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Risk Analysis of Knee Injury in Badminton Jumping Smash

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Abstract

Study purpose. This study aims to analyse the risk of knee injury during the landing phase of the jumping smash movement in athletes from the CPLUSco Badminton Club in Semarang. The jumping smash is a highly explosive and effective attacking technique in the game, but it carries a high risk of injury, particularly to the knee joint due to the pressure exerted during landing.

Materials and Methods. This study employed a quantitative descriptive method with a sample of 10 male athletes aged 14–18 years, selected using purposive sampling. Data were collected through motion capture using a Sony A6000 camera and analysed using Kinovea software version 0.9.5. The primary focus of the study was the landing phase, with biomechanical indicators including landing time (s), right and left knee flexion angles (°), and inter-leg distance during landing (cm).

Results. This study found that the optimal landing duration was in the range of 0.20–0.36 seconds, but there was a mismatch in knee angle and foot position, which was a significant risk factor for knee injury.

Conclusion. The conclusion of this study found that biomechanical evaluation needs to be conducted regularly to reduce the risk of injury.

Keywords: Badminton, Jumping Smash, Injury, Motion Analysis

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Introduction

In the study of sports biomechanics, injury prevention is one of the main focuses, especially in joints that are actively used in dynamic activities. One of the most injury-prone parts of the body is the knee joint, which is particularly at risk of axial and rotational overload, particularly during jumping and landing movements. The knee flexion angle during the landing phase plays an important role in absorbing ground reaction forces and maintaining joint stability. Too little flexion angle or a mismatch in the position of the lower leg can increase stress on the knee structures, potentially leading to injury, both acute and chronic (Lin et al., 2015). In addition, the duration of foot contact with the ground as well as the position of the foot during landing also affect the distribution of forces acting on the knee, which impacts the risk of injury and athletic performance (Teng, Leong, & Kong, 2020).

These aspects of biomechanics are particularly relevant in sports that rely on changes in

Fast directions, repeated jumps, and intense movements, such as badminton. Badminton is a racket sport played in singles or doubles, with motion characteristics in the form of acceleration, deceleration, and various explosive movements in a narrow playing area (Rusdiana, 2020). Among the various techniques in this game, jumping smash occupies a position as one of the most explosive and aggressive attack techniques. A jumping smash is not only for reaching the highest hitting point, but also for giving extra time to prepare the swing in the air so that the shuttlecock can be hit at a steeper angle and at high speed, which ultimately makes it difficult for the opponent to return (Ferreira, Górski, & Gajewski, 2020). This punch is one of the punches that is difficult to master, it needs hard and intensive training so that smash shots can hit the target precisely (Kurniawan & Suganda, 2021). However, the effectiveness of jumping smash in scoring points is proportional to the high risk of injury. especially in the landing phase which puts great pressure on the knee joint (Yeap, Ramasamy, Usman, King, & Razman, 2025).

Based on observations of 12 teenage athletes at CPLUSco Badminton Club Semarang, it is known that jumping smash is a movement that is often done both during training and matches. However, technical weaknesses were found in the landing phase. Most athletes have not been able to optimally control the position of the knee joint when it touches the floor, showing a lack of coordination between the upper and lower body in the transition from the hovering phase to the landing phase, as well as a mismatch in the distance between the legs which can affect posture stability.

Unstable landings and sub-optimal knee flexion angles can increase pressure on the knee structures, especially on the anterior cruciate ligament (ACL). Tibiofemoral compression load at low flexion angles can increase axial load on the ACL, thereby increasing the risk of ligament injury (Markolf, Yamaguchi, Matthew, & McAllister, 2019). Based on this, it is important to analyze the biomechanics of the jumping smash movement, especially in the landing phase, to assess the extent to which the technique can trigger the risk of knee injury. This study aims to analyze the risk of knee injury after jumping smash in badminton athletes, with the hope of providing input for coaching safer and more effective techniques, as well as supporting scientific injury prevention efforts.

Materials And Methods

Study participants

This research uses a quantitative descriptive approach. The subjects of this study were badminton athletes of Club CPLUSco Badminton. The sample size of about 10 out of 12 athletes was determined using purposive sampling technique with the criteria of being aged 14 to 18 years, actively training, being a club member for more than one year, having a minimum number of matches at the Semarang level, and being willing to participate in the research from beginning to ends as indicated by signing an informed consent. From a total of 12 subjects who had been selected in accordance with the established criteria, only 10 people were present and followed the data collection process. The other two subjects were declared invalid because they had not reached the level of regional level matches and were not willing to continue until the research process was completed. The selection of this age range is based on a significant nouronuscular development phase in supporting the efficiency of movement techniques (Oliver et al., 2013).

Study organization

The main purpose of this research is to analyze the landing phase in badminton jumping smash movements. The equipment used includes a Sony A6000 camera, Attanta Kaiser 234V tripod, informed consent, and a laptop with the Kinovea 0.9.5 application. Data collection was done by video analysis method based on kinematic parameters. The instruments used were angle (°) to identify the angle of knee joint movement duration in the safe start, execution, and landing phases, time (s) to determine the effectiveness of movement duration in the start, execution, and landing phases, and distance (m) to measure the distance between the feet and the height of the jumpu when performing smash and landing movements. This parameter is commonly used to assess the quality of movement control during the landing phase, as well as to evaluate the risk of lower extremity injury (Heebner et al., 2017). The data collection steps in this study were carried out systematically. First, the camera was mounted on a tripod and placed in the area of the field used by the athletes to ensure an optimal shooting angle. Next, the sample was asked to perform a jumping smash movement at a predetermined location. Each sample was given the opportunity to perform the movement three times in order to obtain more representative data. After that, the recorded data was analyzed descriptively using Kinovea software version 0.9.5, focusing on certain indicators such as time, knee flexion angle, and distance between feet when landing.

Statistical analysis

The results of this analysis are then presented descriptively to produce recommendations that can be used as a guide in maximizing jumping smash techniques.

Results

This study uses anthropometric data such as height and weight as the basis for analyzing kinematic indicators of jumping smash movements. Anthropometric parameters such as height and weight have a significant relationship with vertical jump performance (Sharma, Gandhi, Meitei, Dvivedi, & Dvivedi, 2017). This confirms that the use of anthropometric data as the basis for kinematic analysis of jumping smash movements can improve the accuracy of biomechanical analysis and serve as a reference in designing injury prevention training programs.

Table 1. Sample Anthropometric Data

n=10	Mean ± SD	Min	Max
Age (years)	16±1,26	14	18
Height (cm)	166,7±3,71	161	172
Body Weight (kg)	59,9±11,92	42	82
BMI (kg/m²)	21,5±4,03	16,2	28,7

Based on the anthropometric data obtained from the ten samples, it is known that the physical characteristics of the athletes show quite diverse variations. The average age of the respondents was in the late teenage range, with height and weight generally reflecting athletic posture. In addition, the body mass index (BMI) values show that most of the samples are in the normal category, which indicates a proportional body condition and supports movement performance in badminton sports. Ideal anthropometric parameters play an important role in producing postural stability and effectiveness of hitting techniques, especially in complex movements such as jumping smash. In the study (Yang & Park, 2024), the camera is placed approximately 3 meters away from the subject to ensure comprehensive visualization of the body, so that identification of body segments and anthropometric data can be performed accurately, both when athletes perform maximum movements and when analyzing their risk potential. Therefore, understanding the body composition of athletes can be one of the important bases in exercise design, injury prevention, and sports performance evaluation (Phomsoupha et al., 2015).

Table 2. Kinematic data

n=10	Mean ± SD	Min	Max
Prefix Phase			
Prefix Time (s)	1,65 ± 0,57	0,44	2,24
Distance Between Legs (cm)	54,665± 21,16	21,69	80,44
Right Knee Flexion Angle(°)	145,81 ± 19,17	110,0	173,2
Left Knee Flexion Angle(°)	159,37 ± 12,91	132,7	172,6
Implementation Phase			
Kick & Jump Time(s)	0,508 ± 0,13	0,26	0,7
Jump Height (cm)	34,971 ± 13,99	13,11	54,13
Right Knee Flexion Angle (°)	142,41 ± 21,96	96,3	178,9
Left Knee Flexion Angle (°)	127,75 ± 28,78	96,8	176,6
Stroke Speed (m/s)	0,152 ± 0,05	0,08	0,24
Stroke Time (s)	0,34 ± 0,28	0,1	0,8
Landing Phase			
Landing Time (s)	0,346 ± 0,09	0,24	0,52
Right Knee Flexion Angle (°)	123,38 ± 25,11	80,5	164,0
Left Knee Flexion Angle (°)	142,83 ± 11,09	119,6	158,3
Distance Between Feet When Landing (cm)	56,896 ± 30,97	18,54	103,24

Kinematic analysis of the jumping smash movement showed variations in performance in each phase of the movement. In the prefix phase, differences in the duration of the initial movement and the distance between the feet indicate that each individual has a different postural strategy to create stability before repulsion. The knee flexion angle that tends to be large in this phase reflects the potential utilization of the stretch-shortening cycle (SSC) mechanism, which is the utilization of muscle elastic energy to increase explosive power when jumping. This finding is in line with research (Markovic et al., 2010) which confirms that SSC plays an important role in optimizing vertical jump performance. In the execution phase, varying jump height and knee flexion angle indicate differences in muscle explosive ability and neuromuscular coordination. These variations can affect the quality of the stroke, especially during the transition from the air movement to the stroke phase. Based on the findings (Ramasamy, Usman, Sundar, Towler, & King, 2024), the effectiveness of jumping smashes is highly dependent on efficient coordination between body segments and control of the center of mass in the air, which maximizes energy transfer from the body to the shuttlecock. Furthermore, in the landing phase, there are differences in foot contact time with the floor and knee flexion angle, which can have implications for injury risk. An excessively long landing time, combined with an extreme flexion angle, can increase axial stress on the knee joint. Time and knee flexion angle in the landing phase of a jumping smash are interrelated in determining the load received by the knee joint. A short landing time without the ideal knee angle can increase the risk of injury, as the impact force is not well dispersed, increasing stress on knee structures such as the ACL and meniscus. This is reinforced by the findings of (Krosshaug et al. 2007), who stated that inefficient landing strategies increase knee joint loading and the risk of ligament injury, particularly to the ACL. Therefore, monitoring these kinematic parameters is essential for technique evaluation and injury prevention in badminton athletes.

Discussion

The analysis of injury risk in jumping smash movements in this study was carried out by utilizing Kinovea software version 0.9.5, which is a two-dimensional motion analysis video application that is widely used in sports biomechanics studies because of its ability to visually and accurately measure kinematic parameters on recorded sports movements (Id et al., 2019). According to (Irawan et al 2019), explaining that biomechanical analysis can help with knowledge of correct techniques and can provide performance evaluation, gradual monitoring and correction records that serve as references and are useful for developing and improving motion performance. This study focuses on the landing phase, which is one of the three main phases in the implementation of jumping smash techniques in badminton, namely the prefix phase, execution phase, and landing phase. The landing phase specifically starts from the time the player makes air contact (racket-shuttlecock) until the foot touches the floor and receives the full ground reaction force, and during this period, the knee flexion angle and valgus angle increased significantly. This indicates that the transfer of impact force to the lower extremities, especially the knees, occurs suddenly during the landing phase, making them susceptible to injury if the technique is not performed correctly (C. L. Hung et al., 2020). To evaluate the potential risk of injury in this phase, this study utilized three main indicators, namely landing time (s), right and left knee flexion angles (°), and distance between feet at landing (m).

Prefix Phase | **Kickback** **Drift** | **Landing Phase**

Implementation Phase

Figure 1. Stages of Jumping Smash

Figure 1 shows the stages of the jumping smash movement which consists of three main phases, namely the prefix phase, the execution phase (which includes repulsion and hovering), and the landing phase. In the start phase, players make postural adjustments to prepare for explosive movements, mainly through knee flexion and arm position. The execution phase of a smash is marked by the second push of the lower legs, which generates a vertical jump, followed by a floating phase where coordination between the body's center of mass and the position of the racket is key to maximizing energy transfer and hitting power (Li, Zhang, & Shan, 2023). The final phase, landing, demands good neuromuscular control to maintain body stability and prevent injury due to excessive impact force. A motorically uncontrolled landing can increase axial stress on the knee and ankle joints, so understanding the biomechanics of each movement phase is important for optimal performance and injury prevention (Fort-Vanmeerhaeghe et al., 2016).

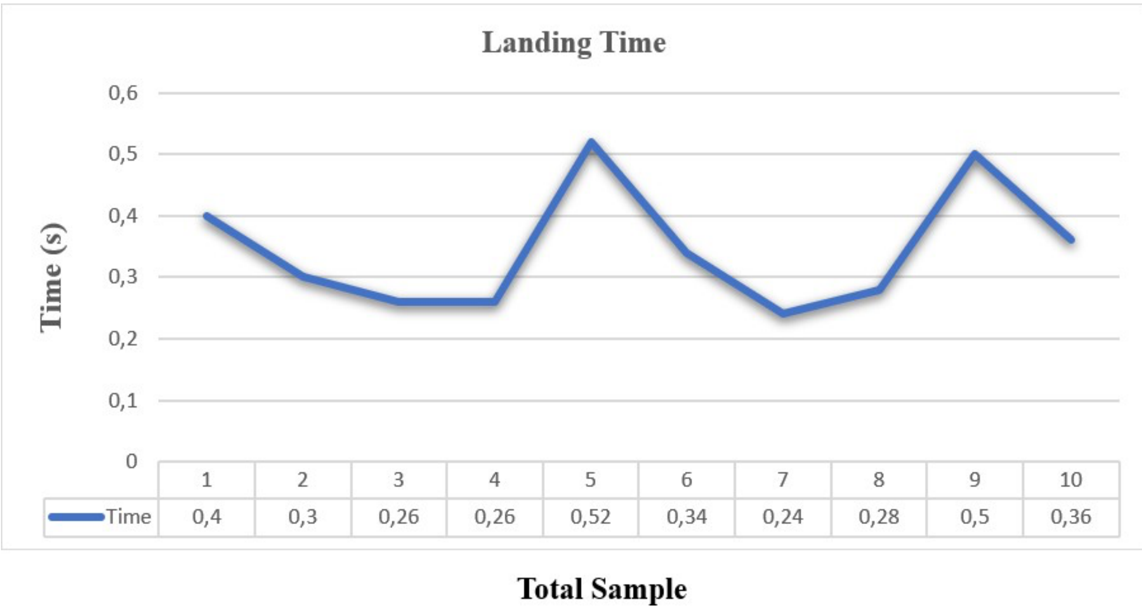

Figure 2. Landing Time Data

Figure 2 the analysis of the landing time indicator showed that the highest value was recorded by sample number 5, with a landing duration of 0.52 seconds, while the fastest duration was shown by sample number 1, with a landing time of 0.24 seconds. The overall average landing time of all samples was 0.346±0.09 seconds, which is generally within the range of time considered biomechanically safe. This finding indicates that most of the athletes who were the subject of the study have good neuromuscular control skills, especially in terms of regulating the moment of body contact with the ground after jumping smash. In this study, the ideal landing time range was found to be 0.20–0.36 seconds. This range is consistent with previous studies showing that the floating phase of a jumping smash generally occurs within the range of 0.20–0.30 seconds (M. H. Hung, Chang, Lin, Hung, & Ho, 2020; Ramasamy et al., 2024), while a duration of up to 0.36 seconds is still acceptable as efficient and safe as long as the landing technique is performed correctly, because in that time range the lower extremity muscles have sufficient opportunity to reflexively contract and absorb the impact force optimally.

Too short a contact time can increase the risk of injury as the muscles do not have enough time to contract and absorb reactive forces from the floor, so the load is passed directly to passive structures such as ligaments and cartilage. Conversely, landing times that are too long may reflect weak motor control and postural instability, which can decrease movement efficiency and increase the risk of overuse injuries. In this study, 70% of athletes demonstrated landing durations that fell within the ideal range, so they could be categorized as not at risk of injury on this indicator. Meanwhile, the remaining 30% showed landing times outside the ideal range, which means they have potential biomechanical risks, especially related to the ability of the muscles to withstand and redirect body weight in a balanced manner.

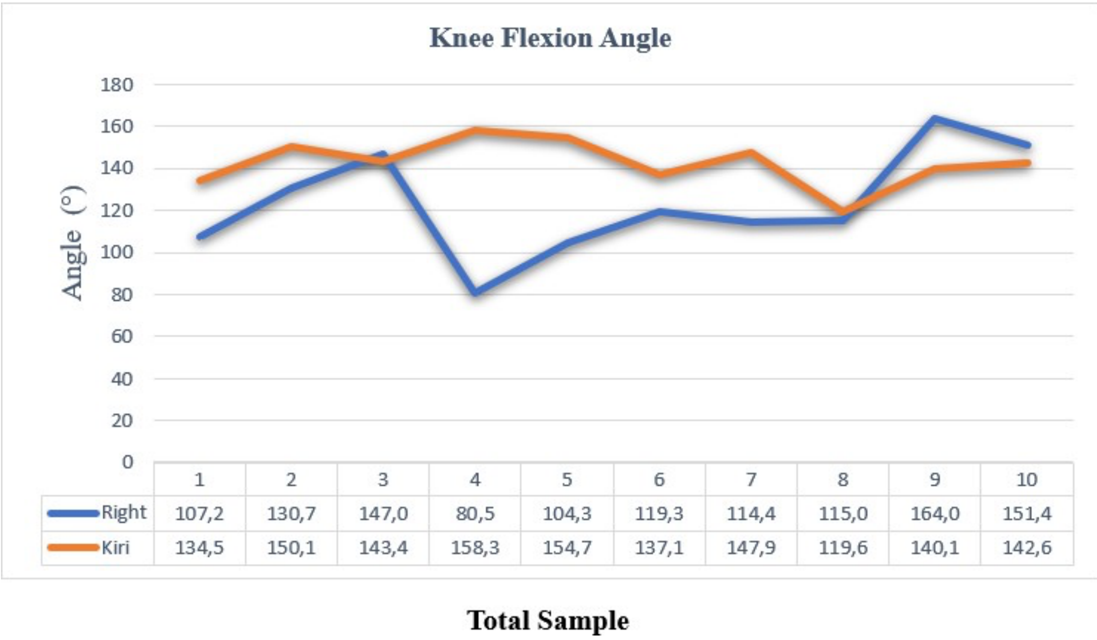

Figure 3. Data of Right Knee Flexion Angle and Left Knee Flexion Angle

Figure 3 the analysis of the right and left knee flexion angles during the landing phase showed a significant variation between individuals. The largest right knee flexion angle was recorded in sample number 9, which amounted to 164.0°, while the smallest value was obtained from sample number 4 with an angle of 80.5°. Meanwhile, the largest left knee flexion angle was also recorded in sample number 4, which amounted to 158.3°, and the smallest angle on the left knee was obtained from sample number 1 with a value of 134.5°. Overall, the average right knee flexion angle was 123.38°, while the average left knee flexion angle was recorded at 142.83 .°

On this indicator, the ideal knee flexion angle in a jumping smash movement is generally reported to be in the range of 85°–105°, which plays an important role in generating power while preventing injury. (Cui, Lam, Gao, Wang, & Zhao, 2022; Heebner et al., 2017; Purnama & Doewes, 2022; Ramasamy et al., 2024). The results revealed that only 10% of athletes had right knee flexion angles in the ideal category, and the remaining 90% still showed risky angle values, either because they were too small or too large. On the left knee, no athletes fell into the non-risk category, with 100% showing a flexion angle outside the ideal range. This suggests that both the right and left sides of an athlete's knee are equally likely to experience biomechanical imbalances during landing. This angle mismatch has the potential to disrupt load distribution in the knee joint and increase the risk of injury, especially to the anterior cruciate ligament (ACL) and meniscus structures (Ford et al., 2015). Although some athletes demonstrated reasonably good landing technique based on time duration, most still demonstrated potential injury risk based on knee flexion angle indicators. This finding was reinforced by a meta-analysis that confirmed that asymmetrical motion mechanics during landing contribute to an increased risk of ACL injury (Romero-Franco et al., 2020).

Figure 4. Distance between legs

Figure 4 shows one of the athletes in the landing phase after performing a jumping smash. It can be seen that the player holding the racket with the right hand rests on the left foot when landing. This pattern is consistent with the dominant use of the right hand to hit the shuttlecock, which is generally followed by the transfer of body weight to the left foot as the main support during landing. Although the momentum of the stroke produces a dominant load towards the right side of the body (racket foot), it is the left foot that receives the most impact force because it is the initial fulcrum when landing. This explains why knee injuries are more common in the non- dominant leg, especially among badminton athletes who often land on one leg after a smash.

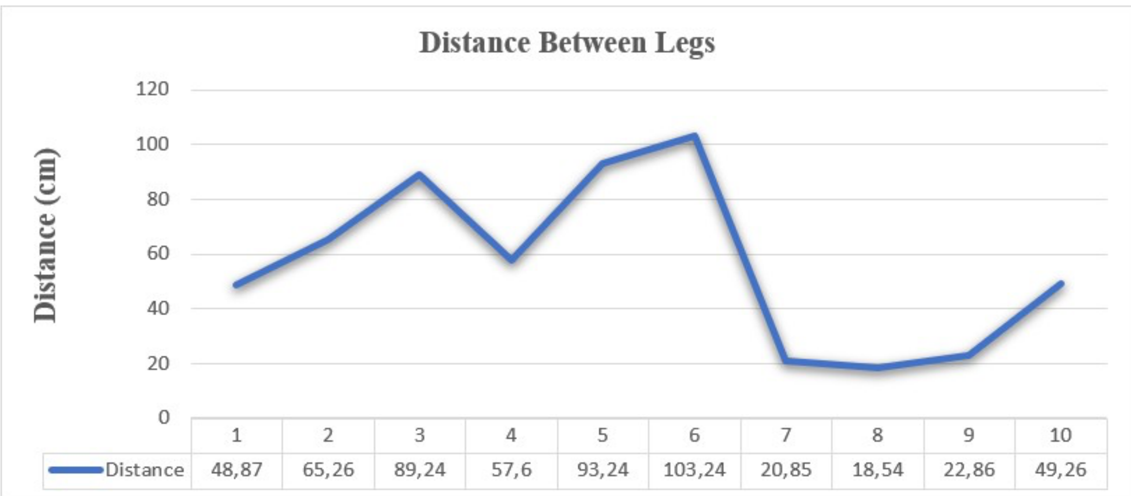

Figure 5. Data of Distance Between Feet

Figure 5 the results of the analysis of the indicator of the distance between the feet during the landing phase of the jumping smash movement show that there is a significant variation between athletes. The widest distance between the feet was recorded in sample number 6, which amounted to 103.2 cm, while the narrowest distance was obtained from sample number 7, which was 20.85 cm. From the overall data obtained, the average distance between the feet during landing was 56.896 cm, which is generally in the medium range. However, when reviewed based on the recommended safe range in sports biomechanics research, which is between 25 cm and 90 cm,. It was found that 60% of athletes were in the risk category, while only 40% of athletes landed in a foot position that was considered biomechanically stable and safe. According to (Teng et al., 2020), extreme foot positions during the landing phase increase the valgus moment of the knee. This increase in moment indicates uneven load distribution between the lower extremities and potentially increases the risk of injury to passive support structures such as the collateral ligaments, meniscus, and anterior cruciate ligament (ACL). This study found that, although the majority of athletes had landing durations that fell within the optimal range, biomechanical mismatches in the distance between feet upon landing remained a significant factor contributing to increased injury risk. This directly affects postural stability and the distribution of impact forces received by the body, potentially causing excessive stress on musculotendinous structures and joints, particularly in the lower extremity area.

Conclusions

Based on the results of the study, the risk of knee injury in badminton athletes is still relatively high, especially after performing jumping smash movements. Assessment of an athlete's movement performance cannot rely on just one indicator, such as landing speed, but must consider the relationship between biomechanical variables that influence each other. A mismatch between the knee flexion angle and the distance between the feet, even if the landing time is optimal, can still cause excessive stress on the knee joint. These three indicators-landing time, knee angle, and leg spacing-form a biomechanical whole that determines the stability of the posture and the body's ability to absorb impact forces. Therefore, it is important for athletes to receive proper and specific technical coaching, especially in terms of stable landing and optimal use of support muscles, so that the risk of injury can be effectively minimized.

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Conflict of interest

There is none

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