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Some kinematics aspects of throwing applied to basketball

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Abstract

Kinematic simulation of sport movements can be considered as an investigation tool for sport scientists. The throw is a motion that most of players, especially from team sport will perform for a hundreds of time in a practice. Sports biomechanics research technique aims to elucidate the improvement of shooting technique in the game of basketball, to improve effectiveness. Motric gesture improvement depends on analyzing the technical execution of it, sequential observation by analyzing each phase of the movement. This study aims to examine aspects of throwing kinematics in sports in general and basketball in particular. For analysis the free throws we used video analysis method and mathematical modeling. Knowledge of kinematic parameters of a throw can contribute to realizing a dynamic model of throwing which ends with modeling the training and achieve the performance. For that we analysis the free throw model and we conclude that it has a stereotypical shooting pattern for all players evaluated and is characterized by a proximal and distal in joint motion for upper and lower body The free throw is characterized by a pattern of angular velocity which varies depending by the joint motion during the release phase.

Keywords: Basketball, free throw,video analysis, mathematical modeling.

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1. Introduction

To integrate research conducted, we must make a brief presentation of the interference domain: MECHANICAL - BIOMECHANICS - SPORTS TRAINING (Figure 1) The link between MECHANICS – SPORT TRAININGS – BIOMECHANICS we can summarize as follow: any exercise is conducted based on laws of mechanics (movement, balance). Exercise by practice leads to a sports results. The sport results are subject to a biomechanical analysis and modeled by the training which can determine the athletic performance.

Starting from the definition of throwing (throwing - can be explained as the act of transmitting a remote object by using the kinetic energy of the body) in this paper aims to define it by identifying its main aspects: velocity and launch angle, trajectory of throwing.

There are many sports where the throw is presents. Depending on the purpose, an object can be thrown at a distance (throw in athletics), to achieve the target (basketball, handball, darts, etc.), or movement preceding another technical procedure (throwing the ball before the service at tennis, volleyball etc.). Some similar study were made by Roland van den Tillaar and Jan Gabri, (2012) in handball, Tan & Miller (1981) which made an analysis of kinematic of free throw styles, Miller and Bartlett (1993, 1996) which have a study about the relationship between basketball shooting kinematics, distance and playing position. In other study S. Satti (2004) made an analysis a perfect basketball shot and Tran & Silverberg, (2008) made a study about the optimal condition for the free throw in men's basketball. The majority of coaches identify shooting as the most important skill of basketball. (Huang, 2006; Miller & Barlett, 1996; Miller & Bartlett, 1993)

It is vital to analyze the kinematics of the shooting arm to understand well shooting (Okubo, Hubbard, 2015). Several previous studies suggested that shooters should keep the ball, wrist, elbow and shoulder in a vertical plane aligned with the target (Knudson 1993).

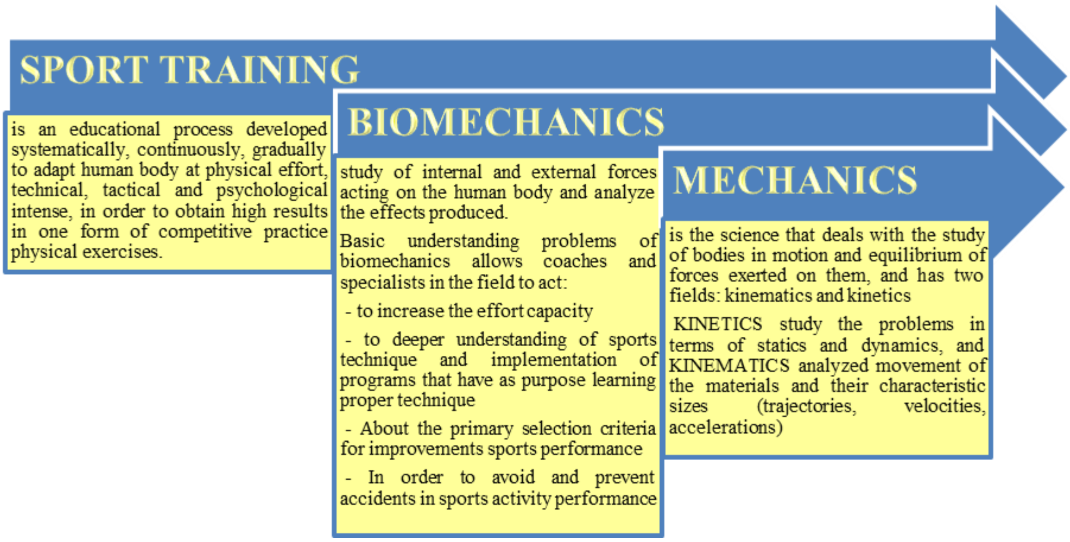

Figure 1. Interference of domains

Two shots were also compared, a missed shot as well as a performed shot, and it was found that no single factor is responsible for determining a shot, but it was the right combination of both the angle and the velocity. In mechanics, the trajectory is considered the flight path of a projectile (object). The motion of the projectile is influencing by many factors:

1. In free fall on the projectile acting the forces of gravity and air resistance;

2. The trajectory of throwing is influence by angle projection (this is the direction of projection with respect to the horizontal) in absence of air resistance. (Figure 2)

- If angle perfectly vertical, trajectory also vertical.
- If angle oblique, trajectory is parabolic.
- If angle horizontal, trajectory is half parabola

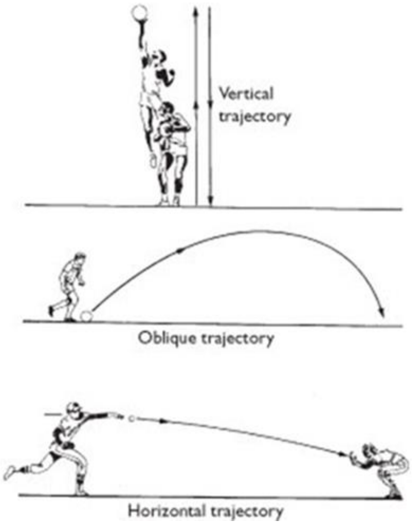

Figure 2. Influence of projection angle on the trajectory

Another factor which influencing the trajectory of throwing is speed of projection. This is the magnitude of projection velocity. If the angle of launch is constant the range of throwing is influence by the speed of projections. In the case of vertical trajectory, the speed of projection, determine the maximum vertical displacement (in slam-dunk and jump shot from basketball, pole vault, high jump) and for un oblique projection, the speed determining the height and the horizontal range of trajectory. (Figure 3.)

If the speed of projection is constant, another factor is influence the trajectory. This is the height of launch.

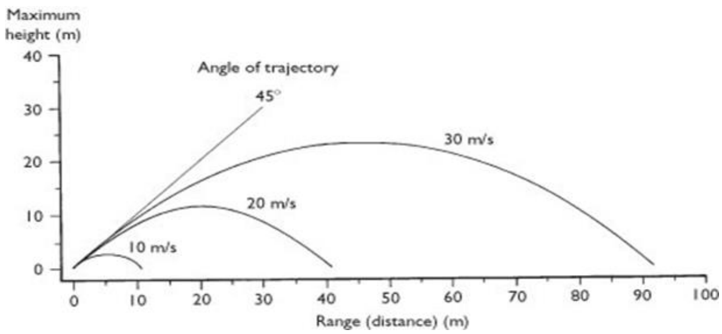

Figure 3. Influence the speed of projection on the range of trajectory

Hypothesis: Knowledge kinematic aspects can contribute to modeling the training?

2. Methods

The methods used to analyze the free-throw were:

1. Video analysis: This method we used to observe the phases of the movement and we obtained the information about movement of body (arm, trunk, legs) and the angles between segments (Fagaras, 2015). All the images were processed using Adobe After Effects.

2. Mathematical modeling: - with this method by using the Math Cad program, we have achieved the optimal launch angle; launch speed, optimal trajectory for which disposal is valid and their correlation with the height of the player.

The objectives of the study were:

a. to examine aspects of throwing kinematics in sports in general and basketball in particular.

b. analysis of free throws from biomechanical point of view, the phase sequence in the basic mechanism of motion, angles between segments;

c. Creating a mathematic model based on kinematic aspects of the throw and made the correlation with the height of players.

3. Results

Parabolas have been extensively studied since people started throwing stuff at each other, and they shape the outcome of many ballistic sports, such as baseball, golf, football, shot put and more. But they reach their apex in basketball, where field goals and free throws demand precision control of parabolas.

Table 1. In basketball, for a shooting to be valid it must meet some conditions

Table 1. Factors determinating for a valid free throw

Nr. crt.	FACTORS DETERMINATING FOR A VALID THROW	
1	THE HEIGHT OF THE BALL TOWARD THE BASKET AT THE TIME OF LAUNCH	Height of basket Height of player Body positions in the moment of launch
2	ANGLE OF RELEASE	The distance from the basket The height of player in the moment of launch
3	SPEED OF RELEASE	The forces applied in the moment of stretching the arm : a) Shoulder, Elbow, Wrist b) The movement in the joint

4. Discussion

For a better understanding the kinematics we took for analysis the case of free throw. We made biomechanical analyses of the throw and we study all the phases of the throw. In modern basketball, the procedure of making a free throw, is carried out is the one with one hand. The basic mechanism of free throws can be structured into 4 stages or moments:

A) Preparatory phase

B) Flexion of the body

C) Throw itself

D) Final position

This analysis offer information about the movement of body (arm, trunk, legs), the angles between segments.

To have a better image about all kinematics aspects of throwing we have made a mathematical model of the free throw. In carrying out mathematical modeling of free throw we followed several steps and we left the following assumptions:

- Throwing the ball should be directly in the basket (without hitting the panel or ring);

- Air resistance is zero.

- Rotation of the ball is zero (We ignore any spin the ball may have because the ball goes directly in the basket – net shot, not hitting the panel or the rim).

- No error in the roll side (player throws right In this case the model we'll create is two dimensional. If we consider the sideways errors the model will be more realistic, but three-dimensional one)

- Player height is 170 cm.

Shooting the ball in basketball game is done on a slant path at an initial rate ***v_0*** which makes an angle with the horizontal α_0. We breaks down the movement of the ball into two movements (Figure 4):

- On the horizontal direction as the axis Ox, ($v_0\cos\alpha_0$)

- On vertical direction as the axis Oy ($v_0\sin\alpha_0$) where α_0 is the initial launch angle.

Because the horizontal direction Ox is neither a force, it appears that the motion will be uniform with constant velocity $v_x = v_{0x}$.

In the vertical direction, on the ball *acting* the force of gravity G, hence the motion will be uniform range with gravitational acceleration g and initial speed v_0y.

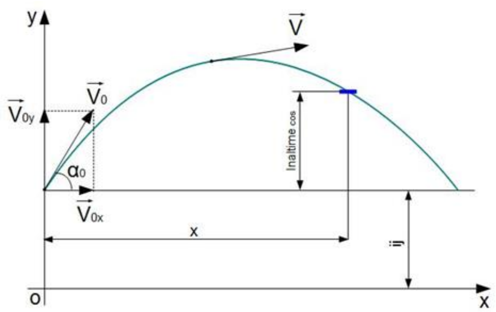

Figure 4. Graphic representation of throwing – decomposition of movement in two directions

Knowing the parameters, the ring diameter (di), the thickness of the ring (gi), the ball radius (rm), the distance from the free throw line to the panel (field a), the distance from the panel to the rim (distance ip), we could determine minimum distance, average and maximum for which throwing is valid. In this case, we have three possibilities: the ball goes into the basket closer to the previous rim (xmin), enter the basket ring right through the middle (xmed) or between the cart closer to the rear rim (xmax). (Figure 5)

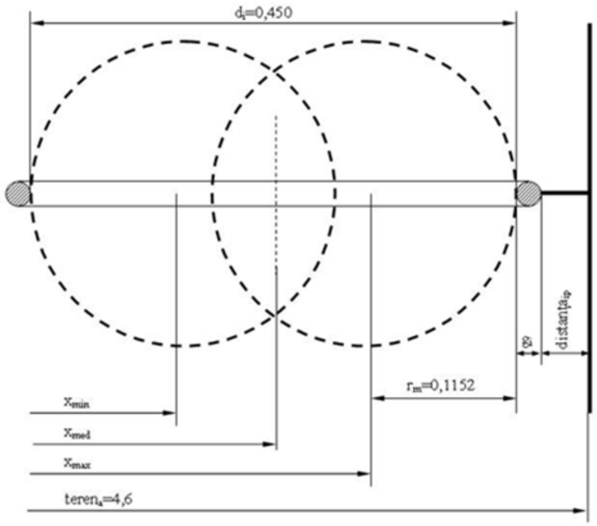

Figure 5. Graphic of distance xmin, xmed, xmax which throwing is valid

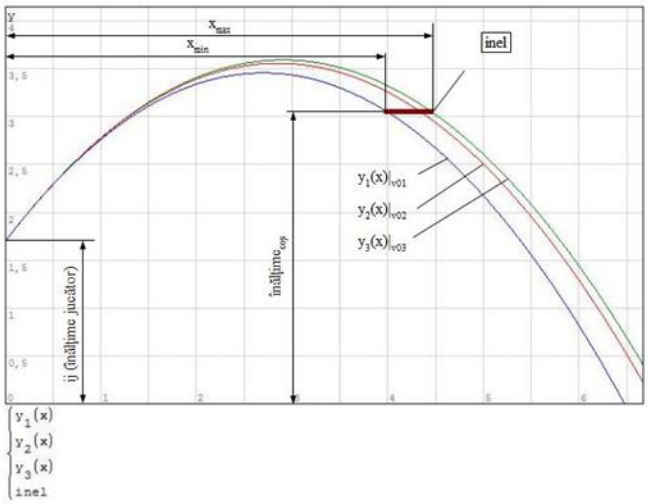

Figure 6. Graphical representation of the ball trajectories for v_{01}, v_{02}, v_{03}

The equation of motion of the ball is defined by:

$$v_o := \frac{x}{\cos(\alpha)} \times \sqrt{\frac{g}{2[x\tan(\alpha)+ij-y(x)]}} \quad (1)$$

where *x* takes place the value of: x_{min}=4.099 m, x_{med}=4.209 m şi x_{max}=4.319 m, for ij_1=1.60 m, ij_2=1.70 m şi ij_3=1.80m. (ij_1, ij_2, ij_3 define the height of players)

To establish the mathematical model we follow some steps:

a) Determination of the ball launch angle for 3 speed data. It established the following initial speeds for which the equations of motion are determined and plot trajectories:

$$v_{01} := 7,3899 \quad v_{02} := 7,6 \quad v_{03} := 7,6698$$

b) Determination of initial speed (minimum and maximum) by throwing for a player who throws the ball with ij height at a given angle α_{01}:

c) Determination of release angles (minim and maxim) of throwing, for a player with height ij which throw the ball with initial realize speed v_0, so the throw be valid (the ball goes in).

d) represent the velocity and launch angle of shooting the ball for minimum distance, average and maximum for which throwing is valid (x_{min}, x_{med}, x_{max}) correlate with height of players (ij_1=1.60 m, ij_2=1.70 m şi ij_3=1.80m).

Due the realizations of this model, we wish to highlight the angle of release and initial velocity for those the throw is validated. So, we can conclude:

- The best throw is not passing by middle of the rim, but closer to the back side of the rim;
- As the player is taller the throw is much easier (in terms of initial speed and release angle - the margin of error is greater than the shorter players);
- As you are smaller, the release angle is bigger (this is confirmed by the height from which release the ball: a shorter player has a wider area of coverage than a top player);

From the same initial speed release and the same distance xmin, there are two different angles (αmin şi αmax) for that disposal is valid. For each distance and player's height there are an initial velocity and optimal release angle for that throw to be valid.

The validity of this model was verified only on athletes group for those who was made the film. The obtained dates were compared with the found dates by the analyses of similar studies. So, in the analyzed studies the release angle varies between 52^0 and 60^0, that confirms the dates of our model. (Alexander & Way,2002) Also, the initial speed of release vary between 6,7 m/s and 7.7 m/s, and in our model this is between 7,3 m/s and 7.7 m/s.

5. Conclusion

As conclusion, the whole analysis about kinematics aspect of throwing we can synthesize on these:

1. The free throw model has a stereotypical shooting pattern for all players evaluated and is characterized by a proximal and distal in joint motion for upper and lower body. The free throw is characterized by a pattern of angular velocity which varies depending by the joint motion during the release phase. The coordination of those represents the critical factor in determining the validity of a throw. Stable postures of the body and a smooth movement through release appear to be characteristics of more successful shooting motions.

2. Qualitative analysis of joint angles compared with time was made to observe statistically significant differences between valid and invalid throws.

3. We identified three cases for an invalid throw:

a) If the player put excessive force in throwing arm, jump forward (shorter throw distance), launch angle of the ball too low, incoordination arms – legs – ***the throw is too long.***

b) If the player had insufficient force in throwing arm, made a back-balance (increase shot distance), launch angle of the ball is too high, incoordination arm-legs – ***the throw is too short.***

c) ***If the throw is deviated*** the angle of entry is too small, or there are some causes which made the deviation of throwing to the left, or to the right.

4. We considered that the biomechanical analysis of any motric gesture from sport, in our case the throw in basketball game can contribute to a better representation of the movement and also permit the modeling of training focusing of those aspects which stops the performance.

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