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ORIGINAL RESEARCH

Shot mechanical analysis according to shooting performance in youth basketball players

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Abstract

In basketball, shooting stands out as a vital technique directly affecting the game results. Identifying shooting mechanics early in a basketball player's career can significantly develop shooting performance in subsequent years. This study aimed to explore shooting percentages based on angular positions of joint parts in the shooting techniques of youth basketball players. Fifteen male participants (average age: 14.1±0.7 years, height: 180.7±7.9 cm, body weight: 65.4±10.0 kg, sports experience: 4.7±0.4 years) voluntarily participated in the study. They were divided into high shooting rate (n: 7) and low shooting rate (n: 8) groups. Both groups attempted 60 shots from the free throw line (20 shots), right forward position (20 shots), and left forward position (20 shots). Joint angle values during the initial and final shooting phases were compared between groups using Independent t-tests. Significant differences were found between groups in the shoulder part during the beginning phase and the wrist part during the final shooting phase ($p<0.05$). These findings underscore the potential for targeted enhancement of shooting mechanics among young basketball players through posture analysis (joint angle parts) using both performance assessments and electronic software tools.

Introduction

Basketball is a complex sport branch which has many components of performance (conditional characteristics, technical tactics, etc.). Optimizing this complex structure is important for success. Basketball is a sport branch with high physical, physiological, biomotor (strength, speed, endurance, flexibility, mobility, reaction, balance, agility, and coordination), technical-tactical and psycho-mental characteristics (Pamuk et al., 2023; Kılınç, 2008; Makaracı & Soslu, 2022). It is difficult to attribute success in basketball to a single criterion (Gocentas et al., 2004); however, being tall in physical structure is considered an advantage (Carter et al., 2005). It has been emphasized that physical structure, technique, tactics and mental abilities come to the fore in branches that are performed with the ball (basketball, football, etc.) and that technical tactics are as important as physical fitness for optimal performance (Tsunawake et al., 2003; Smith & Thomas, 1991).

Technique is considered very important in sports. Naturally, some sports have a high technical aspect (gymnastics) while others have a low technical aspect (athletics/running). Technique means performing the basic movements of the branch in the most economical way suitable for the purpose (Sevim, 2002; Muratlı et al., 2005). Or it is the ideal model of movement in a sporting discipline (Çetin, 1997). The ideal model of a sport also refers to an optimal movement form that is the result of practicing the movement many times in different ways.

In team sports, the foundations of this formation include movements that lead to the result in the shortest time unit, use the least energy consumption, and have the lowest error rate against the opponent. The movement practiced by every athlete cannot be considered technical. Because of the formation of the basic movement over time, the positioning of the joint system according to neuromuscular coordination is a result of the body's adaptation mechanism. In the adaptation mechanism, the body basically aims to perform movements in the most economical way suitable for the continuous purpose. When the difficulty level of technical learning is examined at the beginning of the sport, it is seen that while a lot of effort is made at first and less effort is made as the technique is

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established with repetitions of movement (Kılınç & Pamuk, 2022).

In basketball, technique plays an important role in both offensive and defensive systems. Especially the technical training received in the younger categories is very important in terms of constituting the basis of success in sports life (Makaracı et al., 2022). It is important that the technical movement taught in the younger categories is similar to the ideal model and meets the criteria (Kılınç & Pamuk, 2022). In the development process of children, it is accepted that the correct technical models they receive in the younger categories will be the basis for their future sports life. In the technical development of children or beginners in sports, the scientific knowledge, experience and technical evaluation of the coach/sports scientist play an important role. In the period of technical development, if the strengths and weaknesses are not evaluated in training, it can be thought that it may bring many deficiencies in determining the shape of the training in the development period. Basketball consists of the basic techniques of dribbling, passing, shooting and rebounding. While every technique is important, the shot is the most important factor in determining the score of the game (Struzik et al., 2014). Errors related to mechanics analysis and correct technique need to be taught repeatedly from a younger age. In basketball, shooting is the most important technique and the most important factor that directly affects the result of the game (Button et al., 2003). Release angle, speed and height play an important role in shooting technique (Miller & Bartlett, 1993, 1996).

The technical factors governing shooting apart from strength are stated as follows (Raiola & D'isanto, 2016): a. Starting height of the ball, b. Air resistance, c. Ball release rate, d. From a biomechanical point of view, the ball exit angle is related to the shot, the lower limb (foot, leg and thigh), the trunk (stabilizing musculature of the body in jump) and the upper limb (hand, forearm and arm). The main muscle groups of the upper extremity that intervene during the movement of the throw are: a. Flexors forearm: brachial, b. Flexors of the arm: anterior deltoid, grand pectorals (upper fibers), and biceps coracobrachialis, c. Extensor forearm: triceps, d. Pronator of the forearm: pronator tires and square, e. Extensors of the hand: extensor the radial and ulnar, radial extensor short and extensor ulnar, f. flexors of the hand: radial and ulnar, g. Flexors of the last four fingers of the hand: lumbrical, interosseous, flexor superficial and deepof the fingers (Raiola & D'isanto, 2016).

In general, the evaluation of technical development is done visually by coaches on the field (Apostolidis et al., 2004). Although there are many models in technical evaluation, the American Alliance for Health Physical Education, Recreation and Dance technical tests can be given as a few examples (AAHPERD, 1984). Technical evaluation can be difficult to implement as it needs to be carried out under field conditions. Therefore, coaches and sports scientists mostly prefer laboratory tests. This is mainly due to its high validity and reliability (Stapff, 2000). However, laboratory testing can sometimes be a disadvantage when time, cost, and availability in field conditions are taken into account. It also does not adapt to the field and competition conditions.

In our country (Türkiye), technical evaluation in basketball is done within the visualization framework and there are limited studies. Practically, in field conditions, the technical evaluation of basketball players' shooting technique is limited. Sports scientists have generally focused on biomechanical analysis of shots. In biomechanical analyses, the number of participants within the analysis may be limited as it requires detailed studies (Chen, 2014). Biomechanical analysis and evaluation processes can be time-consuming (Zhen et al., 2015). The difficulty of technical analysis is the difficulty of evaluating the positions taken by the joint parts during the movements performed by the primary athlete, as well as the difficulty of comparing the movement performed with the standards. For example, it was stated that many elements such as the position of the body, the velocity of the ball, and the rotation of the ball should be evaluated during the shot (Knudson, 1994). In technical evaluation, it is necessary to evaluate the process, body positions and the shape of the movement from the starting point to the end point of the movement. Due to these difficulties, it is very difficult to perform technical analysis in field conditions. In addition, the fact that basketball is a team sport is a disadvantage for the sports scientists. Technical analysis of each athlete separately creates some problems in the validity and reliability of visual evaluations. It can be said that analyzing the body in field conditions is a very difficult and time-consuming process for sports scientists.

In this study, we aimed to provide athletes and coaches with more detailed and real-time data by analyzing shooting mechanics in basketball from an angular perspective and evaluating shooting performance according to different positions (e.g. free throw line, sideline). The aim of this study was to investigate the effects of the angular conditions of the joint parts in the shooting position of the basketball players who train regularly in the youth basketball team on the shooting percentages by analyzing them practically in computer environment.

Methods

Participants

In our study, 15 male basketball players who regularly train at younger categories of Tofaş Sports Club in Bursa province participated voluntarily. Tofaş Sports Club, which has an important history in basketball in Turkey, has made significant contributions to Turkish basketball in terms of both club achievements in the Super League and athlete development. The participants in this study are members of the Tofaş Basketball Club youth team who regularly train and compete. None of the participants had any joint or muscle-tendon injuries. Fourteen were right-handed, while one was left-handed.

Procedure

In our study, two groups were formed: High Shooting Rate Group (HSRG) and Low Shooting Rate Group (LSRG). When creating the groups, athletes were assessed based on their average shooting rates (i.e., 30 successful shots). Those with below-average shooting rates were classified as LRSG, while those with above-average rates were classified as HRSG. The figures are determined as; High Group n: 7 (HSRG) (age 14.1±0.7 years, height 180.7±7.9 m, body weight 65.4±10.0 kg, sports age 4.7±0.4 years), Low Shooting Rate Group (LSRG) n: 8 (age 14.1±0.9 years, height 1.81±10.1 m., body weight 67.3 kg. and sports age 4.3±0.7 years).

Shooting Tests Measurements

The shooting tests were planned over the three zones shown in Figure 1. 20 shots were taken from each zone. During the shooting sessions, shots were taken from the free throw shooting zone (zone 2) in a static manner, while shots were taken from zones 1 and 3 (right-left forward zone 5.80m the distance between the closest end of the hoop in the direction of shooting and the marked spot where the basketball player stands is measured as 5.80 meters. This distance was chosen for the forward zones (zones 1 and 3) because it is close to the 3-point shooting zone and serves as an intermediate distance for 2-point shots. All shots were taken as free throw shots (shooting technique used in shooting area number 2) to ensure standardization. Participants were instructed to stand in their best shooting position (Starting Position) and to maintain their body positions after releasing the ball (Ending Position). It was requested that all shots from the three areas be aimed directly at the rim. Out of a total of 60 shots from three zones, those who score 30 shots and more were included in the High Shooting Group (HSRG). Those who scored 30 shots or less were included in the Low Shooting Rate Group (LSRG).

In the APPA technical analysis program, the position in which the basketball players received the basketball ball in the overhead area in the shooting position from the number 2 zone was determined as the *Shot Starting Phase* (for standardization) and asked to stay in the position where the basketball leaves the hand; this position was also determined as the *Shot Finishing* Phase.

High-resolution camera and APPA-Bastek Technical Analysis program were used in the study.

Figure 1. Shooting zones of the youth basketball players participating in the study. The shooting areas were designated as follows: 1) Left Forward, 2) Free throw Shot, and 3) Right Forward.

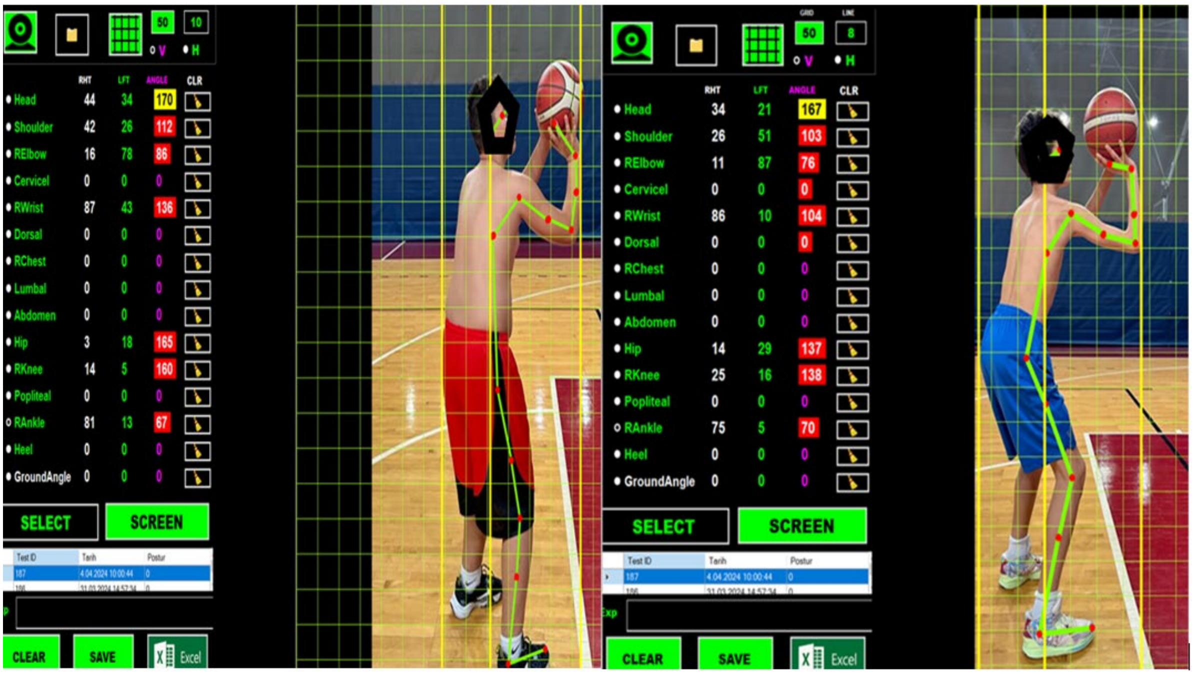

Figure 2. Analysis of the joint angles of the groups with high shooting rate (right photo) and low shooting rate (left photo) in the position of the initial phase of shooting.

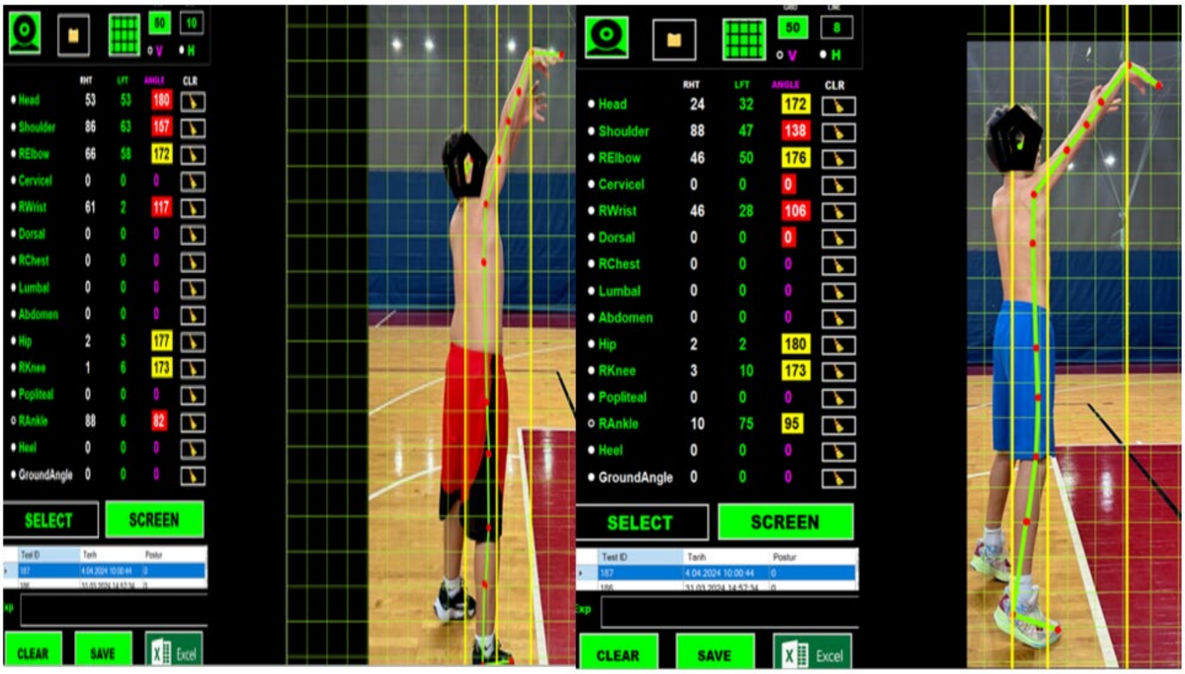

Figure 3. Analysis of the joint angles of the groups with high shooting rate (right photo) and low shooting rate (left photo) in the position of the final phase of shooting.

APPA Bastek Technical Analysis Program: It was printed in Visual Studio IDE, using the C# programming language WindowsForm within the framework of the algorithm. Codes were written regarding the joint parts accepted as references in the literature for technical evaluation. In the program, the photographs taken with a digital camera according to the technical position were transferred to the part determined in the APPA Bastek Analysis program (Kılınç, 2021). Canon EOS 4000D(18 Megapixel) was used in basketball analysis photo shootings. To stabilize photographic shooting, photos were taken from a distance of 3 meters and a height of 1.5 meters. For consistency, shooting positions from all three areas were fixed as for a free throw shot, and angular evaluations were performed using the same software.

To ensure standardization, photographs were taken in a fixed position after the ball was brought to the head area during the initial phase of shooting. In the finishing phase, the basketball player was instructed to maintain their position after the ball was released, and photographs were taken and analyzed accordingly. Analyzing the entire starting and finishing phases of the shot requires a detailed biomechanical system. However, in field conditions, basketball coaches often make technical corrections and improvements by observing the beginning and finishing phases of the shot. The analysis system we use aims to provide a practical tool that offers visual (photographic) and numerical (angular) data suitable for use in field conditions.

Data Analyses

(Independ t test) was applied for two group comparisons as statistical procedures. Head, shoulder, elbow, wrist, and hip, knee, and ankle joints were compared angularly with Shot Starting Phase (HSRG) and (LSRG). And also Head, shoulder, elbow, wrist, and hip, knee, and ankle joints were compared angularly with Shot Finishing Phase (HSRG) and (LSRG).

Results

In the physical posture position, seven areas can be evaluated angularly according to the Lateral (side) posture (Head, Shoulder, Right Elbow, Right Wrist, Hip, Right Knee, and Right Ankle). Okazaki & Rodacki (2018) also made angular analyzes over eight areas in their studies. 3 reference points were determined for the calculation of the internal angle of each part. For example, in the evaluation of the elbow, the distal point of the lateral deltoid (1 marker), the point where the cubital region forms the outer and innermost curves (2 markers), and the styloid process of the radius on the lateral side (3 markers) were marked with the mouse in the program. A line connecting the three marker points was then automatically drawn by the program. In the subsequent calculation, the second (2) marker point was accepted as the center point and the interior angle was calculated. The formula for the interior angle was ((180-(first interior angle + second interior angle).

In the angular calculation of the joint parts in the Start and End Positions, all joint parts were calculated according to the marked marker (P2) and the internal angles were calculated. For example, in the analysis of the wrist part in the Start position, P2 Processus Styloid, P1 Forearm midpoint and P3 were determined as the junction point of the metacappal and middle finger. All analyzes were carried out with the same methodological structure.

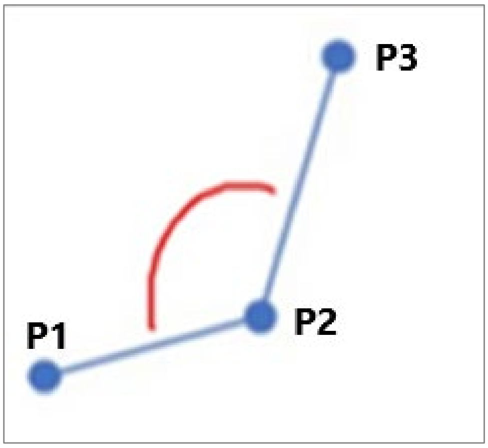

Figure 3. Methodological structure of calculating the internal angle in the starting and finishing shooting positions.

Table 1
Information on the high shooting group and low shooting group of basketball players participating in the research.

Variables	Groups	n	Mean ± SD	df	p
Age (year)	High Shooting Rate Group	7	14.1 ± 0.7	13	0.912
	Low Shooting Rate Group	8	14.7 ± 0.9		
Body height (cm)	High Shooting Rate Group	7	180.7 ± 7.9	12	0.705
	Low Shooting Rate Group	8	181.2 ± 10.1		
Body mass (kg)	High Shooting Rate Group	7	65.4 ± 10.0	12	0.002*
	Low Shooting Rate Group	8	67.3 ± 12.3		
Sports Experience (years)	High Shooting Rate Group	7	4.7 ± 0.4	12	0.036*
	Low Shooting Rate Group	8	4.3 ± 0.7		

** p<0.05*

Table 2

High shooting group and low shooting group basketball players participating in the research: Left-hand photo.

Positions	Groups	Mean ± SD	df	p
Right forward Zone 3 (Number)	High Shooting Rate Group	11.5 ± 3.2	13	0.042*
	Low Shooting Rate Group	8.0 ± 2.8		
Free throwline Zone 2(Number)	High Shooting Rate Group	11.8 ± 1.9	13	0.000*
	Low Shooting Rate Group	6.7 ± 2.2		
Left forward Zone 1(Number)	High Shooting Rate Group	15.2 ± 2.2	13	0.002*
	Low Shooting Rate Group	10.1 ± 2.9		
Average shot	High Shooting Rate Group	38.7 ± 5.4	13	0.000*
	Low Shooting Rate Group	24.8 ± 4.4		

** p<0.05*

Table 3

Comparison of the joint angles of the groups with high shooting rate and low shooting rate in the position of the initial phase of shooting.

Variables	Groups	Mean ± SD	df	p
Head (°)	High Shooting Rate Group	171.5 ± 5.0	11.8	0.809
	Low Shooting Rate Group	170.8 ± 2.1		
Shoulder (°)	High Shooting Rate Group	99.8 ± 13.6	11.4	0.043*
	Low Shooting Rate Group	114.8 ± 10.8		
Elbow(°)	High Shooting Rate Group	71.2 ± 11.3	11.9	0.194
	Low Shooting Rate Group	79.4 ± 10.7		
Wrist(°)	High Shooting Rate Group	129.7 ± 17.9	10.8	0.122
	Low Shooting Rate Group	115.8 ± 12.7		
Hip (°)	High Shooting Rate Group	138.7 ± 9.1	8.7	0.301
	Low Shooting Rate Group	147.1 ± 18.5		
Knee (°)	High Shooting Rate Group	132.4 ± 7.2	8.4	0.830
	Low Shooting Rate Group	144.7 ± 15.5		
Ankle (°)	High Shooting Rate Group	72.0 ± 3.7	8.3	0.232
	Low Shooting Rate Group	75.7 ± 6.8		

** p<0.05*

Discussion

In our study, we compared the differences in the technical shooting (start and finish phase) of basketball players with high accuracy rates in basketball shooting position compared to the group with low shooting rates. In the literatüre, it is seen that angular values and ball velocity are emphasized in basketball shot analysis. The position of the joint parts forming the kinetic motion chain of the angular probolic (curvilinear) trajectory of the basketball ball was determined. Stabilization of the feet during shooting and neuromuscular (neromuscular) optimization in this position is important.

Chen (2014) determined the true knee angle values as left knee angle 165.4±4.7 and right knee angle 162.7±5.4 degrees in the shot biomechanical analysis of basketball players. In our study, it was determined as 169.5±7.4 (HSRG) and 168.3±5.9 degrees (LSRG) in the shot finishing position. (Pan et al. 2021) in their study using Kinect camera in (2021) determined the shoulder angle as 125±14.44 degrees, elbow angle as 117.05±15.22 degrees, wrist angle as 130.76±21.96 degrees, hip angle as 158.89±6.16 degrees, knee angle as 141.23±11.82 degrees, ankle angle as 108.39±10.58 degrees. In a similar study conducted by Silverberg et al. (2003), they have examined the ball leaving the hand and the scoring or missing of the shot through a certain formulation.

Table 4
Comparison of the joint angles of the groups with high shooting rate and low shooting rate in the position of the final phase of shooting.

Variables	Groups	Mean ± SD	df	p
Head (°)	High Shooting Rate Group	174.4 ± 3.7	13	0.786
	Low Shooting Rate Group	175.2 ± 3.6		
Shoulder (°)	High Shooting Rate Group	137.1 ± 5.6	13	0.323
	Low Shooting Rate Group	141.8 ± 10.9		
Elbow(°)	High Shooting Rate Group	176.2 ± 2.9	13	0.715
	Low Shooting Rate Group	175.5 ± 4.8		
Wrist(°)	High Shooting Rate Group	107.0 ± 10.4	13	0.024*
	Low Shooting Rate Group	88.2 ± 16.7		
Hip (°)	High Shooting Rate Group	171.7 ± 5.1	13	0.332
	Low Shooting Rate Group	169 ± 5.2		
Knee (°)	High Shooting Rate Group	169.5 ± 7.4	13	0.735
	Low Shooting Rate Group	168.3 ± 5.9		
Ankle (°)	High Shooting Rate Group	82 ± 7.9	13	0.066
	Low Shooting Rate Group	93 ± 12.7		

** p<0.05*

In our study, all joint areas were analyzed and it was determined that the shoulder area was effective. It was observed that there were differences especially at the beginning of the shot and there were significant differences (p>0.05) in the wrist area at the end of the shot. While high-resolution cameras and motion analysis offer significant advantages, they are less effective than photo analysis for correcting visual techniques. Research indicates that photo analysis is especially superior in evaluating and correcting errors in anatomical shots, such as those involving knee, wrist, and arm rotations. In their definition of shooting, Raiola & D'isanto (2016) stated that in order to change the state of motion of the ball, the force of movement starting from the shooter's feet and progressing up to the fingertips in the body and ending should be applied to direct the ball to the desired target. In our study, systematic analysis was performed in all joints in all technical movements of the body and angular values of these parts were determined. Mondoni (2002) reported that when various shots from different positions and distances are analyzed, the trajectories performed by the ball form a parabolic curve depending on the angle of movement of the ball. Raiola & D'isanto (2016) focused on 4 main issues out of strength in their shot analysis study. These are examined as a starting height of the ball. b. Air resistance. c. Ball release rate. d. Ball release angle (wrist volar flexion). In our study, in relation to these four basic issues, the posture position of the wrist after the shot was taken was evaluated during the finishing phase of the shot. There was no statistically significant difference (p>0.05) between the high shooting rate group (HSRG) and the low shooting rate group (LSRG). However, there was an angle difference of 10 degrees. In other words, it was determined that the volar flexion was angularly lower than the volar flexion in the group with high shooting rate. When evaluated in terms of this position, it is seen that the high shooting rate group shows a lower position of the fingertips after the ball leaves the hand. In a similar study, it was the increasing angular velocities of both shoulder flexion and elbow extension and the increasing velocity of the center of mass in the direction of the hoop. They reported that hand release angles for the two shorter distances (52-55°) tended to provide an advantage of a steep entry angle into the basket. While those at the longest distance (48 50°) were closer to those requiring the minimum possible release speed (Miller & Bartlett. 1996). In a similar study conducted by Okazaki & Rodacki (2018), it was determined as ankle 14.37 degrees, knee 169.84 degrees, hip 171.8 degrees, shoulder 102.5 degrees, elbow 139.9 degrees, wrist 208.07 degrees in the release of the ball from the hand in children. In our study, the angles are determined as the following; ankle HSRG (82) LSRG (93) degrees, knee HSRG (169.5) LSRG (168.3) degrees, hip HSRG (171.7) LSRG (169) degrees, shoulder HSRG (137.1) LSRG (141.8) degrees, elbow HSRG (176.2), LSRG (175.5) degrees, wrist HSRG (107) LSRG (88.2) degrees. Although we think that the differences found in some joint parts in our study may be due to our evaluation in the stable shooting position, we also think that the body joint parts may have more closed angular values in the jump shot. In our study, it is seen that joint angular values in both high and low shooting rate groups in static position are parallel in most of them. When comparing our study with existing literature on angular analysis of basketball shots, we anticipate finding both similarities and differences. The variation in instantaneous angular values during a player's shot reflects the inherent characteristics of the technique. Different positions can occur within the period from the initial to the final phase of the shot. While a holistic evaluation of the movement is crucial, focusing on the initial and final phases of the shot could be a key to establishing a reference for the shot analysis. Raiola & D'isanto (2016) stated that the result of the shot analysis provides some technical scientific elements referred to in sports practice, not only from the point of view of the scientific and theoretical study of the subject but also as a tool for further validation of training programs at all times (Altavilla & Raiola, 2014, 2015). It is a good idea to remember that the highest level of coordination allows the player to perform the movement successfully and retain the possibility to change and adapt to the "real situation" while maintaining efficiency. Silverberg et al. (2003) reported that shooting accuracy depends on the skill level and testing of the shooter. In addition to the importance of skill level in accurate shots, it can be said that it is important to ensure the correct technique formation of the body positions, neuromuscular coordination, nerve-muscle coordination, and making many repetitions inaccurate shots. It has been stated that the angular values of the shot and the options of ball velocity controls have gained importance in the studies as well as the articular positions of the shot (Veljović et al., 2021).

As a result of the synthesis of the data we recorded, analysis methods can be used in the practical APPA computer program to determine the shooting technical positions of coaches and sports scientists working in the basketball branch. However, in order to establish norm values, biomechanical analysis of the static and jump shot techniques of good shooters should be performed. Especially in the younger period, the shooting position (in the beginning main and finishing phases) needs to be practiced with a lot of repetition and test analysis. In addition, we think that norm values will be formed over time with the increase of these and similar studies and that coaches and sports scientists working in this field can contribute to the development of the basketball branch by using the data.

Authors' Contribution

Study Design: ÖP, FK; ÖP; Statistical Analysis: FK; Manuscript Preparation: ÖP, FK; Funds Collection: N/A.

Ethical Approval

The study was approved by the Karamanoğlu Mehmetbey University of Research Ethical Committee (Faculty of Medicine; 05-2024/03) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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The authors declare that the study received no funding.

Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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