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Analysis of Security Risks and Countermeasures in Olympic Games: Lessons from Beijing, London, and Rio

Security management is a fundamental concern in large-scale international sporting events, as it directly affects personal safety, economic stability, and social order. The Olympic Games, as one of the most influential global sporting event, face complex and multifaceted security risks. This study conducts a comparative analysis of three Olympic Games—Beijing 2008, London 2012, and Rio 2016—to identify key security threats and evaluate the effectiveness of preventive measures. The results indicate that terrorism remains the most prevalent security threat, while challenges related to food safety, transportation security, and economic integrity also persist. In response, host cities have implemented a range of strategies, including the establishment of centralized security command systems, the deployment of multi-level monitoring networks, the integration of technological innovations, and the enhancement of interdepartmental coordination and public participation. In addition, context-specific approaches, such as regional epidemic control and emergency response planning, have been effectively applied. The study concludes that future Olympic Games should adopt a comprehensive and adaptive security management framework that integrates technological advancement, intergovernmental cooperation, and public engagement to strengthen resilience and minimize potential risks.

Keywords: Olympic Games, Security risk assessment, Risk management strategies, Terrorism prevention, Public safety, Event security governance

Introduction

Security is a major concern when major international events are held, especially large-scale sporting events that attract extensive media coverage and large crowds, such as the Olympic Games. However, the terrorism is the worst security issue throughout the Olympic Games. During the Beijing Olympic Games, several security incidents occurred, including stabbing attacks and terrorist bombings, some of which resulted in fatalities. Moreover, the Rio 2016 Olympic Games faced a significant terrorist threat following the attack in Nice on 14 July. All these severe terrorist threats endanger the security of participants in the Olympic Games. In Olympic history up to the 2016 Paralympic Games, 9 athletes died while completing or participating in their sports. In addition, 14 Olympic participants died due to other causes, including terrorism and other issues. Moreover, Olympic-related incidents have also resulted in fatalities among non-participants. For example, during the preparation for the Rio 2016 Olympic Games, 11 workers died while building Olympic facilities. According to Chen (2008), although China ranked first in the Olympic scoreboard, it was the Olympic security that still should be regarded as the "first gold medal" of the Beijing 2008 Games, emphasizing that without security, all other achievements lose their significance [1]. Therefore, the success of hosting the Olympic Games should not be measured solely by the number of medals won, but also by the host country's responsibility to minimize security risks and ensure the safety of all participants. Governments must effectively manage security risks to guarantee public safety. Consequently, evaluating the security risk

management measures of previous Olympic Games and drawing lessons for future Olympic security planning has become an important research focus.

Risk is unavoidable, and exists in peoples' daily lives and public events. Risk based on safety management usually is called risk management, which should be analysed concerning the natural hazard and help with risk prevention and control [2]. According to Toohey and Taylor (2008), it was not until the twentieth century that risk took on a more negative perspective related to "how to avoid genuine or perceived hazards" [3]. According to Silvers (2009), "risk is any condition or occurrence that might affect the outcome of an event or event activity and might expose an event organization to loss measured in terms of probability and consequences" [4]. Security risk does not belong to a specific type of risk, Liu and Jiang (2009) [5] divided the risk into political risks, economic risks, diastral risks, human risks, event operation risks, site equipment risks, technical risks and event risks in eight types, the security could be related to any type of risk [5]. Security is more likely to be listed under political risks because the extent of the involvement of a central government and its attitudes to an event such as the Olympic Games, for example, might determine levels of funding and support. Managing security risks at modern sporting events means trying to prevent the occurrence of security problems rather than responding to them after they have arisen.

According to Fuller and Drawer (2004), a certain level of risk always occurs in the sports management process, even when reasonable precautions have been implemented [6]. Besides that, security risks are now crucial and increasing terrorist threats and security is a vital aspect of organizing major sports events with escalating costs it is also important for protection of personal safety. According by Liu and Jiang (2009), the security risks exist in the process of a sport event, relating to every participant not only the players. Therefore, finding the appropriate security risk management strategy is essential to ensure the security of all those involved in the events; competitors, spectators and the personnel involved in managing the event [5]. Mentioned in the study of Silvers (2009), "Security management covers the sourcing, selection and deployment of the personnel and equipment to be used to provide protective services and support for the event project, and the implementation and supervision of the appropriate command and control systems to ensure its efficiency" [4]. Security risk does not have a clear definition and can relate to health, personal safety, financial security, and other areas. Security risks can be categorized into terrorism and political threats, public transportation and venue security, equipment and food safety, and other related issues. This paper examines security risks, including terrorism, as well as security incidents that occurred during the Olympic Games, affecting athletes and other stakeholders involved in the event.

According to Liu and Jiang (2009), the term *risk management* first appeared in Gallagher's report, *Risk Management: New Phase of Cost Control*, published in 1950 [5]. According to Silvers (2009), the process of risk management for the events is defined as a deliberate and planned process to adjust to the change of the surroundings and environment [4]. In order to apply risk management effectively, it is vital to understand the dynamics of risks, including identifying, analysing, assessing or evaluating, treating or managing, and monitoring and reviewing risks [2]. The first step in risk management is to identify risks, that is, risk identification [5]. Risk identification is the process of determining which factors could prevent the completion of a project, event, or business objectives. Risk assessment is based on the analysis of all uncertainties and risk factors, to assess and predict the probability of occurrence of risks and the magnitude of the loss, so as to identify the key risks and determine the overall risk level [7]. And the treating reviewing process is to use effective measurements to react and minimize them.

Shone and Parry (2004) classified the events into four different levels based on their sensitivity: low risk events, medium risk events, high risk events and higher levels of risks [8]. The low risks events are usually indoors, and are based at only one venue, making security easier to monitor; for instance, an indoor tennis event. Events, such as annual sports events or festivals, are considered as medium risk events. The high-risk events such as the Olympic Games have increased participants and venues compared with small sports events (*ibid.*). Therefore, the nature and scope of the event dictate differing levels of risks. According to Leopkey and Parent (2009), an expanded definition of risk management for sports events was proposed: "a proactive process that involves assessing all possible risks to the events and its stakeholders by strategically anticipating, preventing, minimizing, and planning responses to mitigate those identified risks", as the findings show the importance and pervasiveness of risk management throughout the preparation and hosting of a major sporting event [9]. Mentioned in the study of Liu and Jiang (2009), safety is not only the minimum requirement of holding an Olympic Games successfully, but also a criterion to test whether the games were

successful or not [5]. Thus, it is very important to make pre-caution measurements on controlling the occurrences of those risks in the Olympics.

The reason for focusing on the Beijing, London, and Rio Olympic Games is that, in many ways, they serve as case studies for future Olympics, particularly in how they responded to post-9/11 terrorism. These were three past Olympic Games that were hosted in Asia, Europe, and South America. They share some common and different security problems with different reacting methods in hosting the Olympic Games, these cases can be used as meaningful references and they are useful and crucial to summarize a general security risk management mode for the future Olympic Games.

Some researchers have focused on the risk management for meetings and events but not on specific sports events, which did not deal with the comparison between different sports risks and lack of setting up a sports management mechanism. Ammon and Blair (2004) emphasized the need for a sports facility management and they based his view on the plan of those sports revenues to avoid the occurrences of the risks [10]. In addition, Spengler, *et al.* (2006) analysed the risk management in sports and recreations but they did not concentrate on domestic and international sports events and their case studies [11]. Some Chinese researchers included the risk management of large-sports events in their papers [12, 13]. Liu and Jiang (2009) made a general analysis of risk control and risk avoidance [5]. However, all of them are in Chinese which will take significant efforts to translate.

In this research, the materials mentioned above will be used as references to analyze the Beijing 2008, London 2012, and Rio 2016 Olympic Games. The study aims to identify the similar security risks they faced and how they responded, as well as the different risks that occurred in each country. It also seeks to propose mechanisms to defend against security risks in future Olympic Games. Therefore, this research will help fill gaps in the current literature on risk management in sports.

Methods and materials

The main research strategy of this project is case study. Thornhill *et al*. (2012) defines that the case study is one way of exploring a research topic or phenomenon within its context or within many real-life contexts [14]. Beijing 2008, London 2012 and Rio 2016 Olympic Games were used as case studies to analyse the risks and the management models. The three past Olympic Games were successful and represented different sporting cultures from the East and the West. As a result, they faced different conditions and adopted different measures to manage security risks. This study uses these three Olympic Games as case studies to develop a mature and comprehensive risk management model that can be applied to future Olympic Games. The case study approach is an excellent way of testing if existing approaches are effective in a practical situation in the future.

Qualitative research is a critical research approach, which consists of different opinions and standpoints. It is an inductive view of the relationship between theory and research [15]. Risks are everywhere and the types are multiple. Management models vary and people's evaluations of those risks are different. Therefore, qualitative comparisons of different sports events were analysed and different roles of people's opinions on one specific sports event were conducted critically in order to analyse the risk management in these three Olympics.

In this study, a total of 7 participants (one British researcher and the others Chinese) contributed 11 interview samples, 5 of whom provided information about the Beijing Olympic Games, 3 about London, and 3 about Rio. Depending on participants' availability, some individuals related to the respective Olympic Games were selected as interviewees, while others were researchers studying the risks associated with mega-sport events. In this circumstance, participants might provide detailed information based on their experience, involvement, and studies that could not be collected from previous data and literature.

The areas with which they were familiar included:

- Security issues that occurred during the Olympic Games
- Preventive measures addressing security risks implemented by the host governments
- A summary of security risk management and suggestions for future Olympic Games risk management.

The interviewees were chosen because some were direct participants in the events, while others were experts in this field of study. Therefore, their experiences, research, and feedback provided valuable insights into the risk management strategies deployed at major sporting events. These insights can be used in the development of risk management models for future events such as the Olympic Games.

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In this project, apart from one face-to-face semi-structured interview conducted in English with the British interviewee, all other interviews were conducted online in Chinese and were later translated into English. Fylan (2005) defines a semi-structured interview as a simple conversation in which the researcher has a clear idea of what they want to find out, allowing interviewees to express their ideas freely [16]. Compared with structured interviews, semi-structured interviews balance pre-planned questions with greater flexibility [17].

The semi-structured online interview has unique advantages, particularly when compared with the geographical limitations of a face-to-face interview. According to Gurber et al. (2008), online interviews are cheaper as they save money on travel, venue hire and accommodation costs [18]. However, online interviews also have some limitations. For example, it can be difficult to arrange a convenient time with interviewees due to time differences between countries. They require internet access and electronic devices with video platforms and cameras, which are not as convenient as face-to-face interviews. Therefore, based on the strengths and weaknesses of the semi-structured interview, all the interviews with Chinese participants in this project were conducted via QQ or WeChat, which are widely used in China for long-distance communication and have functions similar to Skype. The interviews were conducted in Chinese to facilitate understanding for the interviewees. Thus, they were able to respond immediately. Apart from the online interviews mentioned above, the following interview processes were used.

- Preparations

As mentioned by DiCicco-Bloom and Crabtree (2006), researchers should first explain the purpose of the interviews and the significance of participants' involvement in the research, in relation to the research background and objectives [19]. Both semi-structured interviews begin with general, open-ended questions designed in advance, but the interviewer has the freedom to ask additional questions during the interview to gain a deeper understanding of the participants' perspectives [20]. To ensure a smooth interview process, a pre-test was conducted. This involved testing the quality of the internet connection, sound and lighting effects, proper gestures to present the best facial expressions, and whether to use a power amplifier for the music.

- Process

The aim of the interview was to explore the experts' experience of organising previous sports events, in order to gain a better understanding of the current sports risk management mechanism. The researchers could also formulate probing questions based on words repeated by respondents to gain further explanations or information [21]. This could provide further information and resources. Several changes will be made when interviewing different managers about different events. According to Hennink et al. (2010), social and communication skills are needed for an effective and smooth interview process [22]. Effective facial expressions were needed in both interviews to help interviewees feel comfortable and relaxed, in order to obtain more profound and detailed answers in both face-to-face and online interviews. It was difficult to record the online interview with a camera, so only the voice was recorded as the interview progressed.

- Completion

Extra basic recorders will be used during each interview to record conversations for data interpretation. This process will be explained to interviewees before each interview. Warren et al. (2003) mentioned that the recorded interviews ended with saving the recorded materials, switching off the machine, ceasing to ask questions and thanking the interviewees for their participation [23]. After the interview, the recordings were played several times and translated into English. Therefore, an accurate Chinese-English translator was also needed for the translation process.

To specify security risk types and understand the security measures adopted by the Olympics to address these issues, the questions were divided into four relevant dimensions.

The research question for this project is: "What are the security risks and risk management measures in the current Olympic Games?" To collect and analyse the necessary data, the following process was conducted:

- Collect and translate relevant Chinese interview transcripts into English.
- Read each transcript and identify repetitive topics.
- Classify these topics under the proposed dimensions (security risks, security risk management measurements, security risk management in the current Olympic Games, and recommendations for the security risk management of future Olympic Games).
- Read these topics to find similarities or summarise a general conclusion.
- Form a comprehensive security risk management model to be applied to future Olympic Games.

Results and Discussion

Security risks

a. Security issues occurred during the Olympic Games. The following table summarises the security risks that existed during the previous three Olympic Games (Table 1).

Table 1

The main problems encountered at the three Olympic Games

Beijing 2008 Olympic Games	London 2012 Olympic Games	Rio 2016 Olympic Games
• Terrorism threat and other political security risks • Security issues in public transport • Public arena and equipment security risks • Food security issues • Natural disaster hazard risks • Air pollution security issues	• Terrorism threat and other political security risks • Security issues in public transport • Public arena and equipment security risks • Food security issues • Information security risks	• Terrorism threat and other political security risks • Security issues in public transport • Public arena and equipment security risks • Food security issues • Economic issues leading to social security risks • Public health security issues (virus threat, water pollution).

As shown in Table 1, terrorism and other political issues appeared to be the most common security issue during the three Olympic Games. Three of the interviewees mentioned terrorism at different events *(No. 5, male, Beijing; No. 1, male, London; No. 3, male, Rio)*. Food safety, public transport safety, public equipment security and other issues occurred simultaneously during the three Games. For example, one interviewee *(No. 3, male, London)* said that *"London's subways and buses do not have security equipment installed, and they don't have the security check process..."* The natural disaster safety issues and air pollution problem appeared to pose significant health and safety threats in Beijing *(No. 5, male, Beijing).* Information security issues also occurred during the London Olympics *(No. 1, male, London).* Furthermore, the Rio Olympics faced social security issues resulting from economic problems and health threats caused by viruses. *"Rio was faced with acute contradictions between rich and poor, which caused chaos on the streets. I did not feel secure there." (No. 1, male, Rio).*

b. Types of security risk

According to the answers provided by the interviewees, most of them gave subjective insights into what they thought were security risks. These included food safety, transportation security risks, security risks during sporting competitions, and health risks caused by pollution. As mentioned in the study by Liu and Jiang (2009), risk types include political, economic, diastral, human, event operation, site equipment, technical and event risks [5]. Based on the various types of security risk identified in these three Olympic Games by my interviewees, the security risks in this study coincide with the classification method and can be categorised into the eight common categories shown in Table 2. Conversely, the security risk types share some differences with the risk types, overlapping and interacting with each other.

Table 2

The types of risk encountered at the three Olympic Games

Beijing 2008 Olympic Games	London 2012 Olympic Games	Rio 2016 Olympic Games
• Terrorism threat and other political security risks (political, economic, human and event security risks) • Security risks in public transport (human security risks, economic security risks) • Public arena and equipment security risks (event operation risks, site equipment risks) • Food security risks (human security risks, event security risks) • Natural disaster hazards (natural disaster security risks, economic security risks and human security risks) • Air pollution security risks (human security risks)	• Terrorism threat and other political security risks • Security risks in public transport • Public arena and equipment security risk • Food security risk • Information security risks (technical security risks)	• Terrorism threat and other political security risks • Security risks in public transport • Public arena and equipment security risks • Food security risks • Economic issues leading to social security risks • Political, economic and human security risks, as well as event security risks. • Public health security risks (virus threat, water pollution) • Human security risks

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c. Security risk management process

The risk management process was introduced in three main steps. These are the identification, assessment and evaluation of security risks for mega-sport events, and the reaction process. Specifically, risk identification is the first step in finding the source of security risks and is the key to determining where the risks exist *(No. 1, female, Beijing) believes that the risk identification process should follow the four principles of risk avoidance, risk retention, risk reduction and risk transfer.*

The assessment and evaluation process lays the groundwork for the risk reaction process. One interviewee mentioned that the assessment process is vital for judging the level and effect of risks *(No. 5, male, Beijing).*

The reaction process is the most essential part of security management, as it deals with preventing the occurrence of security risks and minimising their impact. One interviewee suggested that this process should involve concrete measures that the government needs to implement *(No. 1, male, London).* In addition, the government needs to strictly adhere to the security risk management process, using case studies and clear risk principles *(No. 2, male, Beijing).*

Summary of security risks at the three Olympic Games

Table 3 summarises the main findings of this research.

Table 3

The main approaches adopted in these three Olympic Games

Beijing 2008 Olympic Games	London 2012 Olympic Games	Rio 2016 Olympic Games
• Set up a security command system • Build a security command team with training • • Form a security network supported by the public • Search for new technology to improve security protection • Ask for international cooperation • • Carry out multi-area monitoring • • Make security and contingency protection plans	• • Set up a security command system • Strengthen website security • • Arrange security personnel and equipment • • Carry out multi-area monitoring • • Train for security emergencies • Search for new technology to improve security protection • • Make security practices and contingency plans	• Set up a security command system • Make a security plan • Arrange security personnel and equipment • Control the virus invasion • Progress army security control by region • Input the police budget • Crack down on crime

a. Set up a security command system and create security practices and contingency plans.

The Beijing, London and Rio Olympic Games all set up effective security command systems and made security practices and contingency plans in advance to ensure safety *(No. 3, male, Beijing; No. 2, female, London; No. 2, female, Rio).*

The Beijing Olympic Games set up emergency plans to respond to emergent situations. Cao (2006) mentioned that the Beijing Olympic Games set up 52 security plans and 594 concrete execution solutions during the Games [24]. As for the London and Rio Olympic Games, the Home Office also published separate documents entitled *"London 2012 Olympic and Paralympic Safety and Security" and "Security in the Rio 2016 Olympic and Paralympic Games"* to identify potential security risks and the related measures and plans for how the authorities and relevant personnel should respond to these risks.

b. Search for new technology to supervise security

Both the London and Beijing Olympic Games attempted to use technological innovations to ensure security *(No. 3, male, Beijing; No. 1, male, London).*

c. Multi-area monitoring

Another important approach adopted by the Chinese and British governments was multi-area monitoring.

"The security control area of Beijing 2008 was divided into three zones: The first was the "Big Beijing security circle", which included all airports, railway stations, and highway traffic junctions; the second was the perimeter of the Olympic Village; and the third was the perimeter of each stadium. (No. 1, female, Beijing): "London's security measures were divided into three categories: land, water, and air. The air security operation was the biggest in the UK during peacetime" (No. 1, male, London).

d. Strong security protection personnel and equipment were arranged.

The British and Brazilian governments arranged strong security protection personnel and equipment. The governments dispatched large amounts of police forces and were equipped with strong military equipment *(No. 2, female, London; No. 1, male, London).*

According to the official materials, the Rio government also employed large numbers of personnel and pieces of equipment to ensure safety.

Security risk analysis of the three Olympic Games

Apart from the above essential measures, other actions were mentioned according to the different situations in these three countries.

a. Security risk measurement analysis for the Beijing Olympic Games

The Beijing Olympic Organising Committee has demonstrated significant operational advantages in security risk prevention, as it is closely integrated with the Beijing municipal government. Together with central and local government departments, the Committee forms a unified system. This multilevel framework of supervision, control, and management is unmatched by that of any other country.

The Beijing Municipal Meteorological Bureau conducted a meteorological disaster risk assessment, while the Beijing Municipal Seismological Bureau completed the *Olympic Games Earthquake Risk Assessment and Countermeasure Report*. These assessments provided an important basis for strengthening earthquake emergency safeguards and ensuring the smooth running of the 2008 Beijing Olympic and Paralympic Games in the face of natural disaster risks. The Beijing Meteorological Bureau also developed disaster and emergency plans, including the successful implementation of cloud seeding operations during the opening ceremony. In response to potential political risks relating to Taiwan, Tibet and Xinjiang, as well as the threat of international terrorism, the Chinese government used the central government propaganda system to emphasise that any intentional interference or destruction of the Olympics would not be tolerated. China was supported by the whole nation and the public firmly backed the government's project, which helped to successfully manage security risks [5]. Therefore, forming a security network supported by the public was a distinctive action adopted by the Chinese government. The 2008 Olympic Games also established a security risk team with well-organised training (No. 5, male, Beijing). The study by Liu and Jiang (2009) also revealed that the Beijing Olympic security department had established an international police liaison department, and that the International Olympic Committee had hired security experts and previous Olympic security command staff as consultants, in order to seek international cooperation [5].

b. Security risk analysis for the London Olympic Games

The British government has done a lot of preparatory work to ensure the success of the Olympic Games and deal with the threat of terrorism in London. First of all, the government established an organisational guarantee mechanism for the Olympic Games and published the document London 2012 Olympic and Paralympic Safety and Security to ensure the preparation and hosting processes were fully planned and arranged. The British government also invested £1 billion in Olympic security, and the London police station set up the National Olympic Coordination Centre at Scotland Yard headquarters. The London government has asked relevant staff to undergo training to reach a certain level of proficiency in order to be permitted to perform certain tasks (No. 1, Male, London).

During the Olympic and Paralympic Games, high-level officials from all departments and agencies involved in security and emergency services took command at the coordination centre. Large-scale army deployment with advanced equipment also provided a powerful advantage in security prevention. Multi-area monitoring was carried out. *"London's security measures were presented in three aspects for the Olympics: land, water, and air. The air security operation was the biggest in peacetime in the UK." (No. 1, male, London).* London also took action to strengthen website security in response to the emergence of information security issues.

c. Security risk analysis for the Rio Olympic Games

Brazil has suffered its worst economic growth, stagnation and inflation since 1930 due to depressed commodity prices. The country has also faced ongoing problems such as domestic political instability and economic recession. Robberies and explosions occurred frequently; therefore, apart from the standard measures, the Brazilian government implemented security measures throughout different regions due to their

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unique characteristics. Large numbers of armed police patrolled the airport and the Olympic Stadium, and the crackdown on crime increased. In addition, virus control was another essential measure taken by Rio: *"...new measures were introduced to prevent the spread of the virus; all venues and the population were tested, and insecticides were sprayed. Each venue would have a fixed agent for inspection and monitoring." (No. 2, female, Rio).*

It should be noted that, except for one interviewee *(No. 2, female, Rio),* all the other interviewees had a negative attitude towards the success of the current Olympic Games since Brazil was still facing serious social security problems.

Recommendations for the security risk management of future Olympic Games:

a. The government should set up a risk control policy and multi-dimensional control, which should be the main guide when dealing with security issues *(No. 1 and No. 3, both male, Beijing and London respectively).*

b. Request multi-faceted cooperation

Cooperation was mentioned in all areas, including the public and government sectors, private and public partnerships, and the various armed forces. This cooperation establishes a network for carrying out all-round supervision, prevention and control.

"Cooperation is essential. The public need to support the government in any case." (No. 5, male, Beijing).

"... strengthening the command and coordination of the military police is essential." (No. 2, male, Beijing).

"The private and public sectors need to work together. To counteract global terrorism, host nations should seek support from other nations, for example the USA" (No. 1, male, London).

"Host nations should seek support from other nations, for example the USA" (No. 1, male, London).

c. Set up an effective security command system

The security command system is the response mechanism established by the government to help prevent and control security issues. Two interviewees believe that the command system is useful for managing risks *(No. 1, female, Beijing; No. 3, male, London).*

d. Set up contingency plans

Contingency plans provide guidance on how the government should react in an emergency. Apart from that, these contingency plans should be combined with effective training to ensure they can be applied in real conditions in a timely and accurate manner *(No. 3, male, Beijing).*

e. Search for new technology to supervise security

"Preparations should be made for the adoption of emerging technology, new products and manufacturers to achieve perfection." (No. 1, female, Beijing).

Last but not least, all measures should be based on the real situation and be flexible rather than fixed. *(No. 5, male, Beijing).* Since each country has its own culture, as well as different political and economic systems, there is no fixed security model or regulation that can be forced upon a country. Conversely, the dominant principle is to consider which measures could best solve a country's own security issues.

Conclusions

The three Olympics Games in Beijing, London and Rio were all facing the most serious security issue: terrorism. Food safety, public transport safety and security of public equipment were among the problems that occurred simultaneously during the three Games. Furthermore, the different games reflected various security issues, such as natural disaster security risks in Beijing, information security issues in London, and economic issues leading to health security problems in Rio. The security risk identification, assessment, evaluation and reaction process must be followed when conducting security risk management. However, different security problems require different government measures. Apart from the common measures, such as setting up a security command system and carrying out multi-area monitoring, a distinctive approach adopted in Beijing was to build a security network supported by the public, under the influence of the whole-nation system. Virus control was an important method in Rio due to Brazil's health security issues, while London sought ways to address information security problems.

Following the above analysis, these suggestions could inform the development of a comprehensive future Olympic security risk management model.

• Use the successful experiences of past Olympics as references.

Overall, the Beijing, London and Rio Olympic Games were successful in minimising and preventing security risks, although some may have a different opinion of the Rio Olympic Games due to serious economic and security issues. However, Rio's security was still satisfactory in terms of avoiding terrorist attacks, and it also performed well in terms of virus control. Therefore, future Olympics should follow these examples and combine theory with practice.

• Comprehensive and multiple prevention measures

This project identifies the security risk measures applied to these three Olympic Games and aims to implement them comprehensively. Security management must be carried out from multiple angles to avoid any loopholes in future Olympics. Nip problems in the bud.

• Be flexible and adaptable in variable environments

Different countries have different national conditions, and there is no fixed security model that can be applied perfectly to all Olympics. The measures must be flexible enough to be applied to real situations.

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A Study of Kazakh Judokas Hypohydration Levels During Training at a Weight-Stable Period

Elite judo athletes frequently utilize rapid weight loss (RWL) strategies, which can trigger dehydration during competition periods. While previous research has documented hypohydration during competition, this study aimed to determine the hydration status of elite male and female Kazakh national team judokas during a non-competitive, weight-stable preparation period and to examine changes across a typical training day. A descriptive, repeated-measures study was conducted with 18 competitive judo athletes (9 men and 9 women) from the Kazakh national team. Hydration status was evaluated using urine specific gravity (USG), urine color (UC), and body weight (BW) measured in the morning, immediately before training, and immediately after training. Hypohydration was defined as a USG>1.020 g/mL. Mean USG values did not differ significantly among measurement times (Morning: 1.027 ± 0.006; Pre-training: 1.026 ± 0.005; Post-training: 1.025 ± 0.006; p=0.14). Similarly, UC remained stable across the day (p=0.40). However, BW significantly decreased during the training session (p=0.002), dropping from a pre-training mean of 66.34 ± 16.06 kg to a post-training mean of 65.71 ± 15.78 kg. Hypohydration was highly prevalent: 15 athletes were hypohydrated in the morning, 17 were hypohydrated before training, and all 18 athletes (100 %) were hypohydrated following the training session. Hypohydration is a widespread and persistent condition among elite Kazakh judo athletes, even during weight-stable periods without competitive pressure. The high prevalence of hypohydration suggests that suboptimal fluid intake may be an ingrained habit rather than a response to acute weight-cutting. These findings highlight an urgent need for hydration education and intervention strategies to optimize training quality and protect athlete health.

Keywords: hydration, judo, Kazakh judokas, weight-stable period, hypohydration, training session, judo athletes

Introduction

Judo is an Olympic combat sport where athletes resort to rapid weight loss (RWL) methods before competitions to gain a competitive advantage [1]. RWL typically involves strategies that create physiological stress, such as fluid restriction, sauna use, and exercising in plastic clothing [2, 3], which can trigger dehydration [4]. Dehydration is defined as the acute loss of total water content in the body and is widely accepted to negatively impact athletic performance, including muscle strength, endurance, motor skills, and cognitive function [5, 6, 7]. Additionally, it is known that dehydration causes cardiovascular load and physiological strain through increased heart rate and decreased cardiac output [8].

Despite the negative effects of dehydration on performance, hypohydration (e.g., urine specific gravity — USG > 1.020 g/mL) was found to be prevalent in judo athletes during the competition period, even during the rehydration process after official weigh-in [9, 10]. While the new rules implemented by the International Judo Federation (IJF), such as weighing athletes approximately 15 hours before competition and limiting weight gain to 5 %, aim to ensure athletes compete in an optimal state of hydration, studies show that despite these regulations, elite judo athletes still exhibit a high rate of RWL and remain hypohydrated [9, 11, 3, 12, 13, 14].

Considering the negative effects of hypohydration and its prevalence during competition periods, it is important for athletes to maintain optimal hydration status during training periods when they are not required to lose weight. However, some studies in the literature have shown that even young and adolescent judo ath-

letes are frequently dehydrated during training sessions in the preparation period [14, 15]. These findings suggest that judo athletes may have insufficient knowledge of hydration strategies or that their RWL habits may have carried over into their training period. This raises the question of whether elite-level senior athletes can maintain their hydration status even during weight-stable training periods without competitive pressure. A recent study has filled this gap by showing that even during a weight-stable training camp, elite senior judo athletes exhibited a high level of hypohydration (92.6 %), and training sessions exacerbated this condition [14]. This finding suggests that hypohydration has become a deep-rooted problem in the elite judo community and is not just a condition specific to the competition period.

In this context, the aim of this study is to determine the hydration status of competitive male and female judo athletes from the Kazakhstan national team, who are in a non-competitive, weight-stable preparation period, through measurements of urine specific gravity (USG), urine color (UC), and body weight (BW), and to examine their changes on training day. The findings aim to confirm the prevalence of dehydration during training even among elite national team athletes, thereby highlighting the urgent need for hydration education and intervention strategies for these athletes.

Methods and Materials

Study Design

This single-blinded study was descriptive in nature and followed a repeated-measures design. This study aimed to determine and compare the magnitude of dehydration via USG, UC and BW in competitive men and women judo athletes in training environment. Body mass and urinary measures of hydration were evaluated in the morning, pre and post-training in Kazakh judo team.

Participants

Nine men and nine women judo athletes from the Kazakh national team voluntarily participated in the current study. All athletes were eligible to participate in the study, i.e. they did not participate in any competition in the last one month and have any injuries, trained regularly, were healthy enough to compete in the national championship. Data were collected during trainings in the preparation period. Written informed consent form was obtained from each athlete before the measurements and the study was carried out in accordance with the latest version of Declaration of Helsinki.

Measurements

Body composition: Athletes' height was measured with a stadiometer to the nearest 1 cm and their body mass was measured to the nearest 0.1 kg using a digital scale.

Hydration status: A urine sample was taken from each athlete immediately before each body mass measurement. The samples were placed in plastic cups and USG was determined with a digital refractometer (ATAGO PAL-10S, Japan) and UC was classified by the same researcher each time. As soon as the urine samples were analyzed for USG, they were immediately disposed. USG was classified according to suggestion by National Athletic Trainers' Association hydrated (<1.020) and hypohydrated (≥1.020) [16]. USG whose correlation with urine osmolality that is acceptable as gold standard for hydration measurement in combat sports was r=0.89 (p=0.000) is accepted as an affordable, valid and reliable tool to monitor hydration status in combat sports [17].

Statistical Analysis

Data analysis was carried out using JASP software (Version 0.19.1.0, The Netherlands). Mean, standard deviation and 95 % confidence interval for mean (CI) was presented. Data normality was checked with Shapiro-Wilk test and skewness and kurtosis coefficients. A one-way repeated measures ANOVA was implemented to see changes in USG, UC and BW of the athletes among different measurement times (i.e., morning, before and after the training session). When the assumption of sphericity was violated, Greenhouse-Geisser correction was used. In case of a significant difference, a post-hoc comparison with Holm correction was made. Effect size for analysis of variance was classified according to eta-squared (η2) and classified 0.01, 0.06 and 0.14 as trivial, medium and large effect, respectively [18]. Significance was set at $p<0.05$.

Results and Discussion

According to one-way ANOVA, athletes' USG values did not differ among measurement times ($F_{2,34}$=2.11, p=0.14, η2=0.11, ES= Medium). USG values of the athletes were 1.027±0.006, 1.026±0.005 and 1.025±0.006 in the morning, pre and post training, respectively.

UC were similar at different time points ($F_{1.47,24.97}$=0.86, p=0.40, η2=0.05, ES= Medium). Athletes' UC was classified as 5.11±1.57 for the morning, 4.83±1.54 for the pre-training and 5.22±1.31 for the post-training.

Athletes' BW differed significantly at different measurement times ($F_{2,34}$=15.98, p<0.001, η2=0.49, ES= Large). Athletes' BW did not change between the morning and pre-training points (p>0.05), but athletes significantly lost weight during the training session (p=0.002). BW of the athletes can be seen in Table 1.

Table 1

Athletes' BW changes in the morning, pre and post-training

Time points	Mean ± SD	95 % CI
Morning	66.34 ± 16.06	58.35-74.33
Pre-training	66.34 ± 16.06	58.35-74.33
Post-training	65.71 ± 15.78	57.85-73.55

Athletes' hydration classification can be seen in Figure 1. As seen in the figure, most of the athletes were hypohydrated according to morning USG values and they arrive at training hypohydrated and completed it hypohydrated again.

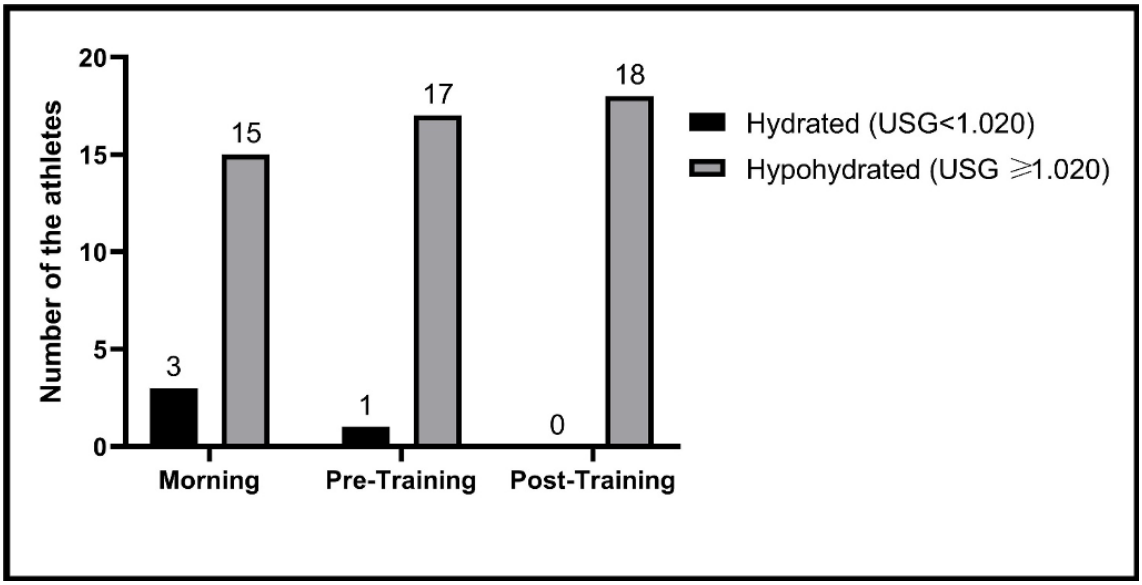

Figure 1. Athletes' hydration classification in the morning, pre and post-training

Conclusions

The aim of the present study was to observe the hydration practices of Kazakh judo athletes during a training day. The main finding of this study was the widespread condition of hypohydration among elite male and female Kazakh judo athletes, even during a weight-stable, non-competitive training camp. The consistently high mean USG values and high rates of athletes classified as hypohydrated (USG>1.020) at all measurement times strongly support this conclusion. Our findings indicate that 17 out of 18 athletes presented hypohydration at the pre-training assessment, and all completed the training session in a hypohydrated state. This underscores that suboptimal fluid balance is not confined to the acute weight-cutting phase but may represent a persistent concern in elite judo.

The mean USG values observed in this study (ranging from 1.025±0.006 to 1.027±0.006) suggest that hypohydration, previously well-documented in competitive environments, has become habitual even when competition pressure is absent. This level of dehydration is comparable to that reported in similar studies on judo athletes during both training and competition periods [19, 13, 3, 9, 12, 20, 14]. For instance, one study found elite judo athletes averaged 1.027±0.005 pre-weigh-in and 1.025±0.005 pre-match, despite a 15-hour recovery period [3]. Crucially, the USG values did not show a statistically significant difference over the course of the training day, suggesting that fluid intake was insufficient to counteract sweat loss during train-

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ing or to fully recover from prior fluid deficits. This mirrors findings in elite senior judo athletes where hypohydration worsened across a 24-hour period despite free fluid intake [14].

The significant decrease in body weight (BW) observed during the training session confirms that the judo training provided a substantial physiological load resulting in fluid loss through sweating. The lack of subsequent change in USG or UC suggests that the consumed fluids post-training were inadequate to restore the fluid balance. This persistent state of hypohydration carries significant risks for the athletes. Dehydration is known to negatively impact athletic performance, impairing muscle strength, endurance, motor skills, and cognitive function [21, 5, 22]. Furthermore, hypohydration increases the cardiovascular load, a phenomenon marked by elevated heart rate and decreased cardiac output, which can increase physiological strain during exercise [8, 23]. Acute dehydration, for instance, has been shown to impair judo-specific performance and significantly elevate heart rate responses during the Special Judo Fitness Test (SJFT) [4]. Therefore, while the current study focused on a non-competitive period, the observed hypohydration levels place the athletes at chronic risk of sub-optimal recovery and training adaptation.

The observation that elite athletes remain chronically hypohydrated, even during a period without the external pressure of making weight, suggests that the practices typically associated with RWL may have become ingrained behaviors. RWL often relies on fluid restriction and other methods that induce dehydration [24]. It has been noted that the high prevalence of hypohydration in elite combat sport athletes is related to insufficient fluid intake habits rather than other factors like sex [10]. This raises the question of whether this behavior stems from a habitual carryover from competitive periods or a fundamental knowledge gap in appropriate fluid intake for optimal recovery and performance. Given that judo athletes are exposed to RWL practices from an early age, establishing poor hydration habits early may explain the resistance to adequate fluid intake even years later.

A few limitations should be acknowledged. First, the modest sample size, while representative of an elite cohort, should be considered when generalizing results. Second, the study design did not monitor fluid intake to precisely quantify the degree of under-rehydration, and urine markers, while practical, have noted limitations when applied to the athletic population with high muscle mass. However, the large magnitude and consistency of hypohydration observed across all measures provide a strong foundational finding.

For future research, longitudinal studies should track fluid intake and educational interventions specifically aimed at improving hydration knowledge and habits in elite judo athletes during preparatory periods. This is critical because mitigating the adverse effects of hypohydration is essential for enhancing training quality, maximizing recovery, and protecting the long-term health of elite judokas.

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Effects of Aerobic Exercise on Inhibitory Control in Methamphetamine Addicts: A Systematic Review and Meta-Analysis

This systematic review and meta-analysis aimed to evaluate the effects of aerobic exercise (AE) on inhibitory control among individuals with methamphetamine (MA) addiction and to examine potential dose–response relationships influenced by gender and intervention parameters. Randomized controlled trials (RCTs) investigating AE interventions targeting inhibitory control in individuals with MA addiction published before July 2024 were systematically retrieved from six databases (PubMed, Web of Science, Embase, Cochrane Library, CNKI, and Wanfang). Methodological quality was assessed using the Cochrane Risk of Bias Tool. Meta-analyses were conducted with RevMan 5.3, and publication bias was examined using funnel plots and Egger's test via Stata MP 18.0. The certainty of evidence was graded using the GRADE approach. Nine papers comprising 11 studies with a total of 587 participants were included. Although most studies showed a moderate risk of bias due to incomplete reporting of blinding, the pooled analysis demonstrated significant benefits of AE on inhibitory control. Specifically, AE significantly improved behavioral accuracy (n = 455, SMD = 0.77, 95 % CI: 0.14–1.40, p = 0.02) and reduced reaction time (n = 498, SMD = −0.51, 95 % CI: −0.84 to −0.18, p = 0.002). Subgroup analyses indicated that the magnitude of improvement was associated with gender and varied according to intervention duration, frequency, and exercise modality. Aerobic exercise exerts a significant positive effect on inhibitory control in individuals with methamphetamine addiction. The outcomes suggest a potential dose–response pattern moderated by gender and specific intervention parameters. These findings provide empirical support for integrating structured aerobic programs into rehabilitation protocols for MA addicts. Future research should refine exercise prescriptions and elucidate the underlying neurobiological mechanisms driving these cognitive benefits.

Keywords: aerobic exercise; methamphetamine; inhibitory control; meta-analysis; reaction time

Introduction

Methylamphetamine (MA) addiction is a chronic substance use disorder in which continued use of MA impairs brain functioning, resulting in a reduced ability to control impulses to use MA and ultimately leading to addiction [1]. A total of 64 million people worldwide will have a substance use disorder by 2022, a growth rate of more than 80 % in the last five years, with the drug-using population growing by nearly 20 %, but only 1 in 11 will be able to receive treatment, instead of a downward trend [2]. Long-term drug use requires financial support, and most drug users do not have a stable financial source, which leads to an increase in the crime rate [3]. Drug abuse places are mostly in public areas, which can also lead to negative impacts on the enjoyment of recreational and public spaces, as well as local children who may be exposed to these places [3]. Therefore, curbing drug abuse can be effective in improving social stability and the well-being of the population.

Drug use can cause serious physical and psychological harm, and one of the core symptoms of MA addiction is impairment of inhibitory control [4]. Inhibitory control is an important component of executive functioning, a conscious ability to control behavior. Impairment of inhibitory control is recognized as an important cause of craving and relapse after withdrawal [5]. Therefore, how to increase control over drugs or drug cues by improving inhibitory control in MA addicts becomes critical in helping to accomplish detoxification.

Aerobic Exercise (AE) can regulate the internal environment and enhance the immunity of the body [6], as an effective therapeutic means, AE is not only low-cost, but also has the advantages of ease of operation, which is widely used in the field of rehabilitation and health care [7]. In recent years, more and more studies have focused on the potential of AE in improving inhibitory control. It has been shown that open-ended skill activities can improve inhibitory control well [8], and a large number of studies have confirmed that inhibitory control can be improved to a certain extent in MA addicts after exercise intervention [9, 10]. However, it has also been suggested that the ameliorative effects of AE are not significant in smoking addicts [11] and this area remains highly controversial. Although studies have examined the effects of AE on inhibitory control in MA addicts, the current findings are inconsistent and systematic Meta-analysis is lacking.

Therefore, by searching domestic and international databases, conducting a comprehensive assessment of relevant literature, systematically analyzing the effects of AE on inhibitory control in MA addicts, and exploring its possible influencing factors, the present study aims to provide a scientific basis for MA abstinence and an effective exercise intervention program for drug addicts.

Methods and materials

Literature search strategy

In this study, searches were conducted in English databases (PubMed, Web of Science, Embase, Cochrane library) and Chinese databases (China Knowledge Network, Wanfang) to collect randomized controlled trials (RCTs) on the effects of AE on inhibitory control in MA addicts, and the search timeframe was from the construction of each database to July 2024. The search strategy combined subject and free terms, as well as tracking citations of included literature and reading relevant Meta-analysis literature to ensure a comprehensive collection of relevant studies. Chinese search formula: (aerobic exercise OR exercise) AND (drug OR methamphetamine OR substance addiction OR drug addiction) AND (inhibition control OR inhibition OR control) AND randomized controlled trial. English search terms: (aerobic exercise OR exercise) AND (drug OR methamphetamine OR substance addiction OR drug addiction) AND (inhibition control OR inhibition OR control) AND (randomized controlled trials OR RCTs) control) AND (randomized controlled trials OR RCT). This study is registered with the International Prospective Registry for Systematic Evaluation (PROSPERO) (No. CRD42024573123).

Inclusion and exclusion criteria

This study used the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA), and based on strict adherence to the study methodology and requirements of the PRISMA, the inclusion and exclusion criteria were developed based on the characteristics of PICOS included in each study. Specifically: Study subjects included MA-addicted individuals with no history of mental illness, infectious diseases, or contraindications to exercise, who voluntarily participated (no restrictions on gender, ethnicity, or age), excluding non-MA-addicted populations; Interventions included effective non-acute exercise-based AE interventions for MA addicts, excluding acute exercise and non-AE interventions; control measures comprised routine rehabilitation (including drug abstinence education, legal education, occupational health, daily activities, routine nursing, etc.), excluding groups receiving intervention measures; Outcome measures included behavioral paradigms assessing inhibitory control using Go/No-go, Stroop, or Stop-signal tests (primary: higher accuracy indicates stronger inhibitory control; secondary: lower reaction time indicates stronger responsiveness), excluding measures unrelated to inhibitory control; Study types included RCTs (randomized controlled trials), excluding experimental designs and non-RCT studies.

Literature screening and data extraction

Literature was imported into EndNote to eliminate duplicates, and two researchers independently screened the literature according to the inclusion and exclusion criteria, extracted data, and reviewed each other after the statistics were completed, and discussed the main points or referred to third-party opinions in case of disagreement. Extracted data: first author, year of publication, country, sample size, gender, age, years of drug use, intervention, frequency of intervention, duration of intervention, and outcome indicators. If the description of the original study data was unclear or information was lacking, the data were collected

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through other channels, or attempts were made to contact the authors by email, and the literature was excluded if there was no information from other sources or no response from the authors.

Quality assessment

In this study, the methodological quality assessment of each RCT was conducted using the RCT risk of bias evaluation criteria provided by the Cochrane Collaboration, which included: (i) randomized sequence generation; (ii) allocation scheme concealment; (iii) blinding applied to subjects and staff; (iv) blinding applied to outcome data assessment; (v) completeness of outcome data; (vi) selective reporting bias; and (vii) other potential sources of bias. Quality assessment was conducted independently by two investigators and reviewed with each other, and in case of disagreement, discussion or reference to a third investigator's opinion was made until agreement was reached. Meanwhile, the quality of evidence for each outcome indicator was evaluated using the GRADE evidence grading system, which was categorized into four grades: high, intermediate, low, and very low. If there were differences in ratings, a third researcher was involved in the discussion and agreement was reached.

Statistical analysis

Meta-analysis was performed using RevMan 5.3 software provided by the Cochrane Collaboration. I^2 was used to measure the degree of heterogeneity between studies. If $I^2 \geq 50$ % and $P < 0.1$, the effect sizes were combined using a random effect model (RE); conversely, a fixed effect model (FE) was used. RE was used if the source of heterogeneity could not be explained by clinical or methodological differences. For data that could not be combined, descriptive analyses were performed. Continuous variables were expressed using mean difference (MD) and 95 % confidence interval (CI) when the effect measures or units of the interventions were consistent; otherwise, standardized mean difference (SMD) and 95 % CI were used. CI. The significance level was set at $P < 0.05$. To assess the effect of heterogeneity on the results, this study conducted sensitivity analyses using a case-by-case exclusion method and comparison of models with different effects to minimize the impact of high heterogeneity and small sample effects on the reliability of Meta-analyses. Stata MP 18 was used to draw funnel plots to assess publication bias. If the information is biased, the funnel plot will show asymmetry, and the degree of asymmetry is proportional to the degree of bias.

Results of the literature search

A total of 1,382 documents were obtained through database searches and other sources. After reading the titles and abstracts to screen and exclude non-RCTs and clinical trials with inconclusive data, 9 documents were finally included, with a total of 11 studies, of which 1 study was published in Chinese and 10 in English, with a total of 587 patients, and the flowchart of the literature search is shown in Figure 1.

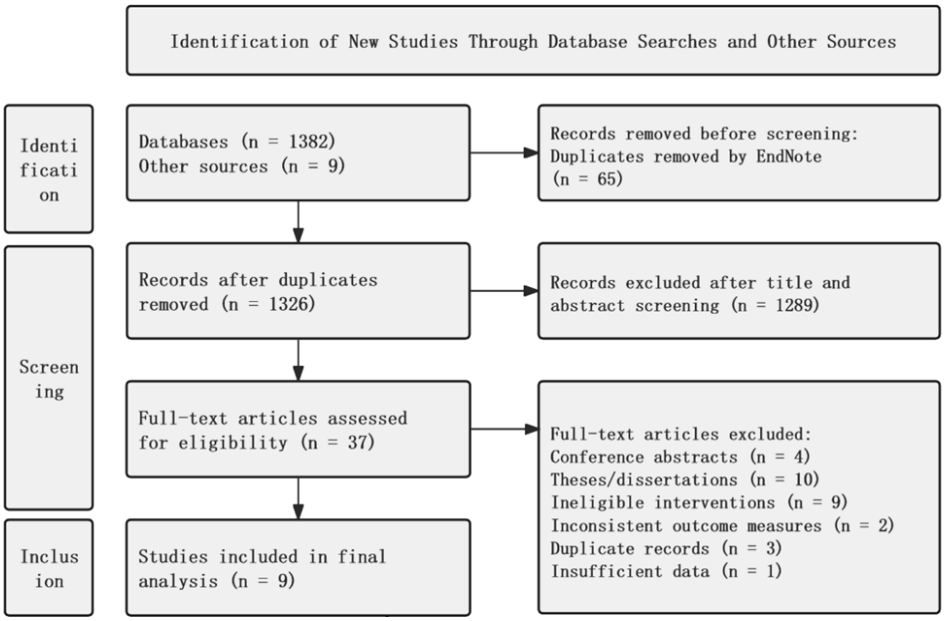

Figure 1. Flowchart of Literature Retrieval

Basic information and data extraction for included studies

Basic information on included studies (Table 1)

Table 1

Basic information on included studies

Inclusion of studies	nations	sample size	(a person's) age	distinguishing between the sexes	Years of drug use	Type of intervention		intervention period	outcome indicator
		T/C	Age (T/C)	M/F	T/C	T	C		
Chen 2021A[12]	sino	19/21	29.58±1.01/ 33.24±1.73	male	5.53±0.75/ 6.62±0.84	Aerobic exercise, 30 minutes three times a week	read	12 weeks	①
Chen 2021B[12]	sino	17/21	32.53±1.16/ 33.24±1.73	male	6.82±0.56/ 6.62±0.84	High-intensity aerobic exercise, 30 minutes three times a week	read	12 weeks	①
He 2021A[13]	sino	16/16	41.88±13.44/ 42.81±11.54	male	11 from 0–5 years, 2 from 5–10 years, 3 from 10+ years / 9 from 0–5 years, 2 from 5–10 years, 5 from 10+ years	Tai chi, three times a week, 25 minutes each time	routine	4 weeks	①③
He 2021B[13]	sino	16/16	41.88±13.44/ 42.81±11.54	male	11 from 0–5 years, 2 from 5–10 years, 3 from 10+ years / 9 from 0–5 years, 2 from 5–10 years, 5 from 10+ years	Tai chi, three times a week, 25 minutes each time	routine	4 weeks	①③
Liu 2021[14]	sino	43/46	29.93±7.91/ 28.96±8.27	women	8.05±3.84/ 7.82±3.57	Aerobic exercise, 40 minutes five times a week	routine care	12 weeks	①③
Liu 2023[15]	sino	23/23	28.48±3.30/ 27.66±3.66	male	8.16±3.81/ 8.44±3.62	Treadmill exercise, 40 minutes five times a week	health education	8 weeks	①③
Shen 2021[16]	sino	35/37	39.31±10.33/ 39.37±9.28	daughter	unreported	Tai chi, three times a week, 60 minutes each time	Regular activities	12 weeks	①
Wang 2017[17]	sino	25/25	32.20±6.97/ 34.76±7.96	hybrid	6.94±4.48/ 6.99±4.86	Aerobic exercise (cycling, jogging, jumping rope), 30 minutes three times per week	routine care	12 weeks	②
Zhu 2022[18]	sino	40/37	34.61±5.12/ 34.94±6.58	male	8.57±7.14/ 8.92±5.31	Group aerobics, 36 minutes five times a week	routine care	12 weeks	②

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Continuation of Table 1

Inclusion of studies	nations	sample size	(a person's) age	distinguishing between the sexes	Years of drug use	Type of intervention		intervention period	outcome indicator
		T/C	Age (T/C)	M/F	T/C	T	C		
Zhu 2023[19]	sino	32/32	30.30±5.28/ 29.80±5.51	male	5.20±1.65/ 5.65±1.54	Cycling, running exercise, 40 minutes three times a week	conventional treatment	8 weeks	②
Zhang Yanhui 2024[20]	sino	25/22	28.13±1.81/ 27.28±1.62	women	unreported	Rehabilitation exercises, 30 minutes twice a week	read	10 weeks	④

Note. T stands for experimental group; C stands for control group. ① Stroop; ② Go/No-go; ③ 2Back; ④ Stop-signal.

Data extraction

Exercise prescription variables included exercise modality, exercise frequency, exercise duration, and intervention period. Specifically, exercise modalities were programmed as regular AE and Tai Chi or rehabilitation exercises. Exercise frequency was categorized as: ≤2 times/week, 3-4 times/week, or 5–7 times/week [21]; exercise duration was categorized as: less than 45 minutes, 45–60 minutes [21]; and intervention period was categorized as: ≤8 weeks or >8 weeks. Patient characteristics included gender (male; female).

Bias Risk and Evidence Quality Assessment

The risk of bias of the included studies was assessed independently by two researchers using the Cochrane Collaboration's risk of bias assessment tool, with a third researcher involved to resolve any discrepancies through discussion. The results of the assessment showed that there was a low risk of bias for randomized sequence generation, allocation concealment, data completeness, selective reporting, and other biases; there was a high risk of bias for participant blinding; and the majority of the literature did not report the blinding of the outcome assessment in full, so the risk of bias for this component was unclear (Fig. 2).

The GRADE software assessment showed that the quality of evidence was intermediate for paradigm correctness and low for response time. This may be due to the fact that some of the literature did not use allocation concealment or did not implement blinding in its entirety, thus leading to some limitations in the study.

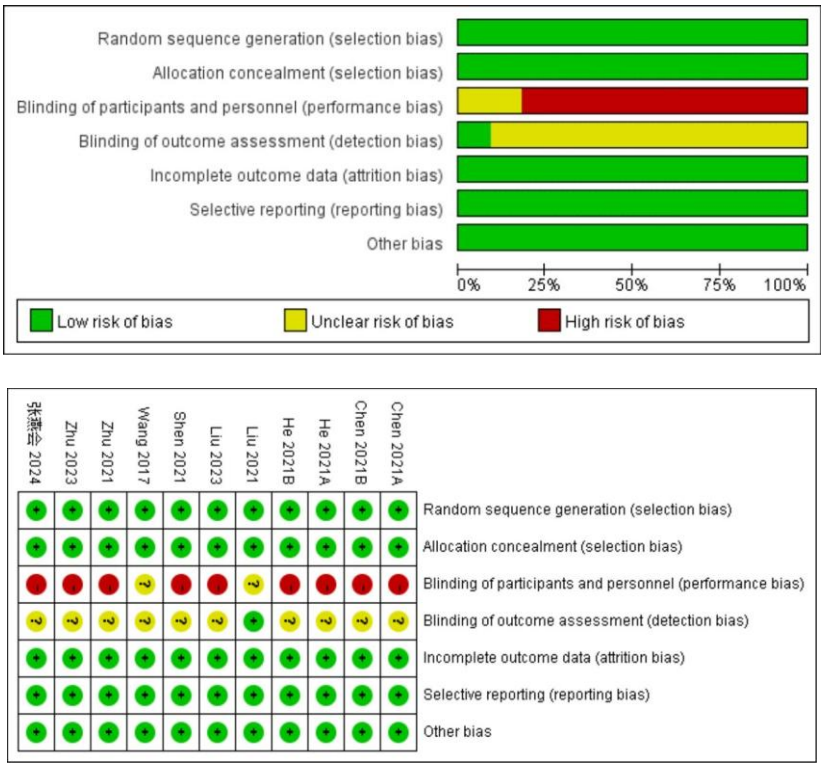

Figure 2. Overall risk of bias evaluation

Results

Meta-analysis and subgroup analysis

Meta-analysis

AE was able to significantly improve the correctness of the behavioral paradigm in MA addicts [SMD = 0.77, 95 % CI (0.14, 1.40), p = 0.020] and significantly improve response time [SMD = -0.51, 95 % CI (-0.84, -0.18), p = 0.002], as shown in Table 2. In analyzing the between-study heterogeneity, the use of the single study-by-study exclusion method found that Wang 2017 [17] had a large impact on inter-study heterogeneity of results, and after their exclusion, the combined results of the remaining RCTs showed a significant decrease in study-by-study heterogeneity between correct rates of behavioral paradigms (I2=63 %, P =0.030), and the SMD range after further exclusion of the single studies was -0.58~ -0.42, I2ranging from 63 %~ 72 %, suggesting more robust results.

Table 2

Intervention effects of AE on inhibitory control in MA addicts

Outcome indicator	Inclusion of studies	I2/%	Meta-analysis results	
			SMD (95 % CI)	P-value
Paradigm correctness	7 (455)[14-20]	90	0.77 (0.14,1.40)	0.02
response time	10 (498)[12,12,13,13,15-20]	63	-0.51 (-0.84,-0.18)	0.03

Subgroup analysis

Subgroup Analysis of Paradigm Correctness

In this study, subgroup analyses of paradigm correctness were conducted for gender, exercise mode, exercise frequency, exercise duration, and intervention period. The results showed that the subgroups of males, exercise frequency of 5–7 times/week, single intervention time of 36–60 minutes, and exercise cycle of 4–8 weeks had better efficacy than the control group. However, the small number of studies in the Tai Chi and Rehabilitation Exercise subgroups and the high heterogeneity among the remaining subgroups need to be interpreted with caution (Table 3).

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Table 3

Subgroup analysis of paradigm correctness rates

Subcomponent group		Number of studies included	I2/%	Subgroup analysis results	
				SMD (95 % CI)	P-value
distinguishing between the sexes	male	3[15,18,19]	49	0.30 [0.18,1.02]	0.005
	female	3[14,16,20]	68	0.15[-0.34,0.64]	0.550
sports	Regular Aerobic Exercise	5[14,15,17–19]	91	1.14 [0.34,1.94]	0.005
	Tai Chi, Rehabilitation Exercise	2[16,20]	0	-0.09[-0.45,0.27]	0.630
exercise frequency	≤2 times/week 3-4 times/week	1[20] 3[16,17,19]	- 96	-0.23 [-0.80,0.35] 0.82 [0.49,1.14]	0.440 <0.001
	5–7 times/week	3[14,15,18]	0	0.48 [0.21,0.76]	<0.001
exercise duration	25–35 minutes	3[17,18,20]	96	1.20[-0.62,3.01]	0.200
	36–60 minutes	4[14–16,19]	62	0.53[0.13,0.94]	0.010
intervention period	4–8 weeks	2[15,19]	0	0.81 [0.42,1.20]	<0.001
	9–12 weeks	5[14,16–18,20]	93	0.79[-0.09,1.66]	0.080

Subgroup analysis at the time of reaction

In this study, gender, exercise mode, exercise frequency, exercise duration, and exercise cycle subgroups were analyzed at the time of response, and the results showed that the efficacy of an exercise cycle of 4–8 weeks was better than that of the control group, and the heterogeneity between the remaining subgroups was high (Table 4).

Table 4

Subgroup analysis at the time of reaction

Subcomponent group		Number of studies included	I2/%	Subgroup analysis results	
				SMD (95 % CI)	P-value
distinguishing between the sexes	male	7[12,12,13,13,15,18,19]	58	-0.56[-0.91,-0.21]	0.002
	women	2[16,20]	90	-0.68 [-1.93,0.57]	0.280
sports	Regular Aerobic Exercise	6[12,12,15,17,19]	73	-0.47 [-0.92, -0.03]	0.040
	Tai Chi, Rehabilitation Exercise	4[13,13,16,20]	79	-0.39[-1.06,0.28]	0.260
exercise frequency	≤2 times/week 3-4 times/week	1[20] 7[12,12,13,13,16,17,19]	- 53	-1.34[-1.98,-0.70] -0.40[-0.73,-0.08]	<0.001 0.020
	5–7 times/week	2[15,18]	88	-0.44 [-1.50,0.63]	0.420
exercise duration	25–35 minutes	7[12,12,13,13,17,18,20]	68	-0.67[-1.09,-0.25]	0.002
	36–60 minutes	3[15,16,19]	46	-0.19 [-0.59,0.22]	0.360
intervention period	4–8 weeks	4[13,13,15,19]	16	-0.35[-0.68,-0.02]	0.040
	9–12 weeks	6[12,12,16-18,20]	79	-0.62[-1.13,-0.11]	0.020

Sensitivity analysis

In this study, we sensitized studies with high heterogeneity in paradigm correctness and response time by excluding individual studies one by one. After excluding the studies of Wang 2017 et al. [17] the combined effect of paradigm correctness was SMD = 0.37,95 % CI (0.04, 0.71), P = 0.03; I2decreased from 90 % to 63 %, which was a significant decrease in heterogeneity and significantly different from the control group (P < 0.05); after excluding the other individual studies, the combined effect SMD ranged from 0.74~ 0.94 for I2 and 90 %~ 92 % for I2, which were significantly different from the control group except for Zhu2023 [19] (P < 0.05); the combined effect at response was SMD = -0.51, 95 % CI (-0.84, -0.18),

P = 0.002; The range of SMD after excluding single studies was 0.58~ 0.42, I2of 63 %~ 72 %, suggesting a more robust result, all of which were significant compared with the control group (P < 0.05).

The study by Wang 2017 et al. [17] included patients whose subjects' sex was mixed braided, and whose intervention was a combination of exercises, which may be a source of heterogeneity. Excluding this study, the combined effects of SMD and I2 for paradigm correctness were within a relatively robust range, further supporting the robustness of the results.

Publication bias

Since only seven studies were included in the paradigm correctness, this study only tested for publication bias in the literature about the time of reaction, and there was asymmetry in the lower part of the funnel plot, which may have publication bias, but the method relies on subjective judgment and the results may be uncertain. For further validation, the Egger regression method was used to test for publication bias, and the results showed that there was no significant publication bias in the Egger regression test (|t| = 0.76, P = 0.470) at the time of reaction.

Discussion

The aim of this Meta-analysis was to investigate the effect of AE on inhibitory control in MA addicts. Relevant studies were screened through a systematic literature search, applying standardized inclusion and exclusion criteria, and effect sizes were calculated.

Findings suggest that AE significantly improves inhibitory control in MA addicts. Exercise significantly improves depressive symptoms and physical health in substance addicted patients [22], and as an adjunctive treatment, it also alleviates psychiatric disorders induced by substance addiction [23], which enhances inhibitory control, which may be related to dopamine conversion rate. It has been shown that structured exercise improves the dopamine conversion rate, increases dopamine release, synthesis and secretion, and suppresses its concentration for a period of time after exercise [24], improves the D2/D3 receptor deficits in dopamine in MA addicts [25], repairs the midbrain-limbic dopamine system, attenuates euphoria triggered by MA, and reduces MA craving, thus facilitating inhibitory control. In addition, AE enhances inhibitory control by promoting synaptic plasticity [26] and increases brain-derived neurotrophic factor (BDNF) [27], which not only affects inhibitory control and neuroplasticity [28] but is also associated with the survival and function of dopaminergic neurons [29]. Endogenous dopamine also plays an important role in the improvement of response time, which only occurs when movement is coordinated with signals from higher brain centers [30].

Subgroup analyses revealed significant differences in the role of gender in the AE intervention. AE significantly improved inhibitory control in male addicts and had little effect on female addicts, which is consistent with the findings of a Meta-analysis on drug addiction [31]. The relatively high heterogeneity in the female subgroup may affect the statistics of the effect sizes and therefore needs to be interpreted with caution. Interestingly, a study conducted in older adults with subcortical ischemic vascular cognitive impairment found that AE significantly increased inhibitory control in females and had a negative effect in males [32]. This may be due to a common functional single nucleotide polymorphism in the prepeptide domain of the BDNF gene, which causes an amino acid substitution at position 66 from valine (Val) to methionine (Met), known as the Val66Met substitution. In carriers of the BDNF Met allele, this is associated with reduced activation of attentional targets in the dorsolateral and dorsomedial prefrontal cortex [33]. The Val66Met polymorphism has been associated with susceptibility to neuropsychiatric disorders, especially schizophrenia, and with depression, anxiety, and other disorders with gender-specific dimorphisms [32, 34]. MA addicts may be due to the substitution of Val for Met in the BDNF, which leads to dimorphisms in inhibitory control. In a study on subcutaneous white adipose tissue and dimorphism, it was shown that male subcutaneous white adipose tissue was more enriched in aspects related to aerobic metabolism and also showed strong dimorphism [35]. Thus, AE may play a greater role in the improvement of inhibitory control in MA addicts in males. Currently, the mechanisms underlying the gender differences in the effects of AE on inhibitory control in MA addicts are unclear, and the influence of gender on the effects of exercise interventions needs to be further explored in future studies. However, the present study mainly investigated RCTs of 4–12 weeks, so whether AE below 4 weeks or above 12 weeks has the same results for MA addicts still needs to be analyzed by including a large number of gender-controlled RCTs at a later stage. Exercise mode: conventional AE significantly improved correct rates, but heterogeneity between studies was high. Heterogeneity decreased significantly after excluding the study of Wang 2017 [17], which may be related to the combined exercise intervention used in this study. Both AE and combined training significantly improved functional motor ability, and the improvement effect of combined training was better [36], so combined exercise may

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have a more significant improvement effect on inhibitory control in MA addicts. The results supporting AE are consistent with previous studies that have demonstrated the ability of AE to significantly improve inhibitory control in MA addicts [37, 38]. Although the subgroup analysis showed that Tai Chi and Rehabilitation Exercise were not significant compared to the control group, the heterogeneity shown in their subgroup analysis was high and has been confirmed by other studies [39], so the role of Tai Chi and Rehabilitation Exercise could not be denied in this study, and it needs to be further verified by high quality studies in the future. In addition, this Meta-analysis included only two studies on correct rate of Tai Chi and rehabilitation exercise intervention modalities, and the between-group heterogeneity of group performance at response time according to exercise modalities was high, and subgroup analyses according to exercise modalities may have resulted in less reliable findings because of the limited number of studies and high heterogeneity. More RCTs should be conducted to investigate the effects of different forms of exercise on inhibitory control in MA addicts. Exercise frequency: the results of subgroup analyses showed that the frequency of engaging in AE training had a significant effect on the intervention effect, and the intervention effect of AE was most significant in 3-4 sessions/week compared with 5–7 sessions/week of AE. Unfortunately, there were not a sufficient number of studies testing the effect of exercise interventions ≤2 sessions/week on inhibitory control. Importantly we found a more significant effect of interventions at moderate frequencies compared to high frequencies. Previous reviews have described the effects of exercise at low and moderate frequencies and similarly demonstrated that moderate frequency exercise had the best intervention effect [40, 41]. However, this result needs to be interpreted with caution as the heterogeneity of the exercise frequency subgroups was all relatively high. There was no significant difference between the AE intervention group, which was 5–7 times per week at the time of response, and the control group. This may be related to the fact that exercise induces mental fatigue and a decrease in perceptual ability, and that the speed and accuracy of decision-making decreases with increasing fatigue [42], and that too many interventions per week may cause increased fatigue in patients, leading to a decrease in responsiveness. Duration of exercise: results obtained in the subgroup of 25–35 minutes need to be interpreted with caution due to high heterogeneity, but previous studies have shown that ≤45 minutes of exercise per session had the most significant effect in improving executive function [40]. However, in the subgroup of 36–60 minutes, the AE intervention group was significantly different from the control group, and although heterogeneity was high, taking a study-by-study approach to exclusion revealed a significant decrease in heterogeneity after excluding the Shen 2021 [16] study ($I2= 0$ %, $p < 0.001$), and since only Shen 2021 [16] one study had an intervention duration of 60 minutes, exercise time may be the source of heterogeneity. The excluded studies all had an intervention time of 40 minutes, so the present study hypothesized that an AE intervention at 40 minutes per session could significantly improve inhibitory control in MA addicts. Again, this is consistent with previous studies that have concluded [43]. Since the present study included only a single 60-minute intervention, it is not yet possible to determine whether a 60-minute exercise session has a beneficial effect on inhibitory control in MA addicts. Further RCTs are needed to investigate the effects of varying intervention durations on inhibitory control in this population. Subgroup analyses of response times revealed high heterogeneity in both groups, and the results obtained need to be interpreted with caution. Exercise period: in the subgroup of 4–8 weeks of exercise intervention, both the rate of paradigm correctness and response time were better than the control group, which could significantly improve inhibitory control [44], while the difference between the subgroup of 9–12 weeks of exercise intervention compared with the control group was not significant but the heterogeneity between the groups was higher, therefore, we do not speculate that the 9–12 weeks of exercise intervention did not have an effect on inhibitory control of MA addicts, and, the previous studies have shown that 12 weeks of AE can significantly improve inhibitory control and cognitive ability in MA addicts, and more high-quality studies are needed in the future to further validate the effect of exercise cycles on inhibitory control in MA addicts. Considering the influence of exercise dose effect, exercise intervention cycles should not be less than 4–8 weeks.

Limitations of this study

The overall quality of the literature included in this study was moderate, with some limitations. Most of the literature did not fully report on blinding, which may have had an impact on the posttest results. A publication bias test at the time of response showed no significant publication bias. In addition, only Chinese and English literature were included in this study, which may be deficient in the comprehensiveness of the included literature; the patients included in the study were all Chinese, which may be less valuable as a reference for other countries or regions; and there was a large amount of heterogeneity among studies, and the included literature was carefully read, but no direct evidence of the source of heterogeneity was found. More

randomized controlled trials should be conducted in follow-up to explore the effects of AE on inhibitory control in MA addicts.

Conclusions

This meta-analysis provides robust evidence that aerobic exercise (AE) significantly enhances inhibitory control in individuals with methamphetamine (MA) addiction. The magnitude of improvement was influenced by gender and exercise modality, and a dose–response relationship was evident across exercise duration, frequency, and intervention period. Specifically, male participants achieved greater improvements in inhibitory control when engaging in AE three to seven times per week, approximately 40 minutes per session, for a minimum of four weeks.

These findings underscore the potential of structured AE as a complementary strategy in cognitive rehabilitation programs for MA addicts. Future studies should further explore the optimal exercise prescriptions and elucidate the neurobiological mechanisms underlying these improvements to guide evidence-based clinical practice.

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Complex correction of coordination abilities of female volleyball players with degree I overweight

According to the World Health Organization [1], recent years have seen an increase in the prevalence of obesity among people of different age groups worldwide. Obesity is associated with numerous impairments affecting various organs and physiological systems at the level of the whole organism. Consequently, the prevention and treatment of excess body weight have become a problem of global importance. In this regard, the Russian Federation is no exception, as demonstrated by Academician of the Russian Academy of Sciences I.I. Dedov and colleagues [2]. There is broad consensus that obesity is largely a consequence of reduced physical activity (hypodynamia). Accordingly, increasing physical activity represents one of the key approaches to addressing this problem. At the same time, the concepts of maladaptation (adaptation syndrome, stress syndrome) developed by G. Selye [3], as well as the theory of functional systems proposed by P.K. Anokhin [4], remain relevant. These theoretical frameworks formed the methodological basis of the present study. In addition, a comprehensive approach was employed that combines a chemical (pharmacological) stimulus derived from the main research area—namely, the pharmacology of protatranes—with a physical stimulus in the form of training.

The study investigates the effects of the developed program on agility, balance, and other essential coordination abilities required for successful volleyball performance in 17-18-year-old female students with stage I obesity. Changes in coordination parameters before and after the intervention were analyzed.

Keywords: stage I obesity, intervention, Tricevit dietary supplement, students, 17-18-year-old females, motor activity, motor coordination, intervention

Introduction

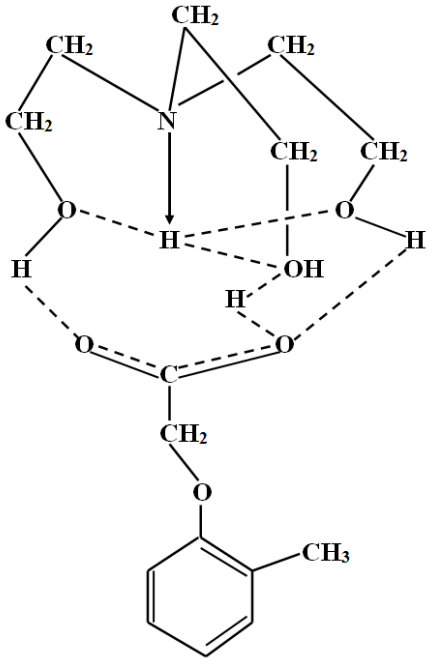
According to WHO estimates, overweight occurs in 25–30 % of adults and 12–20 % of children worldwide [1]. Russian studies conducted at the Institute of Clinical Endocrinology revealed that over 2.7 million adolescents (12–17 years) in Russia are overweight, with approximately 500,000 of them suffering from obesity [2]. Given the importance of public health, the Government of the Russian Federation encourages the active participation of all segments of the population in health-enhancing physical activity [5]. Physical education has a comprehensive impact on the human body, which functions as a complex system with multilevel regulation. In pedagogical practice, special attention is paid to maintaining the health of the younger generation, including students with various health and physical development disorders. It is important to develop in students a conscious desire to improve their health, actively using health, pedagogical, and medical methods. In particular, volleyball, being the most widespread and accessible sport and physical activity in the world, can serve as an effective tool for preventing insufficient physical activity and obesity, including improving coordination skills [6]. Therefore, there is a need to develop innovative and effective approaches to restoring impaired coordination skills in overweight individuals. In this context, the drug trecrezan, which has a broad spectrum of biological action [7, 8, 9] has attracted particular attention. Trecrezan is the progenitor of a new class of biologically active compounds—protatranes [10, 11], which obey the formula:

$$\mathbf{X\text{-}N{+}H(CH_2CH_2OH)_3}$$

The chemical base of Trecrezan is oxyethylammonium methylphenoxyacetate, which is available as a powder and packaged in 1.0 kg jars. Trecrezan follows the formula:

$$\mathbf{[2-CH_3C_6H_4OCH_2COO]^-\,[NH(CH_2CH_2OH)_3]^+}$$

and has the following form:



Trecrezan, like its derivatives such as Tricevit [12], is available as a dietary supplement. However, the effects of Tricevit have been insufficiently studied. This determined the objective of this study: to determine the effectiveness of Tricevit for the comprehensive correction of coordination abilities in subjects suffering from stage I overweight.

Methods and materials

The study subjects were female students aged 17 to 18 years diagnosed with stage I obesity, whose body mass index (**BMI**) was between 30–34.

The study focused on the coordination abilities of the girls.

All subjects (50 girls in total) were divided into the following groups.

- A control group (16 girls), whose participants played volleyball exclusively and did not take any dietary supplements.

- Throughout the year, the first group (16 girls) received two courses of the dietary supplement Tricevit alongside their training. Each participant received a daily dose of 300 mg. Each course lasted 21 days, with the first starting in early fall and the second in early spring.

- The second group (18 girls) received three courses of the dietary supplement Tricevit throughout the year during training. The first and second courses were identical to those in the first experimental group, and the third course began during the 28th week of training, before the end of the school year.

Thus, the entire pedagogical experiment lasted one academic year.

To assess the girls' level of coordination development, a battery of tests was administered, including shuttle run; seated tennis ball throw with legs apart; pendulum-throw-target test; overhand tennis ball catch; 30-second alternating hand ball bounce on the floor; tests assessing coordination and movement harmony; cyclic exercises involving cross-coordination and plane changes; sequential exercises with plane changes; and various rhythmic exercises performed in the frontal plane. Conventional pedagogical supervision methods were applied throughout the study. In developing coordination skills, emphasis was placed on the repetition-based, game-based, and alternating methods, as well as the method of strictly controlled exercises. Training was conducted three times a week, each session lasting 90 minutes. When developing the training plan, the methodological recommendations of Yu.D. Zheleznyak [13, 14] were used as a basis. A pedagogical experiment and mathematical statistics were used as the primary research tools. In addition, information gleaned from scientific and pedagogical sources was analyzed and systematized.

The methodological basis of the study was G. Selye's concept and P.K. Anokhin's theory of functional systems [3, 4].

Statistical data processing was performed using the Statistica 10, Statgraphics Plus 2.1, and MS Excel 2010 software packages. Factor influence was calculated according to [15].

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Results and Discussion

We present data collected from a group of girls who did not use the dietary supplement Tricevit (control group). The results of this series of studies are summarized in Table 1.

Table 1

Changes in Coordination Skills of Female Volleyball Players (Control Group)

Indicator	1-test	2-test	3-test
Overhand Tennis Ball Catching (points)	2,7±0,2	3,5±0,2*	4,3±0,2*
Pendulum-Throw-Target (points)	4,8±0,1	5,9±0,2*	8,1±0,4*
Shuttle run 4x9 (seconds)	20,1±0,1	19,1±0,1	18,7±0,1*
Right-handed tennis throw; seated, feet apart (meters)	9,1±0,2	11,5±0,3*	12,4±0,3*
Bouncing the ball on the floor, alternating hands, for 30 seconds (times)	15,7±0,4	18,7±0,5*	26,1±0,8*
Coordination and combination of movements (number of errors)	10,0±0,3	9,1±0,3*	7,5±0,2*
Cyclic exercises with cross-coordination performed with changing planes (points)	2,5±0,1	3,5±0,2	4,0±0,3*
Sequential exercises with changing planes (points)	2,6±0,2	3,6±0,3*	4,0±0,3*
Various rhythmic exercises in the frontal plane (points)	2,1±0,2	3,3±0,2*	4,0±0,4*

Note. * - $p<0.05$ in relation to initial values.

Based on the data presented in Table 1, we can conclude that volleyball training in the control group of subjects produced positive and statistically confirmed improvements in coordination skills.

Next, we examined coordination skills in female students in the first experimental group, who twice took the dietary supplement Tricevit in combination with physical exercise. The data are presented in Table 2.

Table 2

Changes in the coordination skills of female volleyball players (first experimental group)

Indicator	1-test	2-test	3-test
Right-handed tennis throw; seated, feet apart (meters)	9,2±0,1	13,7±0,2	19,4±0,2*
Pendulum-Throw-Target (points)	4,8±0,1	6,9±0,2	9,8±0,3*
Shuttle run 4x9 (seconds)	20,1±0,2	18,1±0,1	15,3±0,1*
Overhand Tennis Ball Catching (Points)	2,7±0,1	4,5±0,1	5,7±0,3*
Bouncing the ball on the floor, alternating hands, for 30 seconds (times)	15,7±0,4	19,9±0,6	29,9±0,9*
Coordination and combination of movements (number of errors)	10,0±0,3	7,9±0,2	6,0±0,2*
Cyclic exercises with cross-coordination performed with changing planes (points)	2,5±0,1	3,8±0,2	4,3±0,2*
Sequential exercises with changing planes (points)	2,6±0,2	3,8±0,3	4,5±0,3*
Various rhythmic exercises in the frontal plane (points)	2,1±0,2	3,8±0,3	4,2±0,3*

Note. * - $p<0.05$ in relation to initial values.

Based on the data presented in Table 2, it can be concluded that systematic use of the dietary supplement Tricevit over two courses within one academic year has a statistically significant positive effect on the coordination skills of female students. This effect is more pronounced and positive compared to changes in the control group.

In the final series of observations, we studied the coordination skills of female students belonging to Experimental Group 2. Table 3 presents the obtained data.

Table 3

Changes in the coordination skills of female volleyball players (second experimental group)

Indicator	1-test	2-test	3-test
Right-handed tennis throw; seated, feet apart (meters)	9,2±0,1	13,8±0,2	21,3±0,2*
Pendulum-Throw-Target (points)	4,8±0,1	7,5±0,3	10,9±0,3*
Shuttle run 4x9 (seconds)	20,1±0,1	17,6±0,1	14,1±0,1*
Overhand Tennis Ball Catching (Points)	2,7±0,2	4,9±0,2	6,5±0,2*
Bouncing the ball on the floor, alternating hands, for 30 seconds (times)	15,7±0,4	21,9±0,3	32,5±0,5*
Coordination and combination of movements (number of errors)	10,0±0,3	6,44±0,2	4,1±0,1*
Cyclic exercises with cross-coordination performed with changing planes (points)	2,5±0,1	4,1±0,1	5,4±0,1*
Sequential exercises with changing planes (points)	2,8±0,2	4,3±0,2	5,1±0,3*
Various rhythmic exercises in the frontal plane (points)	2,2±0,2	4,3±0,1	5,5±0,2*

Note. *- $p<0.05$ in relation to initial values.

The results obtained, presented in Table 3, indicate a significant positive impact of a comprehensive approach, including three doses of the dietary supplement Tricevit throughout the year, on the coordination characteristics of female students. Thus, the study results are logically interpreted based on the principles of the functional systems theory proposed by P.K. Anokhin and incorporate G. Selye's concept of the adaptation syndrome. It offers a comprehensive analysis of the mechanisms of the body's adaptation to changing environmental conditions, emphasizing the interconnectedness and integration of diverse physiological processes. In particular, functional systems theory allows us to analyze behavior not as a simple set of individual reflexive reactions, but as a goal-oriented activity aimed at achieving a specific beneficial result. Within the framework of the aforementioned theories, we found it possible to present our interpretation of the obtained data in the form of a diagram in Figure 1.

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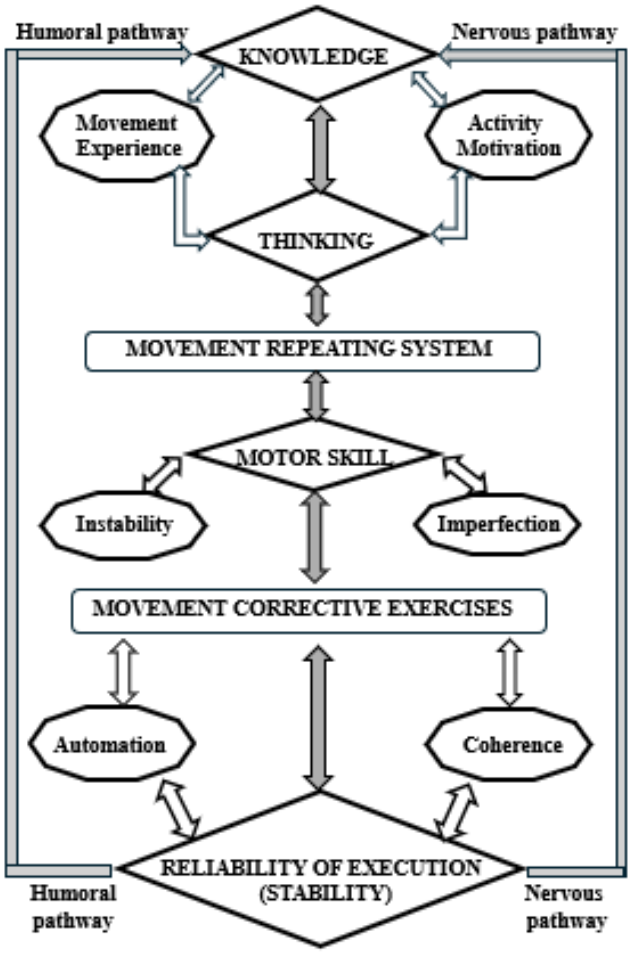

Figure 1. *Schematic diagram of the step-by-step correction of the body's coordination skills under complex influences

Notes. *- the diamond-shaped diagram indicates the key stages in the formation of a holistic behavioral act—the development of stable motor coordination; accordingly, the connections (direct and inverse) are indicated by shaded arrows. At each stage, as can be seen from the ovals, the possibility of forming additional subsystems of a particular format (meaning) is demonstrated, with the presence of the presented connections (unshaded arrows) to the key stage. Finally, this diagram, although simplified, highlights the key feedback pathways from the end point (the result of an action) to the initial stage of a behavioral act, namely the generation of a thought regarding the need to act. Thus, we believe the presented diagram indicates a multi-stage process of goal achievement, as well as the formation of a series of interconnected subsystems or multi-parameter systems of interconnected regulation. It is important to emphasize that the idea of conjugated (alian) reflexes, put forward by C.S. Sherrington (Nobel Prize!) [16], fits harmoniously into the system of maintaining homeostasis (adaptive responses). This theory, which is a significant step in the development of the theory of reflexes, provides a more complete understanding and explanation of both generally accepted and experimentally established characteristics. At the same time, in implementing physical education methods, we strictly adhered to the directives and recommendations set forth in regulatory documents, including specialized educational materials and teaching aids, which is an important component of the study.

Conclusions

1. An assessment of the dynamics of health indicators convincingly demonstrates that comprehensive correction using the dietary supplement Tricevit in combination with physical activity in female students suffering from stage I obesity demonstrates a pronounced positive effect.

2. The approach we have developed represents one of the new ways to solve the problem of obesity, which nevertheless requires further research.

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