THREE-DIMENSIONAL KINEMATIC ANALYSIS OF HIGH AND LOW TRAJECTORY KICKS IN SOCCER

PRASSAS, S.G.; TERAUDS, J. & NATHAN, T.A.
Department of Exercise and Sport Science
Colorado State University
Fort Collins
Colorado 80523
USA

Success in soccer stems, in part, from the ability of players to control the ball and to position it in the appropriate place on the field, that being to another player or to the net. Depending on the particular situation, a player might have to direct the ball towards the intended target by projecting it high or close to the ground. Consequently, soccer players practice extensively the two types of kicks. Coaches, in order to provide sound instructional advice, have attempted to determine qualitatively the factors that differentiate the one from the other.

Kicking has been studied biomechanically for a varierty of reasons, such as in search of evidence to prove the existence of sophisticated motor control programs for gross body movement (Phillips,1985), to test the theory that in order to achieve high velocities at a distal extremity there must be sequential muscular contraction from proximal to distal muscles resulting in summation of segmental velocities (Robertson & Mosher, 1985), to study the interaction between segments in rapid motion (Putnam, 1983; Roberts & Metcalfe, 1968), and to study lower extremity kinetic relationships under various conditions (Zernicke & Roberts, 1978; 1976; Roberts, Zernicke, Youm & Huang, 1974). In addition, several studies have attempted to describe and explain specific mechanical aspects of the activity, such as the determinants of the flight of the kicked football (Macmillan, 1975), the path of the foot during kicking (Macmillan, 1976) and the effects of foot velocity and rigidity to the velocity of the ball (Asami, 1985).

To date, there is no published data comparing the mechanical similarities and differences among the various types of soccer kicking, including the high and low trajectory kicks. The purpose of this study was to examine the high and low trajectory kicks in soccer and to determine the kinematic variables that differentiate them. The finding could either support or reject the qualitative instructional suggestions regarding body position found in coaching.

METHODS

Twelve high and twelve low trajectory kicks performed by a skilled subject (age: 28 yrs; height: 1.78 m; mass: 77 kg) were videotaped utilizing two cameras, a NAC 400 Video Recording System (set at 200 fps) and a Panasonic PV-330 60 Hz video camera. A cube of known dimensions, placed at the position of the ball, was also videotaped for calibration purposes. Nine trials of each kicking type were digitized utilizing an Ariel Performance Analysis System. Three-dimensional coordinates of 16 body points modelling the human body as a 15 rigid link system, and the coordinates of the ball were calculated by combining the video images of the two cameras utilizing the direct linear transformation (DLT) method (Abdel-Aziz & Karara, 1971). The raw data was digitally smoothed with cut-off frequencies of 6 Hz (body points) and 12 Hz (ball) before being submitted to further analysis. Dempster's (1955) data as presented by Plagenhoef (1971) was utilized to predict the segmental and total body anthropometric parameters necessary to solve the mechanical equations.

RESULTS

The coordinates of the 16 body points and the coordinates of the ball were calculated by considering the X axis in the anterioposterior direction, the Y in the vertical, and the Z in the mediolateral (all results are presented with regard to the Z axis (XY plane), except if noted otherwise). Table 1 presents joint angles of high trajectory kicks (HTK) and low trajectory kicks (LTK). With the exception of the ankle joint angle of the kicking extremity, all (Mean) joint angles were significantly different ($p < 0.01$) between the two types of kicks. Projection ball velocities, ball launch angles and foot placement on the ball at the moment of contact are shown in Table 2. Tables 3 and 4 present selective kinematic parameters of the kicking and support extremities, trunk and hip segments, and position of the subject's center of gravity (CG) with respect to the ball at the point of contact. Examination of this data reveals that although some differences exist in the various kinematic parameters of the two types of kicks they do not ultimately result in a significantly different inclination of the foot when it strikes the ball. The significant differences in ball launch angle are due to the ball being struck at a lower point in the high trajectory kicks (Table 2).

Figure 1 shows representative angular velocities of the shank and thigh segments for both types of kicking. In agreement with related literature, the thigh segment's angular velocity peaks prior to ball contact and decreases thereafter. The shank's angular velocity increases rapidly at the later stages of knee joint extension peaking approximately at ball contact.

TABLE 1
Joint Angles of the Kicking (K) and Support (S) Extremities (degrees)

		High Kick		Low Kick
Ankle Joint Angle (K)	Mean	135.496		137.501
	SD	10.840		5.999
Knee Joint Angle (K)	Mean	138.948	**	114.196
	SD	4.824		2.275
Hip Joint Angle (K)	Mean	173.701	**	150.002
	SD	4.030		3.156
Ankle Joint Angle (S)	Mean	93.968	**	105.694
	SD	4.323		4.767
Knee Joint Angle (S)	Mean	125.375	**	133.990
	SD	5.078		4.862
Hip Joint Angle (S)	Mean	146.561	**	135.057

** *p<.01*

TABLE 2
Projection Ball Velocities and Angles and Foot Placement on the Ball at Contact

		High Kick		Low Kick
Ball Velocity (m/sec)	Mean	21.617		23.387
	SD	.999		2.662
Ball Angle (degrees)	Mean	18.928	**	6.106
	SD	6.576		4.893
Vertical distance of foot above/below ball mid-line at contact (m)	Mean	-.064	**	.004
	SD	.015		.012

** *p<.01*

TABLE 3
Selective Kinematic Parameteres of the Kicking Extremity

		High Kick		Low Kick
Foot Angle	Mean	117.209		110.019
	SD	13.564		10.422
Shank Angle	Mean	72.706		67.520
	SD	5.741		9.321
Thigh Angle	Mean	113.759	**	133.324
	SD	3.561		3.496
Thigh Angle Vel.	Mean	461.630		413.235
(at ball contact)	SD	81.661		100.103
Shank Angular Vel.	Mean	1232.646	*	1632.130
(at ball contact)	SD	417.351		143.090
Knee Joint ROM	Mean	35.389	**	25.530
	SD	6.131		8.074
Hip Joint ROM	Mean	47.974	**	62.469
	SD	4.839		3.982

Joint and segment angles in degrees. Angular velocities in degrees per second.

* $p < .05$

** $p < .01$

DISCUSSION

The various instructional suggestions offered in soccer coaching literature as to the mechanisms by which the ball is projected at different launch angles, revolve around the body position, including the striking foot, at the moment of contact. The coaching recommendations converge to the idea that for the high kick, the "body" should be leaning backward at ball contact, with the shank of the kicking extremity in a more perpendicular position while the opposite is acclaimed for the low kick. In addition, it is recommended that the toes of the striking foot should be pointing downward more in the low kick than in the high. The data presented in this study only partially supports these coaching recommendations. For example, the trunk angle to horizontal (Table 4), being closer to a perpendicular position for the low kick would give the impression that the subject's body is leaning forward in this type of kick as suggested in the coaching literature. The data reveals that, in actuality, there are no significant differences in body lean between the two kicks. In fact, the CG was slightly further back in the low kick than in the high kick (Table 4).

TABLE 4
Selective Kinematic Parameters of the Support Extremity, Trunk and Hip Segments at Ball Contact. Horizontal Position of the Center of Gravity (CG) with respect to Ball at Contact

		High Kick		Low Kick
Shank Angle	Mean	71.800	**	83.752
	SD	3.559		5.264
Thigh Angle	Mean	126.425	*	129.763
	SD	3.846		2.233
Trunk Angle	Mean	107.459	**	103.326
	SD	1.448		2.240
Hip Angle	Mean	5.992	**	17.205
(x-axis)	SD	1.915		1.904
Hip Rotation	Mean	38.444	**	59.111
(y-axis)	SD	5.388		6.451
Hip Angular Vel.	Mean	-214.889	*	-381.539
(y-axis)	SD	183.809		106.449
Position of CG	Mean	.170		.197
at contact (m)	SD	.029		.010

Joint angles, hp rotation in degrees. Angular velocity in degrees per second.
** $p<.01$
* $p<.05$

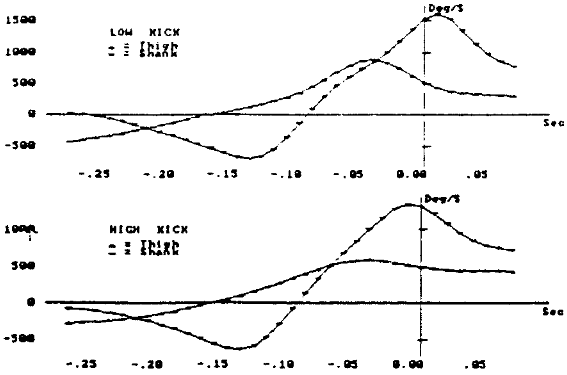

Figure 1. Angular velocity of the thigh and shank segments

Contrary to the coaching beliefs, there were also no significant differences in the inclination of the kicking extremity's foot and shank segments. The significant differences in ball launch angle found in this study (Table 2) were the result of the ball being hit at a significantly higher point in the low kick when compared to the high kick. This in turn, as the data in Table 4 indicates, was the result of a significantly elevated hip of the kicking extremity and a more perpendicular shank segment of the supporting extremity.

Although there were no significant differences in ball velocity between the two types of kicks, there were significant differences in the mechanisms by which they were achieved. The present data (Table 3) indicates that the high kick requires larger knee joint range of motion (ROM) to counteract the smaller hip joint ROM and smaller hip segment (transverse) rotation (Table 4). The shank angular velocity at contact was significantly larger in the low kick, which would yield higher ball velocities only if the ball was struck with the same part of the foot and with the same body rigidity. These parameters were not quantified in the present study so no definite conslusions on this topic can be made.

The representative history of thigh/shank angular velocities shown in Figure 1 do not indicate any substantial differences in segment interaction for the two types of kicks. It appears in both instances that the slowing down of the thigh segment transfers angular momentum and facilitates a rapid increase in the shank's angular velocity, which peaks at approximately the time of contact.

CONCLUSION

The present study reveals that there are significant differences in several kinematic parameters of the low and high trajectory kicks. These differences aim in placing the striking foot in a position to "loft" the ball when the intention of the kicker is to launch the ball high, and "propel" it horizontally when the intention is to kick it low. "Lofting" or "propelling" is accomplished by striking the ball below or above its mid-line, respectively, and not by having the foot and/or shank at different positions.

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