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# ORIGINAL

# IN-DEPTH GENDER-PERSPECTIVE EXAMINATION OF ACL INJURIES IN BADMINTON PLAYERS' ONE-LEG LANDING

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## ABSTRACT

Anterior Cruciate Ligament (ACL) injuries, which affect the knee's anterior cruciate ligament, are mutual in sports, especially among players who participate in activities that need rapid breaks and modifications in direction. Such injuries may require considerable rehabilitation and they can have a major influence on an individual's sports performance. This analysis intends to evaluate the ACL injuries in badminton players' one-leg landing. Thirty badminton athletes were involved in this investigation. Individuals back-stepped to the backhand side while simultaneously performing a striking motion overhead, landing on the impact plate with one leg, and then rebounding to the initial phase. Gender, weight age, height, and experience were all reported. Kinematics and kinetic information regarding the position of the left knee joint and impacting instances were collected. Those data were compared and analyzed by independent t-test employing the SPSS analytical tool. This investigation found significant kinetic and kinematics variations in the ankle joints, hip, and knee of individuals while landing in a risky position regarding ACL injuries. There were no substantial variations in the median age and badminton playing experiences. We determined that there is a significant association between female players' high knee value angles during risky landing positions and the probability of ACL injuries.

**KEYWORDS:** ACL, Injuries, Badminton Players, One-Leg Landing, Gender-Perspective.

## 1. INTRODUCTION

In badminton, an Anterior Cruciate Ligament (ACL) injury can be the riskiest lower extremities injury (Nagano et al., 2020). The majority of lower limb ACL injuries are non-contact in nature, making it the most prevalent form of injury. A higher frequency of this kind of injury generally occurs in fast sports involving diagonal slicing, bending, and landings (X. Zhou et al., 2022). The intricate competitive badminton sport requires frequent, forceful pauses, direction adjustments, and landings. Badminton is becoming more and more popular, bringing a lot of female athletes to play. Injuries associated with badminton are not well studied, despite its popularity. In badminton, injuries to the lower extremities are most prevalent. About 26 % of all injuries to the knee are ACL injuries, which are regarded as one of the most severe lower limb injuries (Arbonés et al., 2023; Shen et al., 2022).

### 1.1 Gender Disparity in ACL Injury Rates

According to earlier research (Zulfikri et al., 2021), female athletes experience ACL injuries around two to six times more frequently than male players. Playing badminton, women are more likely to suffer an ACL injury, much like players in other sports. Over a decade, studies on Injury to the ACL among players in their senior and junior years of secondary school revealed that the expectation was higher for women than for men to have an ACL injury $(1.36: 0.48)$, with players of badminton in senior and junior high schools that are women experiencing an ACL injury at a rate that was 4.2 and 4.8 greater than the number of male athletes by many times, respectively. To avoid such injuries, it is important to comprehend whether female badminton competitors are at greater risk of getting an ACL injury (Qin et al., 2023).

### 1.2 Risk Factors and Neurological Control

Researchers have investigated the gender variations in potential ACL injury hazard variables extensively because women players have a higher incidence of these injuries (L. Zhou et al., 2022). These risk factors include differences in anatomy, hereditary and neurological function among male and female athletes, as well as variations in menstrual and hormonal cycles. Neurological control elements have received much attention recently, mainly because they are easier to manipulate than the preceding components. These factors can be changed by their active behaviors (Liu et al., 2022).

### 1.3 Neuromuscular and Kinematic Variations

Determining the gender disparities in ACL risk rates could require a

comprehension of the kinematic and neuromuscular variations in particular actions (Kaldau et al., 2021). When professional soccer players, both male and female, performed unintentionally reducing landings, it was seen that the female gastrocnemius muscles were more active than the males. Furthermore, poor interaction patterns that result in abnormal knee postures could be linked to a higher incidence of ACL injuries in females. This is because muscle co-activation and knee stability are strongly related (Rangasamy et al., 2022).

### 1.4 Single-Leg Landing Maneuvers in Badminton

Badminton athletes' ACL injuries primarily develop in the landing on one leg alone maneuvers after a rearward side aerial motion, as different landing techniques in various activities result in distinct associated hazards for ACL injuries (Fu et al., 2021). Figure 1 depicts the process of left-leg landing maneuvers in badminton.

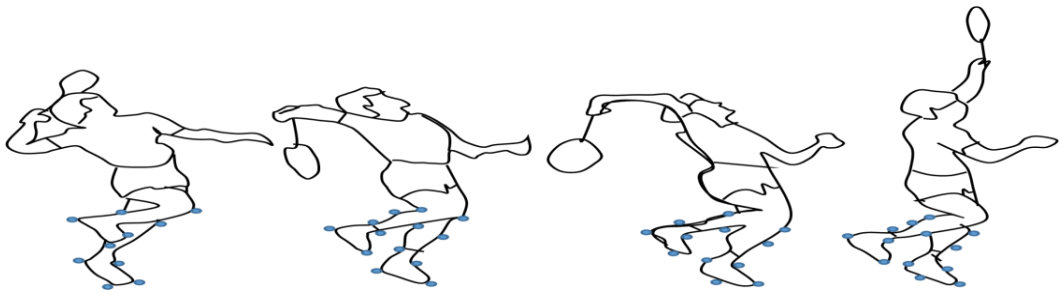

**Figure 1:** Process of left-leg landing

To explore the causes behind female badminton players' greater risk of injury in a left-leg landing phase associated with male athletes, researchers investigated sexuality variations in neurological control mechanisms throughout the post-impact period of landing (Herbaut & Delannoy, 2020).

### 1.5 Motivation of the Study

The different biomechanics and injury trends observed in men and women motivate research on injuries to the ACL in badminton athletes during one-leg landings from a gender perspective. Examining how anatomical differences, hormones, and movement patterns affect ACL injuries throughout landing provides valuable information for developing specific preventative and rehabilitation strategies for each gender. The specific objective of the focused strategy is to reduce the incidence and severity of ACL injuries among badminton players.

### 1.6 Contribution of the Study

- This study examines knee, ankle, and hip joints about ACL injuries experienced by badminton competitors during one-leg landing.

- This study looks at the kinetic variations in the landing leg of male and female badminton athletes and kinematics to emphasize the possible elevated risk of ACL injuries.

- According to the study, woman badminton players had higher (knee valgus angles and durations through single-leg landing), which raises the possibility of ACL injuries.

- ACL injuries could be decreased by customizing training programs and injury prevention tactics to the biomechanical variations between male and female badminton players.

- The following parts: A summary of the literature review is given in part 2, a more detailed description of the techniques is given in part 3 as well a discussion and analysis are presented in part 4. Part 5 provides a conclusion.

## 2. Related Works

The study (Zhang et al., 2023) aimed to characterize whether male and female competitors' legs and ankle rigidity varied according to gender throughout a single-leg land action that occurs after a handshake-lateral aerial view in the backline. In the test, eight male and eight female competitors competed. For both male and female athletes, leg and knee stiffness were measured individually during the landing phase. By examining the biomechanical differences between male badminton players' two legs when they fall on their ace leg, the paper (He, 2022) aimed to offer some recommendations for minimizing sports injuries. Ten male players of badminton were chosen to serve as the themes. They executed the one-leg foot strike maneuver 3 times with success. When it relates to badminton one-leg landing methods, a study (Zhang & Hu, 2023) suggested looking into possible explanations for why women experience a greater incidence of ACL injuries than men do. Using force plates, electromyography (EMG), a marker-based motion capture system along with lower limb kinematics and ground response forces, a total of sixteen people (eight men and eight women) participated in the badminton one-leg landing assignment. The paper (Hu et al., 2023) investigated the connection between the sequence of gluteal muscular contraction and dynamic (knee joint control) during high-risk badminton one-leg landing assignments. A one-leg landing test was executed by thirty-four badminton players following a backhand side overhead shot. Weak knee biomechanics signs might be a reason for worry regarding ACL damage during a single-leg landing job after an aerial badminton stroke, according to the article (Hu et al., 2022). It was claimed that a muscle control strategy-focused proactive program can alter the kinematics of the knee joint, reducing the chance of ACL injury. The research (Sasaki et al., 2022) analyzed the variations in each direction's amplitude based on landing a leg and ages, contrasting the

incidence of elevated trunk accelerations among junior and adolescent badminton athletes during single-leg landing following an overhead stroke. Thirteen junior and twenty-one teenage athletes and thirty-eight female badminton players participated in 2record matches while sporting a tri-axial accelerator on their back area. The purpose of the research (Kubasik et al., 2022) was to evaluate how young competitors, aged 10 to 12, responded to badminton instruction in terms of their knee's axial stability. The functional movement screens (FMS) were another tool used to examine the individuals. The research comprised one hundred sixteen youngsters. Sixty-eight kids who regularly played badminton made up the research group. The paper (Hung et al., 2020) examined the surprising way impacting orientation and striking movement affect landing mechanics following a backhanded laterally leap smash and landing, with a focus on joint rigidity coupled with torque variations in three lower limb joints. Full neurological rehabilitation may assist female badminton players perform better in their sport and lessen their asymmetry, according to the research (Zhao et al., 2021). Based on the functional movement screening pretest values, 38 participants were split into two groups: a low-risk group (LG) and a high-risk group (HG), with 22 and 16 individuals in each. Table 1 shows the relevant studies' purpose results and limitations.

**Table 1: (a)** Goals, Findings, and Constraints of literature review

| REF | OBJECTIVE | LIMITATIONS | FINDINGS |
|---|---|---|---|
| **(KURIHARA ET AL., 2024)** | The study investigated the link between school-age female badminton players' experiences with lower limb injuries and their dynamic balancing function, using the modified star excursion balance test as a screening tool. | The primary drawback of the study is its exclusive emphasis on female badminton players who are of school age. They can restrict the applicability of the results to other demographics or sports. | The study found a significant correlation between the modified Star Excursion Balance Test (mSEBT) and lower limb injury history, with the injury group having higher dorsiflexion angle and lower arch height ratios. |
| **(CHEN ET AL., 2022)** | The research determined performance and possible injury risks by calculating the decelerative kinematics and decrease in the joint force of contact during forward lunges in badminton. | The research included the use of the generic model provided by the Open Sim system, which is frequently researched in the literature. | In badminton, forehand lunges produced more horizontal deceleration of the mass center and torso than backhand lunges, quicker touchdown hip abduction, and higher compressional ankle contact force. |

**Table 1: (b)** Goals, Findings, and Constraints of literature review

| REF | OBJECTIVE | LIMITATIONS | FINDINGS |
|---|---|---|---|
| **(ROSTAMI ET AL., 2024)** | The present research displayed a quasi-experimental design since both the experimental group and the control group received an intervention. | The study's limitations include the inability to evaluate STOP-X program longevity among female basketball players and the potential for larger exercise screening samples. | Significant variations were seen in the variables of knee valgus angle, total dynamic balance score, and static balance among the groups for testing and control as a result of the STOP-X program. |
| **(GRACE ET AL., 2024)** | Todetermine if hamstring grafting combined with ACL repair (ACLR) results in decreased hamstring endurance nine to thirteen months after surgery. | The study examined the endurance of the hamstring muscles at increasing submaximal effort, potentially excluding other factors that might be contributing to declines in anterior cruciate ligament performance following reconstruction. | The hamstring endurance test revealed a statistically significant difference between the intact and damaged limbs of the ACL group, but not between the uninjured and control group legs. |
| **(PENG ET AL., 2023)** | To examine knee biomechanics and possible injury risks in badminton lunges, the study also looked at the effects of foot location and distance on in vivo knee performance in left-forward lunges. | The study's primary objective is to examine in vivo knee bone mobility using a dual fluoroscopy imaging system (DFIS); however, because of shooting perspective constraints, data on first contact and maximum flexion were gathered and analyzed independently. | The study found that while there was an increase in knee flexion, and ground response force (GRF), there was no appreciable change in knee muscle activation between the maximal lunge and external foot rotation. |
| **(SONG ET AL., 2023)** | The research evaluated trunk movement and external tissue disturbance in ACL injury films and investigated the relationship between regulated ACL activation and trunk movement tasks in persons without injuries. | The research struggled to capture movement in the horizontal direction due to lack of quantification, camera location mistakes, and issues, while 3D image-matching methods were limited to knee joints. | The study suggested that mid-flight external trunk disruption may increase ACL loading factors, potentially aiding in understanding ACL injury processes and developing screening and preventive measures. |

### 2.1 Problem Statement

The risk of ACL injuries in badminton athletes after certain strokes, like overhead shots, is a major issue when it comes to one-leg landing maneuvers. Female athletes continue to be more susceptible to ACL injuries despite developments in our knowledge of biomechanics and injury causes, which highlight the need for focused therapies. In badminton, the intricacies of ACL injury risks during one-leg landing necessitate a multifaceted strategy that incorporates neuromuscular training, biomechanical analysis, and injury prevention strategies specific to the demands of the game. Proactive programs that highlight joint stability, muscle control, and landing mechanics can lower the chance of injury to the ACL and enhance badminton players' performance, which benefits their long-term health and athletic achievement.

## 3. Materials and Methods

The paper examines how to reduce the probability of ACL injuries in badminton athletes by concentrating on the biomechanical elements and neuromuscular training strategies during one-leg landing approaches. The research will incorporate qualitative analysis of muscle control strategies and injury prevention initiatives with a quantitative assessment of landing mechanics employing motion capture systems, force plates, and electromyography. To collect information on joint kinematics, muscle activation structures, and landing strategy variations, a group of male and female badminton competitors will participate part in controlled landing activities. The objective of the study via strategies and resources is to offer data for focused actions that lower the risk of ACL injuries while enhancing player performance and safety. The examination found crucial kinetic and kinematics differences in the ankle joints, hip, and knee of individuals while landing in a risky position regarding ACL injuries.

### 3.1 Ankle Joints

Significant variability in ankle plantar flexion, eversion (valgus), dorsiflexion, and inversion (varus) angles have been identified in the research, suggesting that the ankle's response to landing forces varies, which could affect the likelihood of ACL injuries in badminton. Figure 2 shows the movements of ankle joints.

### 3.2 Hip

The hip joint movement patterns at dangerous landing postures were seen to vary, with notable variances in hip flexion, abduction, and external rotation angles. These variations can have an impact on the risk of ACL damage in badminton. Figure 3 shows the various movements of hip joints.

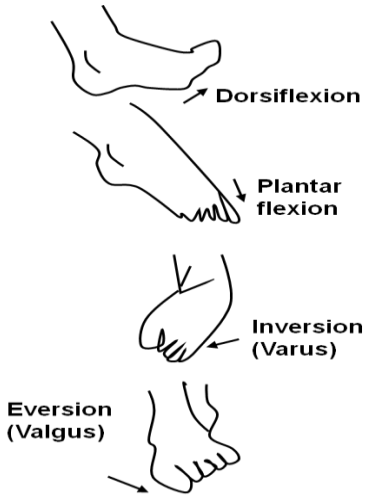


**Figure 2:** Ankle Joints

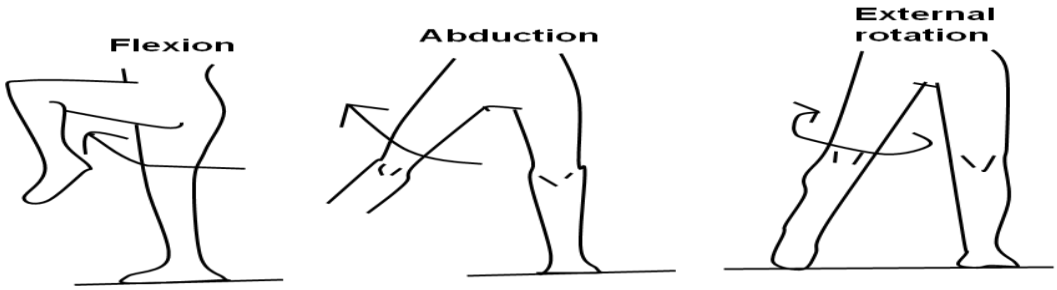


**Figure 3:** Hip joints

### 3.3 Knee

The study revealed unique kinetic and kinematic patterns in the angles and forces of the knee joints, suggesting different levels of strain and possible points of injury susceptibility during landing, especially with ACL damage causes. Figure 4 illustrates the movements of the knee force joints.

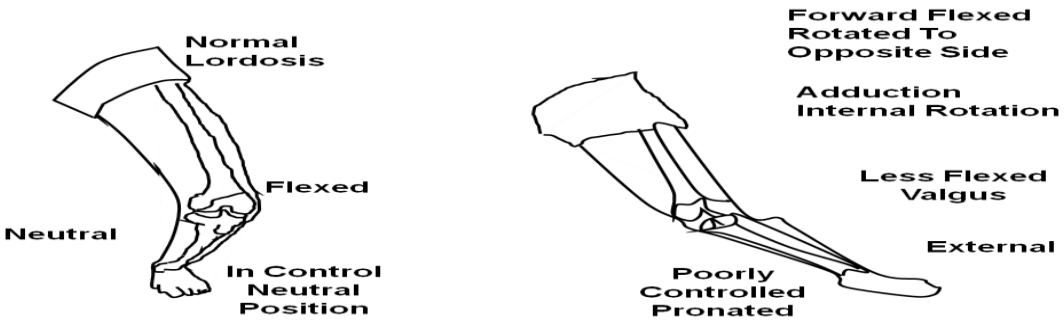


**Figure 4:** Knee joints

### 3.4 Participants

Thirty badminton athletes involved in this investigation, including fifteen male and fifteen female professional players of badminton, were involved in the research (Table 2). Examination of their medical histories revealed that each of

the participants had previous evidence of weakened muscles, restricted flexibility or movement in any joint, or surgery related to the trunk, spinal column, or extremities. Every participant used their right hand to hold the ball. Every participant in the research was given the informed consent agreement before commencing.

**Table 2:** Description of professional players

| FACTORS | FEMALE (N=15) | MALE (N=15) | $p$ VALUE |
|---|---|---|---|
| **AGE** | 24.35±5.12 | 22.56±2.34 | 0.310 |
| **WEIGHT** | 50.30±4.11 | 71.10±9.75 | 0.002 |
| **HEIGHT** | 152.50±4.92 | 169.10±3.52 | 0.000 |
| **EXPERIENCE** | 3.10±3.01 | 5.25±4.21 | 0.489 |

## 4. Experimental Equipment

The KISTLER 3-D force measurement equipment (Model No. 9287B) was used to collect the kinetic data. Exterior transmission amplification was part of its setup. A sample frequency of 1000 Hz was used. It gathered information in tandem with the system of VICON. The VICON ultraviolet high-speed recording of the motion device (Model No. T40), was used to collect the kinematics-related data. Ten infrared detectors with excellent resolution were part of the system. The sensor had a 14 mm diameter and a 200 Hz frequency of sampling. The Vicon Motion Capturing Camera Equipment was utilized to record the movements of the ankles, knees, hips, horizontal, forward, and transversal surfaces.

### 4.1 Research Action

A single-leg landing holding the ball overhead was the motion that was examined in this investigation. The challenger hits a sort of high ball called an overhead ball. A single arm should be raised above the head to prevent the ball in the backside or the middle of the pitch and the ball should be returned to the opponent's field. The striking point is over the head, the whole body leans backward, the front leg moves ahead, the left leg gets support from behind to keep balancing and the medial portion of the left leg touches the floor earlier than moving to the complete foot. Lower extremity injuries are common during the transition of the knee region stretching to its maximal position.

### 4.2 Testing Procedure

Proceeding to the actual test, every participant received a thorough explanation of the process and goal of the test. Furthermore, the basic information of participants was gathered, which included their gender, years of badminton experience, ages, height, and weight, (Table 1). Figure 5 simulates actions that are associated with an increased risk of ACL damage in badminton.

To complete the overhead strokes and a one-leg landing, each participant had to take a single step backward to the backhand side of the court for badminton, which has been linked to an extremely dangerous posture for ACL injuries. The study categorized the moment of landing as the time between initial impact on the plate of force and maximal knee flexion during testing, as ACL injuries frequently occur during this phase.

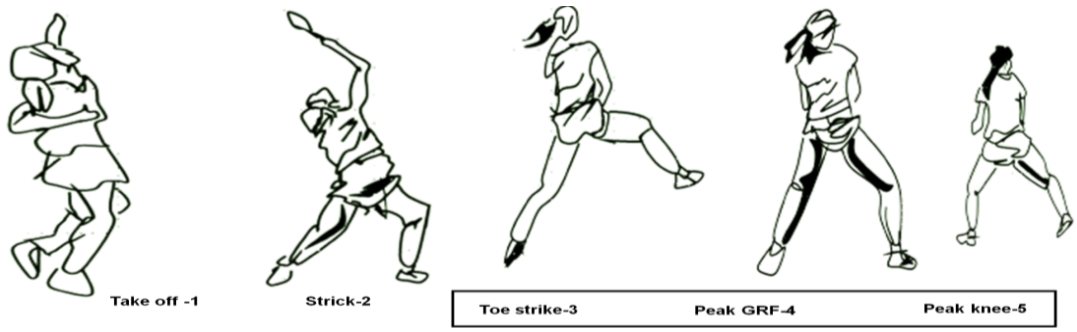


**Figure 5:** Standing on one leg during a backward aerial stroke

Individuals recruited the assistance of a skilled trainer to walk each participant through the correct test motions to reduce individual variations and guarantee the correctness of the experimental findings. It placed markings at an angle of 45° on the badminton court. They subsequently had to make a hasty trip back to the commencement. Before the official test, every individual was required to complete a 15-minute warm-up that included running, leaping, and many high-clear swings to lower their chance of injury. After that, participants were instructed to complete between 3 and 5 successful attempts, taking a 30-second break among each test to prevent exhaustion. The players participate with the identical shuttlecock and badminton racket, together with the same experimental supplies, to further reduce any possibility of mistakes in the experiment.

### 4.3 Data Analysis

The data was analyzed using an experiment that included the individual successfully landing inside the pressure plate despite overtaking the exterior. The Visual 3D software was used to evaluate the kinematics and kinetics statistics collected in the horizontal, frontally, and transversal plane of the hips, knee, and ankles joints. The results are shown as means standard deviation (SD) for each trial. The data analysis was limited to the force stage of landing following an overhead stroke since ACL injuries occurring without contact typically accidents in the initial phases of landing. The exact times of the left leg's initial contact (IC) and toe of landing (TOL) on the stance plate were first identified and their values were subtracted. The threshold values were set at 30 N. The landing impact phase was determined by measuring the distance between the toe's IC toward the ground to the maximum knee flexion (MKF). Every piece of information in kinematics was normalized for time and the force

stage was illustrated by a range of 0% to 100% as MKF. In the impact phase, the “dorsiflexion/plantar flexion, inversion/eversion and adduction/abduction angles of the left ankle at IC and MKF were ascertained from each trial, along with the flexion/extension, adduction/abduction and internal/external rotation angles of the left hip and the flexion/extension and varus/valgus of the left knee.” In the stance phase, the lateral/medial flexion, posterior/anterior, and tension/compression of the left ankle's angles at MKF and IC were ascertained from each trial. Exterior knee valgus energy peak values were taken from IC to MKF and normalized to body weight and height. By employing an independent t-test and T-tests in pairs with a crucial threshold of $p$=0.05, a mathematical evaluation of the kinematics and kinetic data between male and female badminton players was conducted using SPSS version 14 software.

## 5. Result and Discussion

### 5.1 Knee Variations

Assessing female badminton players to male players, the average length of the force stage was much shorter for the female players. MKF angle among male and female participants during the stance phase did not significantly differ ($p$=0.008). In the (Initial Contact-p=0.002), Maximum Knee Flexion ($p$=0.008), and maximum (knee valgus angle - p=0.006), the knee valgus angle was considerably greater in the women players than in the men players. Table 3 presents an overview of the kinematic alterations in the leg (knee joint) throughout the position period.

**Table 3:** Kinematics during the positioning stage in the Knee

| VARIABLE | MALE | FEMALE | P-VALUE |
|---|---|---|---|
| **EXTENSION (+) INITIAL CONTACT** | -24.32°±7.23° | -29.13°± 7.85° | 0.184 |
| **FLEXION (-) MAXIMUM KNEE FLEXION** | -61.62°± 11.64° | -58.14° ±7.68° | 0.425 |
| **MAXIMUM KNEE FLEXION TIME (% OF STANCE PHASE)** | 52.04% ±16.70% | 31.56% ±11.67% | 0.008** |
| **VALGUS (+) INITIAL CONTACT** | -5.14° ±4.34° | 5.10° ±6.89° | 0.002** |
| **VARUS (-) MAXIMUM KNEE FLEXION** | -9.32° ±6.98° | 4.37°± 11.95° | 0.009** |
| **MAXIMUM VALGUS ANGLE** | -3.96° ±4.26° | 7.62°±9.61° | 0.006** |
| **EXTERNAL ROTATION (+) INITIAL CONTACT** | -2.39° ±0.99° | -1.68° ±1.59° | 0.268 |
| **INTERNAL ROTATION (-) MAXIMUM KNEE FLEXION** | -2.71°±4.53° | -3.42° ±4.39° | 0.739 |

***Note:*** **makes an important distinction ($p < 0.05$), **makes a most crucial variation ($p < 0.01$)*

The maximum knee extension moment $(p = 0.043)$ and knee exterior rotation moment in $IC(p = 0.018)$ in female players were substantially greater than those in male players during the impact period. Male players' knee valgus

moments appeared to be lower than 'female players' during the force stage, this difference became significant in the $IC$ $(p = 0.034)$. Table 4 summarizes the variations in the knee joint moment during the impact period.

**Table 4:** Kinetic during the Force stage in Knee

| VARIABLE | MALE | FEMALE | P-VALUE |
|---|---|---|---|
| **EXTENSION (+) INITIAL CONTACT** | $-0.18 \pm 0.25$ | $-0.09 \pm 0.27$ | 0.435 |
| **MAXIMUM EXTENSION MOMENT** | $0.64 \pm 0.38$ | $1.06 \pm 0.48$ | 0.043* |
| **FLEXION (-) MAXIMUM KNEE FLEXION** | $0.29 \pm 0.44$ | $0.47 \pm 0.46$ | 0.346 |
| **VARUS (-) MAXIMUM KNEE FLEXION** | $0.17 \pm 0.17$ | $-0.02 \pm 0.25$ | 0.126 |
| **VALGUS (+) INITIAL CONTACT** | $0.04 \pm 0.13$ | $-0.09 \pm 0.14$ | 0.034* |
| **EXTERNAL ROTATION (+) INITIAL CONTACT** | $-0.05 \pm 0.08$ | $0.07 \pm 0.05$ | 0.018* |
| **MAXIMUM VALGUS MOMENT** | $0.19 \pm 0.15$ | $0.13 \pm 0.19$ | 0.317 |
| **MAXIMUM EXTERNAL ROTATION MOMENT** | $0.16 \pm 0.19$ | $0.13 \pm 0.09$ | 0.512 |
| **INTERNAL ROTATION (-) MAXIMUM KNEE FLEXION** | $-0.04 \pm 0.12$ | $0.06 \pm 0.08$ | 0.123 |

The variance in knee lateral Extension (+) Initial Contact/media Anterior (-) Maximum Knee Flexion force between Female and male players was seen in the IC, with a significant difference ($p$=0.003) between the two groups in the initial stages. When comparing female to male players, the maximum (knee) compression force was substantially higher ($p$=0.026). Table 5 provides a summary of the variations (knee joint force) during the impact period.

**Table 5:** Knee force during the impact phase

| VARIABLE | MALE | FEMALE | P-VALUE |
|---|---|---|---|
| **LATERAL (+) INITIAL CONTACT** | $-00.39 \pm 0.48$ | $00.45 \pm 0.49$ | 0.003** |
| **ANTERIOR (-) MAXIMUM KNEE FLEXION** | $-00.72 \pm 1.06$ | $-00.98 \pm 00.83$ | 0.566 |
| **MEDICAL (-) MAXIMUM KNEE FLEXION** | $-00.11 \pm 0.28$ | $-00.36 \pm 0.37$ | 0.167 |
| **POSTERIOR (+) INITIAL CONTACT** | $00.22 \pm 0.73$ | $00.33 \pm 00.89$ | 0.766 |
| **TENSION (-) INITIAL CONTACT** | $1.15 \pm 00.58$ | $00.61 \pm 00.6$ | 0.033* |
| **MAXIMUM POSTERIOR FORCE** | $00.96 \pm 00.39$ | $00.58 \pm 00.75$ | 0.173 |
| **COMPRESSION (-) MAXIMUM KNEE FLEXION** | $-1.25 \pm 2.05$ | $-2.18 \pm 1.99$ | 0.329 |
| **MAXIMUM COMPRESSION FORCE** | $-2.78 \pm 2.47$ | -5.70 $\pm$ 2.69 | 0.026* |

## 5.2 Hip and Ankle Variations

The hip flexion angles of male and female athletes during the impact

phase are contrasted using MKF in Figure 6(a). It indicates the female players' hip flexion angles were considerably lower than those of male players throughout the initial impact stage following the landing. This could be an indication of changes in muscle activation patterns or biomechanics since it demonstrates that their hips flex differently during this period of movement. The hip abduction angle after the impact phase utilizing the IC approach is a primary objective of the comparison in Figure 6(b). During the impact phase in the IC, female players' hip abduction angle was substantially less than that of male players. It suggests a variation in the way their hips proceed outward upon contact, which can be connected with management or support systems. The hip external rotation angles of male and female athletes throughout the impact phase are compared using MKF in figure 6(c). Female players showed significantly higher hip external rotation angles and hip internal turning angles in the MKF of the impact phase than male players. It suggests that there is a variation in the way their hips rotate or twist at this phase of movement.

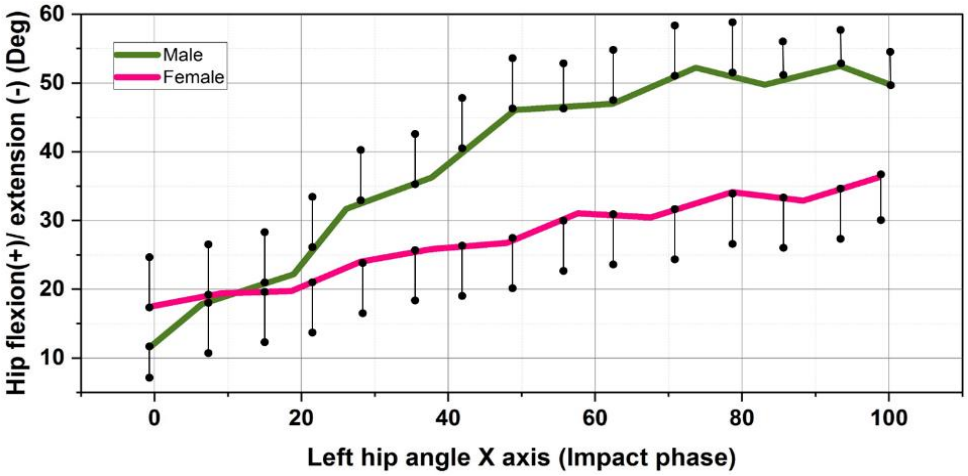


**Figure 6 (a):** Hip flexion (+)/ extension (-)

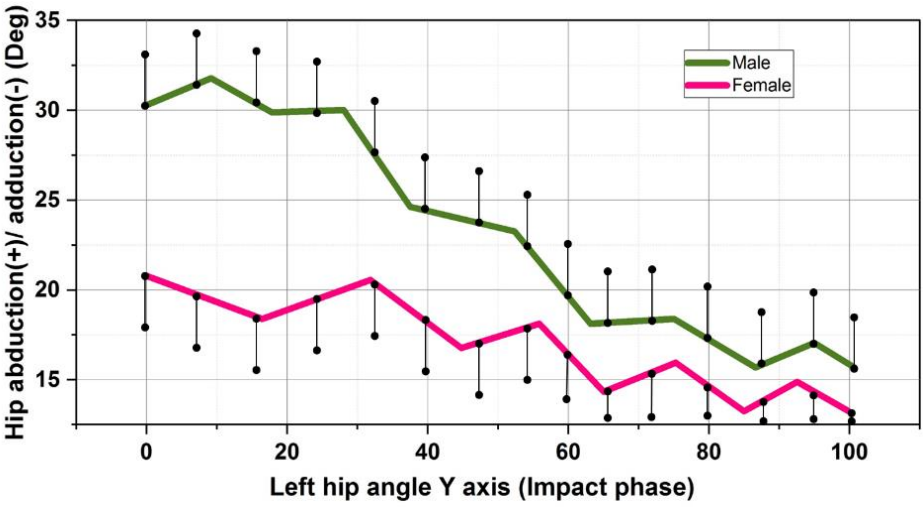


**Figure 6 (b):** Hip abduction (+) and adduction (-)

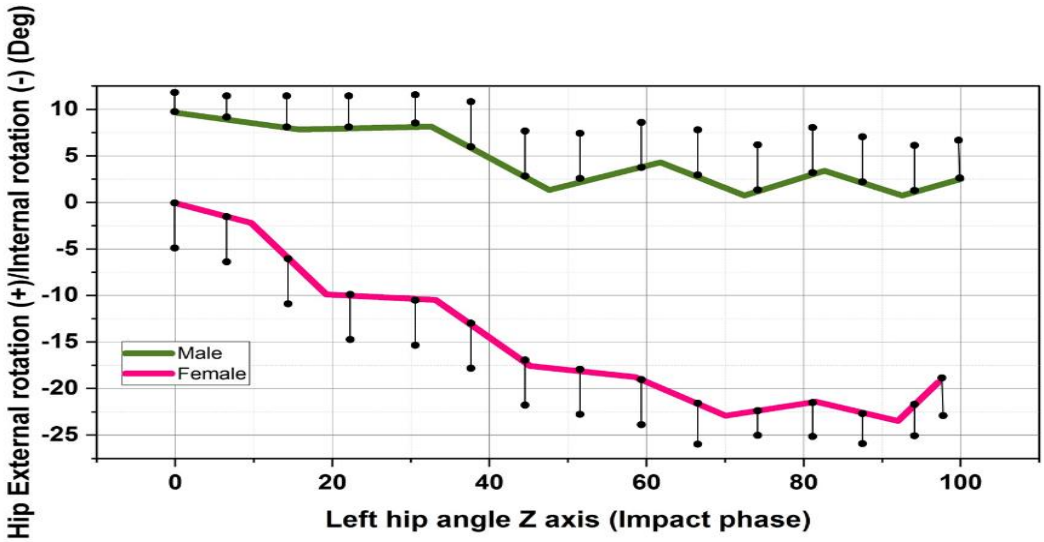


**Figure 6 (c):** Hip rotation, internal (+)/ external (-)

Ankle dorsiflexion angles throughout the IC employing MKF are the primary focus of Figure 7(a). During the impact phase in MKF, the female players showed significantly bigger ankle dorsiflexion angles. This suggests that there could be variations in the degree to which their ankles flex upward during contact, which might influence their stability or force-absorbing capacity. This pattern can be executed by Figure 7(b), which analyses yet another facet of joint motion or biomechanics. The findings can suggest that female and male athletes' knee flexion during landing differs significantly, which might be important information for comprehending landing mechanics and any injury concerns. The ankle inversion angles of male and female athletes throughout the IC are assessed using MKF in 7 (c). When compared to male players, female players demonstrated much greater ankle inversion angles. This implies a variation in the inward preference of their ankles during this stage, potentially impacting their balance and susceptibility to injuries.

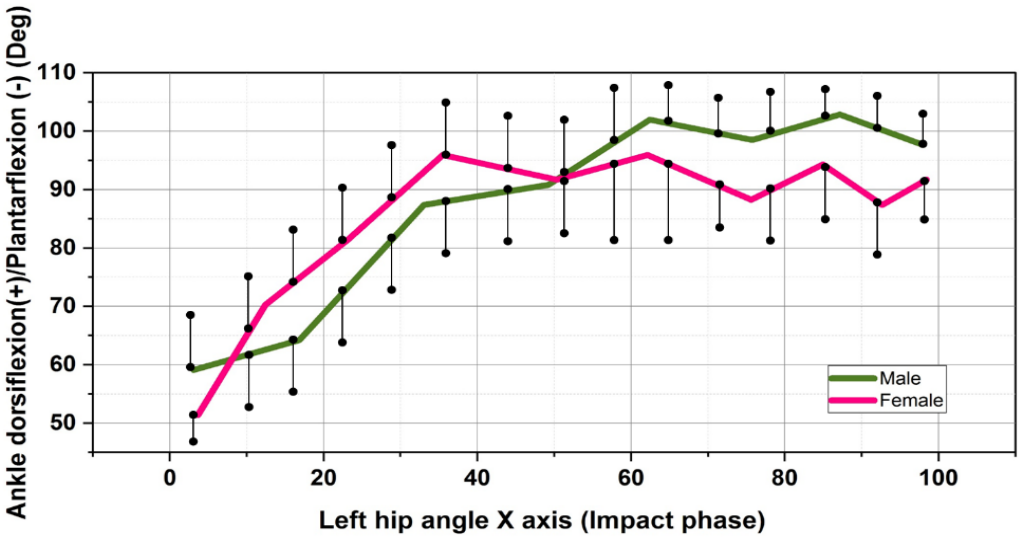


**Figure 7 (a):** Ankle of Dorsiflexion/plantar flexion

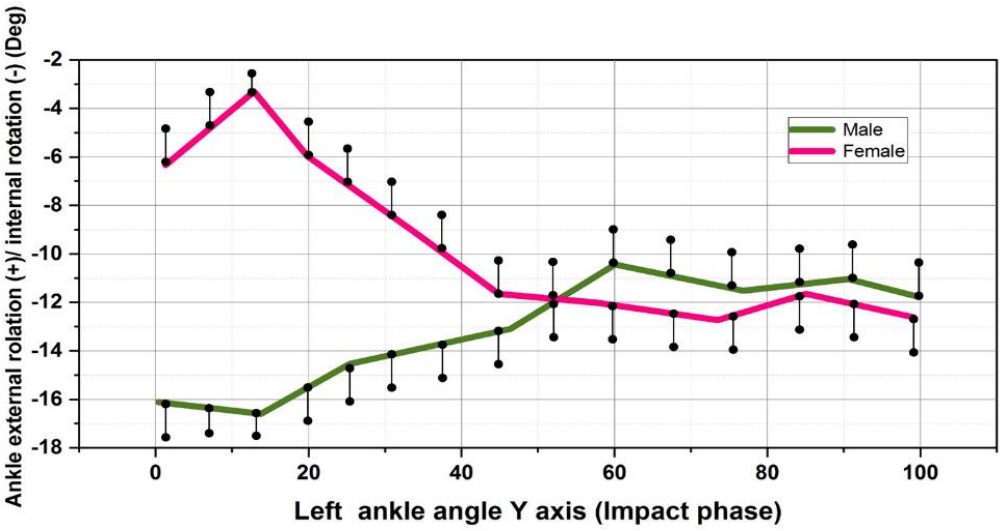


**Figure 7 (b):** Ankle of Adduction/abduction

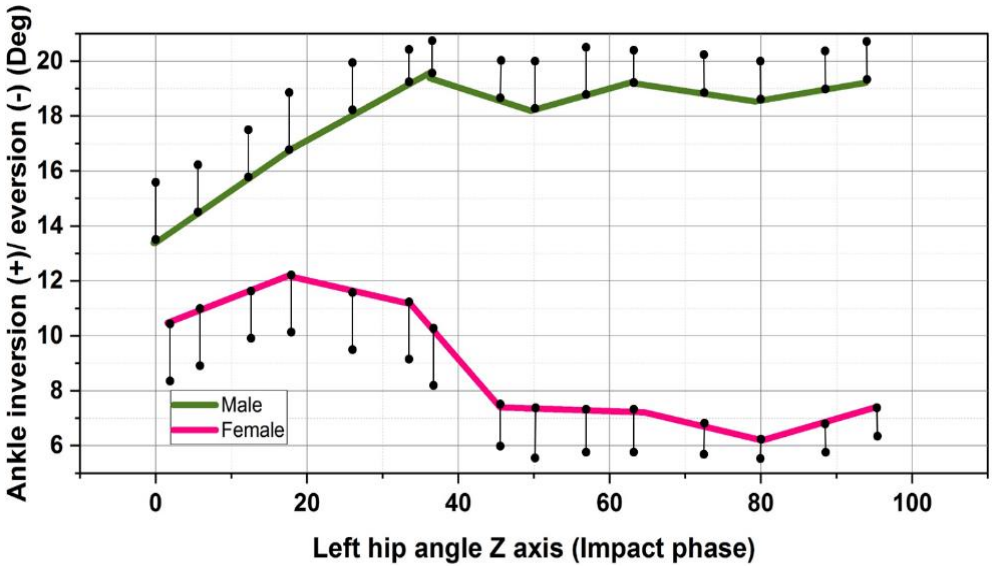


**Figure 7 (c):** Ankle of Inversion/eversion

The above findings represent crucial kinematic disparities among male and female athletes as they land and impact. In comparison, men and women often represented lower hip abduction, higher hip external rotation, bigger ankle inversion, and larger ankle dorsiflexion. These findings offer data regarding potential biomechanical differences that can influence performance and injury prevention, as well as gender-specific changes in hip and ankle joint motions throughout the IC of landing.

### 5.3 Discussion

The kinematic and kinetic variations between male and 'female badminton players' landing legs were investigated in the study. The ankle joints, knees, and hips during landing were demonstrated to differ significantly between male and female athletes. Male competitors had extended stance

stages and higher internal rotation angles; whereas female players displayed shorter stance phases, bigger hip external rotation angles, and more knee compression force.

The varus angle of the knee and the greater medial knee force individuals experience during the impact phase situate male badminton players at greater risk of ACL damage. The chance of ACL damage is reduced in female athletes, nevertheless, since they land with greater lateral force and a knee varus angle. Male and female athletes experience different injury rates, which cannot be attributed to a greater knee valgus position and instant landing. The landing force stage was characterized by lower hip abduction in IC and a lower ankle inversion angle in MKF for female participants. When making compensatory landing postures in high-risk badminton motions, female players employed an ankle inversion method rather than a hip joint in the plane of rotation. According to the study, 'female badminton players' greater knee valgus position, greater (knee lateral forces in IC) and higher compression force during impacts phases increase their risk of knee injury.

## 6. Conclusion

In badminton, one-leg landings following overhead strokes can cause anterior ACL injuries to the knees opposite the racket-hand side. Female badminton players showed a greater knee valgus angle than male players when landing single-leg in landing postures linked to ACL injury.

Although in both male and female badminton players, the greater valgus moment of the landing knee does not serve as a predictive factor for ACL injuries. Another important reason for the difference in ACL injury rates between male and female athletes is the simultaneous mechanical and dynamic changes in the joints at their ankles, knees, and hips. While age, weight, height, and experience had been given, the research did not consider additional variables like muscular strength, flexibility, or past injuries, which could influence the outcomes.

### 6.1 Limitations

The study's limitations included a small sample size, non-random subject acquisition, and scant information on the participants' muscular strength, girth, maximum jump elevation, calcium, mineral, and vitamin D profile. Additionally, landing force and data collecting could be impacted by restrictions in laboratory design and apparatus.

### 6.2 Future Research

Future attempts to reduce ACL injuries in female badminton players

need to take into account the enhancement of one-leg flexibility during the pre-landing practice stage.

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