Postural control impairment in young competitive badminton players with knee injuries: A comparative study on balance deficits

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ABSTRACT

Balance is critical, particularly in high-paced sports like badminton, where quick movements are frequent. The purpose of this study is to explore how knee injuries affect the balance, both static and dynamic, of badminton players compared to their healthy counterparts. This cross-sectional study recruited 80 male badminton players with 40 in the knee injury group (KIG) and 40 in the healthy group (HG). Static and dynamic balance was analysed using balance error scoring system (BESS) and Y-balance test (YBT) respectively. An independent t-test was used to analyse the significant difference in both static and dynamic balance between two groups. BESS showed significant difference between both groups in tandem stance (p = .00) and total BESS scores on the firm surface (p = .00). The YBT showed significant changes only in the anterior direction between the group, for dominant leg (p = .001) and non-dominant leg (p = .001). No significant differences were observed in other directions. Players with knee injuries show postural control impairments, including higher errors and reduced anterior reach exhibiting a potential health risk. These deficits compromise static and dynamic balance, emphasizing the need for targeted balance training and rehabilitation intervention.

Keywords: Sport medicine, Dynamic balance, Sports performance, Postural stability, Knee pathology, Health risk.

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INTRODUCTION

Maintaining postural stability and dynamic balance is essential for athletes, especially in sports characterized by quick movements and abrupt changes in direction, such as badminton. Postural stability is the capacity to keep the body's centre of mass within the base of support, while dynamic balance is the ability to manage body position while in motion (Malwanage et al., 2022).These elements are vital for achieving the best possible performance and avoiding injuries in badminton, a sport that requires agility, rapid reaction times, and accurate footwork. Research has indicated that lower limb injuries make up 40-80% of all badminton injuries, with the anterior cruciate ligament being the most severe damage to the lower limb (Marchena-Rodriguez et al., 2020). The most prevalent injuries among badminton players are knee joint, followed by injuries to the back, ankle joint, and knee joint (Kang & Ramalingam, 2018). The most prevalent knee joint injury is the anterior cruciate ligament (ACL) damage, with noncontact incidents accounting for 70% of all ACL injuries. Landing and sudden changes in direction primarily cause these injuries (Reeves et al., 2015).

Competitive badminton players often sustain lower-limb injuries, including knee injuries, which can affect their postural stability and dynamic balance (Pardiwala et al., 2020). Knee joint injuries can result in reduced proprioception, decreasing muscle strength and impaired neuromuscular control. The sensorimotor system primarily governs the functional stability of the knee joint during voluntary movement. As a dynamic system, it plays a role in transmitting and combining somatosensory, vestibular, and visual information to the central nervous system, allowing for adaptation to the environment (Solomonow & Krogsgaard, 2001). Changes in incoming sensory information, which could be due to damage to mechanoreceptors around the joint, can then lead to disruptions in sensorimotor control (Adachi et al., 2002). These factors can have a detrimental effect on an athlete's balance and their ability to perform the quick, multi-directional movements necessary in badminton (Alikhani et al., 2019). Nevertheless, conflicting results suggest that these changes may not necessarily be associated with the ability to maintain balance while standing (Lee et al., 2015). Earlier literature observed a significant relationship between previous lower limb injury and dynamic balance using modified star excursion test (Kurihara et al., 2024). Evidence strongly indicates that individuals with lower limb injuries experience a significant decrease in postural stability. In addition, the degree of sway during single leg stance was considerably increased in the group with lower limb injuries compared to the healthy individuals (Lehmann et al., 2017).

Understanding the differences in postural stability and dynamic balance between badminton players with and without knee injuries can inform targeted rehabilitation and injury prevention strategies. Previous research has highlighted the importance of footwork and agile reactions in badminton performance (Kuo et al., 2022). Studies have also emphasized the role of anthropometric factors, such as arm length and wrist flexibility, in determining badminton skill level (Jaworski & Żak, 2015). However, there is a paucity of research directly comparing postural stability and dynamic balance between young, competitive badminton players with and without knee injuries. In view of this, the current study aimed to investigate the difference in static and dynamic balance between injured and non-injured young competitive badminton players.

METHODS

Participants

This cross-sectional study recruited 80 young male competitive badminton players, aged between 18 and 25, from 4 local badminton academic clubs in the Klang valley, Malaysia. The participants were selected using a purposive sample method. To meet the inclusion criteria the participants must be registered academic club players, have competed in at least two national tournaments, experienced a knee injury and had caused them to stop participating in sports and cured 6 months before the beginning of this study. Participants with the history of vestibular disorders, lower limb fractures and surgery were excluded from the study. The participants were allocated into two groups of 40 each: the knee injury group (KIG), consisting of participants who have previously suffered a knee injury, and the healthy group (HG), consisting of individuals who have not encountered any knee injuries.

Sample size estimation

The required sample size was determined using the GPower 3.1 software, and it was observed to be 40 participants in each group, keeping the effect size (ρ) of 0.3, using a two-tailed test with a power of 0.80 (1-β) (Faul et al., 2007).

Ethical approval

The study obtained ethical approval from the Institutional Research and Ethical Committee with reference number INTI-IU/FHLS-RC/BPHTI/7NY12022/004 prior to commencing the project. The objectives, potential benefits, and risks of the study were explicitly communicated to all participants, and their informed consent was obtained.

Outcome measurement

Balance Error Scoring System (BESS)

The BESS has moderate to good reliability to assess static balance (Bell et al., 2011). The balance assessment involves three postures performed on two distinct surfaces: a firm and a foam surface. The three postures consist of the double leg stance, single leg stance, and tandem stance. The athlete will assume a stance with hands placed on hips, eyes closed, and feet consistently positioned according to the chosen stance, without wearing shoes. In the double leg stance, the feet are positioned flat on the testing surface, with approximately the width of the pelvis between them. During the single leg stance, the athlete should balance on their non-dominant leg while keeping the opposite leg bent at the hip by about 20°, at the knee by about 45°, and in a neutral posture in relation to the body's side-to-side movement. In the tandem stance, one foot is placed in front of the other with heel of the anterior foot touching the toe of the posterior foot. The athlete's non-dominant leg is in the posterior position. The duration of the trial is 20 seconds. Determine the quantity of errors while maintaining the correct posture. The examiner should commence counting mistakes once the individual has taken up the appropriate testing posture. When numerous faults happen simultaneously, just one of them is considered. The maximum allowed number of errors for a single condition is 10. A number ranging from 0 to 60 is used to measure balance and error rate, with lower values indicating greater balance and fewer errors. The sum of errors in each trial is calculated to determine the final score, which is measured on a scale of 60.

Y Balance Test (YBT)

The Y Balance Test (YBT) is a test that assesses dynamic balance and risk of injury by having the athlete balance on one leg and reach as far as possible in three directions: anterior, posteromedial and posterolateral. The athlete should be directed to place their hands on their hips and slide the first box forward using their right foot as far as possible before returning to the starting position. The distance reached must be measured in centimetres. They must then repeat this process with the same foot three times. Once they have successfully completed three reaches with their right foot, they may proceed to do the same with their left foot. When the athlete has completed three successful reaches on both feet, they can move on to the next direction for testing. The YBT showed good interrater test-retest reliability with an acceptable level of measurement error among multiple raters with excellent reliability (ICC = 0.88- 0.99)(Shaffer et al., 2013).

The relative reach distance was calculated using by: Relative reach distance (%) = Absolute reach distance / limb length * 100.

Data analysis

The data collected were analysed using IBM SPSS Statistics, version 26.0 (IBM Corporation, Armonk, NY, USA). Continuous data was represented in mean and standard deviation. An independent t-test was employed to analyse the significant difference in static and dynamic balance between two groups.

RESULTS

A total of 40 subjects in this study with a mean age of 20.70 ± 2.68 years, with BMI 21.90 ± 2.69 were recruited. Their mean training days are 5.27 ± 1.63 per week, with 14.17 ± 5.69 of training hours. The subjects participated in approximately 2 competitions per month. The demographic characteristics of the participants for the two groups were presented in Table 1.

Table 1. Demographic of the participants.

	KIG (N = 40) (Mean ± SD)	HG (N = 40) (Mean ± SD)
Age	21.90 ± 2.47	19.70 ± 2.35
BMI	22.62 ± 2.90	21.36 ± 2.39
Training days/week	5.35 ± 1.61	5.15 ± 1.74
Training hours/week	15.63 ± 4.75	12.67 ± 6.30
Competitions/month	2.30 ± 0.46	2.15 ± 0.53

Note. BMI- Body Mass Index, SD- Standard deviation.

Table 2. Comparison of balance tests scores between injured and healthy group.

Outcomes	KIG (N = 40) (Mean ± SD)	HG (N = 40) (Mean ± SD)	t-value	*p*-value
BESS	9.03 ± 1.56	7.60 ± 1.63	3.99	.00*
YBT (D)	81.75 ± 10.07	86.73 ± 11.63	2.04	.04*
YBT (ND)	82.40 ± 11.82	86.63 ± 12.93	1.67	.09

*Note. *D = dominant leg; ND = non-dominant leg, BESS – Balance Error Scores, YBT – Y Balance Test.*Statistically significant difference between groups (p < .05).*

Table 2 determined that there was a statistically significant difference between injured and uninjured players with regards to the total scores of BESS ($p < .05$). However, there was no significant difference between either group with regards to the total scores of YBT (D), and YBT (ND).

Table 3. BESS scores between injured and healthy group.

BESS	KIG (N = 40) (Mean ± SD)	HG (N = 40) (Mean ± SD)	t-value	*p*-value
Firm surface				
DL	0.13 ± 0.33	0.10 ± 0.30	0.35	.72
SL	1.50 ± 0.81	1.47 ± 0.64	0.15	.87
TS	1.15 ± 0.53	0.20 ± 0.40	8.96	.00*
Total	2.78 ± 0.891	1.77 ± 0.78	5.480	.00*
Foam surface				
DL	0.18 ± 0.38	0.23 ± 0.42	0.55	.58
SL	3.68 ± 0.82	3.25 ± 1.17	1.87	.06
TS	2.40 ± 0.59	2.35 ± 0.58	0.38	.70
Total	6.25 ± 0.95	5.82 ± 1.21	1.738	.86

*Note. *DL = double leg stance; SL = single leg stance; TS = tandem stance.*

According to the findings in Table 3, there was a statistically significant difference observed between injured and uninjured players in terms of the average values of firm surface tandem position. Additionally, there was also a statistically significant difference observed between injured and uninjured players in terms of the average values of total scores of firm surfaces. The statistical significance level was set at $p < .05$. Considering the YBT score between the dominant and non-dominant legs, except in the anterior direction ($p < .05$), all the other directions are found to be in-significant at .05 levels (Table 4).

Table 4. YBT scores between injured and healthy group.

YBT	KIG (N = 40) (Mean ± SD)	HG (N = 40) (Mean ± SD)	t-value	*p*-value
Dominant leg				
ANT	57.00 ± 5.79	62.08 ± 4.15	4.502	.001*
PM	61.65 ± 10.39	63.90 ± 10.24	0.957	.34
PL	63.68 ± 7.86	64.72 ± 10.64	0.502	.61
Non-dominant leg				
ANT	57.31 ± 4.70	61.75 ± 6.67	3.437	.001*
PM	62.70 ± 9.42	65.30 ± 9.97	1.199	.23
PL	63.52 ± 10.58	64.00 ± 9.36	0.213	.83

*Note. *ANT = anterior; PM = posteromedial; PL = posterolateral. *Statistically significant difference between groups (p > .05).*

DISCUSSION

This study highlights the considerable effect that knee injuries have on postural control and balance in the young, competitive badminton player. The significant differences observed in the static balance between injured and non-injured athletes, particularly in BESS scores, highlight how knee injuries affect proprioception and neuromuscular control. Injured players demonstrated definite postural instability on firm ground and in tandem, where these deficits were most obviously apparent. This finding is consistent with prior research demonstrating that knee injuries, particularly those affecting ACL, compromise proprioceptive feedback mechanisms, reducing an athlete's ability to maintain a stable stance (Adachi et al., 2002; Solomonow & Krogsgaard, 2001). This impairment likely results from damage to mechanoreceptors within the knee joint, which is critical for accurate joint positioning and balance (Al-Dadah et al., 2020; Haggerty et al., 2021; Zeng et al., 2022). With adequate sensory feedback, players can maintain stability, which is particularly challenging in a sport like badminton that requires rapid and agile movements (Lee et al., 2015; Pardiwala et al., 2020).

The observed deficiencies in dynamic balance, assessed via YBT, further illustrate the extent of impairment in injured players. Although the differences in YBT scores were significant only in the anterior reach direction, this finding is particularly relevant for badminton players, as anterior reach stability is crucial for forward lunges and quick directional changes (Kurihara et al., 2024; Powden et al., 2019). This directional-specific deficit might indicate a disruption in the anterior kinetic chain’s neuromuscular coordination, potentially stemming from altered muscle activation patterns and joint positioning post-injury (Alikhani et al., 2019). This can predispose athletes to develop muscle imbalances following the recovery from knee injury due to adaptations in movement patterns to prevent stressing the injured knee. This adaptation may hinder the efficacy of forward and multi-directional movements, which are essential in badminton (Kuo et al., 2022). Therefore, rehabilitation protocols for injured badminton players should consider targeted interventions to restore anterior stability and strengthen proprioceptive control in the anterior reach direction (Jaworski & Żak, 2015; Reeves et al., 2015).

The results of this study carry essential implications for injury prevention and rehabilitation strategies in competitive badminton. For injury prevention, our findings suggest that targeted proprioceptive training exercises could mitigate the risk of knee injuries by enhancing neuromuscular control and balance (Arumugam et al., 2021; Ghaderi et al., 2020). Applying such balance training exercises on firm surfaces, particularly in tandem stance conditions, may enhance the body's sensorimotor control for injury prevention (Muehlbauer et al., 2012). Furthermore, the study's findings indicate that dynamic balance training should emphasize multi-directional stability, with particular attention to the anterior reach direction, to prepare athletes for the demands of the sport (Bell et al., 2011). Preventative programs could incorporate single-leg squats, lunges with balance components, and proprioceptive drills using wobble boards or foam surfaces to build resilience against injury (Jaworski & Żak, 2015).

For rehabilitation, these findings underscore the need for comprehensive balance assessments in athletes with knee injuries to better tailor post-injury programs. A focus on restoring proprioceptive function and improving neuromuscular control in the affected knee joint is crucial. Rehabilitation protocols could integrate static and dynamic balance exercises, progressing from simple stances to complex movements that mimic sports-specific demands. Exercises targeting single-leg stability, multi-directional lunges, and dynamic tasks on varied surfaces (such as foam and firm surfaces) may address the deficits observed in this study and restore functional balance. Moreover, training regimens that challenge the vestibular and visual systems could also prove beneficial, as these systems are integral to maintaining postural stability, particularly in dynamic sports environments (Malwanage et al., 2022).

The results of this study also add to the general knowledge of the association between knee injuries and postural control abnormalities. In the past, badminton was known for its requirement to be agile, have good reaction time, and have good footwork (Arnando et al., 2024; Kuo et al., 2022; Malwanage et al., 2022). However, this research found that balance was critical to achieving high-level performance and avoiding the recurrence of injury. The dynamic nature of badminton, which involves high-speed directional changes, frequent jumping, and sudden stops, places substantial demands on an athlete's postural stability. As a result, insights into balance deficits might give an athlete a competitive advantage and longevity (Han et al., 2022; Jaworski & Żak, 2015; Kuo et al., 2022).

The limitations of this study should be acknowledged. First, its cross-sectional design limits the ability to draw causal inferences between knee injuries and balance impairments. Longitudinal investigations would offer more information on how balance problems arise and evolve after a knee injury and how postural control changes as the injury evolves. Additionally, the study's sample was restricted to competitive badminton players aged 18–25, limiting the generalizability of the findings to other age groups and skill levels. Including a more diverse sample of athletes could help clarify whether these balance deficits are specific to younger, competitive players or extend across various age groups and experience levels. Finally, although the BESS and YBT are widely used to assess balance, further tests incorporating both proprioceptive and neuromuscular aspects of balance could provide a more complete picture of balance impairments in injured athletes. Future research could benefit from combining balance assessments with electromyography or motion analysis to capture neuromuscular activation patterns and joint kinematics better.

CONCLUSION

This study highlights knee injuries' significant impact on static and dynamic balance in young competitive badminton players. Injured players demonstrated considerable deficits in static balance, particularly in the tandem stance on firm surfaces, and showed reduced dynamic stability in the anterior reach direction. Therefore, balance-focused interventions should be incorporated in preventive and rehabilitative programmes for badminton players. By addressing balance deficits, coaches and rehabilitation professionals can improve postural control, reduce re-injury risks, and enhance athletic performance.

AUTHOR CONTRIBUTIONS

VKP,HTD - Data collection, conceptualization, writing original draft; VKR,AVS,PRM - Formal analysis, methodology & data curation; BEO & SP: Review & editing & literature review search.

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No potential conflict of interest was reported by the authors.

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