INTRA-INDIVIDUAL VARIABILITY FOR BASKETBALL FREE THROWS

R. E. Vaughn and B. Kozar

Boise State University
Boise, Idaho, USA

INTRODUCTION

Several studies have attempted to identify differences between subjects in the performance of basketball free throws (Hudson, 1982; Ryan, 1989; Satern, 1992; Tsarouchas, 1988). These researchers have used as few as one trial and as many as four trials per subject. None of these studies reported intra-individual variability. Motor control researchers (Newell, 1993) state that considering the degree of freedom of the sensorimotor system, "it seems impossible for a given individual to generate identical movement patterns on successive attempts at performing the same task." If intra-individual variability is a component of athletic performance, multiple measures would be necessary to arrive at a valid representation of that performance. Bates (1983) concluded that in order to obtain stable subject-condition values for ground reaction forces in running, the average values from a minimum of eight to ten trials are necessary.

Also, previous free throw studies have utilized two-dimensional analysis techniques. An examination of the directional errors for 1042 free throws by NCAA Division I men's varsity basketball players revealed that 32.8% of missed free throws were off-line to the left, and 19.5% were off to the right (Vaughn, 1993). This is indicative of movement outside the sagittal plane. However, a three-dimensional analysis of free throw shooting has not been reported in the literature. The purpose of this study was to complete a three-dimensional kinematic analysis of the intra-individual variability for basketball free throws.

METHODOLOGY

All free throws attempted by members of an NCAA Division I men's varsity basketball team during 15 home games and 18 practice sessions distributed throughout one season were videotaped. Two 8mm camcorders were placed approximately 40 m to the right and 40 m in front of the free throw line. Subjects selected for analysis were those who attempted a minimum of 29 free throws in home games for the season. Five subjects met this criterion. A total of 648 free throws (FT) were videotaped for these five subjects during games (317 FT) and regular team practices (331 FT).

The result of each free throw was classified into one of nine categories: swish (no contact with the rim of the basket), short make (contacted front of rim), long make (contacted back of rim and/or backboard), left make, right make, short miss, long miss, left miss, or right miss. A representative sample of free throws was selected that approximated each player's overall performance both in accuracy and error tendency. For example, if 33% of a player's shots were swishes, then one-third of the trials analyzed were randomly selected from the total number of swishes for that subject.

The subjects' free throw percentages ranged from 56.5% to 83.8%. In order to ensure that the analyzed free throws were representative of overall performance, the number of free throws chosen for analysis was based on attaining a success ratio for the sample as close as possible to each subject's overall free throw percentage. For example, if a subject's overall percentage was 83.8%, then 12 free throws were selected for analysis -

10 makes and 2 misses - a percentage of 83.3%. The number of free throws analyzed varied from 10 to 14 for each subject. The maximum difference between overall free throw percentage and the success rate on analyzed free throws for any one subject was 1.8%. The free throw percentage for the 60 free throws analyzed was 73.3%, compared to an accuracy rate of 73.6% for the 648 free throws recorded.

Video records selected for analysis were digitized using the Peak Performance Technologies system. The Direct Linear Transformation (DLT) technique was used to calculate the x,y,z coordinates of 21 body landmarks and the ball. A fourth-order Butterworth digital filter with a frequency cutoff of 6 Hz was used to smooth the data. Kinematic variables included range of motion (ROM) at the wrist, elbow, shoulder, hip, knee, and ankle joints; trunk rotation; arm horizontal abduction/adduction; foot elevation angle; release velocity and angle; release height, expressed as a ratio of standing height; and vertical and horizontal center of gravity (CG) position.

For each subject, the means of the various kinematic parameters were calculated to determine a representative movement pattern for that subject. Intra-individual variability was defined as the standard deviations of the various kinematic parameters for each subject. Intra-individual variability measures were then compared to the inter-individual differences, which were defined as the standard deviations of the kinematic parameters among subjects.

RESULTS and DISCUSSION

Results, shown in Table 1, indicate that inter-individual variability was greater than intra-individual variability for most of the kinematic measures. The largest differences were for shoulder, hip, knee, ankle, and vertical CG ROM. This indicates that for the subjects in this study, the greatest differences in individual free throw style occurred in the early stages of the movement. For instance, one subject started in a deep squat position, whereas another began with an erect posture. Similar differences in style are often observed at all skill levels.

Table 1. Kinematic parameters for basketball free throws.

Parameter	Mean	Inter-individual variability	Intra-individual variability
Wrist ROM (°)	54.1	8.1	11.7
Elbow ROM (°)	80.4	7.2	11.7
Shoulder ROM (°)	82.4	16.1	10.8
Hip ROM (°)	32.6	17.9	8.3
Knee ROM (°)	55.1	23.0	6.7
Ankle ROM (°)	40.3	11.2	7.3
Trunk Rotation ROM (°)	11.5	5.0	5.4
Arm Abd/Add ROM (°)	6.4	8.0	3.8
Foot Elevation Angle (°)	17.8	6.2	4.7
Release Height Ratio	1.30	0.03	0.03
Release Velocity (m/s)	6.86	0.09	0.24
Release Angle (°)	52.7	3.0	1.8
Vertical CG ROM (m)	0.25	0.10	0.03
Horiz. CG @ Release (%)	53.3	7.3	7.0

Intra-individual variability was greater than inter-individual variability for wrist and elbow ROM. According to the closed-loop theory of motor control (Adams, 1971), a performer uses feedback from the early stages of the movement to make adjustments in the latter stages. Thus, variability in initial joint actions (i. e. ankle, knee, hip, etc.) that are beyond tolerable system parameters would be counterbalanced by subsequent joint actions. Since the elbow and wrist are the last two elements in the kinematic chain, it may be possible that the higher observed values in intra-individual variability for these two kinematic parameters represents this motor control mechanism at work.

The results of this study do not support the notion that a free throw shooter can retrieve a motor program from memory and precisely reproduce that movement pattern. This suggests that intra-individual variability is an inherent component of movement, and contraindicates forming definitive conclusions about a subject's movement pattern on the basis of one trial.

Trunk rotation and arm abduction/adduction are non-sagittal plane movements overlooked in a two-dimensional analysis. The ROM for these two variables found in the present study suggest that these actions do contribute to the performance of this movement. This supports the case for utilizing three- dimensional analysis techniques for studying free throw shooting.

CONCLUSION

The findings of this investigation indicate that intra-individual variability appears to be an intrinsic component of the basketball free throw, and implies that multiple samples may be required to ensure representative data. Further, the measurement of notable movement outside the sagittal plane suggests that three-dimensional techniques may be appropriate for studying the free throw.

ACKNOWLEDGEMENT

This study was partially funded by a grant from the Boise State University Faculty Research Grant Program.

REFERENCES

Adams, J. A. (1971). A closed-loop theory of motor learning. J Motor Behav 3:111-150.

Bates, B. T., Devita, P., Kinoshita, H. (1983). The effect of intra- individual variability on sample size. In Biomechanical Aspects of Sports Shoes and Playing Surfaces. B. M. Nigg and B. Kerr (eds.). pp. 191- 198. Calgary: University of Calgary Press.

Hudson, J. L. (1982). A biomechanical analysis by skill level of free throw shooting in basketball. In Biomechanics in Sports. J. Terauds (ed.). pp. 95-102. Del Mar, CA: Academic Publishers.

Newell, K. M. and Corcos, D. M. (1993). Issues in variability and motor control. In Variability and motor control. K. M. Newell and D. M. Corcos (eds.). pp. 1-12. Champaign, IL: Human Kinetics Publishers.

Ryan, P. and Holt, L. E. (1989). Kinematic variables as predictors of performance in the basketball free-throw. In Biomechanics in Sports VII. W.E. Morrison (ed.). pp. 79-88. Victoria, Australia: Footscray Institute of Technology.

Satern, M. N. and Keller-McNulty, S. (1992). Use of position-time graphs to compare free throw shooting styles of adult male and female basketball players. Human Move Stud 22:13-33.

Tsarouchas, E., Kalamaras, K., Giavroglou, A., Prassas, S. (1988). Biomechanical analysis of free shooting in basketball. In Biomechanics in Sports VI. E. Kreighbaum and A. McNeill (eds.). pp. 551-560. Bozeman, MT: Montana State University.

Vaughn, R. E. and Kozar, B. (1992). Directional errors in basketball free throw shooting. Unpublished raw data.