Mühendislik Bilimleri ve Tasarım Dergisi
11(4), 1270-1281, 2023
e-ISSN: 1308-6693

Journal of Engineering Sciences and Design
DOI: 10.21923/jesd.1181476

Araştırma Makalesi Research Article

AN OPTIMIZATION STUDY ON THE SUCCESS OF THE 3-POINT SHOOTING IN BASKETBALL

Hasbi KIZILHAN[1*]

[1] Suleyman Demirel University, Faculty of Engineering, Department of Mechanical Engineering, Isparta, Türkiye

Keywords

Optimization, 3-Point Shooting, Adams View, Ball Release Parameters, Basketball.

Abstract

A successful shot in basketball is critical to winning a game. Especially, the shot from the 3-point line both scores more points compared to other shots and draws the fans into the game more. The success of the 3-point shooting (3PS) depends on many factors, including the release height of the ball, jump height and physical characteristic. These parameters must be optimally adjusted for a successful shot. The aim of this study is to find the appropriate velocity and angles for a successful 3PS by combining the ball release parameters. For the optimization, the design parameters, and the distance of the ball to the basket were defined as input and output variables to the Adams/View Insight module, respectively. While the velocity and angle input values were taken in accordance with the literature studies, the release height of the ball was calculated depending on the height, jump height and joint angles of the player. The optimization results reveal what the appropriate angle and velocity values should be for players having different heights for a successful 3PS. It should be emphasized that this study has been put forward to bring a different interpretation to basketball with an engineering approach.

BASKETBOLDA 3-SAYILIK ŞUTUN BAŞARISI ÜZERİNE BİR OPTİMİZASYON ÇALIŞMASI

Anahtar Kelimeler

Optimizasyon, 3-Sayılık Atış, Adams View, Top Bırakma Parametreleri, Basketbol.

Öz

Basketbolda başarılı şut maçın kazanılmasında kritik öneme sahiptir. Özellikle 3-sayı çizgisinden atılan şut, hem diğer atışlara kıyasla daha fazla sayı kazandırmakta hem de taraftarı oyunun içine daha fazla çekmektedir. 3-sayılık atışın (3PS) başarısı topun bırakılma yüksekliği, zıplama yüksekliği ve fiziksel karaktersizlik gibi faktörlere bağlıdır. Başarılı bir şut için bu parametrelerin optimum bir şekilde ayarlanması gerekir. Bu çalışmanın amacı top bırakma parametreleri kombine edilerek başarılı bir 3-sayılık atış için uygun hız ve açıların bulunmasıdır. Optimizasyon çalışması için, tasarım parametreleri ve topun çembere olan uzaklığı Adams/View Insight modülüne sırasıyla girdi ve çıktı değişkenleri olarak tanımlanmıştır. Hız ve açı girdi değer aralığı literatür çalışmalarına uygun olarak alınırken, topun bırakılma yüksekliği oyuncunun boyu, zıplama yüksekliği ve eklem açılarına bağlı olarak hesaplanmıştır. Tasarım parametrelerinin değerlerine bağlı olarak 1859 iterasyon gerçekleştirilerek sonuçlar bulunmuştur. Sonuçlar farklı boydaki oyuncuların başarılı bir 3-sayılık atış için uygun açı ve hız değerlerin ne olması gerektiğini göstermektedir. Bu sonuçlara göre; 1.82 m, 1.86 m ve 1.92 m boya sahip oyuncular sırasıyla 40° ve 8.75 m/s, 45° ve 8.75 m/s ve 50° ve 8.5 m/s açı ve hızda topu bıraktıkları zaman, 3-sayılık şut atışı çembere girebilecektir. Şu önemle vurgulanmalıdır ki bu çalışma basketbol sporuna mühendislik yaklaşımıyla farklı bir yorum getirmek amacıyla ortaya konulmuştur.

Alıntı / Cite

Kizilhan, H., (2023). An Optimization Study on the Success of the 3-Point Shooting in Basketball, Mühendislik Bilimleri ve Tasarım Dergisi, 11(4), 1270-1281.

Yazar Kimliği / Author ID (ORCID Number)

H. Kizilhan, 0000-0001-9433-0171

Makale Süreci / Article Process	
Başvuru Tarihi / Submission Date	28.09.2022
Revizyon Tarihi / Revision Date	28.07.2023
Kabul Tarihi / Accepted Date	17.08.2023
Yayım Tarihi / Published Date	30.12.2023

[*] İlgili yazar / Corresponding author: hasbikizilhan@sdu.edu.tr, +90-246-211-0822

AN OPTIMIZATION STUDY ON THE SUCCESS OF THE 3-POINT SHOOTING IN BASKETBALL

Hasbi KIZILHAN[1†],
[1] Suleyman Demirel University, Faculty of Engineering, Department of Mechanical Engineering, Isparta, Türkiye

Highlights

- The focus of this paper is to find the appropriate velocity and angles for a successful 3PS.
- For a successful 3PS, the ball release parameters have been optimized by using Adams/View Insight module.
- Optimization work will increase the percentage of success in the 3-point shooting rate in basketball.

Purpose and Scope
In this study, an optimization study on the performance of a shooting which is from the 3-point line was presented by combining the ball release parameters (height, the release velocity, and the release angle of the ball) in MSC Adams/View environment.

Design/methodology/approach
In the present study, an optimization study has been carried out for a successful 3PS by combining the ball release parameters. Within the study, previously the exact dimensions of FIBA basketball court were visualized in the Adams/View. After modelling the basketball court, design variables are needed for optimization study. Design variables are the release height, release the velocity and the release angle of the ball. While the velocity and angle input values were taken in accordance with the literature studies, the release height of the ball was calculated depending on the height, jump height and joint angles of the player. For the optimization, the design parameters, and the distance of the ball to the basket were defined as input and output variables to the Adams/View Insight module, respectively.

Findings
With the study, it is revealed that a guard player with an average height of 1.92 m can shoot successfully at what speed and angle when he releases the ball. In other words, it can be said that a successful basketball throw can be achieved when a player with a height of 1.92 m shoots with a 45° release angle and 8.75 m/s release velocity. It is seen that the success of the 3-point shot in basketball will increase when the ball is thrown with the appropriate ball releasing parameters. The optimization study can reveal that a player whose throw height can be determined can make a successful shot if he releases the ball at what speed and angle. Optimization work will help to achieve a high success rate in 3-point shots in basketball.

Originality
In this study, an optimization study was carried out in MSC Adams/View environment by using the ball release parameters as the input ball distance to the basket as output. The results obtained are capable of answering the following questions. At what angle can a released ball reach the ring for a 3-pointer? Which angle can a dropped ball reach to the basket for 3PS? Which velocity and angle are necessary to be a successful 3PS in case of a player who has certain height throwing the ball? The study presented here is carried out to bring an interpretation to basketball from an engineering point of view.

† İlgili yazar/Corresponding author: hasbikizilhan@sdu.edu.tr, +90-246-211-0822

1. Introduction

The goal of every player in basketball is to score points. A good shot gets the points, and the points brings the game. In this sport, players can make jump shots, set shots, lay-ups and free throws to score points. Jump shot is the most effective shooting technique disorders (Knudson, 1993; Zwierko et al., 2017). This shooting technique constitutes 67% of the shooting styles used in the NBA in the 2014 season (Boddington et al., 2019). The technique is a complex and technically difficult type of movement in which the player throws the ball into the basket while he is in the air. Many factors must be optimized together to achieve an effective shot in this technique (Okubo and Hubbard, 2015; Rojas et al., 2000; Satti, 2004). These factors are the release height of the ball, the release velocity of the ball, and the release angle of the ball to the ground counterclockwise (Okazaki and Rodacki, 2012). The factors affecting shooting success in basketball and the relationship among these factors are shown in Figure 1.

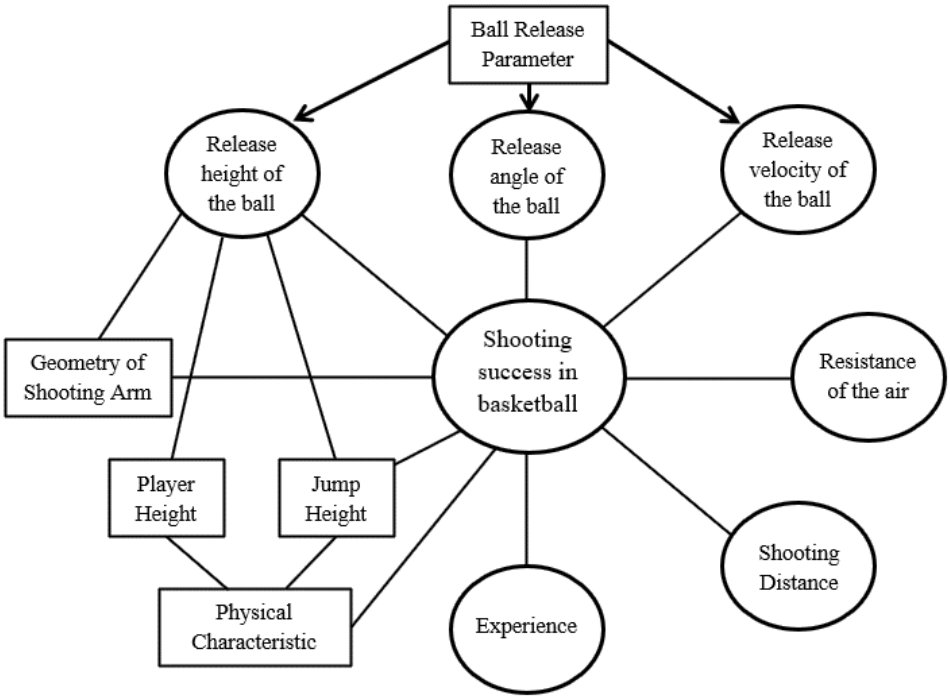


Figure 1. Factors affecting shooting success in basketball (Okazaki et al., 2015)

The first of the parameters affecting the success of the jumping shot technique is the release height of the ball. It depends on kinematic variables such as the player's jump height, height, and joint angles. The determination of the height and the body kinematics parameter is usually done by using camera capture and different measurement methods. The Casio Exilim camera was used to determine the angles of shoulders and hip joints' rotation during a jump shot (Štirn et al., 2019). The MVN Biomech motion capture system was used to determine the joint angular velocity of young basketball players during the jump shot (Podmenik et al., 2017). In a study carried out to examine the effect of fatigue on shooting kinematics during consecutive shots, Li et al., 2021 found the release height of the ball for female players as 2.015 m by using the Xsens (Xsens technologies B. V., Netherlands) MVN inertia suit system. In a study carried out by Slawinski et al., (2018) to examine the effect of repeated sprints on the kinematics of 3PS, the kinematic variables of the players during the shooting were determined by being used the Xsens MVN inertia suit system. In this study, the release height of the player who is not tired was measured as 2.35 m (Slawinski et al., 2018). Çelik et al., (2013) used a camera system to analyze the kinematics of the player during 3PS. In the study, the subjects' height of shot was determined as 2.83 m. Miller and Bartlett, (1996) used camera systems to measure the ball release height of the players having different heights during the shooting from 6.4 m. In this study, the release height of the ball was measured as 2.30 m, 2.52 m and 2.23 m for guard, forward and centers players, respectively (Miller and Bartlett, 1996). As can be seen in studies in the literature, high-tech measurement technologies are needed to obtain different parameters of the player.

One of the parameters that affect the success of shooting is the release angle of the ball. Throwing the ball at an appropriate angle increases the success of the ball's pass into the basket. In literature, the release angle of the ball during the jump shot has been revealed as ~53° (Elliott and White, 1989) and 48°-50° (Elliott, 1992) for female players and 44°-47° (Elliott, 1992), 47°-52° (Miller and Bartlett, 1993), 48°-55° (Miller and Bartlett, 1996), 44°-47° (Rojas et. a., 2000) and ~65° (Okazaki and Rodacki, 2012) for male players. As you can see, the release angle of the ball varies according to the player and the distance where the shot is made. This change has also been demonstrated in the study that belongs to Miller and Bartlett. They carried out a study to reveal how there is a

relationship between shooting distance and shooting parameters for players in different positions (guard, forward and center). In this study, it was revealed that the release angle of the ball decreases with the increase of the shot distance (Miller and Bartlett, 1994). Literature studies have shown that the release angle of the ball changes in shots made from different distances. In our article, since an optimization study will be performed for 3PS, it will be more useful to examine the literature on how the release angle of the ball changes in the 3-point line. Slegers et al., (2021) recorded 75 3PS and measured the average release angle of the ball 49.7° during 3PS. In a study performed to examine the effect of dehydration on technique of 3PS and performance, the release angle of the ball was taken as 51° (Louis et al., 2018). Slawinski et al., (2018) measured the release angle of the ball as 51.1° during 3PS for U18 basketball players having am average height of 1.90 m. Çelik et al., (2013) examined the kinematic analysis of the shots thrown from the 3-point line (6.75 m) by players playing in different leagues and they measured the release angle of the ball as 50.72° for players with a height of 1.91 m.

Another parameter to consider for a successful shot is the release velocity of the ball. Throwing the ball at an appropriate velocity is extremely important. Throwing the ball fast or slow will decrease the success of the shot as well as affecting the movement of the body parts. The shooting distance of the player also affects the release velocity of the ball. The release velocity (5.68 m/s, 6.27 m/s and 8.36 m/s for guards) of the ball for players in different positions varies according to the distance of the shot (2.74 m, 4.57 m and 6.40 m) (Miller and Bartlett, 1996). Chakraborty and Meher, (2013) revealed that the release velocity of the ball during the shot varies in the range of 4.24-7.06 m/s in their measurements taken by being used a camera system. The release velocity of the ball is higher for shots from the 3-point line compared to other shots. In a study carried out to observe the effect of sprint on the kinematics of 3PS in basketball, the release velocity of the ball was measured as 7.77 m/s (Podmenik et al., 2017). In another study, the release velocity of the ball that is from behind the 3-point line (6.75 m) was determined as 5.85 m/s on average (Slawinski et. a., 2018). In a study about the relationship between individual oscillation variability in basketball with distance and shooting performance, Slegers et al., (2021) determined the average release velocity of the ball as 3 m/s during 3PS. Louis et al., (2018) conducted a study in which the release velocity of the ball was 7.84 m/s.

In our study, an optimization study on the performance of a shooting which is from the 3-point line was presented by combining the ball release parameters (height, the release velocity, and the release angle of the ball) in the MSC Adams/View environment. In the study, firstly, the exact dimensions of FIBA basketball court were visualized in the Adams/View (Adams MSC., 2020). The height calculated by considering the player's height (H), jump height (H_{JA}) and joint angles is the release height value of the ball. Height is defined as the first design variable. Then, the angle and velocity information in accordance with the values of the release velocity and angle of the ball during 3PS in the literature were defined to the Adams/View environment as the other design variables. A measurement was taken for the distance between the position of the ball at the time of release and the basket. An objective defined by the measurement as the optimization output was created by using the Design Create Objective tool. Finally, an optimization study was carried out in the Adams/Insight module to give an answer for the three design variables (the release height, the release angle, and the release velocity of the ball). We hypothesized that the obtained results would give us answers to the following questions: At what angle can a released ball reach the ring for a 3-pointer? Which angle can a dropped ball reach to the basket for 3PS? Which velocity and angle are necessary to be a successful 3PS in case of a player who has certain height throwing the ball? The study presented here is carried out to bring an interpretation to basketball from an engineering point of view.

This paper is organized in way of presenting how the ball release parameters are determined, the optimization study, results, and discussions after the introduction.

3. Methods

2.1. Basketball Court and Ball Release Parameters

In this study, an optimization study was carried out based on the ball release parameters (the release height, the release velocity and the release angle of the ball) for 3PS. In the study, firstly, basketball court dimensions in FIBA (International Basketball Federation, 2020) standards were visualized in the simulation environment. As it can be seen in Figure 2, the court dimensions in FIBA standards are 28 x 15 meters. The height of the basket from the ground is 3.05 meters, and the diameter of the basket is 0.45 m (at the top of Figure 2). In FIBA standards, the 3-point line is drawn 6.6 meters from the center of the basket to the corners and 6.75 meters across. Also, ball number 7 having a circumference of 0.75 m, a diameter of 0.24 m and a weight of 0.575 kg was used for 3PS. paper is organized in way of presenting how the ball release parameters are determined, the optimization study, results, and discussions after the introduction.

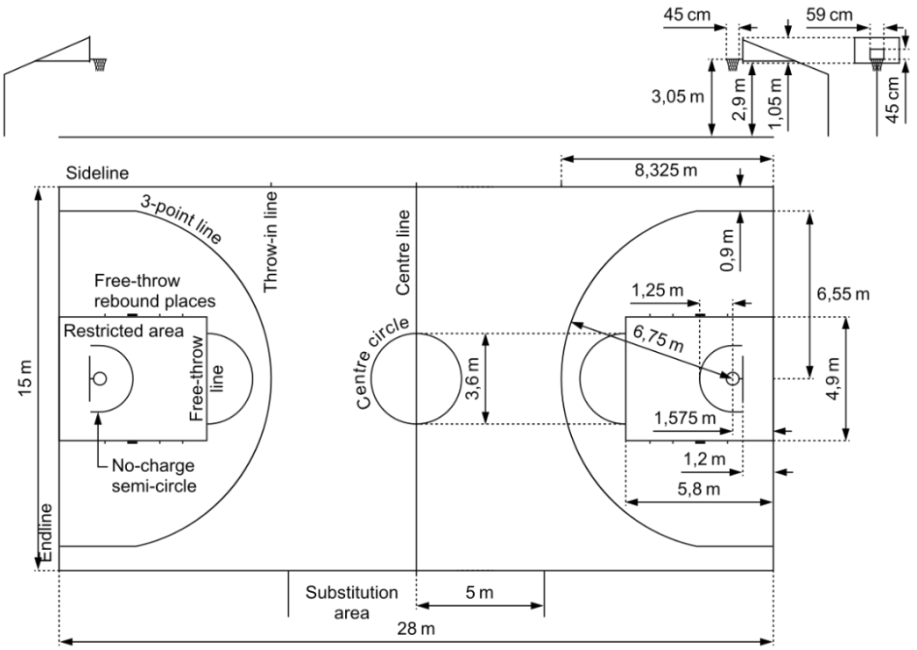


Figure 2. Basketball court dimensions in FIBA standards (International Basketball Federation, 2020)

In basketball, to consider a shot as a 3PS, it is necessary that this shot should be thrown behind the 3-point line. If the player's foot touches the 3-point line, his shot is not accepted as 3 points. In the optimization study, the shot that is thrown is shown in way of considering it as 3 points shot.

2.2. Release Height of the Ball

One of the most important factors determining the success of shooting in basketball is the release height of the ball (Hamilton and Reinschmidt, 1997). The release height of the ball depends mainly on many factors: The player's height, his jumping ability and the player's shooting characteristics.

Height is an important element in the basketball game. No matter how talented the short players are, it is difficult to maintain continuity in this game. Because tall players are more effective in catching the ball, rebounding and blocking thanks to their height and arm length. The increase in the length of the body limbs of the tall players in proportion to their height gives these players an advantage. Dirillis et al., (1964) generalized the relationship between the lengths of human body parts and human height (H) as it is shown in Figure 3. In other words, as human height increases, the other limb lengths increase according to the coefficients shown in the figure. They have the advantage of releasing the ball higher since taller players have long arms. The limb lengths, which vary depending on the human height, will be used to calculate the release height of the ball.

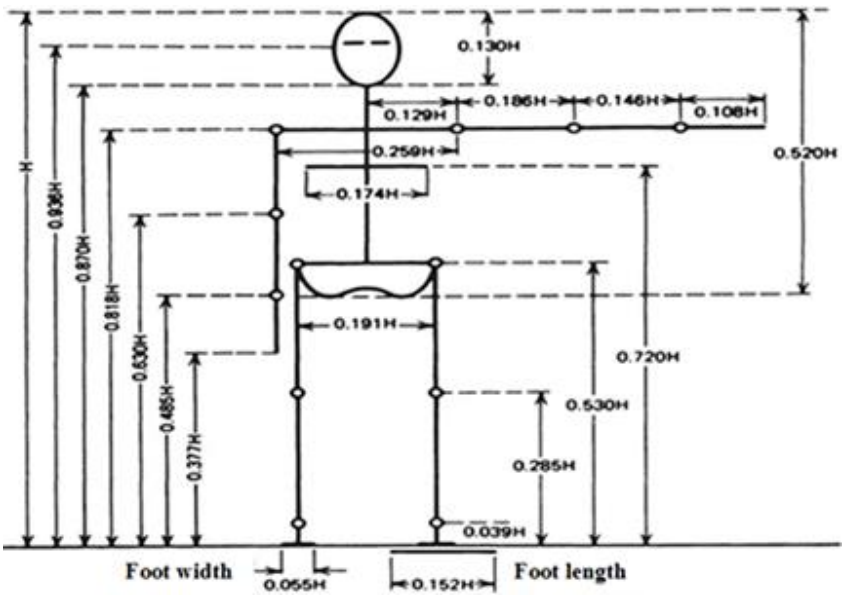


Figure 3. Length of other body parts relative to human height (Dirillis et al., 1964)

Jumping is one of the most basic movements performed by basketball players. The jump is used for different purposes such as blocking, rebounding, stealing and shooting. In basketball, the jumping ability of players directly affects the release height of the ball (Okazaki and Rodacki, 2015). Different studies have been carried out in the literature to reveal the relationship between the height of the players and their jump height. In these studies, the counter movement jump (CMJ) movement is seen as a useful tool that can be used to predict the jumping ability in basketball (Struzik and Zawadzki, 2013). Altavilla et al., (2018) measured the jump height as 0.432 m for 40 basketball players with an average height of 1.954 m. Struzik and Zawadzki, (2013) revealed that basketball players with an average height of 1.931 m can jump to a height of 0.368 m. Ziv et al., (2010) wrote a review article to compare the vertical jump performance of male and female basketball players. In this study, it is summarized that the jump height is 0.22-0.48 m for female athletes and 0.40-0.75 m for male athletes.

Multiple factors must be technically brought together for a successful 3PS in basketball. During 3PS, the joint angle of the player's lower and upper limbs changes depending on the player's shooting technique. Since 3PS is a long-distance shot, the joint angles differ according to the player's height. Miller and Bartlett, (1996) found the angles of the shoulder and elbow joints as 124° and 135° for guards, 131° and 143° for forwards, and 115° and 143° for centers, respectively during the shooting from 6.40 m. Loise et al., (2018) calculated the angles of the player's ankle, knee, hip shoulder, elbow and wrist joints as 111°, 164°, 189°, 105°, 185° and 141°, respectively at the moment the ball is thrown during 3PS. Elliot and White, (1989) measured the ankle, knee and hip shoulder, elbow, and wrist joint angles as 143.6°, 166.5°, 178.9°, 107.3°, 129.9°, and 208.1°, respectively, in the ball-release position during 10 3-point shooting. As can be seen in the literature, the joint angles of the players vary during 3PS.

In the optimization study that will be done the release height of the ball will be defined as a variable input. As it can be seen in the literature studies, the height varies with three parameters: The jump height, the joint angles and the height of the player. In this study, the release height of the ball (H_{RH}) was determined as follows. The players who use 3PS at most in basketball are shooting guards. These players' average height is 1.92 m (Zarić et al., 2020). In this study, it is assumed that the shooting guards have a minimum height of 1.86 m and a maximum height of 1.98 m. Then, body limb lengths were calculated according to the coefficients generalized by Dirillis et al., (1964). A height value was calculated by considering the joint angles in the literature during 3PS. The release height of the ball (H_{RH}) was found by adding an average of 40 cm jump height (h_{jh}) to calculated height value. The joint angles at the time of ball release and the calculated release height of the ball for a 1.86 m player are shown in Figure 4a and 4b. It should be emphasized here that the joint angles and jumping ability of the player vary according to the shooting situation and physical characteristics of the player. In this study, since an optimization study will be carried out according to the ball release parameters, the release height of the ball was determined by taking into account the average values.

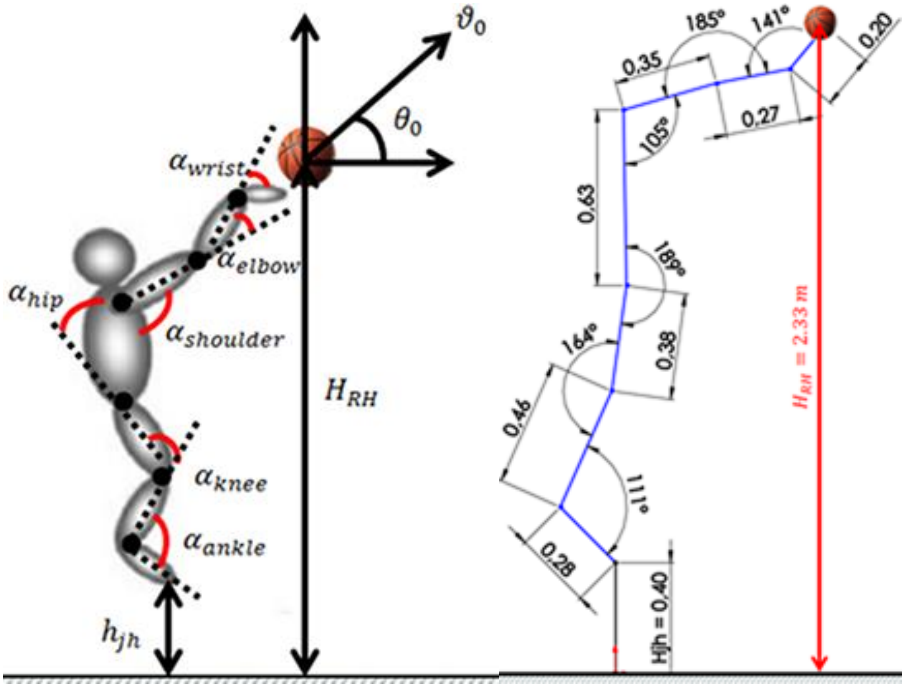


Figure 4. (a) The joint angles at the time of ball release and (b) the calculated release height of the ball for a 1.86 m player

2.3. Release Velocity of the Ball

The release velocity of the ball during the shooting in basketball is one of the important parameters that directly affect the success of the shot. Therefore, it is important that the ball is thrown at a suitable velocity. It has been revealed in literature studies that the release velocity of the ball during 3PS changes at velocities of 5.85–8.71 m/s. The optimization study will be carried out for two different 3 points shots, from the corner and opposite of the basket. Therefore, the release velocity of the ball during 3PS was taken at velocities varying between 5.75 m/s and 8.75 m/s. The velocity value was determined as 0.5 m/s in way of being 5.75 m/s to 8.75 m/s increase.

2.4. Release Angle of the Ball

In literature studies, one of the parameters that affect the successful releasing of the ball to the basket is the release angle of the ball. Figure 5 shows the release angle of the ball and this angle value for 3PS was determined at values ranging from 49.7° to 51.1° in literature studies. Hence, the release angle of the ball in the optimization study will be taken as between 45°and 53° in way of being 0.1° increase to be compatible with the literature studies.

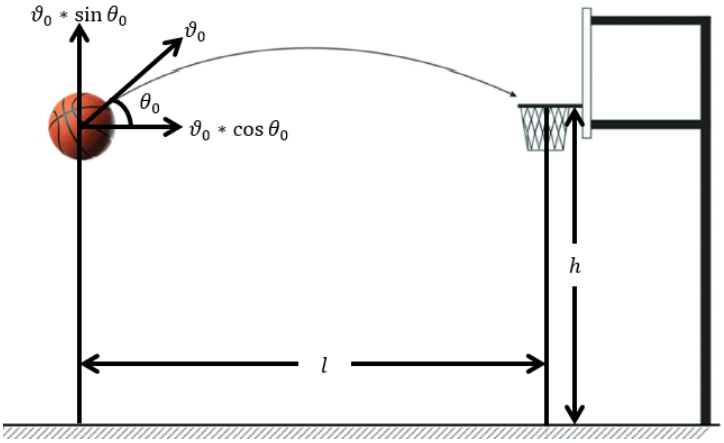


Figure 5. The conceptualization of the release angle and velocity of the ball (Przednowek et al., 2018)

Considering the releasing situation as in Figure 5, the trajectory of the ball is parabola. Here, the distance between the center of the basket and the point of the ball is l and the height of the basket from the ground is h. The velocity value required for a given θ_0 angle value can be found with the help of the equations given in (Halliday et al., 2013).

3. Optimization Study

In this study, an optimization study will be carried out depending on the ball release parameters for 3PS. For optimization study, the semi-basketball court in FIBA standards was visualized primarily in the Adams/View environment (Adams MSC., 2020). Figure 6 shows the top and isometric view of the semi-basketball court. The 3-point line is determined according to FIBA standards, and it is modelled as 6.6 m from the basket to the corners and 6.75 m from the front. The height of the basket from the ground was taken as 3.05 m and the diameter of the basket was taken as 0.45 m.

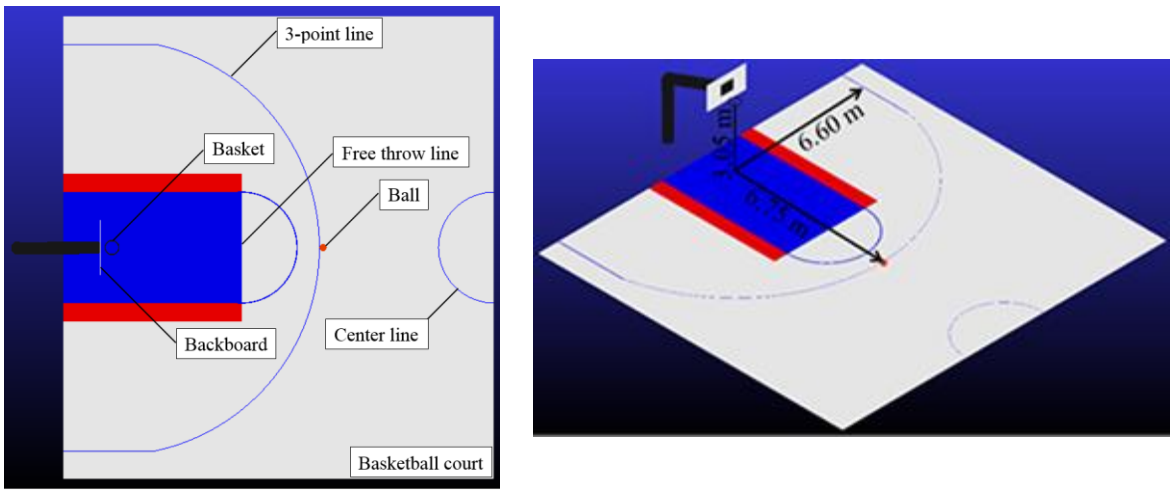


Figure 6. Top and isometric view of the semi-basketball court visualized in Adams/View

After modelling the basketball court, design variables are needed for optimization study. There are 3 design variables; the release height, release the velocity and the release angle of the ball. These variables can be defined by using the Create a Design Variable tool in the Adams/View Design Exploration menu. There are different options for entering different value ranges for design variables in the Design Variable tool. In this study, the maximum and minimum values of the design variables were entered by using the option of "absolute min and max values" definition. The release velocity and the release angle of the ball are defined based on studies in literature. The release height of the ball was calculated as it was explained in Chapter 2. The max., min. and standard values of the design variables were entered in the Design Variable tool as it is shown in Table 1. The standard value in the Design Variable tool is the value assigned for the initial simulation. The standard values of the design variables were accepted as the average of the minimum and maximum values. The Design Variable tool allows assigning any number of values between the minimum and maximum values of the design variables. Here, to reduce the number of analyzes, values are assigned in way of having the increase of the velocity as 0.25 m/s, the increase of angle as 1° and the increase of height as 0.01 m. The wind effect was ignored in the optimization study (Zhiwen et al., 2017).

Table 1. Standard, max. and min. values of design variables

Design Variable	Standard Value	Min. Value	Max. Value
Height (m)	1.92	1.86	1.98
Velocity (m/s)	7.25	5.75	8.75
Angle (degree)	45	40	50

The potential response of the optimization study must be determined in advance. Therefore, before the optimization study was carried out, an objective creation was done. The objective was created by using the Create Design Objective tool found in Adams/View Design Exploration. It should be specified how the objective was created in the tool will be defined. Here, the objective is defined by a measurement. This measurement is the distance between the center of mass of the ball and the center of the basket. The measurement was taken by being used the point-to-point measurement tool in Adams/View Design Exploration. The created objective will appear as a potential response value or in other words, output value in the Adams/View Insight module.

Adams/View Insight is a module that allows multiple simulations while modeling (mscsoftware.com, 2010). The operating logic of the Insight module is shown in Figure 7. The optimization study will be carried out in the Insight module. Before switching to the Insight module, a simulation was conducted to test whether the model worked correctly or not for 3PS. The transition to the Insight module was made by using the Adams Insight Export tool in the Design Evaluation. The Insight module automatically brings up the predefined inputs and output. Insight environment offers you the opportunity to perform the optimization study by grouping the design variables (height, angle and velocity) as Factors and the output variable (objective) as Responses. The Design part in the Insight module shows the solution sets for the optimization study. In the optimization study, the DOE Response Surface research strategy in the Design Specification section was used. In the Model part, the relationship between the inputs and the output of the optimization study is determined. The Insight module allows to set the level of relationship between inputs and outputs as Linear, Interactions, Quadratic and Cubic. In this study, Linear Modeling was chosen. When an increment of 1° is taken for the angle, 0.25 m/s for the velocity, and 0.01 m for the height, 1859 different combinations emerge. The Work Space section shows the combinations created for the three design variables. The answer of output variable is obtained by trying each combination one by one. After all these steps, the simulation process was started by using the Run command and the results were saved as .req.

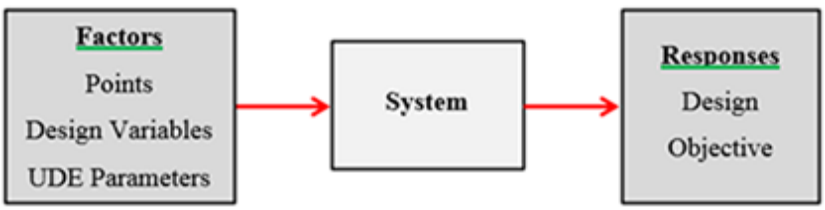
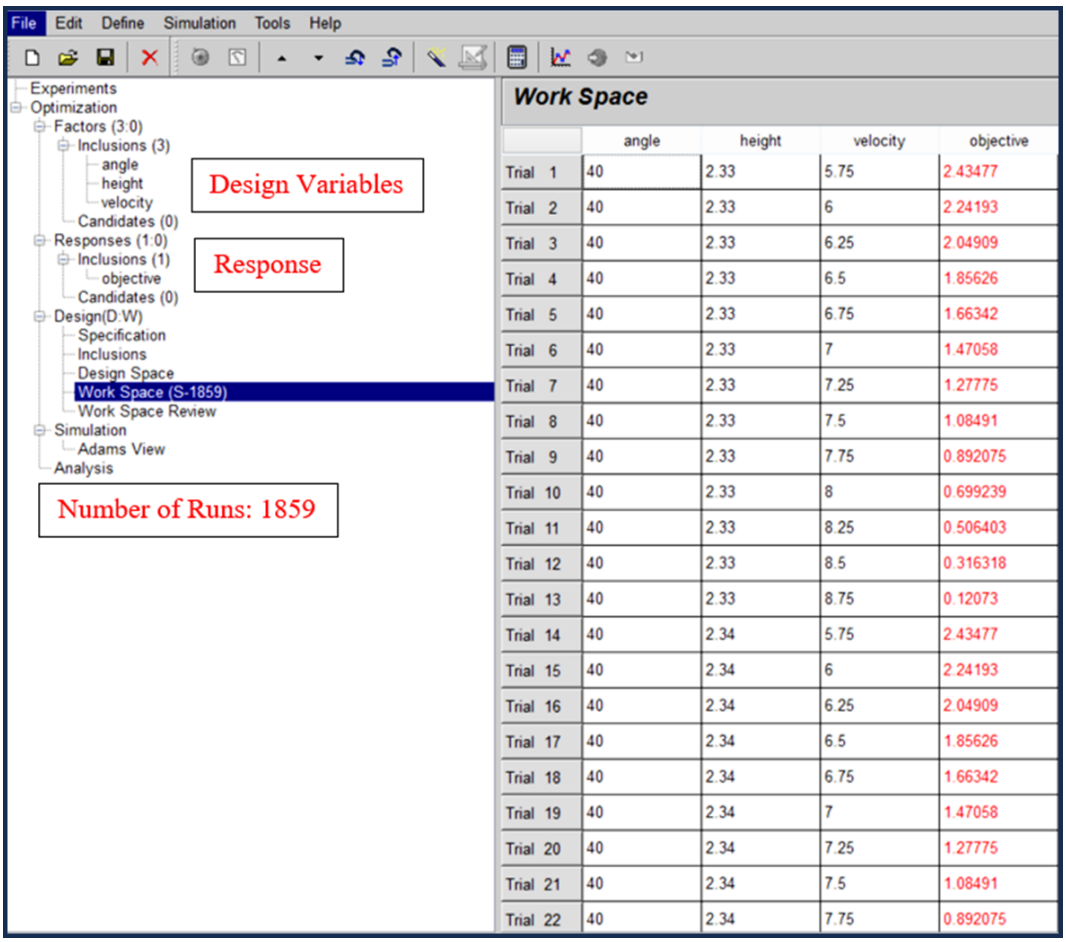


Figure 7. The operating logic of the Insight module

4. Results

In this study, an optimization study is carried out for 3PS by combining the ball release parameters. 3PS is made from across the basket. While the design variables of the release velocity and the release angle of the ball were taken from the literature, the ball release height is calculated depending on the joint angles, jump height and the height of the player.

The Adams/Insight module combines design variables to give a response (objective). In this study, the height, velocity and angle design variables are entered to the Insight module as inputs, while the distance of the ball to the basket is obtained as the response output. Figure 8 shows the response output (objective) for the first 22 combinations of 1859 combinations which depending on the design variables. The Work Space environment gives the output value for each combination of design variables. The table here can be interpreted as follows: When the release angle of the ball is 40°, the release height of the ball is 1.86 m and the release velocity of the ball is 8.75 m/s, the distance of the ball from the basket is 0.12073 m. That is, when a player having a height of 1.86 m releases the ball into the basket at the specified angle and velocity, this 3PS can be counted as a goal.



Work Space

	angle	height	velocity	objective
Trial 1	40	2.33	5.75	2.43477
Trial 2	40	2.33	6	2.24193
Trial 3	40	2.33	6.25	2.04909
Trial 4	40	2.33	6.5	1.85626
Trial 5	40	2.33	6.75	1.66342
Trial 6	40	2.33	7	1.47058
Trial 7	40	2.33	7.25	1.27775
Trial 8	40	2.33	7.5	1.08491
Trial 9	40	2.33	7.75	0.892075
Trial 10	40	2.33	8	0.699239
Trial 11	40	2.33	8.25	0.506403
Trial 12	40	2.33	8.5	0.316318
Trial 13	40	2.33	8.75	0.12073
Trial 14	40	2.34	5.75	2.43477
Trial 15	40	2.34	6	2.24193
Trial 16	40	2.34	6.25	2.04909
Trial 17	40	2.34	6.5	1.85626
Trial 18	40	2.34	6.75	1.66342
Trial 19	40	2.34	7	1.47058
Trial 20	40	2.34	7.25	1.27775
Trial 21	40	2.34	7.5	1.08491
Trial 22	40	2.34	7.75	0.892075

Figure 8. Design variables, response and the first 22 combinations in the Insight module

1859 combinations created with ball release parameters are tried one by one in Adams/Insight module. The response output of the 1859 iteration namely, the distance of the released ball to the basket, is shown in Figure 9. The goal here is to get the ball into the basket. In other words, the output response is close to zero. It is seen that the response output takes values close to zero for different values of the ball release parameters.

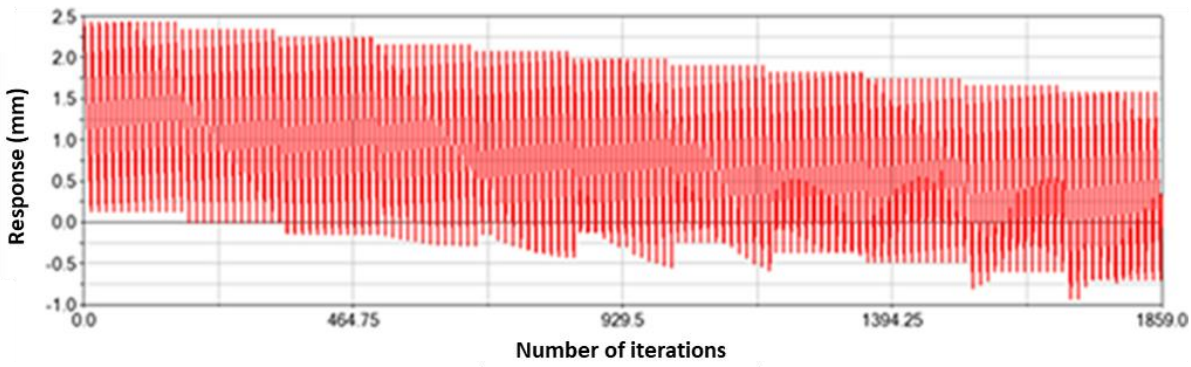


Figure 9. The response obtained for 1859 Iteration.

The Adams/Insight module establishes a relationship between the design variables and the output variable. If a correct mathematical expression can be obtained between the inputs and the output, there is no need to optimize for different intermediate values. As it is stated before, the order of the relationship between inputs and output is determined as Linear in this study. The mathematical expression for Linear modeling is given in Equation 7. The unknown coefficients in this equation are given in the Term Coefficients section as a result of the optimization. The values obtained are: $a_1 = 10.539$, $a_2 = -0.091032$, $a_3 = -0.085506$, $a_4 = -0.75166$ ve e =-0.05833.

$$R = a_1 + a_2 * F_1 + a_3 * F_2 + a_4 * F_3 + e \qquad (1)$$

Here:
F_1 : The value of the first factor,
F_2 : The value of the second factor,
F_3 : The value of the third factor,
a_{1-4} : Coefficient values calculated by the optimization,
e : Error value minimized by the optimization,
R : response value.

According to the output response obtained as a result of the optimization performed, the release velocity and angle of the ball were determined for the players having different heights (1.86-1.98 m). Figure 10 shows the release angle and velocity values of the ball and the response value versus the length. Accordingly, when a player having height of 1.86 m shoots a 3-point field goal at an angle of 40° and a velocity of 5.75 m/s, the ball remains at a distance of 2.43477 m from the basket.

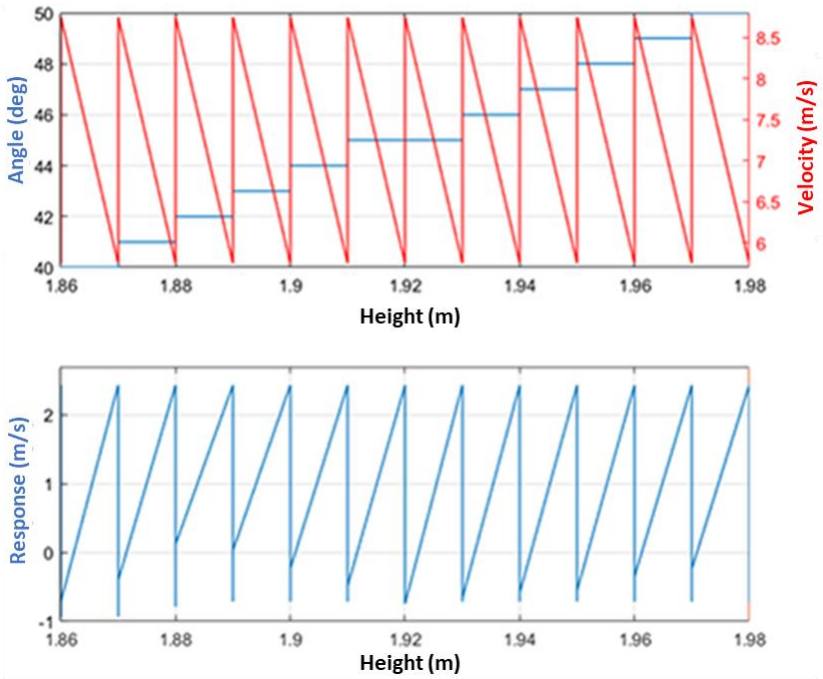


Figure 10. The release angle and the release velocity of the ball versus the height of the player graph and the response (objective) versus the height of the player graph

5. Discussion and Conclusion

The study presented here is an optimization study in the Adams/Insight module by combining ball release parameters. The angle and velocity design parameters are taken in accordance with the literature (Miller and Bartlett, 1996; Chakraborty and Meher, 2013; Çelik et al., 2013; Slegers et al., 2021; Louis et al., 2018). The height parameter is calculated according to the player's height, joint angles and jump height. Essentially, as in the studies presented in the literature (Štirn et al., 2019; Podmenik et al., 2017; Li et al., 2021; Slawinski et al., 2018; Miller and Bartlett, 1996), the height of the player at the moment of releasing the ball should be measured with different measurement techniques. Because the height of the basketball player's ball release depends on many factors such as releasing style, joint angles and jumping ability, as it is emphasized in the literature. However, the study presented here is an optimization study for the initial phase. For this reason, while the height of the player is being calculated, approaches in the literature were used.

They are the guard players who use the 3-point shot the most in basketball. These players have an average height of 1.92 m (H). With the study, it is revealed that a guard player with an average height of 1.92 m can shoot successfully at what speed and angle when he releases the ball. In other words, it can be said that a successful basketball throw can be achieved when a player with a height of 1.92 m shoots with a 45° release angle and 8.75 m/s release velocity. It is seen that the success of the 3-point shot in basketball will increase when the ball is thrown with the appropriate ball releasing parameters.

The optimization study can reveal that a player whose throw height can be determined can make a successful shot if he releases the ball at what speed and angle. Optimization work will help to achieve a high success rate in 3-point shots in basketball.

In future studies, during 3PS, the release height of the basketball player will be found with different measurement systems, so a more realistic optimization study will be carried out in the future. Also, there will be a focus on the study of the 2-point shooting in basketball or the different hitting styles in the game of tennis.

Supplementary Data

Table S1 Values of the response (objective)
(XLXS)

Conflict of Interest

No conflict of interest was declared by the authors.

References

ADAMS MSC., 2020. Adams basic full simulation package. Available from www.mscsoftware.com.

Altavilla, G., D'isanto T., Di Tore P.A., 2018. Anthropometrics characteristics and jumping ability in basketball. Supplementary Issue: Spring Conferences of Sports Science. Costa Blanca Sports Science Week, 26-28 April 2018. Calpe. Alicante, Spain.

Boddington, B.J., Cripps, A.J., Scanlan, A.T., Spiteri, T., 2019. The validity and reliability of the basketball jump shooting accuracy test. Journal of sports sciences, 37(14): 1648-1654.

Chakraborty, B., Meher, S., 2013. A trajectory-based ball detection and tracking system with applications to shooting angle and velocity estimation in basketball videos. 2013 IEEE 2013 Annual IEEE India Conference (INDICON), 12-15 December, Mumbai, India.

Çelik, E., Alptekin, A., Kılıç, Ö., 2013. Basketbolda Eski ve Yeni Üç Sayı Atış Çizgilerinden Kullanılan Başarılı Atışların Kinematik Analizi. Pamukkale Journal of Sport Sciences, 4(4): 67-77.

Drillis, R., Contini, R., 1964. Bluestein M. Body segment parameters. Artificial limbs, 8(1): 44-66.

Elliott, B., White, E., 1989. A kinematic and kinetic analysis of the female two point and three-point jump shots in basketball. Australian Journal of Science and Medicine Sport, 21(2): 7-11.

Elliott, B., 1992. A Kinematic comparison of the male and female two point and three-point jump shots in basketball. Australian Journal of Science and Medicine Sport, 24(4): 11-18.

Halliday, D., 2013. Resnick R, Walker J. Fundamentals of Physics. John Wiley & Sons.

Hamilton, G.R., Reinschmidt, C., 1997. Optimal trajectory for the basketball free throw. Journal of sports sciences, 5(5): 491-504.

https://simcompanion.mscsoftware.com/resources/sites/MSC/content/meta/DOCUMENTATION/9000/DOC9352/~secure/insight_md2010.

International Basketball Federation (FIBA), 2020. Official Basketball Rules, https://www.fiba.basketball/documents/official-basketball-rules/2020.pdf.

Knudson, D., 1993. Biomechanics of the basketball jump shot-Six key teaching points. Journal of Physical Education, Recreation & Dance, 64(2): 67-73.

Li. F., Li, Z., Borović, I., Rupčić, T., Knjaz, D., 2021. Does fatigue affect the kinematics of shooting in female basketball? International Journal of Performance Analysis in Sport, 21(5): 754-766.

Louis, J., Dinu, D., Leguy, E., Jacquet, M., Slawinski, J., Tiollier, E., 2018. Effect of dehydration on performance and technique of three-point shooting in Elite Basketball. Journal of Sports Medicine and Physical Fitness, 58(11): 1710-1711.

Miller, S., Bartlett, R., 1996. The relationship between basketball shooting kinematics, distance and playing position. Journal of sports sciences 14(3): 243-253.

Miller, S., Bartlett, R.M., 1993. The effects of increased shooting distance in the basketball jump shot. Journal of sports sciences, 11(4): 285-293.

Okazaki, V.H.A., Rodacki, A.L., Satern, M.N., 2012. A review on the basketball jump shot. Sports biomechanics, 4(2): 190-205.

Okazaki, V.H.A., Rodacki, A.L.F., 2021. Increased distance of shooting on basketball jump shot. Journal of sports science & medicine, 11(2): 231.

Okubo, H., Hubbard, M., 2015. Kinematics of arm joint motions in basketball shooting. Procedia Engineering, 112: 443-448.

Podmenik, N., Supej, M., Čoh, M., Erčulj, F., 2017. The effect of shooting range on the dynamics of limbs angular velocities of the basketball shot. Kinesiology, 49(1): 92-100.

Przednowek, K., Krzeszowski, T., Przednowek, K.H., Lenik, P., 2018. A system for analyzing the basketball free throw trajectory based on particle swarm optimization. Applied Sciences, 8(11): 2090.

Rojas, F.J., Cepero, M., Ona, A., Gutierrez, M., 2000. Kinematic adjustments in the basketball jump shot against an opponent. Ergonomics, 43(10): 1651-1660.

Satti, S. 2004. "The perfect basketball shot." Spin. Vol. 2.

Slawinski, J., Louis, J., Poli, J., Tiollier, E., Khazoom, C., Dinu, D., 2018. The effects of repeated sprints on the kinematics of 3-point shooting in basketball. Journal of human kinetics, 62(1): 5-14.

Slegers, N., Lee, D., Wong, G., 2021. The Relationship of Intra-Individual Release Variability with Distance and Shooting Performance in Basketball. Journal of Sports Science and Medicine, 20(3): 508-515.

Štirn, I., Nadja, P., Supej, M., Erčulj, F., 2019. Rotation of shoulder and hip axes during a basketball jump shot. International Journal of Performance Analysis in Sport, 19(2): 167-178.

Struzik, A., Zawadzki, J., 2013. Leg stiffness during phases of countermovement and take-off in vertical jump. Acta of bioengineering and biomechanics, 15(2): 113-118.

Zarić, I,, Kukić, F., Jovićević, N., Zarić, M., Marković, M., Toskić, L., Dopsaj, M., 2020. Body height of elite basketball players: do taller basketball teams rank better at the FIBA World Cup?. International journal of environmental research and public health, 17(9): 3141.

Zhiwen, W., Pengtao, W., Lianyuan, J., Bowen, T., Canlong, Z., Zhenghuan, H., 2017. Analysis of Influencing Factors of Shooting Rate Based on Trajectory Prediction of the Basketball, 14th Web Information Systems and Applications Conference (WISA) (pp. 176-180). IEEE.

Zwierko, T., Popowczak, M., Woźniak, J., Rokita, A., 2017. Visual control in basketball shooting under exertion conditions. The Journal of sports medicine and physical fitness, 58(10): 1544-1553.

Ziv, G., Lidor, R., 2010. Vertical jump in female and male basketball players—A review of observational and experimental studies. Journal of science and medicine in sport, 13(3): 332-339.