

Injury patterns in collegiate demonstration taekwondo athletes using association rules

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- A Study Design
- B Data Collection
- C Statistical Analysis
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Dictionary:

Demonstration

taekwondo: A form of taekwondo focused on performance, emphasizing dynamic and artistic techniques.

Association rule: a data analysis method used to identify meaningful relationships between variables.

Injury pattern: common types and trends of injuries observed within a specific group.

Python: dynamic programming language (in Excel integrates Python's data analysis and visualization capabilities directly into Excel, allowing you to write Python code in cells to process Excel data

Technique – *noun* a way of performing an action [45].

Innovative agonology (INNOAGON) – is an applied science dedicated to promotion, prevention, and therapy related to all dimensions of health and the optimization of activities that increase the ability to survive (from micro to macro scales) [20-22].

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Abstract:

Background and Study Aim: Lower extremity injuries are common among collegiate demonstration athletes, but there is limited research on their specific patterns. The cognitive goal of this research is knowledge about this category of injuries. The application goal is to provide recommendations on the prevention of this category of injuries and thus increase the personal safety of athletes.

Material and Methods: A cohort of 231 taekwondo athletes was surveyed using a questionnaire designed by experts to gather information on injury occurrence, frequency, context, and treatment methods. Data analysis was conducted through frequency analysis and the apriori algorithm, a method of association rule mining, utilizing Excel 2019 and Python.

Results: The most frequently injured sites were the ankle, toes, and knee, with ankle injuries exhibiting a notably high recurrence rate. The most prevalent injury pattern identified was *during a demonstration* → *airborne movements, vertical/horizontal rotations, obstacle techniques* → *ankle* → *surgical intervention*. The subsequent patterns included *during a demonstration* → *airborne movements, vertical/horizontal rotations, obstacle techniques* → *knee* → *immobilization (cast)* and *during a demonstration* → *airborne movements, vertical/horizontal rotations, obstacle landing* → *knee* → *physiotherapy*.

Conclusions: These results underscore that the airborne and rotational maneuvers characteristic of demonstration taekwondo are significant contributors to ankle and knee injuries. Such injuries often necessitate extensive medical interventions, highlighting the critical need for preventive strategies. A complementary approach, as a fundamental method used in the exploration (research and education) of innovative agonology, opens the prospect of improving interventions, both diagnostic and directly related to psychomotor activity in the preparatory process and the public presentation of taekwondo motor perfection. Therefore, a key element of preventive strategies is to resist the temptation to achieve unique visual and marketing effects at the expense of health risks.

Keywords: complementary approach, innovative agonology, physical therapy, rotational movements

1. Introduction

There are different perspectives on the answer to the question: *what does an injury mean to an athlete?* However, there is no disagreement that sports injuries are a major factor that negatively affects athletes' performance [1]. Injuries are not merely physical damage but also contribute to decreased athletic performance and psychological stress. In severe cases, injuries can even jeopardize an athlete's career sustainability [2]. Therefore, minimizing injuries is essential for enhancing athletic performance.

Significant efforts have been made by institutions and academia to prevent sports injuries. For instance, the International Olympic Committee (IOC) and the Fédération Internationale de Football Association (FIFA) have implemented various initiatives to prevent and manage sports injuries [3]. In academia, studies have been conducted to investigate the causes of injuries through surveys and propose preventive measures. The authors of previous research emphasize the necessity of proactively analyzing injury types, injury-prone areas, and post-injury treatment strategies to prevent sports injuries [5]. Since sports injuries arise from complex factors, providing a definitive explanation is challenging. However, identifying the causes and mechanisms of injuries in advance can serve as valuable information for injury prevention.

Taekwondo is categorized into *kyorugi* (sparring), *poomsae* (forms), and demonstration events. Among these, demonstration taekwondo requires athletes to perform complex and visually striking techniques to earn higher scores. As a result, demonstration team members frequently attempt high-difficulty techniques [6]. While these advanced skills contribute to the development of the discipline, concerns about injury risks among athletes are increasing. According to a study by Cheon and Park [7], approximately 85% of demonstration taekwondo athletes reported experiencing a sports injury within the past year, highlighting the severity of injury risk in this category.

Authors of previous studies on injuries in demonstration taekwondo analyzed the prevalence of chronic sports injuries [8], have examined injury-related factors [9], explored injury-inducing mechanisms [10]. These studies provide valuable insights for injury prevention strategies among demonstration taekwondo athletes.

However, existing research primarily focuses on identifying injury-related factors, injury frequency, and general injury trends. There remains a gap in understanding the precise mechanisms through which injuries occur during demonstrations. For instance, prior studies often report only the injury rate associated with a specific technique (e.g., a high injury incidence during technique A), limiting their applicability. Given the unique nature of demonstration events, a more comprehensive analysis is required – one that examines not just injury frequency but also the sequence of injury occurrence, contributing factors, affected areas, and subsequent treatments. To address this limitation, association rule mining can be applied as an analytical method. Association rule mining is an unsupervised learning technique designed to extract patterns and structures from data [11]. This method identifies relationships and hidden associations among variables within large datasets, providing actionable rules that support prediction and decision-making.

The cognitive goal of this research is knowledge about this category of injuries. The application goal is to provide recommendations on the prevention of this category of injuries and thus increase the personal safety of athletes.

2. Material and Methods

Study participants

In this study, collegiate demonstration taekwondo athletes were selected. The purpose, background, and details of the study were explained to the participants, and only those who voluntarily agreed to participate were included in the survey. Participants who were unwilling or uncomfortable documenting their past injuries were excluded from the study. As a result, a total of 250 athletes were initially surveyed. However, 19 participants met the exclusion criteria, leading to a final sample of 231 participants (Table 1).

Table 1. Characteristics of research participants.

Variable		N	%
gender	male	191	82.7
	female	40	17.3
athletic experience	less than 5 years	126	54.5
	less than 7 years	32	13.9
	more than 7 years	73	31.6
national team status	experienced	32	13.9
	no experience	199	86.1

Data collection instrument

The development of the instrument (*Items for Investigating Injury Patterns*) involved a panel of eight experts: three taekwondo professors, two demonstration coaches, and three experts in item development (who held three rounds of meetings) The items were created considering the purpose and scope of the study.

To investigate injury patterns, the survey included items related to the timing of injuries, frequency of injuries, injury circumstances, and treatment methods (Table 2). Furthermore, to provide more detailed information about taekwondo demonstration athletes' injuries, the survey asked about the most frequently injured body parts. The survey items also provided basic characteristics of the research participants, such as gender, athletic experience, and national team status (Table 1).

Table 2. Criteria for developing *Items for Investigating Injury Patterns*.

Question	Response content	
When does the injury occur?	during competition	during training
When did the injury occur?	injury during airborne movements, vertical/horizontal rotations, or obstacle/technique execution	injury during airborne movements, vertical/horizontal

			rotations, or obstacle/landing process
	injury caused by breaking boards during strikes / injury caused by assistants / injury from supporting equipment		injury due to demonstration environment (terrain, ceiling, lighting, etc.)
How was the injury treated?	surgery ice	cast rest	physical therapy

Data collection procedure

First, the principal investigator visited the university to which the taekwondo demonstration team members belong, explained the purpose and content of the study, and then administered the survey to the demonstration team members who voluntarily agreed to participate. If the demonstration team members were unable to participate due to reasons such as competitions or classes, the investigator contacted them by phone, explained the study, and administered the survey using an online Google form. Second, the collected survey responses were transcribed using the Excel program, and responses that were incomplete or unanswered were excluded. Third, the transcribed data was recoded into a format suitable for frequency analysis and association rule analysis.

Data processing method

Frequency analysis of the injury locations was performed using Excel to calculate injury frequency, re-injury frequency, and percentages. In addition, to identify patterns in the injury locations, the association rule method was applied using Python. The apriori algorithm was used in the association rule method to derive injury patterns. The association rule method calculated support, confidence, and lift indices, with a minimum support set at 0.001 and confidence set at 0.05 for the analysis. For lift, the patterns with higher values were used as the reference for deriving results. A lift value greater than 1.00 indicates that the probability of both items occurring together is higher than the expected probability. The formulas for calculating support (Equation 1), confidence (Equation 2), and lift (Equation 3) are given below.

$$\text{Support } (A, B) = P(A \cap B) \quad \text{Equation 1}$$

$$\text{Confidence } (A \rightarrow B) = \frac{P(A \cap B)}{P(A)} \quad \text{Equation 2}$$

$$\text{Lift} = \frac{P(B|A)}{P(B)} = \frac{P(A \cap B)}{P(A)P(B)} = \frac{\text{Confidence}}{P(B)} \quad \text{Equation 3}$$

3. Results

Frequency and re-injury based on injury locations among taekwondo demonstration team members

The results indicated that among the three lower body injury locations, ankle injuries were the most frequent, with 163 cases (82.7%), followed by re-injuries, with 118 cases (72.3%) occurring after the initial ankle injury. The second most frequent injury location was toe injuries, with 118 cases (51.1%), and the third was knee injuries, with 108 cases (46.8%) (Table 3).

Table 3. Frequency and re-injury analysis based on lower body injury locations.

Category		Frequency (count)	Frequency (%)	Re-injury frequency (Count)	Re-injury rate (%)
Ankle injury	injury present	163	82.7	118	72.3
	no injury	68	17.3		
Knee injury	injury present	108	46.8	32	29.6
	no injury	123	53.2		
Toe injury	injury present	118	51.1	56	47.4
	no injury	113	48.9		

The patterns of injuries among taekwondo demonstration team members (overall)

The most frequent injury pattern was *during competition → airborne, vertical/horizontal rotation, performing obstacle techniques → ankle → surgery*, which had the highest lift value. The second most frequent pattern was *during competition → airborne, vertical/horizontal rotation, performing obstacle techniques → knee → cast*, and the third was *"during competition → airborne, vertical/horizontal rotation, obstacle landing → knee → physical therapy* (Table 4).

Table 4. The patterns of injuries among taekwondo demonstration team members (top 3 by lift).

Antecedents	Consequents	Support	Confidence	Lift
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle technique performance, surgery	ankle	0.047	0.491	3.139
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle technique performance, cast	knee	0.014	0.049	3.084
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle landing process, physical therapy	knee	0.016	0.231	2.918

The pattern based on injury locations among taekwondo demonstration team members

The most frequent injury pattern for the ankle, knee, and toe injuries was *during competition → airborne, vertical/horizontal rotation, performing obstacle technique → surgery*. The second most common injury pattern for both ankle and knee injuries was *during competition → airborne, vertical/horizontal rotation, performing obstacle technique → cast*, while for toe injuries, the second most common pattern was *during competition → airborne, vertical/horizontal rotation, obstacle landing process → surgery* (Table 5).

Table 5. Analysis of injury patterns based on injury locations among taekwondo demonstration team members (top 3 by lift).

Antecedents	Support	Confidence	Lift
Ankle injury			
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle technique performance, surgery	0.123	0.5178	3.462
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle technique performance, cast	0.055	0.541	2.263
Injury during obstacle technique performance, airborne, vertical/horizontal rotation, surgery	0.149	0.700	1.904
Knee injury			
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle technique performance, surgery	0.146	0.428	2.423
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle technique performance, cast	0.060	0.769	2.252
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle landing process, surgery	0.085	0.208	1.713
Toe injury			
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle technique performance, surgery	0.153	0.509	3.091
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle landing process, surgery	0.011	0.037	2.213
Injury during competition, airborne, vertical/horizontal rotation, injury during obstacle landing process, ice therapy	0.011	0.071	2.095

4. Discussion

An important finding of these studies is the most frequent injury pattern for the ankle, knee, and toe injuries was *during competition → airborne, vertical/horizontal rotation, performing obstacle technique → surgery*. This suggests that, regardless of the injury location, injuries occur during technical performance in competition situations, and the severity of the injuries is high (requiring surgery).

However, this specific sporting competition (taekwondo demonstration) is preceded by training that involves high-difficulty techniques such as rotations, jumps, and airborne movements, making it a sport with a high risk of injury [12, 13]. As a result, frequent injuries among athletes lead to halting or abandoning their training [14-16].

The results show that ankle injuries were the most frequent, followed by toe and knee injuries. Notably, ankle injuries had a high re-injury rate. Ankle injuries were the most common injury site, with 82.7% of injured individuals experiencing ankle

injuries. Previous studies on demonstration athletes also report ankle injuries as the most common [15, 16], supporting the findings of this study. The cause of ankle injuries can be attributed to the dynamic kicking and rotational movements typical in taekwondo demonstrations, which place excessive stress on the ankle joints. Maintaining balance while performing these movements is crucial, and insufficient rehabilitation during the recovery process can increase the risk of re-injury. In fact, 72.3% of those injured reported experiencing ankle re-injuries, indicating the need for preventative measures for ankle injuries among demonstration team members.

Toe injuries were the second most common injury site, with 51.1% of participants experiencing them. Toe injuries occur due to repeated impacts with the mat, landing after a technique, and performing breaking techniques [14, 17], highlighting the inherent risk to the feet in taekwondo demonstrations. Particularly, toe injuries are preventable through proper protective equipment, emphasizing the need for toe protection gear or appropriate taekwondo footwear for demonstration team members. Knee injuries were reported by 46.8% of the injured participants and were primarily caused by jumps, kicks, and rotational movements. To prevent knee injuries, it is crucial to regulate the frequency of high-risk movements, along with implementing strengthening exercises and technical training for knee protection.

Second, the analysis of injury patterns among the demonstration team members revealed a tendency for ankle injuries to occur as a result of airborne and rotational techniques during competition. This suggests that the technical demands during competitions increase the athletes' fatigue, which in turn contributes to a higher incidence of ankle injuries [18]. Moreover, when ankle injuries lead to surgery, it can significantly impact an athlete's career, emphasizing the need for training methods and technical analysis aimed at preventing such injuries. The second most frequent injury pattern was related to knee injuries, which were shown to occur during competition. Furthermore, the use of a cast for treatment indicates the severity of the knee injury. The third most frequent injury pattern involved knee injuries leading to physical therapy, which suggests that these injuries are relatively less severe. Nevertheless, the recurrence of injuries could have long-term negative effects on an athlete's career sustainability. To address this issue, it is essential to explore methods to reduce injury risks, such as improving landing techniques during training. Additionally, because injuries in one area may be linked to other parts of the body, preventing injuries in advance is crucial [19, 5].

However, such a general implication is insufficient both from a methodological perspective and in terms of application in the broadly understood sense of prevention, i.e. beyond the practice of taekwondo. The recommended complementary approach is the basic method of the new applied science of innovative agonology [20-22] and covers both methodological issues [23-27] and practices related to preventive medicine and broadly understood survival from the micro (personal safety) to the macro scale [28-43].

An example of a complementary approach, especially in terms of health risk analysis, is the work of Solovjov et al. [44] on swimmers' shoulder injury prevention by correctly evaluating technical errors. Taking into account the recommendations of INNOAGON, including the cited example of research on young swimmers, the findings of this study can serve as a key resource for developing injury prevention strategies and countermeasures tailored to the unique characteristics of taekwondo demonstration events. However, this study does have some limitations. For instance,

it did not analyze injuries in more detail by categorizing them according to specific demonstration techniques (e.g., jumping, airborne movements, rotations) or considering gender differences. Despite these limitations, the study provides significant insights into the occurrence of injuries in taekwondo demonstration events. Based on this information, future research could aim to develop predictive models to detect injuries, which could help reduce injury rates among athletes practising not only taekwondo.

5. Conclusions

These results underscore that the airborne and rotational maneuvers characteristic of demonstration taekwondo are significant contributors to ankle and knee injuries. Such injuries often necessitate extensive medical interventions, highlighting the critical need for preventive strategies. A complementary approach, as a fundamental method used in the exploration (research and education) of innovative agonology, opens the prospect of improving interventions, both diagnostic and directly related to psychomotor activity in the preparatory process and the public presentation of taekwondo motor perfection. Therefore, a key element of preventive strategies is to resist the temptation to achieve unique visual and marketing effects at the expense of health risks.

Data Availability Statement: The data supporting this study's findings are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

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