

# Kinematic Analysis of the Basketball Free Throw in Preparation Phase of Elite Athletes

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Received August 23, 2021; Revised September 24, 2021; Accepted October 28, 2021

## Cite This Paper in the following Citation Styles

(a): [1] Diellza Shaqiri Kelmendi, Florian Miftari, Murat Tekin, "Kinematic Analysis of the Basketball Free Throw in Preparation Phase of Elite Athletes," *International Journal of Human Movement and Sports Sciences*, Vol. 9, No. 6, pp. 1204 - 1212, 2021. DOI: 10.13189/saj.2021.090614.

(b): Diellza Shaqiri Kelmendi, Florian Miftari, Murat Tekin (2021). *Kinematic Analysis of the Basketball Free Throw in Preparation Phase of Elite Athletes*. *International Journal of Human Movement and Sports Sciences*, 9(6), 1204 - 1212. DOI: 10.13189/saj.2021.090614.

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**Abstract** The purpose of this study was to analyze the kinematic parameters of the body for the preparation phase of the free throw to improve the efficiency and sport performances. The study includes a total twenty elite basketball players from the Kosovo Super League teams: K.B. Prishtina, K.B. Kerasani and K.B. Lipjan. Basketball shooting measurements were conducted during the training of the 2018 year. Filming of the basketball shooting techniques is done with three Canon HD cameras, set at 90-degree angles, which can reproduce sixty pictures per second. 12 variables of kinematic parameters of body were selected for analysis. Only one successful shot from each player was taken for analysis. Analysis is done with Kinematic Analysis System (APAS), outputting the required results and values of the kinematic indicators. The data collected were processed by statistical analysis software "IBM SPSS 20", and statistical parameters were determined using the methods: arithmetic mean, standard deviation, minimum score, maximum score, Skewness and Kurtosis. The confirmation of the mutual influence of the variables was done by the Pearson's coefficients correlation method. The findings of this study show that in the preparation phase for a free throw shot in basketball, variables such as knee angle, wrist angle, thigh angle, and elbow angle have shown to be the kinematic parameters that have the greatest impact on finalizing a successful free throw in basketball. The scientific contribution of this research also provides new insights into the optimal model of basketball player performance during free-throw.

**Keywords** Basketball, Free Throw, Kinematic Parameters of Body, Kinematic Analysis System, Performances, Pearson's Correlation

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## 1. Introduction

Basketball is the second most popular international sport in the world [1-3], claimed that basketball involves more than 450 million licensed basketball players registered from 200 different countries. Free throws in the sport of basketball, for the most part of the match, is the most important component in determining the outcome and winning the match [4-6]. Free throw shooting is a combination of co-ordination, accuracy and sub-maximal velocity [7,8]. Since it requires sub maximal velocity, there are endless arrangements of segmental combinations needed to achieve a successful free throw shot [9,10].

The researches [11-14] explained that talented players are not born capable but can be developed with proper training, and by using the scientific approach. Basketball has changed in recent decades, and this is mainly due to scientific innovations in the application of biomechanical principles, improving optimal performance, especially in shooting [15,16]. The refinement of shooting techniques in basketball sport relies on detailed biomechanical analysis. The biomechanics, due to its investigation area linked to mechanic, has subdivisions of study the kinematic and kinetic shooting [17,18]. The kinematic describes a movement realized by body segments which correspond to the coordination degree demonstrated by an individual realizing natural movements of different sports [19]. In basketball studies biomechanical research has focused on various aspects including basic shooting techniques [20,21]. The description, definition, and explanation of the

biomechanical characteristics of the motorics is of particular importance. Throwing accuracy is the application of precise kinematic characteristics, degree of force and rhythmic quality, regardless of the distance and position of the hoop [22,23]. Evaluation of key kinematic indicators in quality basketball players gives accurate information on technical level and technical improvement possibilities. For accurate basketball shooting, a proper shooting pattern plays a very important role, according to the authors [24].

Recent studies have confirmed the interrelationship between the correctness, efficiency and effectiveness of throwing movement and that they are dependent on hand-eye coordination, motor control, muscle contraction capacity, cerebral cortex plasticity, body segment position and technical level of execution [25,26]. The increased efficiency of free throws involves precision, concentration and correct biomechanics. The biomechanics of free throws in basketball depends on the correlation between the angles of the body segments involved in the movement and the speed of execution [27-29].

Numerous studies have shown that the failure of free throws is conditioned by an insufficient correction of this skill in the learning stage and by the weak attention paid to the corrective feedback [30,31]. The kinematic analysis of free throws in basketball through the filming and sensors allows the identification of the efficiency aspects and of the execution limits in order to optimize the technical training program, and implicitly of the sports performances. The analysis of the free throw movement in the basket will allow the identification of the angular and trajectory changes of the movement, which are important aspects regarding the correctness and the technical efficiency of this finishing skill in basketball. The aim of this research was the kinematic analysis of the free-throw in basketball, which is very often used in the game of basketball, to improve the technical efficiency and sport performances; and to adapt and individualize the training programs.

## 2. Material and Methods

### 2.1. Participants

This research includes a total of twenty professional Kosovo Super League basketball players (players from basketball clubs: K.B. Prishtina, K.B. Kerasani, and K.B. Lipjani). The arithmetic mean and the standard deviation of the anthropometric parameters in the experimental sample were: weight  $84.90 \pm 7.86$  kg, height  $192.10 \pm 6.62$  cm. Inclusion criteria: active athlete at the level of performance

level, age between 18-25 years, male sex, good health, without recent injuries, participation in the all sports training program. All participants were informed about the details of the study and all of them were voluntary.

### 2.2. Experimental Setup

#### 2.2.1. Preparation

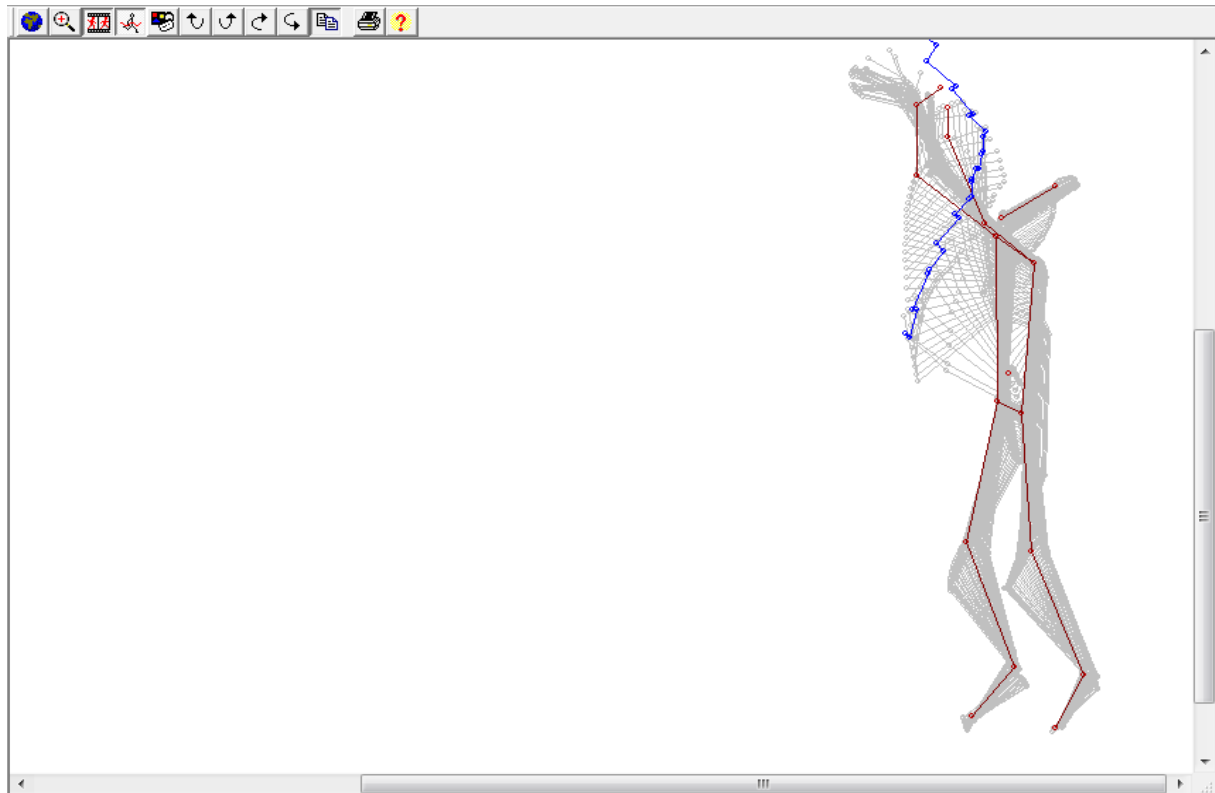
Filming of the shootings for measurements were conducted during the 2018 training season. For the kinematic analysis, the free throwing technique is selected, which includes this stage of analysis: starting from preparing for the ball release, until the final touch of the ball release.

#### 2.2.2. Completion

We analyze 2 anthropometric parameters of body: body mass (BM), body height (BH). For this study 13 variables were selected for body kinematics analysis: knee angle (right side) at beginning phase (KABP), knee angle (right side) on completion phase (KACP), thigh angle (right side) at beginning phase (THABP), thigh angle (right side) on completion phase (THACP), wrist angle (right side) at beginning phase (WABP), wrist angle (right side) on completion phase (WACP), elbow angle (right side) at beginning phase (EABP), elbow angle (right side) on completion phase (EACP), arm angle (right side) at beginning phase (AABP), arm angle (right side) on completion phase (AACP), ball release time (BRT), center of gravity in the initial phase of the shot preparation (CGIPSHP) and center of gravity in the final phase of the shot preparation (CGFPSHP) (Figure 1).

### 2.3. Methods of Data Collection and Processing

The filming of the basketball shooting performance techniques is done with three Canon cameras, set at optimal angles, which can reproduce 60 frames per second. Kinematic analysis of the shootings in basketball has been carried out by many researchers using the same cameras as in this study, namely 60 Hz video cameras [10,32,33]. At first, the calibration frame was filmed at the place where the techniques were performed. The dimensions of the frame were 200cm x 200cm x 200cm. The camera's alignment has been positioned so that all points of reference of the athlete's body are under the camera lens and visible. Analysis is done according to the performance of the Kinematic Analysis System (APAS), outputting the required results and values of the kinematic indicators (Figure 1).



**Figure 1.** The trajectory of the ball movement (blue line), until its release, (preparatory phase) to the free throw, for a one subject of study

## 2.4. Statistical Processing Methods

The data collected were processed by statistical analysis software “IBM SPSS 20”, and statistical parameters were determined using the methods: arithmetic mean, standard deviation, minimum score, maximum score, Skewness, and Kurtosis, t - Student test, 95% Confidence Interval of the Difference. Kolmogorov-Smirnov Z was used to testing distribution normality, whereby samples standardized, after which they are analyzed compared to a standard normal distribution. For this study was considered as level of probability  $p \leq .05$ . The confirmation of the mutual influence of the variables was done by the Pearson’s coefficients correlation method.

## 3. Results

Table 1 presents the results of the basic statistical parameters of the 15 anthropometric and kinematic indicators of the basketball player’s body for the free-throw preparation phase. Parallel to this, the explanation of the parameter results in the completion phase is as follows. The results of the arithmetic averages and the standard deviation of the knee angle (right side) at the completion

phase showed the following values:  $152.50 \pm 7,84^{\circ}$ . Results of arithmetic averages and standard deviation in this study for the thigh angle variable (left side) have shown these values  $167.00 \pm 4,21^{\circ}$ . Results of arithmetic averages and standard deviation of the variable wrist angle (right side) at the beginning phase showed this value  $155.30 \pm 13,26^{\circ}$ . The results of the arithmetic averages and standard deviation of the variable arm angle (right side) at the beginning phase, have shown this value  $52.30 \pm 13,60^{\circ}$ . The variable elbow angle (right side) at the completion phase, have shown this value  $138.90 \pm 11.78^{\circ}$  and the time between lifting and releasing the ball, have shown this value  $(0.45 \pm 0.10 \text{ sec})$ . The arithmetic averages and the standard deviation of the variable distance between the center of gravity at the initial and final phase showed these values by  $99.30 \pm 9.15 \text{ cm}$  and  $123.15 \pm 6.84 \text{ cm}$ .

The results of Table 2 indicated that all kinematic indicators were normally distributed; all asymptotic significance of kinematic indicators were  $p > .05$ . The level of probability of t-Student test highlighted statistical significant of all anthropometric and kinematic indicators of the body of elite basketball players in the free-throw preparation phase, related to  $p < .05$ .

**Table 1.** Results of basic statistical parameters of the kinematic indicators of the body of elite basketball players in the free-throw preparation phase

kinematic indicators	Minimum	Maximum	Mean	Std. Dev.	Skewness	Kurtosis
BM (kg)	74.00	100.00	84.90	7.86	0.43	-1.11
BH (cm)	178.00	203.00	192.10	6.62	-0.22	-0.49
KABP ( <sup>o</sup> )	99.00	149.00	122.45	14.70	0.58	-0.92
KACP	137.00	165.00	152.50	7.84	-0.81	0.03
THABP	112.00	162.00	135.85	15.99	0.25	-1.13
THACP	152.00	179.00	169.60	6.40	-1.10	1.84
WABP	127.00	175.00	155.30	13.26	-0.59	-0.19
WACP	128.00	176.00	152.75	12.33	0.19	-0.07
EABP	54.00	119.00	85.55	18.72	0.43	-0.42
EACP	118.00	155.00	138.90	11.78	-0.32	-1.01
AABP	27.00	80.00	52.30	13.60	0.24	-0.11
AACP	109.00	145.00	128.90	8.56	-0.42	0.66
BRT	0.21	0.63	0.45	0.10	-0.48	0.79
CGIPSHP	82.00	118.00	99.30	9.15	0.43	0.08
CGFPSHP	111.00	134.00	123.15	6.84	-0.39	-0.57

**Table 2.** Descriptive statistics of the kinematic indicators of the body of elite basketball players in the free-throw preparation phase

	t	p	95% IC		Kolmogorov-Smirnov Z	Asymp. p
			Lower	Upper		
BM (kg)	48.306	.000	81.221	88.578	1.091	.185
BH (cm)	129.840	.000	189.003	195.196	.544	.928
KABP ( <sup>o</sup> )	37.247	.000	115.569	129.330	.862	.447
KACP	87.021	.000	148.832	156.167	.785	.569
THABP	37.993	.000	128.366	143.334	.638	.810
THACP	118.469	.000	166.603	172.596	.609	.852
WABP	52.381	.000	149.094	161.505	.641	.806
WACP	55.391	.000	146.978	158.521	.556	.917
EABP	20.434	.000	76.787	94.313	.885	.413
EACP	52.740	.000	133.387	144.412	.567	.905
AABP	17.203	.000	45.936	58.663	.737	.649
AACP	67.353	.000	124.894	132.905	.748	.630
BRT	20.956	.000	.407	.497	.565	.907
CGIPSHP	48.511	.000	95.015	103.584	.789	.563
CGFPSHP	80.535	.000	119.949	126.350	.507	.960

t – Student test; p – level of probability; 95% IC - 95% Confidence Interval of the Difference; Asymp. p - Asymptotic significance

Table 3 presented the results of the Pearson coefficients correlation of the kinematic indicators of the body of basketball players in the free-throw preparation phase. The variables which showed high correlations with statistical significance at the level ( $p = 0.01$ ) were: body mass and body height with correlation coefficients of (0.70); body height and center of gravity in the final stage with correlation coefficients of (0.64); knee angle (right side) at beginning phase and knee angle (right side) at completion phase with correlation coefficients of (0.55); knee angle (right side) at beginning phase and thigh angle (right side) at beginning phase with correlation coefficients of (0.79);

knee angle (right side) at beginning phase and thigh angle (right side) at completion phase with correlation coefficients of (0.63); knee angle (right side) at beginning phase and center of gravity in the initial phase of preparation for throwing with correlation coefficients of (0.63); thigh angle (right side) at beginning phase and center of gravity at start-up stage with correlation coefficients of (0.59); elbow ankle (right side) at completion phase and arm angle (right side) at completion phase with correlation coefficients of (0.67); the center of gravity at the initial stage and the center of gravity at the final stage with correlation coefficients of (0.83).

**Table 3.** Results of the Pearson coefficients correlation of body kinematic indicators of elite basketball players in the free-throw preparation phase

Indicators	BM	BH	KABP	KACP	THABP	THACP	WABP	WACP	EABP	EACP	AABP	AACP	BRT	CGIPSHP	CGFPSHP
BM	-	0.70**	0.26	0.49*	0.16	0.16	0.44*	0.11	-0.13	0.28	0.15	0.06	0.27	0.39	0.48*
BH	0.70**	-	0.09	0.25	-0.10	0.03	0.34	0.13	-0.20	0.51*	0.25	0.29	0.53*	0.40	0.64**
KABP	0.26	0.09	-	0.55**	0.79**	0.38	-0.22	-0.03	0.00	0.02	-0.04	-0.16	0.12	0.63**	0.26
KACP	0.49*	0.25	0.55**	-	0.33	0.72**	0.01	-0.10	0.11	0.15	0.10	0.12	0.03	0.29	0.38
THABP	0.16	-0.10	0.79**	0.33	-	0.45*	-0.08	0.24	0.03	-0.04	-0.17	-0.30	-0.12	0.59**	0.20
THACP	0.16	0.03	0.38	0.72**	0.45*	-	-0.12	0.09	0.19	0.22	-0.19	0.00	-0.04	0.16	0.19
WABP	0.44*	0.34	-0.22	0.01	-0.08	-0.12	-	-0.22	-0.11	0.08	0.27	0.11	-0.08	-0.03	0.11
WACP	0.11	0.13	-0.03	-0.10	0.24	0.09	-0.22	-	0.13	0.36	-0.29	0.16	0.09	0.02	0.05
EABP	-0.13	-0.20	0.00	0.11	0.03	0.19	-0.11	0.13	-	0.08	0.26	0.29	0.30	0.06	0.05
EACP	0.28	0.51*	0.02	0.15	-0.04	0.22	0.08	0.36	0.08	-	-0.07	0.67**	0.32	0.09	0.25
AABP	0.15	0.25	-0.04	0.10	-0.17	-0.19	0.27	-0.29	0.26	-0.07	-	-0.03	0.22	0.39	0.50*
AACP	0.06	0.29	-0.16	0.12	-0.30	0.00	0.11	0.16	0.29	0.67**	-0.03	-	0.13	-0.21	-0.02
BRT	0.27	0.53*	0.12	0.03	-0.12	-0.04	-0.08	0.09	0.30	0.32	0.22	0.13	-	0.39	0.54**
CGIPSHP	0.39	0.40	0.63**	0.29	0.59**	0.16	-0.03	0.02	0.06	0.09	0.39	-0.21	0.39	-	0.83**
CGFPSHP	0.48*	0.64**	0.26	0.38	0.20	0.19	0.11	0.05	0.05	0.25	0.50**	-0.02	0.54*	0.83**	-

\*\*p&lt;0.01

## 4. Discussion

Basketball shots show that they are a major component of any attack [35,36]. The aim of the study was to perform an analysis of 13 kinematic parameters of free throws in basketball, using video-recording and the Kinematic Analysis System (APAS), to improve technical efficiency and sports performance; and to adapt and individualize training programs. The results of our study contribute to the extension of the knowledge highlighted by the previous studies regarding the identification of the relevant corporal kinematic aspects of the free throws regarding the execution technique in the preparation phase. Numerous studies that have focused on evaluating aspects of motor control in performing technical completion skills have established that it is influenced by human visual and functional performance, and this research confirms the aspects and results of our study [37,38].

The variables such as knee angle (right side) at the beginning phase, is one of the most influential and most important kinematic body parameters in the preparation and finalization of the successful basketball shot. Also our results of the thigh angle variable (left side) correspond with the results of the author [40]. Another study [41], concluded that pre-firing force must come directly from the extension of the legs, moving through the thighs, shoulders, arms, and hands, causing a dominant effect or an open kinetic chain for making accurate throws. About the variable wrist angle (right side) at the beginning phase showed the findings of previous studies [42,44]. Author Saenz et al. [45], showed that the right wrist remains one of the most effective variables in the success of finalizing a successful shot in the basketball. Button et al. [46], showed that to improve the accuracy of basketball throws, arm, forearm, and hand movements are very important for a successful basketball shot, information supplemented by the results of our study on the variable arm angle (right side) at the beginning phases the are in accordance with previous studies [47,48]. All preparation for shooting and finalizing it from different distances is done by coordinating mostly the upper extremities, while the curvature of the elbow is also of great importance. The time between lifting and releasing the ball and the variable distance between the center of gravity at the initial and final phase, completed the results of a few studies [49,53].

The findings of this study of Pearson's coefficients correlation of the kinematic indices of the body on free-throw realization. Variables: body mass, body height, center of gravity in the initial and final stages, knee, thigh, elbow angles and wrist angle (right side) at completion phase, are the variables with the highest correlations and the greatest effect on achieving successful throwing in the basketball. The findings of these results correspond with the results of authors some researches [40,54,55], when analyzing the kinematics of free throws in basketball, accurate and inaccurate ones, and concluded that

successful free throw performance is related to the knee angle and hand speed with a high positive correlation ( $p < 0.01$ ;  $r = 0.75$ ). Since the right knee angle is the variable that has the greatest effect on the success of free-throw preparation phase in basketball.

Future research directions will be able to focus on: full kinematic analysis of free throws including the preparation phase and the completion phase; complex analysis of visual and tactical acuity in carrying out free throws; analysis of corrective feedback through the use of specialized software analysis and interpretation of movement and bodily kinematic aspects. The strengths of the study consist in the multitude of analyzed kinematic parameters of the free throw in the preparation phase which was less studied compared to the completion phase; the relatively large number of elite athletes involved in the study; combining the use of filming with motion kinematic analysis software. Limitations of the study: non-inclusion in the study of a female sample; lack of analysis of visual control and corrective feedback of movement; limited duration of study.

## 5. Conclusions

Without decreasing the importance of any element of the game of basketball, we can say that shooting is the most important and crucial element in this beautiful game. The technical elements are very effective when a player knows how to select and perform a certain and precise movement in game development. Proper application of the kinematic parameters of the body, when shooting from different distances has the effect of successfully finalizing the shots in the basket.

In the preparation phase for free throw shooting, the findings of this study on the variables: knee angles, wrist angle, thigh angle and elbow angle have shown that it is precisely these kinematic parameters that influence greater in finalizing a successful basketball throw. The combination of body kinematic parameters turns out to be essential in finalizing successful free-throw shots. The results of this research enrich the scientific knowledge of kinematic analysis in basketball game and the technical training of free throw.

## Acknowledgements

K. B. Prishtina, K. B. Kerasani and K. B. Lipljan. Thank you, basketball clubs. Author Contributions: Conceptualization. F.M, D.S.K, and M.T; methodology. F.M, D.S.K, and M.T; software. F.M, D.S.K, and M.T; validation. F.M, D.S.K, and M.T; formal analysis. F.M, D.S.K, and M.T; investigation. F.M, D.S.K, and M.T; resources. F.M, D.S.K, and M.T; data curation. F.M, D.S.K, and M.T; writing—original draft preparation. F.M, D.S.K,

and M.T; writing—review and editing. F.M, D.S.K, and M.T; visualization. . F.M, D.S.K, and M.T; supervision. F.M, D.S.K, and M.T; All authors have read and agreed to the published version of the manuscript. Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki. and approved by the National center for sports medicine-NCSM, Prishtina, Kosovo. Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Conflicts of Interest: The authors declare no conflict of interest.

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