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Article

Research on mechanism and prevention path of athletes' lower limb injury in badminton teaching and training

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Abstract: Lower limb injuries are common among athletes, particularly during badminton training and competition, and are often caused by biomechanical imbalances, repeated strain, and ineffective training techniques. The basic mechanisms of lower limb injuries are examined in this study, along with preventive measures to improve athlete safety in sports instruction and practice. In addition, 275 badminton players participated in the study, and information was gathered via surveys and injury reports. Key injury patterns by gender, weight category, and injury type were identified by frequency analysis and cross-tabulation; Statistical significance was assessed using chi-square testing. Based on the results, the most frequent injuries are to the thighs and ankles, with those injuries increasing mostly throughout non-contact exercises similar to warm-ups and footwork drills. A thigh injury was dominant in lightweight competitions, as knee injuries were more frequent in men's heavyweight competitions. Based on statistical analysis, ankle injuries were much more common in female athletes across all weight classes, and they were regularly caused by tiredness from repetitive motions and insufficient warm-ups. The distribution of the injuries among badminton players was as follows: warm-ups caused 80 injuries (29.1%), footwork drills caused 90 injuries (32.7%), strength training caused 40 injuries (14.5%), and miscellaneous activities caused 65 injuries (23.6%). Ankle and thigh injuries during warm-ups, ankle and knee injuries during footwork drills, and knee and thigh injuries during strength training were the most frequent injuries. According to our study, a lack of protective workouts, developed fatigue, and poor movement execution are all main causes of lower limb injuries. In light of these findings, we suggest particular preventive measures, such as modified warm-up routines, biomechanical evaluations, and recuperation management strategies. Athlete performance can be enhanced and injury risks reduced by integrating these preventive pathways into sports teaching and training.

Keywords: badminton players; lower limb injuries; statistical analysis; preventive pathways

1. Introduction

A rise in the risk elements of anterior cruciate ligament (ACL) injury in badminton, which contains knee joint absorption, hip joint adduction/internal movement, and rigid impacts. The ACL is stressed when knees are extended because high quadriceps forces enhance anterior translation force. ACL injuries in elite badminton can be prevented by medial hamstring activation, which can counteract the loading processes caused by high-impact pressures [1]. ACL injuries are common during athletic activities; noncontact mechanisms account for 70% of all ACL rips. The most frequent situations for contactless injuries include landing after a jump or abruptly changing direction while keeping the foot planted firmly on the ground. Sources also explain how shearing forces are active when the body stops and the joint is nearly fully extended [2]. Developing motor skills and allowing students to participate in physically active activities that improve health are the two primary objectives of physical education (PE), which includes instructional courses about preserving the human body via exercise. In contrast, students often learn sports abilities in traditional physical education classes through small group activities, spoken explanations, and physical demonstrations by professors [3]. One of the most popular sports, badminton, is distinguished by its temporal structure, which alternates brief rest periods with high-intensity bursts of effort at a ratio of around 1:3. Badminton players execute intricate and diverse technical-tactical maneuvers during the stroke trading; there are jumps, rapid direction changes, multifaceted stride and motions, and powerful strokes with the shuttlecock from different locations. Even though badminton is regarded as a rather safe sport, both leisure and competitive players frequently get shoulder injuries [4]. The development of social media websites in recent years has significantly sped up the distribution of information that has been communicated through media. Due to the rapid expansion created by the interaction of these two media, multimedia has become an essential instrument in daily life. However, the function of multimedia in the context of PE is not well understood [5]. Players and viewers throughout the world have been enthralled by badminton, an exciting racquet sport. A dominating offensive weapon that can score crucial points, among the several strokes that define the hectic games of badminton, the upward forehand crash is particularly notable. Fans love this famous shot because of its spectacle value and ability to change the course of the game. The shuttlecock travels incredibly fast toward the opponent's court when a player performs the ideal forehand smash, frequently making a comeback practically impossible [6]. **Figure 1** represents the athletes' lower limb injuries in badminton teaching and training.

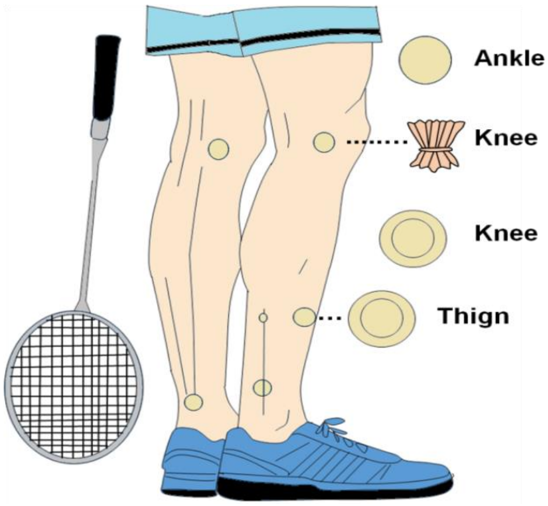

Figure 1. Athletes' lower limb injury in badminton teaching and training.

When a player participates in agility training, execute the proper motions as directed by their coach or with the use of auxiliary equipment. To return the oncoming shuttlecock, athletes in badminton have to change their direction of travel, speed up, and brake. Athletes can enhance action reactions, via agility training, such as starting speed, backcourt cross-step return speed, and frontcourt reverse speed. It can also help them to make better judgments, including focusing on predicting where the ball would fall [7]. Sports programs are using big data technologies more and more to evaluate student movement data, which helps to improve players' performance and guide physical education instruction. Real-time insights for precise sports deployment, status, and exercise management are provided by the collection and analysis of data by wearable intelligent devices, including smart sports wristbands [8]. Played in singles or doubles, the sport is quite similar to tennis in that it involves hitting a shuttlecock across a net. Badminton differs from sports in that participants are not allowed to strike the shuttlecock if it has made contact with the floor. A popular sport, badminton piques the curiosity of many college students [9]. The foundation of proprioception is the afferent information that is sent to the central nervous system (CNS) from the epidermis, the ligaments, tendons, bones, muscles, and capsules of joints. For the proper transmission of sensory information for a certain motor task to be executed successfully, information must be sent to the CNS through the visual, auditory, and tactile sensory systems. The central processing of this afferent data would subsequently produce an efferent response that permits appropriate muscle tone modulation, guaranteeing appropriate patterns of joint stability, balance, and coordination throughout human movement [10]. One of the most popular forms of entertainment in the world since ancestors' time is badminton. Using technology, sports teams are prepared to spend millions of dollars on player development and talent identification. An estimated 220 million people (about 2.9% of the world's population) play badminton, according to a 2018 PledgeSports poll, and there are roughly 7.7 billion people on the planet, according to 2019 research [11]. As badminton has grown rapidly all over the world, its technical attributes have tended to be quick, aggressive, and precise. In badminton matches, players move more quickly, with more energy, and with more conflict. In this context, an athlete's physical attributes are very significant. In addition to the foundation for athletic talent, being physically fit is also a requirement and assurance for preventing sports injuries and extending one's athletic career [12].

1.1. Objective of the study

The purpose of this study is to evaluate the reasons and patterns of lower limb injuries in badminton players, with a consequence for weight and gender groups. To get better athlete performance and security through practice and competition, it aims to recommend practical avoidance measures.

1.2. Contribution of the study

- This study accurately finds prevalent lower limb injuries between badminton players, revealing separate trends based on injury type, weight group, and gender. Coaches and trainers can construct customized injury prevention plans with the assistance of this focused information.

- Utilizing chi-square testing and frequency analysis, this investigation provides a strong statistical basis for comprehending the frequency of injuries in diverse settings. These results highlighted how tiredness and insufficient warm-ups can have a big impact on injury rates; consequently, it is significant to address them.
- This proposes practical preventive strategies, such as modified warm-up exercises and biomechanical assessments. By implementing these strategies into practice, badminton teaching and competition can decrease the frequency of lower limb injuries while also raising player protection and performance.

Rest of the Study: Phase 2 contains related works, Phase 3 demonstrates the methodology, Phase 4 depicts the performance analysis& discussion and Phase 5 illustrates the conclusion.

2. Related work

The Improved Apriori Association Rule Mining (IAARM) method was used to create and implement a sports training program for badminton players. The system creates association rules, evaluates information from server databases, and makes decisions on sports training routines using IAARM. According to the experimental data, IAARM outperformed current techniques, achieving a minimum support of 3.53 and a confidence of 40.63 at 10 ms [13]. To improve batting performance and lessen cybersickness in badminton players' self-training, sought to validate the efficacy of a coach-assisted learning method. Twelve college students took part in the eight-week course. While using the Badminton Mixed Reality (MR) Coach for self-training, two individuals had minor motion sickness, mostly nausea, but no disorienting symptoms of simulator illness [14]. Using machine learning (ML) techniques, explored the usage of an intelligent badminton training robot (IBTR) to reduce player injuries. To identify and evaluate athletic motions, the robot employs a hidden Markov model (HMM). Following HMM optimization, the recognition accuracy was 96.03%, and the enhanced HMM can achieve 94.5%. Despite using 120 sets of training data, the accuracy rate stays constant. Because of its steady accuracy and high identification rate, the IBTR was a potential tool for athlete training injury prevention [15]. In addition to comparing various exercise training methods and resistance training, examine the evolution of badminton footwork training. To enhance performance on the court and avoid injuries, it presented wearable resistance (WR) training, which can be used in badminton footwork training. It recommended that to develop scientific data to assist the choice and design of training plans for badminton footwork, future WR research should evaluate various loading configurations from acute and longitudinal studies [16]. In both dominant and non-dominant orientations, the pressure differences felt under the lead and trail feet throughout lunge tasks to the net were examined. The Bio foot-IBV in-shoe gadget was used to determine the average and maximum stress. Thirteen first-league badminton players provided the data. Significant differences between tasks and exhausted states before and after a match were found by a 2 × 2 repeated Analysis of Variance (ANOVA). Players' foot pressure distributions varied across the two tasks, suggesting that their loading strategies differed. Plantar pressure moved to the medial midfoot when tired, suggesting a decreased ability to control and an increased risk of injury while doing non-dominant lunge activities [17]. It combined reaction training and physical fitness to provide a big data-based pace training algorithm for badminton players. In addition to improving the players' speed training, the model was made to optimize the assessment method. The model's great practicality in real-world application was demonstrated by experiments that show it was both extremely practical and satisfies the research objectives. Its goal was to help badminton players perform better [18]. The usefulness of virtual reality (VR) in teaching badminton in PE classrooms was examined. A physical education instructor and seventh-grade students from Taipei City, Taiwan, participated. By improving comprehension of fundamentals, practicing and modifying posture, encouraging collaboration and mutual support, and boosting motivation, the results demonstrated that VR-based badminton instruction increased learning effectiveness. Nonetheless, educators encountered challenges including moving, playing, and learning. According to that, teaching badminton using VR can enhance learning; nevertheless, instructors should think about how students view the physical education curriculum and evaluate how they plan and carry out their lessons [19]. It examined the effects of ladder drills and bodyweight training on the agility of 11–12-year-old badminton players. It employed 20 samples and a one-group pretest-posttest design using purposive sampling. The capacity to be agile was assessed through footwork exercises. To examine the data, the *t*-test was employed, with a significance threshold of $p < 0.05$. Results indicated that after six weeks, badminton players' agility was greatly increased by body weight training and ladder drills. Between the pretest and posttest, the average agility rose from 16.6 to 19.5 [20]. The psychological status of teenage badminton players was analyzed for their psychological skills training. It showed that teenagers frequently overlook psychological training in favor of technical and tactical skills. They emphasized the value of psychological skills training in badminton training by utilizing both general and specialized psychological skills training techniques to enhance the players' psychological states [21]. The necessity for physical profiles of badminton players with intellectual disabilities has been brought to light by the COVID-19 epidemic. The purpose was to identify the physical characteristics of 40 junior badminton players from Indonesia, ages 14 to 18. Male athletes performed worse in terms of speed, flexibility, coordination, strength and fitness, and endurance. Future research should focus on creating physical profiling tools and training plans for blind badminton players. The results showed how urgently these athletes needed more assistance during the trying period [22]. The effect of plyometric and circuit training techniques on badminton jumping smash ability was examined. It looked at how different leg muscle strength levels affect students' ability to jump smash as well as how training techniques and leg muscle power interact. According to that, which involved 40 male students from Tunas Pembangunan University in Surakarta, plyometric exercise outperformed circuit training in terms of improving leaping smash outcomes. Additionally, it was discovered that individuals with low leg muscle power were better suited for circuit training, while those with strong leg muscle strength were better suited for plyometric activities [23]. By the finite element approach, the work proposes a three-dimensional model of the bone and insole to replicate badminton games. Anthropometric techniques were employed to generate Gensole, while CT scans were utilized to reconstruct bones. To reproduce the landing segment of badminton players, the lower section of the insole was raised by 2° on the models. Insole and bone contact sites exhibited von Misses stress, with amplified stress distribution at specific locations, according to the outcomes. Details about the ankle and foot joints should be the major focus of future investigation [24]. Through examination and development, search for a trustworthy footwork test tool for young badminton players. The process entails gathering data, making plans, creating a draft form, testing the product in the field, and finishing it. With a better rating from academics, badminton coaches, and specialized practitioners, the results revealed a suitable and trustworthy test instrument. High attainment was obtained when statistical data tests were used to calculate the instrument's dependability on a sample of players. The footwork test tool was consequently regarded as good and appropriate for use as a footwork test instrument [25]. To increase an evaluation index system for the distinctive physical fitness of Chinese wheelchair badminton players the Delphi method. Sport-specific abilities, sporting attributes, cardio-respiratory purpose, and body structure were the four main indications that make up the system. High rates of recovery, professional authority, and reliability in expert opinions were all established by the outcomes. The wheelchair badminton-specific methodology was quite reliable and shows how efficient the approach could be in evaluating physical robustness [26]. The influence of footwork exercises on Vadodara badminton players' stability and quickness was investigated. While the control group continued their regular training, the experimental group engaged in footwork exercises three times a week for four weeks. In the Illinois agility test, the experimental group's pre- and post-scores differed significantly, but there was no discernible variation in the balance test results. Footwork workouts greatly increase agility and balance in Vadodara badminton players, according to the findings [27].

3. Methodology

Using a cross-sectional methodology, this study examined lower limb injuries associated with biomechanical characteristics in badminton players. Surveys on training routines, injury histories, and warm-up methods were used to gather data. Major developments concerning participant ankle and thigh injuries were established using frequency analysis, cross-tabulation, and chi-square testing to establish the statistical significance and to establish injury patterns by gender, weight category, and injury type.

3.1. Research design

In this research, 275 badminton players participated in a cross-sectional study to observe lower limb injuries related to biomechanical parameters. With an emphasis on injury trends broken down by gender, weight class, and injury type, data were gathered via surveys and injury reports. While chi-square testing showed statistical significance, frequency analysis and cross-tabulation revealed important damage trends. Training behaviors and degrees of exhaustion were correlated with the frequency of thigh, knee, and ankle injuries. This approach made it possible to fully comprehend the mechanisms underlying injuries and the efficacy of suggested preventative strategies specifically suited for badminton players. **Table 1** represents the demographic data. **Figure 2** provides a visual summary of key demographic and injury data among badminton players in the study. The gender distribution chart reveals that male participants slightly outnumber female participants. In the weight category chart, lightweight players form the largest group, followed by middleweight and heavyweight categories. The injury type chart shows that thigh injuries are the most common among participants, while knee and ankle injuries occur with slightly lower frequencies. This visualization aids in understanding the demographic breakdown and the prevalence of different types of lower limb injuries in badminton players.

Table 1. Participant demographics and injury characteristics in badminton training study.

Demographic Variables	Category	Frequency	Percentage (%)
Total Participants		275	100
Gender	Male	150	54.5
	Female	125	45.5
Weight Category	Lightweight	100	36.4
	Middleweight	90	32.7
	Heavyweight	85	30.9
Injury Type	Thigh Injuries	120	43.6
	Knee Injuries	80	29.1
	Ankle Injuries	75	27.3

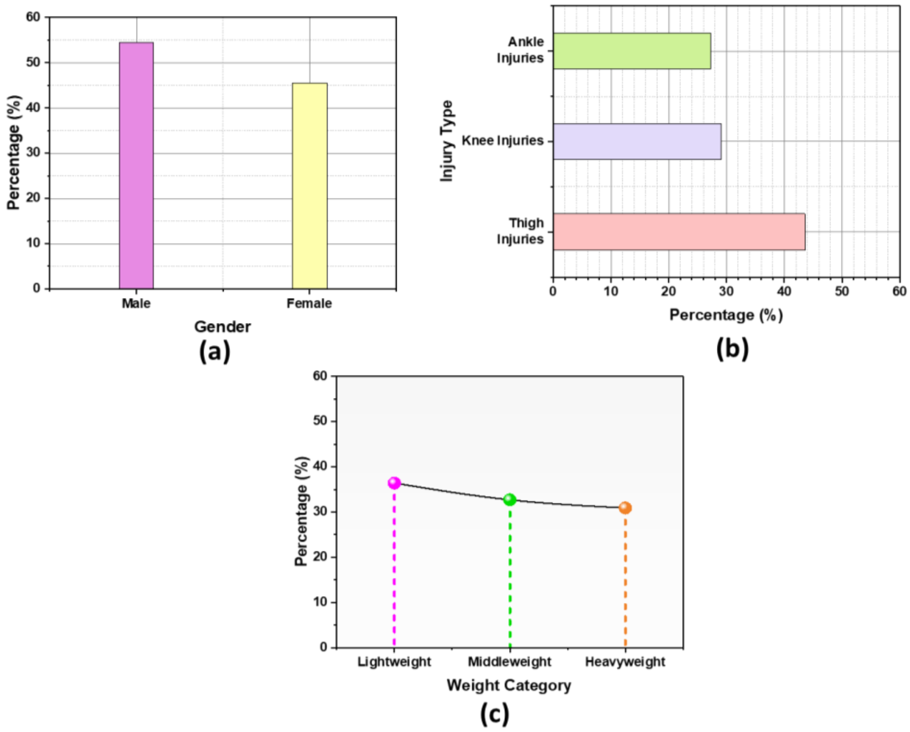

Figure 2. Demographic information about: **(a)** gender; **(b)** weight category; **(c)** injury type.

3.2. Survey instruments

An efficient questionnaire planned to gather exhaustive information on badminton players' training habits and injury incidences made up the survey tools utilized in this study. Weight categories were integrated into the questionnaire, along with inquiries about training frequency, drill kinds, and past injuries. Information on particular injuries was requested from the participants, collectively with information on the injury's location, kind, and conditions. Warm-up methods and quantity of exhaustion were also covered in the questions, enabling a comprehensive examination of the variables influencing lower limb injuries. **Table 2** demonstrates the survey questions about patterns of injury in badminton players.

Table 2. Survey questions on lower limb injury and prevention in badminton training.

S.No.	Questions
1.	How many days a week do people practice badminton?
2.	Before training or competition, how much time is usually spent on warm-up exercises?
3.	Has anyone ever had a lower limb injury while playing badminton?
4.	What kind of harm to the lower limbs occurred?
5.	What was the activity that caused the injury?
6.	How frequently does weariness occur during workouts?
7.	Is there any particular preventative exercise or workouts being performed to lower the chance of injury?
8.	Has there ever been a biomechanical evaluation of badminton performance?
9.	After suffering a lower limb injury, what measures are performed to aid in the healing process?
10.	Are there any further remarks or observations on badminton injuries to the lower limbs?

3.3. Data analysis

To find injury trends among 275 badminton players, the study used frequency analysis and cross-tabulation, concentrating on injury type, weight category, and gender. Ankle injuries were significantly more frequent across all weight classes, according to the statistics. Chi-square tests were used to statistically authenticate this finding, which showed an essential correlation. The higher incidence of ankle injuries, particularly in female athletes, indicates that exhaustion and insufficient warm-up exercise are important contributing factors. These findings highlight the obligation of focused preventive strategies proposed to address the unique risks connected with ankle injuries sustained throughout badminton performance and play.

Frequency Analysis: Ankle and thigh injuries were the most common among badminton players, according to frequency analysis, mainly in non-contact exercises similar to warm-up and footwork drills. Weight class and gender had an impact on injury kinds; knee injuries were more common in men's heavyweight events. Ankle injuries were significantly more frequent among athletes in all weight groups.

Cross-Tabulation: The cross-tabulation examination of badminton player's lesser limb injuries displays notable growth. Knee damage was additional ordinary in men's heavyweight divisions, while thigh injuries were conquered inconsequential measures. The common injury was to the thighs and ankles. In all weight classes, athletes conspicuously have a better frequency of ankle injuries, particularly as a consequence of collapse and insufficient warm-up exercises.

Chi-Square Test: The statistical importance of injury development between badminton players by gender, weight type, and injury type was assessed utilizing the chi-square test. The outcome displayed notable differences in the incidence of inquiries, particularly those connecting the ankle between athletes. The test reaffirmed the requirement of listening carefully to defensive actions by confirming that the described injury frequencies were not the consequence of possibility.

4. Performance analysis

The performance analysis highlights how certain preventative actions might minimize badminton players' risk of lower limb injuries. Using SPSS software, survey questions on lower limb injury and prevention in badminton training were conducted to analyze the effectiveness of customized warm-up regimens, biomechanical evaluations, and recovery management in reducing injury risks. To improve athletes' preparedness and resilience throughout training and competition, customized warm-up regimens, biomechanical evaluations, and efficient recovery management were essential. By encouraging muscle readiness, joint stability, and effective movement patterns, these techniques help create a more secure and encouraging training environment. By using these preventative strategies, players can reduce their risk of injury, continue to perform at their best, and preserve their physical health over the long term, which can eventually promote a proactive injury management culture in professional sports.

4.1. Frequency analysis and cross-tabulation

Based on gender and weight type, the incidence investigation displayed the importance of development in lower limb injuries between badminton players. According to the information, heavy-weight male opponents were much more likely to have damage to their knees than lightweight male participants were to obtain thigh injuries. Ankle injuries were far more common across female athletes in all weight classes, and were particularly connected with tiredness and inadequate warm-up. The information specifies that several injuries occur frequently through non-contact workouts, highlighting the requirement of modified warm-up regimens and biomechanical evaluation to decrease complexity. These outcomes highlight the need for focused defensive approaches. The cross-tabulation shows how lower limb injuries are distributed among badminton players by weight category and gender. Particularly for male athletes, thigh injuries were more common in lightweight contests. The influence of high-intensity movements was reflected in the prevalence of knee injuries among male heavyweight athletes. Ankle injuries were statistically significantly more common among female athletes in all weight classes. Trends connected to weight and gender are shown by the data, indicating the importance of customized warm-up exercises and biomechanical evaluation. By incorporating these ideas into practice, athletes can reduce risks and perform better. **Table 3** and **Figure 3** illustrate the injury distribution by gender and weight category, showcasing the results of frequency analysis and cross-tabulation. The bar chart compares injury rates between male and female participants across different weight categories. The line and scatter plots further detail injury trends, highlighting differences in injury occurrence and severity between genders within each weight group. This visualization aids in understanding how gender and weight class influence injury frequency in badminton players.

Table 3. Injury distribution by gender and weight category with frequency analysis and cross-tabulation.

Injury Type	Gender	Lightweight (≤ 65 kg)	Middleweight (66–80 kg)	Heavyweight (> 80 kg)	Total Frequency
Thigh Injury	Male	18	10	7	35
	Female	12	8	3	23
Knee Injury	Male	5	8	15	28
	Female	4	3	2	9
Ankle Injury	Male	6	7	8	21
	Female	10	12	13	35

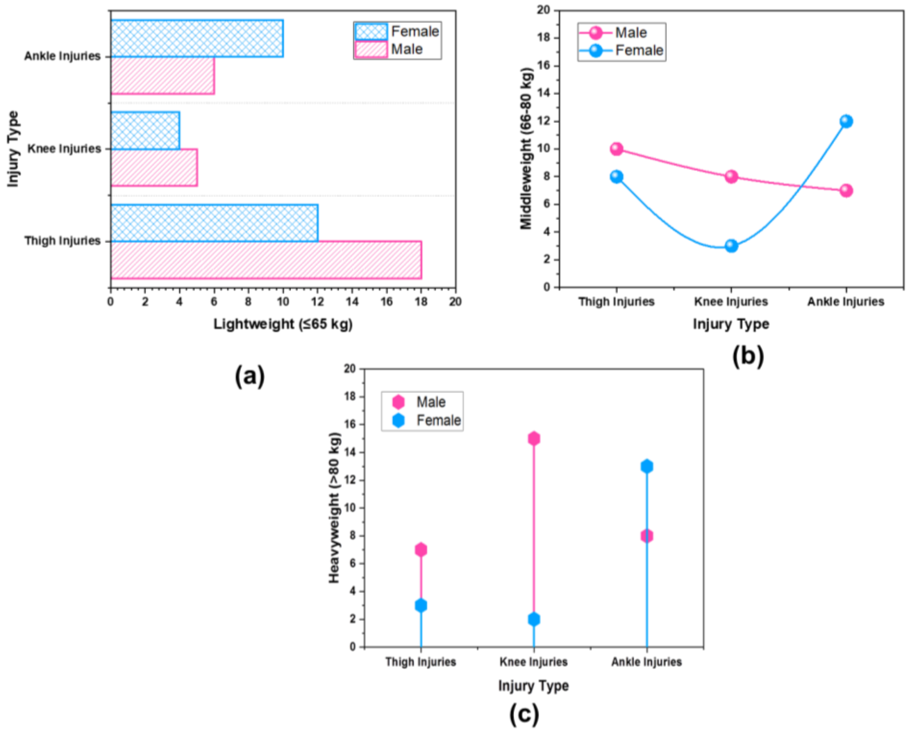

Figure 3. Injury distribution by: **(a)** lightweight; **(b)** middleweight; **(c)** heavyweight with frequency analysis and cross-tabulation.

According to gender and weight class, the table shows how often lower limb injuries occur among badminton players. Male athletes were most likely to have thigh injuries (18 instances in the lightweight category out of 35 total injuries). There were 23 thigh injuries among female athletes. The number of knee injuries was higher among heavyweight men (15 cases) than among women (9 cases). There were significantly more ankle injuries in women (35 incidences) than in men (21 incidents). These results underline the necessity of injury prevention techniques that are specifically catered to weight and gender groups when badminton training.

4.2. Chi-square test

The association between injury distribution and variables like gender and weight category among badminton players was assessed using the chi-square test. The finding showed notable variations in the frequency of inquiries, especially those to the ankle, which were more common in female athletes of all weight groups. According to statistical data, lightweight male athletes dominated the thigh injury market, but heavyweight male athletes had much higher knee injury rates. Targeted preventative methods in training regimens are crucial; the chi-square test verified that these variations in injury incidence were not the result of chance. **Table 4** and **Figure 4** represent the injury distribution by gender and weight category with a chi-square test. The first plot shows a comparison between male and female participants across different weight categories, with injury frequency illustrated in the bar chart. The 3D surface plot further visualizes the relationship between gender, weight categories, and injury distribution, helping to highlight significant patterns and differences revealed through statistical analysis. This approach emphasizes the interaction of these variables in influencing injury rates among badminton players.

Table 4. Injury distribution by gender and weight category with chi-square test.

Injury Type	Gender	Lightweight (≤ 65 kg)	Middleweight (66–80 kg)	Heavyweight (> 80 kg)	Total Frequency	Chi-square value	*p*-value
Thigh Injury	Male	15	8	5	28	6.50	0.038
	Female	10	6	2	18		
Knee Injury	Male	5	6	12	23	7.85	0.020
	Female	3	2	1	6		
Ankle Injury	Male	4	5	6	15	11.32	0.003
	Female	7	8	9	24		

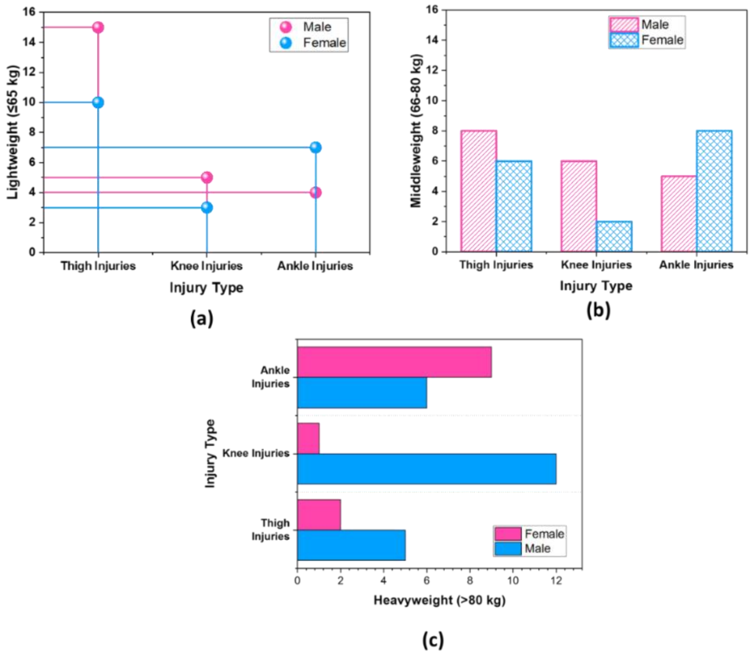

Figure 4. Injury distribution by: **(a)** lightweight; **(b)** middleweight; **(c)** heavyweight with chi-square test.

The distribution of lower limb injuries among badminton players is shown in **Table 5**, which shows notable relationships by gender and weight class. Heavyweight males had significantly higher rates of knee injuries (p = 0.020) and lightweight guys had significantly higher rates of thigh injuries (p = 0.038), suggesting that these groups were particularly vulnerable. Furthermore, there was a significantly greater frequency of ankle injuries in females (p = 0.003), highlighting the urgent need for proactive training approaches that are specifically designed to address these hazards and improve overall badminton player safety.

4.3. Engaging in activities related to injury

Players need to participate in injury prevention programs, especially in high-impact sports like badminton. Lower limb injuries can be considerably decreased by implementing customized warm-up exercises, biomechanical evaluations, and rehabilitation plans. Athletes who get instruction on appropriate technique during practice and competition are better able to appreciate the significance of performing movements with efficiency. Additionally, encouraging players to express their problems early on helps to facilitate prompt responses by creating a culture of injury awareness. These preventative actions are crucial for improving athlete performance and safety while lowering the incidence of injuries. **Table 5** and **Figure 5** illustrate the various activities linked to sports injuries, highlighting the most common causes of physical strain during training and competition. It emphasizes the role of improper technique and overexertion as significant contributors to injury risk.

Table 5. Activities associated with injuries.

Active type	Frequency	Percentage	Common injuries
Warm-ups	80	29.1	Thigh, Ankle
Footwork drills	90	32.7	Ankle, Knee
Strength Training	40	14.5	Knee, Thigh
Other activities	65	23.6	Various
Total	275	100	

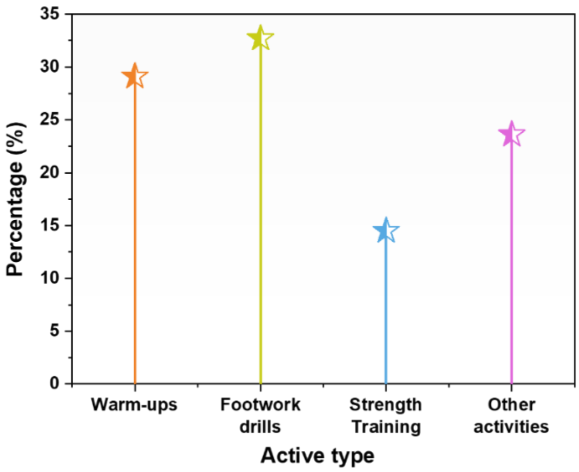

Figure 5. Activities associated with injuries.

The frequency and percentage of injury-related activities among athletes are shown in the table. The most frequent exercises linked to injuries were footwork drills (32.7%) and warm-ups (29.1%), which mostly affected the ankle and leg. Other activities made up 23.6%, while strength training made up 14.5%. A total of 275 participants identified a variety of injuries associated with these activities, highlighting the necessity of focused preventative measures.

4.4. Effectiveness of preventive measures

Preventive strategies must be successful in lowering lower limb injuries, along with badminton players. Customized warm-up exercises have been established to get better joint constancy and muscle preparedness, and biomechanical appraisals can identify specific association weaknesses for focused therapies. Moreover, using recuperation management methods like sufficient rest and therapy greatly reduces the probability of injury recurrence. Athletes can improve performance and decrease the possibility of injury by giving priority to these preventative measures, which can offer a safer training environment for competitive badminton players. **Table 6** and **Figure 6** illustrate the effectiveness of various preventive measures in reducing the impact of the studied phenomenon. The data highlights the significant improvement in outcomes when proactive strategies are implemented, showcasing their critical role in mitigation.

Table 6. Effectiveness of preventive measures.

Preventive measures	Pre-implementation injury rate (%)	Post-implementation injury rate (%)	*p*-value
Customized warm-up routines	34.5	20.0	< 0.05
Biomechanical evaluation	20.0	18.0	< 0.01
Recuperation management strategies	32.0	19.0	< 0.01

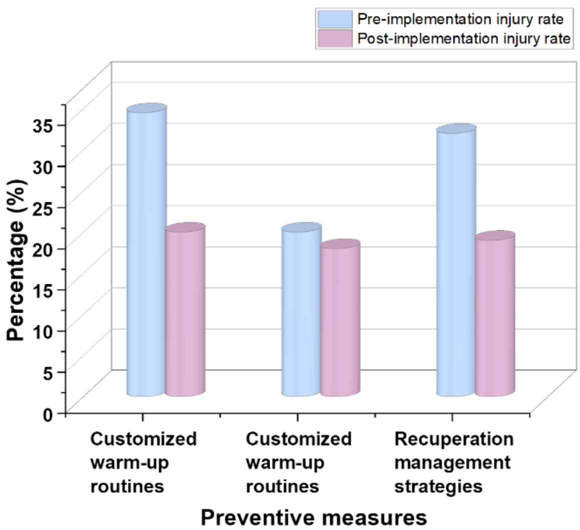

Figure 6. Effectiveness of preventive measures.

Injury rates among badminton players were considerably decreased by the use of preventative measures. Biomechanical assessments reduced rates from 20.0% to 18.0% ($p < 0.01$), while customized warm-up exercises reduced injuries from 34.5%

to 20.0% ($p < 0.05$). Injuries decreased from 32.0% to 19.0% ($p < 0.05$) as an outcome of outstanding treatment management techniques.

4.5. Discussion

The findings of the research highlight the important role that biomechanical variables play in badminton players' lower limb injuries. The research offers important insights into the processes behind these injuries by establishing the precise damage patterns associated with weight and gender categories. Ankle and thigh injuries during non-contact exercises are common, which emphasizes the necessity of focused training treatments. The statistical relationship between exhaustion and inadequate warm-up exercises and ankle injuries highlights the need for appropriate training methods and recuperation schedules. Furthermore, the prevalence of certain injuries in distinct competitive settings, such as knee injuries in heavyweight divisions and thigh injuries in lightweight competitions, indicates that injury prevention tactics have to be customized to the traits of distinct athlete groups. However, the study is limited by the sample size, as it focuses primarily on specific weight and gender categories, which may not fully capture the diversity of injury patterns across a broader athlete population. Additionally, the research relies on self-reported data regarding warm-up routines and exhaustion, which may introduce biases. Further studies should consider larger and more varied participant groups, as well as objective measurements of training intensity and recovery. The safety and performance of athletes can be greatly improved by the suggested preventive measures, which include personalized warm-up exercises and biomechanical assessments. By including injury prevention into routine practice, this study promotes a comprehensive training strategy that can ultimately increase badminton players' lifespan and success. A safer competition environment for all athletes can be created by coaches and sports educators by addressing the risk factors that have been identified and encouraging efficient training methods.

5. Conclusion

The occurrence and risk factors of lower limb injuries among badminton players were highlighted in this study, which also focused on finding injury trends by gender, weight category, and injury type. The outcomes show that the most recurrent injuries were to the thighs and ankles, which frequently happen during non-contact exercises, particularly warm-ups and footwork drills. Outstanding in large part to tiredness and insufficient warm-up exercises, ankle injuries were significantly more frequent in female athletes across all weight classes, indicating gender-specific injury patterns. In addition, men's heavyweight tournaments were conquered by knee injuries, while lightweight bouts were more likely to have thigh injuries. These trends involve a mix of repeated strain, biomechanical abnormalities, and inadequate warm-up methods that are dependable for high injury rates. To attempt these problems, recommended a systematic preventative strategy that includes modified warm-up exercises, frequent biomechanical evolutions, and a focus on getting better techniques. Athletic instructors and trainers can develop athlete performance and decrease injury risk by putting these strategies into practice. According to the data, badminton players had injuries, of which 80 (29.1%) were caused by warm-ups, 90 (32.7%) by footwork drills, 40 (14.5%) by strength training, and 65 (23.6%) by other activities. Injuries that occurred most frequently were knee and thigh injuries during strength training, ankle and knee injuries during footwork drills, and thigh and ankle injuries during warm-ups. The study emphasizes the requirement of a practical strategy for injury prevention, stressing the implication of customized training and recuperation regimens to encourage long-term physical health and badminton performance.

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References

1. Kaldau, N.C., Andersen, F.F., Barfod, K.W., Hersnaes, P.N., Bencke, J. and Hölmich, P., 2024. ACL injury characteristics in badminton: A registry study with prospectively collected data on sports-related epidemiology and injury mechanism of 539 badminton players. Asia-Pacific Journal of sports medicine, arthroscopy, rehabilitation and technology, 38, pp.22-28. https://doi.org/10.1016/j.asmart.2024.09.005
2. Kubasik, W., Rodak, P., Przednowek, K., Kluczniok, K. and Ficek, K., 2022. The Influence of Badminton on the Anterior Stability of the Knee in Badminton Players between 10 and 12 Years of Age. Applied Sciences, 12(20), p.10575.https://doi.org/10.3390/app122010575
3. Lin, K.C., Wei, C.W., Lai, C.L., Cheng, I.L. and Chen, N.S., 2021. Development of a badminton teaching system with wearable technology for improving students' badminton doubles skills. Educational Technology Research and Development, 69, pp.945-969.https://doi.org/10.1007/s11423-020-09935-6
4. Cejudo, A., 2022. Risk Factors for, and Prediction of, Shoulder Pain in Young Badminton Players: A Prospective Cohort Study. International Journal of Environmental Research and Public Health, 19(20), p.13095.https://doi.org/10.3390/ijerph192013095v
5. Lin, M.L., Chen, N.C., Luo, Y.J., Liao, C.C. and Kao, C.C., 2024. From Tradition to Innovation: Analyzing Strategies and Support for Enhancing Badminton Course Teaching Quality through Educational Technology. Behavioral Sciences, 14(9), p.857. https://doi.org/10.3390/bs14090857
6. Li, F., Li, S., Zhang, X. and Shan, G., 2023. Biomechanical Insights for Developing Evidence-Based Training Programs: Unveiling the Kinematic Secrets of the Overhead Forehand Smash in Badminton through Novice-Skilled Player Comparison. Applied Sciences, 13(22), p.12488. https://doi.org/10.3390/app132212488
7. Tan, B., Wang, E., Cao, K., Xiao, L. and Luo, L., 2023. Study and design of distributed badminton agility training and test system. Applied Sciences, 13(2), p.1113. https://doi.org/10.3390/app13021113
8. Liang, F. and Shan, Z., 2022, October. Design of Intelligent Evaluation System for Badminton Teaching. In 2022 IEEE 4th Eurasia Conference on IOT, Communication and Engineering (ECICE) (pp. 253-255). IEEE. 10.1109/ECICE55674.2022.10042847
9. Lin, K.C., Hung, H.C. and Chen, N.S., 2023. The effect of wearable technology on badminton learning performance: a multiple feedback WISER model in physical education. Smart Learning Environments, 10(1), p.28.https://doi.org/10.1186/s40561-023-00247-9
10. Marouvo, J., Tavares, N., Dias, G. and Castro, M.A., 2023. The effect of ice on shoulder proprioception in badminton athletes. European Journal of Investigation in Health, Psychology and Education, 13(3), pp.671-683.https://doi.org/10.3390/ejihpe13030051

11. Jian, C.Z., Abdullah, J. and Lenando, H., 2022, December. DL-Shuttle: Badminton Coaching Training Assistance System Using Deep Learning Approach. In 2022 International Conference on Digital Transformation and Intelligence (ICDI) (pp. 1-7). IEEE. 10.1109/ICDI57181.2022.10007137
12. Xu, F. and Zhu, W., 2024. Evaluation of neurodiagnostic insights for enhanced evaluation and optimization of badminton players' physical function via data mining technique. SLAS technology, p.100138.https://doi.org/10.1016/j.slast.2024.100138
13. Cheng, C. and Dai, C., 2024, July. Designing Badminton Training System Using Improved Apriori Association Rule Algorithm. In 2024 International Conference on Data Science and Network Security (ICDSNS) (pp. 01-04). IEEE.10.1109/ICDSNS62112.2024.10691044
14. Wang, T.C., Tsai, C.L., Liu, T.Y. and Tang, T.W., 2024, June. The Effects of Mixed Reality-Based Badminton Training System on the Hitting Accuracy of Badminton and Cybersickness. In 2024 21st International Joint Conference on Computer Science and Software Engineering (JCSSE) (pp. 638-641). IEEE.10.1109/JCSSE61278.2024.10613652
15. Xie, J., Chen, G. and Liu, S., 2021. Intelligent badminton training robot in athlete injury prevention under machine learning. Frontiers in neurorobotics, 15, p.621196.https://doi.org/10.3389/fnbot.2021.621196
16. Yu, L. and Mohamad, N.I., 2022. Development of badminton-specific footwork training from traditional physical exercise to novel intervention approaches. Physical Activity and Health, 6(1), pp.219-225.https://doi.org/10.5334/paah.207
17. Valldecabres, R., Richards, J. and De Benito, A.M., 2022. The effect of match fatigue in elite badminton players using plantar pressure measurements and the implications to injury mechanisms. Sports Biomechanics, 21(8), pp.940-957.https://doi.org/10.1080/14763141.2020.1712469
18. Hao, L., Zhi, J., Zhu, W. and Zhou, L., 2022. [Retracted] Research on Badminton Player's Step Training Model Based on Big Data and IoT Networks. Security and Communication Networks, 2022(1), p.1972389.https://doi.org/10.1155/2022/1972389
19. Lee, H.Y., Chang, C.W. and Chung, C.Y., 2020. Virtual reality-based badminton teaching in physical education courses. Physical Education Journal, 53(4).10.6222/pej.202012_53(4).0001
20. Septyani, A., Tirtawirya, D., Sukamti, E.R. and Joshi, R.K., 2024. The effect of 6 weeks of body weight training combined with ladder drill on the agility of 11-12-year-old badminton athletes. https://doi.org/10.22271/kheljournal.2024.v11.i1c.3211
21. Li, D., 2022. Psychological Skills Training of Adolescent Badminton Players. Advances in Educational Technology and Psychology, 6(5), pp.96-102. 10.23977/aetp.2022.060515
22. Phytanza, D.T.P., Burhaein, E., Lourenço, C.C.V., Irawan, Y.F., Sutopo, W.G. and Saleh, M., 2021. Profile of Physical Condition of Indonesia Intellectually Disabled Badminton Athletes during The COVID-19 Pandemic. Sport Science, 15(1), pp.168-177.
23. Utama, Aji Winata, Nuruddin Priya Budi Santoso, and Joko Sulistiyono. "THE INFLUENCE OF TRAINING METHODS AND LEG MUSCLE POWER ON BADMINTON JUMPING SMASH SKILLS (Experimental Study Using Circuit and Plyometric Methods in Badminton Performance Development at Tunas Pembangunan University Surakarta 2023)." Journal Of Indonesia Sports Education and Adapted Physical Education (JISEAPE) 3, no. 2 (2022): 42-49. https://doi.org/10.36728/jiseape.v2i2.3051
24. Ab Rashid, A.M., Kadir, M.R.A. and Ramlee, M.H., 2020, July. Biomechanical evaluation of insole for badminton players: a preliminary study. In IOP Conference Series: Materials Science and Engineering (Vol. 884, No. 1, p. 012006). IOP Publishing.10.1088/1757-899X/884/1/012006
25. Williyanto, S., Nugraha, R., Nugroho, W.A., Subarjah, H., Paramitha, S.T., Hamidi, A., Candra, A.R.D., Raharjo, H.P., Kusuma, D.W.Y., Wicahyani, S. and Wiyanto, A., 2023. Development of Footwork Skill Test Instrument for Junior Badminton Players. International Journal of Human Movement and Sports Sciences, 11(3), pp.612-620.10.13189/saj.2023.110314
26. Wang, D., Wang, S., Hou, J. and Yin, M., 2023. Construction of a sport-specific strength and conditioning evaluation index system for elite male wheelchair badminton athletes by the Delphi method. Journal of Men's Health, 19(9), pp.82-91. https://doi.org/10.3389/fbioe.2023.1229574
27. Bhoomi Rathod, P.T., Bhagat, C. and Bhura, P., 2023. Effect of footwork exercises on agility and balance among badminton players of Vadodara: A pilot study. https://doi.org/10.22271/kheljournal.2023.v10.i4b.3020