KINEMATIC ADJUSTMENTS IN BASKETBALL SHOOTING AT THREE DISTANCES

WALTERS, M.; HUDSON. J.; BIRD, M.
University of North Carolina at Greensboro
Greensboro, North Carolina
USA

In the sport of basketball, the ability to shoot the basketball is a key skill. Though shooting techniques have changed, as Cooper (1990) acknowledges, shooting one handed, with one hand behind the ball and the other to the side, has become the common method of shooting both jump shots and free throws. Since shooting is such an integral part of the game, an ability to shoot successfully from a variety of distances would naturally be desirable. Consequently, identifying the characteristics which skilled performers use to achieve success across different distances should be useful information to coaches, teachers, and players.

The search for the determinants of success is compounded by the nature of shooting which allows for "endless combinations of sequential contributions in conjunction with numerous projection angles and velocities which can result in shots which directly or indirectly fall through the basket" (Hudson, 1982, p. 95). Martin suggests using a movement analysis approach to describe good shooting skill and advocates the use of kinematic variables. Yates and Holt (1982)- examined kinematic characteristics of 10- and 20-foot jump shots but did not report how the 10-foot shot differed from the 20-foot shot. In general they found that the ball was released while the body was moving upward in a predominantly vertical path and that the body, shoulder, elbow, wrist, and hand all contributed to ball projection.

In two studies of free throw shooting, elite, male basketball players were described in terms of kinematic variables. Hayes examined ball velocity and the contribution that each body segment made to ball velocity. Within this elite group of subjects there was little variability of the ball velocity at release. He also found that early in the propulsion phase, the lower body was the main contributor; at the end of the propulsion phase, the forearm's contribution increased, and finally, just before release, the hand provided the major contribution. Tsarouchas, Kalamaras, Giavroglou and Prassas (1990) analyzed elite free throw shooters as well. Based on one successful shot from each subject, they concluded that the trajectory of the ball prior to and after release approximated the same linear path. Combining the results of Hayes and Tsarouchas et al., it appears that coordination may be an important element in good shooting.

With shooting, certain characteristics are thought to exist within consistently successful shooters, although individual variation among noncrucial elements is common. For example, Hudson (1985b) compared elite and good free throw shooters and found little variability within elite shooters on the kinematic variables which distinguished skillfulness. There was, however, greater variability on characteristics which were inconclusive predictors of skillfulness. In another study of free throw shooting, Hudson (1985a) examined successful shots relative to unsuccessful shots. Within the elite shooters, there were no trends to separate the made from the missed shots. She concluded that these players were using individual strategies of adjustment and that a case study approach should be employed in future studies of highly skilled shooters. Tsarouchas et al. also found that there were individual differences within good shooters in that some had a "low" elbow technique while others used a "high" elbow technique in their shooting form.

Although free throw studies provide information about what may be important to success in shooting from 4.6 m, there is limited information about kinematic variables which are associated with success at other distances. Hence, the purpose of this study was to analyze field goals taken from three different distances. Specifically, do kinematic characteristics increase systematically as distance from the goal increases? Further, do more successful shooters differ from less successful shooters in terms of kinematics?

METHOD

The subjects for this study were four collegiate female basketball players who play the guard position where good shooting form is essential. These participants were selected on the basis of their proven shooting ability as assessed by coaches. The subjects were right handed and ranged in height between 168 and 170 cm. Two were characterized as long-range shooters based on their success at all three distances. The other two were considered mid-range shooters based on their success at the two shorter distances and lack of success at the longest distance. The distinction between long- and mid-range shooters was on the basis of the ability to make shots beyond the 6 m mark.

The subjects shot from the left side at a 45^0 angle to the basket at distances of 4.3, 5.2, and 6.1 m. The subjects were given time to warm up. Each subject then shot all her shots in succession. Someone else rebounded and passed to each subject to encourage the use of a game shot technique. Each one stepped to the 4.3 m mark and shot five shots. That subject then moved to the 5.2 m distance and shot five times and then moved to the 6.1 m distance and shot five times. The subjects were filmed continously through the 15 trials using a Panasonic camcorder with a 1/1000 high speed shutter. The camera was perpendicular to the plane of movement at a distance of 10 m from the right side of the shooter.

One shot was selected from each distance for each subject and digitized using the Peak Performance System. Criteria for selection were success first and then what appeared most typical for that shooter. All analyzed shots were successful with the exception of the two mid-range shooters at 6.1 m. Points digitized were the right and left toe, heel, knee, hip, shoulder, elbow, and wrist. In addition, the right knuckle was digitized as was the ball and the head. All shots were then smoothed and analyzed by the Peak Performance System. Variables calculated included angular and linear displacements and velocities of selected segments and the center of mass.

This investigation has a case study approach instead of a statistical approach (Hudson, 1985a). Emphasis was given to how a subjects were similar, what changes were made as they moved further from the basket, what differences were distinguished between long-range and mid-range shooters and what stylistic variations existed.

RESULTS AND DISCUSSION

All the shooters demonstrated good shooting form. They were balanced, pushed off the ground with both feet, moved the ball to the face area before extending to release, used one hand to shoot and one to guide, kept their shooting elbows in line with that side of the body, extended their elbows, and showed a strong follow through motion with a snapping of the wrist and backspin on the ball, releasing the ball after leaving the ground.

One of the twelve shots is illustrated in Figure 1. The preparation, release, and follow through phases are depicted by the path of the ball and the position of the body. The linear path of the ball before, during, and immediately after release described by Tsarouchas et al.(1988) is evident in the third panel. Because this path is more rectilinear than curvilinear it appears to be an example of a push pattern as discussed by Kreighbaum and Barthels (1985) in their chapter on throw and push pattern. The shooting form of the four subjects for the 5.2 m shot is shown in Figure 2. The basic difference between subjects in terms of ball path occurs during the preparation phase and is a function of receiving a pass before shooting and of initiating with their particular style. The two long-range shooters are depicted on the left and the two mid-range shooters are depicted on the right.

All shooters recorded high wrist angular velocities, evidenced with an overall group average of 1276 ^{0}/s. All were able to release their shot within one frame of their peak angular wrist velocity, though the hand is the last segment where adjustments can be made prior to release.

Group averages for ball velocity increased across distance. The horizontal averages were 4.10, 4.32, and 4.92 m/s and the vertical velocities were 5.31, 5.58 and 5.80 m/s at 4.3, 5.2, and 6.1 m respectively. Thus, the ball velocities increased as the subjects moved out in distance. In other words, this kinematic variable increased, or scaled, with an increase in distance. Also, ball velocity changed little within distances, as suggested by Hayes.

Horizontal and vertical ball velocity at release is given for each subject in Table 1. Though all appear to scale ball velocity to some degree, the long-range shooters show a more consistent pattern and ability to scale systematically. An example would be long-range shooter 2 whose horizontal values were 4.03, 4.23 and 4.86 m/s and whose vertical values were 5.37, 5.90, and 6.21 m/s. The mid-range shooter 1 showed an increase in the first two shots in the horizontal ball velocity but then showed an increase in the first two shots in the horizontal ball velocity but then showed an inconsistent rise in the 6.1 m. shot. Also, the mid-range shooters failed to increase their vertical velocities as much as their horizontal velocities. Therefore, the difference between the horizontal and vertical ball velocities grew less as distance increased. A fairly systematic scaling in both horizontal and vertical velocities appears to be an important aspect of the better long-range shooters.

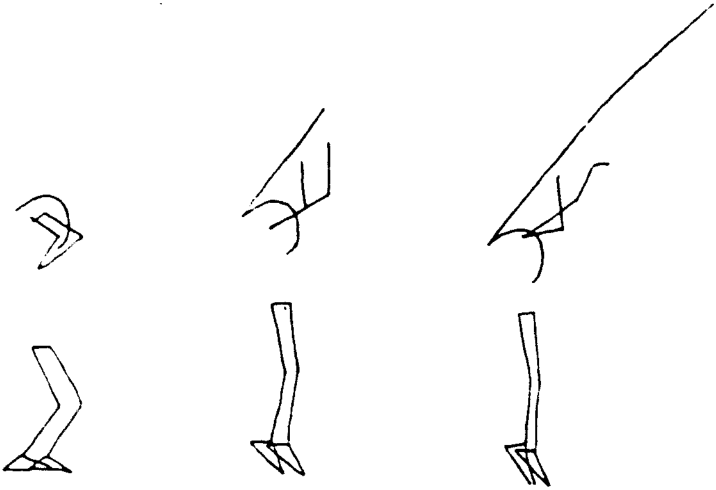

Figure 1: An example of one shot showing preparation, release and follow through.

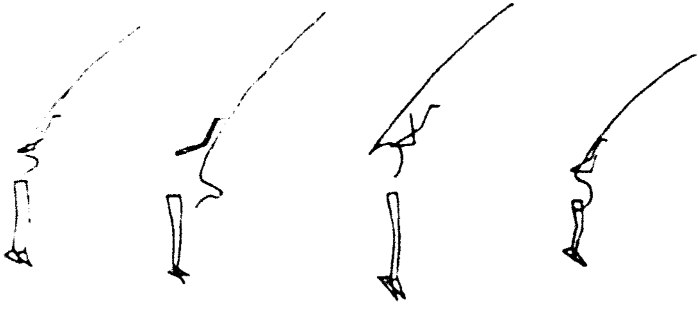

Figure 2: Final position of the four shooters in the 5.2 m shot.

TABLE 1
Linear Velocities by Subject and Shooting Distance

	Shooting Distance (m)	Ball Velocity at Release (m/s)		COM Velocity at Release (m/s)		Maximum and Minimum COM Vertical Velocities (m/s)	
		Horiz.	Vert.	Horiz.	Vert.		
Long-range Shooter 1	4.3	3.88	5.33	0.21	0.86	1.98	-0.66
	5.2	4.24	5.40	0.27	1.12	1.84	-0.73
	6.1	4.72	5.81	0.52	1.50	2.33	-0.83
Long-range Shooter 2	4.3	4.03	5.37	0.01	0.90	1.94	-0.72
	5.2	4.23	5.90	0.02	1.17	1.89	-0.87
	6.1	4.86	6.21	0.35	1.36	2.03	-0.85
Mid-range Shooter 1	4.3	4.03	5.30	0.09	1.54	2.00	-0.82
	5.2	4.42	5.48	0.08	1.60	1.92	-0.90
	6.1	5.15	5.41	0.36	1.57	2.05	-0.80
Mid-range Shooter 2	4.3	4.46	5.24	0.58	1.32	1.72	-0.67
	5.2	4.41	5.54	0.28	1.60	1.91	-0.62
	6.1	4.95	5.78	0.75	1.53	1.94	-0.67

Just as scaling was evident in the composite product variable of ball velocity at release, scaling occurred in a composite process variable, center of mass (COM). The COM velocities (i.e., horizontal at release, vertical at release, vertical maximum, vertical minimum) for all subjects are given in Table 1. In successful shots, scaling occurred in vertical center of mass velocity at release. Both of the long-range shooters scaled the vertical COM at release and showed a tendency to scale the horizontal dimension. The two mid-range shooters did not scale the 6.1 m shot and did not scale the horizontal velocity. Values for minimum center of mass vertical velocity, or maximum downward velocity, for the long-range shooters either scaled or indicated a scaling tendency. The two mid-range shooters did not show a consistent pattern across the three distances.

In summary, the two long-range shooters either scaled or showed the tendency to scale in the vertical and horizontal COM velocities at release and in the maximum downward COM velocity of each shot. The long-range shooters made systematic increases in their center of mass values, relying on their center of mass velocities to contribute systematically to their shots. The mid-range shooters, though successful at two out of the three distances, and showing some scaling effects in the two shorter shots, seem unable to scale their center of mass velocity when necessary.

In addition to the composite product and process values, segmental values support the same scaling effect. Though all shooters scale in linear ball velocity, segmental linear velocities, though influenced by other factors, illustrate the distinction between the long-range shooters and the mid-range shooters. For example, at release, across distance, long-range shooters 1 and 2 increased the vertical linear velocity of the knee (shooter 1: 0.91, 1.10, 1.32 m/s; shooter 2: 0.91, 0.93, 1.15 m/s). Mid-range shooters 1 and 2 did not show the same pattern in the knee (shooter 1: 1.51, 1.62, 1.54 m/s; shooter 2: 1.48, 1.74, 1.55 m/s). Thus, scaling the linear velocity as distance increased to the 6.1 m shot was evident in the long-range shooters but not in the mid-range shooters.

In summary all shooters used a push pattern. All were off the ground and still ascending at release of all shots. All shooters released the ball at or within one frame of peak angular velocity of the wrist. Both the long-range and the mid-range shoooters scaled at some point, with some body part or parts, in an attempt to systematically increase their ball velocity across the three distances. Apparently these good shooters were able to make adjustments during the course of their shot, prior to release.

The long-range shooters appeared to have a systematic plan for generating the velocity necessary for all distances. The long-range shooters across the three distances evidenced a scaling of horizontal and vertical ball velocity and achieved this through a systematic scaling of center of mass and individual body segment velocities. The mid-range shooters did make adjustments in order to scale the ball velocities from 4.3 to 5.2 m. If they had been successful at the 6.1m distance, some of the same patterns which existed for the long-range shooters might have existed for them. As it was, the mid-range shooters were unable to scale to the 6.1 m distance.

Though similar patterns existed for all shooters in key elements, individual variation did exist. Figure 2 provides an example of individual variation. From left to right, the first shooter exhibits a staggered stance, uses more of a jump and places the ball at her forehead prior to release. The second shooter initiates her shot lower and brings it to the side of her head prior to release. The third shooter brings the ball over her head in her preparation phase. The fourth shooter initiates the ball in a smooth curve to a position in front of her face prior to release. Individual variation lends itself to questions about coordination patterns. Those who deviate outside of a particular pattern, as in the shooter in Figure 1, may be limited in scaling ability by the style of shooting. Also, if a particular coordination pattern can be detected for a shooter, variations from that pattern on an unsuccessful attempt can provide useful information. Further analysis of coordination could prove helpful in understanding the ability to shoot skillfully.

CONCLUSIONS

1. All shooters at all distances used a push pattern of coordination, released the ball while ascending, and achieved high angular velocities of the wrist which peaked near the instant of release.
2. All shooters scaled some kinematic process and product variables as a function of increasing distances from the goal.
3. Compared to mid-range shooters, long-range shooters employed a more consistent strategy of scaling composite velocities (i. e., ball and COM) as a function of increasing distance from the goal.
4. Individual variation does exist independent of success.

REFERENCES

COOPER, J. (1988). A biomechanist looks at basketball. In E. Kreighbaum & A. McNeill (Eds.), Biomechanics in sports VI. Del Mar, CA: Academic Publishers.

HUDSON, J. L. (1985a). Diagnosis of biomechanical errors using regression analysis. In J. Terauds & J. Barham (Eds.), Biomechanics in sports II. Del Mar, CA: Academic Publishers.

HUDSON, J.L. (1985b). Prediction of basketball skill using biomechanical variables. Research Quarterly for Exercise and Sport, 56, 115-121.

HUDSON, J.L. (1982). A biomechanical analysis by skill level of free throw shooting in basketball. In J. Terauds (Ed.), Biomechanics in sports. Del Mar, CA: Academic Publishers.

KREIGHBAUM, E. & BARTHELS, K. (1985). Biomechanics: a qualitative approach for studying human movement. 2nd ed. Minneapolis, MN: Burgess Publishing Company.

MARTIN, T. (1981). Movement analysis applied to the basketball jump shot. The Physical Educator, October, 3, 127-133.

TSAROUCHAS, KALAMARAS, GIAVROGLOU, & PRASSAS. (1988). Biomechanical analysis of free shooting in basketball. In E. Kreighbaum & A. McNeill (Eds.), Biomechanics in sports VI. Del Mar, CA: Academic Publishers.

YATES, G., & HOLT, L.E. (1982). The development of multiple linear regression equations to predict accuracy in basketball jump shooting. In J. Terauds (Ed.), Biomechanics in sports. Del Mar, CA: Academic Publishers.