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A BIOMECHANICAL ANALYSIS OF THE INSTEP KICK MOTION IN SOCCER

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Introduction

The instep kick is one of the more fundamental and frequently used skills in the game of soccer. As many players perform the instep kick, it is often performed approaching from a diagonal.

In earlier investigations on the kicking motion of the instep kick, Asami et al. (1968) have suggested that the power of knee extension has an effect on the ball velocity. Togari (1972) has reported on the difference between top players and minor players in the swing motion kinematics obtained from film analysis.

Roberts and Metcalf (1968) have taken a cinefilm of the kicking motion in three dimensions (above, side and front) by means of 16mm high speed cameras, and suggested that the factors which govern the swing velocity are mainly hip rotation at the start of kicking, hip flexion and then knee extension just before impact.

Aitchison and Lees (1983) have reported that in successful kicking the position of the leg and the foot at impact is important. Kermond and Kong (1978), Bloomfield et al. (1979) and Elliot et al. (1980) have investigated the development of the punt kick, and the relation between performance parameters obtained from the cine film and the ball distance kicked. Lindbeck (1983) has suggested that muscles are pre-stressed during impact as the result of the impulsive moments occurring in the hip joint, and Hoshizaki (1984) has determined the relative influence of isokinetic quadriceps leg strength on motor coordination in maximal kicking. Plagenhoef (1971) has reported on the relation between the swing velocity, striking mass at impact and the ball velocity obtained from film analysis. Togari (1972) has reported on the importance of the supporting leg position and knee joint angles in successful kicking, and Isokawa (1981) and Kermond and Kong (1978) have reported the relation between the ball velocity and ground reaction force.

However, in the literature, there are few studies which investigate the relative influence of approach angle on ball velocity. The purpose of this study was (1) to determine the relationship between the kinematic data (velocity of toe, ankle, knee and hip) and ball velocity at different approach angles and (2) to determine the relationship between the kinetic data (ground reaction force and moment) and ball velocity at different approach angles.

Methods and Procedures

Six male soccer players ranging in age from 20 to 36 years were selected as subjects. The subjects were asked to perform a maximal instep kick with a one step approach to the kick.

The approach angle was set so that zero degrees represented the direction in which the ball was kicked. The subjects were asked to perform the kick three times each at approach angles of 0, 15, 30, 45, 60 and 90 degrees.

The kicking motions were recorded from the side by a 16mm Locam camera operating at 150 frames per second. This camera was set on a tripod and was positioned at right angles to the plane of the kicking. In the camera view were the subject, trial identification number, and horizontal and vertical reference lines. A conversion factor for changing film distances into real-life measurements was determined by filming a reference marker of known length in the plane of movement.

The force platform was used to consecutively measure the ground reaction force of the supporting leg from the landing to the end of the follow through. The vertical, frontal and lateral forces were measured as well as the torque about the vertical axis. The force signals were recorded and analysed by computer to determine the peak force and torque during the forward swing, the impact force and torque, and the integral of force from the landing to the impact. Measures of the ball velocity and the velocity of the kicking leg markers on the toe, ankle, knee, and hip were obtained from a film motion analyser (NAC Movias 200AEH).

Results

Kinematic analysis

The peak velocities of the toe, ankle, knee and hip during the instep kick with one step approach were measured at each approach angle. The results are presented in Table 1.

Table 1. The peak velocity of striking limb and ball

Approach angle	Toe $m\ s^{-1}$		Ankle $m\ s^{-1}$		Knee $m\ s^{-1}$		Hip $m\ s^{-1}$		Ball $m\ s^{-1}$	
(degrees)	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	18.08	0.74	12.79	0.18	7.36	0.51	2.78	0.20	18.73	0.95
15	18.29	0.94	12.61	0.42	7.14	0.69	3.13	0.45	19.12	1.23
30	18.32	0.96	13.07	0.36	6.70	0.48	2.72	0.12	19.87	1.14
45	18.01	0.45	12.14	0.29	6.25	0.48	2.42	0.23	20.14	1.58
60	18.09	0.90	12.28	0 27	6.09	0.39	2.29	0.20	19.46	1.59
90	15.38	0.76	10.77	0.33	4.11	0.46	1.48	0.21	19.13	1.64

Peak hip velocity occurred as the supporting foot landed on the force platform, and then gradually reduced with flexion of the hip joint. The peak velocity of the hip was maximum at an approach angle of 15 degrees, but reduced as approach angle increased.

Knee velocity reached its peak between 40-70 ms after peak hip

velocity was reached. The peak velocity of knee was maximum for the straight approach and gradually reduced as the approach angle increased.

Ankle and toe velocities reached their peak just before impact, and from 40-50 ms after the peak velocity of knee. The peak velocity of ankle and toe was at 30 degrees.

The maximal ball velocity was at an approach angle of 45 degrees. This was 0.37 $m\ s^{-1}$ faster than the ball velocity which was generated at maximum ankle velocity at an approach angle of 30 degrees. It was noted that the approach angle required to gain the maximum ball velocity was 15-30 degrees larger than that of the maximum ankle velocity.

Kinetic analysis

Figure 1 shows a typical example of the ground reaction forces recorded at an approach angle of 15, 45, 60 and 90 degrees and peak values are given in Table 2. The peak vertical force during forward swing did not change noticeably with approach angle. The difference between the maximum and minimum vertical force was less than 92N. However the peak lateral reaction force tended to increase as the approach angle increased while the peak of frontal reaction force tended to decrease.

Table 2. The peak of three dimensional ground reaction force and torque during forward swing

Approach Angle	Vertical Force (N)		Frontal Force (N)		Lateral Force (N)		Peak of Torque (Nm)		Torque at Impact (Nm)	
(degrees)	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	1362	124.2	398	77.5	68	29.9	1.2	5.0	7.5	4.1
15	1395	154.6	388	77.3	212	60.5	-1.7	5.7	4.4	5.2
30	1410	202.1	377	82.3	328	76.5	-4.8	5.4	3.4	7.0
45	1432	178.6	306	88.7	433	127.2	-8.1	3.8	2.4	6.8
60	1439	212.6	243	72.0	489	104.4	-8.9	4.6	-1.4	6.9
90	1454	294.8	63	92.2	583	114.8	-11.4	2.6	-1.8	2.2

The mean time from the landing of the supporting leg to ball impact was measured at each approach angle but this showed no change. However, there was a difference between subjects which was caused by their different kicking patterns. There might be two kicking patterns in the performance of the instep kick with one step. One of them used a large back swing and this resulted in a longer kicking time. The other used a small back swing and moved the lower leg forward sharply by knee extension and this resulted in a shorter kicking time (Table 3).

The integral of the force from the landing of the supporting leg to impact was determined at each approach angle. The integral of vertical and lateral force tended to increase slightly as approach angle increased, but the integral of frontal force decreased as approach angle increased.

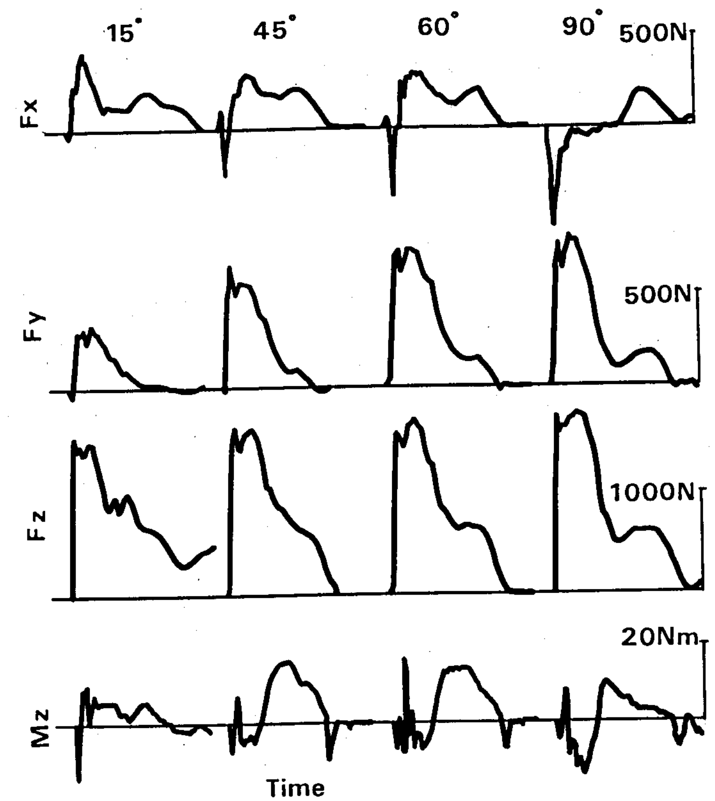

Figure 1. The raw data shown are examples of three dimensional force and moments at 15, 45, 60 and 90 degrees approach angle

Table 3. The integral of three dimensional ground reaction force and swing time from landing of supporting leg to impact

Approach Angle (degrees)	Vertical (Ns) Mean	SD	Frontal (Ns) Mean	SD	Lateral (Ns) Mean	SD	Swing Time (ms) Mean	SD
0	155.4	11.2	35.9	11.9	6.9	1.9	134.6	10.6
15	153.4	17.2	33.8	11.5	22.8	8.1	135.6	17.3
30	157.4	19.2	31.5	13.2	35.7	9.4	136.2	17.8
45	161.0	24.0	22.1	10.8	46.8	14.5	141.2	14.5
60	177.3	32.9	14.4	10.6	60.8	14.5	143.7	10.4
90	195.2	44.9	-17.3	2 6	71.3	15.4	150.0	6.1

Discussion

Kinematic analysis

There have been few studies which have investigated the effect of approach angle on ball velocity in soccer. Plagenhoef (1971) and Asai et al. (1980) have investigated the effect of straight and diagonal approaches on ball velocity and leg swing velocity. These studies emphasized that the diagonal approach caused greater ball velocities and leg swing velocities than the straight approach. It was considered that there might be an optimum approach angle to produce a maximum ball velocity and leg swing velocity. In this study, the peak ankle velocity, taken to be swing velocity, was maximum between an approach angle of 0 and 30 degrees. On average, the maximum swing velocity was at an approach angle of 30 degrees, but the peak of ball velocity was maximum within the range of 30-45 degrees, with a maximum velocity at 45 degrees. Togari (1972) and Isokawa (1980) have reported that the ball velocity was significantly related to the swing velocity ($r = 0.80$), but in these studies, the approach angle was constant in all trials. Plagenhoef (1971) suggested that both swing velocity and striking mass have an effect on the ball velocity. Fixation of knee and ankle joints at impact changes as the approach angle changes, and the striking mass also changes, therefore the resulting ball velocity changes too.

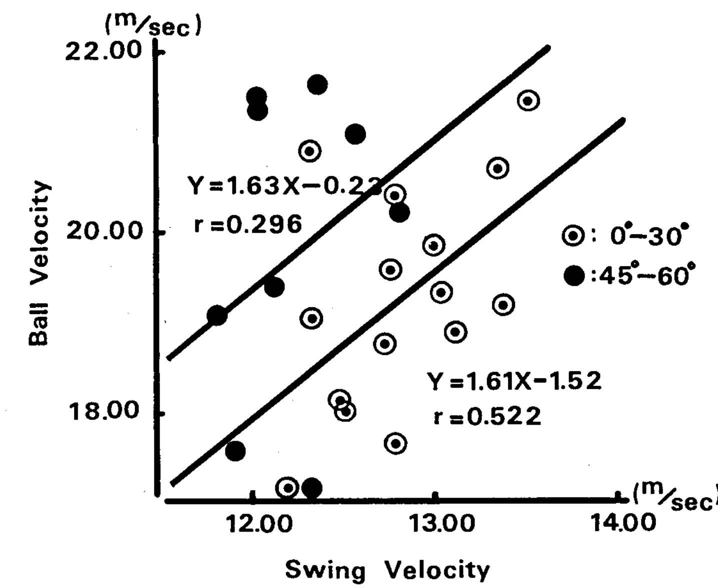

Figure 2. Relationship between swing velocity and ball velocity at 0-30 degrees, and 45-60 degrees approach angle

Fig. 2 shows the relationship between swing velocity and ball velocity at 0-30 and at 45-60 degrees. Ball velocity was significantly correlated with swing velocity at 0-30 degrees ($r = 0.522$, $P < 0.05$), but not significantly correlated at 45-60 degrees. Ball velocity at 45-60 degrees tended to be about 1.5 $m\ s^{-1}$ larger than that at 0-30 degrees for the same swing velocity.

In this study although ankle velocity was lower at an approach angle of 45 than at 30 degrees, the ball velocity reached maximum at 45 degrees It is considered that the reason for this is due to the increased striking mass, depending on a greater fixation of knee and ankle joints. Shibukawa (1973) has demonstrated the effect of joint fixation on the ball velocity using a kinetic model, assuming that joints of man were linked at the joints of hip, knee and ankle. He has reported that the increase in striking mass depended on the fixation of joints and affects the ball velocity. From these results, it is considered that optimum approach angle for the instep kick with one step is about 45 degrees.

Kinetic analysis

The peak vertical force changed little as the approach angle increased. However, the peak frontal force showed a reduction, gradual at first and then marked, as the approach angle increased. The lateral force showed a reverse trend. These trends would be expected as the approach angle varied from 0 to 90 degrees as the applied frictional force of impact is orientated increasingly in the lateral direction. However, the change in direction of the applied horizontal friction force is not constant and this suggests that some weight shift from the lateral to the frontal direction takes place between the approach angles of 0 and 45 degrees to keep the latter component high. Beyond an approach angle of 45 degrees this weight shift cannot be effected and so the peak frontal force rapidly reduces.

The torque at impact is noted to reduce with increasing approach angle. The torque is a reflection of the vertical twist imparted to the body by the action of the swinging leg. In the straight approach no rotation of the leg about a vertical axis is required in order to kick the ball straight ahead. Therefore the torque measured is the positive resistance torque due to the assymetry of body movement. As the angle of approach increases the leg has to be actively rotated about a vertical axis in order to kick the ball straight ahead. This actively generated torque reduces the resistance torque supplied to the body via the ground contact. At an approach angle between 45 and 60 degrees the active torque completely balances the body motion. At 60 degrees and above the active torque applied to the leg is an excess of that required to perform the kick and a negative torque results. An angled approach would serve to reduce the torque applied to the foot and may be considered as a sound injury prevention technique.

Consistent with the peak forces, the time integrals of the forces to impact demonstrate similar trends. The vertical impulse showed a more marked increase as approach angle increased and this could be explained by the greater time it takes to make the kick from landing to impact. This is reflected in the increased values of swing time.

In conclusion it can be said that an approach angle of between 30 and 60 degrees will be likely to produce greatest ball velocity while minimising torque applied to the foot. The peak vertical forces and impulses will not be minimised but these change relatively little. The horizontal frictional forces are greatest within this range of approach angle.

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