Law. Human. Environment

Journal homepage: https://environmentalscience.com.ua/en
Law. Human. Environment, 17(1), 174-189

UDC 796
DOI: 10.31548/law/1.2026.174

ISSN 2663-1350
E-ISSN 2663-1369

Artificial intelligence in the fight against doping: Between breakthrough and ethical and legal dilemma

Tahmina Taghi-zada
PhD in Medicine
Azerbaijan National Anti-Doping Agency (AMADA)
AZ1065, 8 Izmir Str., Baku, Azerbaijan
https://orcid.org/0000-0001-8219-5056

Rufat Efendiyev*
PhD in Economics
Azerbaijan National Anti-Doping Agency (AMADA)
AZ1065, 8 Izmir Str., Baku, Azerbaijan
https://orcid.org/0000-0001-8319-2957

Article's History:

Received: 19.09.2025
Revised: 24.12.2025
Accepted: 26.02.2026
Published: 27.03.2026

Abstract

The introduction of artificial intelligence (AI) into doping control procedures transforms decision-making and requires verification of the validity, reproducibility and non-discriminatory nature of models. The study aimed to comprehensively examine the possibilities and limitations of AI in anti-doping activities, with an emphasis on the identification of ethical dilemmas and the assessment of the effectiveness of new technological solutions in international and national practices. The study uses qualitative content analysis, comparative legal analysis, and critical assessment of regulatory and ethical frameworks to analyse legal restrictions, the integration of AI technologies into Azerbaijan's anti-doping policy and international practice. The results obtained highlighted the significance of the key provisions

Suggested Citation:
Taghi-zada, T., & Efendiyev, R. (2026). Artificial intelligence in the fight against doping: Between breakthrough and ethical and legal dilemma. *Law. Human. Environment*, 17(1), 174-189. doi: 10.31548/law/1.2026.174.

*Corresponding author

of the AI Development Strategy for 2025-2028, which create a regulatory and ethical framework for the application of technologies in Azerbaijan's anti-doping control, as well as the requirements of the Council of Europe Convention, which ensure the protection of human rights, transparency, accountability and the prevention of discrimination in the use of AI in sport. The results also showed ongoing ethical and legal risks, such as the limited explainability of AI models, the lack of procedural protections for contesting automated decisions, and the possibility of algorithmic bias being reinforced by uneven training data. These risks could jeopardise the legitimacy of AI-based anti-doping control and the effective protection of athletes' rights. However, the analysis revealed significant risks of algorithmic bias, insufficient transparency and explainability of intelligent systems, threats to the privacy and rights of athletes, and socio-economic inequality in access to technology

Keywords: technology development strategies; machine learning algorithms; personal data protection; regulatory frameworks; risks of technology application

Introduction

Modern sport is dominated by significant improvements in athletes' performance and an intensifying fight against doping, which requires new and effective control methods. AI offers revolutionary opportunities to improve the accuracy and speed of detecting violations by processing large amounts of diverse data, including biometric and biochemical indicators and performance results. However, the introduction of AI raises serious ethical issues, ranging from risks of privacy violations and algorithmic bias to the opacity of decisions, which can lead to unfair accusations.

Despite technological advances, the use of AI in anti-doping control remains insufficiently regulated and studied, especially in terms of ethical and legal aspects. Anti-doping systems rely primarily on retrospective analysis, whereas AI can move towards proactive monitoring and prediction of violations. The lack of a comprehensive ethical and legal framework poses threats to the protection of athletes' rights and necessitates the development of balanced approaches that ensure transparency, fairness and accountability in the use of AI in sport.

For example, H. Ryoo *et al.* (2024) demonstrated that the use of AI significantly improves the efficiency and accuracy of detecting doping violations through automated data analysis, but at the same time emphasise the risks associated with the quality of information and potential algorithmic bias. The results of the study by S. Ibrahimova and M. Bagirzade (2024) showed that the development of AI contributes to the digital transformation of economic activity and increased efficiency in various industries, including sports, through automation, new business models, and improved information management. In addition, F. Jalilova (2025) emphasised that the current stage of digital transformation is characterised by the widespread use of information technology in the economy, but full trust in AI is still limited: weak AI systems only improve the performance of tasks within human capabilities, while strong AI can surpass humans.

A study by M.R. Rahman and W. Maass (2024) proposes the use of generative models, specifically Generative Adversarial Networks (GANs), to synthesise blood test data in order to improve the effectiveness of indirect methods of detecting doping. The authors showed that synthetic samples generated by the model reliably mimic real ones, which can expand the available data

sets without violating the privacy and rights of athletes. V. Ratten (2024) noted that the use of AI in sport could change the interaction between athletes and the control system, creating both new opportunities for personalising anti-doping measures and ethical challenges related to interference in the private sphere. In turn, D. Chen *et al.* (2025) demonstrated that AI can improve the accuracy of developing anti-addiction drugs, which creates prospects for creating more effective means of detecting and preventing the use of prohibited substances. Moreover, F. Lauritzen and G. Holden (2022) emphasised that the effectiveness of detecting anti-doping rule violations is not determined by the volume of samples collected but increases significantly when using an intelligence-led approach to test planning, which highlights the value of AI for optimising anti-doping strategies.

On the other hand, A. Figus (2024) noted that AI is transforming sport by enabling athletes and coaches to obtain valuable analytical data that contributes to improved performance, pointing to the potential of AI to improve anti-doping methods through more accurate analysis of indicators. The results of a study by J.J. Ooi *et al.* (2025) demonstrated that the use of AI in sports science can improve accuracy of prediction of results and prevention of injuries compared to traditional methods, confirming the potential of AI to more accurately detect doping through the analysis of athletes' performance indicators. Additionally, E. Dudnic and N. Dudnic (2025) determined that the lack of uniform standards and transparent statistics complicates the fight against doping, and the improvement of anti-doping tests inevitably leads to more sophisticated methods of circumvention, which requires the continuous development of detection technologies.

The reviewed studies do not sufficiently address the comprehensive assessment of ethical aspects and practical implementation of AI in anti-doping systems, including the specific features of Azerbaijan and other countries. Therefore, the study aimed to provide a comprehensive analysis of the potential and limitations of AI in anti-doping activities, incorporating national and international experience. The main objectives included analysing the regulatory and ethical framework for the introduction of AI in the anti-doping sphere, assessing the effectiveness and specifics of the use of modern AI technologies in international and national anti-doping programmes, and identifying key risks and ethical challenges associated with the use of AI in doping control.

Materials and Methods

To study the regulatory context and legal restrictions on the use of AI in Azerbaijan's anti-doping policy, methods of comparative legal analysis of key documents, systematisation of regulatory provisions, and ethical and legal content analysis were used. This identified the main requirements for security, transparency, personal data protection, and procedural safeguards when introducing AI into national anti-doping control. In particular, provisions of the state Artificial Intelligence Strategy of the Republic of Azerbaijan for 2025-2028 (Order of the President..., 2025) relevant to anti-doping issues (e.g., data security and personal information protection, use of AI to improve the efficiency of procedures, creation of a regulatory framework for the ethical use of AI, and attracting investment) were highlighted and analysed. National legislation is also relevant, including Law of the Republic of Azerbaijan No. 447-VQ "On Strengthening the Fight Against the Use of Doping Substances and Methods in Sport" (2016), as well as the activities of the Azerbaijan National Anti-Doping Agency (AMADA, 2025).

International recommendations and standards were also considered, including the United Nations Educational, Scientific and Cultural Organisation (UNESCO) International Convention

against Doping in Sport (2010), the Anti-Doping Convention of the Council of Europe (1989), and the Opinion of the European Data Protection Board (EDPB, 2024). The study was based on the World Anti-Doping Agency (WADA) World Anti-Doping Code (WADA, 2021a), WADA Code Implementation Support Programme (CISP) (WADA, 2021b), WADA International Standard for the Protection of Privacy and Personal Information (ISPPPI) (WADA, 2021c) and the structure of the Council of Europe Framework Convention on Artificial Intelligence (2024), which sets legal and ethical standards for the use of AI tools in sport.

In addition, the experience of using the Athlete Biological Passport (ABP) was analysed, and ensemble models combining Extreme Gradient Boosting (XGBoost) and Multilayer Perceptrons (MLP) were considered (Divya *et al.*, 2024; WADA, 2026). To systematise and summarise the key areas of AI integration into international anti-doping practice, a comparative analysis of modern approaches was used, highlighting their essence and objectives. The focus was on human-centred and hybrid decision-making models, multilateral governance and ethical auditing, standardisation and data integrity, and the balance between innovation and ethical requirements.

Ethical and legal content analysis and quantitative data analysis methods were used to analyse the risks and ethical challenges of using AI in anti-doping control, reflecting the specific features of training AI models in the anti-doping field. Key risks and ethical challenges were identified, such as algorithmic bias and fairness issues, transparency, explainability and accountability, data privacy and security, impact on athletes' rights and procedural safeguards, as well as socio-economic and global inequality. To illustrate bias and data unevenness, the distribution of AI model training samples was visualised according to the conditions of collection of biological samples with recombinant human erythropoietin (rhEPO), and significant imbalances were also shown.

Results

Regulatory context and legal restrictions on the use of AI in Azerbaijan's anti-doping policy

The application of AI technologies in the anti-doping field is associated not only with scientific and technical challenges, but also with the need to comply with regulatory, legal and ethical standards. Given the high sensitivity of athletes' personal, biometric and behavioural data, any AI solutions in this area require strict regulation, transparency and legal certainty. In Azerbaijan, the regulatory framework governing the introduction of AI in the context of anti-doping policy is being shaped primarily at the intersection of national strategies for digitalisation, information security and the protection of individual rights. In this context, the state's Artificial Intelligence Strategy of the Republic of Azerbaijan for 2025-2028 is central, as it was the first comprehensive document to define the priority areas of AI policy in the country (Order of the President..., 2025). The strategy lays down regulatory guidelines and institutional mechanisms that are potentially applicable to the field of sport, including monitoring compliance with anti-doping rules (Table 1).

Table 1. Provisions of the Strategy relevant to anti-doping policy

Strategy position	Contents	Meaning of the anti-doping policy
1	General provisions and approval of the Strategy as the main document	Legal framework for AI development in the country, including sports
3	Analysis of information security risks in government agencies when using AI	Protection of personal and biometric data of athletes

Table 1. Continued

Strategy position	Contents	Meaning of the anti-doping policy
5.1.3	Use of AI to improve government efficiency and service quality	Automation and increased transparency of anti-doping procedures
6.1.1.2.3	Establishment of a regulatory framework for responsible and ethical AI	Ethical standards for AI in sport and doping control
6.1.2.2.3	Data security and personal information protection	Legal protection of athletes' data and anti-doping tests
6.1.3.2.2	Staff training in AI and data management	Training AI specialists for sports analytics and monitoring
8.4.1	Measures to attract investment in AI technologies	Securing funding for innovative anti-doping AI solutions

Source: compiled by the authors based on Order of the President of the Republic of Azerbaijan No. 530 "On the Approval of the 'Artificial Intelligence Strategy of the Republic of Azerbaijan for 2025-2028'" (2025)

These provisions may be interpreted as relevant to the application of AI in Azerbaijan's anti-doping policy, particularly regarding the processing of sensitive data and security. Given the transdisciplinary nature of anti-doping activities, the integration of AI in this area requires not only technological adaptation but also comprehensive compliance with legal and ethical requirements in line with international standards. In this regard, it is necessary to analyse the regulatory, legal and ethical frameworks that ensure the legality, validity and fairness of the use of AI systems in doping control.

One of the key conditions for the lawful introduction of AI into the anti-doping sphere is compliance with personal data protection standards, especially those relating to athletes' biometric and medical characteristics (Wojdala *et al*., 2022). According to the EDPB recommendations (2024), the creation and use of AI models based on personal data must be conducted in full compliance with the provisions of the General Data Protection Regulation (GDPR) (2016). Among the mandatory conditions for the lawful use of personal data in AI models are: ensuring the lawfulness, fairness and transparency of processing; limiting the purposes and scope of data collection; applying appropriate measures to protect data and ensure confidentiality; providing data subjects with the opportunity to exercise their rights (to access, correct, and delete data); conducting a preliminary data protection impact assessment; ensuring the anonymity of model results and excluding the possibility of re-identification. The EDPB (2024) emphasises that even if a model has been trained on personal data, its use can only be considered permissible if the data has been obtained and processed lawfully. Otherwise, even a technically effective model may be deemed illegitimate under European law. This requirement is particularly relevant for AI systems used in anti-doping monitoring and behaviour analysis, where there may be serious consequences for athletes' careers and reputations.

In this context, international legal and institutional support mechanisms are key to the implementation of AI in the anti-doping field. The development and application of AI should be integrated into the CISP, which was created to address gaps in the implementation of the World Anti-Doping Code and to combat systemic doping violations (WADA, 2021a; 2021b). The effectiveness of these strategies is ensured by combining them with transnational control mechanisms applied, for example, in combating money laundering under the Anti-Doping Convention of the Council of Europe (1989), as well following the International

Convention against Doping in Sport (2010) and national legislation, including the Law of the Republic of Azerbaijan "On Strengthening the Fight Against the Use of Doping Substances and Methods in Sport" (2016).

The integration of AI into CISP ensures the ethical and legal legitimacy of systems, including transparency, accountability, and the prevention of bias, meeting the requirements of Council of Europe Framework Convention on Artificial Intelligence (2024). The convention requires that all stages of the AI life cycle comply with the principles of procedural fairness, prevent discrimination, ensure trust, and respect human dignity. This excludes AI abuses such as involuntary surveillance and automated assessment without appeal. Anti-doping AI initiatives should consider both the CISP and the principles of Convention on Artificial Intelligence, forming a lawful and ethically sustainable practice. Figure 1 presents a structured outline of the main chapters and articles of Convention, which systematises the key principles and requirements for the development and application of AI, incorporating human rights, democracy and the rule of law.

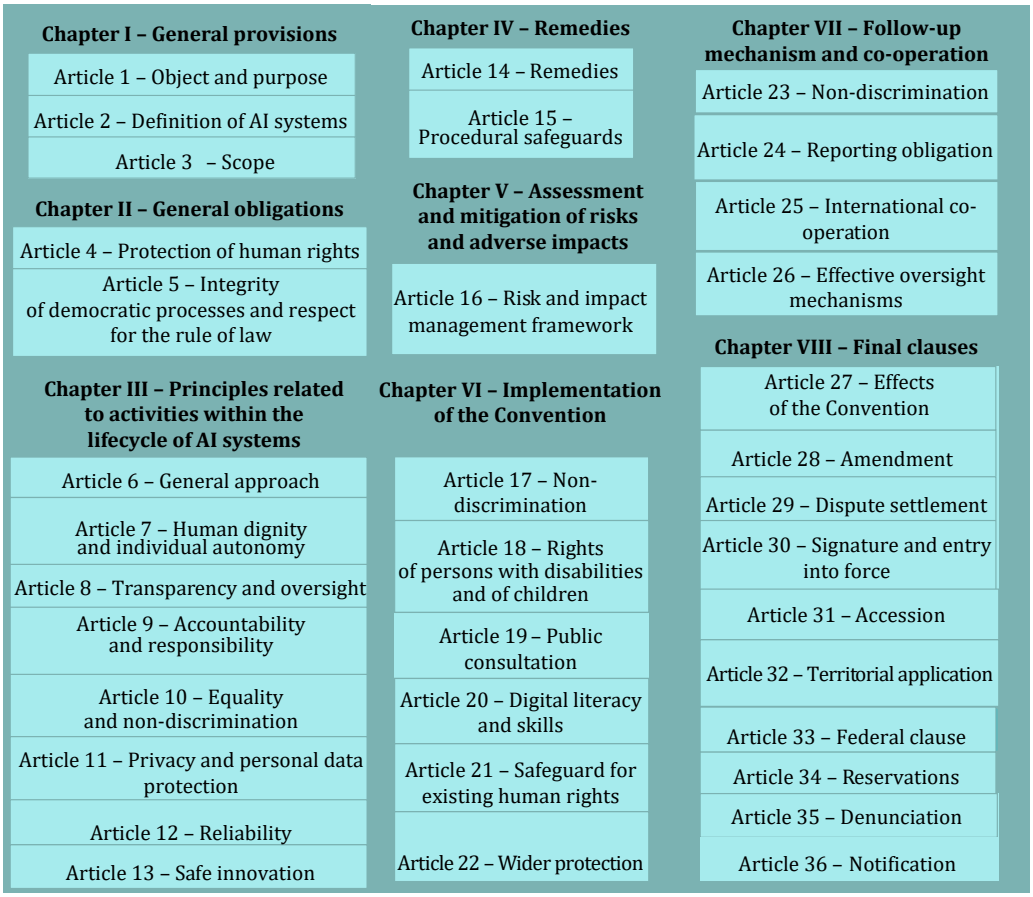

Figure 1. Structure and key provisions of Convention on Artificial Intelligence

Source: compiled by the authors based on Convention on Artificial Intelligence (2024)

In other words, Convention on Artificial Intelligence (2024) establishes comprehensive standards for the life cycle of AI systems, aimed at protecting fundamental rights and freedoms, ensuring transparency, accountability and fairness, and preventing discrimination and abuse of AI technologies, forming a legal basis for the responsible and ethical use of AI in various fields, including anti-doping policy. However, in the current practice of applying AI in anti-doping control, significant problems remain, primarily in terms of transparency and the lack of formalised appeal mechanisms. Although Article 14 of Convention explicitly obliges states to provide procedural safeguards for individuals affected by decisions made with the involvement of AI, such safeguards have only been partially implemented in the field of sport. In this regard, regulatory bodies should implement mandatory transparency protocols that can challenge AI-based decisions in full compliance with Article 14 of Convention.

Although AI reduces reliance on retrospective testing, most such systems function as "black boxes". This makes it significantly more difficult for athletes and regulatory bodies to determine or challenge decisions made based on algorithmic conclusions. Athletes are also often deprived of an effective opportunity to challenge algorithmically formulated suspicions. An additional concern is the low explainability of the models used; most of them remain closed and opaque, which undermines the confidence of athletes and sports organisations in the anti-doping system.

Thus, the regulatory context for the use of AI in Azerbaijan's anti-doping policy is based on international obligations, national priorities, and ethical and legal requirements. Despite the advantages of AI, significant challenges remain related to algorithm transparency, data protection, and the lack of clear procedures for challenging decisions. To mitigate risks, Explainable AI (XAI) needs to be institutionalised, smart regulation implemented, and international standards adapted to national conditions.

Integration of AI into international anti-doping practice: Cases and approaches. The introduction of AI into international anti-doping practice requires not only technical precision, but also comprehensive interdisciplinary oversight, including ethical, scientific and legal aspects. The active participation of athletes in the management of AI systems is becoming a key element in ensuring transparency and fairness in decision-making related to doping control. One significant tool for such participation is the creation of Athlete Consultation Committees (ACCs), which provide a platform for direct dialogue between athletes and developers of anti-doping AI policies. These committees help to address athletes' interests, which increases trust and legitimacy in the technologies used.

In addition to involving athletes, close cooperation between AI ethics specialists, sports science experts and lawyers working in the field of sport and law is required to develop a harmonised international regulatory framework. Such cooperation can produce universal standards that ensure transparency, protection of rights, and fairness in the use of AI in anti-doping control, minimising the risks of abuse and discrimination. Furthermore, there is an increased emphasis on the automated monitoring of athletes' biomedical data using machine learning and intelligent analysis methods.

Anomaly detection systems based on AI algorithms are increasingly being integrated into the ABP structure (WADA, 2026). Such algorithms can quickly and accurately detect deviations in biomarkers that potentially indicate the use of prohibited methods or substances. As highlighted in WADA reports (2026), research grants are focusing on projects aimed at developing applied AI tools for analysing athletes' haematological data and biomedical parameters. Such technologies

can reduce the time lag between the emergence of suspicious data and the assignment of targeted testing, thereby increasing the effectiveness of anti-doping efforts (Smailov *et al*., 2025).

The next stage in improving methods is the use of ensemble models combining, for example, XGBoost and MLP, which demonstrate high accuracy in data analysis in specific disciplines, including weightlifting (Dhou & Orudzheva, 2025). These hybrid models accommodate both biological markers and the dynamics of athletic performance, expanding the possibilities for interpreting suspicious deviations. In international practice, Bayesian spline models used for longitudinal profiling of individual performance trajectories are emphasised. This approach facilitates a more refined distinction between an athlete's natural progress and results possibly attributable to the use of prohibited substances. In addition, AI systems capable of recognising complex patterns based on the integration of various types of data (performance metrics, demographic characteristics, biochemical indicators) contribute to the formation of a more comprehensive and adaptive anti-doping monitoring architecture.

In turn, the use of predictive models based on AI algorithms represents a promising direction in the development of doping control strategies at the international level. Such models potentially redirect the resources of anti-doping organisations towards more targeted testing focused on athletes with elevated risk indicators. This approach facilitates the transition from predominantly random testing to more analytically sound forms of monitoring. For further analysis, it is worth summarising the key areas for the effective and ethically sound integration of AI algorithms into international anti-doping practice (Table 2).

Table 2. Key areas for effective integration of AI into anti-doping practice

Approach	Essence	Target
Human-centred and hybrid decision-making models	Combining automated analysis with expert assessment	Preservation of procedural fairness and accountability
Multilateral governance and ethical auditing	Establishment of ethics committees and a transparent algorithm audit system	Increasing trust and preventing algorithmic bias
Standardisation and data integrity assurance	Harmonisation of data collection and monitoring methods	Reducing false positives and enhancing reliability
Balancing innovation and ethics	Pilot projects, phased implementation and impact assessment	Elimination of the risks of excessive supervision and social discrimination

Source: compiled by the authors based on Y. Zhang *et al.* (2020), K. Dhou and L. Orudzheva (2025), P. Mahajan (2025)

The areas outlined above highlight the need for a comprehensive and balanced approach to AI implementation, addressing both technological and ethical-legal standards. Thus, the integration of AI into international anti-doping practice demonstrates significant potential for improving the accuracy, speed and effectiveness of procedures, especially in the context of risk-based and targeted testing. However, despite technological advances, unresolved challenges remain related to transparency in decision-making, algorithmic fairness, and legal safeguards for athletes. To overcome these risks, broader implementation of XAI principles is needed to make algorithms comprehendible and subject to external scrutiny; strengthening the role of athletes in the development and monitoring of anti-doping models, including through ACCs; and developing multi-level governance mechanisms to ensure that AI systems comply with the human rights standards enshrined in Convention on Artificial Intelligence (2024) and WADA strategic documents.

Risks and ethical challenges of using AI in anti-doping control. The introduction of AI algorithms into anti-doping practice not only

creates opportunities to improve the effectiveness of detecting violations but also raises a range of ethical and legal issues. These challenges relate to ensuring algorithmic fairness, data protection, procedural transparency, respect for athletes' rights, and maintaining a global balance in access to technology. Table 3, which reflects the main areas of risk analysis, is presented to systematise the key threats and their possible consequences.

Table 3. Key risks and ethical challenges of using AI in anti-doping control

Risk	Short description	Potential consequences
Algorithmic bias and fairness issues	AI models rely on historical data, which may contain hidden biases that affect the assessment of athletes based on race, gender, region, and social status. False positive accusations are possible	Increased discrimination, unfair accusations, and declining trust in the anti-doping system
Transparency, accountability and responsibility	Many AI systems operate as "black boxes", making it difficult to verify the validity of decisions and appeal them	Unfair sanctions, violation of the right to defence, and a decline in trust in the system
Data privacy and security	Processing large volumes of athletes' biometric and medical data with the risk of leaks and misuse	Violation of the right to privacy, reputational and legal consequences
Impact on athletes' rights and procedural safeguards	Decisions based on opaque algorithms and probabilistic assessments may undermine the principle of presumption of innocence	Increase in unlawful sanctions, complication of the appeal process and protection of rights
Socio-economic and global inequality	Uneven access to cutting-edge AI technologies and expert support across different countries and federations	Widening gap between rich and poor regions, unfairness in sport

Source: compiled by the authors based on H. Westerbeek (2025), M. Kusan and A. Arin (2025), T.S. Petersen *et al.* (2025)

In other words, algorithmic bias requires special attention to the quality and diversity of training data to minimise discrimination and false accusations. It is necessary to investigate the influence of historical distortions and training models on balanced samples. Transparency and explainability are critical to ensuring athletes' rights to defend themselves and appeal decisions. Data privacy requires strict security standards, given the sensitivity of the information (Krutsevich *et al.*, 2019). Protecting athletes' procedural rights involves implementing human oversight mechanisms and fair case review. Lastly, addressing global and socio-economic inequalities is a substantial aspect of ensuring a fair and equitable fight against doping in all countries.

On the other hand, the use of AI systems in anti-doping practice is associated with an increase in the volume of biometric and sports data processed, which poses significant challenges in terms of ensuring the confidentiality and protection of athletes' personal data. It is necessary to ensure strict compliance with international standards similar to the GDPR (2016), which guarantee the rights to data protection and privacy (Barlybayev and Turginbayeva, 2025). For example, WADA (2026) allocates significant resources to research and development of new methods, focusing not only on effectiveness but also on the ethical aspects of data processing, including security and respect for athletes' privacy. Such a comprehensive policy helps to minimise the risks of information leaks and strengthen trust in anti-doping systems at all levels.

Overall, the integration of AI into anti-doping practice represents a substantial step in the evolution of sports governance, with enormous potential to enhance the integrity, fairness and effectiveness of testing. However, to ensure trust and accountability, the implementation of AI must be conducted on an ethical basis, in compliance with legal norms and in the interests of athletes. The

implementation of principles of explainability, fairness and regulatory safeguards will enable the global anti-doping system to maximise the benefits of AI while preserving the fundamental values of fairness, transparency and integrity in sport.

At the same time, the significant technological progress enabled by AI is accompanied by serious ethical dilemmas related to algorithmic opacity, personal data protection, and the fairness of decisions made based on probabilistic models. To achieve a balance between the effectiveness of AI and the protection of athletes' rights, a human-centred, transparent and ethically sound approach with multilateral control and international cooperation is needed. The successful integration of AI into the anti-doping sphere is only possible if strict ethical standards are implemented to guarantee confidentiality, transparency and global fairness, thereby transforming AI from a potential ethical dilemma into a real breakthrough that supports the spirit of fair competition and a new era of sports governance.

Discussion

This study showed that the use of AI in anti-doping control significantly improves the accuracy of detecting violations and optimises the allocation of testing resources, while emphasising the significance of ethical aspects such as algorithm transparency and the protection of athletes' rights. In particular, the XGBoost algorithm demonstrated high accuracy (92%), F1-score (95%) and sensitivity (68%) rates, demonstrating its effectiveness in recognising potential violations and minimising the omission of suspicious data. The study by H. Ryoo *et al.* (2024) also recorded an improvement in the effectiveness of doping detection using AI: the accuracy of prediction models based on the Athlete Performance Passport (APP) reached 53.8%, and ABP monitoring improved by 25-30%, which coincides with the conclusions about increased accuracy and resource rationalisation. However, the study noted the risks of algorithmic opacity and bias, confirming current concerns about fairness and the need for regulatory oversight. Thus, the results of both studies complement each other, highlighting both the technical advantages of AI and the importance of ethical and legal issues for its successful implementation in anti-doping systems.

The results revealed that the regulatory and ethical frameworks governing the use of AI in Azerbaijan's anti-doping policy require strict transparency, protection of athletes' personal data, and fair appeal procedures, which are key to the legitimacy and trustworthiness of AI systems. At the same time, S. Robertson's (2025) study emphasised the importance of integrating AI into the decision-making structure while maintaining a balance between technological capabilities and human control to improve efficiency and fairness. The aforementioned study emphasised the role of ethical, legal and procedural aspects in the successful implementation of AI. Similarly, the current study contributes to the research of regulatory requirements and international standards, such as the GDPR (2016) and Convention on Artificial Intelligence (2024), applicable to the anti-doping field.

The study highlighted that the use of AI in anti-doping improves the accuracy and personalisation of testing, optimising resources. Similarly, B. Millington *et al.* (2025) emphasised the potential of AI for large-scale data analysis, accuracy, personalisation and prediction in sport. Thus, the study complemented the current findings by adding a socio-cultural context and questions of AI legitimacy in sport. For its part, the study by K. Shankar (2024) emphasised the importance of innovation in analytical technologies to maintain the integrity of competitions and detect even minimal traces of prohibited substances. In contrast to the present study, which analysed algorithmic approaches and legal aspects, the aforementioned

research addressed the technical improvement of laboratory methods, complementing a comprehensive approach to combating doping by combining AI and high-precision analytical tools.

The results of this study emphasised the effectiveness of AI in improving the accuracy and optimisation of anti-doping control. Similarly, W. Zuo *et al.* (2024) noted the significant potential of AI in identifying and developing talent in team sports, emphasising the use of various AI methods to adapt to the specifics of the sport and the importance of integrating expert experience. In other words, this study complements the present research by highlighting the role of AI not only in doping control but also in the development of sports personnel, which contributes to the comprehensive improvement of the sports industry.

The study demonstrated that the use of AI in anti-doping significantly improves the accuracy of detecting violations and optimises the allocation of resources, while paying particular attention to ethical aspects such as algorithm transparency and the protection of athletes' rights. In turn, the study by K. Bingham *et al.* (2025) demonstrated the effectiveness of web-based educational programmes that raise athletes' awareness of doping and reduce their propensity to use it. Thus, technical advances in doping detection and preventive educational measures complement each other, forming a comprehensive and human-centred approach to combating doping in sport.

The results also confirmed that the use of AI in anti-doping control improves the accuracy of detecting violations and optimises testing resources, while emphasising ethical aspects such as transparency and the protection of athletes' rights. Similarly, R. Ningthoujam (2025) demonstrated that despite a significant increase in the number of tests at the Olympic Games, doping remains a serious problem requiring constant innovation in detection methods, including retrospective testing. In addition, a study by R. Owen *et al.* (2024) highlighted the potential of AI for comprehensive analysis and prediction of complex phenomena in sport, such as injuries, complementing the current approach to using AI to improve the effectiveness of anti-doping measures and demonstrating the technology's capabilities in solving multifaceted problems in sports science.

An analysis of the role of international legal and institutional mechanisms, such as WADA and the CISP programme, in integrating AI into anti-doping practice has shown that the use of AI algorithms within the ABP can significantly improve the accuracy and speed of anomaly detection. This improves targeted testing and minimises time delays. In contrast, a study by S. Gopu (2024) highlighted the importance of WADA's technological and organisational efforts to improve the effectiveness of doping detection and strengthen the global system for preventing violations. Both studies note that despite technical progress, serious challenges remain in terms of transparency, fairness of algorithms, and the need to strengthen legal safeguards for athletes.

The study revealed that the development of AI technologies increases the effectiveness of anti-doping control by improving the accuracy of detecting violations and optimising the allocation of resources while complying with ethical standards and athletes' rights. On the other hand, a study by J.-H. Eom (2023) introduced a new form of doping: brain doping through transcranial stimulation, highlighting the associated ethical and legal challenges, including issues of fairness, safety, and restrictions on athletes' right to self-determination. In other words, this study complemented the present research by analysing new technologies that may pose additional risks to the integrity of sport. Together, they highlight the need for a comprehensive approach involving regulatory measures and international cooperation to ensure

fairness and protect athletes' rights in the context of technological progress.

The study identified key regulatory provisions and ethical guidelines for the use of AI in anti-doping, confirmed the high effectiveness of the XGBoost algorithm, and highlighted the risks of algorithmic bias, insufficient transparency, and socio-economic inequality in access to technology. In contrast, H. Liu (2026) analysed the use of AI for the prevention of sports injuries through the analysis of biomechanical data and real-time movement monitoring, which prevents injuries and improves the training process. Despite the difference in objectives, both studies demonstrate the potential of AI to improve safety and efficiency in sport, highlighting the importance of integrating technology with consideration for the individual characteristics of athletes and a comprehensive approach to sports science.

Overall, this study addressed the technical, regulatory, and ethical aspects of AI application in anti-doping control, emphasising the need for algorithm transparency and athlete rights protection, as well as the significance of integrating multilateral governance models to enhance fairness and effectiveness. In turn, the study by T. Piatkowski *et al.* (2024) analysed the social and cultural dynamics surrounding the use of image and performance enhancers, as well as the challenges of anti-doping policy in the context of celebrity influence and controversial cases. In other words, the two studies complement each other, combining technological and ethical-legal analysis with a socio-cultural perception of the complexities of modern anti-doping, which can be used in the formation of more comprehensive and adaptive strategies to combat doping in sport.

Thus, this study is notable for its comprehensive approach, which combines the technical effectiveness of AI algorithms with an in-depth analysis of the regulatory and ethical aspects of AI use in anti-doping control, striking a balance between innovation and the protection of athletes' rights. In contrast to studies that address social or technical issues, this research offers a systematic view that includes international standards, data management, and algorithm transparency, which helps to increase the trust and legitimacy of anti-doping measures. The study expands on existing research by proposing an integrated solution that promotes the fair, effective, and ethically sound use of AI in sport.

Conclusions

The results of the study indicated that the use of AI in Azerbaijan's anti-doping policy is regulated by a set of national strategies and international legal norms, among which the state AI Development Strategy and Convention on Artificial Intelligence are substantial. These documents set regulatory guidelines that ensure the protection of athletes' personal and biometric data, the transparency of algorithms, and compliance with ethical standards, which is particularly relevant for increasing the trustworthiness and legitimacy of AI systems in doping control. Despite the existence of a legal framework, modern practice faces problems of insufficient explainability of AI models and the lack of formalised procedures for appealing decisions.

The study affirms that, from an ethical and legal standpoint, the incorporation of AI into anti-doping control must be based on legally binding international norms and domestic regulatory frameworks that provide accountability, transparency, non-discrimination, and strong protection of personal data. Athletes' rights and the presumption of innocence are at stake since the results show that current methods are still insufficient in terms of procedural safeguards and viable recourse against automated determinations. Therefore, in order to ensure adherence to human rights values and the rule of law, the legal and acceptable use of AI in anti-doping practices necessitates the

institutionalisation of explainable algorithms, enhanced human oversight, and clearly defined appeal mechanisms.

However, despite significant progress in researching the regulatory context, ethical guidelines, and international integration of AI applications in anti-doping control, limitations remain related to insufficient model explainability, lack of standardised appeal mechanisms, and risks of algorithmic bias. Going forward, it is recommended that XAI be mandatorily implemented to increase the transparency of decisions, that ACCs be created to accommodate their interests, and that interdisciplinary regulatory models be developed to ensure fairness and the protection of rights. Long-term research into AI fairness, the improvement of data protection measures, and the development of comprehensive risk minimisation strategies that address international standards such as WADA and Convention on Artificial Intelligence and Human Rights are notable.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Anti-Doping Convention of the Council of Europe. (1989, November). Retrieved from https://rm.coe.int/168007b0e0.

[2] Azerbaijan National Anti-Doping Agency (AMADA). (2025). Retrieved from https://www.amada.az/en/.

[3] Barlybayev, A., & Turginbayeva, A. (2025). Development and implementation of an advanced fuzzy expert system for the assessment of information security risks. *Journal of Computational and Cognitive Engineering*, 4(4), 570-580. doi: 10.47852/bonviewJCCE52024683.

[4] Bingham, K., Lazuras, L., Barkoukis, V., Elbe, A.-M., Moustakas, L., & Ntoumanis, N. (2025). Transforming anti-doping education with web-based interactive programs and applications: A scoping review. *Emerging Trends in Drugs Addictions and Health*, 5, article number 100175. doi: 10.1016/j.etdah.2025.100175.

[5] Chen, D., Jiang, J., Hayes, N., Su, Z., & Wei, G.-W. (2025). Artificial intelligence approaches for anti-addiction drug discovery. *Digital Discovery*, 4(6), 1404-1416. doi: 10.1039/D5DD00032G.

[6] Council of Europe Framework Convention on Artificial Intelligence and Human Rights, Democracy and the Rule of Law. (2024, September). Retrieved from https://rm.coe.int/1680afae3c.

[7] Dhou, K., & Orudzheva, L. (2025). Data integrity and AI ethics. In X. Zhou & H. Al-Samarraie (Eds.), *Institutional guide to using AI for research* (pp. 185-204). Cham: Springer. doi: 10.1007/978-3-031-94809-1_9.

[8] Divya, R., Karunanithi, K., Ramesh, S., & Raja, S.P. (2024). A hybrid multilayerperceptron-extremegradientboost approach for precise state of charge and state of health assessment. *Advances in Electrical Engineering, Electronics and Energy*, 8, article number 100591. doi: 10.1016/j.prime.2024.100591.

[9] Dudnic, E., & Dudnic, N. (2025). Anti-doping control in sport. In *Conference: The international scientific congress "Sports. Olimpysm. Health"* (pp. 50-51). Chisinau: State University of Physical Education and Sport. doi: 10.52449/soh23.17.

[10] Eom, J.-H. (2023). Brain doping in sports and human rights: Brain doping from the perspective of anti-corruption. *Korea Anti-Corruption Law Association*, 6(2), 153-181. doi: 10.36433/kacla.2023.6.2.153.

[11] European Data Protection Board (EDPB). (2024). *EDPB opinion on AI models: GDPR principles support responsible AI*. Retrieved from https://www.edpb.europa.eu/news/news/2024/edpb-opinion-ai-models-gdpr-principles-support-responsible-ai_en.

[12] Figus, A. (2024). Sport and artificial intelligence: What policies and perspectives? *Geopolitical Social Security and Freedom Journal*, 7(1), 65-74. doi: 10.2478/gssfj-2024-0005.

[13] General Data Protection Regulation. (2016, May). Retrieved from https://gdpr-info.eu/.

[14] Gopu, S. (2024). Fair play: Understanding doping prevention and detection in sports. *ShodhKosh: Journal of Visual and Performing Arts*, 5(6), 219-223. doi: 10.29121/shodhkosh.v5.i6.2024.3853.

[15] Ibrahimova, S., & Bagirzade, M. (2024). Digital economy and artificial intelligence. *The Caucasus-Economic & Social Analysis Journal of Southern Caucasus*, 58(1), 102-112. doi: 10.36962/CESAJSC5801024-102.

[16] International Convention against Doping in Sport. (2010, September). Retreived from: https://unesdoc.unesco.org/ark:/48223/pf0000188405.

[17] Jalilova, F. (2025). Who is the person of the artificial intelligence era? In *Conference: International scientific-theoretical conference "Artificial intelligence in the modern art space: Problems and perspectives"* (pp. 388-394). Baku: Azerbaijan State University of Culture and Arts. doi: 10.25045/ASUCAAI.2025.68.

[18] Krutsevich, T., Pengelova, N., & Trachuk, S. (2019). Model-target characteristics of physical fitness in the system of programming sports and recreational activities with adolescents. *Journal of Physical Education and Sport*, 19, 242-248. doi: 10.7752/jpes.2019.s1036.

[19] Kusan, M., & Arin, A. (2025). Ethical and security issues: The impact of artificial intelligence in sports management. *Acta Science and Intellectus*, 10(2), 78-88.

[20] Lauritzen, F., & Holden, G. (2022). Intelligence-based doping control planning improves testing effectiveness – perspectives from a National Anti-Doping Organisation. *Drug Testing and Analysis*, 15(5), 506-515. doi: 10.1002/dta.3435.

[21] Law of the Republic of Azerbaijan No. 447-VQ "On Strengthening the Fight Against the Use of Doping Substances and Methods in Sport". (2016, November). Retrieved from https://e-qanun.az/framework/34359.

[22] Liu, H. (2026). Artificial intelligence sports injury warning system based on biomechanics in college sports. *International Journal of High Speed Electronics and Systems*, 35(02), article number 2550009. doi: 10.1142/S0129156425500090.

[23] Mahajan, P. (2025). *The soul of the AI: Governance, ethics, and the future of human-AI integration.* Shirpur: R.C. Patel Institute of Technology. doi: 10.5281/zenodo.15789678.

[24] Millington, B., Naraine, M., Wanless, L., Safai, P., & Manley, A. (2025). Sport and the promise of artificial intelligence: Human and machine futures. *Sociology of Sport Journal*, 42(4), 341-350. doi: 10.1123/ssj.2024-0150.

[25] Ningthoujam, R. (2025). Anti-doping rules violations in modern Olympic games. *The Journal of Sports Medicine and Physical Fitness*, 65(7), 974-980. doi: 10.23736/S0022-4707.25.16691-7.

[26] Ooi, J.J., Choo, Y.H., Yunus, A.P., Lim, W.H., & Khoo, S.Y. (2025). Review on advancements in artificial intelligence and its applications in sports. *International Journal on Robotics Automation and Sciences*, 7(1), 58-63. doi: 10.33093/ijoras.2025.7.1.7.

[27] Order of the President of the Republic of Azerbaijan No. 530 "On the Approval of the 'Artificial Intelligence Strategy of the Republic of Azerbaijan for 2025-2028'". (2025, March). Retrieved from https://e-qanun.az/framework/59218.

[28] Owen, R., Owen, J.A., & Evans, S. (2024). Artificial intelligence for sport injury prediction. In C. Dindorf, E. Bartaguiz, F. Gassmann & M. Fröhlich (Eds.), *Artificial intelligence in sports, movement, and health* (pp. 69-79). Cham: Springer. doi: 10.1007/978-3-031-67256-9_5.

[29] Petersen, T.S., Holmen, S.J., & Ryberg, J. (2025). AI, doping and ethics: On why increasing the effectiveness of detecting doping fraud in sport may be morally wrong. *BMJ Journals, National Library of Medicine*, 51(2), 102-106. doi: 10.1136/jme-2023-109721.

[30] Piatkowski, T., Gibbs, N., Turnock, L., & Duff, C. (2024). The IPEDs assemblage: Tracing the entanglements of biomedicine, technology, enhancement and anti-doping policies in sport and society. *Health*, 30(1), 3-21. doi: 10.1177/13634593241306569.

[31] Rahman, M.R., & Maass, W. (2024). Generative artificial intelligence in anti-doping analysis in sports. In C. Dindorf, E. Bartaguiz, F. Gassmann & M. Fröhlich (Eds.), *Artificial intelligence in sports, movement, and health* (pp. 81-93). Cham: Springer. doi: 10.1007/978-3-031-67256-9_6.

[32] Ratten, V. (2024). Sport artificial intelligence. In *Sport entrepreneurial ecosystems: Technology innovation perspectives* (pp. 79-91). Singapore: Springer. doi: 10.1007/978-981-97-8923-8_8.

[33] Robertson, S. (2025). Human and artificial intelligence integration for decision-making in sports performance. In D. Memmert (Ed.), *Artificial intelligence and machine learning in sports science* (pp. 79-90). Berlin: Springer. doi: 10.1007/978-3-662-70155-3_6.

[34] Ryoo, H., Cho, S., Oh, T., Kim, Y., & Suh, S.-H. (2024). Identification of doping suspicions through artificial intelligence-powered analysis on athlete's performance passport in female weightlifting. *Frontiers in Physiology*, 15, article number 1344340. doi: 10.3389/fphys.2024.1344340.

[35] Shankar, K. (2024). *Overcome anti-doping analysis hurdles with latest advanced technologies*. Retrieved from https://www.researchgate.net/publication/379154069.

[36] Smailov, N., Zilgarayeva, A., Pavlov, S., Turusbekova, B., & Sabibolda, A. (2025). Optimization of non-invasive glucose monitoring accuracy using an optical sensor. *Informatyka, Automatyka, Pomiary W Gospodarce I Ochronie Środowiska*, 15(4), 65-70. doi: 10.35784/iapgos.7696.

[37] Westerbeek, H. (2025). Algorithmic fandom: How generative AI is reshaping sports marketing, fan engagement, and the integrity of sport. *Frontiers in Sports and Active Living Sports Management, Marketing, and Economics*, 7, article number 1597444. doi: 10.3389/fspor.2025.1597444.

[38] Wojdala, G., Trybulski, R., Bichowska, M., & Krzysztofik, M. (2022). A Comparison of electromyographic inter-limb asymmetry during a standard versus a sling shot assisted bench press exercise. *Journal of Human Kinetics*, 83(1), 223-234. doi: 10.2478/hukin-2022-0084.

[39] World Anti-Doping Agency (WADA). (2021a). *World anti-doping code*. Montreal: WADA.

[40] World Anti-Doping Agency (WADA). (2021b). *Code Implementation Support Programme (CISP)*. Retrieved from https://www.wada-ama.org/en/code-implementation-support-program.

[41] World Anti-Doping Agency (WADA). (2021c). *International standard for the protection of privacy and personal information (ISPPPI)*. Montreal: WADA.

[42] World Anti-Doping Agency (WADA). (2026). *Scientific research.* Retrieved from https://www.wada-ama.org/en/data-research/scientific-research.
[43] Zhang, Y., Bellamy, R.K.E., & Varshney, K.R. (2020). Joint optimization of AI fairness and utility: A human-centered approach. In *Proceedings of the AAAI/ACM conference on AI, ethics, and society* (pp. 400-406). New York: Association for Computing Machinery. doi: 10.1145/3375627.3375862.
[44] Zuo, W., Arede, J., Shang, X., & Leite, N. (2024). Application of artificial intelligence in team sports talent identification: A systematic literature review. In *Conference: 2024 international conference on sports technology and performance analysis* (pp. 429-433). New York: Association for Computing Machinery. doi: 10.1145/3723936.3724003.

Штучний інтелект у боротьбі з допінгом: Між проривом та етичною та правовою дилемою

Тахміна Тагі-зада
Доктор філософії з медичних наук
Національне антидопінгове агентство Азербайджану (AMADA)
AZ1065, вул. Ізмір, 8, м. Баку, Азербайджан
https://orcid.org/0000-0001-8219-5056
Руфат Ефендієв
Доктор філософії з економічних наук
Національне антидопінгове агентство Азербайджану (AMADA)
AZ1065, вул. Ізмір, 8, м. Баку, Азербайджан
https://orcid.org/0000-0001-8319-2957

Анотація

Впровадження штучного інтелекту (ШІ) в процедури допінг-контролю змінює процес прийняття рішень і вимагає перевірки валідності, відтворюваності та недискримінаційного характеру моделей. Мета дослідження полягала у всебічному вивченні можливостей та обмежень ШІ в антидопінговій діяльності, з акцентом на виявленні етичних дилем та оцінці ефективності нових технологічних рішень у міжнародній та національній практиці. У дослідженні використовуються якісний контент-аналіз, порівняльно-правовий аналіз та критична оцінка нормативно-правових та етичних рамок для аналізу правових обмежень, інтеграції технологій ШІ в антидопінгову політику Азербайджану та міжнародну практику. Отримані результати підкреслили важливість ключових положень Стратегії розвитку ШІ на 2025-2028 роки, які створюють регуляторну та етичну базу для застосування технологій в антидопінговому контролі Азербайджану, а також вимог Конвенції Ради Європи, які забезпечують захист прав людини, прозорість, підзвітність та запобігання дискримінації у використанні ШІ в спорті. Результати також показали існуючі етичні та правові ризики, такі як обмежена пояснюваність моделей ШІ, відсутність процедурних гарантій оскарження автоматизованих рішень та можливість посилення алгоритмічної упередженості через нерівномірність навчальних даних. Ці ризики можуть поставити під загрозу легітимність антидопінгового контролю на основі ШІ та ефективний захист прав спортсменів. Однак аналіз виявив значні ризики алгоритмічної упередженості, недостатньої прозорості та пояснюваності інтелектуальних систем, загрози для приватного життя та прав спортсменів, а також соціально-економічної нерівності в доступі до технологій

Ключові слова: стратегії розвитку технологій; алгоритми машинного навчання; захист персональних даних; нормативно-правові рамки; ризики застосування технологій