Risk assessment of safety accidents in small and medium gyms

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Abstract. A risk assessment model for safety accidents in small and medium-sized gymnasiums is constructed by performing risk assessments on the characteristics of the events held in small and medium-sized gymnasiums, the risks of safety accidents, and the offset of accident risks. The risk index evaluation method is used to clarify the risk of security accidents in small and medium-sized gymnasiums based on the scale of the events, the scale of the events, the types of venues, the event cycle, the circulation of people, the types of people, fire risks, crowds of people, space, safe evacuation, event management and Correlation calculation method of 12 evaluation indicators for emergency management and control. According to this, the risk of safety accidents in small and medium-sized gymnasiums is classified, and the feasibility and rationality are verified.

1. Introduction

The gymnasium is divided into three types: large, medium and small gymnasiums. Among them, there are more than 8,000 seats of gymnasiums, and less than 3,000 are small gymnasiums. The number of medium-sized gymnasiums is between 3000 and 8000. From the perspective of stadium accidents around the world, no matter what type of accident, it will pose a threat to human life and safety. The best way to deal with the disaster itself is to contain the disaster before it happens. Therefore, a security early warning system is needed to monitor the status of the entire stadium in real time, and to give the risk index of the crowd at a certain moment. Let the management of the stadium to judge risks in advance, so as to take effective measures to curb the evolution of risks. In recent years, most of the new gymnasiums in China are gymnasiums, but the small and medium-sized gymnasiums established many years ago are still in use and there are still many security risks.

This article constructs an assessment system for the safety accident risks of small and medium-sized gyms. Multi-influence factors that affect the safety of small and medium-sized stadiums are extracted, and comprehensive analysis is performed to obtain a more realistic safety warning system. The influential factors of safety and security of stadium personnel are searched and determined in various ways to strengthen the safety management of stadium personnel. It is convenient for the security management personnel of the small stadium to monitor the level of risk in the stadium in real time.

2. Construction of safety accident risk assessment system for small and medium-sized gyms

2.1. Evaluation index system
According to the data survey, it is concluded that fire-fighting and crowded stampede accidents account for more than 90% of all casualties in safety accidents. Therefore, fire risk, crowd gathering, and space are used to represent the risk factors for safety accidents in sports events. According to the attributes of the events held in the gymnasium, it is determined that the accident risk offset factors mainly include safety evacuation, activity management, and emergency management and control. In addition, expert inspections have obtained a Kappa coefficient of 0.86 (significant p < 0.001), which indicates that the experts’ views are quite consistent. Based on this, a risk assessment index system for safety accidents in small and medium-sized gyms has been established. The first-level indicator is the risk model of the safety accident of sports events. The second-level indicators include the characteristics of the event, the risk of the security accident, and the offset of the accident risk. Accident risks include fire risk, crowd gathering, and space. Accident risk offsets include safety evacuation, activity management, and emergency control. That is, there are 12 factors for the three-level indicators [3].

2.2. Model index calculation
Based on the above evaluation system, the expression of the model of the safety accident risk index for sports events is

$$T_{ar} = \beta_{rp} \cdot A_{rc} \cdot R_{oc} \quad (1)$$

In the formula: $T_{ar}$ is the safety accident risk model index for sports events, $\beta_{rp}$ is the event characteristic index, $A_{rc}$ is the safety accident risk index, and $R_{oc}$ is the accident risk offset index.

2.3. Analysis of Event Risk Model Analyses

2.3.1. Event Characteristics Index. According to the literature [3], it can be known that the danger index is related to the characteristics of the event, the scale of the event, the type of venue, the period of the event, and the characteristics of the crowd. The characteristics of the crowd include the circulation of the crowd and the type of the crowd. Take values for six three-level risk indicators.

The value of the game nature is as follows: the value range of competitive performance events is 1 to 2 (such as gymnastics, diving, shooting, etc.); the value range of the same competitive game is 3 to 5 (such as track and field, football, basketball, etc.); the value range of the same fighting game is 4 to 5 (such as boxing, Sanda, wrestling, etc.).

The value of the event scale is as follows: the number of live audiences is less than 750 and the value is 1; the number of live audiences is 750 – 2250 and the value is 2; the number of live audiences is 2250 – 4500 and the value is 3; the number of live audience is 4500 – 6000 and the value is 4; the number of on-site audiences is 6000 or more and the value is 5.

The value of the venue category is as follows: the value range of the all-open stadium is 1 to 3; the value range of the semi-open stadium is 2 to 4; the value range of the fully enclosed stadium is 3 to 5. The value of the competition period is as follows: the value range of the temporary (1 ~ 2 d) event is 1 to 3; the value range of the short-term (≤7 d) event is 3 ~ 5; the value range of the long-term (> 7 d) event is 1 to 3.

The crowd circulation depends on whether the participants of the live event (including spectators, athletes, referees, etc.) frequently circulate, and the value range is 1 to 5. Crowd types include temporary crowds and cohesive crowds: temporary crowds represent audiences without a unified target and no leadership, and the value range is 1 to 3; cohesive crowds represent audiences with a common goal and no leadership, and the value range is 1 to 5.

2.3.2. Safety Accident Risk Index. Safety accident risk index is an index to measure the safety accident risk of sports events. Among them, the risk of security accidents includes traffic accidents inside and outside the arena, chaos in the opening and closing fields, emergency incidents such as fire and bomb attacks, and damage to venue facilities. The use of historical archives of sports event safety accidents and brainstorming methods to assess the likelihood and severity of risks, and found that the most
representative of sports events are fires, crowded stampedes, building sites, and public health and social security accidents. Therefore, in constructing the model, the safety accident risk index mainly considers the fire index, the aggregation index and the place index.

The fire index is based on the idea of the "Daohua Fire and Explosion Index". It mainly uses the space characteristics of the stadium to characterize its danger \[4\]. It consists of the gym space factor and the fire danger factor. Among them, the space factor of the gymnasium is usually determined by the fire resistance of the place, the fire protection level, the nature and quantity of dangerous materials, and the degree of crowd gathering. Comprehensive consideration of the dangers caused by fire accidents directly caused by personnel burns and indirect accidents caused by crowded stampede accidents, so the space factor of the stadium is determined by the annual fire probability and crowd density correction factor of the stadium.

The clustering index represents the degree of crowd gathering, and is composed of the accident susceptibility coefficient of sports events, the total number of people in the venue and the effective activity area, the flow speed of the import and export crowd, the average speed of crowd movement, and the crowd gathering correction coefficient. The larger the aggregation index, the higher the risk of crowd aggregation.

The venue index represents the risk of the stadium itself, including internal risk factors and external risk factors. Internal risk factors include design risks, layout risks, and decoration equipment risks, while external risk factors include risks caused by the surrounding environment, natural environment, and social environment \[5\].

2.3.3. Accident risk offset index. The accident risk offset index is an index that measures the magnitude of the risk factor for offset accidents, and consists of an evacuation index, an emergency index, and a management index. The evacuation index is an important indicator for measuring the safety of public places. The evacuation time, crowd density, and relative evacuation evaluation capacity are used to represent the difficulty of evacuation. The emergency index selected 15 evaluation standards, monitoring and evaluation, disaster insurance, institutional responsibilities, training drills, emergency resources, early warning notices, rescue and rescue, public security traffic, evacuation and evacuation, communication and communication, command and control, site cleanup, aftercare, and review and review. Indicators for evaluation. The management assessment is divided into four parts: site management, crowd management, monitoring management, and emergency management, including fire inspection, equipment maintenance and repair, safety inspection, smoking management, fire regulations, evacuation passage inspection, safety responsibility system, management rules and regulations, and personnel. Training and education, crowd monitoring and management system, and safety publicity and education 20 items.

3. Calculation of Risk Assessment Models for Small and Medium-sized GymnasiuMs

3.1. Event Characteristics Index \(\beta_{rp}\)

\[
\beta_{rp} = 1 + \frac{S}{30} \tag{2}
\]

\[
S = \sum_{i=1}^{6} S_i \tag{3}
\]

In the formula: \(S_1\) is the hazard index of the nature of the event, \(S_2\) is the hazard index of the scale of the event, \(S_3\) is the hazard index of the venue category, \(S_4\) is the hazard index of the event cycle, \(S_5\) is the crowd circulation hazard index, and \(S_6\) is the crowd type hazard index.

3.2. Safety Accident Risk Index \(A_{rc}\)

For the safety accident risk index \(A_{rc}\), the three types of risks that are considered to have a high probability of occurrence are fire and fire accident risks, crowded stamping and building site accident risks. Therefore, the safety accident risk index \(A_{rc}\) is the sum of the fire index \(A_\_ \ (rc, F)\), the aggregation index \(A_\_ \ (rc, C)\), and the place index \(A_\_ \ (rc, S)\). which is
\[ A_{rc} = A_{rc,P} + A_{rc,E} + A_{rc,S} \]  

### 3.2.1. Fire index.

\[ A_{rc} = S_r \left( \frac{G}{60} \right) \]  
\[ S_F = S_{F1} + S_{F2} \]  
\[ G = \sum_{i=1}^{15} G_i \]

In the formula: \( S_r \) is the space factor of the stadium, and \( G \) is the fire danger coefficient. \( S_F \) is usually determined by the fire resistance of the site, the degree of fire prevention, and the degree of crowd gathering. Therefore, \( S_F \) is determined by the annual fire probability coefficient and the crowd density correction coefficient. \( S_{F1} \) is the annual fire probability coefficient of the site, and \( S_{F2} \) is the population density correction coefficient. The fire risk coefficient \( G \) is related to 15 factors, which are the basic space coefficient \( G_1 \), the building structure characteristic coefficient \( G_2 \), the building fire rating coefficient \( G_3 \), and the heat conductivity of the building wall. Coefficient \( G_4 \), Decoration material coefficient \( G_5 \), Fire load density coefficient \( G_6 \), Window opening coefficient \( G_7 \), Fire spacing coefficient \( G_8 \), Safety evacuation distance coefficient \( G_9 \), Reasonability and compliance coefficient of fire zone division \( G_{10} \), Fire capacity coefficient \( G_{11} \), Fire protection facilities Coefficient \( G_{12} \), evacuation system coefficient \( G_{13} \), fire water source coefficient \( G_{14} \), and fire management coefficient \( G_{15} \).

### 3.2.2. Aggregation index.

The aggregation index indicates the high degree of crowd gathering, and this index is closely related to the occurrence of crowding and stamping accidents in sports events. which is

\[ A_{rc,E} = \alpha \cdot \rho \cdot v \cdot \bar{v} \cdot K \]  

In the formula: \( \alpha \) is the accident susceptibility coefficient of the stadium; \( \rho \) is the density of the crowd in the stadium; the unit is \( \text{person} \cdot \text{m}^{-2} \); \( v \) is the average speed of the crowd moving in the stadium, the unit is \( \text{m} \cdot \text{s}^{-1} \); \( K \) is the correction coefficient of crowd gathering, and it is determined by factors such as age, gender, physiology, psychology, education level, safety awareness and safety behavior.

### 3.2.3. Place Index.

\[ A_{rc,S} = \omega \cdot R \cdot \left( 1 + \frac{E}{55} \right) \]

In the formula: \( \omega \) is the domino effect coefficient, which is determined by the degree of difficulty that may cause the accident chain; \( R \) is the inherent risk value of the stadium, determined according to the space characteristics of the stadium; \( E \) is the environmental risk value is the surrounding environmental risk value \( E_1 \), naturally The sum of environmental risk \( E_2 \), social environmental risk \( E_3 \), and political environmental risk \( E_4 \).

### 3.3. Accident risk offset index \( R_{oc} \)

According to statistics, from 2005 to 2011, there were 20 congested stampede accidents in stadiums around the world, including 329 deaths and 1079 injuries. These accidents cast a shadow on sports events. It is particularly important to evaluate the safety evacuation capabilities, emergency response capabilities, and event management levels of sports events. These three aspects have also become key factors for offsetting accident risks. which is

\[ R_{oc} = \left( 1 - k_v R_{oc,v} \right) \cdot \left( 1 - k_E R_{oc,E} \right) \cdot \left( 1 - k_M R_{oc,M} \right) \]

In the formula: \( R_{oc} \) is the accident risk offset index; \( R_{oc,v} \) is the evacuation index; \( R_{oc,E} \) is the emergency index; \( R_{oc,M} \) is the management index; \( k_v, k_E, k_M \) are risks Cancellation coefficient, and \( k_v = 0.01, k_E = 0.15, k_M = 0.35 \).
3.3.1. Evacuation index.

\[ R_{oc,V} = \rho \cdot T \cdot \left( L_{EV} + \frac{\phi \cdot C_{ev}}{100} \right) \] (11)

In the formula, \( L_{EV} \) is the relative distance for safe evacuation of the stadium, which does not meet and comply with the Code for Fire Protection of Building Design. The values are 0 and 1, respectively; \( T \) is the allowable time for safe evacuation of the stadium, the unit is min; \( C_{ev} \) is the value of the evacuation capacity of the stadium; \( \phi \) is the evacuation compensation coefficient. The value ranges from 0.20 to 0.25, and the default value is 0.20.

3.3.2. Emergency index.

\[ R_{oc,E} = n \left( 1 + \frac{C_{em}}{150} \right) \] (12)

In the formula, \( n \) is the number of emergency teams that can reach the scene of a sporting event within 10 minutes and has the processing capability; \( C_{em} \) is the actual value of the emergency capability assessment. There are emergency prevention, preparedness, response and recovery.

3.3.3. Management Index.

\[ R_{oc,M} = 1 + \frac{C_{m}}{200} \] (13)

\[ C_{m} = \sum_{i=1}^{20} C_{mi} \] (14)

In the formula: The management index \( R_{oc,M} \) is related to the safety management assessment score of the stadium. This assessment is mainly divided into 4 parts: stadium management, crowd management, monitoring management, and emergency management. There are 20 items in total, and each reference value ranges from 1 to 10; \( C_{m} \) is the total score of the safety management assessment of the stadium; \( C_{mi} \) is the actual score of the i-th of the 20 safety management assessments of the stadium.

3.3.4. Model parameter value range and grade division.

According to formulas (1) to (14) and the value range of each evaluation parameter, it can be concluded that the value range of the index index \( T_{ar} \) of the sports event safety accident risk model is 1 to 150. In the formula: The value range of the characteristic index \( \beta_{rp} \) is 1.2 ~ 2.0; fire index \( A_{rc,F} \) ranges from 6.25 to 44.00; aggregation index \( A_{rc,C} \) ranges from 0.12 to 28.00; location index \( A_{rc,S} \) The value ranges from 5.5 to 40.0; the evacuation index \( R_{oc,V} \) ranges from 0.5 to 8.0; the emergency index \( R_{oc,E} \) ranges from 1 to 6; The management index \( R_{oc,M} \) ranges from 1 to 2. Based on this, the sports event safety accident risk model index \( T_{ar} \) is divided into 6 levels according to the value, that is: 1 to 5 is the lightest; 5 to 10 It is lighter; 10 ~ 30 is medium; 30 ~ 60 is very large; 60 ~ 100 is very large; 100 ~ 150 is extreme.

4. Experimental results

According to the above formula and the scores of various indicators, due to space limitations, the specific indicator scores are omitted. The value of the risk index of Wuhan Gymnasium is shown in Table 1. The results indicate that the security level of the Wuhan Gymnasium at the 2019 World Military Games Taekwondo Stadium is relatively low.

| symbol | meaning | value |
|--------|---------|-------|
| \( \beta_{rp} \) | the event characteristic index | 1.63 |
| \( A_{rc} \) | the safety accident risk index | 35.025 |
| \( R_{oc} \) | the accident risk offset index. | 0.11 |
| \( T_{ar} \) | the safety accident risk model index for sports events | 6.38 |
5. Conclusion
The accident risk is divided into 6 levels, and the organizer can formulate corresponding preventive measures according to the risk level of the event. Applying a model to comprehensively evaluate the accident risk of the Wuhan Gymnasium, the venue of the Taekwondo project of the 2019 World Military Games, through the specific calculation of each parameter, it is concluded that the accident risk level is light, which is consistent with the official evaluation results, indicating that the model is feasible and reasonable.

According to the calculation results of Wuhan Gymnasium, it is found that personnel management has an important impact on the risk of safety accidents in the entire gymnasium. On the basis of the existing hardware facilities of the gymnasium, strengthening staff management can effectively avoid risks.

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References
[1] Guo Wei. (2009) Study on the safe evacuation of gymnasium personnel [D]. Xi'an University of Architecture and Technology.
[2] Rong Mingyan. (2004) Study on crowd gathering and evacuation risks in Olympic stadiums [D]. Nankai University.
[3] Su Ronghai. (2017) Safety accident risk assessment of sports events [J]. Beijing Normal University. 08:62-66.
[4] Dong Ruipeng. (2013) Activity accident risk management; theory and practice [M]. China Labor and Social Security Press. Beijing.
[5] Yu Zili. (2018) Fire field simulation and personnel evacuation of a cylindrical shell roof stadium [D]. Harbin Institute of Technology.