

# To Assess Liability Determination of School Badminton Injury Accidents: an Analysis Framework

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## Abstract

In recent years, public concern has intensified regarding the assessment of culpability in school sports-related badminton injuries. Although existing studies have examined liability principles from a legal standpoint, there is a notable lack of research exploring the evolution of culpability determination through the lens of "law and economics." To address this gap, we introduce the evolutionary game model, a pivotal theoretical tool in "law and economics," to investigate the factors influencing the strategic choices of involved parties and to identify the most applicable liability principle for injuries incurred during school athletic events. Our findings indicate a strong correlation between both the costs of accident compensation and prevention and the strategic selection of the responsible party. Furthermore, we demonstrate that while both proportional and strict liability principles can effectively determine fault in school sports injuries, they influence party behaviour differently. Specifically, the proportional liability principle may incentivize schools and students to exercise "appropriate caution" to mitigate the risk of sports-related injuries, in contrast to the strict liability principle.

**Keywords:** School Badminton, Injury Severity, Gender Differences, Age pattern, Prevention Measures.

## Introduction

This study aims to identify the frequency and types of injuries associated with playing competitive badminton. Despite being a non-contact sport, badminton requires players to leap, lunge, change directions rapidly, and move their arms swiftly to hit the shuttlecock from various postural positions. Consequently, the physically demanding nature of competitive badminton matches may lead to frequent limb injuries. While it has long been believed that badminton injuries are generally minor, there is insufficient empirical evidence to substantiate this claim. According to Izen, the most common acute and subacute injuries in badminton include tears, sprains, strains, bruises, cuts, and fractures of the shoulder and lower limbs. He also notes that elbow injuries are the most prevalent arm injuries, while persistent shoulder strain often results in chronic bursitis and tendonitis. Mills further identifies common injuries among badminton players, such as tennis elbow, heel bruises, lower back injuries, friction burns, and eye ailments (Armstrong & Van Mechelen, 2023). Recent investigations have reported cases of eye injuries among badminton players. Chandran found that two-thirds of all sports-related eye injuries in Malaysia were attributable to 63 ocular injuries sustained by badminton players over a five-year period, with inexperienced players being more susceptible. In Canada, 11 badminton-related eye injuries were documented during the 1976-1977 season, including two cases of legal blindness (Aresta et al., 2023). While previous reports on injuries to badminton players have

often relied on personal observation and experience rather than systematic data collection, this research aims to provide comprehensive information on the frequency and types of injuries that male and female badminton players are likely to experience.

Injuries sustained by students due to school-sponsored physical education programs, after-school sports training, other school-sponsored physical activities, and at school-owned or -operated athletic venues are commonly referred to as "school sports badminton injury accidents" (Dennie & Young, 2019; Giese et al., 2021). The personal safety and healthy development of children, as well as the development of physical education activities in schools, are closely linked to effective preventive measures against these incidents. Despite this, there has been a recent increase in school sports badminton injury accidents, leading to a rise in compensation disputes (involving medical costs, disability, and compensation fees) and subsequently, an increase in lawsuits concerning the determination of accident culpability (Hashemi et al., 2021; Hogan et al., 2021). Statistics indicate that of the 121 sports injury cases heard by Beijing courts at various levels, 68.6% involved claims for psychological compensation (Höner et al., 2023). Additionally, another study examining 203 cases found that schools were deemed 60% liable for injury incidents, with most responsibility determinations based on the theory of fault liability (Jerebine et al., 2022). As Wang (2016) illustrated, identifying injuries is a critical step in resolving physical education disputes, protecting physical education rights (including bodily and property rights), regulating school physical education conduct, and

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preventing the decline of physical education quality and students' fitness levels. In this context, schools have a legal obligation to provide relief to injured students, protect the school's legitimate interests and rights, and maintain order in physical education classes. Therefore, investigating the imputation of school sports badminton injury disputes is beneficial for fostering the healthy development of school sports while also protecting students' rights.

### **Risk Factors Associated with Badminton**

- The dynamic nature of the game should be emphasized. Due to the high-impact movements involved in badminton, such as leaps, lunges, rapid direction changes, and accelerations, there is an increased risk of injury.
- Emphasize the significant strain that the dynamic movements in badminton place on the musculoskeletal system, particularly on the lower extremities, including the ankles, knees, and hips. This strain can result in sprains, strains, and tears in the muscles, ligaments, and tendons.
- Repetitive Motions: Discuss how the persistent tension on specific muscle groups and joints caused by repetitive motions, such as lunges and overhead smashes, can lead to overuse injuries like tendinitis and bursitis.
- Shoulder Problems: Players who frequently execute overhead shots are more prone to shoulder issues, such as rotator cuff strains or impingement syndrome, due to the rapid arm movements required to strike the shuttlecock. The intense and repetitive nature of these movements' places significant stress on the shoulder joint and surrounding muscles, increasing the risk of these types of injuries.
- Potential Collisions: Implement precautions to prevent players from colliding during intense rallies or while attempting to reach the shuttlecock. Such incidents can lead to cuts, bruises, or fractures, especially in crowded or poorly organized playing areas.
- Discuss how the fast-paced nature of the game can induce fatigue and a decline in concentration, thereby increasing the likelihood of errors and subsequent injuries due to lapses in judgment or coordination.
- Environmental Elements: Improper maintenance or neglect of environmental elements, such as lighting, ventilation, and the condition of the playing surface, can lead to accidents and injuries.

### **Objective of the Study**

Rather than examining school sports injury incidents through the lens of legal economics and evolutionary game theory, this study approaches the imputation process from a novel perspective. Prior research has largely overlooked this aspect and has paid minimal attention to the consideration of maximizing the parties' interests—specifically, the challenge of

identifying a liability principle that facilitates a mutually beneficial outcome for all parties involved. This challenge is a significant difficulty in resolving such conflicts in court proceedings. In this context, the research presents a new perspective on fault determination in school sports injury incidents and introduces an innovative method for analysing the strategies employed by the parties involved. Specifically, we aimed to evaluate the effectiveness of legal principles, the strategic decisions made by parties in school sports injury cases, and the critical factors influencing their decision-making. Initially, we identified the factors affecting the strategic choice of culpability in school sports accidents. Subsequently, we employed an evolutionary game model to replicate the accident imputation process. Ultimately, we developed an analytical framework to simulate and compare the effectiveness of various relevant legal concepts in the context of school sports injury imputation.

### **Literature Review**

Numerous studies on the allocation of responsibility for incidents occurring during school physical education classes have been conducted since the 1980s. Current research frequently cites factors related to individuals, equipment, societal influences, administrative aspects, and the overall context as contributing to injuries sustained in school athletic events (Liu & Cao, 2023). Wang and Ren (2022) expanded this framework by including comprehensive management factors, societal elements, and external variables related to administration. Liu (2021) classified the parties responsible for injuries in school sports accidents into five categories: the school, the students, third parties, multiple parties, and force majeure. Recent analysis of 58 court precedents involving school sports badminton injuries revealed that liability and compensation assigned to schools were typically higher than those attributed to other responsible parties (Liu et al., 2023). In China, the legal framework for addressing school sports badminton injury accidents involves civil liability guidelines, as outlined in (Pangrazi & Beighle, 2019), administrative liability regulations under the Measures for the Safe Handling of Student Accidents (SSHA), and criminal liability principles based on (Siedentop, Hastie, & Van der Mars, 2011), all derived from the general principles of the Civil Law of the People's Republic of China. However, as Balsalobre-Fernández and Torres-Ronda (2021) noted, the legislative foundation is insufficiently developed, and the legal approach to handling school sports safety incidents remains inadequate.

Determining the appropriate basis for legal findings in sports injury cases is crucial. In Chinese law, the primary principles for attributing liability in school sports injuries include fault liability, fair liability, no-fault liability, and multiple liabilities. Fault liability posits that liability is determined based on fault; that is, responsibility is assigned when negligence is present,

and no liability arises in the absence of fault. According to the principle of fault presumption, the injured party must provide evidence to counter any presumption of negligence in order to avoid tort liability (Su, 2021). When neither party is at fault, responsibility is allocated according to the fair liability principle, which emphasizes reasonableness and fairness. The no-fault liability principle holds that legal obligations are imposed regardless of fault. The concept of multiple liabilities entails applying general liability rules based on the circumstances of the tort and reinforcing additional liability principles as needed. Han (2009) suggests that for school sports injuries, both the fair responsibility and fault liability principles should be considered. In cases involving specific statutory violations, the no-fault principle and fault assumption can be applied (Waldén et al., 2023). This view is widely supported among scholars. For instance, Yu and Chen (2002) utilized case studies to show that fault liability and fair liability principles should be used to determine culpability in student PE injury incidents. Li (2012) concurred, emphasizing that fault liability should be the primary principle due to the mental capacity required of students to adapt to sports injuries. Additionally, Tan, Xiang and Jiang (2011) developed a fault liability-oriented liability system, incorporating the risk-taking principle, to address the unique characteristics of school sports. From a legal perspective, Wang (2016) criticized the dualistic imputation principle—centring on fault liability and equitable loss distribution—for hindering comprehensive improvement in collegiate athletics. Most of the aforementioned research has concentrated on legal strategies for resolving imputation disputes, aiming to align these matters with legal standards and achieve the fair value objectives of the law. However, there has been limited exploration into the assessment of interests in judicial settlements of sports injury disputes. Existing studies predominantly address theoretical issues, such as safeguarding participants' rights and interests, and the practical and legal foundations for resolving disputes arising from such incidents.

School sports badminton injury incidents, which fall under tort liability, may result in liability being assigned in either direction. This implies that if a school prioritizes student safety above all else, it may face greater financial losses and increased liabilities. Conversely, if the school's focus shifts to minimizing institutional harm, the interests of the students may be compromised. To address the infringement issues associated with school sports badminton injury incidents effectively, it is crucial to balance the interests of the school, the students, and their guardians (Mill, 2016). In this context, the imputation process can be conceptualized as a strategic game involving the school, the injured students, their guardians, and the liability for the accident. The school, as the primary party at fault, aims to minimize its liability. If the legal

framework holds schools responsible for sports injuries, this will incentivize them to invest more in sports facilities and enforce stricter safety policies. Conversely, injured students and their families often seek higher compensation, which may lead to actions such as public demonstrations or media campaigns to protect their interests. This creates a continuous cycle of negotiation and adjustment. The school may either increase compensation, negotiate settlements with the parents, or pursue legal action to defend its interests. Public opinion on the school's new measures will subsequently be assessed. Therefore, evolutionary game theory is particularly relevant for analysing the decision-making processes of both schools and parents, as it encapsulates the iterative nature of strategy selection and adaptation.

## Research Methodology Research Design

This study explores the evolution of liability imputation in school sports badminton injury cases through the framework of an evolutionary game theory informed by law and economics, contrasting with previous research that has predominantly focused on legal perspectives. Prior studies have largely overlooked this dimension and have given minimal attention to the value considerations of maximizing the interests of all parties involved—specifically, the challenge of identifying a liability principle that could facilitate a mutually beneficial resolution. This gap highlights the complexity of resolving such conflicts within actual court proceedings.

Within this framework, the research provides a novel perspective on fault determination in school sports badminton injury incidents and introduces a new approach for analysing the strategies employed by the involved parties. Specifically, the study aimed to evaluate the effectiveness of applying legal concepts, assess the strategic choices made by the parties in these incidents, and identify the key factors influencing their decision-making. Initially, the research examined the elements influencing the strategic determination of culpability in school sports accidents. Subsequently, the accident imputation process was modelled using an evolutionary game framework. This approach allowed for the development of an analytical system capable of simulating and comparing the effectiveness of various legal concepts in the context of school sports injury imputation.

The study employed a longitudinal, retrospective cohort design to investigate badminton injuries occurring over the course of a year. The expanding body of research on this topic supports the use of game models—mathematical tools—to quantitatively analyse the imputation process of campus safety incidents. In practice, the division of responsibilities in school sports accidents resembles a strategic game involving the school, students, and their guardians.

Stakeholders often prioritize short-term benefits, potentially at the expense of broader considerations. Effective long-term campus safety initiatives require collaborative efforts. Both the school and the students are expected to adopt an "appropriate caution" approach in response to accidents. The school's strategy for mitigating liability in safety incidents is dynamic and evolves over time. Consequently, stability cannot be achieved through a single adjustment; rather, incremental changes are necessary to reach an equilibrium. Thus, this study advocates for the use of the evolutionary game model to explore the imputation process in campus safety incidents. Evolving from classical game theory, evolutionary game theory primarily aims to elucidate how individuals or groups learn from and replicate each other's strategies in competitive settings, as well as how they develop their own strategic interests. According to the assumption of bounded rationality, a player or group cannot achieve game equilibrium with a single strategic choice. Rather, equilibrium is attained through a process of continuous interaction, where players gradually adapt and adopt strategies based on the behaviours of others, ultimately leading to a steady-state outcome for the system.

#### **Analysis Framework**

The issue of liability in school sports badminton injuries involves the school, the injured student, and their guardians. Given that the school is predominantly responsible for these incidents, it inherently seeks to refute any evidence that could lead to compensation or even avoid compensation. Conversely, students and their parents, facing potential financial loss from such injuries, may employ aggressive tactics such as pressuring schools or seeking media attention to maximize their compensation claims. In practice, this dynamic often results in an ongoing negotiation over accident liability, where both parties continuously adjust and refine their strategies in response to evolving circumstances, aiming to achieve a dynamic equilibrium. The resultant pattern of interactions over time dictates the attribution of liability in sports injury cases. For instance, if a court rules that the school must cover all expenses, schools may feel compelled to curtail extracurricular sports activities due to the high costs of compensation. This restriction negatively impacts physical education programs and may lead to decreased attention to safety among students, who might otherwise seek personalized compensation. In conclusion, evolutionary game theory offers a robust framework for analysing the internal processes of ascribing liability in sports injury cases. Its application to examine the strategic decision-making, dynamic evolution pathways, and influencing factors of the liability attribution process holds both theoretical and practical significance.

#### **Sample Size**

The study identified a total of 150 reported badminton injuries over the span of one year. Additionally, the

analysis incorporated data from 17,700 injuries involving a cohort of 130,320 individuals.

## **Research Method**

### **A Model for Evolutionary Games**

Given the high frequency of school sports badminton injuries, it is logical to assign financial responsibility to schools to promote the positive development of physical education programs. In the context of evolutionary game theory, both parties involved in school injury incidents are considered bounded rational players. They evaluate the benefits and drawbacks of various strategies and ultimately adopt one based on comparative analysis. Since the optimal strategy is not immediately apparent, participants in the system achieve an equilibrium by emulating the behaviours of more experienced individuals.

#### **The Limitedly Rational Game Participants**

In the hypothetical scenario concerning school sports injuries, the game model of responsibility involves two key parties: the school and the students or their guardians. In cases of badminton-related injuries, the school bears the primary responsibility for compensating the injured parties in accordance with relevant legal frameworks. Furthermore, the school must protect its own legitimate interests and rights while ensuring the effective implementation of physical education programs. Conversely, the students and their guardians, as the primary victims, also have specific legal responsibilities, which include seeking compensation, safeguarding their rights and interests, and participating in athletic activities.

#### **The Effectiveness Ratio**

In cases of ascribed culpability for school sports badminton injuries, the central concept is that, under the law, both parties seek to maximize their interests by making informed decisions based on significant influencing factors.

- (1) The cost of prevention is a critical factor in analysing sports injury occurrences. Adequate funding for preventive measures can significantly reduce both the incidence of sports injuries and the associated legal disputes. The primary components of this budget include expenses for educating students about safety protocols, inspecting and maintaining school sports facilities, training sports instructors, and monitoring students' physical health.
- (2) Cost of Compensation: The distribution of responsibility in sports injury incidents is a pivotal factor influencing both parties' adjustments to their strategies. The overall cost of compensation for school sports badminton injuries comprises two main elements: the losses incurred by the accident, including students' personal and property damages, and the costs associated with



managing the incident, such as litigation expenses, court operational costs, and the time and effort required for dispute resolution.

### Approach to the Game

In the absence of specific, well-defined, and effective legal rules, courts often utilize the concept of fault-based liability to determine legal responsibility for injuries sustained in school sports. This approach involves assigning compensation based on fault, even when fault is not explicitly established (Li, 2012). However, in most cases, schools would face greater liability for sports injuries if the imputation process considered the fair value of the legislation. If the legal allocation of responsibility is deemed unsatisfactory by the school, it may adopt more cautious measures to prevent accidents, such as reducing the scope of school sports, making activities simpler, or even banning them altogether. While these precautionary measures aim to mitigate risks, they may also reduce students' enjoyment of sports and impede the development of physical education programs. This paper hypothesizes that both parties involved—the school and the injured students or their guardians—will choose between adopting adequate caution or less stringent measures in their approach to school athletics.

### Functional Set

The probability that the school will opt for the "appropriate caution" strategy is denoted by  $\alpha$ , while the probability of choosing a "no caution" strategy is  $1-\alpha$ . Similarly, the likelihood that students and their guardians will select the "appropriate caution" strategy is represented by  $\beta$ , with the probability of not adopting any strategy being  $1-\beta$ . The "appropriate caution" strategy refers to the expenditures incurred by schools to minimize sports-related injuries. These expenses encompass student safety education programs, the cost of inspecting and maintaining athletic facilities, the cost of training physical education instructors, and the cost of monitoring students' physical fitness levels. The cost of prevention when students employ the "appropriate caution" strategy ( $cs < cc$ ) is denoted as  $O_s$ . In contrast, the prevention costs associated with the "no caution" strategy are considered negligible and are therefore set to zero. For the purposes of this analysis, we assume that the likelihood of sports injuries is minimal (effectively zero) when both parties implement the "appropriate caution" strategy. Conversely, sports injuries are expected to occur if neither party adopts a cautious approach. Consequently, in the absence of caution, the school bears both the loss costs (associated with student injuries and property damage) and the execution costs (related to the time and financial resources spent on resolving compensation claims and other administrative expenses). Additionally,  $ap$  represents the total loss incurred from the accident, and  $a$  denotes the proportion of compensation responsibility ( $0 \leq a \leq 1$ ) that the school is expected to cover. The fraction of expenses for preventing risky behaviours by students and their

guardians when adopting the "appropriate caution" strategy is represented by  $b$  ( $0 \leq b \leq 1$ ).

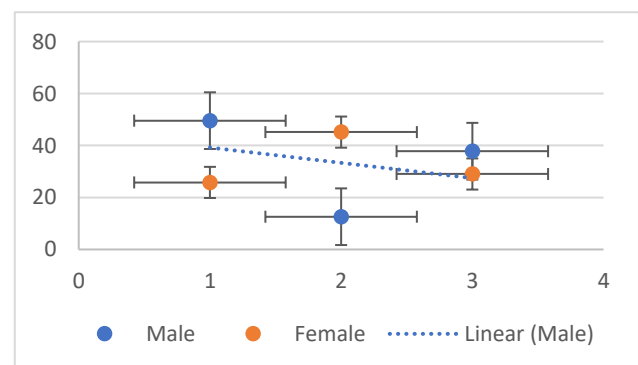
### Data Analysis

In a reliable study, injury severity is depicted through an accident-related chart, measured by the viscoelastic aggregate injury (VSI) for both male and female victims. Injuries are classified into three categories based on severity: light, medium, and severe, using the Abbreviated Injury Scale (AIS). Statistical analysis reveals notable differences in injury severity between genders. For males, minor injuries constitute the majority (49.57%), followed by moderate (37.81%) and severe injuries (12.60%). In contrast, females exhibit a different distribution of injury severity. A higher percentage of female injuries are classified as moderate (45.16%), with severe injuries accounting for 29.03% and minor injuries comprising 25.80%. These gender-based disparities in injury types and severities suggest possible variations in injury patterns between males and females. For instance, a higher percentage of head and neck injuries is observed, and females tend to sustain more minor injuries compared to males. Such differences may be attributed to various factors, including disparities in body size, susceptibility to specific injuries, interaction dynamics, and varying roles and activities. To address these disparities, comprehensive examinations of male and female populations are necessary to gather data on the mechanisms contributing to gender differences in severe injuries. Additionally, preventive and intervention strategies should be tailored to the specific needs of each affected demographic to effectively address these disparities.

**Table 1**

*Injury Severity Distribution*

AIS	Male	Female
Minor	49.57	25.80
Moderate	12.60	45.16
Severe	37.81	29.03

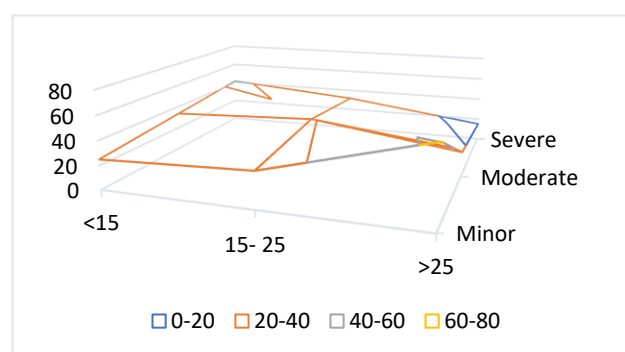


**Figure 1:** Graphical Representation on Percentage of Injury Severity Distribution.

**Table 2**

*Age based Severity Distribution*

AIS	AGE		
	<15	15- 25	>25
Minor	25	29.82	63.63
Moderate	33.33	38.59	21.21
Severe	41.66	31.57	15.15



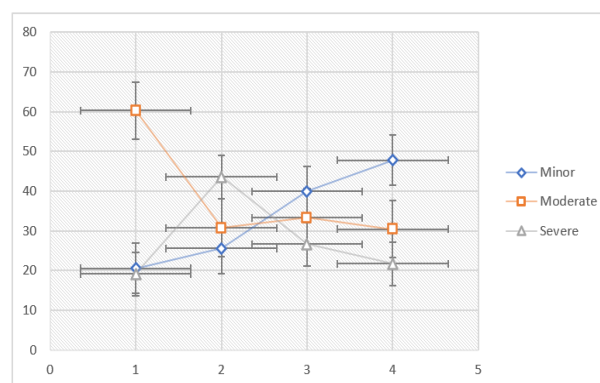
**Figure 2:** Graphical Representation on Percentage of Age based Severity Distribution.

The data presented illustrates the distribution of injury severity across different age groups using the AIS. According to the AIS, injuries are categorized as minor, moderate, or severe based on their severity. The findings reveal distinct patterns of injury severity among different age groups. For individuals under 15 years old, severe injuries are most common (41.66%), followed by moderate injuries (33.33%) and minor injuries (25%). In contrast, the 15-25 age group exhibits a different distribution: moderate injuries are more prevalent (38.59%), followed by severe injuries (31.57%) and minor injuries (29.82%). Among individuals over 25 years old, minor injuries dominate (63.63%), with moderate injuries accounting for approximately 21.21% and severe injuries about 15.15%. These observations suggest that age-related variations in injury severity can be quite complex, with younger individuals often sustaining more severe injuries compared to older individuals. This pattern may be attributed to differences in risk exposure, physical strength, and activity levels across age groups. To develop effective prevention and treatment strategies tailored to different age groups, it is important to understand the patterns of injury severity associated with aging and to address the specific risks and needs of each age category.

**Table 3**

*Setting Based Injury Severity*

AIS	CLUB	COMPANY	SCHOOL	OTHERS
Minor	20.54	25.64	40	47.82
Moderate	60.27	30.76	33.33	30.43
Severe	19.17	43.58	26.66	21.73



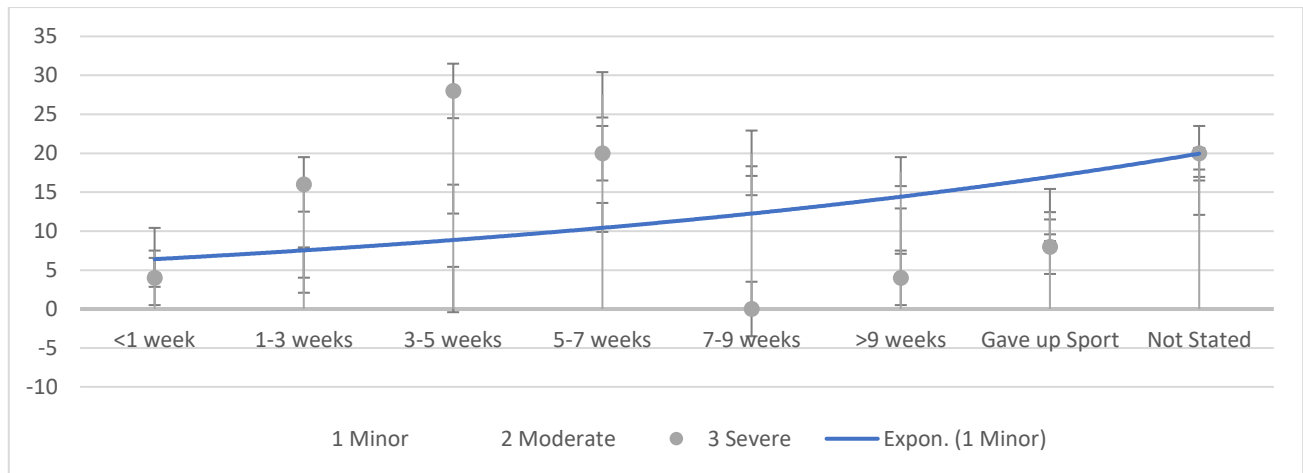
**Figure 3:** Graphical Representation on Percentage of Setting Based Injury Severity.

The data presented outlines the distribution of injury severity across various contexts, including clubs, workplaces, schools, and other settings, as classified by the AIS, which categorizes injuries as minor, moderate, or severe. The findings indicate notable variations in injury severity across these environments. In club environments, injuries are predominantly classified as moderate (60.27%), with minor injuries accounting for 20.54% and severe injuries making up 19.17%. Conversely, in workplace settings, the pattern is distinct, with a higher proportion of severe injuries (43.58%), followed by moderate (30.76%) and minor injuries (25.64%). School-related injuries exhibit a similar trend to clubs, with minor injuries at 40%, moderate at 33.33%, and severe at 26.66%. The "others" category, which likely includes diverse or less-defined contexts, shows a more balanced distribution of injury severity, with minor injuries constituting 47.82%, moderate injuries 30.43%, and severe injuries 21.73%. These findings suggest that the type and severity of injuries vary significantly depending on the environment, influenced by differing activities, risk factors, and environmental conditions. Understanding these differences is crucial for developing targeted injury prevention strategies tailored to specific settings, thereby enhancing safety and reducing the risk of accidents.

**Table 4**

*Sport Absence Severity*

Absence	AIS		
	1 Minor	2 Moderate	3 Severe
<1 Week	4.705	7.5	4
1-3 Weeks	5.88	5	16
3-5 Weeks	14.11	2.5	28
5-7 Weeks	11.76	27.5	20
7-9 Weeks	16.47	20	0
>9 Weeks	17.64	10	4
Gave Up Sport	10.58	12.5	8
Not Stated	18.82	15	20



**Figure 4:** Graphical Representation on Percentage of Sport Absence Severity.

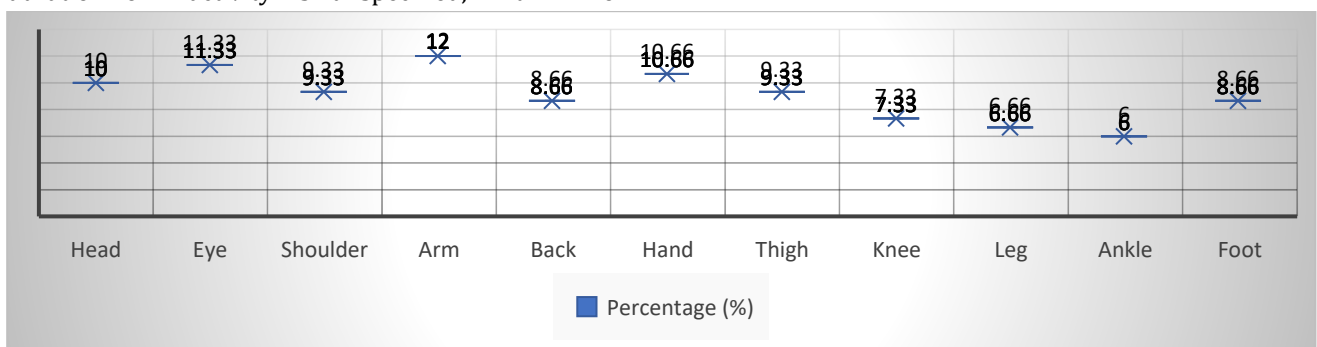
The global data on injury severity, as classified by the AIS, highlights variations in injury outcomes over different periods of inactivity. Injuries are categorized as mild, moderate, or severe, and the data reveal that the duration of discontinuation from sports significantly impacts injury severity. For individuals who have ceased sports practice for more than a week, over 7.5% of injuries are classified as moderate, whereas those who stopped within 1 to 7 days have approximately 4.7% classified as minor and about 4% as severe. Conversely, for individuals who have been inactive for 7-9 weeks, the distribution of injury severity shows a predominance of minor (16.47%) and moderate injuries (20%), with no recent severe injuries reported. Additionally, data on the extent of incapacitation due to injuries indicates that a notable proportion of individuals (12.5%) were classified with moderate injuries, and an even greater proportion (8%) had severe injuries, which significantly hindered their ability to resume sports activities. The analysis also reveals some variation in injury severity when the duration of inactivity is unspecified, with minor

injuries accounting for 20% of the total. These findings underscore the importance of considering both the length of inactivity and the severity of injuries, as these factors can lead to a progressive decline in outcomes and affect individuals' engagement in sports.

**Table 5**

*Body Part Distribution*

Body Part	Frequency	Percentage (%)
Head	15	10
Eye	17	11.33
Shoulder	14	9.33
Arm	18	12
Back	13	8.66
Hand	16	10.66
Thigh	14	9.33
Knee	11	7.33
Leg	10	6.66
Ankle	9	6
Foot	13	8.66



**Figure 5:** Graphical Representation on Percentage of Body Part Distribution.

The data presented illustrates the distribution and frequency of injuries across different body areas. The arm emerges as the most frequently injured body part, accounting for 12% of all reported injuries with a total of 18 cases. It is followed closely by the hand and eye, which represent approximately 11% and 10.66% of the total injuries, with 17 and 16 cases, respectively. Other commonly injured areas include the head (15 cases,

10%), shoulder (14 cases, 9.33%), and back (13 cases, 8.66%). Conversely, the foot and ankle are less frequently affected, with 13 instances (8.66%) and 9 cases (6%), respectively. These findings provide valuable insights into the distribution of injuries among various body regions, indicating areas of heightened risk and potential focus for injury prevention strategies. The high incidence of injuries to the hand,

eye, and arm suggests a need for targeted protective measures or training interventions to mitigate risks. Additionally, understanding the frequency of injuries in specific body areas can aid in prioritizing rehabilitation efforts and optimizing resource allocation to address the needs of affected individuals effectively.

### **Analysing an Evolutionary Game System via Numerical Simulation**

Under the Tort Liability Law of the People's Republic of China (Liu et al., 2015), the principles for determining liability in school sports badminton injury accidents are primarily guided by Article 38 and Article 39. Article 38 stipulates that if a school fails to demonstrate it was not at fault for a sports injury, it will be held to strict tort liability. Article 39 outlines three potential scenarios for liability. First, if the school is found to be at fault, it will bear full responsibility, excluding the students or their guardians. Second, if the school is not at fault but the students or their guardians are deemed negligent, the financial responsibility will fall on them. Third, if both the school and the students or guardians are at fault, each party will be held liable in proportion to their respective degree of fault. To analyse the strategic decision-making of the involved parties under these scenarios, MATLAB R2012a (MathWorks, Inc., Natick, MA, USA) is employed. This modelling helps to clarify the game-theoretic dynamics of school sports badminton injury incidents, and the decision-making processes of the parties involved.

The system parameters are defined as follows:  $a \in [0,1]$ ,  $k=5$ ,  $cc=10$ ,  $cy=6$ ), reflecting the game scenario and legal context. The initial evolutionary strategy ratio for both players is set at (0.5, 0.5). The resulting evolutionary outcome indicates that when the costs associated with preventing accidents in schools, among students, and their guardians are high, both parties will ultimately gravitate toward the evolutionary stable strategy of not exercising caution, as these costs escalate. The parameters are defined as follows:  $a \in [0,1]$ ,  $k=12$ ,  $cc=8$ , and  $cy=10$ . The initial evolutionary strategy probabilities for both parties are set at (0.5, 0.5). Regardless of the legal principle applied to determine accident liability, all participants in the game will ultimately converge on the evolutionary stable strategy when the proportion of prevention costs borne by students and their guardians is significantly high (b). In order to establish the model's relevant parameters, we used the following values:  $a \in [0,1]$ ,  $k=12$ ,  $cc=8$ , and  $cy=4$ . When the financial impact of an accident is considerable, the court will apply the strict liability principle to determine fault. Consequently, the optimal strategy for all parties involved will eventually converge on the evolutionary stable state of (appropriate caution, appropriate caution). Conversely, if the court were to employ the proportionate liability principle in determining fault, the optimal strategy for each party would shift towards the evolutionary stable state of (no caution, appropriate caution) over time.

We specified the following values for the model parameters:  $a \in [0,1]$ ,  $kc=16$ ,  $cy=4$ ,  $k=12$ . The evolutionary results indicate that as students' net benefits from the "appropriate caution" strategy increase over time, the optimal strategy for both parties will eventually converge to the evolutionary stable state of (no caution, appropriate caution), irrespective of the liability principle applied by the court in determining accident responsibility. The model parameters are also specified as follows:  $a \in [0.5,1]$ ,  $\mu=1/100$ ,  $k=1000$ ,  $cc=400$ , and  $cy=1000$ . Regardless of the liability principle employed by the court to determine fault, the optimal strategy for both parties will ultimately converge to the evolutionary stable state of (appropriate caution, no caution) as the school's benefits from implementing the "appropriate caution" strategy increase over time. Both game agents' strategic decisions are significantly impacted by the parameters  $cc$ ,  $cy$ ,  $a$ ,  $b$ , and  $k$ , as seen in the model study that was described before. Here, we will investigate the behavioural patterns of the two parties involved in school sports injury incidents through the application of different responsibility concepts.

### **Analysing Imputation Badminton Regarding the Strict Liability Rule**

According to the Tort Liability Law of the People's Republic of China, under the strict liability principle, the school is held fully accountable for injuries incurred during school sports activities. In particular, when both students and their guardians opt for the "appropriate caution" approach, the school can earn  $-cc$  and  $-k-cy$  from the "appropriate caution" and "no caution" strategies, respectively. Here,  $-cc$  represents the expense of the school in preventing injury accidents, and  $-k-cy$  is the total loss plus the cost of the student's prevention efforts. Furthermore, when both students and their guardians choose the "no caution" approach, the net profit for the school when using the "appropriate caution" strategy is  $-cc-k$  and when using the "no caution" strategy is  $-kc-k$ . Here,  $cc-k$  represents the total loss from the accident, and  $cc-k$  is the sum of the total loss from the accident plus the school's prevention costs.

Under the strict liability rule, the school is unequivocally responsible for any injuries that occur during school sports activities, while neither students nor their guardians would be held liable for such incidents. Within this legal framework, students and their guardians often favour the "no caution" approach to mitigate accident-related costs. Despite the implementation of the "appropriate caution" strategy, the school remains responsible for covering the costs associated with campus injuries. As a result, it is probable that the school will adopt the "no caution" approach as the most advantageous strategy under this principle. Consequently, there is limited financial incentive for the school to adequately support measures aimed at reducing sports-related injuries.

Figure 2 illustrates the results of a simulation study



confirming this trend. Specifically, when the school's preventive costs exceed the costs associated with accidents under the strict liability rule, the strategy choices of both parties converge to the evolutionary stable state of (no caution, no caution). For example, in one elementary school, a football game during recess led to a student sustaining tibia and rib fractures, resulting in the school paying 57,000 yuan in damages and terminating the teacher involved. In another case, a student suffered a broken arm due to inadequate warming up and a slippery surface, leading to a compensation of 30,000 yuan and the dismissal of the coach. Although these incidents are not extreme examples of school sports injuries, the financial impact could be substantial in the case of more severe accidents. From a game theory perspective, the strategy pair (no caution, no caution) appears to be the optimal choice for both parties. Despite potential preventive costs, schools are likely to implement appropriate caution measures to mitigate accident risks due to the unpredictability of injury-related losses. The school's strategic decisions may shift in response to significant accident costs, leading to a preference for cautious approaches mandated by the strict liability rule. This aligns with findings indicating that the school will adopt appropriate caution strategies as net revenue increases. Furthermore, while students may not always act purely rationally, they may still consider the ethical implications of the strict liability rule, such as the potential for severe injuries or long-term disabilities.

## Discussion

This study investigates the efficacy of two imputation principles in analysing school sports badminton injury incidents through the lens of an evolutionary game model. It further elucidates the progression of imputation in these cases. The results reveal that a critical factor in the imputation process of school sports badminton injuries is the cost associated with accident compensation and the preventive measures undertaken by both parties involved. Under the proportionate responsibility rule, both schools and students are more inclined to adopt "suitable care" and "appropriate caution" strategies to mitigate the occurrence of sports injuries, as this rule more effectively regulates their behaviours. As rational economic agents, both schools and students make strategic decisions based on a scientific assessment of their potential benefits and losses related to accident liability (Preatoni et al., 2022). This article indicates that, in the context of preventing injuries in school sports, both students and schools frequently adopt the "appropriate caution" strategy in line with the proportionate responsibility concept. The proportionate liability rule, which operates on the principle of "fault incurs liability, no-fault incurs no liability" (Wang & Ren, 2022), limits the school's responsibility rather than making it absolute. This

approach facilitates achieving accountability remedies post-accident and encourages both parties to mitigate the risk of such incidents by assigning responsibility proportionate to the actual liability. This aligns with the study's findings, which support the principle of fault liability as fundamental (Li, 2012; Waldén et al., 2023; Yu & Chen, 2002; Yu, 2018). This principle is also evidenced in various court cases. For instance, a study revealed that the theory of fault responsibility is applied in 84.3% of school sports badminton injury cases (Kraljić, Šepić, & Drnovšek, 2020). In one case, sixth-grade PE students at a local elementary school experienced a collision during an 800-meter race, resulting in a fall injury. The court, finding both parties negligent, allocated 70% of the responsibility to the school and 30% to the students based on the proportionate liability principle (Smith, 2002). In another case, a student suffered a fatal heart attack during turf hockey practice. The court determined that both the school, for failing to provide necessary protective gear, and the student, for not inspecting their gear, were equally responsible, with each party assigned 50% of the blame (Mill, 2016). The study further demonstrates that the potential costs of responsibility and prevention significantly influence the strategic choices of the parties involved throughout the imputation process.

In the context of school property, the strict liability rule mandates that schools cover medical expenses and related costs incurred due to injuries. Under this principle, courts often determine that schools, as the "strong" party, have superior knowledge regarding the nature of sports and the operational aspects of sports facilities, thereby entrusting them with the responsibility to safeguard students during athletic activities (Liu, 2018). Consequently, this principle serves as an effective mechanism for regulating school behaviour concerning sports injuries and mitigating the occurrence of such incidents. Significant factors influencing this outcome include the potential for substantial financial liability due to sports-related injuries, governmental oversight of school administration, and the broader public perception of the institution (Liu, 2018). To mitigate legal risks associated with injuries, schools may opt to reduce or eliminate extracurricular sports activities rather than implementing preventive measures. This approach is inconsistent with the current educational policies endorsed by the Chinese government and fails to support the holistic and healthy development of students.

## Conclusion

Recent discussions have highlighted a growing interest in the study of injury imputation in school sports. However, there is a noticeable gap in research that examines this issue from a "law-economic" perspective, with most existing studies concentrating

primarily on the legal aspects of fault determination in school sports injuries. This study aims to bridge this gap by applying evolutionary game theory to the problem of injury imputation in school sports incidents. The principal findings of this research are as follows:

- (1) Irrespective of the attribution theory applied to determine liability, the game system will tend to reach the evolutionarily stable state of (no caution, no caution) when the cost of accident prevention is high for schools, students, and their guardians. Conversely, as the cost of accident prevention at school decreases and the net benefit of the school's "appropriate caution" strategy increases, the game system will evolve towards the stability state of (appropriate caution, no caution). Additionally, when the cost of preventing sports accidents for students and their guardians diminishes, leading to an increased net benefit from the "appropriate caution" strategy, the system will stabilize at (no caution, appropriate caution). Finally, as the frequency of accident losses rises and both parties can progressively enhance their positive outcomes through cautious behaviour, the game system will converge to the evolutionary stable state of (appropriate caution, appropriate caution).
- (2) Both the proportional liability rule and the strict liability rule have the potential to encourage stakeholders to adopt "appropriate caution" to mitigate the risk of sports injuries. However, the proportional liability rule emphasizes the fair application of the law, whereas the strict liability rule focuses on social efficiency. Our research suggests that judicial practice should balance considerations of efficiency and fairness. For example, when a court enforces the strict liability

rule in a particular case, the school's liability may be increased. This may prompt the school to adopt preventive measures, which could inadvertently result in reduced sports activities or less challenging physical engagement. While these measures may not benefit school athletics, they could decrease the financial and time costs associated with determining causation and lessen the evidentiary burden on the less powerful parties, thereby reducing disputes over liability. Conversely, when the court applies the proportional liability criterion, significant costs may be incurred in gathering evidence and determining fault. Although this approach may not achieve optimal social efficiency, it may increase the overall societal cost of accidents.

Evolutionary game theory provides a novel analytical framework for examining the strategic behaviour of individuals involved in school sports injury incidents and offers a new perspective on liability assignment in these cases. The distinctive nature of school physical education underscores the need for a multifaceted approach to determining culpability in such incidents. Our research suggests that, within Chinese judicial practice, fair responsibility should complement fault liability in assigning culpability for school sports injuries. However, the study has limitations. It assumes participants are rational economic agents, but in reality, their decisions are influenced by social context and personal values, making their legal attribution behaviour only partially rational. Thus, game theory may have limited applicability. Further research is needed to refine the model, integrate moral considerations, and address the complexities introduced by third parties, such as students, facility contractors, and insurance companies.

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