PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

Impact of perturbation-based balance training on dynamic stability in university basketball players

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim Balance is a critical component of athletic performance, particularly in sports requiring rapid directional changes and stability under dynamic conditions. In basketball, maintaining balance can enhance movement efficiency, reduce injury risk, and improve overall gameplay. The aim of this study was to assess the effectiveness of a six-week balance training program incorporating perturbation techniques in enhancing the dynamic balance of university basketball players.

Material and Methods An experimental study was conducted with 14 male university basketball players aged 19 to 25 years. Participants were randomly assigned to either the Experimental Group ($n = 7$) or the Control Group ($n = 7$). The Experimental Group underwent a six-week balance training program with perturbation alongside their regular training routine, consisting of 18 sessions conducted three times per week. Each session lasted 40–47 minutes and included exercises that altered proprioceptive and vestibular inputs through various stances (e.g., tandem stance, split squat, single-leg stance) and unpredictable perturbations differing in number, speed, and predictability. The Control Group continued with their regular training without additional intervention. Dynamic balance was assessed for all participants before and after the intervention using the Y-Balance Test. Statistical analysis was performed using independent and paired sample t-tests with a significance level set at $p < 0.05$.

Results The Experimental Group showed a significant improvement in dynamic balance after the intervention. Their mean Y-Balance Test score increased from 80.22 ± 4.01 cm pre-test to 89.75 ± 4.38 cm post-test ($p = 0.000$). In contrast, the Control Group showed no significant change, with pre-test and post-test scores of 77.85 ± 9.22 cm and 78.25 ± 8.91 cm, respectively ($p > 0.05$). Between-group comparison at post-test revealed a statistically significant difference favoring the Experimental Group ($p = 0.000$).

Conclusions The six-week balance training program with perturbation effectively enhanced the dynamic balance of university basketball players. Incorporating such training into regular practice routines may improve proprioceptive abilities and reduce injury risk. Coaches and trainers are encouraged to integrate balance training with perturbation techniques to promote optimal balance control and enhance athletic performance.

Keywords: balance training, perturbation, dynamic balance, basketball players, proprioception.

Introduction

Dynamic balance is a significant component of basketball training, affecting movement efficiency, agility, and injury prevention. Given the high-intensity nature of the sport, athletes must continuously adapt to unpredictable changes in posture and external forces. In this context, dynamic balance is a significant component of athletic performance, particularly in sports that involve frequent changes in direction, speed, and physical contact [1]. Basketball, as a high-intensity contact sport, requires players to maintain stability amidst rapid accelerations, decelerations, and collisions with opponents [2]. The ability to sustain dynamic balance under such conditions not only enhances performance but also reduces the risk of injuries associated with loss of balance, such as ankle sprains and falls [3]. Traditional basketball training programs often focus on strength, agility, and endurance, sometimes overlooking the importance of balance training [4]. However, recent research has highlighted the role of specialized balance training interventions in improving proprioceptive function and neuromuscular control [5]. Perturbation-based balance training, in particular, has gained attention

doi:10.15561/20755279.2025.0204

for its effectiveness in challenging the body's equilibrium and enhancing postural responses to unexpected disturbances [6]. This training method involves controlled, unpredictable forces applied to athletes, mimicking real-game scenarios with sudden balance shifts caused by external factors [7]. It aims to improve the reactive and anticipatory mechanisms of balance control, thereby enhancing overall dynamic stability [8].

Studies have shown that such training can lead to significant improvements in balance performance among athletes, yet there is a limited amount of research focusing specifically on its application in basketball players over a defined period [9]. The high level of competition and the substantial effort exerted by players during basketball games significantly contribute to the physical demands of the sport [10]. The increased risk of injuries among players is closely associated with the high intensity of competitive play, which involves rapid movements, frequent jumps, and physical contact with opponents [11]. During official games, a limited number of players are available, resulting in each athlete engaging in prolonged periods of high-intensity activity without substantial rest [12]. This intense level of participation underscores the necessity for players to develop greater dynamic balance and physical conditioning to maintain performance and reduce injury risk during competition.

Research has shown that dynamic balance is an important factor in overall athletic performance [13]. High-intensity physical effort and the associated fatigue, combined with an unpredictable and competitive environment during games, may predispose participants to a higher risk of acute injuries compared to practice sessions [14]. Injuries sustained during games are more likely to result from player contact or other forms of contact than during practices, which are often more controlled and less intense [15]. Unpredictable physical contact and perturbations during intense sports competitions can significantly contribute to acute injuries, particularly when players experience fatigue [16]. When individuals experience fatigue, their focus and dynamic balance tend to diminish, making them more susceptible to perturbations and increasing the likelihood of injuries [17, 18, 19]. Additionally, according to Yde and Nielsen [20], player contact was identified as the primary cause of time-loss injuries, followed closely by non-contact injuries. Incorporating such training into rehabilitation programs has been shown to improve both static and dynamic balance, contributing to better functional outcomes [21]. However, traditional rehabilitative exercises often involve relatively slow perturbations to the sensorimotor system, typically lasting more than 350 milliseconds, whereas empirical observations suggest that injuries can occur within a much shorter time span, between 17 and 50 milliseconds after initial ground contact [22].

Research has investigated the efficacy of perturbation-based training in enhancing neuromuscular responses during rehabilitation. Fitzgerald et al. [23] studied perturbation training in non-operative ACL rehabilitation. Participants receiving perturbation-based balance training alongside standard rehabilitation had fewer knee instability episodes and maintained functional status longer than those undergoing standard programs alone. Furthermore, studies examining the effects of lateral in-flight perturbations during drop landings have demonstrated that such perturbations influence lower-extremity biomechanics in both the frontal and sagittal planes [24]. Athletes tend to adjust their landing mechanics in response to partially anticipated frontal plane perturbations, such as a lateral push or bump from an opponent while airborne [25]. The ability to generate sufficient eccentric extensor and adductor moments around the lower extremity joints is essential for maintaining stability upon landing [26]. Understanding the impact of perturbation-based balance training could provide valuable insights for coaches, trainers, and athletes in designing more comprehensive training programs. This could potentially enhance not only dynamic balance but also the overall functional performance of basketball players [27].

An analysis of previous research has shown that perturbation-based balance training can enhance neuromuscular responses and dynamic stability in athletes. Most studies have primarily focused on addressing issues related to injury prevention and general athletic performance, often overlooking sport-specific adaptations. Despite numerous studies exploring the effects of balance training on injury prevention and performance, there remains a clear need for a more in-depth examination of its specific applications in basketball.

The aim of this study was to assess the effectiveness of a six-week balance training program incorporating perturbation techniques in enhancing the dynamic balance of university basketball players.

Materials and Methods

Participants

This study employed an experimental design to evaluate the effects of a six-week balance training program incorporating perturbation techniques on the dynamic balance of university basketball players. Initially, twenty-seven state-level male basketball players (aged 19–25 years) from Madhya Pradesh were recruited (Figure 1). Eligible participants had a minimum of three years of competitive experience.

Before testing, participants with a history of significant injuries, disabilities, or health conditions that could impair movement competency were excluded. After screening, 13 players were removed due to recent injuries, resulting in a final sample of 14 participants (Table 1).

Randomization was conducted using a computer-generated method, with the 14 eligible participants randomly assigned to either the Experimental Group (EG; n = 7) or the Control Group (CG; n = 7). Allocation concealment was ensured through sealed opaque envelopes to minimize selection bias.

The mean age of the participants was approximately 21.9 years, with an average basketball experience of 4.6 years. Table 2 presents their demographic characteristics, including age, height, body mass, and basketball experience.

Ethical Considerations

The study was conducted in accordance with the Helsinki Declaration, ensuring participant safety and ethical compliance. Written informed consent was obtained from all participants, who were also informed of their right to withdraw at any time.

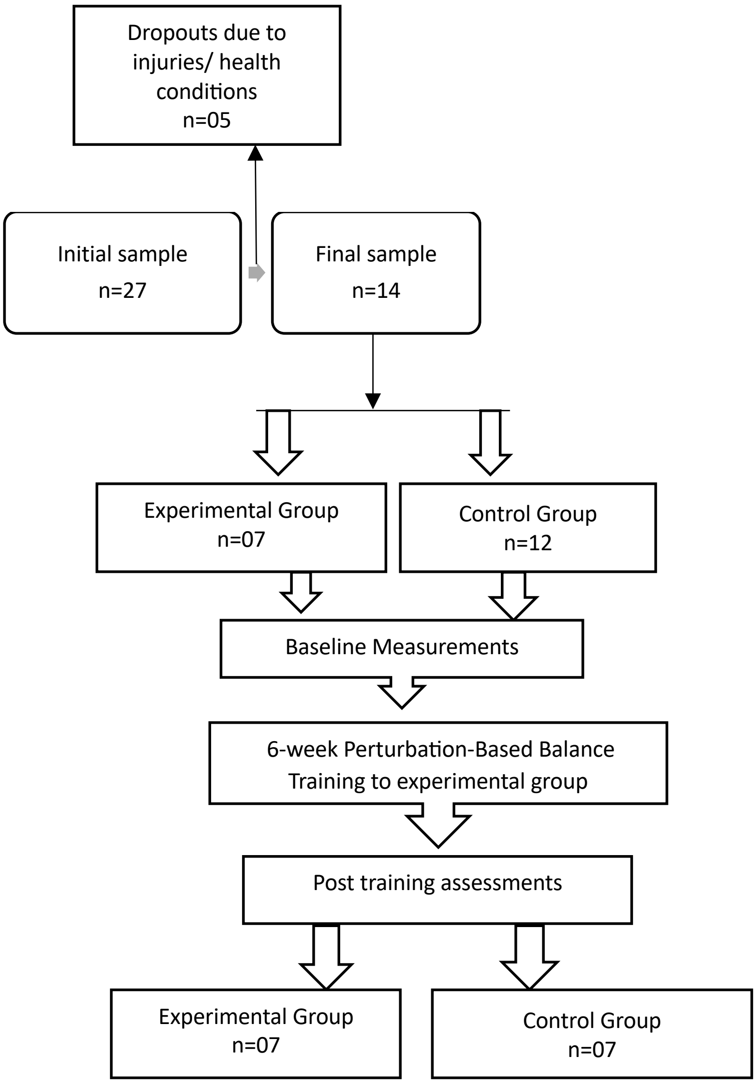

Figure 1. Flow Diagram

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
No lower extremity injuries in the last six months	History of injury within six months prior to study
Normal musculoskeletal function in all joints	Impaired vestibular function
Minimum two years of basketball experience	Neurological impairments affecting balance control
Normal vestibular function	
Normal neurological function	

Study Design

Intervention: Balance Training with Perturbation
The experimental group underwent a six-week balance training program (three sessions per week, totalling 18 sessions) while continuing their regular basketball training. The control group followed their standard training without additional interventions.

The balance training program aimed to improve sensorimotor integration in the central nervous system (CNS) by modifying vestibular and proprioceptive inputs. Exercises were progressively structured from simple to complex movements, with variations in stance (e.g., tandem stance, split squat, single-leg stance, jumping/landing) and perturbation (predictable vs. random, with varying speed and force). These exercises were selected based on evidence supporting their effectiveness in enhancing dynamic balance and sensorimotor sensitivity. Each session lasted 40 to 47 minutes and included a warm-up, main activity, and cool-down (Table 3).

Table 2. Demographic Characteristics of Participants

Variable	Experimental Group (EG) (n = 7) (M ± SD)	Control Group (CG) (n = 7) (M ± SD)	Total (n = 14)
Age (years)	22.1 ± 1.8	21.8 ± 1.6	21.9 ± 1.7
Height (cm)	176.2 ± 5.1	177.4 ± 4.8	176.8 ± 5.0
Body Mass (kg)	72.5 ± 3.9	71.8 ± 4.2	72.2 ± 4.0
Basketball Experience (years)	4.8 ± 1.2	4.5 ± 1.3	4.6 ± 1.2

Table 3. Six-Week Balance Training Schedule

Week	Session	Warm-up (10 mins)	Main activities (25–32 mins)	Cool-down (5 mins)	Total duration
1	Session 1	- Light jogging - Dynamic stretching	Proprioceptive Exercises: - Tandem stance (eyes open) 2×30s - Single-leg stance (eyes open) 2×30s each leg Perturbation Exercises: - External perturbations while standing on both legs (predictable taps to shoulders) 2×45s	- Static stretching - Deep breathing	40 mins
	Session 2	Same as Session 1	Proprioceptive Exercises: - Tandem stance (eyes closed) 2×30s - Single-leg stance (eyes open, cushion surface) 2×30s each leg Perturbation Exercises: - External perturbations while on tandem stance (predictable) 2×45s	Same as Session 1	40 mins
	Session 3	Same as Session 1	Proprioceptive Exercises: - Split squat hold (eyes open) 2×30s each leg - Single-leg stance (eyes closed) 2×20s each leg Perturbation Exercises: - External perturbations during split squat hold (predictable) 2×45s	Same as Session 1	40 mins
2	Session 4	- Light jogging - Dynamic stretching	Proprioceptive Exercises: - Single-leg stance on foam pad (eyes open) 2×30s each leg - Bilateral jumping and landing (focus on soft landing) 2×10 reps Perturbation Exercises: - Unpredictable perturbations while in tandem stance (random taps to shoulders) 2×45s	- Static stretching - Deep breathing	42 mins
	Session 5	Same as Session 4	Proprioceptive Exercises: - Single-leg mini squats (eyes open) 2×15 reps each leg - Single-leg stance on foam pad (eyes closed) 2×20s each leg Perturbation Exercises: - External perturbations during single-leg stance (predictable) 2×30s each leg	Same as Session 4	42 mins

Table 3. (Continued)

Week	Session	Warm-up (10 mins)	Main activities (25–32 mins)	Cool-down (5 mins)	Total duration
	Session 6	Same as Session 4	Proprioceptive Exercises: - Tandem walking forward and backward (eyes open) 2×10m - Bilateral hopping (forward/backward) 2×10 hops Perturbation Exercises: - Unpredictable perturbations during split squat hold (random) 2×45s	Same as Session 4	43 mins
3	Session 7	- Light jogging - Dynamic stretching	Proprioceptive Exercises: - Single-leg stance on wobble board (eyes open) 2×30s each leg - Lateral lunges (eyes open) 2×10 reps each side Perturbation Exercises: - External perturbations during single-leg stance on foam pad (random) 2×30s each leg	- Static stretching - Deep breathing	43 mins
	Session 8	Same as Session 7	Proprioceptive Exercises: - Single-leg deadlift (eyes open) 2×10 reps each leg - Bilateral jumping and 180° turn landing 2×8 reps Perturbation Exercises: - Unpredictable perturbations during tandem walking (random gentle pushes) 2×10m	Same as Session 7	44 mins
	Session 9	Same as Session 7	Proprioceptive Exercises: - Single-leg hopping in place (eyes open) 2×15 hops each leg - Split squat hold on foam pad (eyes open) 2×30s each leg Perturbation Exercises: - External perturbations during single-leg mini squats (predictable) 2×10 reps each leg	Same as Session 7	44 mins
4	Session 10	- Light jogging - Dynamic stretching	Proprioceptive Exercises: - Single-leg stance on wobble board (eyes closed) 2×20s each leg - Bilateral lateral hopping over line 2×10 hops Perturbation Exercises: - Unpredictable perturbations during single-leg stance on wobble board (random) 2×20s each leg	- Static stretching - Deep breathing	45 mins
	Session 11	Same as Session 10	Proprioceptive Exercises: - Walking lunges with torso twist (eyes open) 2×10 reps - Single-leg squat (eyes open) 2×8 reps each leg Perturbation Exercises: - External perturbations during bilateral jumping and landing (random) 2×10 reps	Same as Session 10	45 mins
	Session 12	Same as Session 10	Proprioceptive Exercises: - Single-leg hopping forward/backward over line 2×10 hops each leg - Lateral step-ups on platform (eyes open) 2×10 reps each side Perturbation Exercises: - Unpredictable perturbations during single-leg deadlift (random) 2×8 reps each leg	Same as Session 10	46 mins
5	Session 13	- Light jogging - Dynamic stretching	Proprioceptive Exercises: - Single-leg stance on BOSU ball (eyes open) 2×30s each leg - Bilateral squat on unstable surface (eyes open) 2×12 reps Perturbation Exercises: - External perturbations during single-leg hopping (predictable) 2×10 hops each leg	- Static stretching - Deep breathing	46 mins

Table 3. (Continued)

Week	Session	Warm-up (10 mins)	Main activities (25–32 mins)	Cool-down (5 mins)	Total duration
	Session 14	Same as Session 13	Proprioceptive Exercises: - Single-leg lateral jumps over cones 2×10 reps each leg - Reverse lunges with knee raise (eyes open) 2×10 reps each leg Perturbation Exercises: - Unpredictable perturbations during single-leg squat (random) 2×8 reps each leg	Same as Session 13	47 mins
	Session 15	Same as Session 13	Proprioceptive Exercises: - Single-leg balance with ball toss (eyes open) 2×15 catches each leg - Bilateral jumping onto unstable surface (eyes open) 2×8 reps Perturbation Exercises: - External perturbations during single-leg stance with eyes closed (random) 2×20s each leg	Same as Session 13	47 mins
6	Session 16	- Light jogging - Dynamic stretching	Proprioceptive Exercises: - Single-leg stance on BOSU ball (eyes closed) 2×20s each leg - Bilateral squat jumps with 180° turn 2×8 reps Perturbation Exercises: - Unpredictable perturbations during single-leg balance with ball toss (random) 2×12 catches each leg	- Static stretching - Deep breathing	47 mins
	Session 17	Same as Session 16	Proprioceptive Exercises: - Agility ladder drills (one-leg hops) 2×3 sets each leg - Single-leg hop and hold (eyes open) 2×10 reps each leg Perturbation Exercises: - External perturbations during single-leg lateral jumps (random) 2×8 reps each leg	Same as Session 16	47 mins
	Session 18	Same as Session 16	Proprioceptive Exercises: - Single-leg stance on unstable surface with head movements (eyes open) 2×20s each leg - Multidirectional lunges (eyes open) 2×6 reps each direction Perturbation Exercises: - Unpredictable perturbations during single-leg stance on BOSU (eyes closed) 2×15s each leg	Same as Session 16	47 mins

Outcome Measure: Y-Balance Test

To assess dynamic balance, the Y-Balance Test was performed both pre- and post-intervention. This test is a reliable measure for identifying individuals at risk of injury and evaluating balance performance. Participants were required to balance on one leg while reaching as far as possible in the anterior, posterolateral, and posteromedial directions. Each participant completed one practice trial followed by two recorded trials per leg, with the average score used in data analysis to minimize measurement error.

Balance Training with Perturbation Intervention

In this study, the experimental group underwent balance training with perturbation alongside their regular training routine. Each session, lasting 40 to 47 minutes, included warm-up and cool-down periods. The training aimed to enhance sensorimotor integration in the central nervous system (CNS) by modifying vestibular and proprioceptive inputs. Proprioceptive inputs were altered through various stances (e.g., tandem stance, split squat, single-leg stance, bilateral and single-leg jumping /landing). Vestibular inputs were challenged with perturbations differing in frequency, speed, and predictability (predictable or random). The progression involved combining stances and perturbations, moving from simpler to more complex tasks to improve dynamic balance and sensorimotor sensitivity.

Research Measurement Instrument

To measure participants' balance, strength, and stability, the study employed the Y-Balance Test, a widely recognized tool known for its reliability in identifying individuals at risk of injury [28]. This test required participants to maintain balance on one leg while reaching as far as possible in three specific directions: anterior, posterolateral, and posteromedial. Initially, participants completed practice trials to become familiar with the test procedure. Following this, they performed two valid trials in each direction for both legs, and the results were used for data analysis.

Statistical Analysis

The analysis of dynamic balance data obtained through the Y-Balance Test was performed using IBM SPSS Statistics version 26. To compare dynamic balance performance between the Experimental and Control Groups, an independent samples t-test was conducted. Changes in dynamic balance within the Experimental Group before and after the intervention were examined using a paired samples t-test to assess the effectiveness of the training program. A significance threshold of $p < 0.05$ was applied.

Results

The demographic data for both groups are presented in Table 4.

There were no significant differences between the experimental and control groups in terms of age, height, or weight ($p > 0.05$), indicating that the groups were comparable before the intervention. This homogeneity ensured that any subsequent differences in dynamic balance could be attributed to the training intervention rather than pre-existing physiological variations.

To ensure the assumptions of normality and homogeneity of variance were met, the Shapiro-Wilk test was used to assess the normality of the data, while Levene's test was conducted to evaluate the equality of variances between groups. The results of these tests are presented in Table 5.

All p-values from the Shapiro-Wilk test were greater than 0.05, indicating that the data followed a normal distribution. Similarly, Levene's test showed no significant differences in variance across groups ($p > 0.05$), confirming homogeneity of variance. These results support the appropriateness of using parametric statistical tests for further analysis.

The Y-Balance Test was used to evaluate dynamic balance performance before and after the intervention. Table 6 presents the pre-test and post-test scores for both groups, along with statistical comparisons.

At baseline, there was no significant difference in dynamic balance performance between the groups, confirming their comparability before the intervention ($p > 0.05$). However, after six weeks of balance training with perturbation, the experimental group showed a significant improvement, while the control group's performance remained largely unchanged. The between-group comparison at post-test indicated a statistically significant difference, favoring the experimental group ($p < 0.05$, large effect size), suggesting that the intervention effectively enhanced dynamic balance.

To evaluate the effectiveness of balance training with perturbation, a paired samples t-test was conducted within the experimental group. Table 7 presents the pre-test and post-test results, highlighting changes in dynamic balance performance.

The results indicate a significant improvement in dynamic balance performance within the

Table 4. Demographic Data of Experimental and Control Groups

Variables	Experimental Group (n=7) (M ± SD)	Control Group (n=7) (M ± SD)	p-value
Age (years)	22.5 ± 1.50	23.5 ± 1.00	> 0.05
Height (cm)	170.0 ± 5.60	171.0 ± 5.70	> 0.05
Weight (kg)	65.0 ± 13.50	68.0 ± 12.00	> 0.05

Table 5. Normality (Shapiro-Wilk) and Homogeneity (Levene's Test) Results

Group	Test	W-Statistic (Shapiro-Wilk)	p-value (Normality)	F-Statistic (Levene's)	p-value (Equal Variance)
Experimental Group	Pre-Test	0.967	0.412	1.28	0.275
Experimental Group	Post-Test	0.945	0.278	1.45	0.312
Control Group	Pre-Test	0.973	0.502	1.12	0.295
Control Group	Post-Test	0.959	0.352	1.37	0.288

Table 6. Pre-Test and Post-Test Y-Balance Test Scores Between Groups

Group	Control Group (M ± SD)	Experimental Group (M ± SD)	p-value	Cohen's d
Pre-Test	77.85 ± 9.22	80.12 ± 4.11	0.842	-
Post-Test	78.25 ± 8.91	89.14 ± 4.72	0.000*	2.43 (large)

*$p < 0.05$ indicates statistical significance.

Table 7. Pre-Test and Post-Test Results of the Experimental Group

Group	Pre-Test (M ± SD)	Post-Test (M ± SD)	p-value	Cohen's d
Experimental Group	80.22 ± 4.01	89.75 ± 4.38	0.000*	2.26 (large)

*p < 0.05 indicates statistical significance.

experimental group after six weeks of balance training with perturbation ($p < 0.05$, large effect size). This confirms the effectiveness of the intervention in enhancing balance. In contrast, the control group did not exhibit notable changes between pre-test and post-test measurements, suggesting that regular training alone was insufficient to improve dynamic balance.

Discussion

The present study aimed to evaluate the effects of a six-week balance training program incorporating perturbation techniques on the dynamic balance of university basketball players. The findings indicate that the experimental group, which underwent balance training with perturbation, exhibited a significant improvement in dynamic balance performance compared to the control group, which maintained their regular training regimen without additional intervention.

The improvement in dynamic balance observed in the experimental group can be attributed to the systematic progression of perturbation variations at different intensity levels, effectively preventing performance stagnation. The training protocol was designed to engage both the proprioceptive and vestibular systems by applying deliberate and unexpected shoulder pushes. These stimuli created varied physiological stresses, leading to specific neural and muscular adaptations [29].

The improvement observed in the experimental group aligns with previous research demonstrating the effectiveness of balance training programs in enhancing proprioceptive abilities and dynamic stability among athletes. Specifically, our findings are consistent with those of Lee et al. [21], who reported similar improvements in dynamic balance among basketball players following a six-week perturbation-based balance training program. This consistency reinforces the effectiveness of perturbation-based balance training in improving proprioceptive abilities and reducing injury risk among athletes. Therefore, coaches are encouraged to incorporate such training protocols to enhance both performance and injury prevention in basketball players.

Irrgang et al. [30] emphasized that the vestibular system plays a crucial role in maintaining postural stability, while the visual system contributes to balance control by stabilizing head movements. Proprioception, on the other hand, gathers input from joints, surrounding structures, and receptors to detect limb positioning.

This aligns with the findings of Lee and Lim [31], who trained Wushu players on a trampoline to enhance their proprioceptive awareness. Their intervention improved dynamic balance due to repeated sensory feedback and continuous exposure to perturbation. Additionally, participants were consistently challenged by postural adjustments and shifts in their center of gravity while using the trampoline. The unstable and rebounding nature of the trampoline created a highly demanding environment for proprioceptive and vestibular inputs, further enhancing balance control.

Piegaro [32] found that a four-week balance training program significantly enhanced dynamic balance, supporting the notion that six weeks of perturbation-based training is sufficient to yield significant improvements. Previous studies suggest that the central nervous system (CNS) employs a "throw and catch" mechanism to generate opposing joint torques, allowing the body to maintain balance while standing.

In this study, participants were required to sustain dynamic balance while counteracting destabilizing forces induced by elastic tubing perturbations. The continuous adjustments needed to resist these forces intensified the neural training effect, likely contributing to improvements in dynamic balance [33]. The lack of significant improvement in the control group reinforces the notion that regular basketball training alone may not be sufficient to elicit substantial gains in proprioceptive abilities. The manipulation of proprioceptive and vestibular input through 31 training variations is believed to enhance sensorimotor integration, leading to improved dynamic balance control. Efficient sensorimotor integration within the CNS is a key factor in dynamic balance performance.

Han et al. [34] demonstrated that a four-week balance training program could significantly improve dynamic balance. Thus, the six-week perturbation-based balance training in this study was sufficient to elicit substantial improvements in dynamic balance within the experimental group.

The findings of this study have practical implications for coaches and trainers working with basketball athletes. The improvement in dynamic balance observed in the experimental group can also be attributed to their enhanced ability to maintain stability in response to external perturbations. Given that the human body is inherently unstable, even in a quiet double-limb stance, the central nervous system (CNS) continuously regulates postural control by making real-time adjustments to keep the center of mass within the base of support [34]. Furthermore, Cumps et al. [35] reported that enhancing balance ability is essential for reducing injury risk among basketball athletes. Therefore, the significant improvement in dynamic balance observed in the experimental group may serve as a predictor of a reduced risk of injuries during game-related contacts.

Sniras and Uspuriene [36] highlighted the impact of pre-competition emotional states on athletic performance, showing that higher-level basketball players experienced greater cognitive and somatic anxiety than lower-level players. This underscores the importance of psychological factors in balance training interventions, as emotional regulation may influence motor control and stability in dynamic sports settings.

Limitations and Future Directions

This study has several limitations that should be considered when interpreting the results. First, the sample size was relatively small, which may limit the generalizability of the findings to a broader population of basketball players. Future studies with larger sample sizes are needed to enhance statistical power and external validity. Second, the study focused solely on dynamic balance improvements, without assessing other key performance metrics such as agility, vertical jump height, or sprint speed. Examining these variables in future research could provide a more comprehensive understanding of the benefits of balance training with perturbation.

Additionally, the intervention lasted six weeks, and long-term effects beyond this period remain unknown. Extending the duration of balance training programs and tracking performance over an entire competitive season would help determine the sustainability of improvements and their impact on injury prevention. Further research should also compare different balance training modalities and optimal training durations to refine existing protocols.

Moreover, modifying training variables such as stance variations, unstable surfaces including foam mats, tilt boards, and seesaw apparatus, as well as sport-specific adaptations, may introduce greater proprioceptive and vestibular challenges. Investigating these modifications could help optimize training strategies for basketball players and athletes in other dynamic sports.

By addressing these limitations and expanding the scope of research, future studies can contribute to a deeper understanding of the role of perturbation-based balance training in athletic performance and injury prevention.

Conclusions

This study demonstrated that a six-week balance training program incorporating perturbation techniques significantly improved the dynamic balance of university basketball players. The experimental group showed notable enhancements in proprioceptive abilities and sensorimotor integration compared to the control group, confirming the effectiveness of perturbation-based balance training.

Given the high prevalence of lower limb injuries among basketball players, integrating structured balance training into regular conditioning programs may contribute to both performance enhancement and injury prevention. The large effect size observed in this study supports the inclusion of perturbation-based training as a valuable component of athletic preparation.

These findings highlight the importance of incorporating structured balance training with perturbation into basketball conditioning programs to enhance postural control and reduce injury risk. Trainers and coaches should consider implementing such interventions to optimize athletic performance.

Acknowledgment

We sincerely appreciate the dedication of the basketball athletes who participated in this study. We also extend our gratitude to the coaches and support staff for their invaluable assistance in facilitating the training sessions and data collection.

Conflict of Interest

The authors declare no conflict of interest.

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Cite this article as:
Choudhary PK, Choudhary S, Rajpoot YS, Harod R, Kumar Sonu. Impact of perturbation-based balance training on dynamic stability in university basketball players. *Physical Education of Students,* 2025;29(2):124–134.
https://doi.org/10.15561/20755279.2025.0204

Received: 12.02.2025

Accepted: 31.03.2025; Published: 30.04.2025