COMPARISON OF GROUND-REACTION FORCES WHILE KICKING A STATIONARY AND NON-STATIONARY SOCCER BALL

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This study examined the ground-reaction forces of the supporting leg when kicking a moving or stationary soccer ball with the dominant and non-dominant foot. Ten experienced female soccer players performed two kicks of each condition using a two-step approach. Resultant ground reaction forces were measures via a force platform and normalized for body mass. A 2X2 Repeated Measures ANOVA revealed no significant differences ($p>.05$) for the main effects or interaction. Variations in ball movement or the foot used in kicking do not appear to influence ground reaction forces of the supporting foot when kicking a soccer ball.

KEY WORDS: foot dominance, football, women

INTRODUCTION: Soccer or football, one of the most popular widely played sports in the world is a game in which 11 players on a team advance a ball by kicking or propelling it with any part of the body except the hands and arms. Because the ball is played primarily with the legs and feet, kicking is a crucial aspect of the game and likely a player's most valuable technical asset. The ability to move the ball up and down the field with both the dominant and non-dominant foot is crucial to overall success (Barfield, 1995). Since the game of soccer involves the moving of a ball, the soccer ball is not simply a stationary object. Thus an accomplished player must develop the skill of kicking a ball in all conditions the game may provide including a stationary or moving ball with either foot.

Several factors are associated with the success of kicking a soccer ball. These include an approach phase, placement of the supporting foot, the swing phase of the kicking foot, the contact phase, and the follow through phase (Ahrari, 1995; Wang and Weise-Bjornstal, 1996). The ball may be kicked in various ways, but the instep kick (over the shoelaces of the kicking foot) is considered to be the most accurate and powerful combination kick for passing and shooting (Ahrari, 1995; Barfield, 1995; Olson and Hunter, 1985; Wang and Weise-Bjornstal, 1996). Wang and Weise-Bjornstal (1996) suggested that the approach steps toward the ball should be in a straight line with the intended target. The last step of the approach should be long in order to create a longer distance for increasing the range of the kicking swing motion. The placement of the supporting foot should be along side of and slightly behind the center of the ball a distance of generally 5 to 15 cm depending on the player's size. Because the player's total body weight is supported on one foot it is important that the player maintains good balance with a smooth forward motion transition.

A starting position in which the kicker aligns at a 45° angle to an imaginary line that bisects the ball appears to be the favored position (Ahrari, 1996; Olson and Hunter, 1985). This angle is usually achieved by having the kicker move straight back two paces from the ball and two paces right or left of the ball depending on the preferred foot (Ahrari, 1996; Olson and Hunter, 1985). Furthermore, an approach of two steps appears to produce the highest degree of accuracy (Ahrari, 1995).

Saggini and Vecchiet (1994) analyzed the ground-reaction forces between male and female soccer players. The analysis of the ground-reaction forces showed similar results between the genders except for the first peak vertical force. The females' first peak of the vertical force was reduced by 15% body weight compared to the males. This difference was suggested to be due to greater flexibility of the females allowing greater dorsiflexion at the ankle and a damping of the impact (Saggini and Vecchiet, 1994).

Luhtanen (1988) found a relationship between the force impulse of the supporting leg and the release of velocity of the soccer ball. In a related study, Isokawa and Lees (1988) noted that the relationship between the ground-reaction forces and ball velocity varies with different approach angles. Peak foot and ball velocity is attained between 30 and 45°. Beyond an approach angle of 45° the weight shift of the body cannot be easily adjusted and the peak force and velocities rapidly decline (Isokawa and Lees, 1988).

Barfield (1995) noted no significant difference (p>.10) between dominant and non-dominant limbs among ground-reaction forces correlated with ball velocity when kicking a stationary ball. However, kinematic variables did differ between dominant and non-dominant limbs (Barfield, 1995).

Although there have been numerous studies investigating the biomechanics of kicking a stationary ball, research involving kicking a moving ball is not common. Therefore, the purpose of this study was to measure differences in ground-reaction forces between kicking a stationary and moving soccer ball with the dominant and non-dominant foot.

METHODS: Ten NCAA Division II female soccer players (Mean±SD Age = 19.3±1.2 years; height 170.2±3.2 cm; mass = 68.3±7.9 kg) volunteered as the subjects for this study. All subjects had a minimum of three years of playing experience (Mean 6±1.1 years) and only one subject was left foot dominant. All subjects signed informed consent documents in accordance with Institutional Human Subjects Review Committee Guidelines.

For the stationary condition the ball was placed immediately beside the front end of the force plate. A ramp (similar in appearance to the device used in bowling for children or disabled bowlers) was placed 1.5 m away at a 45° angle from the force plate center and used to initiate the movement of the soccer ball for the non-stationary condition. The ramp was moved to either side of the force plate at the intended direction of the kick according to whether or not the kick was dominant or non-dominant. For each condition, the subject was instructed to use a two-step approach at a 45° angle to the force plate. A white target was placed 6 m away from the force plate to provide a visible target. Following a self-selected five-minute warm-up, each subject practiced each type of condition several times to assure familiarity with all procedures.

Ground-reaction forces were determined at 500Hz using a force plate (Advanced Mechanical Technologies Incorporated, OR6-2000, Watertown, MA USA) mounted flush with the floor surface and connected to an amplifier (SCA3, Advanced Mechanical Technologies Incorporated, Watertown, MA USA) and streamed continuously through an analog to digital converter (Biopac Systems Inc. Santa Barbara, CA USA) to an IBM-compatible notebook computer and diskette. All data were filtered with a 10Hz High pass filter (Winter, 1990) and saved with the use of computer software (Acqknowledge 3.5.2, Biopac Systems Inc. Santa Barbara, CA USA). The ground-reaction forces were recorded in three components: vertical force (F_z), antero-posterior forces (F_y), and medio-lateral forces (F_x) and converted to a single resultant vector.

Each subject performed eight trials (two trials of each condition) in random order. The maximum, minimum, mean and standard deviation values of force relative to body mass are presented in Table 1. A 2X2 Repeated Measures Analysis of Variance (ball movement by foot dominance) was used to determine differences in peak ground-reaction forces relative to body mass.

RESULTS AND DISCUSSION: Values for the resultant ground-reaction forces relative to body mass are presented in Table 1. Results of the repeated measures ANOVA revealed no significant interaction (p >.10) between the conditions (dominant vs. non-dominant foot and stationary vs. moving soccer ball) in terms of peak ground-reaction forces normalized by weight. Furthermore there were no differences (p >.10) found for either of the main effects, dominant vs. non-dominant foot and stationary vs. moving soccer ball.

The results of the current study were in agreement with Barfield (1995) in that no differences were found for the main effect of dominant and non-dominant foot ground-reaction forces. Furthermore, ground-reaction forces were not found to differ (p >.10) for the main effect of the stationary vs. moving conditions. Indeed similarities with previous literature were observed despite the differences in examining resultant vs. individual force components, variations of ball movement, and/or the exact planting location of the supporting foot (Barfield, 1995; Isokawa and

Lees, 1988; Valiant, 1988).
A possible explanation for the lack of significant differences may be attributed to the set-up of the experiment. Because the start of the approach was the same for all trials (a two-step approach at a 45° angle) the subjects were performing essentially the same kick regardless of whether or not the ball was stationary or moving. Therefore, no significant differences ($p > .10$) were found. Another factor may be the subjects' experience (average of six years with a minimum of three) and the fact that they were playing at the collegiate level. Results may differ for less experienced subjects. In addition, because placement of the supporting foot on the force plate was not controlled, differences may occur in relation to kinematic variables or variables mentioned above.

Table 1 Ground-Reaction Forces Relative to Body Mass ($N \cdot kg^{-1}$) for the Supporting Foot While Kicking a Moving or Stationary Soccer Ball with the Dominant or Non-Dominant Foot (N = 10)

	Maximum	Minimum	Mean	SD
Non-stationary				
Dominant	12.97	2.62	7.41	3.09
Non-dominant	12.78	2.84	7.05	2.98
Stationary				
Dominant	11.24	2.82	7.76	2.66
Non-dominant	10.85	3.84	7.45	2.62

CONCLUSION: The similarities in ground-reactions forces of the supporting foot regardless of whether the ball was moving or not or which foot was used would indicate that foot support aspects are a minimal factor in explaining the variability of instep kicking of a soccer ball. This would suggest that other factors would provide more information with respect to this type of soccer kick. Previous research indicates that mass of the kicking foot, angle and speed of the approach, angle and speed of the kicking limb and experience of the kicker will influence velocity of a kicked stationary ball (Lees, 1996). Further study of these variables while kicking a moving ball appears warranted, as the majority of research has thus far dealt with a stationary ball.

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