



Public health risk control in international sports events: Strategy evolution in the post-pandemic period

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Abstract. The COVID-19 pandemic has highlighted the need to revise traditional security strategies for international sporting events and has brought public health issues to the forefront as a systemic component. The study aimed to address the transformation of security management strategies at mass sporting events in the post-pandemic reality. The research methodology was based on the use of such scientific methods as structural and functional analysis, methods of analogy and analytical review, which ensured a comprehensive and integrated coverage of the issue. The study determined that sanitary and epidemiological control has ceased to be a secondary function and has become a structural axis of strategic planning. The examples of the Olympic and Paralympic Games in Tokyo in 2021 and the FIFA World Cup in Qatar in 2022 demonstrated that a high level of efficiency was achieved both under severe restrictions and moderate scenarios, providing digital support and vaccination coverage. In addition, the study determined that digital platforms in the COVID and post-COVID period became central for control and analytics, forecasting and modelling risk behaviour. At the same time, barriers have been identified in the form of inequality of access, politicisation of health and fragmentation of the regulatory framework. As a conclusion, the study proposed to use the concept of integrated risk management, which involved cross-sectoral coordination, adaptive scenario planning and digital support for early warning systems. The significance of the study is determined by the outline of a systematic framework for rethinking security strategies at mass sporting events, which can be used as an analytical basis for the development of practical recommendations

Keywords: digital technologies; risk management; epidemiological control; international coordination; strategic planning

Introduction

The COVID-19 pandemic created a new logic for international sporting events, in which public health risks have become a systemic factor in strategic planning. Furthermore, after 2020, the usual mechanisms for organising such events were unable to guarantee the controllability of biological threats without technological support and regulatory adaptation. The change in the status of sanitary and epidemiological control in the structure of security strategies has led to a rethinking of the role of digital tools, inter-institutional cooperation and prevention policies on a global scale. In this context, the study of public health risk management at the intersection

of sport, digitalisation and biosecurity is becoming increasingly important for the development of new analytical frameworks.

Since 2020, the scientific community has focused on certain aspects of this issue, but an integrated vision of post-pandemic risk management in international sports has not been formed as of 2025. T. Schmidt *et al.* (2024), using the example of the 2020 European Football Championship, determined that the holding of sporting events was accompanied by an increase in COVID-19 cases in several host countries, where generally accepted preventive restrictions were not followed. The researchers

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concluded that mass events without strict epidemiological control can significantly increase local transmission of the virus. At the same time, J.P. Sugden & J.T. Sugden (2020) proposed a critical reflection on the future of global sports governance in the context of epidemiological threats. In particular, the study considered the inequality of access to medical resources the imbalance in the implementation of security policies at the level of international federations and the need to reform governance models. J.J. Reade (2024) considered the relationship between public safety and management approaches to major sporting events, providing general recommendations on safety protocols, including medical response and crowd risk prevention.

F. Bazzanella *et al.* (2021) examined the transformation of approaches to risk management in the context of organising cycling events. The study analysed the changing role of local organisers and the structural restructuring of safety protocols, demonstrating the desire for more formalised and technologically supported decision-making mechanisms. A. Pacak (2020) analysed the social media strategies of professional football clubs in the UK in response to the pandemic crisis. Additionally, another perspective on the problem was presented in the study by J. Carswell *et al.* (2023), which discussed overcoming the consequences of the pandemic in the context of developing the sustainability of tourist and sports destinations. A scientific publication by T.-Y. Chou & P.-Y. Lee (2023) analysed the behavioural and psychological factors that influence people's desire to return to sports activity, given the perception of sanitary safety as a key factor of trust.

Thus, modern scientific discourse showed a multidisciplinary approach to the study of sporting events in the post-pandemic environment, but there was fragmentation in the coverage of the strategic interaction of components. These publications do not form a holistic model of post-pandemic biological risk management that incorporated digital infrastructure, adaptive regulation and interoperability limitations within mass sporting events. In this regard, the study aimed to analyse the model of transformation of public health risk management strategies in the international sports context, incorporating the changes caused by the pandemic and the spread of digital technologies. The implementation of this goal involved the following tasks: to identify functional changes in the security management structure based on a comparative analysis of strategies during and after COVID-19; to provide a theoretical interpretation of the role of digital platforms in the risk management structure; to identify barriers and potential ways to improve the implementation of biosecurity mechanisms.

Materials and Methods

The methodological basis of the study was based on the application of theoretical methods of scientific knowledge, such as structural and functional analysis,

methods of analogy and analytical review, which provided a holistic understanding of the dynamics of transformations in the field of public health risk management in the context of international sporting events during the pandemic (December 2019-May 2023) and post-pandemic (since May 2023).

Based on an analytical review of the models of regulation, institutional interaction and digital monitoring, the transformational vectors of post-pandemic regulation were described. In particular, the mechanisms analysed included: protocols for admission to events, testing models (mandatory polymerase chain reaction (PCR) testing, daily screening), regulations for the movement and creation of isolated bubble systems, algorithms for the operation of digital applications, standardised response procedures in case of symptoms or positive test results. The use of the analytical method ensured a conceptual transition from a fragmented description of individual mechanisms to a unified view of the structure of the updated management paradigm. The regulatory document, such as The playbook international federations. Your guide to a safe and successful Games (2021) developed for the Olympic and Paralympic Games in Tokyo 2021, was involved in the analytical review. The World Health Organization recommendations were used as a conceptual basis, in particular the document Key planning recommendations for mass gatherings in the context of COVID-19: Interim guidance (2021), as well as Fan health information/Covid-19 information & travel policy (2023) of Qatar.

In addition, the study analysed mobile digital applications such as COCOA (COVID-19 contact-confirming..., n.d.), a digital contact recording application used during the Tokyo 2021 Olympic Games; and Ehteraz, a mandatory digital platform in Qatar during the 2022 FIFA World Cup (Al-Kuwari *et al.*, 2022). Furthermore, as a separate example, MY2022, a mobile application with the function of monitoring and verifying the state of public health, was analysed (Knockel, 2022). The analysis of the functionality of these applications was used to trace the transformation of digital solutions as an element of the biosafety system. The regulatory framework was supplemented by statistics contained in the reports of the Johns Hopkins University Centre for Systems Science and Engineering (JHU CSSE) (Research, 2022) on the number of tests, the percentage of positive results among participants, the vaccination rate among the population of the organising countries, and the volume of contact interaction (Understanding vaccination progress, n.d.). The aggregate indicators were used for analytical comparison of the selected security models.

A structural-functional analysis was used for the theoretical construction of a public health risk management system as a complex structure with interconnected functional blocks. This approach covered the organisational components of digital monitoring platforms, regulatory documents, protocol movement systems, testing

algorithms, and regulatory isolation scenarios as elements of an ordered model, in which each component played a stabilising role in ensuring the continuity and predictability of management decisions. The method outlined the internal logical links between such areas as digital verification, protocol regulation, information policy and regulatory modelling of behaviour in the context of potential biological threats. The method of analogy was used to make a theoretical comparison of different types of organisational response models to identify common features that indicated the existence of stable efficiency factors in systems with different parameters. It was used to conceptually compare variable approaches to security organisations. The analogy served as a tool for identifying the interoperability and practical transferability of individual management elements within different regulatory environments, which provided a basis for further unification of approaches to biosafety.

Results

The organisation of large-scale international sporting events, such as the Olympic Games or World Championships, has traditionally been associated with a set of challenges related to security at various levels. Before 2020 and the introduction of COVID-19 restrictions, the threat of terrorist attacks, public order disruptions, man-made accidents, and certain aspects of sanitary control related to food, hygiene, or living conditions remained a priority. At the same time, issues related to public health in a broader sense were largely not treated as independent in strategic planning and were seen as an auxiliary area that did not require centralised decisions or integrated management structures. However, the events related to the COVID-19 pandemic have led to a fundamental rethinking of the principles of organising mass events, particularly the role of security in the healthcare sector (Schütte *et al.*, 2023).

The formation of a new model of risk communication, the expansion of the definition of “threat” in the context of sport, and the global scale of the challenge have led to the institutionalisation of practices that were previously considered temporary or emergency. Thus, the issue of health protection has gone beyond the functional area of medical care, becoming a systemic element that permeated logistics, infrastructure, financial calculations, information policy and diplomatic interactions. Thus, A. Khorram-Manesh *et al.* (2024) noted that determination of risk control as a multidirectional process that required predictability, adaptability and constant monitoring has become particularly relevant. In this context, the role of preliminary analysis of the epidemiological situation, protocol support for the movement of people, management of the flow of information on symptoms and test results, and the creation of effective response mechanisms in case of danger signs have increased. In addition, the set of tools (digital platforms, mobile applications, remote health

monitoring, big data analysis, simulation modelling) used to ensure the sustainable functioning of events in a dynamic environment has significantly expanded. As a result, this shift in focus has led to the need to investigate, how public health risk management strategies have evolved, which models have become dominant in the post-pandemic period, which temporary solutions have turned into institutional practices, and what challenges remain in protecting the health of participants and spectators of international competitions.

Therefore, the emergence of new challenges related to health in a highly concentrated social environment has called into question the effectiveness of previously established strategies that dominated the organisation of sporting events. Until 2020, in the period preceding the pandemic, the dominant focus was on issues associated with safety in the classical sense: organisers focused their efforts on preventing athlete injuries, ensuring food safety at food outlets, and monitoring the sanitary condition of premises and infrastructure (Glebova *et al.*, 2022). At the same time, the epidemiological component was considered a factor of secondary importance that did not require deep integration into the overall risk management system. The limited tools for predicting and preventing the spread of infections, in particular respiratory infections, were not considered a critical threat, as such incidents were either local in nature or remained outside the information field of the sporting event.

With the outbreak of the SARS-CoV-2 pandemic, event organisers were faced with the need to rapidly transform their usual response mechanisms. The existing system was not adapted to long-term global crises of this magnitude, so experimental, temporary or hybrid approaches came to the fore. To minimise the risk of infection, several emergency protocols were implemented, including regular testing of participants, mandatory self-isolation in case of symptoms, the creation of isolated accommodation groups, the so-called “bubbles”, and restrictions on physical contact between delegations (Massey *et al.*, 2021). At the same time, digital technologies ensured prompt monitoring of the health status of participants. These systems actively used mobile applications such as COVID-19 contact-confirming application (n.d.), Enteraz (Al-Kuwari *et al.*, 2022) and MY2022 (Knockel, 2022) to record symptoms, vaccination certificates, digital “health passports”, as well as algorithms that analysed the flow of people to prevent high-risk contacts. At the final stage of the pandemic, when global organisations began to gradually move to long-term planning strategies, a new concept of permanent preparedness for biological threats was formed. Some of the measures that were initially temporary were found to be effective and included in the permanent regulations that apply to all mass events. Among these innovations are the updated standards initiated by international institutions, including Key planning recommendations

for mass gatherings in the context of COVID-19: Interim guidance (2021) and The playbook international federations. Your guide to a safe and successful Games (2021), and document of the Ministries of Health of different countries (Fan health information..., 2023).

In response to the unprecedented global challenges posed by the COVID-19 pandemic, international and national institutions have implemented a set of regulatory and institutional transformations that have radically changed approaches to the organisation of mass sporting events. These shifts have become a vector for ongoing reforms aimed at integrating health risk management into the entire logistics infrastructure of sporting events. At the international level, the main coordinator was the Tokyo Organising Committee for the Olympic and Paralympic Games 2020, which has developed and implemented several mandatory regulatory documents, such as The playbook international federations. Your guide to a safe and successful Games. (2021) that have become a prototype for similar solutions for other mass events. These regulations contained detailed testing protocols, isolation strategies in case of infection, algorithms for the movement of participants, as well as requirements for staying in Olympic venues, incorporating the specifics of each sport. Thus, the Tokyo Organising Committee for the Olympic and Paralympic Games 2020 has initiated the development of industry-specific safety standards that incorporate both epidemiological challenges and the technical characteristics of the competition.

At the same time, the Tokyo Organising Committee for the Olympic and Paralympic Games 2020 and other sports organisations were institutionally supported by the World Health Organization recommendations, which published Key planning recommendations for mass gatherings in the context of COVID-19: Interim guidance (2021). The document, which has been updated several times, emphasised the need for a comprehensive risk assessment, integration of health monitoring measures, clear communication with the public, and readiness to respond quickly to possible disease outbreaks. These recommendations have become the basis for shaping approaches to sporting, cultural and religious events, including at the regional level. In addition, following the new protocols, transparency in risk communication, combating disinformation, digital ethics and protection of personal data used in monitoring the epidemiological situation was emphasised.

In analysing public health risk management strategies in the context of international sporting events, it was useful to consider specific examples of the implementation of such strategies. For example, the Tokyo Olympics in 2021 and the FIFA World Cup in Qatar in 2022 have become testbeds for implementing and evaluating the effectiveness of different approaches to ensuring the safety of participants and spectators. The 2021 Tokyo Olympics was the first major international sporting event held during the active phase of the COVID-19

pandemic. Given the challenging epidemiological situation in Japan and globally, the organisers have developed and implemented a comprehensive system of measures to prevent the spread of the infection among athletes, technical staff and the local population. One of the main solutions was to completely exclude spectators from the stands, which significantly reduced the load on the infrastructure and avoided massive crowds. This decision, although it had economic consequences, was made in the interests of public safety, given the high risk of virus transmission in a dense crowd. In addition, to minimise the likelihood of the internal spread of COVID-19 among the Games participants, a multi-level testing system was implemented, including both pre- and post-event monitoring. All participants had to provide proof of a negative test result before arriving in Japan and were subject to daily screening upon arrival. The athletes, delegation members and support staff were kept in a controlled-access environment to ensure isolation from the outside environment. All movements were strictly regulated, and compliance with sanitary requirements was monitored at all levels. Mask regime, disinfection of premises and physical distancing were mandatory. The effectiveness of the measures taken was confirmed by data showing that out of more than 1 million tests conducted during the Olympic and Paralympic Games, only 299 samples showed positive results, which was 0.03% of the total. Among the approximately 11,000 athletes, who stayed in the Olympic Village, only 15 cases of close contact infection were reported (Akashi *et al.*, 2022). Such statistics indicate a high level of control and effectiveness of anti-epidemic measures. Thus, Japan's experience has confirmed that under strict regulation, even many international participants does not lead to a large-scale spread of the virus, provided that protocols were followed.

However, in contrast to the Japanese approach, which was based on maximum restriction of social interaction, the organisers of the 2022 FIFA World Cup in Qatar have opted for a strategy of moderate liberalisation. The competition was held with spectators, which led to significant flows of fans from different countries and large crowds in stadiums, fan zones and transport hubs. Despite the easing of restrictions, basic protocols remained in place, including digital health monitoring and systems for alerting people to potential infectious threats. The Ehteraz mobile app was used during the event to quickly track contacts and alert people to possible epidemiological risks (Al-Kuwari *et al.*, 2022). Notably, during the championship, there was a short-term increase in COVID-19 cases, but due to high vaccination rates among the local population and tournament participants, as well as the health system's readiness to handle the load, there were no large-scale outbreaks or collapses of the medical infrastructure (Dergaa *et al.*, 2023). A visual comparison of the effectiveness of different approaches to controlling public health risks during these events was presented in Table 1.

Table 1. Comparison of risk control measures

Metric	Tokyo 2021 (Olympic and Paralympic Games)	Qatar 2022 (FIFA World Cup)	Effect
The presence of the audience	Lack of spectators at all venues	More than 3.4 million viewers	It affected the density of contacts and the complexity of control
Vaccination rate of the host country's population	<40% at the time of the event	>95% fully vaccinated	Reduced the risk of severe forms and hospitalisations
Mandatory testing for all participants	Yes (daily PCR for athletes)	Yes (upon entry + selectively during the tournament)	The frequency and scope of testing determined the level of detection
Masks in interior spaces	Mandatory everywhere, even in gyms	Recommended, not required	Determined the probability of airborne transmission
Digital health monitoring systems	Yes (COCOA application)	Yes (EHTEAZ, with QR codes)	Simplified contact acquisition
Number of positive cases recorded among participants	Approximately 0.03%	Data was not made public, but no major outbreaks were reported	Reflected the overall effectiveness of a set of measures

Source: based on M.G. Al-Kuwari *et al.* (2022), *Fan health information/Covid-19 information & travel policy* (2023), *COVID-19 contact-confirming application (n.d.)*, *Understanding vaccination progress (n.d.)*

Notably, both cases did not demonstrate major epidemiological failures, although they used fundamentally different approaches to organisation. This indicated that effectiveness was not determined by the severity of the restrictions, but rather by the context of their implementation, including the level of training, health system mobilisation (including vaccination of the population), technological support and communication policy. Therefore, it was possible to argue that the modern model of organising sporting events was transforming towards a synthesis of epidemiological safety, digital analytics and cross-sectoral coordination (Fahim *et al.*, 2024). The institutional and regulatory shifts initiated during the pandemic have shaped a new governance paradigm that focused not only on ensuring the safe physical presence of spectators and athletes, but also on guaranteeing this safety in the face of biological uncertainty. As a result, this approach has opened new opportunities for the development of sustainable practices aimed at the long-term preservation of public health, even outside the pandemic context.

The practice of holding large-scale international sporting events has shown that innovative digital tools are becoming an effective tool for achieving safety. Therefore, as part of modern health risk management in the organisation of international sporting events, digital technologies have gradually transformed from auxiliary tools to systemic components of the overall biosafety infrastructure. At the same time, their implementation was not limited to the control or verification function, but was expanding towards the creation of sustainable models for monitoring, analytics and early threat forecasting. The process was determined by the transition from reactive to proactive control mechanisms, in which digital solutions provided the ability to adaptively adjust protocols in real-time, analyse behavioural deviations and identify potential infection clusters before symptoms appear.

During and after the pandemic, mobile health passport platforms became universal for digital epidemiology, accumulating data on testing, vaccination status, contact history, and permission to enter designated areas (A COVID-19 health..., n.d.). However, the experience of their implementation has also confirmed a significant number of risks associated with privacy violations, insufficient transparency of algorithms, and inequality of access to digital services. For example, the mandatory MY2022 app used during the Beijing 2022 Winter Olympics had serious vulnerabilities in terms of protecting personal health data, as well as the lack of basic encryption protocols for information transmission (Knockel, 2022). This example raised the issue of the need for a preliminary independent audit of software solutions before their large-scale use on a global scale.

Alongside the technical aspects, geographical and practical challenges have also become more acute. Geographical barriers included inequalities in access to vaccines, differences in regulatory frameworks, differences between countries in data security and privacy policies, and difficulties with standardisation and interoperability. This was compounded by limitations in digital infrastructure and access to technology. In turn, practical challenges include medical contraindications to vaccination, breakthrough infections, uncertainty about natural immunity, and the limited accuracy of standardised tests for assessing the risk of infection (Towett *et al.*, 2023).

To address these challenges, global international coordination of efforts to harmonise regulatory frameworks, improve digital infrastructure and ensure equal access to technology and healthcare resources has become necessary. Investing in research and improving risk assessment and health monitoring systems has also become important. In this case, the use of predictive analytics technologies based on large data sets opened prospects. An example was the collaboration between

the University of Pittsburgh and Amazon Web Services, which resulted in the emergence of a risk prediction laboratory, where artificial intelligence (AI) was used to identify potential diseases of athletes based on data on physiology, logistics trajectories, behavioural variables, and contact chains (Suttles, 2025). Such solutions can improve the accuracy of real-time decision-making and introduce adaptive access control scenarios, but also require clear regulation at the level of international law and alignment with data protection standards.

In the context of post-pandemic risk management in the field of international sporting events, it was worth highlighting the challenges that were emerging at the intersection of biomedical, social, information and

geopolitical vectors. Although the adaptation of many crisis protocols has become a sustainable practice in the organisation of global events, the risks themselves have not lost their relevance. First and foremost, the probability of new pandemic threats, which can be of both viral and bacterial origin, remains high. The evolution of institutional approaches has already considered the need to develop early warning systems and adaptive logistics. However, the challenges of the future may not be limited to the development of contingency scenarios. Here, the need for multi-level scenario modelling that can consider the mutational dynamics of pathogens, climate change factors, and the social responsiveness of the population comes to the fore (Table 2).

Table 2. Systematic classification of determinants of public health risk control during international sporting events

Determinant	Elements
Epidemiological profile	The possibility of new pathogens (viral/bacterial); genetic variation and mutational dynamics of pathogens
Scenario forecasting	Multi-level modelling system; integration of backup epidemiological scenarios
Environmental parameters	Impact of climate change on pathogen transmission; local environmental risks (temperature, humidity, population density)
Social behaviour	Level of social mobilisation; degree of trust in healthcare systems; public perception of risk
Institutional capacity	Availability of early warning systems; adaptive logistics and cross-national coordination
Technological infrastructure	Use of digital platforms for surveillance; ensuring cybersecurity of personal medical data
Healthcare resources	Vaccination coverage based on medical contraindications; scalability and reliability of diagnostic tools

Source: developed by the author

Given the data provided, effective control of public health risks during international sporting events required the integration of an interdisciplinary approach that encompassed both biomedical and socio-institutional factors. The key was to introduce adaptive, digitally supported epidemiological modelling systems that can respond quickly to changes in pathogenic, environmental and behavioural determinants. One of the constant factors of increased risk was the mass movement of fans during events. The density, cross-border nature, and varying levels of vaccination, health insurance, and awareness create an extremely heterogeneous environment in which traditional approaches to infection control lose their effectiveness. A particular challenge was posed by areas of temporary residence/stay (fan camps, hostels, hotels, airport transits), where it was difficult to provide a comprehensive sanitary infrastructure. This factor further reinforces the need for coordination between organisers, municipal services and healthcare systems, as well as the need to expand the responsibilities of logistics partners.

The tendency of public health issue politicisation was also notable, being manifested in the rhetoric around vaccination, testing, masks and digital monitoring. Anti-vaccination movements based on misinformation can significantly reduce compliance with mandatory standards on the part of both spectators and athletes. This situation undermined the effectiveness of even the

most carefully designed protocols, as it threatens not only the epidemiological balance, but also social trust, which was a key factor in the implementation of participatory mechanisms that were the basis of modern biosecurity management in the sports context. At the same time, limited international cooperation in health data exchange remained another significant barrier to building an effective warning and response system. Although some digital solutions were already being implemented towards integration, their effectiveness was often hampered by national regulations, lack of common standards, institutional mistrust and geopolitical tensions. As a result, the system for monitoring the health of both participants and viewers was often fragmented, and the ability to detect and localise potential threats promptly was significantly hampered. All of this showed that public health risk management at global sporting events must respond promptly and effectively to existing challenges and refocus on long-term strategic foresight based on the integration of interdisciplinary data, flexible coordination mechanisms, and strengthened institutional trust on an international scale.

Discussion

Since the spread of the coronavirus infection in 2019, the issue of public health risk management in the context of international sporting events has been at the centre of professional discussions in the field of sports

management, epidemiology and digital policy. Strategic approaches that were formed before the pandemic have undergone transformations that go beyond purely anti-epidemic response and cover a wide range of organisational, regulatory, technical and behavioural factors. In the scientific field, this has led to the formation of several parallel research vectors, each of which highlighted certain aspects of the sports industry's adaptation to the new era of biological threat. However, the systematic generalisation and theoretical coherence of these areas was still in its infancy, which made it necessary to conduct a conceptual analysis of the models that have emerged in response to global challenges. For this reason, an approach that can describe the changing role of sanitary and epidemiological control as a structuring element of security strategies, based on specific cases and theoretical interpretation of digital technologies as a platform for forecasting, verification and management integration, was used.

For instance, the publication by O. Havryliuk *et al.* (2021) were devoted to communicative and discursive practices in the sports sphere during the pandemic. The study conducted an in-depth analysis of the transformation of media communication, highlighting the emergence of new formats for presenting sports content, changes in rhetoric, and the adaptation of information space players to new conditions. Within the framework of the analysis, sports communication was presented as a means of strengthening trust in events taking place under restrictions, as well as a tool for normalising epidemiological behaviour. While the study highlighted information dynamics, this study focused on the organisational and regulatory basis of security, covering not only athletes, but also ordinary citizens. At the same time, both approaches recognised the need to synchronise management decisions with communicative logic. While the author interpreted media communication as a factor influencing public readiness to comply with rules, this study addressed procedural clarity and digital predictability as factors that created the basis for the legitimacy of decisions. As a result, this edition expanded the context of the discussion from media interpretations to managerial integration, enshrined in digital mechanisms that simultaneously performed the functions of control and transmission of normativity.

At the same time, J. Drury *et al.* (2021) outlined the issue of behavioural risks during the opening of mass events during the period of lifting lockdowns. The researchers conducted an in-depth assessment of social dynamics, trust mechanisms, compliance with restrictions, and the potential for collective responsibility as a factor of stability. The study analysed the conditions under which participants agree to protocols and found a dependence on transparency of decision-making, public involvement in rulemaking, and stability of information channels. However, this article examined behavioural variables in the context of digital models that can predict

deviations and detect abnormal trajectories, providing a new line of interpretation between behavioural sociology and analytical digital epidemiology. Such a discussion revealed the potential for combining humanitarian reflection with technological governance, which created a conceptual space for the formation of models of predictive participation that combined behavioural trends with scripted interfaces of digital solutions.

A more detailed analysis of the use of digital security management tools was proposed by C. Meng & W. Rui (2023). The study was based on the concept of a multi-level institutional response based on the example of China. The authors focused on analysing organisational procedures that included filtering fan flows, administering access to facilities, and using QR systems as a sanitary control tool. The concept of coordination between municipal authorities and sports institutions was also given importance. However, for this article, the approach to the Chinese case was interpreted in terms of ethical and legal dilemmas related to the exploitation of personal data. In particular, the analysis of the MY2022 digital app gave grounds to question its effectiveness without proper external audit and privacy protection standards. Thus, although both papers dealt with the same tools, they represented different research perspectives. In this case, the comparison helped strengthen the rationale for the need to introduce standardised regulations and to bring the issue of digital monitoring into the realm of interstate legal and social discourse.

J.A.L. Ludvigsen & J.W. Hayton (2020) analysed the basic organisational framework for the restart of sporting events in a pandemic, with a particular focus on the structure of responsibility between institutional actors, risks to public trust and the need for transparent communication. The analyses described the elements of ethical support, and adaptation of spatial logistics, and substantiated the dependence of the effectiveness of security measures on the quality of interagency coordination. However, the study also did not reveal the importance of using digital tools, touching on them only in the form of general references without functional profile analysis. Instead, this work has demonstrated that digital solutions such as COCOA or Ehteraz not only facilitated the localisation of contacts in practice, but also provided the ability to build scenario models in real-time. Thus, if J.A.L. Ludvigsen & J.W. Hayton (2020) outlined the macro-political mechanisms of risk management, analyses of this study addressed the functional links between protocols and technology platforms.

When studying the issue of security management transformation, it was advisable to pay attention not only to the public, but also to the actual and direct participants of athletes' events. Thus, B.T. Barbosa *et al.* (2020) identified the physiological and psychological aspects of the pandemic's impact on athletes, in the absence of tournament activity, restrictions on training processes, and high levels of anxiety. The study analysed changes

in exercise regimes, adaptation to training in isolation, and the consequences for psycho-emotional stability. As the study addressed only biomedical aspects, strategic or digital event management was omitted. The correlation between these approaches demonstrated that an effective management model should incorporate both epidemiological and logistical dimensions, as well as the condition of the participants themselves. Furthermore, this idea was reflected in the findings that highlighted the need for systematic integration of scenario-based risk modelling that can incorporate behavioural and psychophysiological variables alongside digital data. In the context of this aspect of the issue, this article provided an overview of the University of Pittsburgh's Risk Prediction Lab and Amazon Web Services, which highlighted the importance of exploring the dimension of a multifactorial security construct, in which digital infrastructure was one element.

Thus, the study formulated a systematic vision of the evolution of public health risk management strategies in the international sports context, based on an interdisciplinary analysis of digital tools, regulatory dynamics and organisational practices. A comparison with relevant scientific works has shown both the breadth of coverage and analytical specificity of this work, which can be used to integrate separate approaches to security into a single conceptual field and identify new areas of research, among which the leading ones were risk scenario modelling based on digital behavioural analytics, ethical coding of biosecurity management decisions and harmonisation of regulations at the international level to ensure adaptability to possible future biological threats.

Conclusions

The analysis has shown that modern public health risk management in the sports context was increasingly tending to synthesise technological, regulatory and behavioural factors within a single adaptive system. Digital tools, initially introduced as temporary control measures, have evolved into full-fledged components of the biosecurity infrastructure, capable of providing not only operational contact tracing, but also multidimensional scenario risk modelling based on big data. In this context, the concept of safety has ceased to be a healthcare issue and has been transformed into a cross-sectoral strategy, where technological integration, regulatory

compatibility (in particular, using recommendations of Ministry of Health, World Health Organization and national regulations) and institutional trust were interrelated factors of resilience. The case studies of the Tokyo 2021 Olympic and Paralympic Games and the 2022 FIFA World Cup in Qatar demonstrated a gradual shift from reactive to proactive management models, where protocol flexibility, decision transparency and analytical support form the basis for a new paradigm for organising sporting events in the face of biological uncertainty.

The study has shown that it was the combination of proactive risk modelling and inter-institutional cooperation that can create the preconditions for timely response and sustainability of events in a dynamic epidemiological context. Despite the comprehensive nature of the analysis, the limitation of the study was its theoretical orientation, since the generalisations and conclusions were based on the analysis of documents, digital tools and cases without the involvement of empirical methods that could verify hypotheses, deepen the interpretation of patterns and identify barriers that remained outside the scope of public analytics. In the future, it is advisable to develop empirical models for assessing the effectiveness of digital protocols and their impact on the behavioural dynamics of participants, define criteria for international harmonisation of biosafety standards based on the analysis of regulatory compatibility and legal conflicts, and model multifactorial risks in the sports environment, incorporating geopolitical instability, politicisation of healthcare and growing cyber threats. Thus, the study provided a conceptual framework for further research aimed at improving health management strategies in the context of mass sports events. In combination with the empirical verification of the proposed provisions, this creates the potential for the formation of a stable, transparent and technologically supported security infrastructure in the global sports context.

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Контроль ризиків для громадського здоров'я на міжнародних спортивних заходах: еволюція стратегії в постпандемічний період

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Анотація. Пандемія COVID-19 висвітлила необхідність перегляду традиційних стратегій безпеки міжнародних спортивних заходів та висунула на перший план питання громадського здоров'я як системний компонент. Дослідження мало на меті розглянути трансформацію стратегій управління безпекою на масових спортивних заходах у постпандемічній реальності. Методологія дослідження базувалася на використанні таких наукових методів, як структурний та функціональний аналіз, методи аналогії та аналітичного огляду, що забезпечило всебічне та інтегроване висвітлення питання. У дослідженні було визначено, що санітарно-епідеміологічний контроль перестав бути другорядною функцією та став структурною віссю стратегічного планування. Приклади Олімпійських та Паралімпійських ігор у Токіо у 2021 році та Чемпіонату світу з футболу у Катарі у 2022 році продемонстрували, що високий рівень ефективності досягається як за суворих обмежень, так і за помірних сценаріїв, забезпечуючи цифрову підтримку та охоплення вакцинацією. Крім того, у дослідженні було визначено, що цифрові платформи в COVID-19 та постковідний період стали центральними для контролю та аналітики, прогнозування та моделювання ризикованої поведінки. Водночас були виявлені бар'єри у вигляді нерівності доступу, політизації охорони здоров'я та фрагментації нормативно-правової бази. Як висновок, у дослідженні запропоновано використовувати концепцію інтегрованого управління ризиками, яка передбачає міжгалузеву координацію, адаптивне сценарне планування та цифрову підтримку систем раннього попередження. Практична цінність дослідження визначається окресленням системної основи для переосмислення стратегій безпеки на масових спортивних заходах, яка може бути використана як аналітична основа для розробки практичних рекомендацій

Ключові слова: цифрові технології; управління ризиками; епідеміологічний контроль; міжнародна координація; стратегічне планування