B2-7 ID209

KINEMATIC COMPARISON OF KICKING A STATIONARY AND ROLLING BALL

Shannon Barnes[1], Thorsten Sterzing[2], Kevin Ball[1]

[1]College of Sport and Exercise Science, ISEAL, Victoria University, Footscray, Australia

[2]Li-Ning Sports Science Research Center, Beijing, China

Much biomechanical research has examined stationary ball kicking in soccer. However, most kicks in games are performed on a rolling ball. It is important to evaluate this kick as findings for stationary ball kicking might not transfer. The aim of this study was to compare stationary and rolling ball kicks. Nine skilled soccer players performed three kicks under four pre-kick ball conditions (stationary, rolling 30˚ relative to kick direction, rolling 90˚ relative to kick direction, dribbling). Lower body kinematics were captured using VICON Nexus (250 Hz), analysed in Visual 3D and compared via a factorial ANOVA. No significant difference existed for foot speed at ball contact, or leg kinematics between stationary and rolling ball conditions Further, kinematics did no change regardless of the approach angle of the ball indicating kinematics do not change regardless of pre-kick ball conditions. Future stationary-rolling ball comparison work should examine kinetics, support leg mechanics and foot to ball interaction.

KEYWORDS: Biomechanics, soccer, kick leg.

INTRODUCTION: Kicking is the most important skill in the game of soccer and is used for passing, shooting at goal and clearing the ball from defence. The kicking action has been described as a ‘throw-like’ motion (Putnam, 1991) due to its proximal to distal sequencing. Previous literature has identified and compared different kicking styles, foot-to-ball interaction, kinetics and ground reaction forces (Nunome, Ikegami, Kozakai, Apriantono, & Sano, 2006; Lees and Nolan 1998; Lees, Asai, Andersen, Nunome, & Sterzing, 2010). These studies have found important technical factors associated with performance, have evaluated mechanisms underlying elite kicking and have identified forces involved in the kick. While body of knowledge on soccer kicking is strong, it has predominantly focussed on kicking a stationary ball. This is an important skill in itself as penalties, free kicks and corner kicks involve striking the ball when it is stationary. However it is also important for a player to be able to kick the ball effectively whilst it is moving i.e. upon receiving a pass or running towards the goal. The research that has examined these two kicking conditions has focused on kicking in futsal and the effects of experience on coordination (Barbieri, Gobbi, Santiago & Cunha, 2010; Egan, Savelsbergh & Verheul, 2007, respectively). If differences exist in technique for kicking a stationary ball compared to a rolling ball, then this requires analyses be performed separately to identify mechanisms and performance factors. Thus the aim of the current study is to determine if kinematic differences exist between kicks performed on a stationary ball versus a rolling ball.

METHOD: Nine healthy sub-elite male soccer players (height = 1.82 ± 0.50 m, mass = 77.5 ± 10.5 kg, age = 21 ± 3 years) from the University Soccer Club took part in this study. Participants had a minimum of five years playing experience, minimum four hours weekly exposure to training and match play and were injury free for at least six months prior to testing.
Experiment protocol required the participants to perform three maximal kicks for each condition of the four conditions: stationary ball, rolling ball 30˚ relative to kicking direction, rolling ball 90˚ relative to kicking direction and dribbling directly towards kicking direction. For the stationary and two rolling ball conditions, participants were required to start at a line marked 2 m behind the kicking area on a 45˚ angle (2-3 step run up). For condition four

(dribbling) participants started at a line 5 m behind the kicking area at a 0˚ angle i.e. in the same direction as the kick. The order of kicking conditions were randomised between subjects to avoid potential learning effects. Each participant was allocated a fifteen minute warm-up followed by familiarisation kicks for each condition. Both T-shaped clusters, and individual reflective markers, each 14 mm in diameter (B&L Engineering, Santa Ana, USA), were applied to the body to facilitate three dimensional data collection as used in previous kicking studies for both soccer and Australian football (Ball, 2011). Anatomical landmarks and segments identified were the pelvis, hip, thigh, knee, shank, ankle and foot for both the kick and support leg. Overall a total of 36 markers were placed on each participant (12 static, 24 dynamic). Two FIFA approved size five soccer balls were used during the study. Two ramps were constructed to deliver the soccer ball during the rolling ball conditions 30˚ and 90˚. Both ramps had an elevation of 1.06 m, ramp angle 41.3˚ and produced a ball speed of 3 m/s (similar to the reported 3.2 m/s by Egan et al., 2007) Cardboard of 1.02 m in length was adhered to the end of the ramp and shaped so it slightly curved to eliminate the ball bouncing in transition from the ramp to the floor. To assist in maintaining consistency across all rolling ball conditions, the ball was held to the uprights at the top of the ramp then released with no propulsion so that the ball ran down the ramp with only the influence of gravity. Further, the same member on the research team remained on the ramps throughout the study. Finally each trial was visually observed to ensure the ball did not bounce off the ramp or prior to the kick. In the case of an unsuccessful trial, participants were asked to perform another kick under the same condition.

The player's kicking technique was captured during a single testing session using VICON Nexus 3D Motion Analysis System (OMG Plc, Oxford, UK) consisting of 10 cameras at 250Hz. VICON Nexus was used to reconstruct and label all three dimensional data collected and markers displaying visual gaps of no more than 10 frames were filled using the Woltring spline fill function within VICON Nexus (Reid, Whiteside & Elliot, 2011). Once labelled and interpolated all files from each participant were exported to Visual 3D software (C-Motion, Inc. Germantown, USA) for further processing. In Visual 3D, events were defined at toe-off of the kick foot, heel strike of support leg and instant before ball contact. Displacement data of individual markers was smoothed using a Butterworth Filter with a cut-off frequency of 12 Hz. This cut-off frequency was chosen based on residual analysis, spectral analysis and visual inspection of the data and with reference to previous kicking research within the laboratory. Variables were processed between kick leg toe-off to ball contact using a pipeline created in Visual 3D with the data then exported into Microsoft Excel and using custom-developed templates, individual, group means and standard deviations were collated for statistical analysis for each variable. The mean of the three kicks for each condition were averaged for each individual and then were used in group based analysis that was directly imported into SPSS (Version 20, IBM, New York, USA). A factorial ANOVA was conducted on the mean values for each variable to identify if significant differences exist.

RESULTS: Stationary kicking had the highest foot velocity (17.0 m/s ± 3.5) followed by dribbling (16.6 ± 3.8 m/s), rolling 30˚ (15.8 ± 3.8 m/s) and rolling 90˚ (15.7 ± 3.3 m/s). However there was no significant difference between conditions ($F = .066$, $p = .978$, $\eta_p^2 = .027$). Values for hip angle, knee angle and pelvis angle at ball contact, hip angular velocity and knee angular velocity at ball contact hip and knee range of motion from toe-off to ball contact are reported in Table 1. No statistical differences exist between all conditions across all parameters.

Table 1: Kick leg kinematics from toe-off to ball contact. (Flex = flexion, Ext = Extension, Abd = abduction, Add = adduction, M-L = medio-lateral, A-P = anterior-posterior)

	Stationary		Rolling 30		Rolling 90		Dribbling		F	p	η_p^2
	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Angle at BC (degrees)											
Hip Angle (Flex/Ext)	24.3	7.5	31.3	12.3	30.1	9.5	27.1	9.4	0.926	0.44	0.080
Hip Angle (Abd/Add)	-6.4	22.2	-4.5	20.2	-5.0	20.8	-4.4	20.9	0.016	0.997	0.002
Knee Angle (Flex/Ext)	51.1	12.5	50.9	11.1	50.1	15.4	58.2	12.6	0.746	0.533	0.065
Pelvis (M-L)	-21	9.6	-15.6	11.6	-17.6	11.3	-21	11.4	0.531	0.664	0.047
Pelvis (A-P)	2.0	10.0	0.1	9.2	-0.5	8.5	-2.2	6.1	0.326	0.781	0.033
Pelvis (Vertical)	153.1	7.9	148.5	9.4	145.4	9.2	153.4	7.7	0.002	0.999	0.001
Angular Velocity at BC (degrees/second)											
Hip Angular Velocity (Flex/Ext)	118.9	119.3	125.8	150.6	100.4	163.6	162	125.1	0.303	0.823	0.028
Hip Angular Velocity (Abd/Add)	182.8	168.6	189.8	137.3	192.0	148.5	199.0	195.0	0.015	0.997	0.001
Knee Angular Velocity (Flex/Ext)	1363	345.1	1146.0	292.5	1142.0	301.9	1225	424.1	0.794	0.506	0.069
Range of Motion (degrees)											
Hip Max-Min (Flex/Ext)	41.5	8.0	43.4	9.1	42.1	5.8	42.2	6.7	0.164	0.850	0.013
Hip Max-Min (Abd/Add)	19.3	4.9	16.6	7.1	15.7	7.2	17.3	6.6	0.114	0.892	0.009
Knee Max-Min (Flex/Ext)	92.1	15.0	82.9	16.7	79.5	15.2	89.3	15.2	0.575	0.570	0.046
Knee Max-BC	50.1	10.7	44.1	6.0	44.7	13.0	41.7	15.0	0.225	0.800	0.018

DISCUSSION: Kick leg kinematics did not change when kicking a stationary or rolling ball, nor did they change for different rolling ball approach angles or dribbling. No significant differences were evident between kick conditions and only three medium (no large) effect sizes existed across the eighteen variables. The strongest of these (hip flexion/extension angle at ball contact) was significant at p = 0.44 only suggesting the relationship is a considerable distance from being significant at $p < 0.05$. Further, hip and knee movement patterns were very similar between conditions. This is seen in Figure 1, showing both hip and knee angular velocity time profiles from toe-off until ball contact. These results are supported by previous research examining stationary and rolling ball kicks (Barbieri et al, 2010, Egan et al. 2007) and suggest that findings for kinematic analyses of stationary ball kicking are applicable for kicking a rolling ball.

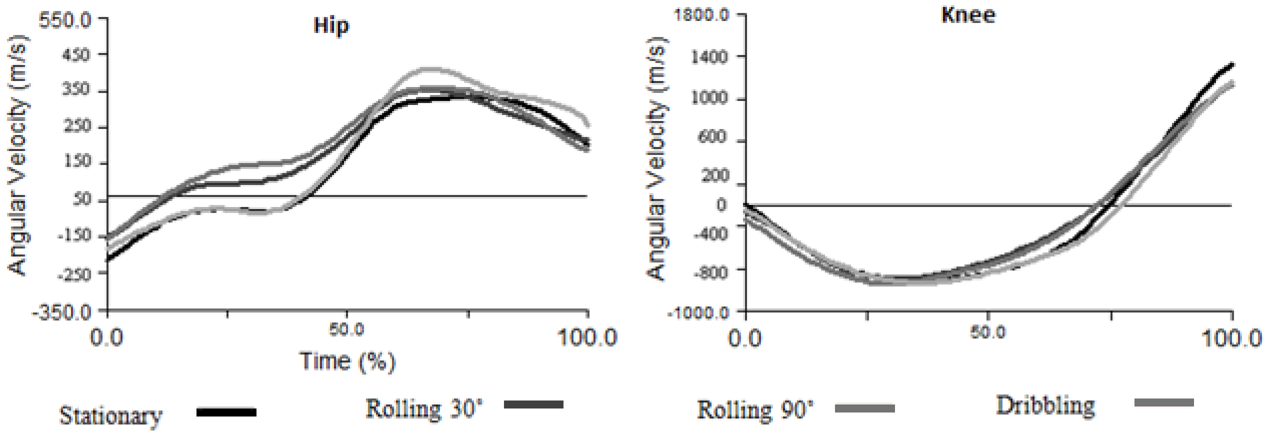

Figure 1: Hip and knee angular velocity curve for kicking under all four conditions.

Previous research has suggested the lack of difference between stationary and rolling ball mechanics might be linked to the generalised motor programme proposed by Schmidt and Wrisberg's (2000). Barbieri et al. (2010) suggested players may use the same motor program for each kick and only make slight adjustments to perform under all conditions. The change in condition and approach angle requires the participants to reprogram an existing motor act with modifications of its original spatiotemporal specifications (Teixeira, Lima & Franzoni, 2005 Van Sonderen, Deniervan der Gon and Gielen (1988), reported that modification of motor parameters is a continuous rather than discrete process. They concluded that modifications of a motor act was an ongoing process and that the original process was not completely inhibited nor replaced by a new set of specifications, but gradually adjusting over time. Egan et al. (2007) also considers coordination pattern as a reason for the similarities between the two kicking conditions although given the similarities

Further research is required to compare possible differences between kicking a stationary and rolling ball. First, the kinetics of the kick leg need to be evaluated to determine if differences exist in joint moments and power as previously reported by Nunome, Asai, Ikegami &Sakurai (2002) for stationary ball kicking. Secondly, foot to ball interaction might be expected to change given the ball has initial velocity in the rolling ball conditions. The support leg and upper body were not evaluated in this study but might also be worth evaluating for differences in both kinematic and kinetic studies. Finally different approaching rolling ball speeds might be expected in games. These could be assessed as faster speeds might be expected to increase the complexity of the interceptive action and possibly require technical change to accommodate this complexity.

CONCLUSION: No significant differences exist for foot velocity, hip and knee kinematics of the kick leg in soccer, between kicking a stationary and rolling ball. Also kick leg kinematics do not significantly change in relation to the angle of ball approach. Based on this, previous research examining kinematics of stationary ball kicking could be generalised to kicking a rolling ball.

REFERENCES

Ball, K. (2011) Kinematic comparison of the preferred and non-preferred foot punt kick. *Journal of Sport Sciences*, 29(14), 1545-1552.

Barbieri, F. A., Gobbi, L. T., Santiago, P. R., Cunha, S. A. (2010) Performance comparisons of the kicking of stationary and rolling balls in a futsal context. *Sports Biomechanics*, 9(1), 1-15.

Egan, C., Savelsbergh, G., Verheul, M. (2007) Effects of Experience on the Coordination of Internally and Externally Timed Soccer Kicks. *Journal of Motor Behaviour*, 39(5), 423-432.

Lees, A., Nolan, L. (1998). The biomechanics of soccer: a review. *Journal of Sports Science*, 16(3), 211-234.

Lees, A., Asai. T., Andersen, T.B., Nunome, H., Sterzing, T. (2010) The biomechanics of kicking in soccer: A review. *Journal of Sports Sciences*, 28(8), 805-817

Nunome, H., Asai, T., Ikegami, Y., Sakurai, S. (2002). Three-dimensional kinetic analysis of side-foot and instep soccer kicks. *Medicine and Science in Sports and Exercise*, 34(12), 2028-2036.

Nunome, H., Ikegami, Y., Kozakai, R., Apriantono, T., Sano, S. (2006) Segmental dynamics of soccer instep kicking with the preferred and non-preferred leg. *Journal of Sports Science*, 24(5), 529-541.

Putnam, C.A. (1991). A segmental interaction analysis of proximal-to-distal sequential segment motion patterns. *Medicine and Science in Sports and Exercise*, 23, 130-144.

Schmidt, R. A., and Wrisberg, C. A. (2000). Motor learning and performance. A problem-based approach. Champaign, IL: Human Kinetics.

Teixeira, L.A., Lima, E.S., Franzoni, M.M. (2005) The continuous nature of timing reprogramming in an interceptive task. *Journal of Sports Science*, 23(9), 943-950.

Van Sonderen, J. F, van, Denier van der Gon. J. J., & Gielen, C.C. A. M. (1988) Conditions determining early modification of motor programmes in response to changes in target location. *Experimental Brain Research*, 71, 320-328.