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Biomechanics Analysis of Normal Jump Shot and Fade-Away Jump Shot in Basketball

Peter Chieng Zhing Cheng[1], Mohd Zamani Ngali[1], Shahrin Hisham Amirnordin[2,*], Syed Faris Syed Omar[3], Ronny Yii Shi Chin[4]

[1] Sports Engineering Advance Research Group (SPEAR), Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia
[2] Centre for Energy and Industrial Environment Studies (CEIES), Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia
[3] National Sports Institute of Malaysia, Kompleks Sukan Negara, Bukit Jalil, 57000 Kuala Lumpur, Malaysia
[4] Xinju (Shenzhen) Semiconductor Technology Co., Ltd., Room 2505, Unit A, Building 11, Shenzhen Bay Science & Technology Ecological Park, Shahe West Road, Nanshan District, Shenzhen City, Guangdong Province, People Republic of China

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ABSTRACT

Basketball players normally use jump shots to score points during a game. The player must shoot the ball depending on their own experience that requires a long period of time to train. The player can learn faster and master the shooting skills with the assistance of video and data analysis. This paper determines the scoring effectiveness, the body posture and release angle of normal and fade–away jump shots in basketball using the biomechanics analysis. Recording devices were used to record the jump shots and the results were analysed by using several software including Wondershare Filmora, KMPlayer, Openpose, MATLAB, and Logger Pro. With the aid of biomechanics formula, MATLAB and Logger Pro software, the shooting angle, acceleration, energy, force, etc data were obtained. Results showed that the average angle of release that scored for both normal and fade-away jump shots were 59.4 and 59.5 degrees respectively. Normal jump shots had been concluded as more efficient due to 15 % higher scoring than the fade-away jump shots while they required 9.5 % less power to perform. Therefore, it was found that the improvement to the Openpose software can benefit many people. In potential future application, instead of detecting human posture, detecting objects might be a breakthrough for future application around the world.

1. Introduction

Basketball is a forceful team activity that required an intermittent dynamic pattern and skillful movement sport. Complex requirements like the combination of personal skills, strategy, motivational aspects, and team plays are needed in the games. There are various movements like shuffling, dribbling, running, and jumping can be seen in basketball games. These movements are

* *Corresponding author.*
E-mail address: shahrin@uthm.edu.my

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orientation, multidirectional, short-lasting, and intense [1]. To have a successful jump shot when shooting, the players are needed to have protection against an opponent, accuracy, speed, and the possibility of releasing the ball from certain distances to the hoop [2]. Throughout the observation of the games, the jump shot is the most effective [3] and the most used shooting technique, without considering the player's character during the game [4].

Many types of jump shots can be performed to aid players in scoring points during basketball games such as normal jump shots, set shots, layups, fadeaway jump shots, etc. The use of a two-legged jump shot is usually performed together with a lay-up and/or free throw [3]. A two-legged jump shot amounts to over 70% of all the shots during the game, which requires a greater level of performance for athletes to complete the jump shot to increase the height at which the ball is released at the highest point [5]. Therefore, the jump shot is considered to be the most elemental technique in basketball and requires a greater performance level [6].

The reason why the players require a greater performance level is that the shot involves the whole body in full motion, with "quick arm movements when jump to propel the ball with a high curved trajectory and to the hoop" [7,8]. The height at which a shot is performed will be affected by the factors of shooter height, jump height, and body position [9,10]. When a player is surrounded by an aggressive defender, he is required to perform the shot at the highest possible release point. Besides, in the shortest time frame, the player must reach the highest release point.

Basketball players usually use jump shots to score points during a game. Jump shot has been categorized into various type and each type will consume a different amount of energy with a unique posture to perform. Different players will perform the jump shot that they are confident. The different jump shot is used in different situation and strategy to help a player play efficiently and score easily during the game. A good posture can help to prevent injury. The player needs to use minimum energy to perform well during the game.

The release angle of the basketball while performing a jump shot can be considered the most crucial element to score. The angle of release varies for each basketball player that depends on the player's height. The most effective release angle is between 45-55 degrees [11,12]. The lower the release angle, the smaller the clearance diameter of the hoop when the basketball reaches the hoop.

The centre of mass is not only an important biomechanical principle within the technique of a basketball jump shot to achieve optimal accuracy within the shot, but it also helps with the understanding of the principle, allowing the player to further improve his performance [13]. The Centre of mass is referring to the point where the mass of the human body is evenly distributed in all directions [14]. The centre of mass for the player is controlled by keeping the body in an upright position, the feet slightly staggered width apart, and the hips squared towards the hoop [15,16]. The slightly staggered stance allows the player to minimize the forward or backward motion of the body. When the player shoots the ball at the highest point of release, the player is required to jump and will additionally apply a force (F) to the ground to accelerate (a) the individual mass (m) upwards [17].

If the player performs a jump shot with a good posture and releases the ball at the most effective angle range, the probability to score a point is higher than the player shooting the ball without any technique. The player will only shoot the ball depending on their own experience which required a long period of training. Previous researchers mainly focused on the probability to score without a comprehensive analysis of the release angle effectiveness. A player has a higher possibility to score if the release angle is within the most effective angle range. This paper investigates the basketball jump shot in terms of scoring effectiveness and its relation to the body posture and release angle with the aid of OpenPose, MATLAB software, and biomechanics calculation. The findings of this paper allow the players to achieve a better performance in shooting while in training and actual games.

2. Methodology

Figure 1 describes the flowchart of the methodology process of this paper. It begins with the selection of players until the data analysis.

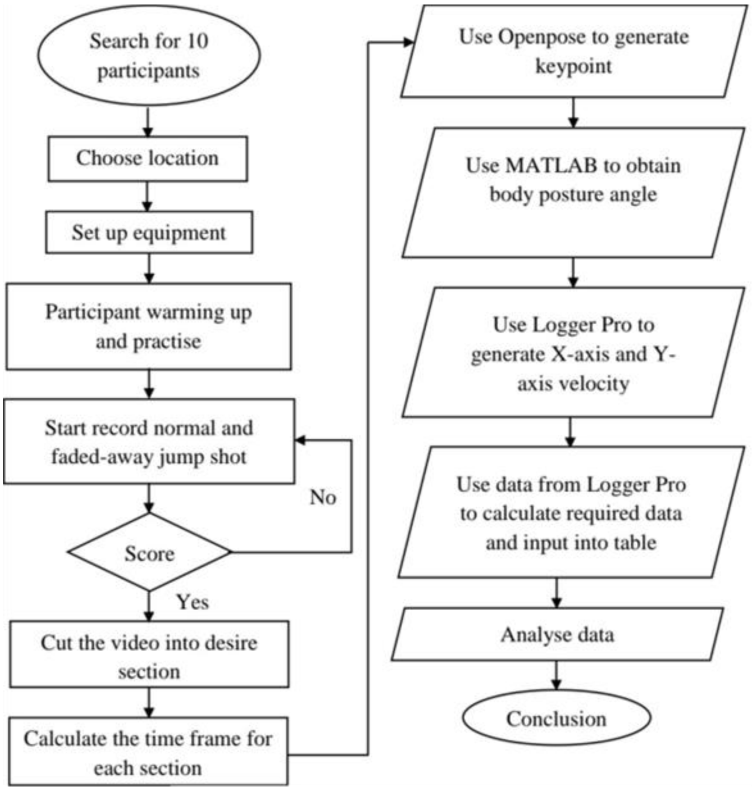

Fig. 1. Research Flow Chart

2.1 Materials

This paper used OpenPose Demo, MATLAB, and Logger Pro. OpenPose is a real-time multi-person human pose detection library that has for the first time shown the capability to jointly detect the human body, foot, hand, and facial keypoints on single images. OpenPose is used to generate keypoints from the short videos that have been produced. Besides that, MATLAB is used to decode the keypoints that are produced from Openpose to get the body posture angle. Moreover, Logger Pro is used to get the X-axis and Y-axis velocities for the ball and triceps to do biomechanics calculations.

2.2 Methods

The JSON files that were generated from OpenPose contained keypoints for each frame from the short video. Then, the JSON files that contain the keypoints will be decoded in MATLAB with some scripts to generate the body posture angles. Besides that, the short videos will be input into Logger Pro to get the X-axis and Y-axis velocity for the ball and triceps by plotting the position of the ball and triceps. The X-axis and Y-axis velocity for the ball and triceps obtained from the Logger Pro are used to calculate the time required for the triceps to fully extend, acceleration, force, joule, momentum, kinetic energy, work, and power of the triceps. Using an HD camera with 16MP to record the video of shooting normal and faded-away jump shots.

2.3 Biomechanics Calculation

To get the most effective jump shot, several equations will be used. The acceleration of triceps extension before releasing the ball can be calculated as follows [18]:

$$a = \frac{v_{final} - v_{initial}}{\Delta t} \tag{1}$$

The force that is generated before releasing the ball is calculated as below:

$$F = ma \tag{2}$$

By using the time difference, Joule of triceps extension before release is calculated as follows:

$$J = F\Delta t \tag{3}$$

When the ball is at the release point, the magnitude of the velocity (v) can be calculated with the combination of its perpendicular components using the following equation:

$$the\ v = \sqrt{{v_x}^2 + {v_y}^2} \tag{4}$$

The momentum of triceps extension when releasing the ball is then calculated using the following equation:

$$p = mv \tag{5}$$

The kinetic energy of triceps extension at releasing the ball is calculated using the following equation:

$$KE = \frac{1}{2}mv^2 \tag{6}$$

The power from the start of triceps extension to release is calculated using the following equations [19], whilst work is equal to the average of kinetic energy.

$$W = KE_{final} - KE_{initial} \tag{7}$$

$$P = \frac{W}{\Delta t} \tag{8}$$

The effectiveness of normal and faded-away jump shots out of 30 shots is calculated below.

$$\text{Effectiveness of normal jump shot} = \frac{N_N}{30} \text{ x } 100\% \tag{9}$$

$$\text{Effectiveness of faded-away jump shot} = \frac{N_F}{30} \text{ x } 100\% \tag{10}$$

By assuming the number of scores within 45 to 55 degrees = N_A, release angle effectiveness of jump shots out of 30 shots is calculated as below.

$$\text{Effectiveness of release angle} = \frac{N_A}{30} \text{x } 100\% \quad (11)$$

3. Results and Discussion

The body posture angle generated from MATLAB was recorded into the table with 30 shots for normal and faded-away jump shots. There was one table to record the average scored value of 10 participants for a normal jump shot as well as a faded-away jump shot. Next tables were recording the average value for triceps energy produced in normal and faded-away jump shots. Moreover, the effectiveness of a successful jump shot was calculated. This research will be using a High-Definition (HD) video camera to record the jump shot of the participants. The biomechanical analysis will be performed using specialized software involving the extraction of kinematic and dynamic information (shooting angle and acceleration, forces, energy, etc.).

Computerized video analysis will be processed using specialized software, Openpose software. Openpose that is adopted in this research is for 2-dimensional (2D) skeleton recognition, and the skeletal coordinates of 18 points (Figure 2) are generated into files in about 5 to 10 frames per second depending on the computer performance. The skeletal coordinate of x as horizontal, and y as vertical is to be used is calculate angles. The biomechanical study focused on the analysis of the characteristics of the key technical elements used for the normal jump shot and faded-away jump shot.

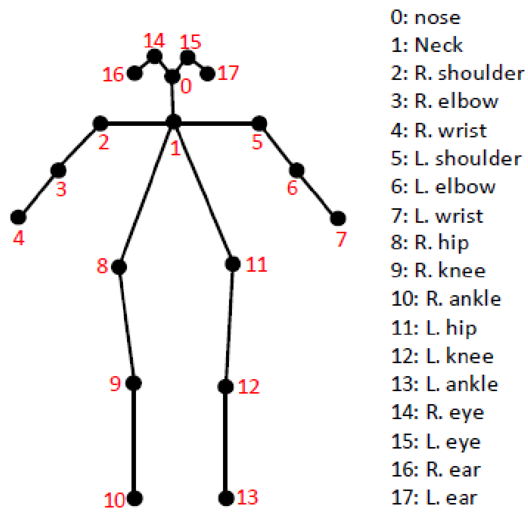

Fig. 2. Skeletal coordinates of 18 key points

Table 1 shows the average angle at the beginning of a normal jump shot that was obtained from MATLAB for 10 of the participants. The participants scored 15.1 times in a normal jump shot which is more than a faded-away jump shot. By referring to the table above, the average release angle of the ball for 10 participants is 59.4˚ which is not within the successful score angle of 45 to 55 degrees as expected. The average angle value of score for the right shoulder, left shoulder, right elbow, left elbow, right hip, left hip, right knee, and left knee are 156.8˚, 69.2˚, 113.5˚, 110.9˚, 166.0˚, 161.4˚, 141.3˚ and 157.6˚ respectively.

Table 1
The average angle at the beginning of a normal jump shot obtained from MATLAB for 10 participants

Normal jump shot		Release angle (˚)	Angle (˚)								
			Right shoulder	Left shoulder	Right elbow	Left elbow	Right hip	Left hip	Right knee	Left knee	Score
Participant	1	59.1	160.4	53.3	110.7	118.5	167.9	164.5	152.7	161.5	18
	2	59.5	151.6	63.7	126.1	110.9	165.1	158.0	140.7	159.6	12
	3	59.3	155.8	70.0	113.3	107.9	167.3	157.7	140.1	164.3	14
	4	59.8	161.1	74.7	114.3	115.2	165.8	162.4	134.5	155.5	17
	5	59.7	157.3	62.2	105.4	111.0	162.4	161.2	131.5	161.5	13
	6	59.4	154.5	68.8	105.0	116.6	167.8	160.6	147.2	157.3	15
	7	58.9	154.6	68.2	107.8	112.1	164.7	161.8	140.4	154.1	19
	8	59.1	162.1	75.4	117.0	91.9	165.2	161.8	141.1	153.1	11
	9	59.6	155.4	73.3	110.8	125.5	167.2	162.4	137.3	157.7	14
	10	59.5	155.6	81.9	124.3	99.8	166.5	163.8	147.3	151.9	18
Average value for scored		59.4	156.8	69.2	113.5	110.9	166.0	161.4	141.3	157.6	15.1

Table 2 shows the average angle at the beginning of the faded-away jump shot obtained from MATLAB for 10 of the participants. The participants scored 10.6 times in the faded-away jump shot which is less than the normal jump shot. By referring to the table above, the average release angle of the ball for 10 participants is 59.5˚ which is not within the successful score angle of 45 to 55 degrees as expected. The average angle value of score for the right shoulder, left shoulder, right elbow, left elbow, right hip, left hip, right knee, and left knee are 153.2˚, 73.6˚, 105.8˚, 113.4, 167.4˚, 160.4˚, 143.9˚ and 153.7˚ respectively.

Table 2
The average angle at the beginning of the faded-away jump shot obtained from MATLAB for 10 participants

Faded-away jump shot		Release angle (˚)	Angle (˚)								
			Right shoulder	Left shoulder	Right elbow	Left elbow	Right hip	Left hip	Right knee	Left knee	Score
Participant	1	60.3	136.7	59.8	86.7	145.4	174.5	165.1	120.8	126.7	11
	2	59.7	156.3	70.2	99.8	101.8	168.7	159.8	151.1	159.0	9
	3	59.3	156.1	71.0	101.8	114.0	167.5	159.6	138.5	157.8	11
	4	59.9	150.9	79.9	131.9	98.9	167.2	168.2	153.8	160.4	10
	5	59.3	156.3	75.4	101.5	114.3	166.2	159.3	148.6	154.7	14
	6	58.9	155.1	81.6	103.3	105.2	165.0	157.9	148.0	150.5	12
	7	60.2	144.0	77.7	109.7	117.9	166.5	158.4	159.1	161.6	8
	8	58.9	159.4	67.7	108.5	116.5	167.3	157.0	137.9	153.0	10
	9	59.0	156.1	83.1	92.2	111.0	165.9	160.3	146.9	155.9	12
	10	59.6	160.8	69.6	123.1	108.4	165.6	158.0	134.3	157.8	9
Average value for scored		59.5	153.2	73.6	105.8	113.4	167.4	160.4	143.9	153.7	10.6

The velocity and time taken for triceps to reach the highest point is obtained from Logger Pro software. The short video is uploaded into Logger Pro software to get the velocity of x and y axis and time taken for the ball to reach its highest point for basketball. The triceps energy is then calculated using the data obtained from Logger Pro and using the formula. Figure 3 and Figure 4 shows the velocity of the x-axis and y-axis for the basketball and the time obtained from Logger Pro respectively. Figure 5 shows the velocity of triceps obtained from Logger Pro.

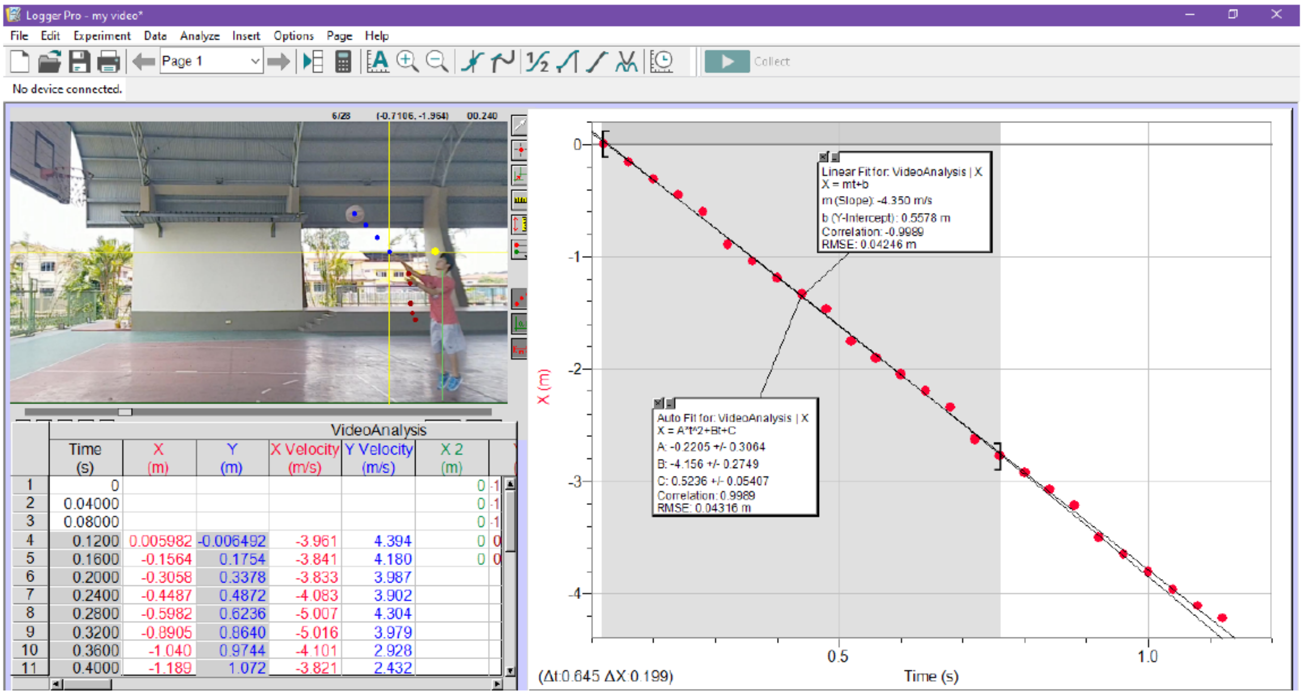

Fig. 3. Velocity of the x-axis for basketball and time obtained from Logger Pro

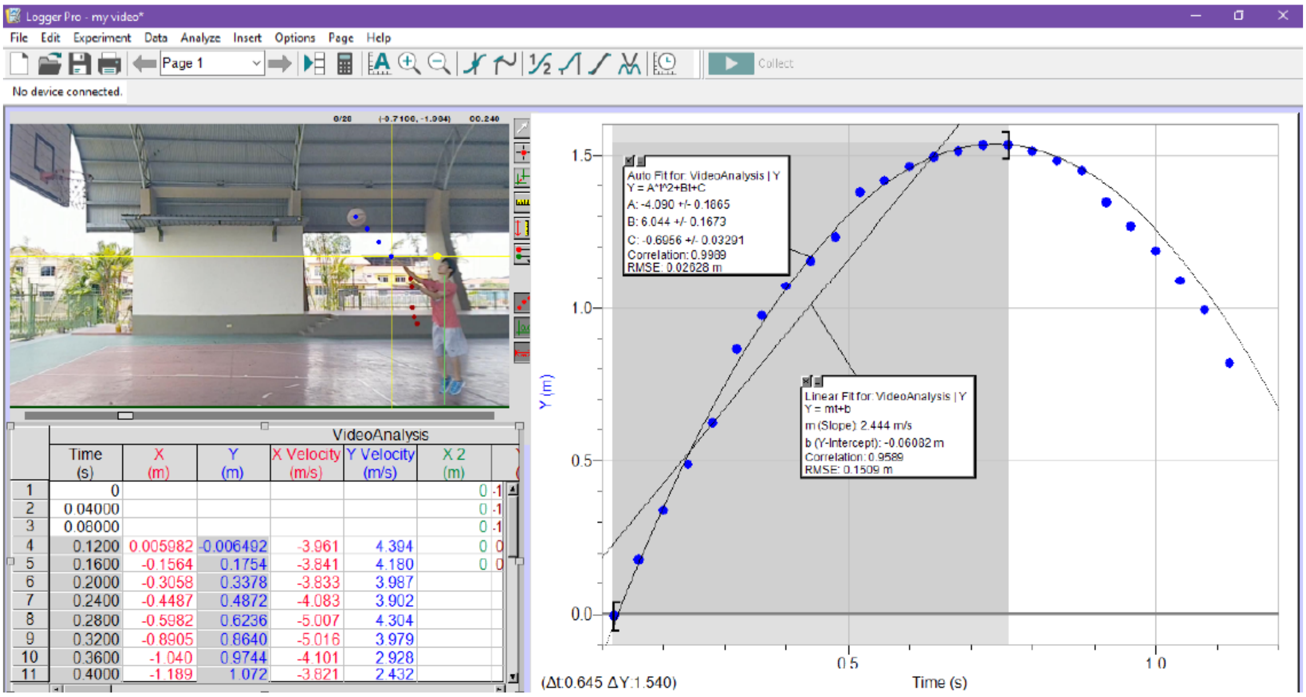

Fig. 4. Velocity of y-axis for basketball obtained from Logger Pro

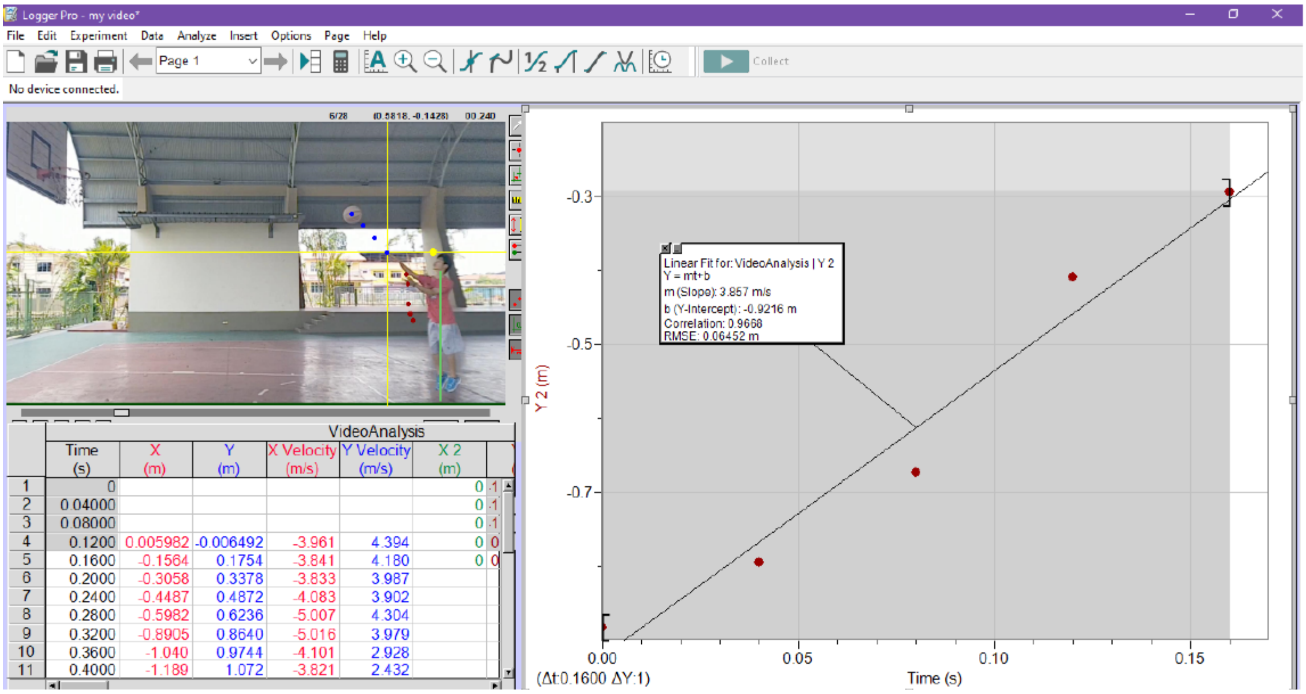

Fig. 5. Velocity of triceps obtained from Logger Pro

Table 3 shows that the time taken for the triceps to reach the highest point for a normal jump shot is slightly longer than the faded-away jump shot. Shorter time also required higher acceleration to meet each other's requirements. The basketball velocity for a normal jump shot is slightly higher than the faded-away jump shot. Faded-away jump shot required more triceps force than a normal jump shot because it needs to lean back while jumping. A normal jump shot gives more impulse (Joule) to a shot from triceps extension while a higher proportion of momentum is from triceps, less from wrist flick. Normal jump shots exerted more kinetic energy and work to the ball. Faded-away jump shot required more power because it has a shorter release time.

Table 3
The average value for triceps scored for a normal jump shot and faded-away jump shot

	Normal jump shot	Faded-away jump shot
Time for triceps to reach the highest point (s)	0.198	0.183
Triceps Acceleration (m/s2)	15.454	15.899
Ball velocity (m/s)	5.291	5.257
Triceps Force (kg·m·s−2)	8.763	9.015
Triceps Joule (kg·m2·s−2)	1.674	1.534
Ball Momentum (kg-m/s)	3.000	2.981
Triceps Kinetic Energy (J)	7.959	7.843
Triceps Work (J)	7.959	7.843
Triceps Power (W)	40.454	44.699

Table 4 shows the effectiveness of a normal jump shot is higher than the effectiveness of a faded-away jump shot which is 14.97% indifferent. From the result in Table 1 and Table 2, the release angle for both jump shots is not within the range of 45 to 55 degrees as expected [20]. Due to the release angle not being in the range, the effectiveness of the release angle cannot be calculated.

Table 4
Effectiveness of successful jump shot

Effectiveness	Percentage
Effectiveness of normal jump shot	50.3%
Effectiveness of faded-away jump shot	35.33%

4. Conclusion

In conclusion, a normal jump shot is more effective than a faded-away jump shot because it produces 9.5% less power to perform the jump shot as compared to a faded-away jump shot. Less power produced means the player will not easily get tired and can perform well in the game. Faded-away jump players must lean back to shoot the basketball which can reduce the percentage to score. The average angle of release that scored for both normal and faded-away jump shots are 59.4 and 59.5 degrees respectively. However, it does not meet the successful score angles as expected which are 45 to 55 degrees. The possible cause of the angle of release not meeting the successful score angles is the height of the players used in the analysis is different because different heights will have different angles of release.

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