A KINEMATIC ANALYSIS OF THE FRONT SET AND BACK SET IN VOLLEYBALL

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Setting techniques have received considerable attention in the volleyball literature. However, universal agreement on the proper or "best" method of executing the setting technique has not been attained. Additionally most skill write-ups focus on front setting with scant attention paid to back setting or other types of set variations. The published resources available to the volleyball coach and player are replete with the subjective and often conflicting information of the various authors, e.g. Scates (1984); Gozansky (1983); Schaafsma, Heck and Sarver (1985).

Few research studies have been conducted on setting techniques and even fewer focus on set variations such as back setting or fast, low set variations. In addition most of the setting research was completed prior to the 1984 Olympics where the world witnessed the emergence of the U.S. men's and women's teams as world powers. Numerous technique changes and new techniques have evolved in recent years as the level of volleyball has reached new heights in this country.

While trying to understand more about the mechanics of good setting technique, also of importance are setting tactics. A setter must be able to deceive the defense with respect to set destination and time of delivery. Disguising the type of set that is being executed is essential in good levels of play in volleyball. Such deception by the setter frequently allows the hitter to attack against a single blocker or a poorly positioned defense which enhances the offense's scoring opportunities. Additionally and equally important is learning what the defensive players should be keying in on which will enable them to "read" the setter and establish a successful defense.

The purpose of this study was to kinematically compare the techniques of front setting and back setting as performed by highly skilled collegiate volleyball setters.

METHODS

The front set (FS) and back set (BS) performance of seven DivisionI collegiate female volleyball players was recorded on high speed film. Subjects were informed of testing procedures and signed consent forms.

The performance records were filmed with a 16 mm Photosonics P-1 camera operating at a transport speed of 200 frames per second. Each subject was filmed for three front set trials and three back set trials. Subjects were given unlimited practice trials before performing the trials used for filming. The camera was located 9.44 m from the sagittal view of each subject. A volleyball training device, "Catch-It, Bask-It", set 5.46 m from the subject was used to provide a vertical and horizontal setting target for the subjects. All data were collected outdoors on a tennis court in natural lighting.

Spatial coordinates were obtained through the utilization of a Sonic digitizer interfaced with an Apple IIe microcomputer. Nineteen segmental endpoints from alternate frames were analyzed by software written by Richards and Wilkerson (1984). Digitizing of each trial began with the point of maximum flexion defining the conclusion of the preparation phase and continued until ball release. The raw data were smoothed with a second order low pass digital filter set at 6 Hz.

Kinematic variables for the biomechanical analysis of the ball were derived from geometric center of the ball as defined by Hudson (1982). Three ball spatial coordinates that shared no common X or Y coordinates were submitted to the triangulation method by Hudson (1982) for X and Y coordinate determination of the geometric center. Ball center coordinates were stored and further analyzed kinematically.

Body position which were represented by angles were selected for analysis for the purpose of delineating and comparing the two volleyball setting techniques. Specific angular kinematics were analyzed. The wrist, elbow, knee, and ankle angles were defined by lines drawn between the articulation of interest and the adjacent joints. Additional angles of inclination of body segments were analyzed. The shoulder angle of inclination was defined as motion around the shoulder articulation formed by a line through the upper arm segment relative to the vertical. The angles of inclination of the trunk, head, and thigh were measured relative to the horizontal around their respective articulations.

The temporal and ball variables analyzed were velocity of ball at release, angle of ball projection, time of ball contact, and distance of ball from the forehead at initial ball contact. Temporal analysis of ball contact was subdivided into absorption phase and propulsion phase. The absorption phase was defined as from the moment of initial contact until slowing of the ball had ceased; and propulsion phase occurred from the end of absorption until ball release.

RESULTS

Joint Kinematics

Many similarities exist between the FS and BS with respect to the use of the various joints studied. Differences were observed between the shoulders, head, and trunk in executing the two types of sets. Table 1 represents angular positions during the following phases of the set: 1) start (S) of body movement toward the ball, 2) at initial ball contact (C), and 3) time of ball release (R). The head was positioned at 73.42 deg (FS-S) and 64.82 deg (BS-S). At release the head had moved a negligible amount in the FS (74.9 deg) while hyperextending to 40.03 deg in the BS. Similar patterns of movement occurred in the trunk. The trunk was positioned at 101.86 deg (FS-S) and 96.45 deg (BS-S). By the time of ball release the trunk had moved to a vertical position for the FS (90.60 deg) and to a hyperextended position for the BS (74.77 deg). Shoulder angles varied from 112.22 deg (FS-S) to 50.45 deg (FS-R). For the BS joint angles varied considerably from 106.14 deg (BS-S) to 23.22 deg (BS-R) indicating a greater range of motion (ROM) in the shoulder joint during the BS.

TABLE 1

JOINT KINEMATICS

JOINT	SET	*M*-Start	*SD*	*M*-Contact	*SD*	*M*-Release	*SD*
Head							
	FS	73.42[a]	10.75	71.96	10.75	74.90	14.01
	BS	64.82	8.84	51.32	4.83	40.03	9.15
Trunk	FS	101.86	4.17	92.32	7.10	90.60	8.32
	BS	96.45	6.57	81.22	6.54	74.77	6.99
Shoulder							
	FS	112.22	29.43	69.27	21.33	50.45	16.94
	BS	106.14	31.40	57.40	14.90	23.22	15.09
Elbow							
	FS	101.07	11.03	141.56	16.39	159.60	11.59
	BS	102.24	19.17	132.06	8.85	153.30	11.23
Wrist							
	FS	151.04	11.23	126.41	10.28	137.89	9.42
	BS	144.08	12.34	130.47	8.74	143.23	8.73
Hip							
	FS	53.13	10.60	72.27	13.67	80.47	13.23
	BS	54.77	12.09	72.94	10.79	84.19	10.99
Knee							
	FS	114.80	13.82	138.33	16.97	150.51	15.63
	BS	114.06	11.25	134.17	10.41	155.40	11.01
Ankle	FS	102.66	11.69	126.23	21.81	134.38	20.23
	BS	108.64	9.48	119.32	14.99	131.92	16.80

[a]Mean values in degrees.

At the onset of ball contact joint extension had occurred in all joints, both for the FS and BS with the exception of the wrist. Most subjects had several changesof direction in wrist/hand movement during setting. Several subjects flexed the wrist prior to contact, hyperextended the wrist during the ball absorption phase and then flexed again during the propulsion phase. It appears that the wrists are not held firm during setting.

A summary of the range of motion of the different joints is presented in Table 2. In studying the ROM experienced by the different body segments, the head position varied from a mean range of 2 deg (FS) to 24 deg (BS). Similarly the trunk positions were observably different with the trunk moving through a range of 11 deg for the FS and 21 deg for the BS. Shoulder ROM differed from 62 deg (FS) to 83 deg (BS). In establishing a hierarchy for the joint ROM's the three most active joints for both types of sets, in order, were the shoulder, elbow, and knee.

Position/time data (Figures 1-4) analyzed from the start of the set to release of the ball revealed two prevalent patterns in the temporal sequence of movement of the shoulder, elbow, hip, and knee. In 8 of 14 trials analyzed the elbows began extending prior to the knees. In Figures 1 and 2 position/time data for Ss 1 executing a FS and Ss3 executing a BS are displayed. Both subjects' patterns demonstrated a pattern of the elbows initiating extension prior to the knees. Additionally there are observable similarities between the joint movements and the temporal sequencing for the FS and BS. In the remaining six trials studied the subjects began knee and elbow extension at approximately the same time. Figures 3 and 4 are representative of such a temporal movement pattern occurring during Ss 3's FS and Ss 1's BS. Again similarities are apparent between the FS and BS with respect to position/time data of the shoulder, elbow, hip, and knee.

TABLE 2

JOINT RANGE OF MOTION SUMMARY

Joint	Front Set[a]	Rank	Back Set	Rank
Head	2	8	24	5
Trunk	11	7	21	7
Shoulder	62	1	83	1
Elbow	59	2	51	2
Wrist	13	6	13	8
Hip	27	5	29	4
Knee	37	3	41	3
Ankle	31	4	23	6

[a]Mean range values in degrees.

Ball Kinematics

Ball kinematic data are included in Table 3. The total time of ball contact was slightly longer in the BS than in the FS. In studying the absorption and propulsion phases it may be noted that more time was spent in the propulsion phase than in the absorption phase. Time for ball propulsion was slightly longer for the BS (BS-P=.061s) than for the FS (FS-P=.49s). Both kinds of sets resulted in similar projection velocities (FS-8.96 m/s; BS-9.09 m/s). Projection angles differed as expected when considering the difference in set destination. A mean projection angle of 62.01 deg for the FS and 108.73 deg for the BS resulted. Distance of the center of the ball to the forehead at contact was 33.77 cm (FS) and 34.47 cm.

TABLE 3

BALL KINEMATICS

VARIABLE	SET	M	SD
Absorption Time (sec)			
	FS	.024	$2.26E^{-05}$
	BS	.025	$5.00E^{-03}$
Propulsion Time (sec)			
	FS	.049	$9.45E^{-03}$
	BS	.061	.01
Total time (sec)			
	FS	.072	.01
	BS	.086	.01
Release Velocity (m/s)			
	FS	8.96	2.18
	BS	9.09	1.79
Angle of Projection (deg)			
	FS	62.01	5.04
	BS	108.73	9.07
Distance of Ball to Forehead (cm)			
	FS	33.77	4.38
	BS	34.47	6.59

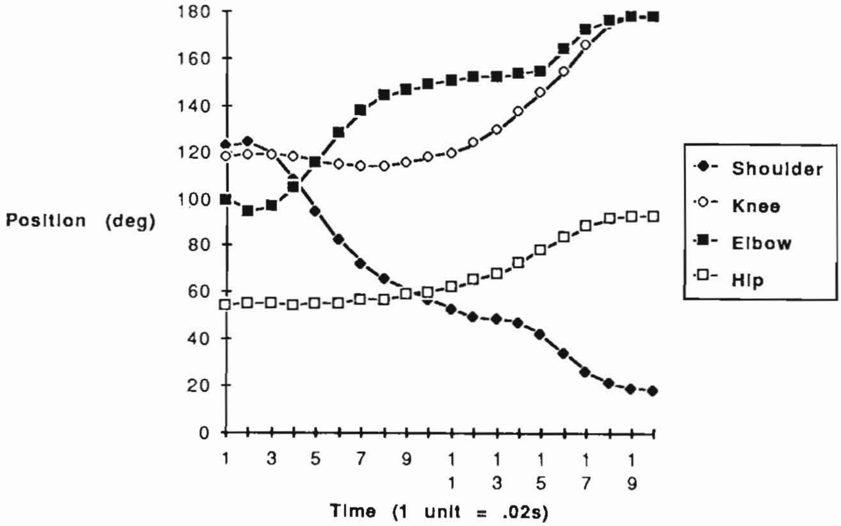

Figure 1. Position/time data for Ss 1's FS

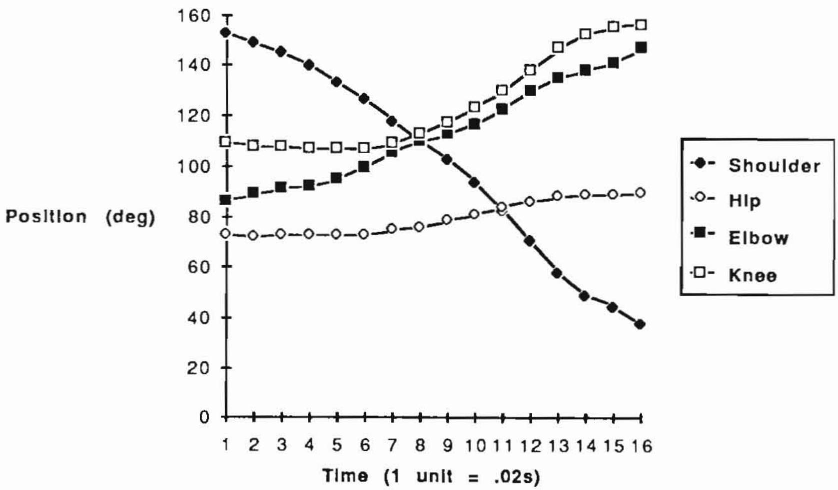

Figure 2. Position/time data for Ss 3's BS

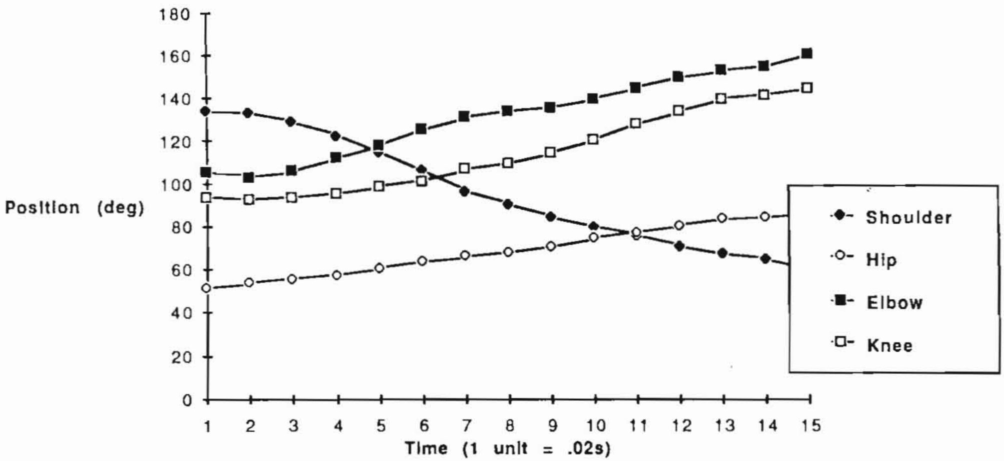

Figure 3. Position/time data for Ss 3's FS

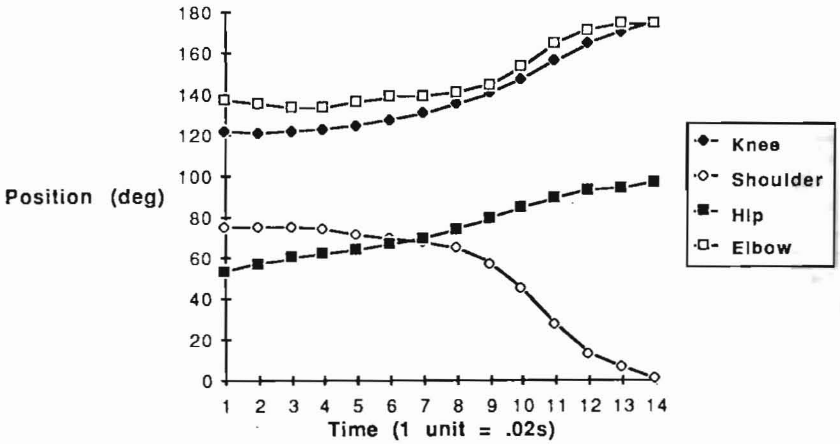

Figure 4. Position/time data for Ss 1's BS

DISCUSSION AND CONCLUSIONS

Within the limitations of this study, it was concluded that the similarities between setters when executing a FS or BS exceed any differences observed. While realizing there is rarely one form that is ideal for every performer, many observations may be made regarding setting technique of the subjects analyzed in this study. From these results the critical kinematic patterns that may dictate success in setting have begun to be identified.

In studying body segment movements during the two types of sets, the head, trunk, and shoulder exhibited the greatest positional variance between the FS and BS. Greater angular displacement occurred during BS execution. This was not unexpected when considering the task of projecting a ball overhead in a backward direction.

The more vertical position of the head and trunk at the start of the back set may provide critical positional cues for the defense in anticipating set destination. Also, the greater hyperextension movements which were experienced by the head and trunk during the BS may be discernible by defensive players. Such information could result in allowing the defense time to make defensive adjustments prior to the attack.

From an offensive standpoint the setter should attempt to minimize body position differences in executing the two types of sets, or at the very least they should attempt to delay as long as possible, positioning the body in an "obvious" back setting posture.

The setters in this study varied to some extent in their setting technique in comparison to what has been reported in some of the volleyball literature. An often reported statement (Scates 1985) regarding the position of the ball in relation to the head is to contact the ball six inches in front of the face. The mean distances (ball-to-forehead) were approximately 13.3 inches (FS) and 13.6 inches (BS). Even allowing for measurement to the edge of the ball instead of the geometric center does not account for such a discrepancy. Ridgway, Hay, & Gench (1985) reported in a recent setting study a mean distance of 13 inches for the FS. A possible explanation of the conflicting reports is that the setters analyzed in this investigation initiated movement toward the ball well before contact.

Schaafsma, Heck, & Sarver (1985) state that little extension begins prior to contact and only in the legs, with the elbows not beginning extension until contact with the ball. Such technique would result in a closer contact point relative to the forehead, and these authors recommend a contact point of approximately six inches from the forehead. More than likely some of these conflicting reports may be caused by the time gap between the time of new techniques or technique modifications being introduced in the sport and such technique changes being written up and published in the volleyball literature.

Movement of body segments prior to contact may be done to make setting more of a striking skill instead of a catching-throwing skill, thereby reducing the potential of an illegal hit. Also such preliminary movement usually results in higher ball release velocities which can reduce the time it takes the set to get to the attacker. Reducing time of delivery also decreases the time the defense has in defending against the attack.

In contrast to statements reporting the relative lack of movement prior to initial ball contact, the majority of the trials analyzed in our study initiated elbow extension prior to the knees, and both elbows and knees began movement almost from the start of both types of sets.

Certain sources suggest that the knees and elbows are positioned at 90 deg at the start of the set and both go to full extension. Our subjects started at a mean knee angle of 114 deg and a mean angle of 101 deg for the elbows. At time of release these joints were not at full extension. Further study would be needed to substantiate if different skill levels of setters selectively utilize body segments in a similar manner to what the subjects in this study exhibited.

In summary, based on the results of this study, the setter should consider the following points:

1) Minimize body position differences between the FS and BS where possible, especially in the head and trunk.
2) Try to delay getting positioned for a BS as long as feasible.
3) Develop strength and flexibility in the shoulders, elbows, and knees.
4) Initiate movement toward the ball, especially in the elbows and knees before contact.
5) Continue extending after ball release to avoid segmental deceleration which may result in a decreased ball projection velocity and a slower time of delivery.

Defensive players should consider the following points:

1) Key in on the head and trunk position of the setter from the onset of the setting technique.
2) Key in on the position of the ball at contact in relation to the the forehead.

Of minor import in this discussion of setting technique is the difficult role of the volleyball official. The average time of ball contact for the FS is .072s and for the BS is .086s. The difficulty in making a judgement call on the legality of the set when the contact time occurs in less than .1s becomes apparent. Perhaps officials are basing their calls on body movements occurring prior to ball contact which may or may not have relevance to the legality of the setter's technique. Perhaps high speed film analysis could also prove beneficial for the official.

While several investigation have analyzed front setting, (Shierman & Wehrman, 1978; Wehrman, 1977; Ridgway, et al., 1985), there are few other studies with which to compare what we have observed in both the FS and BS. The similarities in executing the two types of sets are quite apparent in the level of setter analyzed in this study. This indicates that good setting performance is in part based upon the ability to deceive the defense with respect to the type of set being executed. As better analytical methods and improved technology becomes available for studying setting technique, it is anticipated that our knowledge and understanding of setting biomechanics will be expanded. Until we have more biomechanical data obtained from research and data collected during actual competition on a fair number of athletes, we will not be able to competently assess the amount of technique variability and similarities that exists among setters.

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