Original Article

# Prevalence and Biomechanical Analysis of Knee Valgus and Knee Flexion Angle during Hop Test and Step-down Test among Badminton Players

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## Abstract

**Background:** The knee joint plays a crucial role in various badminton-related functional movements for both stability and mobility. Specifically, an optimal flexion and valgus angle upon landing tasks ensures less injury risk. **Aims:** Thus, the study aimed to investigate the prevalence and biomechanical analysis of knee joint flexion and valgus angle among badminton athletes. **Methods:** Sixty players were included in this study. The study conducted a two-dimensional biomechanical analysis using the Kinovea software to measure the knee flexion and valgus angle while hop and step-down tests, respectively. **Results:** The study found that for the 13–17 age group, the mean knee flexion angle is 109.8° ± 8.0° (right) and 112.9° ± 8.7° (left), whereas for the 18–25-year age group, it is 110.4° ± 10.1° (right) and 111.7° ± 9.6° (left). The knee valgus angle for 13–17 years is 11.0° ± 5.5° (right) and 11.1° ± 5.7° (left), and for 18–25 years, it is 12.6° ± 6.1° (right) and 11.9° ± 4.0° (left). The difference in knee flexion and valgus angle between legs or the age groups did not find statistically different ($P > 0.05$). **Conclusion:** The findings conclude that there was a high prevalence of increased valgus angle among badminton players. However, the flexion angle was found to be optimal. There was no meaningful differences in the knee joint alignments neither between both the legs and the age groups. The study findings can underscore the potential mechanisms and necessary training modifications by emphasising certain neuromuscular control trainings and optimal landing mechanics to ensure a safe and effective badminton-related mechanics, thereby reducing injury risks.

**Keywords:** Biomechanical analysis, knee flexion, landing mechanism, step down, valgus

## Introduction

Badminton is recognised as the second most popular sport in terms of participation, with over 200 million players worldwide engaging in the game at both recreational and competitive levels.[1] This high-intensity, intermittent racket sport requires a significant degree of technical skills, tactical awareness and physical fitness.[1] Players must perform a variety of demanding manoeuvres, including lunging, turning, sprinting, leaping, jumping and landing, all of which are essential for effective footwork and lower-limb movements.[2] In this context, a biomechanical analysis can provide valuable insights into how to enhance these movements.[2]

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Nearly 70% of injuries in badminton players occur in the lower extremities, with the knee joint accounting for over two-thirds of major injuries needing surgery, including fractures (2.6%), ligament tears (71.5%) and cartilage tears (20.3%).[3] This underscores the need for proper training and preventive measures to reduce injury risk.[3]

Landing is crucial in lower limb injuries, generating forces that can be two to twelve times an individual's body weight.

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This requires the joints to absorb significant mechanical shock, while surrounding soft tissues may sustain injuries from increasing impact forces.[4] Limited hip and knee flexion during landing can elevate frontal plane knee motion and moments, increasing knee loading and the risk of anterior cruciate ligament (ACL) injuries.[5] Higher quadriceps contraction at modest knee flexion, along with anterior shear and knee valgus loading, further strains the ACL. Thus, promoting optimal landing techniques that encourage adequate knee flexion is essential to reduce ACL injury risk in athletes.[4,6]

The importance of knee valgus and flexion angles in badminton athletes lies in their significant impact on injury risk and performance. Knee valgus, which involves the inward collapse of the knee, and the degree of knee flexion during dynamic movements such as lunges and landings, are crucial for understanding the loading and stability of the knee joint.[7,8] These factors are essential in preventing injuries, particularly ACL tears, and in enhancing athletic performance.[9] By focusing on these biomechanical elements, targeted neuromuscular training and technique adjustments can be implemented to reduce injury risk and improve lunge efficiency in badminton players.[9]

Excessive knee valgus in badminton can lead to significant consequences, including injury risk particularly, ACL tears, patellofemoral pain syndrome and osteoarthritis.[7] It is often a result of muscle imbalances and misalignments in the lower limbs, which are more prevalent among female athletes. Specifically, during single-leg landings, especially after overhead strokes, increased knee valgus alignment and moment can heighten the risk of ACL injuries.[7,8] This is particularly concerning during backhand-side landings, where the knee endures greater valgus stress, further elevating the likelihood of injury.[7,8]

Impaired knee flexion angle during landing in badminton, specifically a decreased knee flexion can result in reduced jump height and movement speed, which are crucial for effective gameplay.[9] In addition, a greater knee flexion during deeper lunges can elevate ground reaction forces and increase knee compressive and torque demands, further escalating the risk of injury when combined with other risk factors.[7,8] Thus, maintaining an optimal knee flexion angle is essential for balancing performance and injury prevention in badminton.

Understanding knee joint mechanics in badminton is vital due to the sport's demands on the lower extremities, which increases injury risk, particularly to the ACL.[3] Measuring valgus and flexion helps to quantify injury risk factors and identifying modifiable contributors such as trunk control and strength.[8,9] Elite players exhibit a more aggressive knee/ankle strategy with higher loading and better impact attenuation than amateurs.[10,11] Despite numerous thresholds and correlational values, the prevalence or descriptive factors are still debatable. Thus, analysing these angles aids in identifying high-risk movements and developing training programmes to enhance knee stability and reduce injury risks.

While analysing the movements, it was reported that, when three-dimensional (3D) analysis is not available, it has been shown that using two-dimensional (2D) video assessment of human movement is a valid and reliable alternative for measuring dynamic movement activities.[12]

Badminton players with optimal landing techniques and knee joint movement control are at a lower risk of injury, particularly ACL injuries, compared to those with uncontrolled knee movements, especially in valgus and flexion angles.[1,3,7,8] Despite the recognition of these risk factors, there is a lack of studies on their prevalence, particularly among Indian players. This study aims to assess knee joint flexion and valgus angles in badminton players during step-down and hop tasks using a 2D analysis method. The findings could inform injury prevention strategies to enhance player safety and performance.

## Methods

An observational study was conducted involving 60 badminton players selected from a local badminton academy in Bhubaneswar, Odisha. Before the commencement of the study, ethical clearance was obtained (ABS-IEC-2023-PHY-002). Written informed consent was obtained from all the participants before the commencement.

### Participants

The study was conducted from January to May 2024, during which 110 badminton athletes were screened using a convenience sampling method across various badminton clubs. A total of 60 participants, aged between 13 and 25 years and actively playing in clubs, were selected for the study and underwent video analysis. Participants with any recent fractures or musculoskeletal conditions – such as strains, sprains or dislocations occurring within the last 6 months – were excluded from the study.[13]

### Procedure

After being included in the study, participants were instructed to change into minimal, comfortable clothing. Men were asked to wear tight-fit pants or shorts along with a t-shirt, whereas women were instructed to wear tight-fit pants or shorts paired with a t-shirt. This attire was chosen to ensure proper placement of markers and for conducting the test procedure. Reflective markers were placed over the Anterior Superior Iliac Spine (ASIS), the midpoint of the patella and between the two malleoli of the ankle joint to accurately record the knee valgus angle in the frontal plane. To measure the knee flexion angle in the sagittal plane, additional markers were positioned over the greater trochanter of the femur, the midpoint of the lateral knee joint line and the lateral malleolus. A camera was set up on a tripod, positioned 3 m away from the participants on both the lateral and anterior sides, with its height adjusted to align with the athlete's ASIS level from the floor [Figure 1].[12,13]

The participants performed a step-down task in a forward direction while standing on a 20 cm height stepper for three repetitions [Figure 2].[14] As the task performed in a similar box height, those participants who could not able to make it were excluded from further analysis due to the increased box height.

Following this, they were instructed to complete a hop test, also in a forward direction, for three attempts [Figure 3].[15] Both procedures were carried out for each leg. A 2D video analysis was conducted to capture the starting and ending phases of the tasks. All tests were performed on a badminton court. During the hop task, the knee flexion angle was measured on the landing leg, whereas the valgus angle was assessed on the stance leg during the step-down task, using Kinovea software (version 0.8.24, Bordeaux, France).[12,14] Data from the video analysis were then processed to evaluate the participants' biomechanics, focusing on any significant differences between legs and identifying potential areas for improvement in their movement patterns.

### Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY, USA: IBM Corp. Normality of the data was found using the Kolmogorov–Smirnov test. Descriptive analysis was done using mean and standard deviation (SD). Descriptive analysis was done for demographic characteristics of participants, such as the age and gender variables, using *t*-test for continuous variables and the Chi-square statistics for categorical variables. Similarly, for the comparison of joint angles of flexion and valgus variables, between the sides and age groups *t*-test was used, and the significance level was set at $P < 0.05$.

The sample size was calculated using G*Power software (Version 3.1.9.7, Heinrich Heine University, Düsseldorf, Germany) using *a priori* computer required sample size using (level of significance as 0.05, power of the study as 0.80 and at a lower effect size as 0.28). In addition, 10% dropouts were added to the calculated size, and the final sample size was considered as 102.

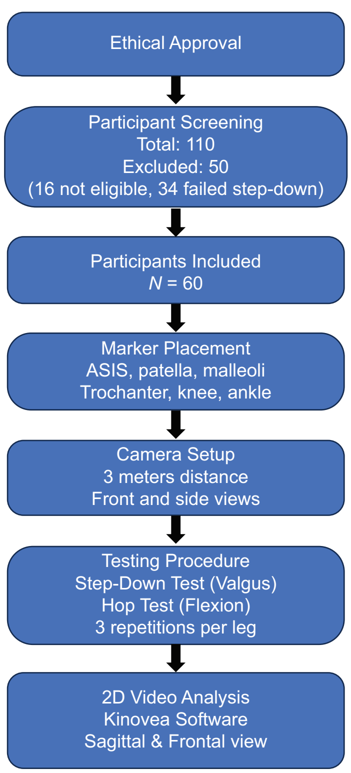


**Figure 1:** Study flow chart

## Results

The present study examined the prevalence and biomechanical analysis of knee valgus and knee flexion during the step-down test and hop test in badminton players. A total of 102 participants were required based on sample size estimation, and 110 individuals were screened for inclusion

**Table 1: Demographic characteristics**

| Age\gender | Age | Males | Females | Total |
|---|---|---|---|---|
| 13–17 years | 14.8±1.3 | 15 | 15 | 30 |
| 18–25 years | 23.4±2.0 | 14 | 16 | 30 |
| Total | | 29 | 31 | 60 |

**Table 2: Baseline comparisons**

| Variables | 13–17 years | 18–25 years | *P* |
|---|---|---|---|
| Age | 14.8±1.3 | 23.4±2.0 | <0.001 |
| Gender (male:female) | 15:15 | 14: 16 | <0.001 |

**Table 3: Joint angles (right vs. left side comparison)**

| Joint angles | Age group | Right (°) | Left (°) | *P* | 95% CI |
|---|---|---|---|---|---|
| Knee valgus | 13–17 | 11.0±5.5 | 11.1±5.7 | 0.94 | −2.79 to 2.99 |
| | 18–25 | 12.6±6.1 | 11.9±4.0 | 0.60 | −3.36 to 1.9 |
| Knee flexion | 13–17 | 109.8±8.0 | 112.9±8.7 | 0.15 | −1.21 to 7.41 |
| | 18–25 | 110.4±10.1 | 111.7±9.6 | 0.61 | −3.79 to 6.39 |

CI: Confidence interval

**Table 4: Joint angles (between age group comparison)**

| Joint angles | Age group | Mean difference (SE) (right) | *P* |
|---|---|---|---|
| Knee valgus | 13–17 | 1.6±0.50 | 0.29 |
| | 18–25 | | |
| Knee flexion | 13–17 | 0.60±2.35 | 0.79 |
| | 18–25 | | |

SE: Standard error

**Figure 2:** Forward step down test (knee valgus)

**Figure 3:** Hop test (knee flexion)

and exclusion criteria. Out of these, 16 participants did not meet the criteria, leaving 94 participants recruited for the study. However, 34 participants were unable to complete the step-down test due to the height of the box being too high. Consequently, the result analysis was conducted on 60 participants.

The study involved 60 participants aged 13–25, divided into two groups: 13–17 years (30 participants: 15 males and 15 females) and 18–25 years (30 participants: 14 males and 16 females). The mean age for the 13–17-year age group was 14.8 years (SD ± 1.3), whereas for the 18–25-year age group, it was 23.4 years (SD ± 2.0) [Table 1].

The baseline comparison of demographic variables such as age and gender was not baseline comparable ($P < 0.05$). For the age group of 13–17 years, the recorded knee flexion angles were 109.8° ±8.0° for the right leg and 112.9° ±8.7° for the left leg. In the 18–25-year age group, the knee flexion angles were slightly higher, measuring 110.4° ±10.1° on the right leg and 111.7° ±9.6° on the left leg [Table 2]. The comparison of knee flexion angle between right and left leg did not change statistically in both the age groups ($P > 0.05$) [Table 3]. Similarly, the mean difference score of right leg flexion angle between the age group (1.60 ± .50) was also not statistically significant ($P > 0.05$), [Table 4]. Regarding knee valgus angles, the 13–17-year age group showed values of 11.0° ±5.5° on the right leg and 11.1° ±5.7° on the left leg. In contrast, the 18–25-year age group exhibited knee valgus angles of 12.6° ±6.1° on the right leg and 11.9° ±4.0° on the left leg [Table 2]. The comparison of knee valgus angulation in the right and left sides in both the age groups was not statistically different ($P > 0.05$) [Table 3]. Similarly, the mean valgus angle difference (0.60 ± .35) between both the age groups was also not found statistically meaningful ($P > 0.05$), [Table 4].

## Discussion

The study analysed the biomechanical characteristics of knee joint flexion and valgus angles in sixty badminton players across two age groups during hop and step-down tests. Using 2D biomechanical video analysis method, the research revealed significant differences in landing tasks that may heighten knee injury risks. These results are consistent with Kimura *et al*., which used 3D analysis to examine knee valgus momentum during single-leg landings, identifying impaired trunk movement and muscle strength as contributing factors to increased valgus angles and injury risks.[8] The average knee joint flexion angle during the hop test reported was 109.8° for the 13–17-year age group and 110.4° for the 18–25-year age group of badminton players. These results align with a 2020 study by Christensen *et al*., which reported an average peak knee flexion angle of 97.2° using 2D video analysis with Kinovea software.[16] A study by Kaldau *et al*. (2021) found that reduced knee flexion during landing increases load on the Achilles tendon in Danish badminton players.[17] Huang *et al*. reported an average knee flexion angle of 64.08° at initial contact during lunges.[18] Another study on jump smash techniques noted an average knee flexion–extension angle of 33.16°.[19] Yeap *et al*. found an average knee flexion angle of 18.4° at foot contact, peaking at 58.0° during jump smashes in Malaysian players.[20] Hung *et al*. reported an average knee flexion angle of 15.27° at landing initial contact, with a maximum of 68.26°.[21] Feng *et al*. (2024) found a mean knee flexion range of 61.62° in single limb landings among Korean players.[22]

The findings on knee flexion range vary among studies due to task selection and measurement phases. This study reported an optimal knee flexion angle during hops, indicating a better landing strategy that reduces injury risk and enhances joint stability in badminton players. This optimal control is likely due to effective strength training of the hamstrings and quadriceps. The hop test assessed knee flexion during landing, providing insights into performance, injury risk and rehabilitation outcomes, and significantly affecting lower limb biomechanics during landing and take-off phases.[15,23,24] The hop test was selected because the knee joint flexion angle during hopping is crucial for evaluating performance, assessing injury risk and guiding rehabilitation. This angle significantly influences the biomechanics of the lower limb during both landing and take-off.[23,24]

The average frontal plane valgus angle for badminton athletes is 11° and 12.6° for ages 13–17 and 18–25 years, respectively. Normal knee joint valgus angles typically range from 7° to 10° during descending phases. Comparatively, existing studies indicate a concerning prevalence of excessive valgus angles among badminton players, increasing the knee injuries risks.[10,13,25] Hung *et al*. reported an average frontal plane knee valgus angle of 8.75° to a maximum of 12.94° during single limb landings in badminton players.[21] A jump smash analysis in Malaysian players showed peak valgus angles of 4.7°–9°,[20] whereas a study on Chinese players found an average of 4.42° during jump smashes.[19] The average knee joint valgus angle during single limb landings, related to ACL injury risk, was 5.14°.[22]

The valgus angle during the step-down task was greater than previously reported. Given the physical demands of single-leg step-downs compared to jump landings, players should exhibit better frontal plane knee control. Excessive frontal plane movements may increase the risk of lower limb injuries, likely due to insufficient practice, training or lack of neuromuscular control training in their routines, which often focus solely on strength training.

The comparison of knee joint flexion and valgus angle between legs and age groups showed no significant differences ($P > 0.05$). Similarly, Feng *et al*. (2024) found no significant differences between male and female badminton players during single-limb landing tasks ($P > 0.05$).[22] However, studies on different badminton strokes and smash techniques and with different movement speed and situations reported significant differences ($P < 0.05$).[19-21] It can be hypothesised that the consistent task and movement demand during the biomechanical analysis led to a statistically non-significant difference among age groups and legs.

The increased mean frontal-plane valgus angles observed in this study align with findings from other Indian and Asian sports biomechanics research. Lateral jump-smash actions in badminton resulted in higher lower-extremity loads, similar to our findings of increased valgus during step-down tasks.[26] Sasaki *et al*. noted age-related differences in trunk acceleration and single-leg landing control among badminton athletes, which supports our observation of slightly higher valgus angles with age due to training adaptations.[3] Pardiwala *et al*. highlighted that Indian badminton players often face knee injuries related to valgus and torsional loading, despite demonstrating adequate knee flexion during jumps.[27] Our results also showed optimal knee flexion for shock absorption, indicating a need for training to enhance frontal-plane stability and prevent injuries.

Our study has limitations. Although our sample size met the criteria and was comparable to previous studies, larger samples could improve the analysis. The height of the box used in the step-down test posed challenges for individuals aged 13–15, suggesting a height-adjustable box is needed. Future research should compare gender and age and include subjects who are ACL-deficient or at risk of knee injuries. Incorporating electromyography could reveal muscular imbalances, and examining experience and training may help develop injury prevention programs for badminton players. Future studies should also assess knee joint angles during badminton-related tasks and the knowledge and practices of knee joint control among athletes and staff. In addition, confounding variables such as foot pronation and pelvic drop angle were not controlled in our study, and addressing these in future research would enhance the understanding of knee injury mechanisms in athletes.

## Conclusion

On analysing the movement mechanics of knee joint flexion and valgus angle in badminton players, the study findings conclude that there was notably increase in valgus knee joint angulation as per the previous reference standards during the step-down task. On the contrary, the flexion angle was found to be optimal. Similarly, on comparing the joint among the age groups or between legs, there were no meaningful differences. These findings underscore an improvement in the landing mechanics during the descending task, especially the medial knee joint projection angle through the addition of neuromuscular control trainings to their routine regimen rather than focussing only on strength factors to optimise the mechanics. Similarly, the athletes or the team members can be made aware of the importance of knee joint medial angulation as an injury risk in badminton during the landing tasks.


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### Conflicts of interest

There are no conflicts of interest.

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