Body Segment Contributions to Free Throw Shooting in Basketball

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The one-hand set shot in basketball forms the basis for most other shots and is used almost exclusively in shooting free throws. There is general agreement that the one-hand set shot involves elbow extension, wrist and finger flexion, and extension of the legs and hips (Hay, 1985; Wooden, 1980; Cousy & Power, 1970). Cooper and Siedentop (1969) have stated that medial shoulder rotation and forearm pronation are also involved. Although the specific timing of segment contributions to basketball shooting has been discussed (Baumgartner, 1975; Cooper & Glassow, 1972), the contribution which each segment makes to ball velocity in the one-hand free throw has not been reported. Therefore, the purpose of this study was to determine the relative contributions of the lower body, trunk, upper arm, forearm, and hand to the ball velocity in the one-hand free throw.

PROCEDURES

Members of the Men's Canadian National Basketball Team were filmed shooting free throws in competitive game conditions. A 16 mm Locam camera, fitted with a 20 mm lens was positioned 10 m back from the sagittal plane of action on the foul line extended. A frame rate of 68 fps was verified by internal timing lights set at 10 Hz. All free throws taken by the Canadian team were filmed. Filming commenced when the subject started his free throw action and ended when the ball was released. From the film, nine successful trials, in which the filmed action was unobstructed by other players, were chosen for analysis. For each trial, the segmental endpoints of the right metatarsal, ankle, knee, hip, shoulder, elbow, and wrist were digitized along with the ball center. Digitizing started when the shooting motion began and ended three frames after release. The coordinates were digitized with a Calcomp 9100 series digitizer interfaced with an Apple IIe microcomputer. The raw position data were smoothed using a second order Butterworth digital filter with a cutoff of 6 Hz. The smoothed data were then differentiated using first order finite differences to obtain the absolute velocities of the segmental endpoints. Once the absolute velocities of the joint centers were determined, a computer program was developed to obtain the relative velocities of the contributing segments. A relative motion analysis was conducted to determine the contributions made by the lower body, trunk, upper arm, forearm, and hand to the absolute velocity of the ball throughout the free throw motion. The velocity of the joint center of the hip was used to represent the contribution made by the lower body. Movement outside the primary plane of action was considered to be minimal. The following relative velocity relationship was used:

$$V_b = V_h + V_{s/h} + V_{e/s} + V_{w/e} + V_{b/w}$$

where: V_b represented the absolute velocity of the ball; V_h, the absolute velocity of the hip; $V_{s/h}$, the velocity of the shoulder with respect to the hip; $V_{e/s}$, the velocity of the elbow with respect to the shoulder; $V_{w/e}$, the velocity of the wrist with respect to the elbow; and $V_{b/w}$, the velocity of the ball with respect to the wrist. The horizontal and vertical velocities were calculated from the relative motion equation and then resultant velocities were derived from these values. From the resultant velocities, the components of velocity acting in the direction of the ball's motion path at each recorded instant of time were the final parameters computed. The relative velocity patterns for each of the segments were examined to determine the contributions of each to the absolute velocity of the ball at selected time intervals.

For purposes of this study the one-hand free throw was divided into two phases, the preparation phase and the propulsion phase. The preparation phase consisted of that time period during which the ball was drawn upward and backward. The propulsion phase consisted of that time period during which the ball was moved upward and forward. The position of the ball during the instant of time between the end of the preparation phase and start of the propulsion phase was labelled the «cocked» position. Release was considered to occur at zero seconds and the time periods preceding release, therefore, were negative.

RESULTS AND DISCUSSION

An illustration of the segment velocity contributions to ball velocity of a representative subject is presented in Figure 1. The average for all subjects is presented in Figure 2. The velocities plotted are the components of resultant velocity acting in the direction of the ball's motion path. The average time for the preparatory phase of free throw shooting was longer and more variable (Mean = .38 s, SD = .127) than the average time for the propulsion phase (Mean = .19, SD = .043). This is probably understandable, given that there is no common starting point of uniform style of lifting the ball to the «cocked» position. In the propulsion phase, however, there is a definite starting point (the «cocked» position) and a definite ending point (the release). Consequently, the length of time taken was less variable in the propulsion phase.

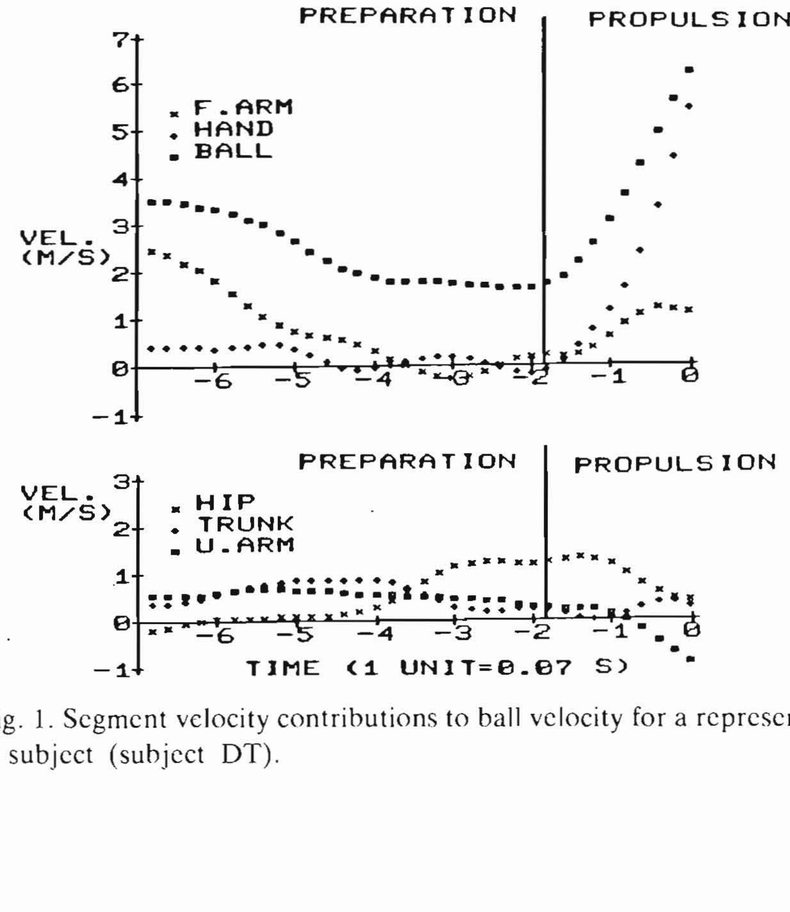

Fig. 1. Segment velocity contributions to ball velocity for a representative subject (subject DT).

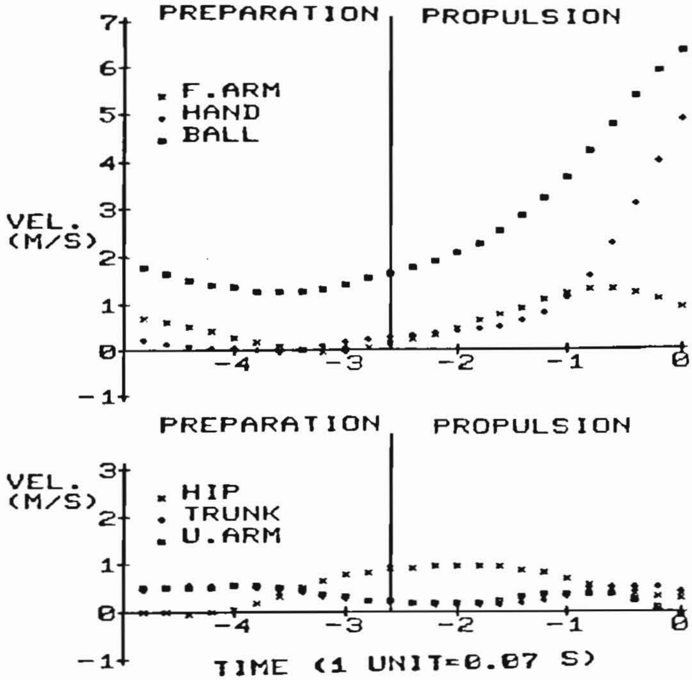

Fig. 2. Average segment velocity contributions to ball velocity for all subjects. The time period over which the average velocities were plotted was the time period of the subject which took the least time.

Tables 1 and 2 show the segment contributions by velocity and percent of ball velocity during the preparation and propulsion phases. The average velocity of the ball throughout the preparation and propulsion phases remained relatively constant until approximately .15 s before release when it started to increase rapidly to its final release velocity. During the preparation phase (see Table 1) the contribution of the hand was consistently low, ranging between −4 and 11 percent. The upper arm made its largest contribution to ball velocity during the preparation phase. In fact, during certain time periods (−.26 s, −.29 s, .32 s), it provided the largest single contribution to ball velocity. The percent contribution of the forearm to ball velocity was 38 at the start of the preparation phase and then decreased to a low of −3 at the end of the preparation phase. The trunk provided a much higher contribution during the preparation phase than during the propulsion phase. The contribution of the hip increased dramatically from a percent value of −2 at the earliest recorded interval of the preparatory phase to a value of 47 during the last interval of the preparatory phase.

TABLE 1
MEAN RELATIVE VELOCITY ANALYSIS (M/S) DURING PREPARATION PHASE AT SELECTED TIMES*

Time (s) (prior to release)		V_h (hip)	+	$V_{s/h}$ (trunk)	+	$V_{e/s}$ (u.arm)	+	$V_{h/c}$ (f.arm)	+	$V_{b/w}$ (hand)	=	V_f (ball)
−.35	$\bar{X}$	(−.03)	+	.45	+	.47	+	.66	+	.20	=	1.75
	SD	.32		.38		.27		.42		.25		.51
	%	(−2.00)	+	26.00	+	27.00	+	38.00	+	11.00	=	100.00
−.32	$\bar{X}$	(−.05)	+	.52	+	.47	+	.48	+	.08	=	1.5
	SD	.32		.37		.25		.36		.28		.41
	%	(−3.00)	+	35.00	+	31.00	+	32.00	+	5.00	=	100.00
−.29	$\bar{X}$	0.4	+	.52	+	.51	+	.27	+	(−.01)	=	1.34
	SD	.34		.36		.19		.26		.25		.36
	%	3.00	+	40.00	+	38.00	+	20.00	+	(−1.00)	=	100.00
−.26	$\bar{X}$	.30	+	.44	+	.51	+	.05	+	(−.05)	=	1.25
	SD	.33		.28		.19		.10		.21		.39
	%	24.00	+	35.00	+	41.00	+	4.00	+	(−4.00)	=	100.00
−.23	$\bar{X}$	.63	+	.32	+	.36	+	(−.04)	+	.06	=	1.32
	SD	.26		.19		.16		.15		.17		.36
	%	47.00	+	24.00	+	27.00	+	(−3.00)	+	5.00	=	100.00

* Velocity is the component of resultant velocity acting in the direction of the ball's motion path.

An examination of the propulsion phase (see Table 2) shows that during the early stages of this phase, the majority of ball velocity was supplied by the lower body (as reflected by the hip's motion). At release, the largest contribution was made by the hand. The percent contribution made by the hip ranged from a high of 55 at the start of the propulsion phase to a low of 4 at release. The percent contribution of the hand was 14 at the start of the propulsion phase and increased to a high of 77 at release. The contribution of the trunk during the propulsion phase was relatively constant, ranging between 6 percent and 14 percent. The percent contribution of the upper arm was 15 at the start of the propulsion phase and decreased to a low of −2 at release. At the start of the propulsion phase, the percent contribution of the forearm to ball velocity was 2. It increased to a high of 33 just before release (−.09 s) and then dropped to a value of 15 at release.

TABLE 2
MEAN RELATIVE VELOCITY ANALYSIS (M/S) DURING PROPULSION PHASE AT SELECTED TIMES*

Time (s) (prior to release)		V_h (hip)	+	$V_{s/h}$ (trunk)	+	$V_{e/s}$ (u.arm)	+	$V_{h/e}$ (f.arm)	+	$V_{b/w}$ (hand)	=	V_f (ball)
−.21	X̄	.83	+	.21	+	.23	+	.03	+	.21	=	1.51
	SD	.22		.14		.19		.19		.15		.25
	%	55.00	+	14.00	+	15.00	+	2.00	+	14.00	=	100.00
−.18	X̄	.91	+	.15	+	.17	+	.20	+	.32	=	1.75
	SD	.22		.14		.19		.25		.19		.27
	%	52.00	+	9.00	+	10.00	+	11.00	+	18.00	=	100.00
−.15	X̄	.94	+	.12	+	.16	+	.46	+	.39	=	2.07
	SD	.30		.22		.14		.35		.31		.45
	%	45.00	+	6.00	+	8.00	+	22.00	+	19.00	=	100.00
−.12	X̄	.92	+	.13	+	.22	+	.76	+	.50	=	2.53
	SD	.40		.33		.18		.51		.37		.72
	%	36.00	+	5.00	+	9.00	+	30.00	+	20.00	=	100.00
−.09	X̄	.79	+	.23	+	.33	+	1.08	+	.81	=	3.24
	SD	.43		.31		.31		.65		.45		.96
	%	25.00	+	7.00	+	10.00	+	33.00	+	25.00	=	100.00
−.06	X̄	.55	+	.40	+	.37	+	1.31	+	1.60	=	4.23
	SD	.41		.19		.41		.61		.64		1.03
	%	13.00	+	9.00	+	9.00	+	31.00	+	38.00	=	100.00
−.03	X̄	.36	+	.49	+	.23	+	1.21	+	3.09	=	5.38
	SD	.36		.16		.52		.45		.75		.75
	%	7.00	+	9.00	+	4.00	+	23.00	+	57.00	=	100.00
Release	X̄	.27	+	.40	+	(−.13)	+	.92	+	4.90	=	6.36
	SD	.35		.42		.48		.42		.60		.20
	%	4.00	+	6.00	+	(−2.00)	+	15.00	+	77.00	=	100.00

* Velocity is the component of resultant velocity acting in the direction of the ball's motion path.

The analyses revealed that the main contributors to ball velocity during the preparation phase were the forearm, upper arm, and trunk during the early motion, with the hip being the major contributor late in the preparatory phase. During the early propulsion phase, the lower body provided the major contribution. The contribution of the hand increased and became dominant at the end of the propulsion phase and the contribution of the forearm increased and then dropped off just before release. Consistent with reports on summation of forces (Bunn, 1972; Dyson, 1973; Northrip, Logan & McKinney, 1974), initially the ball was propelled to the basket primarily by the lower body. The motion then flowed upward to the smaller appendages, until, at release, the ball was propelled primarily by the hand. The variability among subjects in ball velocity at release was relatively low (SD = .19, Mean = 6.35) but at .06 s before release it reached its highest point (SD = 1.03, Mean = 4.23). It appears that just before release, there was considerable variability among subjects in ball velocity but this variability was greatly reduced at release. The low variability in velocity at release is most likely accounted for by the narrow limits of velocity required to drop the ball in the basket from the foul line.

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