies in the fact that, although our conclusions are consistent with those of both other SWOT analyses and non-systematic approaches in the realm of sports science (10, 11), we did not employ a systematic approach to the identification of strengths, weaknesses, opportunities, and threats. Consequently, we cannot guarantee the comprehensiveness of the information provided.

Furthermore, due to the continuous rapid development of artificial intelligence, new strengths, weaknesses, opportunities, and threats may emerge, while some of those discussed here may become less prominent. Future research in this area should aim to assess the application of AI to various aspects of sports science research, coaching, and optimization of athletic performance, utilizing an interdisciplinary approach involving professionals in handling and analyzing data, exercise and training of athletes, and ethical and social issues, among others.

In addition, there is a pressing need to educate sports practitioners in order to ensure that they implement AI properly and optimally, capitalizing on its strengths and opportunities, while mitigating potential threats and weaknesses. In this context, one branch of AI, i.e., Explainable Artificial Intelligence (XAI), is attempting to design machine learning architectures that are more transparent, interpretable, and accountable to human users (so-called “White” or “Glass” as opposed to “Black-Boxes”) (31). In situations where decision-making can exert immediate and long-lasting impacts, such transparency and interpretability are crucial. Understanding the rationale behind analyses performed by AI—including analyses of data on a players performance, prediction of injury, or optimization of game strategy—enables more informed and ethical usage of this technology, while at the same time promoting trust in its analyses.

Summary

The integration of artificial intelligence has immense potential for revolutionizing sports research and coaching. By leveraging the strengths of AI, coaches can gain valuable insights into player



performance, develop innovative training techniques, and enhance overall team strategies. However, it is crucial to address the weaknesses associated with AI technology while considering ethical implications and maintaining human expertise in decision-making processes. AI offers strengths such as automating repetitive and/or time-consuming tasks, performing large-scale analyses, recognizing patterns, predicting future events, and identifying talent. It can help optimize training, prevent injuries, and enhance decision-making. However, there are also weaknesses and threats to consider. The weaknesses include the need for high-quality data, a limited ability to interpret complex sport-specific situations, lack of human intuition, ethical considerations, biases, limited adaptability, costs, and lack of interpretability. Threats include risks to data privacy, legal and regulatory challenges, the integrity and manipulation of data, overreliance on AI, a negative psychological impact on athletes, technological limitations and biases, resistance to change, and overemphasis on quantitative data. It is crucial to address these weaknesses and threats for optimal usage of the strengths and opportunities offered by AI in connection with sports science research, coaching, and the optimization of athletic performance.

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