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The Role of Postural Sway in Free Throw Success: An Analysis in Basketball Players

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Abstract

Free throw shooting is a fundamental skill in basketball that requires precise coordination and balance. Although technical and kinematic factors influencing shooting accuracy have been extensively studied, the potential contribution of postural sway to free throw success remains unclear. The aim of this study is to compare postural sway between successful and unsuccessful free throw shots (b) and to determine gender differences in postural sway during successful and unsuccessful shots. Sixty adult basketball players (30 female, 30 male; age=21.2±1.9 years) participated in this study. Postural sway was assessed during five successful and five unsuccessful free throw attempts using the GYKO inertial sensor system. Sway parameters included ellipse area, length, mean distance, and velocity in the total, medio-lateral, and anteroposterior (AP) directions. A two-way repeated measures ANOVA was used with shot outcome (successful vs. unsuccessful) as the within-subject factor and gender (female vs. male) as the between-subject factor. No significant differences were found between successful and unsuccessful free throws in any postural sway parameters. However, male players demonstrated significantly greater values than female players in ellipse area (F=5.043, p=.029, η^2_p=.080), mean distance (F=18.15, p<.001, η^2_p=.238), medio-lateral mean distance (F=4.21, p=.045, η^2_p=.068), and AP mean distance (F=30.51, p<.001, η^2_p=.345). No gender × shot outcome interaction was observed for any parameter. These findings suggest that while postural sway differs between genders, it does not distinguish successful from unsuccessful free throw attempts in adult basketball players. Postural stability may therefore not be a decisive factor in free throw success.

Keywords: Basketball, Free throw, Shooting accuracy, Postural stability, Postural sway

Introduction

Basketball, one of the most popular sports disciplines worldwide (Amaro et al., 2023; Cabarkapa et al., 2021; Kelmendi et al., 2025), is a physically demanding sport that requires sprinting, running, jumping and shooting skills (Hessam et al., 2023). This sport discipline is characterized by a fast pace, high scoring, and movements that require advanced skills (Cabarkapa et al., 2021). Shooting, a frequently used skill that directly affects the score in basketball (Amaro et al., 2023; Li et al., 2025), can be performed as dunks, jump shots, field goals, three-pointers, layups, and free throws (Wang & Zheng, 2022). While games feature a variety of shots like dunks and three-pointers, players should avoid defense. However, free throws are non-defensive, shooting distance is fixed, and improving accuracy is crucial (Matsunaga & Oshikawa, 2022).

Shooting technique and accuracy are critical elements in basketball (Barataman & Gomez, 2024). In a general context, a basketball shot encompasses all actions involved in throwing the basketball toward the hoop and is considered one of the most complex technical movements in basketball (Yan et al., 2023). Free throws are a fundamental skill in basketball that requires a combination of technique, consistency, mental focus, and the ability to perform under pressure (Kelmendi et al., 2025). Scoring during a free throw requires coordination of the entire body as well as control of the ball's trajectory (Truong et al., 2023).

According to FIBA rules, in a top-level game, a single team averages eighty shots, of which 20-30% are free throws (Gómez et al., 2018; Sirnik et al., 2022; Worobel, 2020). To achieve a high shooting percentage and subsequent winning percentage, every team must have players with high shooting accuracy under different physiological or psychological conditions throughout the game (Pojskic et al., 2018). Because in basketball, just one point can determine the winning team (Betty Retnowulan & Kunta Purnama, 2017) and in this game, it is often seen that a team wins the match with their free throw accuracy, especially in the final minutes (Cabarkapa et al., 2021; Gómez et al., 2018; Meirizal et al., 2022). Therefore, considering the impact of successful free throw performance on the outcome of the game, it is not surprising that basketball coaches place importance on practicing this shot. However, it is known that many players struggle to execute free throws consistently and effectively (Cabarkapa et al., 2021; Gómez et al., 2018). Even the best athletes can miss free throws, and there is a need for in-depth analysis of the factors that influence the underlying mechanism of successful or unsuccessful shots (Matsunaga & Oshikawa, 2022).

A stable posture during a free throw is an important determinant (Barbieri et al., 2017; Gómez et al., 2018; Verhoeven & Newell, 2016). Meirizal et al. (2022) applied the BEEF (balancing, eyes, elbow, follow-through) protocol to strengthen free throw skills. The first element, balancing, involves ensuring postural control with a completely balanced body position. In the free throw technique, the body posture should be as balanced as possible so that the position and direction of the ball do not change (Barbieri et al., 2017). However, elite athletes exhibit better postural performance and different postural strategies than non-elite athletes (Paillard, 2017a). Additionally, increased postural instability may lead to decreased performance (Zemková, 2009). However, skilled athletes, such as basketball players with repeated free-throw practice, may still perform successfully despite increased postural instability (Zemková, 2014, 2022). In basketball, trunk stabilization is a decisive factor for the accuracy of shooting (Worobel, 2020). Moreover, improving postural control by reducing the speed of the center of mass when releasing the ball increases the accuracy of basketball free throws (Verhoeven & Newell, 2016). Also basketball players may get into some asymmetrical positions while displaying certain complex skills during the game and must ensure their postural control accordingly (Piras et al., 2024).

Undoubtedly, one of the important parameters affecting free throw performance is kinematic factors (Kelmendi et al., 2025). These kinematic factors include release height (Kelmendi et al., 2025), knee angle (Ammar et al., 2016), and forearm angle (Cabarkapa et al., 2021). Previous studies have investigated the effect of fatigue (Cengizel et al., 2023; Li et al., 2025), strength training (Barataman & Gomez, 2024; Hessam et al., 2023), and different shooting positions (Amaro et al., 2023) on shooting accuracy. In shooting mechanics, the height and speed at which the ball is released, the angle of flight, stable movement, execution, the player's physical characteristics, shooting distance, and fatigue all affect shooting performance (Okazaki et al., 2015). However, these factors do not fully explain shooting accuracy (Sirnik et al., 2022; Worobel, 2020). In basketball, specifically in free throws, athletes' postural sway may also be an effective element in shot accuracy. Therefore, this study focused on the following questions: Does postural sway affect shooting accuracy? Does postural sway differ between genders in terms of shooting accuracy? To the authors' knowledge, no analysis has been found comparing postural sway differences between successful and unsuccessful free throw shooting performances. Examining free throw performance—which has such a significant impact on game outcomes—in terms of postural sway would provide valuable practical insights for coaches and practitioners. Building on this gap in the field, the aim of this study is (a) to compare postural sway between successful and unsuccessful shots and (b) to determine gender differences in postural sway during successful and unsuccessful shots. Our hypothesis is that postural sway will differ between successful and unsuccessful shots as well as between genders.

Material and Method

Ethics Committee Permission

The study was conducted in accordance with the Declaration of Helsinki, and approval was obtained from the Local Ethics Committee (Research Code: 2023-1574).

Participants

A total of 60 basketball players, including 30 females and 30 males aged 18-25 years, voluntarily participated in the study (Table 1). The inclusion criteria for the study were: (a) being between 18 and 25 years of age, (b) participating in basketball training at least five days per week, (c) having competed as a licensed athlete in basketball, and (d) having a minimum of five years of training experience in basketball. The exclusion criteria for the study were: (a) having experienced any physical injury or undergone surgery within the past six months, (b) participating in another sport in addition to basketball, (c) having performed strenuous exercise within the last 48 hours, and (d) failure to complete the testing protocol. Prior to the study, written informed consent was obtained from all participants. To avoid influencing the athletes' usual free throw technique, they were not informed that the accuracy of their successful and unsuccessful shots would be evaluated. However, all athletes were verbally and in writing informed about the measurement procedures of the study as well as the potential benefits and risks.

Study design

In this study, repeated measurements were performed using a within-subjects design. Athletes were asked to refrain from strenuous exercise for 48 hours prior to the measurement and to avoid consuming any stimulants (such as caffeine) for 12 hours before the measurement session.

Table 1. Characteristics of participants

	Mean ± *SD*	95% CI
Age (years)	21.2 ± 1.9	20.7-21.7
Training experience (years)	11.1 ± 2.7	10.4-11.8
Body height (cm)	183.5 ± 10.5	180.8-186.2
Body mass (kg)	78.5 ± 14.5	74.8-82.2
GYKO height (cm)	153.6 ± 10.1	151.0-156.2

GYKO: Postural sway measurement device

Athletes participated in two separate sessions, 24 hours apart. Measurements were taken between 11:00 a.m. and 2:00 p.m. before the evening training sessions. All athletes were measured at the same time. The first session consisted of information about the study, determination of characteristics, and familiarization. During the familiarization session, the shooting practice was completed after performing 5 successful free throws following a standard warm-up protocol consisting of 5 minutes of dynamic stretching and 5 minutes of static stretching. In the second session, following the same warm-up protocol (without an interval), the ball-specific warm-up was completed with 3 free throw attempts. Then, during 5 successful and 5 unsuccessful shots, the athletes' postural sway was determined by a sensor located on the vest they wore (Figure 1).

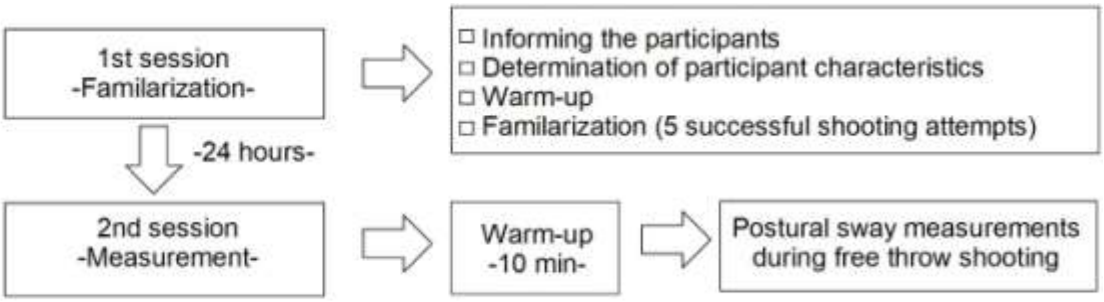

Figure 1. Study design

Experimental Procedure

Participants' height was measured using a stadiometer with 1 mm accuracy (SECA 213, Germany) and their body mass was measured using a scale with 100 gram accuracy (SECA Colorata 760, Germany). Participants were asked to wear light clothing and be barefoot for body height and body mass measurements. Body height was recorded in centimeters, and weight in kilograms. The portable Microgate GYKO Inertial Sensor System (Microgate, Bolzano, Italy) was used to detect the postural sway of basketball players during free throw shots and to compare successful and unsuccessful shots. The GYKO inertial sensor system has been shown to provide acceptable test–retest reliability (ICC = 0.31–0.75) with good reliability for sway variables (ICC ≈ 0.70) and SEM% values ranging from 11% to 41%, indicating satisfactory reproducibility for postural stability assessment (Jaworski et al., 2020).

This inertial sensor is located on a device on the back of a vest worn by athletes and is positioned at the T1-T2 thoracic spine level. After the vests were customized for each athlete, their height from the ground was measured in meters, and each athlete's GYKO height was recorded in the software (Jaworski et al., 2020). The wireless transmission protocol for transferring data recorded by the GYKO sensor was used to transfer data to a laptop computer. After completing the standard warm-up protocol (5 minutes of dynamic stretching, 5 minutes of static stretching), the athletes moved to the free-throw line, took their shooting positions, and recorded their postural sway during 5 successful and 5 unsuccessful shots following 3 practice shots. A separate postural sway recording was taken for each free throw. In the study, ellipse area, length, mean distance, and velocity data were examined in the anteroposterior (AP) and mediolateral directions. All variables examined in the study are presented below:

Area (cm^2): The 95% ellipse of confidence is the ellipse that contains approximately 95% of the points of the trajectory.

Length (cm): It is the total length of the trajectory obtained as the sum of the distances from one point to the next.

Mean Distance (cm): This is the mean distance from the midpoint of the trajectory.

Velocity ($cm \cdot s^{-1}$): This is the mean travel velocity of the trajectory.

Medio-lateral length (cm): The medio-lateral length is the total distance in the medio-lateral direction given as the sum of the absolute distances between two consecutive points in the medio-lateral direction.

Medio-lateral mean distance (cm): This is the mean distance from the midpoint of the medio-lateral trajectory.

Medio-lateral velocity ($cm \cdot s^{-1}$): This is the mean travel velocity of the trajectory in medio-lateral direction.

Anteroposterior length (cm): The AP length is the total distance in the AP direction given as the sum of the absolute distances between two consecutive points in the AP direction.

Anteroposterior mean distance (cm): This is the mean distance from the midpoint of the AP trajectory.

Anteroposterior velocity ($cm \cdot s^{-1}$): This is the mean travel velocity of the trajectory in AP direction.

For each parameter, the average of 5 successful shots was recorded individually as “successful shots”, while the average of 5 unsuccessful shots was recorded individually as “unsuccessful shots”. For athletes who completed five successful shots but had not yet reached five unsuccessful shots, additional attempts were continued. However, this information was withheld from the athletes to avoid influencing their shooting mechanics. After each shot, the shooter remained stationary at the free-throw line, and one of the researchers fed the ball from under the basket for each shot. Each shot was initiated when the athlete felt ready, and this period did not exceed 1 minute. No external verbal stimuli (encouragement or distraction) were provided to the athletes, who performed the measurements in a quiet environment.

Data Analysis

Data are presented as mean ± standard deviation (SD). Prior to the main analyses, the distribution of all dependent variables was examined using the Shapiro–Wilk test to verify the assumption of normality, and the homogeneity of variances was assessed using Levene's test. Postural sway parameters were analyzed separately for the AP and medio-lateral (ML) directions. For each participant, postural sway data were averaged across five successful and five unsuccessful shooting trials. A two-way repeated measures analysis of variance (ANOVA) was performed for each sway parameter, with shot outcome (successful vs. unsuccessful) as the within-subject factor and gender (female vs. male) as the between-subject factor. In the presence of significant main or interaction effects, pairwise comparisons were performed using the Holm–Sidak post hoc procedure. Effect sizes for all ANOVA results were reported as partial eta squared (η^2_p) and interpreted as small (0.01), medium (0.06), or large (0.14) (Cohen, 1988). Statistical significance was set at $p<.05$. All statistical analyses were conducted using 11.0 (Systat Software, Inc., San Jose, California, USA).

Results

There were no significant differences in ellipse area, length, mean distance, and velocity between successful and unsuccessful shots of the basketball players ($p>.05$). Female basketball players showed significantly lower ellipse area values than male players ($F=5.043$, $p=.029$, "moderate" $\eta^2_p=.080$). The analysis revealed a significant main effect of gender, with a higher mean distance in male basketball players compared to female basketball players ($F=18.15$, $p<0.001$, "large" $\eta^2_p=.238$). The gender × shot outcome interaction was not significant in any postural sway parameters (Table 2).

Table 2. Postural sway variables of basketball players during successful and unsuccessful free throw shooting

		S	US	shot outcome	gender	interaction
Ellipse area (cm²)	Total	22.7 ± 13.1	22.8 ± 12.5	.921	.029	.715
	F	19.3 ± 12.6	19.2 ± 10.8			
	M	26.2 ± 12.8	26.4 ± 13.2			
Length (cm)	Total	15.3 ± 2.9	15.1 ± 2.9	.386	.346	.534
	F	14.8 ± 3.1	14.8 ± 3.0			
	M	15.7 ± 2.7	15.4 ± 2.8			
Mean distance (cm)	Total	.93 ± .28	.94 ± .31	.464	<.001	.656
	F	.79 ± .26	.80 ± .26			
	M	1.06 ± .23	1.08 ± .30			
Velocity (cm·s⁻¹)	Total	8.49 ± 1.69	8.52 ± 1.47	.780	.332	.624
	F	8.33 ± 1.70	8.30 ± 1.36			
	M	8.64 ± 1.68	8.74 ± 1.57			

Data are presented as mean±*SD*. S: Successful free throw shooting, US: Unsuccessful free throw shooting, F: Female, M: Male. $p<.05$.

There were no significant differences in medio-lateral length, mean distance, and velocity between successful and unsuccessful shots of the basketball players ($p>.05$). There was a statistically significant main effect of gender, with male basketball players showing greater medio-lateral mean distance compared to female basketball players ($F=4.21$, $p=.045$, "moderate" η^2_p=.068). The gender × shot outcome interaction was not significant (p>.05, Table 3).

Table 3. Medio-lateral postural sway variables of basketball players during successful and unsuccessful free throw shooting

		S	US	shot outcome	gender	interaction
Length (cm)	Total	6.6 ± 1.8	6.5 ± 1.8	.518	.846	.209
	F	6.6 ± 1.7	6.7 ± 1.7			
	M	6.7 ± 1.8	6.4 ± 1.9			
Mean distance (cm)	Total	.71 ± .40	.69 ± .35	.262	.045	.965
	F	.61 ± .35	.60 ± .26			
	M	.80 ± .43	.79 ± .40			
Velocity ($cm{\cdot}s^{-1}$)	Total	3.71 ± 1.03	3.68 ± .96	.609	.802	.518
	F	3.72 ± .94	3.73 ± .89			
	M	3.71 ± 1.13	3.62 ± 1.05			

Data are presented as mean±*SD*. S: Successful free throw shooting, US: Unsuccessful free throw shooting, F: Female, M: Male. *p*<.05.

There were no significant differences in AP length, mean distance, and velocity data between successful and unsuccessful shots of the basketball players (p>.05). There was a statistically significant main effect of gender in mean distance (F=30.51, p<.001, "large" η^2_p=.345). Male basketball players demonstrated significantly greater AP mean distance compared to female basketball players. The gender × shot outcome interaction was not significant (p>.05, Table 4).

Table 4. AP postural sway variables of basketball players during successful and unsuccessful free throw shooting

		S	US	shot outcome	gender	interaction
Length (cm)	Total	12.0 ± 2.5	11.9 ± 2.4	.495	.174	.974
	F	11.6 ± 2.9	11.5 ± 1.7			
	M	12.5 ± 1.0	12.4 ± 2.1			
Mean distance (cm)	Total	2.61 ± 1.02	2.62 ± .90	.844	<.001	.952
	F	2.04 ± .9	2.04 ± .81			
	M	3.18 ± .80	3.19 ± .75			
Velocity ($cm{\cdot}s^{-1}$)	Total	6.73 ± 1.44	6.74 ± 1.28	.919	.131	.107
	F	6.55 ± 1.57	6.40 ± 1.23			
	M	6.90 ± 1.30	7.07 ± 1.25			

Data are presented as mean±*SD*. S: Successful free throw shooting, US: Unsuccessful free throw shooting, F: Female, M: Male. *p*<.05.

Discussion and Conclusion

The aim of this study was to examine the differences in postural sway between successful and unsuccessful free throw shots and to determine whether these differences vary by gender in basketball players. The results showed no significant differences between successful and unsuccessful shots for any of the postural sway parameters (ellipse area, length, mean distance, and velocity) in either the total, mediolateral, or AP directions. However, male players demonstrated significantly greater values than female players in several parameters, including ellipse area, mean distance, medio-lateral mean distance, and AP mean distance, indicating a consistent gender-related difference in postural sway magnitude. No significant gender × shot outcome interaction was found for any parameter. These findings indicate that while postural sway differed between genders, it did not differ between successful and unsuccessful free throw attempts, and thus our hypothesis was only partially supported.

Although no significant differences were found in postural sway between successful and unsuccessful free throw attempts, several factors may account for this finding. First, free throw shooting is a well-learned and highly automated motor skill in trained basketball players, and it is assumed that repeated specific postures and movements may induce postural adaptations (Paillard, 2017a), which likely minimizes variability in postural control regardless of shot outcome. Moreover, in an analysis of repeated basketball free throw shooting, it was noted that while there was no change in center of pressure length in the AP direction during 50 free throws, the values in the medio-lateral direction nearly doubled; however, only a slight increase was observed in unsuccessful attempts (Zemková, 2014). Additionally, basketball free throw shooting is a common task for basketball players, which facilitates the control of postural demands and has been reported not to cause a decrease in accuracy even after high-intensity exercise (Barbieri et al., 2017). These findings indicate that more pronounced side-to-side center of mass movements do not affect free throw shooting accuracy in basketball players. Similar to our study, this suggests that players are able to maintain postural stability during repeatedly performed shots regardless of the shot outcome. Second, successful and unsuccessful shots may primarily differ in upper limb kinematics and release mechanics rather than whole-body postural control, meaning that sway-related differences may be too subtle to detect. Failure to achieve optimal kinematic magnitudes and to maintain postural control within the recommended range during a free throw may potentially lead to an unsuccessful free throw attempt (Cabarkapa et al., 2021). In a study examining postural control and ball release during free throw shooting in basketball players (Verhoeven & Newell, 2016), a decrease in center of mass movement was observed at the moment of ball release, further supporting the notion that postural balance at the moment of release is essential for successful performance. Moreover, trunk stabilization (Worobel, 2020) and knee joint angle (Ammar et al., 2016) during free throw shooting have also been mentioned as critical predictors of performance. Third, players might maintain similar postural strategies to stabilize their center of mass during all shooting attempts, as any excessive sway could disrupt accuracy, thereby leading to a consistent postural pattern independent of outcome. It has been emphasized that experience influences postural responses and standing balance in basketball players, and that athletes develop postural adaptations to stabilize postural sway (Piras et al., 2024). The authors suggested that these postural adaptations should also be examined during free throw shooting. In this regard, addressing a question that could fill the gap in the field, our study found no differences in postural sway between successful and unsuccessful shots during free throw shooting. Lastly, the controlled experimental conditions may have reduced situational stress and fatigue, potentially diminishing the influence of balance-related fluctuations on shooting performance.

The observed gender-related differences in postural sway may be explained by several physiological and biomechanical factors. Males typically have greater body height and mass compared to females, which increases the moment of inertia around the ankle joints and may contribute to larger sway amplitudes (Alonso et al., 2012; Farenc et al., 2003; Hue et al., 2007). A recent study clearly shows that the physical capacities of basketball players play a significant role in their performance (Zhang et al., 2023). On the other hand, a positive relationship has been identified between height, arm length, and arm muscle strength and free throw shooting in female basketball players (Betty Retnowulan & Kunta Purnama, 2017). Therefore, the gender differences observed in our study may be attributed to these physical differences. In addition, differences in muscle strength and neuromuscular control strategies between genders can influence postural stability (Gribble et al., 2009; Mueller et al., 2018; Paillard, 2017b). However, specifically in basketball, Pojskic et al. (2018) found no significant relationship between free throw shooting accuracy and conditional parameters of players. On the contrary, coordination, balance, core strength, and relative average power were found to be significantly correlated with shooting accuracy in basketball players ($r>.58$, $p<.05$) (Zhang et al., 2023). Additionally, postural control is one of the limiting factors of sports performance, which involves multiple sensorimotor processes, and modulations in body sway are required during the execution of sports skills to improve postural control (Barbieri et al., 2017; Zemková & Hamar, 2014). Given the lack of consensus in previous studies and the fact that our study did not assess the athletes' motor characteristics and neuromuscular functions, it is evident that further in-depth analyses are needed in future research. Furthermore regarding the gender-related differences in our study, anthropometric characteristics such as a lower center of mass relative to height in females could facilitate more efficient balance control and result in smaller sway excursions during static tasks (Alonso et al., 2012; Šarabon et al., 2022).

Several limitations of the present study should be acknowledged. First, the sample consisted exclusively of adult basketball players, which may limit the generalizability of the findings to athletes of different age groups, competitive levels, or sports disciplines. Second, only five successful and five unsuccessful free throw attempts per participant were analyzed, which may not fully capture the natural variability of postural control during shooting. Third, postural sway was assessed using a single inertial sensor placed on the trunk, and no additional kinematic or kinetic data (e.g., force plate or multi-segment motion analysis) were collected to provide complementary insights into balance control mechanisms. Additionally, another limitation of this study is related to the measurement device, as postural sway parameters were assessed using a GYKO inertial sensor, for which previous research has reported moderate-to-good test–retest reliability (ICC ≈ 0.62–0.70; Jaworski et al., 2020). This should be considered when interpreting the findings. Finally, the testing was conducted under controlled laboratory conditions without external stressors such as fatigue, game-related pressure, or defensive interference, which may influence postural stability during real-game situations.

This study examined postural sway differences between successful and unsuccessful free throw attempts in adult basketball players and explored potential gender-related variations. The results revealed no significant differences in postural sway parameters between successful and unsuccessful shots, indicating that postural stability, does not appear to be a key factor distinguishing shot outcomes. However, male basketball players consistently exhibited greater sway magnitudes than female basketball players across several parameters, suggesting gender-related differences in postural control strategies during free throw shooting tasks. From a practical perspective, these results suggest that training interventions specifically targeting static postural stability may not directly enhance free throw accuracy in skilled basketball players. Instead, coaches and performance specialists may focus on refining upper limb kinematics, release mechanics, and shot consistency under various game-like conditions. Nonetheless, given the observed gender-related differences in sway magnitude, individualized balance and stability training could be considered as a supplementary component of general physical preparation, particularly for male players who may display greater postural oscillations during shooting.

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