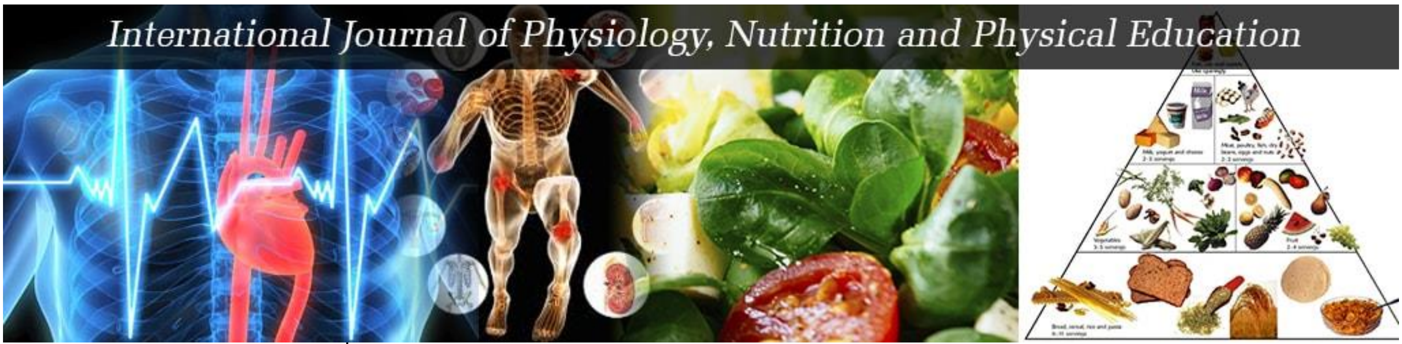
International Journal of Physiology, Nutrition and Physical Education 2025; 10(2): 308-317



ISSN: 2456-0057
IJPNPE 2025; 10(2): 308-317
Impact Factor (RJIF): 5.91

www.journalofsports.com
Received: 04-09-2025
Accepted: 06-10-2025

Dr. Mohammad Thamer Karim
Lecturer, Kirkuk General Directorate of Education, Iraq

Corresponding Author:
Dr. Mohammad Thamer Karim
Lecturer, Kirkuk General Directorate of Education, Iraq

The relationship between the moment of inertia and some kinematic variables in basketball players' shooting

Mohammad Thamer Karim

DOI: https://www.doi.org/10.22271/journalofsport.2025.v10.i2e.3115

Abstract
Basketball shooting is a biomechanically complex skill that integrates precise coordination of multiple body segments. While previous studies have examined kinematic variables such as release angle, velocity, and joint angular displacement, the influence of moment of inertia (MOI) on shooting mechanics remains unexplored. Understanding this relationship is important because MOI determines resistance to angular acceleration, directly affecting the efficiency and stability of movement patterns in high-precision tasks like shooting. This study investigated the relationship between segmental MOI and selected kinematic variables during basketball shooting. Competitive players were assessed using motion-capture technology combined with anthropometric modeling to calculate MOI of the upper and lower limbs. Kinematic parameters including release angle, release velocity, release height, and joint angular velocities were recorded and analyzed through correlation and regression techniques to determine the extent of association between MOI and shooting mechanics. The findings revealed that optimized MOI distributions, particularly in the shooting arm and trunk, were associated with smoother angular accelerations, greater release velocity consistency, and reduced compensatory lower-body movements. These results suggest that MOI plays a significant role in determining the quality and efficiency of shooting performance. This research contributes a novel dimension to basketball biomechanics by explicitly linking MOI with kinematic shooting variables. To the best of current knowledge, no published studies have examined this interaction. The outcomes provide coaches and sport scientists with a new framework for designing training strategies that emphasize both kinematic precision and mechanical efficiency.

Keywords: Basketball shooting biomechanics, moment of inertia, kinematic variables, release angle

1. Introduction

Basketball is a sport where scoring is exclusively achieved by shooting the ball through the hoop, making shooting skill fundamentally important for success. Among various shooting techniques, the standard two-legged jump shot is considered a crucial and frequently used motor skill in the game. Coaches traditionally teach the jump shot based on an optimal movement pattern derived from biomechanical principles. However, each player develops a unique shooting style due to individual characteristics such as body anthropometry, physical capabilities, and prior experience [1, 2]. Even at elite levels, players with similar overall shooting success can exhibit notable differences in their shooting mechanics. These inter-individual variations underscore that there is no single "perfect" technique that fits all athletes, although certain key principles (e.g., proper alignment, timing, and follow-through) are widely emphasized in coaching. Understanding the biomechanical factors behind an effective jump shot is therefore a significant area of sports science research, as it can inform coaching strategies to improve performance and consistency [3, 4].

An effective jump shot depends on the generation of an appropriate ball trajectory during the release phase. Three primary parameters characterize the ball's trajectory at release: the angle of release (the angle at which the ball is launched relative to horizontal), the release velocity, and the release height. These factors jointly determine whether the ball will successfully travel through the hoop. Prior research suggests that successful shots often have a moderately high arc (with release angles in a certain optimal range) and sufficient but not excessive speed. For example, one classic analysis reported that higher shooting success is associated with a release angle of approximately 45°-52° and a relatively lower velocity, when the shot is taken at the peak of the jump. Of course, the optimal combination of angle and velocity can vary with circumstances such as the shooter's distance from the basket and the presence of defenders. Overall, the mechanics of the jump shot involve a complex coordination of the lower and upper body to produce a high, arching trajectory that balances accuracy and sufficient range. Small changes in technique or conditions can alter the ball's flight and thereby influence shooting success [5].

In a dynamic game setting, players must often adjust their shooting technique based on contextual factors. One critical factor is the shooting distance the horizontal distance from the shooter to the basket. As the shooting distance increases, the task of scoring becomes significantly more challenging. Players and coaches commonly report that longer shots are more difficult, and consider increased distance to be the primary factor that alters shooting form and affects the likelihood of scoring. Indeed, empirical game analyses have shown that shooting efficacy (the percentage of shots made) declines as distance increases, and shooting efficacy is well known to be a key discriminator between winning and losing teams [6]. Because scoring efficiency is so pivotal to game outcomes, understanding how distance impacts shooting mechanics is of high practical importance. Simply looking at whether a shot is made or missed provides limited insight, especially for younger or developing players. A missed long-range shot could result from insufficient strength, poor technique, or suboptimal coordination, and each of these issues would require a different coaching intervention. Therefore, examining the kinematic variables of the shooting motion (such as joint angles, velocities, and body positioning) offers valuable information beyond raw shooting percentages. By analyzing movement patterns, coaches and sports scientists can identify which adjustments a player makes (or fails to make) when attempting longer shots, thereby pinpointing areas for technical improvement [7, 8].

A number of biomechanical studies have investigated how players alter their shooting mechanics with increased distance in order to maintain performance. Early foundational work by Miller and Bartlett, for instance, examined jump shots at various distances and documented systematic changes in ball trajectory and body positioning as distance increased. Across multiple studies, a consistent pattern has emerged: as players move farther from the basket, they tend to release the ball at a flatter angle and with greater speed. For example, one study on youth male players found that when shooting from close range, the average ball release angle was about 68°, but at longer range it dropped to about 58°; conversely, release velocity rose from roughly 5.4 m/s to 7.4 m/s as distance increased. Similar trends have been observed in adult players. In experienced adult male athletes, reported mean release angles range around 69-79° for shorter to longer jump shots, while release velocities increase from roughly 4.4 m/s up to 6.9 m/s as distance grows [9, 10]. Female players, in general, have shown lower release angles (around 52° in longer attempts) and also require a fairly high release velocity (around 7 m/s or more) to reach the basket from long range. These adjustments in angle and speed are necessary to compensate for the greater horizontal distance the ball must cover. In essence, to make a successful long-distance shot, a player must launch the ball faster (to cover more ground) but cannot afford to use too steep of an arc, otherwise the ball may fall short or lose accuracy. This interplay of angle and velocity is a fundamental biomechanical constraint of long-distance shooting [11, 12].

In addition to ball trajectory parameters, researchers have explored how the shooter's body movements adapt for longer shots. Key aspects include the displacement of the body's center of mass (CoM) during the jump and the kinematics of various joints (shoulder, elbow, knee, etc.) involved in the shooting motion. Prior studies indicate that as distance increases, players often exhibit greater countermovement (deeper knee bend) and a more pronounced forward lean or horizontal shift of the CoM, presumably to generate additional power and momentum for the shot [13]. For instance, deeper knee flexion allows the player to prolong the upward acceleration phase and impart more energy to the ball at release. Likewise, increased shoulder flexion (raising the shooting arm higher) and faster extension of the elbow and knee joints have been observed in longer shots, contributing to a higher release velocity of the ball. These biomechanical adjustments collectively help the shooter propel the ball farther. However, they can also alter the shot's consistency and accuracy, which is one reason why field goal percentages tend to drop at longer range. In summary, while players instinctively or strategically adjust their technique to meet the demands of distance, those adjustments can come at the cost of reduced precision, highlighting a trade-off that is central to jump shot performance [14].

It is important to note that the majority of existing research on jump shot kinematics has been conducted with adult male athletes or highly skilled players. Far less attention has been given to youth players or female players, especially those who are still developing their skills. This gap in the literature is significant: younger players are still refining their motor abilities, and their physical characteristics (strength, limb lengths, etc.) differ from adults, which might lead them to use different strategies when shooting. In particular, adolescent players and female adolescents in many cases have less muscular strength and power compared to adult males. A novice young female player may not yet possess the upper-body strength or explosive leg power that adult male players use to comfortably shoot from long distances. Consequently, understanding how youth players compensate for longer shooting distances is both a theoretical and practical concern [15]. From a developmental standpoint, these insights can inform age-appropriate training. For instance, if young players are found to excessively alter their form or struggle to maintain proper technique at long range, coaches might prioritize teaching consistent form at shorter distances before gradually extending the range. Additionally, given that female players generally have different strength profiles than males, the adjustments they make could differ in magnitude or nature, for example, they may rely more on technique (e.g. deeper knee bend, greater torso involvement) rather than brute force to generate power for long shots. Identifying these sex- and age-related differences is important for developing tailored coaching feedback. Coaches need to know what to look for when a young player attempts a long shot: whether they are sacrificing form (e.g., throwing from the hip, or leaning excessively) and how that affects performance. With proper insight, coaches can emphasize maintaining key fundamentals (balance, vertical jump, full follow-through, etc.) even as players extend their shooting range [16].

1.1 Contribution of This Study

Given the outlined gaps and challenges, the present study addresses the need for a deeper understanding of how adolescent female basketball players adjust their shooting mechanics with changes in distance. Whereas most prior studies examined adult or male populations, this research focuses on young female players, thereby contributing new evidence on an under-represented group in sports biomechanics literature. The primary aim of this study is to examine the variation in key kinematic parameters of the basketball jump shot when the shooting distance is altered. In particular, we investigate two distances one relatively closer to the basket and one farther and quantify how each of several kinematic variables (including ball release angle, release velocity, release height, center of mass movement, and joint angles/velocities) differ between these conditions. By analyzing within-player adjustments, we can infer which biomechanical changes are employed by young athletes to successfully reach the basket from longer range.

Our work offers several contributions. First, it extends current knowledge of basketball shooting by providing data specific to early-adolescent females, a group for whom strength and skill levels are still developing. Understanding their shooting kinematics can help in devising training programs that build proper technique and prevent the development of flawed habits when range is increased. Second, this study's findings will inform coaching practices: identifying the compensatory mechanisms (e.g., extra knee flexion or increased arm swing) used at longer distances can guide coaches to emphasize or correct certain techniques. Finally, our methodology involving detailed motion analysis with videography and marker-based kinematics demonstrates an approachable way for practitioners and researchers to quantitatively assess shooting form beyond subjective observation. In summary, this study contributes new insights into the biomechanics of the jump shot in youth athletes and provides practical recommendations to support skill development and performance enhancement in basketball.

To achieve these goals, we conducted a controlled experiment with adolescent female players performing jump shots from two distances. We hypothesized that increasing the shooting distance would necessitate multiple adjustments in the players' movement pattern, chiefly to generate greater ball release velocity for covering the longer distance. Specifically, we expected to observe a lower ball release angle and higher release speed at the farther distance, accompanied by changes such as deeper knee flexion, greater shoulder angle, and faster joint angular velocities, compared to the closer distance. The following sections detail the methods used to test these hypotheses, including information about the participants, experimental procedures, and data analysis techniques.

2. Materials and Methods

2.1 Participants

This study involved a sample of adolescent female basketball players recruited from local youth basketball clubs. A total of 27 players took part (mean age 12.1 ± 0.9 years). On average, participants were approximately 153 cm in height (SD ≈ 8 cm) and weighed about 49 kg (SD ≈ 13 kg). All the players were active members of their clubs' teams and had a minimum of two years of regular basketball training experience prior to the study. They practiced around three times per week in their clubs' training programs, which ensured a basic proficiency in the fundamental skills, including shooting. Each participant was medically fit and free of any injuries at the time of data collection, as verified by self-report and parental confirmation. We included only players who were right-hand dominant for shooting (since our motion analysis focused on the dominant side) and who had no orthopedic conditions that could affect their shooting motion.

Basic anthropometric measurements were taken to characterize the participants. Standing height and sitting height were measured to the nearest 0.1 cm using a portable stadiometer (Seca 213, Hamburg, DE), and body mass was measured to the nearest 0.1 kg using a calibrated digital scale (Seca 760, Hamburg, DE). From these measures, an estimate of leg length was obtained by subtracting sitting height from standing height. These anthropometric data are recorded to allow analysis of body proportions, which can be relevant in biomechanical interpretations (for example, longer legs might influence jump mechanics).

Ethical approval for the study was obtained from an institutional research ethics committee before recruiting participants. All procedures were conducted in accordance with the standards of the Declaration of Helsinki for research with human subjects. Because the participants were minors, written informed consent was obtained from their parents or legal guardians, and each player provided assent to participate. The consent form and verbal instructions made it clear that participation was voluntary and that the player could withdraw from the study at any time without any penalty or effect on her team status. Confidentiality of personal data was assured, and each participant was assigned an ID code for data analysis to protect her identity. These ethical safeguards ensured that the study met scientific and ethical standards for research in sports science.

2.2 Procedures

Study Design: We used a within-subject experimental design in which each participant performed a series of standardized jump shots under two distance conditions. The two distances were chosen to represent a moderate range shot and a longer-range shot in youth basketball. Specifically, the distances were 4.75 meters and 5.75 meters from the front of the basketball backboard. The closer distance (4.75 m) is roughly equivalent to a typical youth free-throw or a short field goal range, while the farther distance (5.75 m) approaches the three-point line range for this age group. By comparing performance at these two distances, we aimed to isolate the effects of increased distance on shooting kinematics.

Warm-up: Before any data collection, all participants completed a standardized warm-up to ensure they were adequately prepared and to minimize injury risk. The warm-up lasted approximately 15 minutes and included light cardiovascular activity and dynamic stretching. Players first did a brief jog and some dribbling drills to elevate heart rate and mimic game-like movement. This was followed by a series of shooting drills from short range to engage the specific muscles used in shooting. They also performed dynamic stretches focusing on the lower body (e.g., lunges, leg swings) and upper body (arm circles, shoulder swings) to improve flexibility and range of motion. By the end of the warm-up, each participant was familiar with the shooting task and physically ready to perform maximal effort jump shots.

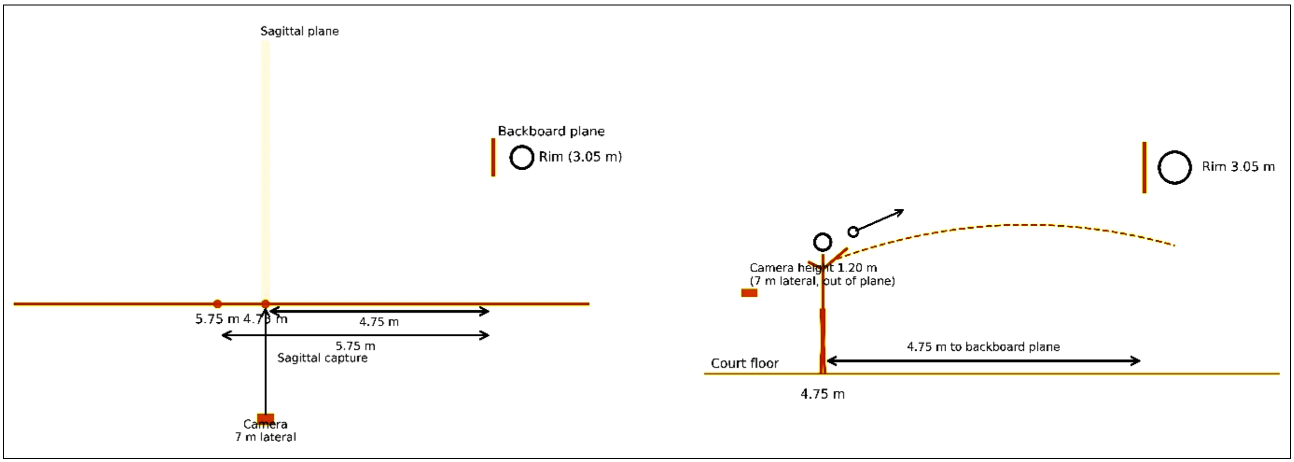


Fig 1: Schematic representation of the experimental setup for data collection. The participant performs a jump shot from the marked distances (4.75 m and 5.75 m) while a high-speed camera, positioned 7 m to the side at 1.2 m height, captures the motion in the sagittal plane. Key body landmarks are marked with reflective markers (shown as yellow dots) on the dominant side to facilitate kinematic analysis.

Shooting Trials: After warming up, each player performed a series of jump shots from the specified distances. The trials were conducted in an indoor basketball court with standard equipment. Each participant performed 10 shots from the 4.75 m distance and 10 shots from the 5.75 m distance, for a total of 20 recorded shots per player (spread over the two conditions). To control for potential fatigue or learning effects, all players performed the trials in the same order: first the 4.75 m shots, then the 5.75 m shots. We opted for a fixed order (shorter distance first) to avoid undue fatigue influencing the longer-distance attempts; given the young age of the participants, starting with the closer shots helped build confidence and ensured that by the time they attempted the long-range shots, they were already accustomed to the testing environment. Between shots, each player was given a brief rest (approximately 20-30 seconds) to recover and refocus, ensuring that each attempt was as consistent as possible.

All shots were taken from a frontal position with respect to the basket (i.e., the player was centered with the hoop, not from an angle). Participants used a regulation youth basketball (Wilson Evolution, Size 6, 566 g) appropriate for their age category. They were instructed to perform their natural jump shot as if in a game. Importantly, to replicate game conditions, we did not allow a stationary set shot; players were required to use a jumping motion and shoot in one fluid action rather than standing still. This instruction was intended to simulate real game scenarios where players typically shoot in motion (jumping vertically) rather than taking static shots, especially at these distances. To standardize conditions further, one of the researchers acted as a rebounder: after each shot, the researcher immediately caught or retrieved the ball (when possible) and passed it directly back to the participant. This procedure ensured that the interval between shots was consistent and that players did not have to chase rebounds, which could induce extra fatigue or disrupt concentration. The direct return pass also simulated a game-like scenario where a player might receive a pass and shoot in rhythm, thereby maintaining identical shooting conditions across trials.

Motion Capture Setup: The core of our data collection involved recording each shot with a high-speed video camera for subsequent kinematic analysis. A digital video camera (Sony Cyber-shot RX100) was used, filming at 120 Hz (i.e., 120 frames per second) to allow precise capture of rapid movements. The camera was positioned to provide a sagittal plane view of the shooter that is, a side view capturing the motion profile. Specifically, the camera was placed 7 m to the right side of the player (for right-handed shooters, capturing their dominant side) and elevated 1.20 m above the ground. Figure 1 illustrates this setup: the camera's line of sight was perpendicular to the plane of motion of the player, ensuring a clear lateral view of the entire shooting action. This distance and height were chosen so that the camera's field of view included the player's full body motion and a portion of the ball's flight trajectory immediately after release. The camera was repositioned slightly (maintaining the 7 m distance and 1.20 m height) when the participant moved from 4.75 m to 5.75 m, to remain perpendicular to the player's new position. Throughout all trials, lighting was consistent and background distractions were minimized to ensure the video quality was suitable for analysis.

During the shooting trials, a second researcher was tasked with tracking the outcome of each shot. For every attempt, it was recorded whether the shot was scored (made basket) or missed, using a binary notation (1 for scored, 0 for missed). This provided an efficacy measure (percentage of shots made at each distance) for supplemental analysis. Although our primary focus was on kinematic differences rather than success rates, recording the outcome allowed us to ensure that participants were attempting genuine shots (not deliberately mis-throwing) and to possibly explore correlations between technique and success in a future analysis. In our design, however, we did not give participants feedback about whether their last shot was made or missed, to avoid any conscious alteration of technique in response; they were simply instructed to shoot to the best of their ability each time.

Marker Placement and Kinematic Recording: To facilitate detailed motion analysis, we employed a 2D marker-based tracking approach. Before the shooting trials, reflective markers (1.5 cm diameter) were placed on specific anatomical landmarks on each player's dominant side. A single experienced investigator applied all markers to ensure consistency in placement. The chosen landmarks correspond to major joints or reference points required to define the segments of the shooting arm and leg. Markers were affixed at the following points: the tragus of the ear (to track head position and as a proxy for upper body orientation), the acromion process at the shoulder (lateral tip to mark shoulder joint rotation center), the lateral epicondyle of the humerus at the elbow, the ulnar styloid (wrist joint), and the head of the fifth metacarpal on the hand. These upper-limb markers outlined the arm and hand motion during shooting. Similarly, for the lower body, markers were placed on the greater trochanter of the femur (hip joint), the lateral epicondyle of the femur (knee joint), the lateral malleolus of the fibula (ankle joint), and the head of the fifth metatarsal on the foot. Collectively, these nine markers (ear, shoulder, elbow, wrist, hand; hip, knee, ankle, foot) provided the necessary reference points to reconstruct the motion of the shooting arm and leg in the sagittal plane. They allow calculation of joint angles (e.g., elbow flexion angle, knee angle) and positions of key points (like the shoulder or hip) throughout the movement.

After the markers were applied and verified for visibility, we proceeded with the video recording of the shots as described. Following the completion of all shooting trials, the video footage was transferred to a computer for analysis. We used Tracker software (Open Source Physics Video Analysis and Modeling Tool, version 5.1.5) to perform frame-by-frame motion analysis on the recordings. Tracker is a software that allows manual or automatic tracking of markers in video files and is widely used for 2D kinematic studies. Prior to analyzing the motion, it was necessary to calibrate the video scale and coordinate system. We performed a planar calibration using a reference object of known dimensions placed in the plane of motion (e.g., a 2-meter measuring rod visible in the frame). This provided a scale (pixels to meters conversion) for distance measurements on the video. Additionally, we employed a 2D Direct Linear Transformation (2D-DLT) technique to account for any minor perspective distortion in the field of view. The DLT calibration used the vertical and horizontal dimensions of the reference object and known court markings to establish a coordinate system and correct scaling. References from the literature were followed for the DLT procedure, ensuring that the computed coordinates of markers would accurately reflect real-world distances. All video analyses (tracking of markers and digitization of coordinates) were carried out by the same investigator to maintain consistency and eliminate inter-observer variability.

Before the main analysis, we conducted a pilot reliability test to ensure our motion tracking methods were producing consistent results. In this pilot, 10 shots from a subset of players (not part of the main 27 or a subset of them) were analyzed twice by the same investigator under identical conditions. We calculated intra-observer reliability coefficients (R) for key outcome measures from these pilot trials. The results showed high reliability: for example, the reliability of measuring the ball release angle was $R \approx 0.91$, release velocity $R \approx 0.87$, and release height $R \approx 0.90$. All these values indicate excellent consistency in the tracking and calculation process (an R value of 1.0 would be perfect, so values in the high 0.8s to 0.9s are very good). This gave us confidence that our kinematic analysis procedure was robust and that any differences observed between the two shooting distances would reflect actual performance differences rather than measurement error.

Kinematic Variables

The kinematic analysis quantified a comprehensive set of variables derived from tracked marker coordinates, selected for established relevance to shooting performance. Ball release parameters were computed at the last video frame in which the shooting hand contacted the ball and the immediately subsequent frame. Release angle was defined as the angle between the horizontal and the line connecting the ball center at release and one frame after, providing the initial flight direction; trigonometric calculations on calibrated coordinates yielded this value. Release velocity represented the ball's instantaneous speed in the first post-release frame, obtained by differentiating positional data in Tracker, and is reported in meters per second. Release height was the vertical position of the ball center at release, expressed in meters using the video's spatial calibration, reflecting contributions from jump elevation and upper-limb extension. Whole-body center of mass (CoM) motion was estimated in the sagittal plane using a standard segmental model, assigning each segment a mass fraction and segmental CoM location from anthropometric coefficients; frame-wise CoM coordinates were then derived from the digitized markers. From these trajectories, two indices were extracted: horizontal CoM displacement, defined as the forward translation from movement onset to take-off, interpreted as an indicator of forward lean or lunge that can add horizontal momentum but potentially destabilize aim; and CoM maximum height, the peak vertical position during the jump, accompanied by the CoM height at ball release to indicate whether release occurred on ascent, at apex, or descent.

Lower-body kinematics focused on hip and knee behavior. Hip height metrics included peak hip vertical position and hip height at release, indexing the extent of lower-limb extension and the temporal proximity of release to jump apex. Knee mechanics were characterized by the minimum knee angle reached during the countermovement (deepest flexion marking the transition from eccentric to concentric phases), the knee angle at release, the peak knee extension angular velocity (reflecting explosive drive), and the knee angular velocity at release. Upper-limb kinematics characterized the shooting arm. Shoulder angle at release (flexion relative to the trunk) indexed arm elevation and potential release-point height, while elbow angle at release quantified the degree of extension at ball departure. For both shoulder and elbow, peak angular velocities across the movement and the angular velocities at the release frame were recorded, since faster segmental rotation typically supports greater ball speed but may influence fine control at the moment of release. Collectively, these variables captured the interplay between trajectory-defining release parameters, whole-body sequencing through CoM behavior, and segment-level contributions from the lower and upper limbs that underpin shot range and consistency.

All the above angles were defined in the sagittal plane (flexion-extension plane) and calculated from the marker coordinates using standard geometric formulas. The motion was conceptually divided into phases for clarity: a preparatory phase (from start of movement until the deepest knee flexion), an action phase (from the deepest knee position up to ball release), and a follow-through phase (from release until landing). Although our analysis emphasized the preparatory and action phases, defining these phases helped ensure we extracted consistent metrics (e.g., identifying the minimum knee angle clearly). Notably, we observed (and it is reported in the results) whether the ball release occurred before or after the peak of the jump (i.e., whether the players released on the way up, at the apex, or on the way down). Prior research suggests that for optimal accuracy, releasing near the apex is beneficial, but in some cases, players might shoot slightly on the ascent when extra power is needed.

For quality control, every tracked trajectory (for markers and calculated variables) was visually inspected. If any irregularities or obvious tracking errors were noted (for instance, a marker jump due to occlusion or motion blur), the tracking for that segment was corrected manually by the analyst to ensure accurate data. Through this detailed procedure, we obtained a reliable set of kinematic data for each shot at each distance.

2.3 Statistical Analysis
All statistical analyses were conducted using IBM SPSS Statistics (Version 26.0, IBM Corp., Armonk, NY). We began by computing descriptive statistics for all variables of interest. For each distance condition (4.75 m and 5.75 m), the mean and standard deviation (SD) were calculated for every kinematic parameter, as well as for the percentage of shots scored (as an indicator of shooting efficacy). These descriptive results provide an overview of the central tendency and variability in the players' performance under each condition.

Prior to comparative analysis, we verified the distribution of each variable to decide on the appropriate statistical tests. The Shapiro-Wilk test was applied to each continuous variable to check for normality of the data. The majority of our kinematic variables (e.g., angles, velocities) met the assumption of normal distribution. In the few cases where a variable showed significant deviation from normal (for example, the distribution of chronological age was non-normal due to the narrow age range), we noted it, but since those were mostly descriptive or not central to the paired comparisons, we proceeded with parametric tests for the main analyses.

To address the primary aim, we compared the kinematic measures between the two distance conditions using paired t-tests. A paired t-test is suitable here because each participant serves as her own control we have two observations (short-distance vs long-distance) for each subject, and we want to test whether the mean difference is significantly different from zero. For each key variable (e.g., release angle, release velocity, knee flexion angle, etc.), a paired t-test was performed to determine if the change from 4.75 m to 5.75 m was statistically significant. Alongside p-values, we computed the effect size for each comparison in terms of Cohen's *d*. Cohen's *d* was calculated as the mean difference between distances divided by the pooled standard deviation. We interpret Cohen's *d* using conventional thresholds: $d < 0.2$ indicates a negligible or small effect, *d* between 0.2 and 0.6 is a moderate effect, *d* between 0.6 and 1.2 is a large effect, and $d > 1.2$ is a very large effect. Reporting effect sizes is important for understanding the practical significance of any differences, for instance, a statistically significant difference in release angle might have a small effect size if the angle change is minor, or a large effect size if the change is substantial and consistent across players.

Given the multiple comparisons being conducted (since we analyze numerous kinematic variables), there is an increased risk of Type I error (false positives). To address this, we set a more stringent alpha level for significance. Instead of the conventional 0.05, we used $\alpha = 0.01$ as our threshold for statistical significance in the t-tests. This adjustment helps control for Type I errors in light of the multiple tests. In other words, only p-values less than or equal to 0.01 were considered evidence of a significant difference between the two shooting distances for a given metric. We also used two-tailed tests since our hypotheses, while directional (we expected certain increases or decreases), still allow for the possibility of any difference.

All results of the statistical tests are presented in the results section with their corresponding p-values and effect sizes. Additionally, we provide confidence intervals (95% CI) for the mean differences to indicate the precision of the estimated changes. The outcomes (scored vs missed percentages) at each distance were compared as well to see if there was a significant drop in success from 4.75 m to 5.75 m, although with our modest sample size the power to detect an efficacy difference is limited.

3. Results
The purpose of this section is to present the descriptive and inferential statistical outcomes of the study, highlighting the differences in kinematic and performance variables between two shooting distances (4.75 m and 5.75 m). The results are organized into three subsections: (a) participant characteristics, (b) shooting performance outcomes, and (c) kinematic variables related to joint positions, angular velocities, and center of mass (CoM) displacement. Each table is accompanied by detailed interpretation to provide a comprehensive understanding of the results.

3.1 Participant Characteristics
Descriptive statistics for age and anthropometric measurements are provided in Table 1**.** These include chronological age, body mass, stature, sitting height, and estimated leg length. Shapiro-Wilk tests were conducted to evaluate normality for each variable. All variables except chronological age demonstrated normal distribution, as indicated by non-significant *p* values, confirming that parametric tests could be applied.

Table 1: Descriptive statistics of adolescent basketball players (n = 27)

Variable	Mean value (95% CI)	SD	Shapiro-Wilk value	*p*
Chronological age [years]	12.07 (11.73-12.41)	0.85	0.213	≤ 0.01**
Body mass [kg]	48.8 (43.8-53.9)	12.8	0.136	0.30
Stature [cm]	153.3 (150.1-156.5)	8.0	0.166	0.14
Sitting height [cm]	69.8 (68.3-71.3)	3.8	0.143	0.43
Estimated leg length [cm]	83.5 (81.0-85.9)	6.2	0.089	0.45

Note: CI = confidence interval, SD = standard deviation, **p ≤ 0.01.

The sample reflects a homogenous group of adolescent players, with relatively consistent anthropometric features. Average body mass (~48.8 kg) and stature (~153.3 cm) fall within the expected range for this age group. The similarity in body proportions supports the assumption that variations in shooting mechanics are more attributable to kinematic factors than to differences in body size.

3.2 Shooting Performance Outcomes
Table 2 presents the descriptive statistics and paired *t*-test results for shooting efficacy and ball release variables at the two distances.

Table 2: Descriptive statistics and paired *t*-test results for shooting efficacy and ball release variables (n = 27)

Variable	4.75 m Mean (95% CI)	SD	5.75 m Mean (95% CI)	SD	*t*	*p*	*d*
Efficacy - Scored [%]	47.5 (42.5-50.0)	12.5	42.5 (35.0-47.5)	12.5	1.559	0.13	0.41
Ball release - Angle [°]	60.4 (58.7-62.1)	4.3	58.7 (57.4-59.9)	3.2	3.438	≤ 0.01**	0.46
Ball release - Velocity [m/s]	6.98 (6.78-7.18)	0.50	7.63 (7.54-7.72)	0.23	-115.437	≤ 0.01**	-1.70
Ball release - Height [m]	1.92 (1.86-1.98)	0.15	1.90 (1.85-1.94)	0.12	1.305	0.20	0.15

Note: CI = confidence interval, SD = standard deviation, **p ≤ 0.01.

The data indicate that efficacy decreased slightly when shooting from 5.75 m (42.5%) compared to 4.75 m (47.5%). However, the difference was not statistically significant, suggesting that players maintained similar success rates across the two conditions.

More notable differences were evident in ball release mechanics. The release angle decreased significantly at the longer distance, averaging 58.7° compared to 60.4° at 4.75 m. This reduction corresponds to a flatter ball trajectory at greater distances. Conversely, ball release velocity increased significantly at 5.75 m (7.63 m/s vs 6.98 m/s), demonstrating the necessity of generating greater release speed to compensate for the additional horizontal distance. Ball release height showed no significant variation, remaining consistent at approximately 1.9 m for both distances.

3.3 Kinematic Variables of the Shooter

Detailed kinematic parameters, including CoM displacement, joint angular positions, and angular velocities, are presented in Table 3.

Table 3: Descriptive statistics and paired *t*-test results for kinematic parameters (n = 27)

Variable	4.75 m Mean (95% CI)	SD	5.75 m Mean (95% CI)	SD	*t*	*p*	*d*
CoM Horizontal displacement [m]	0.14 (0.12-0.16)	0.06	0.23 (0.18-0.27)	0.11	-5.901	≤ 0.01**	-1.04
CoM Maximum height [m]	1.12 (1.09-1.16)	0.09	1.14 (1.12-1.17)	0.06	-1.979	0.06	-0.27
Shoulder release angle [°]	111 (107-115)	10	109 (105-113)	11	-11.060	≤ 0.01**	0.24
Elbow release angle [°]	159 (155-162)	10	158 (154-162)	11	-0.447	0.66	-0.04
Knee minimum angle [°]	114 (110-119)	11	111 (108-114)	9	3.364	≤ 0.01**	0.34
Knee release angle [°]	170 (168-172)	6	170 (167-172)	7	0.774	0.45	0.08
Shoulder peak angular velocity [°/s]	1114 (1029-1199)	214	1175 (1094-1256)	204	-2.958	≤ 0.01**	-0.52
Shoulder release angular velocity [°/s]	470 (420-520)	127	637 (532-743)	267	-5.164	≤ 0.01**	-0.81
Elbow peak angular velocity [°/s]	795 (712-877)	209	860 (784-936)	192	-3.333	≤ 0.01**	1.42
Elbow release angular velocity [°/s]	611 (550-674)	157	580 (523-637)	145	2.783	≤ 0.01**	0.22
Knee peak angular velocity [°/s]	532 (474-590)	146	608 (548-669)	152	-6.097	≤ 0.01**	-0.62
Knee release angular velocity [°/s]	129 (108-151)	55	165 (124-206)	103	-2.305	0.03	-0.44

Note: CI = confidence interval, SD = standard deviation, **p ≤ 0.01.

3.3.1 Center of Mass Displacement

The horizontal displacement of the CoM was significantly greater at 5.75 m than at 4.75 m (0.23 m vs 0.14 m). This finding suggests that players incorporated more forward body motion when shooting from longer distances. The CoM maximum height increased marginally (1.14 m vs 1.12 m), but the difference was not significant.

3.3.2 Joint Angular Positions

Shoulder release angle decreased slightly but significantly at 5.75 m, indicating a more flexed shoulder position at the moment of release. Elbow release angle showed no significant difference between conditions, remaining nearly identical across distances. Minimum knee angle was significantly smaller at 5.75 m, demonstrating that players executed a deeper crouch prior to the jump when shooting from farther away. Knee release angle was consistent across conditions, with no significant differences detected.

3.3.3 Joint Angular Velocities

Angular velocity patterns demonstrated substantial differences across shooting distances. Peak angular velocities of the shoulder, elbow, and knee were all significantly greater at 5.75 m compared to 4.75 m. Shoulder angular velocity at release was notably higher in the longer shot, while elbow angular velocity at release was significantly lower, suggesting an earlier achievement of peak extension during the motion. Knee angular velocity at release was also significantly higher at 5.75 m, further indicating stronger lower-body contribution in long-range shooting.

4. Discussion

The purpose of this study was to investigate how key kinematic aspects of the basketball jump shot (BS) performance change with shooting distance in adolescent female players. It was hypothesized that novice players would make specific adjustments at a longer shooting distance primarily to generate the additional ball release velocity required to reach the basket. The findings support this hypothesis by demonstrating multiple coordinated changes in technique when shooting from 5.75 m compared to 4.75 m. In the longer-distance condition, players exhibited a deeper crouch (greater knee flexion in the preparatory phase) which effectively increased the time and distance over which they could accelerate their bodies and the ball before release. They also showed a tendency to release the ball with the shooting arm in a more flexed shoulder position and a more extended elbow position, indicating a higher arm angle and near-full extension of the arm at the point of release. Additionally, the angular velocities of major joints (shoulder, elbow, and knee) during the shot were generally higher at 5.75 m, contributing to a faster arm swing and leg extension to impart greater speed to the ball. Another clear adjustment was the significantly larger horizontal displacement of the center of mass observed at the longer distance, suggesting that the players allowed their bodies to drift forward more as they shot, potentially as an effort to compensate for the increased range. These modifications collectively enabled the players to increase the ball's release velocity when shooting from farther away, which was necessary to maintain shooting performance at the greater distance.

The relationship between shooting distance, ball speed, and release angle observed in this study is consistent with established principles of projectile motion and with previous research findings. To successfully reach a farther basket, a basketball must be launched with a higher velocity, which was evidenced here by the significantly greater ball release speed at 5.75 m. However, increasing the launch speed typically goes hand-in-hand with a lower launch angle, given the inverse relationship between these two variables in achieving an optimal trajectory. In the present results, the longer shots had a modestly reduced release angle (by approximately 1.7° on average) accompanying the ~9% increase in release velocity. This inverse adjustment of angle and speed aligns with prior empirical studies: experienced male and female players have been reported to shoot with a flatter but faster release when attempting longer shots (e.g. comparing 2-point to 3-point attempts). Similar findings have been noted in youth players, where boys exhibited decreased release angles and increased velocities as distance increased. Interestingly, the magnitude of change in angle and velocity with distance tends to be greater in younger or less experienced players than in experts. In other words, novices show more marked adjustments, whereas highly trained shooters maintain a more consistent technique and only fine-tune their release parameters for longer shots. The results of this study, which focuses on young female players, indeed showed substantial changes in both angle and velocity, reinforcing the idea that movement variability is higher in youth athletes compared to seasoned players.

One of the key adjustments identified was in the depth of the squat prior to the jump. Earlier literature suggests that a deeper crouch (greater knee flexion) in the preparatory phase can increase the distance and time available to generate upward force, thereby allowing a higher release velocity of the ball. As expected, the adolescent players in this study demonstrated a significantly deeper knee bend when shooting from 5.75 m than from 4.75 m (approximately a 3° greater flexion at the deepest point). While this difference might seem small in absolute terms, it is notable given the players' novice status and can meaningfully affect the impulse generated during the jump. By comparison, studies on adult players have reported minimal differences in deepest knee flexion between shorter and longer jump shots on the order of 1° for elite female players and 2° for elite males shooting from various distances. Youth players, however, can show much larger changes; for example, one study on young boys found roughly a 10° increase in knee flexion when distance was increased for their shots. The relatively larger adjustment in knee bending seen in young athletes underscores the contribution of the lower body to achieving sufficient ball speed: lacking the strength and refined coordination of adults, youth players appear to rely more on exaggerated countermovement's (i.e. deeper knee bends) to generate power for longer shots. The deeper squat at 5.75 m in this study likely helped the participants produce a stronger upward thrust and longer extension phase, ultimately contributing to the greater release velocity observed.

Accompanying the increased knee flexion, this study also found that the angular velocities of key joints were higher at the longer distance. A deeper crouch would be expected to result in a more powerful extension, which was reflected in the significant increase in peak knee extension velocity at 5.75 m. Not only did the legs extend faster, but the upper body joints (shoulder and elbow) also moved faster during the execution of the long-distance shot. The shoulder and elbow each achieved greater peak angular velocities in the 5.75 m attempts than in the 4.75 m attempts. This suggests that the players generated more vigorous arm movements likely in an effort to add speed to the ball. By the time of ball release, the shoulder joint in particular was still moving faster in long-distance shots, indicating a strong and continuous drive of the arm upward through the release point. The elbow's angular velocity at release, on the other hand, was slightly lower at 5.75 m despite a higher peak velocity earlier in the motion. This pattern a high peak elbow speed but a slowed speed at release is consistent with the arm reaching full extension a bit sooner during the long-range shot, meaning the elbow was nearly locked out by the time the ball left the hand. This could occur if the player accelerates the arm quickly to build up speed and then cannot continue accelerating once the arm is fully extended. Regardless, the overall effect of the increased joint speeds was a faster-moving shooting motion, which directly enabled the increased ball speed needed for the longer attempt. These findings agree with those of Podmenik *et al*. (2017) and others who observed that greater shooting distance demands higher limb angular velocities to propel the ball sufficiently far. In practical terms, young players intuitively or consciously compensate for distance by moving their limbs more explosively.

Proper coordination of body segments is crucial for a successful jump shot, and the changes seen in shoulder motion further illustrate how players adapted their technique for the longer distance. The shoulder flexion (i.e. raising of the upper arm) at the moment of release was slightly greater during 5.75 m shots. The shooting arm was inclined a bit more upward, which is an important factor for giving the ball a higher arc and sufficient lift. The shoulder joint contributes significantly to the upward force needed to propel the ball vertically as well as towards the basket. In our adolescent group, the shoulder angle at release (approximately 109-111° depending on distance) was similar to values reported for other youth players in the literature. Notably, experienced adult shooters often release the ball with a somewhat lower shoulder position (i.e. less flexion) relative to their younger counterparts. For instance, studies have shown that skilled male players might release with shoulder angles around 128-137° for close vs. long shots and skilled females around 107-114°. The adolescent girls in this study had shoulder angles in that latter range, but the key difference is that expert players tend to adjust this angle very little with distance, whereas the novices showed a measurable change. Some evidence even suggests that female players (who generally have lower upper-body strength and height than males) compensate by using slightly greater shoulder flexion than males to achieve a good arc on long shots. In contrast, male players can rely more on strength and may not need as pronounced an arm angle for longer distances. The fact that our participants demonstrated a significant increase in shoulder flexion at 5.75 m reinforces the idea that when strength is limited, altering the shooting angle of the arm is one way to help the ball cover the necessary distance with a favorable trajectory.

The elbow joint did not show a significant difference in its angle at release between the two distances in this study. This finding aligns with some studies on experienced players, which have found only slight or negligible changes in elbow angle when shooting from different ranges. For example, highly trained players might keep their elbow near the same degree of extension at release, perhaps with a minor tendency to be more flexed (less extended) on longer shots to help with arc and control. Interestingly, research on younger boys noted a different pattern: boys tended to show more elbow extension (a straighter arm) when shooting from farther out. The adolescent girls in the current study did not significantly change their elbow extension with distance, though the mean values suggest their elbows were quite extended (around 158-159°) at release in both conditions more so than what has been reported for experienced adult players. One possible explanation is the lack of upper-body strength in these young athletes. The elbow extension is a major contributor to the power of a shot; players with less strength might naturally maximize their elbow extension (almost fully straightening the arm) to squeeze out as much speed as possible. Thus, even though the elbow angle did not differ by distance here, the consistently high degree of elbow extension underscores how these participants rely on arm extension to generate power, and it hints that any subtle adjustments in elbow usage were constrained by their strength limitations.

Another prominent difference with distance was observed in the movement of the body's center of mass. Shots from 5.75 m involved a significantly greater forward horizontal displacement of the CoM than shots from 4.75 m. In practical terms, the players were jumping forward more noticeably when trying the longer shots. Previous studies have also found that when attempting longer shots, players (especially less experienced ones) tend to exhibit some forward or backward lean, resulting in horizontal body movement. A small amount of forward momentum can help in generating distance on the shot, but too much horizontal movement can be detrimental to stability and accuracy. Highly skilled shooters generally minimize unnecessary body drift; they are often able to jump nearly straight up and land close to the take-off point, which is considered a sound technical model for the jump shot. A stable, vertical jump is thought to improve consistency and shooting accuracy. The significant increase in CoM horizontal shift in our study suggests that these young players have not yet developed the strength or technique to maintain a strictly vertical jump when distance demands increase. Instead, they instinctively lunged forward a bit, perhaps attempting to reduce the range to the hoop by literally moving closer during the jump. While this strategy might momentarily aid distance, it introduces greater variability in the shot (as indicated by the greater movement variability at 5.75 m) and can upset the shooter's balance. This finding highlights an important coaching point: as players develop, they should be encouraged to jump vertically and avoid drifting when shooting, even from long range. Drills and feedback can focus on keeping the trunk upright and preventing the body from leaning or floating forward/backward at release. By reinforcing a stable base and vertical jump, coaches can help players improve their shooting consistency and accuracy.

Analysis of the timing of the jump and shot release in this study provides additional insight. The observations of hip and CoM motion indicated that the ball was typically released *before* the player reached the peak height of their jump. This implies that the shooters were using the upward momentum of their jump to help propel the ball, rather than relying purely on arm strength at the top of the jump. Releasing on the way up allows the kinetic energy from the rising motion to be transferred to the ball. This technique is common and especially useful for players with less upper-body strength. It appears that our participants intuitively employed this timing initiating the shot during the upward phase to compensate for their strength limitations, ensuring the ball had enough velocity at release.

In the context of existing research [17-20], the present study adds valuable data on how adolescent female players adjust their shooting mechanics with distance. Much of the literature on basketball shooting kinematics has focused on adult male athletes or highly skilled players, making direct comparisons to our cohort important for understanding developmental and gender-related differences. The results here confirm that young female players exhibit distinctive adjustment patterns (such as pronounced increases in knee bend and body lean) when the shot distance increases, underlining the influence of both maturity and skill level on shooting technique. These findings should be interpreted with a few considerations in mind. First, the sample size of the study was modest (n = 27) and all players were from a similar age group and skill level. While sufficient to detect key differences, a larger and more diverse sample might further generalize the findings. Second, the order of shooting conditions was not randomized, meaning all players might have performed the same sequence of distances. This could introduce order effects or fatigue that slightly influence the results. Ideally, future studies would counterbalance or randomize the distances to ensure no systematic bias in the performance due to sequence. Third, the kinematic analysis was conducted in two dimensions (2D). A 2D analysis in the sagittal plane captures the primary joint movements for a straight-on jump shot, but it cannot account for lateral or out-of-plane motions and may have limitations in accuracy. A three-dimensional motion analysis could provide more detailed information, such as detecting any sideways deviations or rotations that a 2D analysis might miss. Finally, individual differences in anthropometry and physical abilities (like strength or jump height) were not explicitly controlled or correlated with the kinematic data. Factors such as longer limbs, higher jump capacity, or greater muscle strength could influence how a player compensates for distance. Not accounting for these variables is a limitation, but given the homogeneous group (similar age and all female novice players), the impact may be minor in this study. Nonetheless, future research should consider including measures of strength and body size to examine how they interact with shooting mechanics.

Despite these limitations, the findings yield several practical implications for coaching and youth player development. The adjustments observed particularly the deeper knee bend, increased joint speeds, and forward body lean indicate that young players naturally attempt to muster more power and range when shooting long. However, some of these strategies (like excessive forward drift) may not be optimal for long-term technique. Recognizing that limited strength is a major constraint for young players, coaches should tailor training to gradually improve both the mechanical technique and the physical capacity of the athletes. One recommendation is to initially encourage proper shooting form at shorter distances where players can comfortably reach the basket with correct technique. During the early stages of skill acquisition, maintaining consistency in form is more important than shooting from maximum range. As players build strength and consistency, the shooting distance can be progressively increased while ensuring the technique (stance, jump, and arm motion) remains fundamentally sound. The results from this study suggest that training efforts should focus on key aspects such as the coordination of the jump and release (for example, training players to utilize their legs and core effectively so that they do not have to excessively compensate with arm-only force) and on promoting a vertical jump with good balance. Coaches may also incorporate strength and conditioning programs to address upper-body and lower-body power, helping players achieve the necessary shot range without sacrificing form.

5. Conclusion

This study investigated how segmental MOI shapes key kinematic features of the basketball jump shot in adolescent female players, addressing whether mechanical properties of the limbs and trunk condition release mechanics at moderate (4.75 m) versus longer (5.75 m) ranges. Findings indicated that longer-range attempts were characterized by a lower release angle and higher release velocity, accompanied by deeper countermovement, higher peak joint angular velocities, and greater forward center-of-mass displacement; moreover, upper-limb and trunk MOI profiles aligned with steadier proximal-to-distal timing and more consistent release characteristics. The work contributes a mechanistic link between inertia distribution and coordination, extending kinematics-only evidence and offering an objective screen for individualized coaching. Practically, coaches and performance staff can integrate MOI-informed assessments to emphasize proximal stability, vertical take-off, and controlled distal acceleration, while strength programs target segment mass distribution and power to stabilize release parameters at range. Limitations include a homogeneous cohort, 2D sagittal analysis, fixed condition order, and modeled (not directly measured) inertia. Future research should incorporate 3D capture with musculoskeletal simulation, experimental MOI manipulations, wearable IMU/EMG validation, and longitudinal designs across maturation. Treating MOI as a first-order constraint provides a precise pathway to durable shooting efficiency and reliable long-range accuracy in developing athletes.

References

1. França C, Gouveia ÉR, Coelho-e-Silva MJ, Gomes BB. A kinematic analysis of the basketball shot performed with different ball sizes. Appl Sci. 2022;12(13):6471.
2. Caseiro A, Faro A, França C, Branquinho-Gomes B. Kinematic analysis of the basketball jump shot with increasing shooting distance: comparison between experienced and non-experienced players. Acta Bioeng Biomech. 2023;25(2):61-67.
3. Dai B, Yin Y. Technical analysis of basketball players' shooting movements through video images. Syst Soft Comput. 2024;6:200141.
4. Li F, Dukarić V, Očić M, Li Z, Knjaz D. Influence of fatigue and defensive pressure on three-point jump-shot kinematics in basketball. Appl Sci. 2024;14(20):9582.
5. Li S, Yang J, Mi J, Li Y. The effects of repeated sprints on mid-range and three-point jump shot biomechanics in elite basketball players. PeerJ. 2025;13:e19983.
6. Podmenik N, Supej M, Debevec H, Erčulj F. Common movement patterns of the jump shot while increasing the distance from the basket in elite basketball players. J Hum Kinet. 2021;78:29-41.
7. Slegers N, Love D. The role of ball backspin alignment and variability in basketball shooting accuracy. J Sports Sci. 2022;40(12):1360-1368.
8. Li F, Dukarić V, Orešković D, Simović S, Bi Z. Differences in kinematic parameters of basketball jump shot performed from different shooting positions. In: 9th International Scientific Conference on Kinesiology. 2021. p. 136.
9. Li F, Rupčić T, Knjaz D. The effect of fatigue on kinematics and kinetics of basketball dribbling with changes of direction. Kinesiology. 2021;53(2):296-308.
10. Özdalyan F, Manci E, Gençoğlu C, Gümüş H, Kosova S. Comparison of the shooting angles in wheelchair basketball and basketball players. Eur J Hum Mov. 2022;48:35-45.
11. Smeeton NJ, Meyer J, Klatt S. Perceiving the inertial properties of actions in anticipation skill. Psychol Sport Exerc. 2023;64:102276.
12. Espasa-Labrador J, Martínez-Rubio C, García F, Fort-Vanmeergaehe A, Guarch J, Calleja-González J. Exploring the relationship between game performance and physical demands in youth male basketball players. J Funct Morphol Kinesiol. 2025;10(3):293.
13. Pan H, Li J, Wang H, Zhang K. Biomechanical analysis of shooting performance for basketball players based on computer vision. J Phys Conf Ser. 2021;2024(1):012016.
14. Edriss S, Romagnoli C, Caprioli L, Zanela A, Panichi E, Campoli F, *et al*. The role of emergent technologies in the dynamic and kinematic assessment of human movement in sport and clinical applications. Appl Sci. 2024;14(3):1012.
15. Mahdi WFA, Sami MM, Hussein YN, Mohsen AT. The relationship between arm length and some bio-kinematic variables in 50 m butterfly swimming for Iraqi national swimmers. Int J Sports Sci Arts-Arabic. 2024;78(4).
16. Liu JM, Zaferiou A. Factors contributing to jump heights in two-foot running jumps with and without a basketball. Front Sports Act Living. 2025;7:1597058.
17. Ibáñez SJ, Gómez-Carmona CD, López-Sierra P, Feu S. Intensity thresholds for external workload demands in basketball: is individualization based on playing positions necessary? Sensors. 2024;24(4):1146.
18. He W, Li B. The impact of data-driven metrics on training programs to improve the performance of elite basketball players. J Comput Methods Sci Eng. 2025;14727978251337989.
19. Sha N. Basketball technical action recognition based on a combination of capsule neural network and augmented red panda optimizer. Egypt Inform J. 2025;29:100603.
20. Song SH. Relationship between quiet eye and kinematic characteristics based on expertise in badminton backhand serve. Percept Mot Skills. 2025;00315125251346882.