Biomechanics of the Soccer Free Kick

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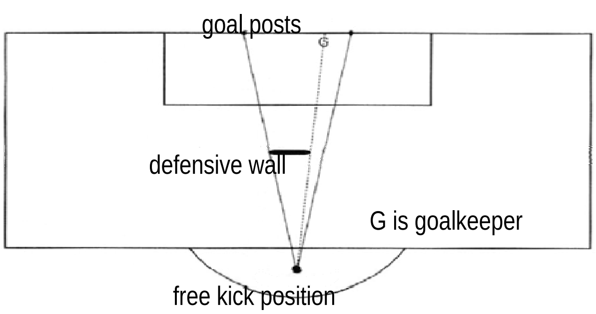
Introduction

In soccer, one of the most opportunistic times to score is during a free kick that is 18 to 25 yards from the goal. To defend a free kick, many teams form a wall. For the ball to make it around this wall and into the goal, many variables come into play. These variables include, but are not limited to: kick kinetics, leg kinematics, and fluid forces on the ball, which will be discussed. Also, a brief discussion of a new soccer ball will be included.



Kick Kinetics

Kicking kinetics largely contribute to the velocity and the spin of the ball after impact. Dorge *et al.* (2002) demonstrated the linear velocity of the knee and the angular velocity of the shank as impacting the velocity of the foot on impact, with the angular velocity of the shank largely causing the velocity of the foot. This angular velocity is produced by positive muscle moments right up until contact is made with the ball, at which negative muscle moments have been observed. Nunome *et al.* (2002) summarized the torques produced in the shank during the kicking motion:

(Table A)
Selected Value of Joint Torques (Nm)

Maximal ankle dorsiflexion torque	22
Maximal knee extension torque	98
Maximal hip adduction torque	115
Maximal flexion torque	249
Maximal external rotation torque	33

Hip flexion was the largest torque produced, indicating that the ability to produce large hip flexion torque may be the most important factor in maximizing ball velocity. However, all torque values contribute to the velocities of the leg, shank, and foot during the kicking phase and directly correlate to the velocity of the ball.

Leg Kinematics

Leg kinematics are important in placing maximum forces on the ball in the best orientation. Previous studies demonstrate the deceleration of the shank right before impact, and the acceleration of the ankle at impact with the ball. In their study, Nunome *et al.* (2006) found that the ankle reached maximum plantar flexion angular acceleration at the middle of impact and plantar flexion reached maximum velocity during the latter half of the ball contact phase. Additionally, Nunome *et al.* (2006) demonstrated the effects of the side-foot and instep kick in producing maximal velocity of the ball. The ball velocity of the side-foot kick (23.4 +/- 1.7 m/s) was significantly slower than that of the instep kick (28.0 +/- 2.1 m/s). The same study references Levanon and Dapena as having concluded that the slower ball speed observed for the side-foot kick was not due to the quality of impact but due almost exclusively to the slower final speed of the foot in that kick. So we see the kinematics of the leg affecting resultant velocity of the ball.

Fluid Forces on Ball

Apart from the kicker's foot, other important forces affect ball motion. Bray and Kerwin (2003) conducted a study of the free kick and found some ways in which Magnus (lift), drag, and gravity forces determine a resultant force on the ball:

$F_{total} = mg + F_d + F_l$
$F_d = -\frac{1}{2}\rho A v^2 C_d \tau$ (drag force)
$F_l = \frac{1}{2}\rho A v^2 C_l \tau$ (Magnus or lift force)

In this study, a skilled athlete performed repetitive kicks while researchers observed the path of the ball. The athlete was asked to produce kicks close to 25m/s at an angle of 16.5° from the horizontal. Researchers were able to determine the drag and lift coefficients for different shots; for example one series found F_d and F_l to be 0.25 and 0.23 respectively with a spin rotation of 83° about the y-axis, almost a perfect sidespin kick. In simulation free kicks parameters of F_d and F_l were 0.28 and 0.26 with perfect sidespin (90°) were chosen. In these settings it was seen how a one degree increase in the angle of kick (i.e. from 16.5° to 17.5°) greatly changed the outcome of the shot. In this example the ball cleared the wall as before but just barley made it under the crossbar of the goal. Any greater increase in angle would have caused the path of the ball to go to high. Similar outcomes occurred with changes in velocity. The increased angle shot attempted at a greater speed would cause the ball to follow a path that did not go into the goal. The spin put on the ball creates the Magnus force and is manipulated to make the ball curve toward the goal. The kicker must predict these fluid forces to land the ball in the goal.

New Ball

Adidas and Loughhorough University's Sports Technology Research Group are working together on improvements that will produce a much rounder ball, making its performance and trajectory truer and more consistent. Players have compared the "+Teamgeist" ball to that of a baseball, being much livelier and faster. Among the improvements is a much smoother surface which will make the ball less susceptible to the effects of Bernoulli's Principle. Less turbulence will be created, but less curving will be possible with the new ball.

Summary

Many factors must be considered in order to execute an effective free kick: velocity, angle, and spin (which effects drag and lift). Skillful leg kinetics and kinematics can be manipulated so that the ball can go around a wall and still go into the goal.

References

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