CONSISTENCY IN KINEMATIC MOVEMENT PATTERNS AND PREDICTION OF BALL VELOCITY IN THE FOOTBALL PLACEKICK

Carole J. Zebas
J. Dirk Nelson
University of Kansas
Department of HPER
Lawrence, KS 66045

Football games can be won or lost "off the foot" of a kicker. It may be a point after touchdown (worth 1 point) or a field goal (worth 3 points). The keys to the success of a kick depend on the strength/power of the kicker's leg and the accuracy with which he can kick the ball through the uprights.

Strength and power in the kicking leg can be gained through a well-designed weight training program. Accuracy can be developed through the knowledge and application of proper mechanics in the kicking motion. Consistency in scoring points comes with repetitious practices.

The description of the biomechanics of kicking in football has been documented in the literature (Becker, 1963; Bunn, 1972; Dodd, 1954; Marshall, 1958; Roberts and Metcalfe, 1968). The early studies examined the straight approach kick since that was the style used in the 1950's and the 1960's. In the early 1970's, two Hungarian brothers, Ed and Pete Gogolak, began a new trend in kicking extra points and field goals called the soccer style kick. A comparison of the straight approach kick and the soccer style kick was the subject of a number of other studies (Bona, 1963; Coffer, 1977; Manzi, 1967; Plagenhoef, 1971). Attention also was focused on the factors affecting the kick for distance (Marshall, 1958) and velocity (Macmillan, 1975; Plagenhoef, 1971). Results regarding factors affecting ball velocity are varied primarily because of the biomechanical parameters examined and the style of kicking used (i.e., straight approach, soccer-style, soccer, and Australian football drop kick).

Only one study could be found in which the issue of consistency in the kicking movement pattern was studied. Phillips (1983) addressed the problem of "operational interrelationships between mechanical variables" in a study of elite kicking performances. She concluded that elite performers tended to be consistent in their kicking motion over several trials. This was supported in a similar study of bowling (Murae et.al., 1973). During a personal conversation with a premier kicker from the National Football League, Nick Lowery (1987) of the Kansas City Chiefs, made a statement supporting these conclusions. He further went on to say that the kicking motion needed to remain consistent no matter from where on the field the kick was made. No literature or research studies were found in support of this statement.

Purposes

An elite soccer style placekicker from the National Football League volunteered to be a part of this study: (1) to determine the kinematic consistency of the placekicking motion from 20,30, and 50 yards; and (2) to determine the biomechanical parameters which best predict final ball velocity in a placekick from these three designated distances.

Methods

Two cameras back and side views, were used to film (100 fps) the kicker from 20, 30, and 50 yards from the goalpost. Nine successful kicks, three from each distance, were subsequently used for computer and statistical analysis. The data were smoothed with a cubic spline routine. A descriptive analysis was applied to selected biomechanical parameters in the kicking motion in the sagittal plane. A stepwise regression was performed on these parameters using ball velocity as the dependent variable.

Results and Sicsussion

The subject of this study is considered to be an elite kicker in the National Football League. He currently is an active player and is highly regarded for his accuracy in kicking field goals. Based on ball velocity (35.65 m/s) and angle of projection (29-33 degrees), he compares favorably with elite performers in other studies.

Study	Ball Velocity	Angle of Projection
Colfer, 1977	28-32 m/s	25-35 degrees
Phillips, 1985	20-31 m/s	25-36 degrees
Plagenhoef, 1971	25-29 m/s	

TABLE 1. MEANS AND STANDARD DEVIATIONS OF THE BIOMECHANICAL PARAMETERS IN KICKING.

PARAMETER	20 yds	30 yds	50 yds	Combined
Ball velocity	33.9 m/s (2.6)	36.8 m/s (0.0)	36.0 m/s (.9)	35.6 m/s (1.9)
Angle of projection	33 deg (3)	31 deg (2)	29 deg (1)	31 deg (2)
KFB	106 deg (4)	107 deg (1)	112 deg (3)	108 deg (4)
KFC	133 deg (2)	136 deg (2)	131 deg (3)	134 (3)
HFC	133 deg (7)	131 deg (1)	131 deg (6)	132 deg (5)
Last step	1.5 m (.01)	1.5 m (.04)	1.5 m (.02)	1.5 m (.02)
Foot to ball	.04 m (.02)	.11 m (.02)	.13 m (.02)	.09 m (.04)
TVBC	359 d/s (19)	425 d/s (41)	421 d/s (35)	402 d/s (43)
TVAC	124 d/s (10)	122 d/s (14)	111 d/s (4)	119 d/s (10)
LLVBC	938 d/s (70)	926 d/s (14)	902 d/s (27)	922 d/s (42)
LLVAC	810 d/s (107)	837 d/s (28)	782 d/s (13)	810 d/s (60)
ADT	103 deg (1)	106 deg (1)	106 deg (0)	105 deg (2)
ADS	115 deg (2)	119 deg (1)	116 deg (1)	117 deg (2)
VRF	10.6 m/s (.4)	11.1 m/s (1.0)	10.7 m/s (.2)	10.8 m/s (.6)
BLV	1.57 m/s (.08)	1.77 m/s (.02)	1.93 m/s (.05)	1.75 m/s (.16)

Table 1 represents the mean and standard deviations of the biomechanical parameters for all kicks.

KFB = knee flexion at back position
KFC = knee flexion at contact
HFC = hip flexion at contact
TVBC = thigh angular velocity before contact
TVBC = thigh angular velocity at contact
LLVBC = lower leg angular velocity before contact
LLVAC = lower leg angular velocity at contact
ADT = angular displacement of thigh
ADS = angular displacement of shank
VRF = linear velocity of kicking foot
BLV - body linear velocity

Overall there was consistency in the kicking motion from within and over the three distances of 20 yds, 30 yds and 50 yds. An examination of the combined averages and the individual distance averages shows little variation in the kinematic parameters. This also was evident in the relatively small standard deviations.

The least variable parameter was the last step length as the kicker approached the ball. The average was 1.5 m for each distance, and when averaged over the three distances also was 1.5m. It should be noted that the step length was approximately 90% of the body height. This was slightly lower than data reported by Phillips (1983) in which the elite performer's step length (stride) was 119% of total body height. This also may be the difference between the straight approach kick and the soccer style kick.

Several other parameters showed a trend toward invariability between distances. Those were the parameters dealing with the flexion of the hip at contact, flexion of the knee at contact, thigh angular velocity before and after contact, lower leg angular velocity before and after contact, angular displacement of the thigh and shank, and the linear velocity of the kicking foot prior to contact.

The standard deviations for the angular velocity parameters appear to be much larger than the standard deviations for the other parameters. This is not too surprising considering the measurement error due to the sampling rate. Phillips (1983) also found this to be true.

Other parameters showed trends in the positive or negative direction as the distances from where the ball was kicked changed. The angle of ball projection decreased as the distance increased. Conversely, the distance from foot to ball of the plant foot (non-kicking leg) increased as the distances increased. This is in agreement with Cooper, et.al. (1982) who stated that the non-kicking leg should move forward closer to the ball when a low trajectory on the ball was desired. Note in this study that the foot started out ahead of the ball on the shortest distance and moved further forward ahead of the ball as the distances increased.

Another noteworthy trend was in the body's linear velocity prior to contact. The approach speed increased as the distances increased. This was supported in a study by Pike (1983) who observed the approach velocities of punters and the distances kicked. It would seem that a transfer of momentum from body to foot would occur, but this was not supported in this study. Perhaps the link is with other parameters not investigated here.

The ball velocity parameter showed consistency over the three distances. There was more variability within the three trials at the 20 yd distance than there was at the 30 yd and 50 yd distances. It could be that concentration is not as intense at this distance as it is for the other distances. The extra point kick (20 yd) is often referred to as an "automatic." Furthermore, distance is not the major focus of the kick so there could be an unconscious effort to swing the leg a little less vigorously through the ball.

Ball velocity is one of the key determinants in the distance a projectile travels. The second purpose of this study sought to explore the kinematic parameters which would best predict ball velocity. The results of the stepwise regression revealed three significant predictors ($p<.05$). Knee flexion of the kicking leg at contact accounted for 52% of the variance in ball velocity. An additional 28% of the ball velocity was accounted for by the lower leg velocity prior to the kick, and 12% by the length of the last step. Combined, these three parameters accounted for 92% of the variance in ball velocity.

These three parameters were in the group of other parameters showing kinematic consistencies within and between distances kicked. The importance of the knee flexion in developing lower leg velocity has been supported in the literature. It usually is referred to as knee extension which would be the case in a straight approach kicker.

Within the limitations of this study, the following conclusions were reached:

1. An elite placekicker does display a consistent kicking motion pattern no matter what the distance of the kick.

2. Given the results of the stepwise regression analysis, it

would behoove a coach or a player to concentrate and develop consistency in the positioning of the knee at ball contact in the last step of the non-kicking foot and in the lower leg angular velocity before contact.

References

Becker, J.W. (1963) *The mechanical analysis of a football place kick.* (M.A. thesis, University of Wisconsin.

Bona, R.C. (1963) *A comparison of the instep kick to the toe kick in football* M.S. thesis, Washington State University.

Bunn, J.W. (1972) Scientific principles of coaching. Englewood Cliffs N.J.: Prentice Hall, Inc.

Colfer, G. R. (1977) A cinematographical comparison of three selected field goal place kicking styles. (Ph.D., Texas A & M University, 1977).

Cooper, J. M (1982), Marlene Adrian, R.B Glassow. Kinesiology. St. Louis: The C.V. Mosby Company.

Dodd, R.L. (1954) Bobby Dodd on football. Englewood Cliffs, N.J.:Prentice Hall, Inc.

Macmillan, M.B. (1975) Determinants of the flight of the kicked football. Research Quarterly. 46 (1):48-57.

Manci, R. (1967) A Comparison of Two Methods of Place Kicking Football for Distance and Accuracy. (M.S. thesis, Springfield College.

Marshall, S. (1958) Factors affecting place-kicking in football. Research Quarterly. 29(3):302-308, October.

Murase, Y., et. al. (1973) Biomechanics in bowling. Fourth International Seminar on Biomechanics. The Pennsylvania State University.

Phillips, S.J. (1985) Invariance of elite kicking performance in Biomechanics IX-B. eds. D.A. Winter, et.al. Champaign, Illinois: Human Kinetics Publishers, Inc. 5B:539-542.

Pike, N.L. (1983) Variability of performance of skilled punters in football. Abstracts of Research Papers. AAHPERD Convention. Minneapolis, MN.

Plagenhoef, S. (1971) Patterns of Human Motion: A Cinematographic Analysis. Englewood Cliffs, N.J.: Prentice-Hall, Inc..

Roberts, E.M. and A. Metclafe. (1968) Mechanical analysis of kicking. in Biomechanics I. eds. J. Wartenweiler, E. Jokl, and M. Hobbelinck. Basel, Switzerland: S. Karge.