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Analysis of Application Scenarios, Risk Challenges, and Collaborative Governance Measures for Artificial Intelligence Empowering Competitive Sports

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ABSTRACT
Artificial intelligence (AI) has become the core power for the digital transformation of competitive sports. Its application scenarios cover three dimensions: precise training and personalized plan formulation, intelligent competition officiating and fairness guarantee, as well as event operation and viewing experience enhancement. Through the integration of multiple technologies, AI promotes the high-quality development of competitive sports, but it faces risk challenges such as data privacy leakage, intensified equity imbalance due to technological resource gaps, weakened subject initiative, and ethical conflicts. To balance the technological empowerment and risk prevention and control, it is necessary to build a multi-party governance system featuring technology innovation empowerment, ethical education collaboration, and cross-domain linkage and coordination, and fully unleash the value of AI through technological optimization, ethical guidance, and multi-party collaboration, thus safeguard the core of sports spirit, and facilitating the construction of a sports power.

KEYWORDS
Artificial intelligence; Competitive sports; Application scenario; Risk challenges; Collaborative governance

1 Introduction

Against the backdrop of the deep integration of building a sports power and the digital economy, artificial intelligence (AI) has become the core power for the digital transformation of competitive sports. Its innovative applications in precise training, intelligent officiating, event operation, and other scenarios have injected strong impetus into the high-quality development of competitive sports. However, during the process of technology empowerment, risks such as data privacy leakage, resource gaps, and ethical conflicts have become prominent, which restricts the healthy development of AI. On this basis, this paper will systematically analyze the core application scenarios and potential risks of AI empowering competitive sports, and explore multiple-party collaborative governance paths, with the aim of providing theoretical and practical reference for releasing technological value, safeguarding sportsmanship, and contributing to the construction of a sports power.

2 Application Scenarios of AI Empowering Competitive Sports

2.1 Precise Training and Personalized Plan Formulation

AI can achieve the innovation of training models through the integration of multiple technologies, so that it has become the core support for enhancing athletes' competitive performance. By leveraging technologies such as biosensors and computer vision, multi-dimensional data of athletes, including physiological indices, movement trajectories, and load intensities, can be collected in real time. Then, through machine learning algorithms, data association can be analyzed to precisely identify technical weaknesses and physical limitations. For instance, the ski-jumping team utilizes the biomechanical intelligent analysis system, digital video recognition and acceleration sensing, to accurately capture movement details and generate optimization suggestions. In addition, AI can also build champion performance models, integrate the technical, tactical and psychological data of top athletes such as Olympic champions, and simulate real training environments such as plateaus and competition venues using virtual reality technology, to customize targeted training plans for different athletes, and achieve the transformation from experience-driven to data-driven training.

2.2 Intelligent Competition Officiating and Fairness Guarantee

The introduction of AI technology has broken the subjective limitations of traditional competition officiating and provided key technologies for ensuring the fairness of competitive sports. The application of image recognition, 3D modeling and other technologies has significantly enhanced the refereeing precision. For instance, the semi-automatic offside detection technology used at the FIFA World Cup Qatar 2022 accurately captures the movement trajectory

through cameras and ball trackers to quickly determine offside situations. Meanwhile, the Guanjun AI refereeing system deployed at the Beijing 2022 Olympic Winter Games can score directly through collecting multi-dimensional data such as movement trajectories and release angles, thus reducing human errors. In addition, the Hawk-Eye technology in badminton matches (Figure 1) and the AI scoring support system in gymnastics not only provide objective data reference for referees, but also enhance the credibility of competition results, thereby maintaining the principle of fair competition in competitive sports [1].

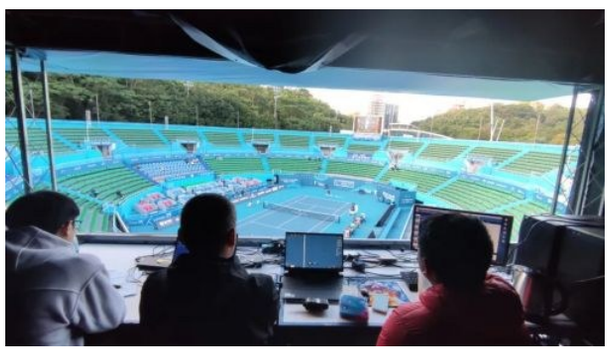

Figure 1 Hawk-Eye Technology (Video Assistant Referee)

Source: Qilu Yidian

2.3 Event Operation and Viewing Experience Enhancement

AI is driving the transformation of event operation towards efficiency and intelligence, while creating a diversified viewing experience. For instance, the 19th Asian Games Hangzhou simplified the process of athlete participation and spectator attendance by integrating AI and NFC technologies with information such as passports and hotel bookings [2]. The Zhejiang University CC98 Cup Football Tournament utilizes AI automated processes to handle online registration and promotion, enhancing the efficiency of event preparation. Virtual reality (VR) and augmented reality (AR) technologies create immersive viewing scenarios. For example, the multi-angle replay and bullet-time effect at the 2024 Paris Olympic Games (Figure 2) enable viewers to enjoy the match details from diverse angles. The autonomous drone system provides an aerial shooting angle, and the AI-driven sponsorship resource matching platform explores the value of event digital assets, which can further enrich the business ecosystem of event operations and the interactive experience of audiences.

巴黎奥运会资格赛期间进行了多镜头回放系统测试。阿里巴巴供图

Figure 2 "Bullet-time" Technology (Source: China Youth Daily Client)

Table 1 Summary of Application Scenario Information

Application Scenarios	Core Technologies	Typical Cases
Precise Training and Personalized Plan Formulation	Biosensors, Computer Vision, Machine Learning,VR	the Biomechanical Intelligent Analysis System in Ski Jumping, the Champion Performance Model
Intelligent Competition Officiating and Fairness Guarantee	Image Recognition, 3D Modeling, Trajectory Tracking	the Semi-automatic Offside Detection Technology at the FIFA World Cup Qatar 2022, the Guanjun AI Refereeing System at the Beijing 2022 Olympic Winter Games, Hawk-Eye Technology
Event Operation and Viewing Experience Enhancement	AI+NFC, VR/AR, Drone, Automated Process	Process Simplification at the 19th Asian Games Hangzhou, Immersive Viewing Experience at the 2024 Paris Olympic Games, and Registration Automation for the CC98 Cup

3 Risk Challenges of AI Empowering Competitive Sports

3.1 Risks of Data Privacy Leakage and Rights Infringement

The integration of AI into competitive sports requires the support of core sensitive data such as athletes ' physiological indices, training plans, and tactical deployments. However, the disorderly expansion of data collection and the lag of protection mechanisms are continuously amplifying the risk of privacy leakage. Professional sports clubs use devices such as heart rate monitoring bracelets and motion capture sensors to comprehensively collect athletes ' physical fitness data, recovery cycles, and even private information such as daily schedules and dietary preferences, which constantly erodes personal privacy. Meanwhile, many data collection platforms lack standardized security management processes. Their data encryption technologies are immature and anonymization processing is inadequate, which not only may lead to the leakage of core tactics and training secrets to affect the outcome of events, but also may result in data abuse and resale to inflict irreversible damage on athletes ' careers and personal rights and interests.

3.2 The Technological Resource Gap Exacerbates the Imbalance in Competitive Fairness

The application of AI technology in competitive sports cannot be achieved without continuous financial investment and complete technological support. The disparityin this prerequisite directly gives rise to a technological gap among different subjects, and seriously undermines the foundation of fair competition in competitive sports. Developed regions can introduce advanced technologies such as 3D motion capture, AI injury early warning, and big data tactical simulation to tailor training plans and rehabilitation systems for athletes [3]. In contrast, underdeveloped regions or niche sports such as shooting and weightlifting, constrained by funding shortages and insufficient policy support, are not only difficult to equip themselves with basic AI tools for movement data analysis and physical fitness monitoring, but also lag far behind in key aspects such as training accuracy and injury prevention and control, which is seriously contrary to the sportsmanship of fair competition.

3.3 Technological Dependence Leads to the Weakening of Subjective Initiative and Ethical Conflicts

The excessive reliance on AI technology is gradually eroding the autonomous judgment and decision-making abilities of athletes and coaches, which in turn is prone to trigger in-depth ethical conflicts. Many sports teams blindly copy the training plans formulated by AI in training, mechanically follow the tactical guidance generated by algorithms during competitions, and completely ignore athletes ' physical feedback and intuitive ability to make on-the-spot adjustments, thus leading to a rigid mode in training and decision-making, and a gradual loss of the capacity to flexibly adapt to actual situations. The application of AI refereeing systems in gymnastics, track and field and other events improves the efficiency of refereeing, but it may squeeze the professional space of traditional referees, and trigger career transition pressures and employment ethics disputes among practitioners [4].

4 Collaborative Governance Measures for AI Empowering Competitive Sports

4.1 Technological Innovation Empowerment: A Core Pillar for Strengthening Collaborative Governance

The effectiveness of collaborative governance directly depends on the maturity and adaptability of technology. It must integrate technology optimization throughout the entire governance process, and make technology the main power for solving governance problems. Research and development institutions should take credibility as the primary goal of technological innovation. They should focus on the construction of interpretable models, and by disassembling algorithmic logic and visualizing decision-making processes, enable coaches and athletes to clearly master the basis for technical judgments, understand the internal logic of training plan adjustments and tactical suggestion generation. A clear decision-making logic can effectively build trust and truly integrate technology into governance practices.

System stability is the fundamental guarantee for technology empowering governance, and any technical vulnerability may lead to chaotic governance. Research and development institutions need to specifically optimize the robustness of the system and design redundant modules in key links. For example, they can preset a backup data processing units in the event refereeing system to ensure that technology is not interrupted in core scenarios. At the same time, they should establish a predictive maintenance mechanism to identify potential problems such as sensor attenuation and algorithm deviation in advance, and proactively avoid the risk of technical failure by monitoring the operating parameters of equipment in real time and analyzing historical fault data. A forward-looking technical design can effectively avoid governance predicaments such as refereeing issues and training interruptions caused by technical malfunctions, and provide stable support for collaborative governance.

Data security is an inviolable bottom line for collaborative governance. Once breached, it not only infringes upon the

legitimate rights and interests of athletes, but also undermines the credibility of governance. To this end, advanced technologies such as biometric and deep learning need to be applied to build a full-lifecycle data security protection system. It is necessary to clarify the scope and boundaries during the data collection phase, strengthen the encryption protection in the transmission process, implement hierarchical management and control at the storage stage, and conduct strict permission audits in the usage phase. In addition, it can draw on the mature experience of the EU's General Data Protection Regulation (GDPR) to embed data security responsibilities into the technical architecture to achieve full-process traceability and controllability of data from generation to destruction. The deep integration of technology and governance can not only free governance from excessive reliance on manual supervision to achieve precise and efficient control, but also build a solid risk defense line through technological means to provide a solid technical support for collaborative governance.

4.2 Ethical Education Collaboration: Safeguard the Core Values of Sportsmanship

Ethical education collaboration is the most humanistic dimension of collaborative governance, which is highly consistent with humanistic theory, and must always be carried out around the human development and the essence of sports. The core value of sports lies not only in the breakthrough of competitive performance, but also in the inheritance of the spirit of fair competition and hard work. The rapid penetration of AI requires the coordinated efforts of ethics and education to set a humanistic boundary for the application of technology. The establishment of an interdisciplinary ethics governance committee is particularly crucial, which can involve multiple forces such as ethicists, sports experts, and athlete representatives. It relies on the professional perspective of ethicists to control value orientation, and depends on the industry experience of sports experts to ensure that the framework is in line with practice. Moreover, it can guarantee the implementation of rights and interests through the genuine demands of athlete representatives. The AI sports ethics framework under the auspices of the committee will focus on balancing technological empowerment and humanistic care to clarify the core position of the sportsmanship, safeguard the subjective value of athletes in the application of technology, and ensure that every technological innovation serves the all-round development of human beings.

The popularization of education is a key support for the implementation of ethical frameworks. It is necessary to build a stratified training system for different groups to make the ethical awareness deeply rooted in people's hearts. For athletes, the training will focus on guiding them to rationally view the value of technology, understand the positioning of technology as an auxiliary tool, and encourage them to fully exert their subjective initiative and creativity to find a balance between technical support and self-judgment. For coaches, the key lies in strengthening the master of the application scale of ethics, making technology serve the formulation of personalized training plans, and always respecting the physical sensations and growth patterns of athletes. For practitioners in technology research and development, event operation and other fields, the training will emphasize professional ethics and guide them to proactively practice ethical standards in technology research and development and application. This two-way collaboration between the guidance of ethical frameworks and the popularization and implementation of education can enable the application of technology to always adhere to the humanistic bottom line, fully unleashing the enabling value of AI, and firmly safeguarding the spiritual core of competitive sports. This framework makes governance both regulated and humanistic, and has become an indispensable spiritual support in the construction of a sports power.

4.3 Cross-Domain Collaborative Governance: Build a Multi-party Governance Ecosystem

The integration of competitive sports and AI involves multiple dimensions such as technology, rules, and rights. The professional limitations of a single entity are difficult to cover the governance needs of the entire chain, so the multi-party collaboration has become an inevitable choice.

The in-depth cooperation between universities and technology enterprises is the core support for ecological construction. By establishing an "AI+ Sports" joint laboratory, they can cultivate compound talents with both professional knowledge and technical literacy in sports in a targeted manner. Focusing on the actual scenarios of competitive sports to develop governance tools, they can precisely match the supply of talents and the innovation of technology with the governance demands, and strengthen the professional foundation of governance. International exchanges of sports organizations can provide a global perspective for governance. By proactively drawing on mature experience of the International Olympic Committee and FIFA, it can promote the establishment of a globally unified AI sports application standard. Conforming to the internationalization trend of competitive sports, it can ensure the consistency of governance standards in cross-border events and enhance the versatility and authority of governance. The participation of athletes' associations makes governance more practical. By deeply engaging in the formulation of governance rules as representatives of athletes' rights and interests, and integrating core demands such as data rights and subject status into rule design, governance can fully reflect the real needs of the practical subjects, thereby laying a solid public support base for governance. Through a diverse ecosystem featuring the collaboration of industry, academia

and research, international alignment and the participation of various entities, the advantage resources and wisdom of all parties can be integrated, to endow governance with professional depth, international perspective and practical resilience, and provide sustained impetus for the development of competitive sports empowered by AI.

Table 2 Summary of Governance Measures

Governance Orientations	Core Initiatives
Technological Innovation Empowerment	Construct explainable AI models, optimize system robustness, establish a full-lifecycle data security protection system
Ethical Education Collaboration	Set up interdisciplinary ethics committees, formulate an AI sports ethics framework, carry out stratified ethics training
Cross-Domain Collaborative Governance	Build industry-university-research joint laboratories, draw on international experience, involve athlete associations in rule-making

5 Conclusion

AI has promoted diverse innovations in competitive sports, such as precise training and intelligent officiating, and has become an important engine for the high-quality development of sports. However, risks and opportunities coexist, and there are multiple risks such as data privacy leakage, and intensified equity imbalance due to technological resource gaps. If these problems are not resolved, they will restrict the healthy development of competitive sports. The collaborative governance system of technology innovation, ethical education and cross-domain linkage not only resolves problems such as data security and fairness imbalance, but also safeguards the core of the sportsmanship. In the future, it is necessary to continuously deepen multi-party collaboration, promote the in-depth integration of technology and sports, and fully release the value of AI in a standardized manner, thus injecting sustained impetus into the modernization of competitive sports, and helping the construction of a sports power reach new heights.

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