THREE DIMENSIONAL KINEMATICS OF THE DIRECT FREE KICK IN SOCCER WHEN OPPOSED BY A DEFENSIVE WALL

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INTRODUCTION

According to the rules of play, the game of soccer is divided into two 45 minute halves. During most of this time, play is continuous. However, when play is stopped, teams have time to strategically position themselves both offensively and defensively. Even though these stoppages account for a relatively small portion of the total "running time," set plays (corner kicks, throw-ins, and free kicks) from restarts have been reported to account for forty percent of the goals scored (Hughes, 1973). Thus, set plays are critical to the outcomes of soccer games. Various studies of the soccer kicking motion have been conducted. Some of these studies have involved an analysis of the forces and moments of the lower extremity (Isokawa and Lees, 1988; Luhtanen, 1988; Zernicke and Roberts, 1978). Others have related mechanical efficiency (Asami et al., 1976), isokinetic leg strength (DeProft et al., 1988; Narici et al., 1988; Too and Hoshizaki, 1984), and electromyographical activity of leg muscles to the soccer kick. However, no studies of the kinematics of the free kick under game-like conditions were found. Thus, the purpose of this study was to investigate selected kinematic parameters of the kicking techniques used in taking a free kick when opposed by a defensive wall.

METHODOLOGY

The subjects for this study were four highly skilled (right foot preference) male soccer athletes in training at the Australian Institute of Sport (AIS). They were selected by the head soccer coach at AIS, from among 18 players on scholarship and in residence, as being best at taking direct free kicks when opposed by a defensive wall.

Figure 1 is a depiction of the data collection setting. Three dimensional kinematic data were derived by the application of direct linear transformation techniques to digitized film that was taken by two synchronized 16mm cine cameras operated at 100 Hz. Note that the film data was analyzed for only the kicks taken from 18.29 m. A video camera positioned with its optic axis perpendicular to a goal and target (91.4 cm square located in the top left corner of the goal) marked on a wall was used to obtain accuracy data on all kicks that cleared the defensive wall and struck the targeted wall. The defensive wall was even though 9.14 m are positioned 7.75 m from the placed ball as a realistic estimate of game conditions required by the laws of the game. Digitization of a paper copy of each video image of the ball striking the targeted wall provided accuracy information relative to the (0, 0) coordinate located in upper left corner of the goal. Note that this corner of the goal formed the fourth quadrant of a Cartesian coordinate plane. Similarly, a paper copy of video images from the overhead camera of the left foot during the stance, right foot step, and left foot plant were digitized. This provided information about body and foot translation and orientation in the two step approach used by all subjects (see Figures 2 A and B). Each subject was given ten trials. All trials were recorded via the two video cameras. The cine cameras were used for successive trials until the subject's kick struck within the target. These successful performances were selected for further kinematic analysis.

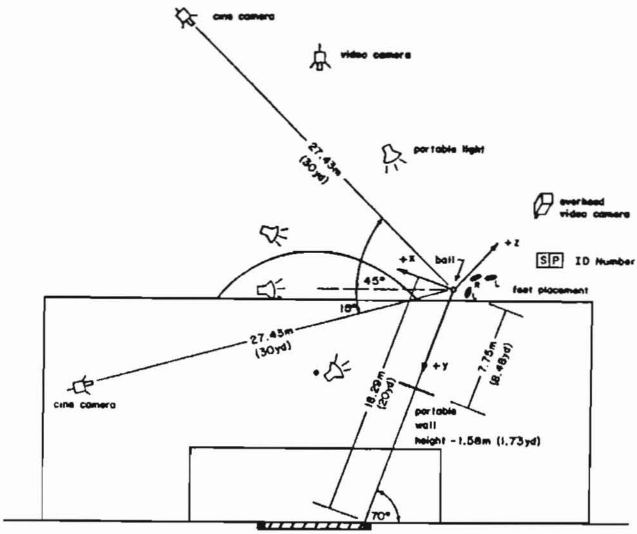


Figure 1. Data collection setting.

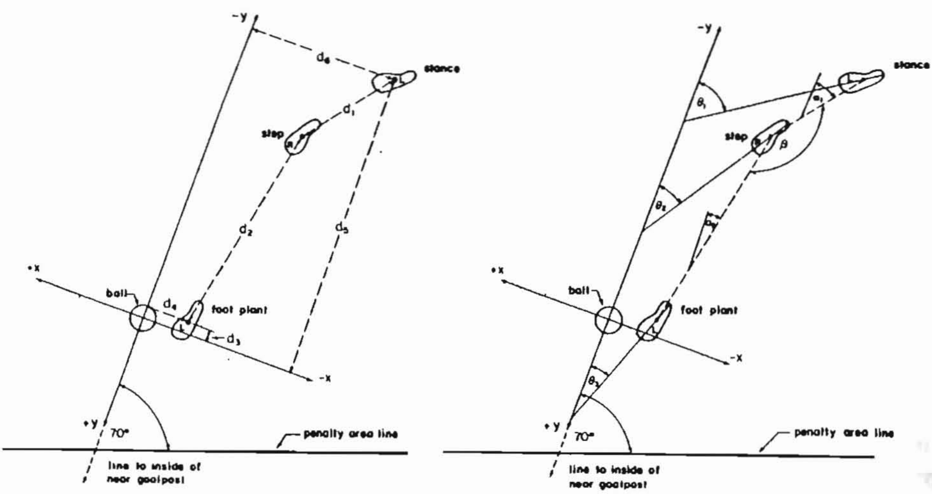


Figure 2. Body and foot translation and orientation in the two step approach.

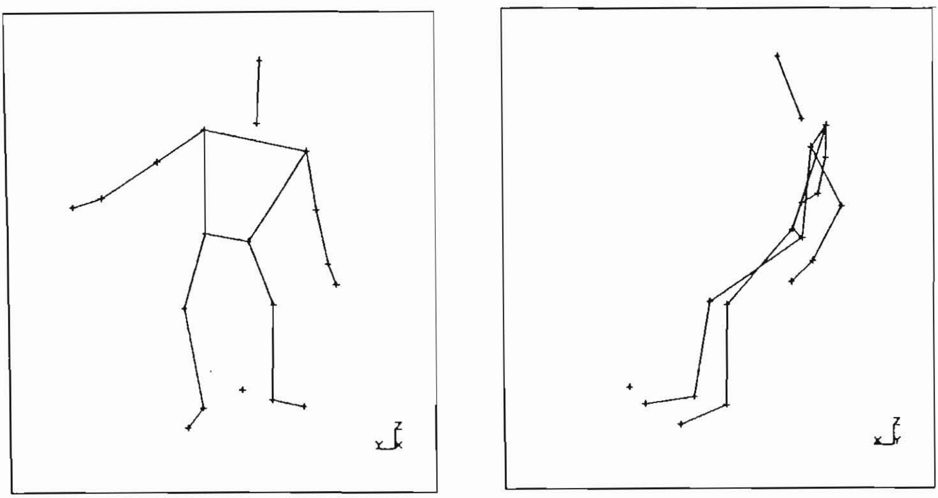
RESULTS

Table 1 includes the correlational matrix between performance parameters and target accuracy.

Table 1. Correlations between performance parameters and target accuracy.

Close/Far	Dist. 3	Dist. 4	θ_3	β	Target X	Target Y
Dist. 3	1.00	.070 -.542 -.196 -.209	.303 -.138 .316 .278	.239 -.513 -.396 -.372	-.256 .068 .315 .463	-.278 .350 -.089 .094
Dist. 4	-.864 -.177 -.203 .043	1.00	-.358 .527 -.456 .127	.355 .223 .560 -.731	-.640 .075 -.407 -.391	-.795 -.772 -.469 .193
θ_3	.010 .027 .410 .326	-.008 -.125 .075 .472	1.00	-.379 .595 -286 -.117	-.251 -.240 .806 .560	.161 -.541 .247 .827
β	.106 -.273 .104 .015	-.031 -.550 .579 -.663	.107 .081 .600 -.308	1.00	-.271 .142 -.203 -.071	-.245 -.095 -.653 -.005
Tar. X	.170 .394 .857 .342	-.416 -.072 -.328 .316	.292 -.127 .290 .603	.538 -.149 .082 -.491	1.00	.758 .298 .217 -.163
Tar. Y	.275 .168 -.056 .804	-.420 -.590 -.479 -.242	.083 .309 .414 .139	.549 .558 -.048 .612	.833 .515 .095 .054	1.00

Figure 3 is a depiction of the orientation of the body at ball contact. The orientation of the body segments are summarized in Tables 2 and 3. These represent one successful performance by each subject.



a) b)

Figure 3. Sample projection (subject A) of body segments at ball contact from close range onto two orthogonal planes. a) view from perpendicular to the Y-Z plane; b) view from perpendicular to the X-Z plane.

The angle of projection and resultant velocity of the ball in one successful performance by each of the subjects was summarized. The means and standard deviation for the projection of the ball in the X-Y and Y-Z planes, relative to the Y-axis, were 7.2°

± 3.4 and 20.2° ± 0.8, respectively. The resultant ball velocity was 17.96 ± 0.77 m/s.

Tables 2. Mean projection of body segments at ball contact from close range onto two orthogonal planes (°).

	Plane			
Segment	X-Z Mean	(sd)	Y-Z Mean	(sd)
Right foot	9.75	(3.3)	33.25	(12.5)
Right shank	78.25	(9.7)	104.00	(8.8)
Right thigh	35.50	(2.5)	70.75	(2.2)
Left foot	22.25	(2.1)	165.75	(4.3)
Left shank	85.00	(6.7)	94.50	(10.3)
Left thigh	45.00	(3.6)	94.50	(14.5)
Trunk	75.25	(3.6)	25.50	(4.7)

Table 3. Relative planar joint angles at ball contact from close range (°).

Joint	Right Mean	(sd)	Left Mean	(sd)
Ankle	109.5	(5.4)	105.5	(10.4)
Knee	137.5	(9.0)	132.3	(9.9)
Hip	129.0	(10.2)	149.8	(6.8)

DISCUSSION

The within subjects approach characteristics were very consistent as demonstrated by relatively small standard deviations across parameters. Across subjects, the approach characteristics were similar. However, each subject demonstrated his own style. Some correlational relationships between approach characteristics and kicking accuracy were evident but not consistent across all subjects. At impact from close range, body segment orientation across subjects was similar. Resultant ball velocities and angles of projection for shots kicked into the target were very similar, as would be expected, because they determine the outcome of the performance. However, the ball was kicked to the right of the Y-axis by an average of 7.2°. This was permitted because lateral spin caused the ball to curve back to the left. No subject was able to put top spin on the free kick. However, the kicking action employed minimized back spin on the ball.

CONCLUSIONS

All subjects had similar patterns of approach to the ball. However, few correlations between approach parameters and kick accuracy existed. Those that did exist did not demonstrate a consistent pattern across all subjects. At impact, subjects also demonstrated similar body segment orientations and ball projection characteristics. In general, there appears to be a relatively narrow band of performance characteristics in the kicks that were evaluated. However, each subject appears to have their own style in performing a successful free kick.

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