THE KINEMATICS OF INACCURACY IN BASKETBALL SHOOTING

Stuart Miller, Leeds Metropolitan University, Leeds, U.K.

INTRODUCTION: Basketball shooting is an accuracy based skill in which substantial deviations from the target cannot be tolerated, as points are awarded for shots on a binary scale. A considerable amount of research has been devoted to examination of the characteristics of successful performance in many sports, including basketball shooting (e.g. Miller and Bartlett, 1996), but little has considered the factors which cause inaccuracy. Research designed to identify the primary factors which influence unsuccessful performance may lead to modifications of technique which reduce the influence of such undesirable factors.

Of the few published works to have examined inaccurate motor performance, most have studied single-degree-of-freedom movements which bear little relation to reality in sport (e.g. Corcos *et al*., 1988).

It would be expected that, as a skill for which the dominant component is maximisation of accuracy, good shooters' movement patterns would be characterised by consistency. It may therefore be anticipated that inaccurate performance would be characterised by variation from the desired movement pattern. Thus, it is hypothesised that the kinematic factors which cause inaccurate performance would be characterised by greater variability.

The aim of this study was to determine the kinematic characteristics of unsuccessful performance.

METHODS:

Thirteen right-handed subjects participated in the study, details of whom are shown in table 1. All subjects were experienced basketball players.

	Age (yrs)	Mass (kg)	Stature (m)
Mean	21.9	77.5	1.81
S.D.	3.8	10.3	0.09

Table 1. Subject characteristics.

Subjects attempted shots on a regulation basketball court from a distance of 6.40 m (3-point shot) measured perpendicular to the plane of the backboard. Shots were attempted in groups of no more than 6, and continued until 5 unsuccessful attempts had been made. Only shots which missed in the sagittal plane (i.e. long or short) were included in the analysis.

A tripod-mounted Panasonic video recorder operating at a frame rate of 25 Hz and placed perpendicular to the plane of ball release was used to record images of all shot attempts. Raw data were digitised at a sampling frequency of 50 Hz by using a video playback unit which split each frame into its constituent fields. Digitising began a minimum of three frames prior to the first perceived movement of the shooter and finished a minimum of three frames after ball release. As interest centered on the shooting arm and bilateral symmetry of the lower body was assumed, only the right side of the body was digitised.

Data were smoothed using a cross validatory quintic spline procedure based on the data of Woltring (1986). All procedures followed the recommendations of the British Association of Sport and Exercise Sciences for two-dimensional data collection (Bartlett *et al*., 1992).
Selected upper and lower body kinematic data were selected for analysis based on a theoretical model (figure 1) adapted from that of Miller and Bartlett (1993). Segment lengths may be ignored in this model as a within-subjects research design was used.

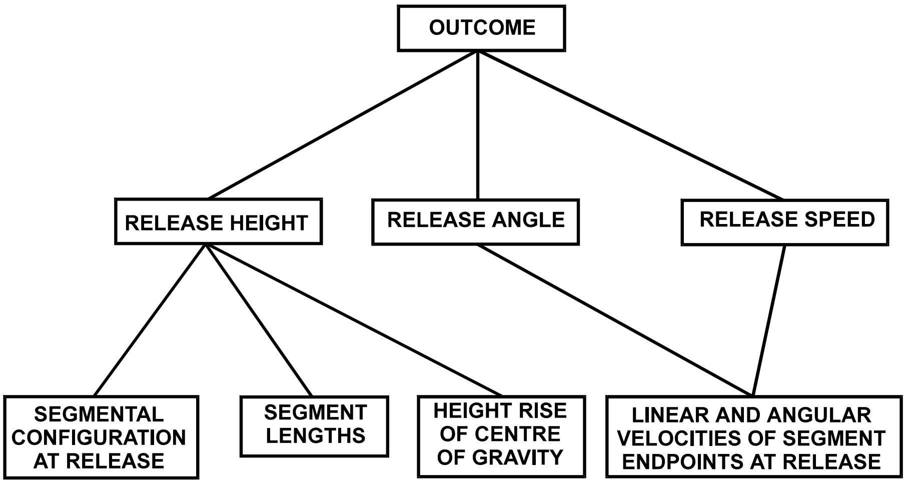

Figure 1. Theoretical model of basketball shooting.

Variability was measured using the root mean square of the error term from a one-way analysis of variance for repeated measures (RMS_E). This measure does not suffer from the limitations of other methods of measuring reliability such as coefficient of variation and intra-class and inter-class correlation coefficients.

RESULTS AND DISCUSSION:

	Score	**Miss**
3MCP (m)	2.99 ± 1.18	3.06 ± 1.18
DEF (m)	1.58 ± 0.64	1.70 ± 0.64
Mass centre (m s^{-1})	1.54 ± 0.89	1.53 ± 0.88
3MCP (m s^{-1})	5.49 ± 2.31	5.58 ± 2.39
Wrist (m s^{-1})	3.89 ± 1.66	3.87 ± 1.71
Elbow (m s^{-1})	3.08 ± 2.00	3.10 ± 2.03
Shoulder (m s^{-1})	2.01 ± 1.04	2.01 ± 1.07
Hip (m s^{-1})	1.68 ± 0.78	1.68 ± 0.75
Ankle (m s^{-1})	1.50 ± 0.70	1.49 ± 0.71
DEF (m s^{-1})	0.70 ± 0.65	0.68 ± 0.63

Key: 3MCP = Third metacarpophalangeal joint; DEF = Distal end of foot.
Table 1. Mean (± RMS_E) for linear displacement and velocity at release.

No significant differences were found between the mean values of successful and unsuccessful shot attempts for linear displacement or linear velocity measures ($p < 0.05$, table 1). Variability in linear displacement of the proximal and distal ends of the kinematic chain were identical, however, unsuccessful shots were released closer to the basket, as indicated by the greater mean linear displacement of the third metacarpophalangeal joint. This may have influenced outcome, as a change in horizontal distance of only 0.12 m would result in the ball making contact with the hoop.

Linear velocity measures also had similar variability. It would seem that the dispersion of linear displacement and velocity variables does not influence accuracy.

	Score (1)	Miss (1)	Score (2)	Miss (2)
Wrist	2.51 ± 0.20	2.50 ± 0.17	8.74 ± 4.10	10.00 ± 4.69
Elbow	2.30 ± 0.21	2.30 ± 0.19	16.49 ± 3.68	16.77 ± 3.25
Shoulder	2.16 ± 0.19	2.18 ± 0.19	6.06 ± 3.11	6.30 ± 2.86
Hip	2.99 ± 0.11	2.97 ± 0.11	1.22 ± 1.73	1.27 ± 1.89
Knee	2.86 ± 0.14	2.86 ± 0.14	3.97 ± 2.57	3.89 ± 2.64
Ankle	2.27 ± 0.16	2.25 ± 0.16	6.13 ± 3.59	6.37 ± 3.71

Table 2. Mean (± RMS_E) for angular displacement (1) and velocity (2) at release.

Variability in angular displacement measures for successful and unsuccessful shots were also similar (table 2). No significant differences were found between mean values ($p > 0.05$). Consistency of angular displacement at release shows that both successful and unsuccessful shots were released with the same segmental configuration. Angular velocity at release, known to strongly influence ball release speed, tended to be greater for unsuccessful shots.

Differences in variability of joint angular velocities were not necessarily in the direction predicted by the hypothesis, as both elbow and shoulder variabilities were larger for successful shots.

Variable	Score	Miss
Release speed (m s^{-1})	7.48 ± 3.34	7.55 ± 3.21
Release angle (°)	51.7 ± 22.6	52.0 ± 22.3
Release height (m)	2.15 ± 0.91	2.16 ± 0.87

Table 3. Mean (± RMS_E) for primary release parameters.

Variability in the primary factors determining outcome was not as expected in that slightly greater values were found for successful shots (table 3). There were no significant differences between means ($p > 0.05$). The relative differences in variability, however, were small, being less than 4%. It would seem that, contrary to popular coaching theory, players do not have to reproduce identical movement patterns to be consistently successful shooters. In fact, the converse may be true, whereby variability is an integral part of success in basketball shooting. Such a position would be consistent with dynamical systems theory. It must also be noted that deviations from the ideal horizontal range of less than 2% may be sufficient to result in an unsuccessful shot. This may be due to changes in release parameters that are sufficiently small to be masked by other factors.

Further research is necessary to identify the influence of variability on skill development in multi-segmental accuracy-based movements, specifically whether it is characterised by the minimisation of variability, or whether variability has a positive influence on performance.

CONCLUSION: The expectation that greater variability would be found for unsuccessful shots could not be supported. Segmental configuration and linear velocities of segment endpoints at release were independent of outcome.

Successful and unsuccessful shots could not be identified by differences in the variability of their primary release parameters.

It would seem that variability in multi-segmental accuracy-based movements may be an inappropriate method of identifying the factors which cause inaccuracy, and that variability is an integral aspect of such skills.

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