Kinematic Variables as Predictors of Performance

In the Basketball Free-throw

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Two of the most commonly used shots in basketball today are the jump shot and the free-throw shot. Accuracy in shooting increased from the 1940's when Bob Davies's and Max Zaslofsky's shooting percentage ranged from 31 to 37%l, to the 1970's with National Basketball Association (NBA) players Lou Hudson, Jerry West and Oscar Robertson averaging approximately 45 to 50% during their professional careers.

It appears that free-throw shooting accuracy has not progressed as rapidly. The National Association of Basketball Coaches of United States (NABC) Research Committee statistics shows that the mean free-throw shooting percentages in men's college basketball in the United States remained between 68% and 69% for the past 20 years and that 20 to 25% of a team's scoring came from the free-throw line (Hays and Krause, 1987).

Reynolds and Whiddon (1983) indicate that free-throws account for 20% of the total points scored in a basketball game.

Analysis of the Atlantic Universities Basketball Conference (in North Eastern Canada) free-throw shooting statistics from the 1985-86 season involving six teams during actual games, indicated that the shooting percentage of teams had a mean of 69%, while the top free-throw shooter averaged 96.7% under game conditions. The 1983 Dalhousie University Men's Varsity Basketball team's free-throw statistics showed that they lost 11 games that season by an average of 5.3 points per game (they shot 67% from the free-throw line for the season). Hays and Krause (1987) believe that four to six games per year are decided at the free-throw line, as suggested by an Oklahoma Christian College season in which 14 games were decided by five points or less.

Much of the information that coaches have been disseminating has been based on subjective opinion, indicating that perhaps too many different techniques or insignificant components of how to shoot free-throws are being taught. A large continuum from the poorly skilled to the highly skilled free-throw shooter at all levels of basketball competition continues to exist, exemplifying the need for further investigation in this area.

If, from a kinematic perspective, the critical skill components could be identified, reduced and sequenced in a logical progression, improvement in performance could result. This study utilized cinematographic analysis from three different views (overhead, frontal and sagittal) and multiple linear regression prediction equations to identify the critical skill components (factors) that would account for the variance in accuracy amongst subjects of varying skill levels.

METHODS

Selection of Subjects

Sixty-seven right-handed subjects were pretested to determine their shooting accuracy with 25 S's whose free-throw percentage scores ranging from 30% to 100% accuracy being selected. The pretesting protocol consisted of each subject shooting 100 free-throws in sets of ten, with their shooting percentages then calculated from the hundred trials. The selection criterion ensured that half of the sample (minimum of 12 S's) was above the mean (69%) and half below the mean. The selections consisted of the following sample: Five male students from The Introduction to Basketball Laboratory at Dalhousie University, five S's from King's College men's varsity basketball team, one member of the 1980 Canadian Olympic Basketball team residing in Halifax and one former NBA draft choice.

Cinematographical Procedures and Spatial Arrangements

The filming session occurred on the practice basketball court of the Dalhousie University Field House. The S's were filmed from three perspectives: Overhead, frontal and sagittal views using the free-throw line as the focal point of reference (Figure 1). The lateral view was recorded with a locam 16 mm high speed camera at a rate of one hundred frames per second, (model 51.DC) equipped with a 10 mm lens. The camera was mounted on a tripod set at 1.25 meters from the floor and positioned at 9.14 meters, to the right of the subject perpendicular to the free throw line. Because only right-handed subjects were used, the shooting arm could readily be seen. The overhead view filmed with a Bolex 16 mm camera operating at 50 frames per second and was positioned approximately over the subject's head 4.1 meters above the floor. This was to obtain the necessary angles of the upper torso movements, feet placement and ball dynamics.

The front view was filmed with a Bolex 16 mm camera mounted on a tripod set at 1.25 meters from the floor and positioned 5.75 meters from the free throw line, under the backboard, operating at 50 frames per second. Kodak VNX 7250 high speed coloured reversal, double perforation, 400 ASA film was used.

Two banks of lights were set at right angles to the sagittal plane of the subject (4.5 meters) and illuminated three to five meters around the subject. Light banks of 20,000 watts were necessary with the 400 ASA film for shooting at 100 frames per second with a 1/300 of a second exposure time. The cameras were balanced by means of water level. Two cue cards were stationed at 1.22 meters to the left of the subjects on an angle in view of all three cameras. They were used to record the subject's trial information on film. The subjects were allowed to warm up on their own by shooting practice free-throws before they were actually filmed shirtless. The basketball used was a Molten Official JB-77 model, numbered one through eight across the panels of the ball, to facilitate the counting of the spin of the ball. The panels were taped with vertical and horizontal points to indicate the mid-point of the ball which was held in a manner to show the panels. There was a straight line taped on the floor from the top of the key area to the baseline down the center of the key area directly to the mid-point of the rim 7.01 meters. Some of the tape was not in view of all three cameras; consequently, a plumb line was lined up from the end of the tape at the top

of the key to mid-point on the stand, from which the reference of the sagittal and frontal perspectives. A wooden panel was placed behind the subject and lines up with the plumbline while a similar panel to the side facing the sideview camera was lined up with the free throw line. They were also used to insure vertical and horizontal references.

The area where the subjects stood on the free-throw line was optional within a prescribed area (Figure 1). The subjects were allowed to familiarize themselves with the testing enviornment for thirty seconds before shooting.

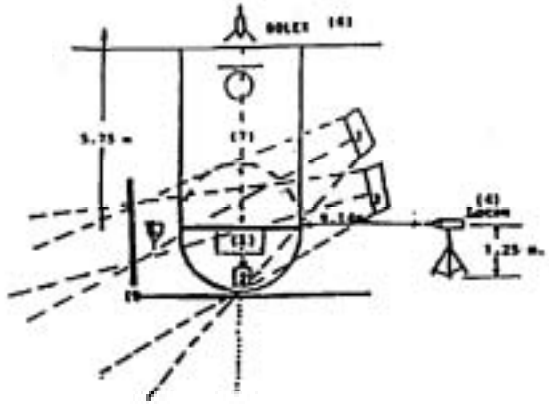

Figure 1: Spatial arrangement for film data collection

1. Area subjects can stand in to shoot
2. Stand with overhead Bolex camera 4.1m (13.5ft)
3. Spatial arrangements of lights 4.57m (15 ft.) to subject
4. Side view Locam 9.15m (30ft) Height 1.25m (4.1ft)
5. Cue cards 1.22m (4ft)
6. Front view Bolex 5.75 (18.9ft) Height 1.25m
7. Tape down center of key to underneath backboard 7.01m 23'
8. Bolex (both set at 50 fps) and the Locam (set at 100 fps)
9. Two panels designating vertical and horizontal references

Two important criteria during filming were that all subjects were asked for a subjective appraisal to determine if the shot was representative of their normal style. If the subject reported otherwise, a third shot was filmed with the bad shot being omitted. Secondly, for the film to have been a successful take, the subjects must have been caught on the lateral and frontal cameras starting from the point of deepest knee flexion and the overhead

view filming commenced after the subject had familiarized themselves with the shooting area. After the position of the feet were filmed a verbal cue was given by the overhead cameraman, upon which all three cameramen filmed simultaneously until a few frames after the release of the ball. Since the basket was not in view of any of the cameras, success or failure of the shots attempted were recorded manually for each subject.

DATA ANALYSIS

Digitizing procedures consisted of one of the two shots

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6. Front view Bolex 5.75 m.(18.9 ft.)
7. Tape down center of key to underneath backboard 7.01 m.(230ft.)
8. Bolex (both set at 50 fps) and the Locam (set at 100 fps)
9. Two panels designating vertical and horizontal references

filmed randomly selected and manually digitized using the methods outlined in the manual for Cinema Computer Analysis (Alexander et al. 1974), from which the following information was derived:

1. Angular positions of the primary joints and limbs associated with shooting a basketball corresponding to the "ready" and "release" positions.
2. Angular displacements of the ball.
3. Time factors determined by frame counting.

Statistical Analysis

The desired objective was to isolate the four to seven predictor variables which correlated highly with the criterion variable (free-throw shooting percentage accuracy of the subject) without necessarily being significantly correlated with each other.

The stepwise multiple regression took the best variable and built the equation adding a new variable to each step until it formed the best possible equation which predicted the criterion variable from the group of predictor variables.

The Cyber computer program randomly selected the two test groups (tstgrp 1.00 = 60% for developing the equation and tstgrp 2.00 = 40% for cross validation) and utilized the Statistical Package for Social Sciences-X (SPSS-X, 1986) program for analyses.

The cross validation process was performed once the regression was completed. This is a technique which allowed the researchers to make a scientific assessment as to whether the predication worked with a second test group, the 40% sample in this study (Huck et al. 1974). The prediction equation was used on the remaining 40% to predict a criterion score (percentage of accuracy) for each subject.

The correlation coefficient for the criterion variable versus predicted variables for all 25 subjects was R = .781 which was significant at P < .001 level. The cross validation of group 2 (40%) resulted in a correlation coefficient of R = .683 which was significant at P < .05 level.

The results indicated that the prediction equation was sufficient to suggest the use on a similar sample, thus accepting the hypothesis that kinematic factors (predictor variables) can account for the variance in accuracy among players of wide ranging abilities in the basketball free-throw.

RESULTS

The results of the final multiple regression analysis model and the cross validation indicated that the variables derived were the ones most significantly contributing to the prediction of accuracy of free-throw shooting. Three variables formed a significant regression equation which accounted for 84% of the variance of scores from the subjects with a .781 correlation coefficient on all 25 subjects and an R of .918 for group 1, significant at the P < .001 level and an R of .683 when cross validated on group 2.

1. Variable 12, angle of the trunk from the horizontal (lateral view) at the ready position, accounted for 48% of the variability in the equation.
2. Variable 2, angle formed by the long axis of the feet relative to each other from the overhead view accounted for 24% of the variability in the equation.
3. Variable 8, angle of the right foot segment (elevation from the floor) at release from the horizontal (lateral view) accounted for 12% of the variability in the equation.

The three variables mentioned formed a significant equation accounting for 84% of the variance in prediction of accuracy of free-throw shooting (Table 1).

TABLE

Regression Analysis Summary Table

Step	Multr	Rsq	Adjrsq	F(equ)	Sig F	Fsqch	Fch	Sigch	Variable		Betain	Correl
1	.6941	.4818	.4386	11.20	.006	.4818	11.20	.006	IN:	V11 (trunk at start)	.6941	.6941
2	.8481	.7192	.6881	14.10	.001	.2374	8.39	.001	IN:	V02 (long axis of feet)	-.8507	.6642
3	.9182	.8430	.7959	17.80	.000	.1238	7.90	.019	IN:	V8 (right foot at release)	.3644	.5504

Estimated Score for Subject #1:

Y = -191.55 + .998 (right foot elevation from the floor at release = 26) - 1.03 (long axis of the feet = 9) + 2.76 (vertical trunk lean at the ready position = 88) = 67.74 prediction of accuracy for subject #1.

DISCUSSION

The final regression analysis and cross validation process indicate that three factors can account for a significant (84%) amount of variance in the prediction of accuracy with regard to the free-throw shot. The highly successful shooters demonstrated that at the ready position of the free-throw shot, there was a range of three to ten degrees of backwards trunk lean, which was either maintained or moved slightly forward during the shot. In essence the trunk (position) assists in the propulsion of the shot, by permitting leg drive to occur without the center of gravity moving forward beyond the free-throw line.

The angular measurements of the long axis of the feet relative to each other, of the highly accurate free-throw shooters straddling the taped center line ranged from 14 to 18 degrees. The use of the prediction equation indicates that there is a certain range which is conducive to highly accurate shooting performance; because proper feet alignment negates under and over rotation of the shoulder girdle.

There was some degree of foot elevation from the floor in the majority of subjects however the lower percentage shooters showed less foot elevation from the floor, than the moderate or high percentage shooters. The high percentage shooters exhibited foot elevation from the floor ranging from 19 to 41 degrees.

These above factors along with the proper sequential kinematics of the free-throw shot yielded sufficient results to suggest a profile of highly successful free-throw shooter.

CONCLUSION

Visible Kinematic Factors that Influence the Prediction of Accuracy of Free-throw Shooting from a Coaching Perspective

The following factors were statistically associated with the high prediction of free-throw shooting accuracy as demonstrated by the test sample(profile of 85% plus accuracy free-throw shooter):

1. The high percentage shooter demonstrated angular alignment of the long axis of the feet ranging between 14 to 18 degrees (straddling center line to the basket).
2. The high percentage shooters demonstrated (93 to 100 degrees) backward vertical trunk lean at the ready position which they either maintained or moved slightly forward during the release of the ball.
3. The high percentage shooters demonstrated increased right foot segment elevation (19 to 41 degrees range) at the release position

Figure 4. Low percentage shooter at "ready position"

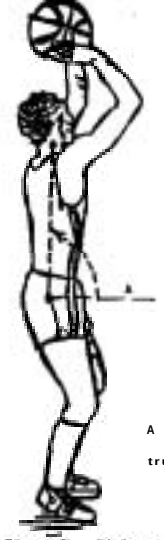

Figure 5. High percentage shooter at "ready position"

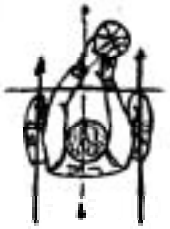

Figure 6. Small angle of the long axes of the feet of low percentage shooter (under 14 degrees)

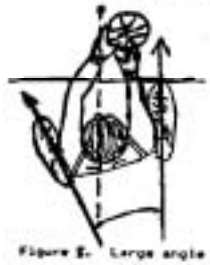

Figure 7. Large angle of the long axes of the feet of low percentage shooter (over 18 degrees)

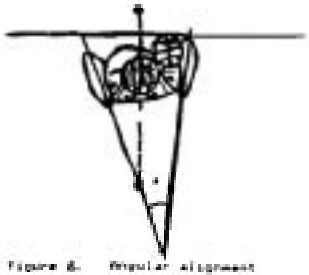

Figure 8. Angular alignment of the long axes of the feet of the high percentage shooter straddling the center line (14-18 degrees)

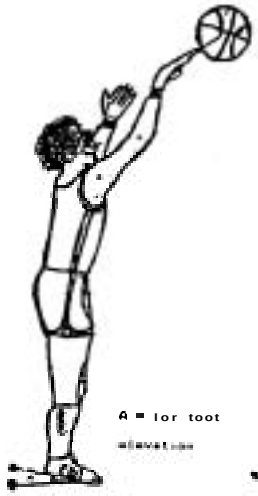

Figure 9. Foot segment elevation of lor percentage shooter at release

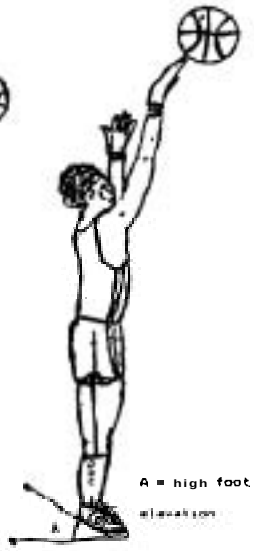

Figure 10. Foot segment elevation of high percentage shooter at release

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