BIOMECHANICAL ANALYSIS OF FREE SHOOTING IN BASKETBALL

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According to the statistical results of the XXV European Basketball Championships held in Athens in 1987, 19.05% of the total points scored were from free shots. It was also found that the percentage of successful free shots, of the 40 highest scores, in this championship had the highest correlation coefficient (r) with the remaining successful types of shots. This indicates that accuracy in free shooting is highly related to a player's total accuracy.

In spite of its importance, research on free shooting is limited. Hudson (1982) studied the relationship between selected biomechanical parameters of free throw shooting in players of varying abilities. She concluded that stability and a greater ratio of the height of release to the standing height is related to higher skill; whereas, angle and velocity of projection are not independently related. Rush (1976) and Hay (1978) also reported that successful free shots are not dependent on either the angle, velocity, or height of the ball release.

The present study investigated the free shooting performance of two groups of highly skilled players that demonstrate (in the XXV European Championship) either a high (>80%) or low (<65%) percentage of successful free shots. In addition, the performance of two players belonging to the first group but differing in free shooting techniques, were also studied.

Methods

During the championship, 110 free shots executed by 60 players, were filmed with a Locam 16mm high speed camera set at 100 fps. The camera was extended 15m from the free shot line, with its optical axis perpendicular to the plane of motion.

One successful shot from each of the 22 players that had performed at least 20 free shots in the competition was chosen for analysis. A Weibercer analyzer and an Altek digitizer interfaced with an IBM compatible computer were utilized for data reduction and analysis. The Hanavan model (Havanan, 1964) was incorporated in a standard 2- dimensional analyzing program. The players were divided into two groups according to their percentage of success in free shooting. Group one (N=10, Height=1.92 $\pm$ .042) had a rate of success > 80%. Group two (N=12, Height = 2.07 $\pm$ .09m) had a rate of success < 65%.

In both groups we investigated:

1) The trajectory of the ball.
2) The geometric movement of the players body segments.

In order to find a relationship between the trajectory of the ball prior to and after its release, we estimated a parabolic correlation coefficient between 5 points of the trajectory of the balls center before the release and 5 points after the release, employing the method of least squares. In the case that these 10 points are located in the same parabola, theoretically the correlation is 1.

Another comparison was made using the angle and height of the ball release, the ball displacement and the length of the arch it covered from the initial position until its release, as well as its horizontal displacement from the player's toe to the point of release (Figure 1). In addition, the geometric movement of the body's segments, i.e., each segments initial and final (at release) angle with respect to the horizontal, and the percentage of the segments participation in the total horizontal, and vertical displacement of the ball were measured and compared. All above parameters (means and standard deviations) were statistically compared to the percent of free shot accuracy. There was also a comparison made between groups relating each of the individual factors.

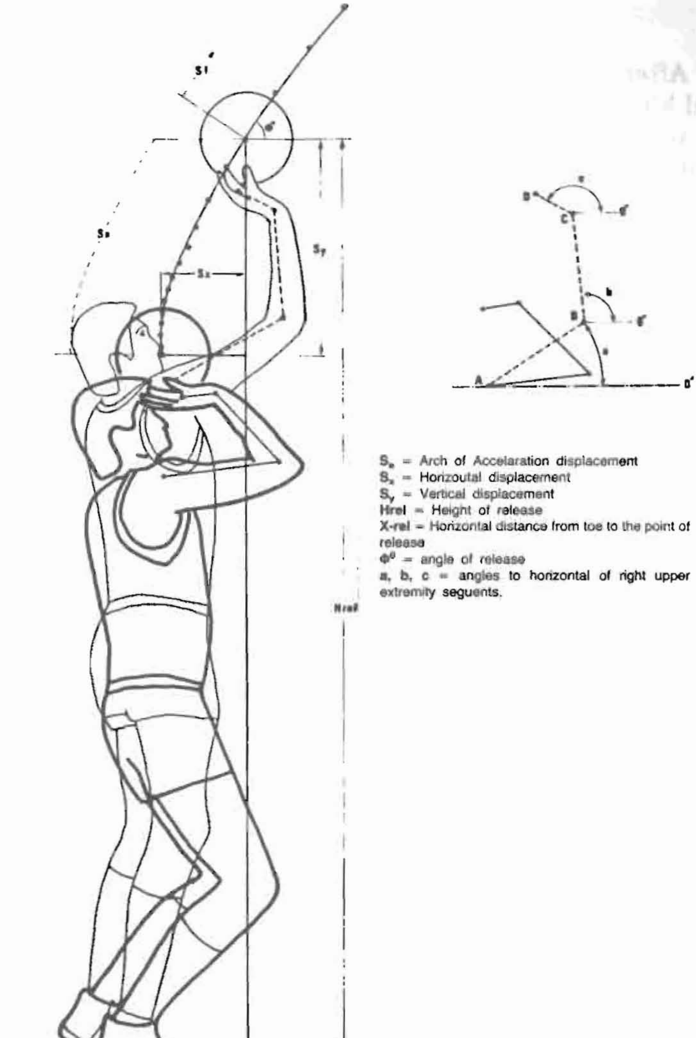

Figure 1.

Kinematic parameters of the pre-flight phase in free shooting (a). Geometrical characteristics of the right upper extremity (b).

After evaluating the results of the two groups, we analyzed selected kinematic parameters of the upper extremity for two highly skilled players belonging to the first group, but representing two different approaches in the performance of the free shot.

Results and Discussion

Comparison between the 5 trajectory points of the center of the ball before and after its release reveals a high correlation between these points. The correlations are:

0.9986 $\pm$ 8.2 E4 for group 1.
0.9965 $\pm$ 2.7 E3 for group 2.
0.9974 $\pm$ 2.3 E3 for both groups.

This means that these points belong to the same parabola in both groups. However, since there is a significant difference (p .05) between the groups standard deviations, it is reasonable to assume that the above (trajectory) approximation is more accurate for group 1 (80%).

Kinematic parameters relative to the position of the ball at release are presented in Table 1. None of these parameters was significantly related to the rate of success in free shooting, which is in agreement with the literature (Hudson, 1982..). There were some significant differences between group comparisons, but it is doubtful that these differences can completely explain the differences in the rate of success.

Table 2 presents the initial and final angles to the horizontal for the various body segments. Notice that there are significant differences among the two groups ($p < .05$) concerning the initial position of the arm, but not the final. Notice also the similarity of the forearm positions for both groups.

Table 3 presents the percentage of body segment contribution to the horizontal and vertical displacement of the ball prior to release. It is evident that the lower extremities (as a whole) contribute mainly to the vertical displacement of the ball. The contribution of the trunk segment is negligible in both directions, whereas the hand's contribution is evenly divided between the two. among the other two segments of the upper extremity, the forearm contributes mainly to the horizontal displacement and the arm segment to the vertical.

Table 1. Kinematic characteristics of acceleration displacement.

Kinematic characteristics	Group 1 Mean	±S.D.	Group 2 Mean	±S.D.
Angle of release (°)	49.88	2.66	50.6	5.68*
Length of the arch of Acceleration displacement (m)	0.56	0.1	0.69	0.4***
Horizontal Displ (m)	0.3	0.06	0.32	0.07
Vertical Displ (m)	0.47	0.08	0.55	0.25**
Height of release (m)	2.48	0.05	2.62**	0.15**
Horizontal displacement from toe to point of release (m)	0.16	0.05	0.18	0.08

*p<1 **p < .05 ***p< .01

Table 2. Initial and final angles to horizontal of body segments. (°)

Body Segments	Group 1 Initial M±S.D.	Group 1 Final M±S.D.	Group 2 Initial M±S.D.	Group 2 Final M±S.D.
Hand	180.3±19.6	115.9±107	192±33	128.3±16
Forearm	135±6.9	82±5.3	131.6±19*	81.5±10
Arm	18±10	41.2±5.6	26±18	40±9
Trunk	88.6±4	87±4	86±6	87.3±4
Thigh	104±6	91.5±3	107±6	92.5±4
Shank	57.7±8.4	77±7	56±9	77.5±7.5
Foot	158±5.5	147±6.1	158.2±20.5	148.5±8

*p< .1

Table 3. Body segment % contribution to horizontal and vertical dispalcement of the ball

Body Segment	Group 1 Vertical	Group 1 Horizontal	Group 2 Vertical	Group 2 Horizontal
Hand	20.3±5.35	19.4±7.8	24±8.6	22.4±29
Forearm	21.1±2.7***	100±21.7	18.6±15	102±28
Arm	27.6±14	-24.5±12.5***	17±20	-31±67.11
Trunk	-0.14±0.63	5.3±10.7	0.21±55	-4.9±9
Thigh	4.5±3.3	48.6±25.3	6.5 ±4.3	67±20
Shank	14.5±9.4	-58.4±29.3	16.3±8	-67±19
Foot	9±6.2	7.4±5.4	12.4±5	10±38

*** p < .01

The initial and final angles to the horizontal for the forearm and arm segments of two players representing two different techniques are presented in Table 4. Subject N.G. (80% free shot accuracy) represents the "high elbow" technique; whereas, subject P.G. (86% free shot accuracy) represents the "low elbow" technique. In the " high elbow" technique, the subject initiates the movement with the ball held (approximately) in front and above the forehead. In the "low elbow" technique, the ball is held (approximately) in the front of the chest.

Table 4. Initial and final anlges to horizontal for selected body segments for two subject (degrees).

	Subj. N.G. (80%)		Subj.P.G.(86%)	
	Initial	Final	Initial	Final
Forearm	145.7	73.2	128.8	81.7
Arm	34.9	47.9	10.7	45

Figures 2a and 2b represent the relative velocities of the elbow and wrist joints for the "high" and "low" elbow techniques. The differences in the initial positioning of the forearm and (especially) the arm segments are reflected in the shapes of the joints' velocity curves. Notice, for example, in Figure 3b, the large alterations in the horizontal and vertical velocities of the elbow joint which are the result of the arm's low initial position. Notice also, that since the range of arm movement for the player with the "high elbow" technique was small (a = 12), the elbow joint's velocity is smaller.

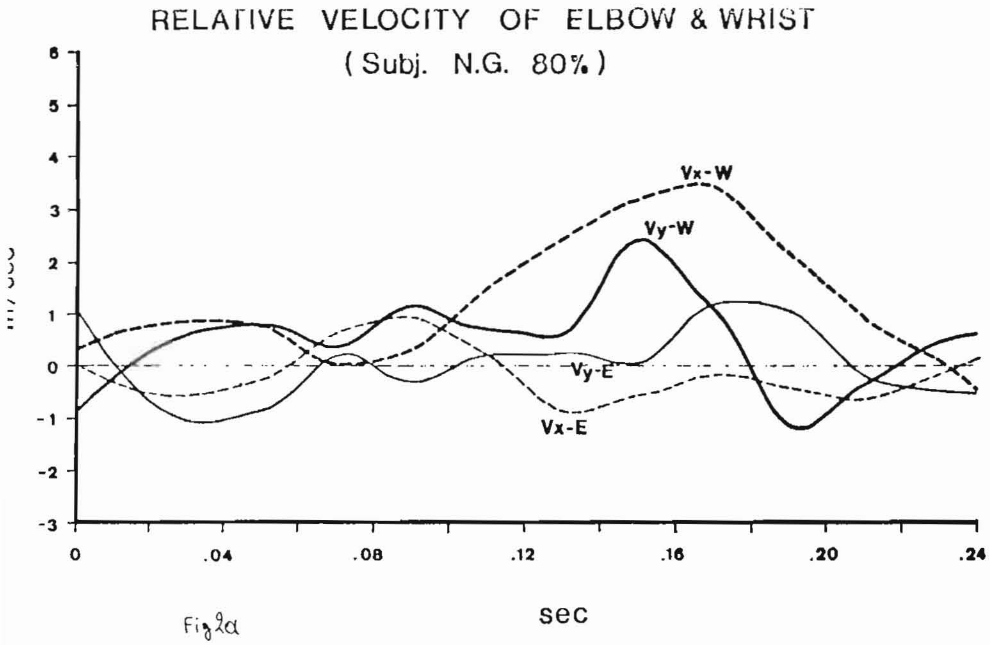

Figure 2a. Horizontal and vertical velocities of the wrist (W) and elbow (E) joints for subject N.G.

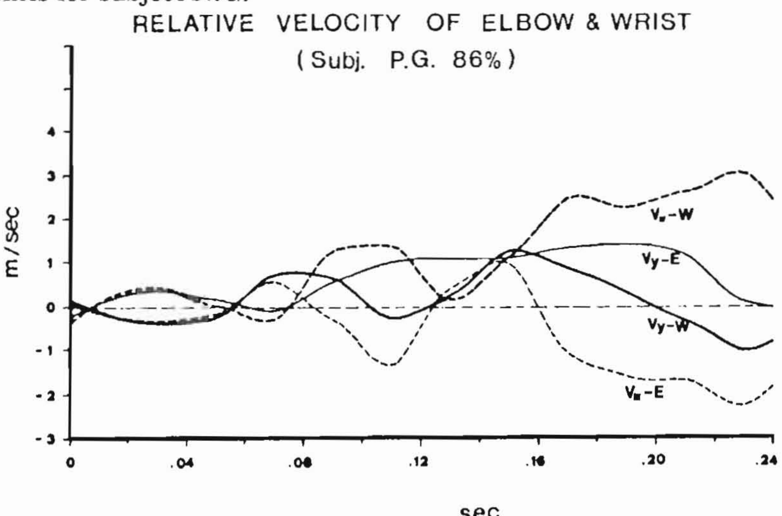

Figure 2b. Horizontal and vertical velocities of the wrist (W) and elbow (E) joints for subject P.G.

In Figures 3a and 3b, we can observe that the player with the "low elbow" technique displays a greater difference between the relative and effective horizontal velocities of the wrist joint than the player with the "high elbow" technique. This is because this technique produces larger negative velocities especially at the elbow joint. (see Figure 3b). These negative velocities are included in the calculations of the effective (absolute) velocities.

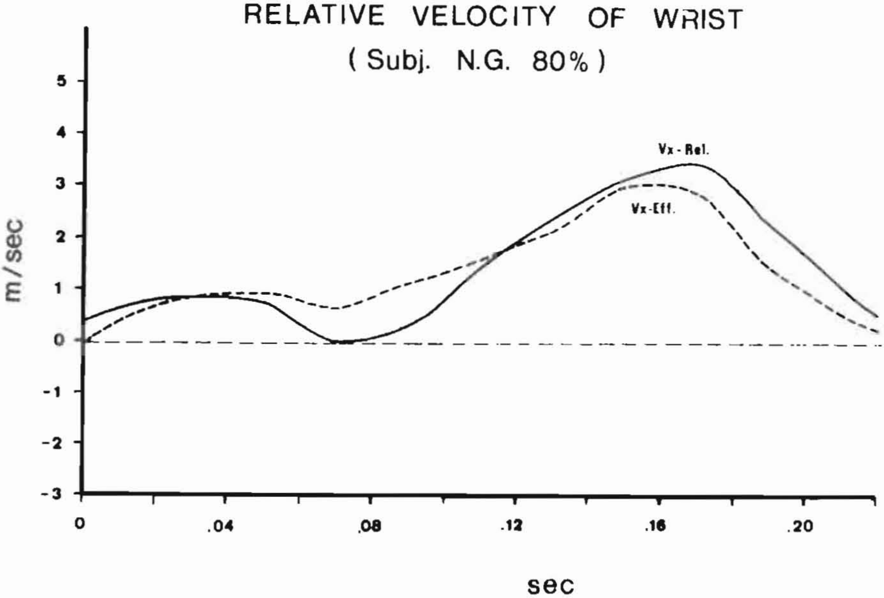

Figure 3a. Relative and effective (absolute) velocity of the wrist joint for subject N.G.

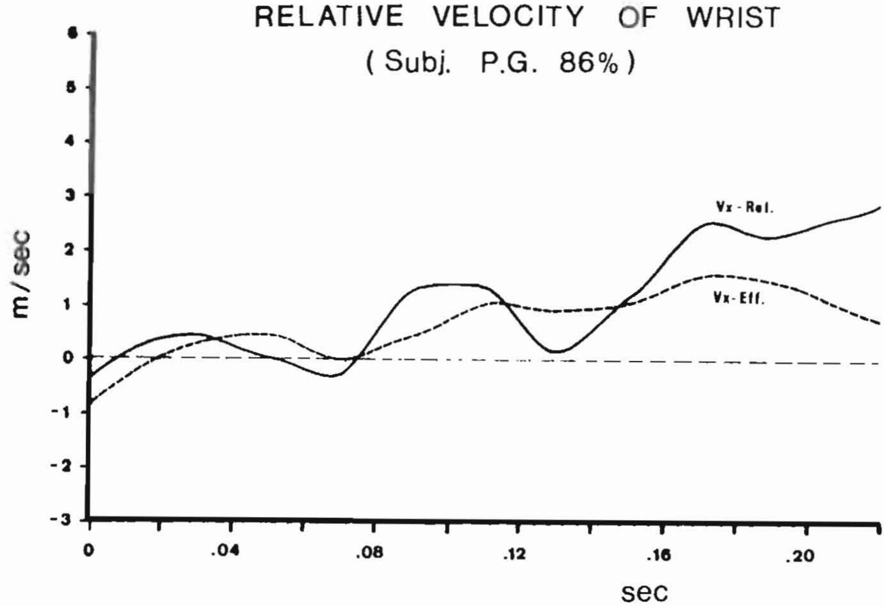

Figure 3b. Relative and effective (absolute) velocity of the wrist joint for subject P.G.

The hand segment behaves geometrically as an extension of the forearm acting just prior the release of the ball. Although not included in this report, our data shows no major differences between the two techniques with regard to this segment's movement.

Conclusions

Based upon the study's finding, the following conclusions appear to be justified:

1. The trajectory of the ball prior to and after its release belongs to the same parabola. However, for players with a higher rate of success in free shooting, the two portions of the ball's trajectory approximate the same parabola more accurately.

2. An analysis of the angle and height of ball release, the ball's displacement prior to release, as well as the initial and final angles of the body's segments with relation to the horizontal, shows that they do not correlate with the rate of success in free shooting.

3. The lower extremities (as a whole) contribute mainly to the vertical displacement of the ball. The trunk's contribution to both the vertical and horizontal directions is negligible. The arm's contribution is in the vertical direction and the forearm's is in the horizontal. The hand contributes evenly in both displacements.

4. The "high" and "low" elbow techniques differ basically at the initial arm position. When using the "high elbow" technique the influence of the arm movement is small, and therefore not as complex as the movement used in the low elbow technique.

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