

THE EFFECTS OF INCREASED DISTANCE ON BASKETBALL SHOOTING
KINEMATICS

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INTRODUCTION

Success in basket ball is largely dependent upon the ability to project the ball through the basket, and the skill of shooting has long been recognised as one of the most important in the game (Hay 1987). From the moment of release, the ball is a projectile, and as such is subject to the laws governing projectile motion. The principal factors determining outcome are as for any projectile, namely speed, height and angle of release and air resistance.

At any given shooting distance, release speed and release angle are interdependent. The minimum required value of release speed is that at which the ball is released at an angle determined by the following equation:

$$\text{Release angle} = 45^\circ + \frac{1}{2} \text{ angle of incline to the basket}$$

Brancazio (1984)

It may be seen that as release height increases, a lower angle of release is required for minimum release speed. For any specific release angle, however, release speed increases with increasing distance from the basket. The angle of entry of the ball into the basket, dependent upon release speed and angle, is also a major factor in determining success. Approaching the basket vertically would allow the greatest errors as the ball "sees" the basket as a circle. At shallower approaches, this becomes increasingly ellipsoidal until a point where the diameter of the ball is greater than the apparent diameter of the hoop. For the ball to approach the basket at a steep angle requires a similarly large angle of release which, with reference to Brancazio's equation, requires a large release speed. Mortimer (1951) has demonstrated that the seriousness of a 1° error in release angle increases with the release angle, thus whilst a high release allows a greater margin for error in distance, these errors will not be accentuated so much at lower angles of release, thus increasing accuracy. Based upon margin for error, Hay (1987) determined that the optimal range of release angles for a 4.57 m shot was 52-55°. Releasing the ball further from the ground has also been demonstrated to be beneficial to accuracy by Maugh (1981). This is commonly achieved using the jump shot, in which the ball is released whilst the shooter is airborne. To provide the force necessary for the ball to reach the basket requires extension of the elbow joint and flexion of the shoulder and wrist joints, the latter from a hyperextended position. Miller and Bartlett (1991) found that the increased force required at greater shooting distances was derived from a larger contribution from the elbow extensor and shoulder flexor muscles. Evidence also exists for a greater horizontal component of movement during the jump when shooting further from the basket (e.g. Elliott and White, 1989; Miller and Bartlett, 1991). Data of the latter author also suggests that release occurs both closer to the time of take-off and with a greater centre of mass velocity in the direction of the basket.

Thus the following objectives were formulated:-

1. To investigate the relationships between release speed, release angle and release height with shooting distance.
2. To determine the changes in shooting technique used to achieve the required release parameter values with particular attention to:-
 - a) the jump,
 - b) angular displacements and angular velocities of the major joints.

METHODS

All data was collected at the games of the 16th Universiade, over a five day period (20th - 24th July, 1991). Two gen locked, tripod-mounted Panasonic F-15 video cameras, located approximately 10 m above the court surface were used to record three dimensional performance images. The optical axes of the cameras were placed at approximately 90° to maximise the accuracy of three dimensional coordinate reconstruction. Images were recorded onto video tape via Panasonic NV-180 recorders. Calibrations were such that the orthogonal axes were parallel to and at right angles to the backboard (Figure 1). The digitising rate was 50 fields/second.

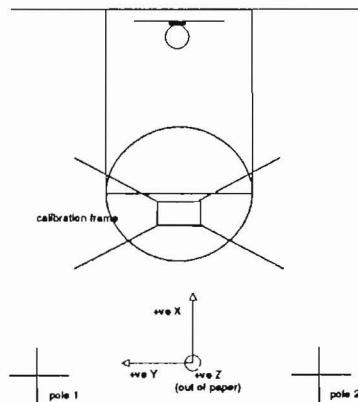


Figure 1. Plan view of calibration

RESULTS

All subjects played for one of those teams which reached the quarter final stage of the men's tournament. Fifteen sequences were selected for analysis, consisting of five shots taken in each of the three shooting ranges previously described. All shots analysed were attempted straight at the basket i.e. without use of the backboard. A successful shot was defined as one which passed through the basket without contact with the backboard, as such contact would indicate errors in release parameters. As such, all shots analysed were successful. Sequences were analysed from 0.40 s prior to take-off to 0.20 s post ball release.

Sequences were digitised and three dimensional coordinates obtained using a Direct Linear Transformation algorithm correcting for linear lens distortion implemented for the Acorn Archimedes computer by Bartlett (1990). A standard 14 segment, 18 point model of the human performer was employed, using the data of Dempster (1955), corrected for tissue fluid loss, with one extra point to represent the centre of the ball.

As stated, subjects were divided into three groups:

- Group 1 - short range shots attempted from a distance of not greater than 3.66 m.
- Group 2 - medium range shots attempted from distances between 3.66m and 5.49 m.
- Group 3 - long range shots attempted from distances of greater than 5.49 m.

One sequence was re-digitised twice, with an intervening period of at least 48 hours to satisfy reliability requirements, and a further time by a person unconnected with the study for the purposes of objectivity. A one way analysis of variance yielded f -ratios ≤ 0.95 (thus showing no significant differences at the $p < 0.05$ level of confidence) for selected parameters (centre of mass speed, elbow joint angular velocity and knee joint angular displacement).

DISCUSSION

Findings are presented in Table 1. Mean ball release angles ranged between $47.8 \pm 5.82^\circ$ (Group 2) and $51.9 \pm 5.54^\circ$ (Group 3), whilst mean release speeds increased with shooting distance (Group 1 = $3.04 \pm 0.65 \text{ m.s}^{-1}$; Group 3 = $6.25 \pm 0.80 \text{ m.s}^{-1}$). Based upon Brancazio's equation, it would seem that subjects in the present study released the ball at angles which are a compromise between those requiring the minimum amount of force to the ball and those allowing the greatest margin for error.

	Group 1		Group 2		Group 3	
	X	S.D.	X	S.D.	X	S.D.
Shoulder ang. velocity at release (rad.s^{-1})	2.61	1.00	2.41	1.30	2.66	1.20
Max. shoulder angular velocity (rad.s^{-1})	2.71	0.96	2.54	0.89	3.19	1.30
Elbow ang. velocity at release (rad.s^{-1})	5.28	1.70	7.51	1.40	8.71	1.30
Max. elbow angular velocity (rad.s^{-1})	5.87	1.80	7.17	0.72	8.91	1.20
Wrist angular velocity at release (rad.s^{-1})	4.28	1.80	2.78	2.50	2.17	0.40
Max. wrist angular velocity (rad.s^{-1})	6.67	1.04	3.99	0.71	3.11	1.00

Table 1. Upper body angular velocities at release and maximum values.

Maximum values of angular velocity of the elbow joint were found to occur prior to or at the moment of release, whilst the value at release increased with shooting distance. A contrary trend was found for the wrist joint. Shoulder flexion angular velocities tended to be similar for all shooting distances. As ball release speed is partially determined by the maximum angular velocities of these joints, and their values at release, the data would suggest that elbow extension plays a more important role than wrist or shoulder flexion in providing the increased force necessary for the ball to reach the basket at greater shooting distances. Angular displacements of the shoulder axis in the horizontal plane reveal a tendency for rotation so that the shooting side is forward, suggesting that rotation facilitates alignment of the elbow and wrist joints with the eyes as proposed by Hay (1987).

Angles of the centre of mass velocity vector at take-off with respect to the forward horizontal decreased between short and medium range shots ($87.8 \pm 14.6^\circ$ and $78.4 \pm 1.8^\circ$ respectively). This trend did not, however, continue between medium and long range shots. Increasing centre of mass speeds in the direction of the basket at release as shooting distance increased would indicate that elite shooters utilise the component of centre of mass velocity in the direction of the basket to aid force provision to the ball.

	Group 1		Group 2		Group 3	
	X	S.D.	X	S.D.	X	S.D.
Shoul. axis rot. at rel. ($^\circ$)	15.0	8.50	28.9	9.78	24.9	11.4
Hip axis rot. at rel. ($^\circ$)	8.16	15.0	16.3	11.3	25.8	8.79
Time from release to peak of jump (s)	-0.04	0.05	0.03	0.09	0.08	0.05

Table 2. Selected parameters for the jump shot.

All subjects increased ball release height by shooting whilst airborne. However, the timing of release was found to occur closer to take-off as shooting distance increased. All groups tended to display similar foot positioning, with the foot on the side of the shooting

arm forward. Mean values were similar to those reported by Penrose and Blanksby (1976). Medio-lateral separation values ranged between 0.36 ± 0.10 m (Group 3) and 0.47 ± 0.05 m (Group 2). Horizontal plane foot angles reveal that the foot on the side of the shooting arm (the front foot) tended to point towards the target, and the foot on the side of the non-shooting arm (the rear foot) was turned out from the body, and would suggest it is the foot-forward technique that is commonly employed in jump shooting, with the rear foot turned outward as an aid to medio-lateral stability.

	Group 1		Group 2		Group 3	
	X	S.D.	X	S.D.	X	S.D.
F. foot to shot direction (°)	3.8	39.6	7.8	18.8	9.5	14.5
R. foot to shot direction (°)	24.1	36.1	14.8	17.9	22.6	13.3
Medio-lateral foot sep. (m)	0.38	0.30	0.47	0.05	0.36	0.10
Ant.-post. foot sep. (m)	0.17	0.11	0.10	0.14	0.09	0.09

Table 3. Foot placement data.

CONCLUSIONS

1. The increase in ball release speed increased with shooting distance (Groups 1-2, 1-3, $p < 0.01$; Groups 2-3 $p < 0.05$) was found to be due to increased elbow extension angular velocity and centre of mass velocity at release.
2. The time from take-off to release exhibited an inverse relationship with shooting distance. This allowed an increasing amount of body momentum to be utilised to aid force provision to the ball.
3. All subjects rotated the hip and shoulder axes, so that the shooting arm side was forward, in order to facilitate alignment of the elbow and wrist joints with the eye in order to improve accuracy.

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