KINEMATIC PARAMETERS OF BASKETBALL JUMP SHOTS PROJECTED FROM VARYING DISTANCES

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INTRODUCTION

The ability to score points is critical to a team's success in the game of basketball. The inclusion of the 3-point shot in the American collegiate game (19 ft 9 in or 6 m) in 1986 contributes to the team's ability to catch up when behind or pull away when ahead. To optimize team and player shooting accuracy, coaches stress that players recognize their shooting limits and take shots from within their "shooting range." Shooting jump shots from varying distances from the basket requires the player to manipulate multiple variables which determine success. Recent investigations on female players identified changes in kinematic variables as shooting distance increased (Elliott and White, 1989; Walters et al., 1990). The distances used in these studies, however, were determined a priori by the researcher and may or may not reflect the player's maximum possible shooting distance. The purpose of this study, therefore, was to identify changes in kinematic parameters of jump shots projected from varying distances by intercollegiate basketball players as distance from the basket increased until each reached his/her maximum distance.

METHODOLOGY

Subjects - Eight NCAA Division I intercollegiate level players, four males and four females, were the subjects of this investigation. Mean age for the males was 20.8 (± 2.3) yrs, mean height was 196.3 (± 4.3) cm, and mean mass was 87.4 (± 13.2) kg. Mean age for the females was 20.3 (± 0.7) yrs, mean height was 172.8 (± 4.3) cm, and mean mass was 63.4 (± 3.8) kg. All subjects were right handed shooters.

Data Collection - Sagittal views of all jump shots taken by each subject were filmed with a Locam model 51 camera positioned 12.2 m from the player's right side and operating at a speed of 100 fps. Artificial lights were included in the filming area. Subjects were allowed to practice at each distance until they felt ready to perform. Gender appropriate competitive ball sizes were used.

Each subject took his/her first shot from a distance of 10 ft (3 m) directly in front of the basket and took as many shots as needed to make a total of three successful baskets. A successful basket was defined as a ball that did not touch the backboard nor the rim prior to passing through the hoop. After making three successful baskets from 10 ft, the subject moved to the free throw line, a distance of 15 ft (4.6 m). The lights and camera were also moved. Practice was once again allowed until the subject indicated readiness for filming. Subjects shot at this distance until three "successful" baskets out of a maximum of 10 attempts were made. Filming stopped once three successful baskets were completed and the lights, camera, and subject were moved back 2 ft (0.6 m) directly in front of the basket and filming procedures repeated. Subjects continued on in like manner until each reached a distance from which s/he could no longer make three "successful" baskets out of a maximum of 10 attempts.

Data Reduction - One trial from each distance for each subject was selected for digitizing. Trials digitized were ones in which a "successful" basket was made and the entire shooting motion was captured on film. Criteria for trial selection were unable to be met for one of the male subjects shooting from 17 ft (5.2 m). Nineteen segmental endpoints and ball center were digitized with a Graf/Pen sonic digitizer from the start of the shooting motion to 0.1 s after ball release using software written by Noble et al. (1988). Digitized coordinates were stored in an IBM-compatible 486 microcomputer for analysis. Raw data were smoothed with a low-pass digital filter using a cutoff frequency individually determined for each point digitized based on a harmonic analysis of the raw data (Noble et al., 1988). Eight kinematic variables were analyzed from the filtered data: a) angle of projection, b) velocity of projection, c) angle of trunk inclination at ball release, d) shoulder angular velocity at ball release, e) elbow angular velocity at ball release, f) vertical height of the center of gravity at its highest point, g) vertical height of the center of gravity at ball release, and h) horizontal displacement of the center of gravity from the moment of greatest knee flexion to ball release.

RESULTS

All four males successfully made three baskets from a distance of 27 ft (8.2 m) directly in front of the basket. Two of the females reached a maximum distance of 25 ft (7.6 m), one 23 ft (7.0 m), and one 19 ft (5.8 m). Tables 1 and 2 contain means and standard deviations for the kinematic variables analyzed.

Table 1. Means and standard deviations of kinematic parameters for females.

	F10	F15	F17	F19	F21	F23	F25
N =	4	4	4	4	3	3	2
ANGL (°)	54.86	53.21	51.37	51.45	51.67	50.21	53.75
	3.13	3.45	3.29	1.94	2.46	5.25	1.11
VEL (m/s)	5.43	6.35	6.51	6.69	7.70	7.97	8.74
	0.18	0.53	0.49	0.52	0.23	0.31	4.40
TRKINC (rad)	1.62	1.61	1.60	1.63	1.64	1.62	1.60
	0.04	0.03	0.02	0.07	0.11	0.06	0.01
SHDVEL (rad/s)	4.99	6.20	7.27	7.41	9.76	10.59	11.56
	1.43	2.58	3.10	1.96	2.56	3.73	5.27
ELBVEL (rad/s)	9.99	11.11	13.23	12.99	14.60	15.79	15.50
	0.94	1.64	2.97	1.50	0.19	1.56	4.03
CGPEAK (m)	1.24	1.23	1.31	1.35	1.32	1.32	1.35
	0.08	0.06	0.08	0.07	0.05	0.04	0.04
CGREL (m)	1.23	1.19	1.27	1.30	1.25	1.24	1.23
	0.08	0.05	0.10	0.09	0.03	0.02	0.02
HORZDISP (m)	0.02	0.00	0.05	0.09	0.09	0.12	0.08
	0.03	0.03	0.07	0.11	0.06	0.07	0.00

Mean angle of projection decreased as distance increased (F10=54.9°, F23=50.2°; M10=53.5°, M27=42.9°). Accordingly, mean velocity of projection increased (F10=5.4 m/s, F23=8.0 m/s; M10=4.8 m/s, M27=8.2 m/s) as did shoulder and elbow angular velocity at release (Shoulder: F10=5.0 rad/s, F23=10.6 rad/s; M10=3.2 rad/s, M27=4.6 rad/s; Elbow: F10=10.0 rad/s, F23=15.8 rad/s; M10=7.4 rad/s, M27=11.0 rad/s). Mean angle of trunk inclination at release, however, did not change as distance increased (F=1.6 rad, M=1.5 rad).

Table 2. Means and standard deviations of kinematic parameters for males.

	M10	M15	M17	M19	M21	M23	M25	M27
N =	4	4	3	4	4	4	4	4
ANGL (°)	53.49	52.66	51.29	49.18	50.65	46.72	48.40	42.92
	6.13	8.79	5.15	3.00	4.71	4.95	3.72	6.80
VEL (m/s)	4.82	6.06	6.73	6.87	7.15	7.57	7.19	8.20
	0.72	0.65	0.21	0.45	0.47	0.31	1.88	0.71
TRKINC (rad)	1.60	1.53	1.54	1.53	1.52	1.51	1.52	1.51
	0.05	0.08	0.07	0.08	0.07	0.08	0.09	0.07
SHDVEL (rad/s)	3.16	3.42	3.49	4.31	4.59	4.36	4.86	4.56
	1.95	0.94	0.41	0.77	1.41	1.07	0.79	0.65
ELBVEL (rad/s)	7.40	9.92	9.29	11.03	11.60	10.80	11.71	10.96
	3.06	1.71	1.28	2.02	2.37	0.42	1.12	0.33
CGPEAK (m)	1.36	1.40	1.41	1.45	1.47	1.51	1.41	1.56
	0.13	0.09	0.06	0.06	0.07	0.06	0.25	0.05
CGREL (m)	1.35	1.39	1.41	1.45	1.45	1.49	1.37	1.52
	0.11	0.08	0.07	0.06	0.07	0.07	0.23	0.07
HORZDISP (m)	-0.02	-0.02	0.02	0.01	0.06	0.08	0.08	0.11
	0.00	0.04	0.02	0.09	0.09	0.06	0.10	0.13

Variables:

ANGL	Angle of Projection (°)
VEL	Velocity of Projection (m/s)
TRKINC	Angle of Trunk Inclination at Ball Release (rad)
SHDVEL	Shoulder Angular Velocity at Ball Release (rad)
ELBVEL	Elbow Angular Velocity at Ball Release (rad)
CGPEAK	Vertical Height of Center of Gravity at Highest Point (m)
CGREL	Vertical Height of Center of Gravity at Ball Release (m)
HORZDISP	Horizontal Displacement of Center of Gravity from Greatest

Distances:

10 ft=3.0 m	15 ft=4.6 m	17 ft=5.2 m
19 ft=5.8 m	21 ft=6.4 m	23 ft=7.0 m
25 ft=7.6 m	27 ft=8.2 m	

Ball release occurred at similar vertical heights of center of gravity as distance increased (F10=1.2 m, F23=1.2 m; M10=1.4 m, M27=1.5 m). Males released their shots around the peak of their vertical jumps. Females, however, released their shots at the peak of their jump at 10 ft, 15 ft, and 17 ft, but released their shots before reaching the peak of their jump for distances of 19 ft (peak=1.4 m, release=1.3 m), 21 ft (peak=1.3 m, release=1.2 m), and 23 ft (peak=1.3 m, release=1.2 m). Although release height did not change for the females as shooting distance increased, the actual height they jumped did. Mean horizontal displacement of center of gravity increased as distance increased (F10=0.02 m, F23=0.12 m; M10=-0.02 m, M27=0.11 m).

DISCUSSION

Angle and velocity of projection, the end products of the shooting motion, and height of the ball at release determine the ball's horizontal distance, thereby affecting the success or failure of the jump shot. Subjects in this investigation decreased angle and increased velocity of projection as shooting distance increased. The findings of this study are similar to those of Elliott and White (1989) and Walters et al. (1990) who investigated females shooting from increasing distances. Trunk angle of inclination at release contributes to release height of the ball. Since trunk inclination did not change as shooting distance increased, one can assume that this variable did not affect the players' shooting range. All subjects in this investigation had a near-vertical (vertical=1.57 rad) trunk at release (Tables 1 and 2).

The males of this investigation had a consistently lower angle and velocity of projection than did the females when shooting from the same distance.(Tables 1 and 2). This finding can be explained when height of release is considered. The males were taller than the females (F=172.8 cm; M=196.3 cm). In addition, vertical position of the center of gravity at release was higher for the males at every shooting distance (F10=1.23 m, M10=1.35 m; F23=1.24 m, M23=1.49 m; M27=1.52 m). Hence, their projection values should be lower than the females'.

Elliott and White (1989) found that the female players in their study developed the extra velocity required to project the basketball at the greater distance of the two investigated (4 m and 6.25 m) by changes in the upper body rather than in the lower body. Inspection of the shoulder and elbow angular velocities at release in Tables 1 and 2 reveals higher angular velocities at release as distance increased and velocity of projection increased. In addition, higher angular velocities are noted for the females than the males at all distances to produce the higher ball projection velocities previously noted. To generate these greater ball velocities, it is interesting to note that the females increased both their shoulder and elbow angular velocity as shooting distance increased (Shoulder: F10=5.0, F23=10.6 rad/s, Elbow: F10=10.0, F23=15.8 rad/s), whereas the males relied more on their elbow than the shoulder (Shoulder: M10=3.2, M25=4.9 rad/s; Elbow: M10=7.4, M25=11.7 rad/s).

Penrose and Blanksby (1976) noted that as distance from the basket increased, the players in their study reduced the height of their jump, had more horizontal displacement, and released their shot earlier in relation to the peak of the jump. Walters et al. (1990) found that the females in their study released the ball prior to reaching the peak of their jump from all three distances (4.3 m, 5.2 m, and 6.1 m). Likewise, Elliott and White (1989) found that the ball was released earlier in the flight period by the females studied when shooting from 6.25 m than from 4 m. The males in this study, however, jumped higher and released the ball higher as distance increased. Moreover, they were fairly consistent in releasing the ball around the peak of their jump. The females, on the other hand, jumped a little higher as distance increased, but released the ball at a nearly consistent height, regardless of shooting distance.

Overall, horizontal displacement increased for both the males and females as shooting distance increased in agreement with Elliott and White (1989) and Penrose and Blanksby (1976). Horizontal displacement was similar (within 2 cm), however, between the males and females at the same distances.

CONCLUSIONS

The results of this study suggest that males and females have similar strategies - they decreased angle and increased velocity of projection, increased shoulder and elbow angular velocity at release, increased jump height, increased horizontal displacement, but did not change their angle of trunk inclination at release - and dissimilar strategies - the males released the ball near the peak of their jump, females released before peak as distance increased, the females used both their shoulder and elbow whereas the males used primarily their elbow to increase ball velocity - to solve the movement task of shooting jump shots from increasing distances.

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