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Biomechanical analysis of accuracy penalties-kicking performance for Turkish Soccer players: Group-based analysis without goalkeeper

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Abstract

Background and Study Aim: It is stated that kinetic performance factors are important in the successful execution of accurate kick-penalties, thus, its offer excellent performance despite a substantial kinetic method change in their implementation. The aim of the study is to biomechanical analysis of accuracy penalties-kicking performance for Turkish soccer players.

Material and Methods: The study group consisted 15 male students of Turkish Regional Amateur League players (Age: 21.08± 1.56 years old). Two video cameras placed at optical axes X&Y filmed penalty-kick performance of the subjects. we analysed the best three scores by video analysis Dartfish 9.0 software. Standard statistical methods were used for the calculation of mean±SD. the Statistical significance at p<.05 for Pearson product—moment correlations.

Results: Accurate penalty-kicks showed significant positive relationship of knee Pi angle value in backswing, ball Contact phases, trunk angle value in ball contact with the accuracy at p<.01. Significant negative relationship of inclination_body angle value, time of foot contact at p<.01, and distance pivot foot&ball value at p<.05 in the follow-through phase.

Conclusions: Such knowledge should aid in clarify the relationships between variables of penalty kicking during The performance phases and accuracy. the present preliminary investigation of accurate penalty-kicks performance indicates Support-leg characteristics demonstrated in knee angle values an important factor in Backswing, Ball Contact phases with the accuracy of penalty kicking. also, the Foot Contact time and Inclination_Body angle in that.

Keywords: biomechanics, kicking, penalty, accurate, soccer.

Introduction

Soccer is one type of sports game [1]. Today, soccer is becoming very popular throughout the world [2, 3]. It is a ball sport with many demands on the basic technical and tactical skills of the individual player [4], namely dribbling techniques, kicking techniques, and passing techniques [5]. The soccer kick is considered the most powerful of the playing techniques [6, 7]. There are many factors that influence the success of a ball kick, but the three dominant factors to consider are accuracy, strength, and swing [8, 9].

In a most studies [10–13], soccer kicks is accounted the important actions in the game, but a powerful kick is not always a successful one because accuracy has a bearing on a kick's success for goal scoring. Seeing the importance of the accuracy of ball kicking in soccer games, research is needed to improve the performance of soccer players when shooting the ball [14]. Especially the penalty kick, as the probability to score on a penalty kick in soccer is about 80% [15], the importance of penalty kicks is underpinned by the fact that the average number of goals in professional soccer is about 2.5–2.7 [15, 16].

In the following decades, penalty shootout has become the standard tie-breaking procedure in knockout tournaments [17]. Therefore, variations of kick penalties performance become an important factor as a football player [18]. Since most penalties are predicted successful, the player taking the kick is usually under great mental pressure [19], especially facing a goalkeeper who is might be known to be good, when a penalty miss could mean the immediate loss of the match. According to the current rulebook of soccer, laws of the game 2019/20, "when competition rules require a winning team after a drawn match or home-and-away tie, the only permitted procedures to determine the winning team are: (a) away goals rule; (b) two equal periods of extra time not exceeding 15 minutes each; (c) kicks from the penalty mark" [5]. Thus, research examining accuracy in penalty-kicking in other tasks is also in constant development [20–22]. Penalty shootouts performance have inspired

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many academic researchers to investigate the issue of kinetic performance, the accurate in shooting, as they offer excellent performance despite a substantial kinetic method change in their implementation [23].

In our opinion, the course of movement of the body is an important factor [24, 25] in the successful execution of kick-penalties, besides, there are many principle of physics in soccer games [26–28]. One of application of physics in soccer game is when someone kick the ball [7, 29]. The kicking motion of the ball is included in the biomechanics [14]. Biomechanics is the main field of objective research into the mechanical and technical rules relating to the movement, methods of various kinetic skills [30, 31]. So an analysis of the biomechanics of the specific skills that are performed [32, 33] by soccer athletes permit optimal sports performance [26, 34]. In particular, we address the performance of penalty shootouts in soccer (biomechanical of penalties kicking) from this point of view.

The aim of the current study was to biomechanical analysis of accuracy penalties-kicking performance for Turkish soccer players. To do so, kinematical variables of performance, results of accuracy test for penalty-kicking were determined in these tasks without goalkeeper. Wehypothesized that, during the performance of penalty-kicking without goalkeeper, the values of variables analysed would be increase.

Material and Methods

Participants.

15 male universities students of $\mathbf{T}_{\text{urkish}}$ $\mathbf{R}_{\text{egional}}$ $\mathbf{A}_{\text{mateur}}$ $\mathbf{L}_{\text{eague}}$ players (eight right-footed and Seven left-footed) participated as the subjects in this study (Age: 21.08± 1.56 years old, Experience: 10.81± 2.09 years old, Body Mass: 68.85± 6.89 kg, Size: 1.76 ± 0.06 m). To represent a higher skilled cohort of penalty-kickers, all participants were competing regularly in competition and performed of penalties-kick during a match (full forwards, half forwards and center line players). In addition, all participants were in good health (no injuries which could alter kicking performance in penalties) in the previous six months. The study complied with the Helsinki declaration for human experimentation and the participants provided written consent to participate with the condition of keeping personal data secret like names...etc. Approval to conduct the study was obtained from the Ethics committee institute of Physical Education at the Abdelhamid Ibn Badiss University of Mostaganem, Algeria.

Research Design.

Two video cameras filmed penalty-kick performance in rectangular frame and capture area 5*4 m, these cameras were placed at optical axes X and Y. Camera1: canon EOS 700D, video resolution: 4 megapixels (2304x1728 pixels), recording speed: 25 fps/50fps, 6.5 m perpendicular to the front plane of the ball, with altitude 0.77 m for Right Lateral View. Camera2: Fujifilm NINEPIX HS35 EXR, video resolution: 1808p, recording speed: 25 fps/50 fps, 5 m perpendicular to the front plane of the ball, with altitude 0.9 m for posterior view (Figure 1). The subjects wore reflective markers to track their motions. Markers were applied in three places on the lower legs (hips, knees, and ankle), and Down the neck with the least possible number of occlusions. In order to measure the accuracy of the penalty-kick, the players were asked to kick a ball with their dominant leg towards a football goal (FIFA regulations; 2.44 m high and 7.32 m wide) placed 11 meters away (penalty). The video analysis was done by Dartfish 9.0 software.

The study was conducted on the football stadium of the Faculty of Sports Sciences at Selçuk University in Konya, Turkey. at 13^{h}45. The weather was; -2°Temperature, 64% Humidity, 81% cloud cover, 11.3^{km} visibility, 3.4km/h wind, 1012.0mb pressure, -8° dew point. In the penalty kick scenario, the subject chooses a space in goal for kicking penalty (Figure 2), then he tries to kick ball in space chosen. We have a drip ladder for that: a/ three (03) points if kick's the ball into the chosen space. b/one point (01) if kick's the ball into any of the side spaces of the chosen space. Without that, we give him zero point (00). Every subject performed five (05) trials with the best three (03) scores recorded for analysis. All kicks were in the legal position defined by FIFA's laws.

All data collected by cameras enabled kinematic computations using Dartfish 9.0 software. The data provided by the analysis system displayed a two-dimensional model. The measurements of position vectors matched the origin of each reflective marker. In this study, The Variables kinematical were Analysed through each phase of Soccer penalty kick phases; Approaching, The Backswing, Ball Contact, Follow-through. Refer to Figure 3 for shows the variables analysed.

Statistical Analysis: All results were analysed using

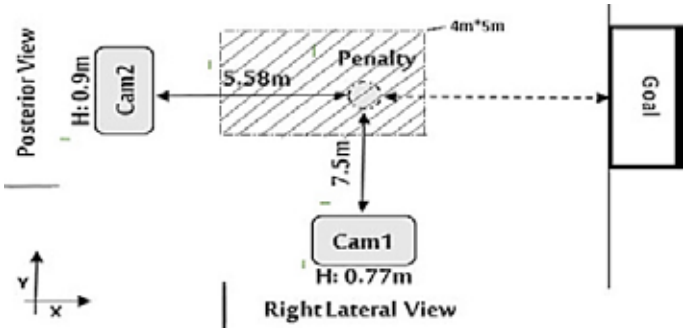

Figure 1. The method chosen to calculate the variables analysed in two-dimensional.

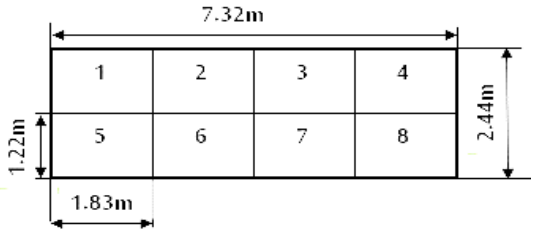

Figure 2. Spaces chosen for Accuracy penalty-kicking test.

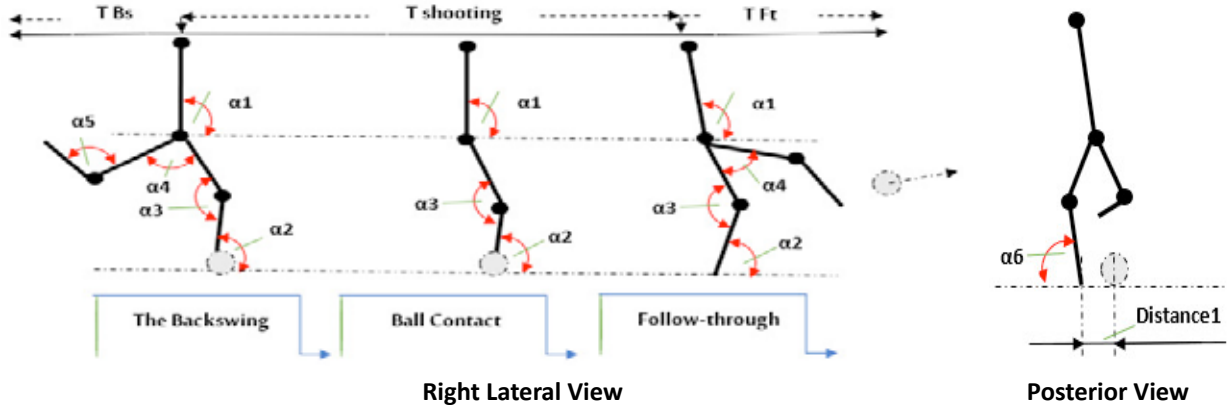

Figure 3. (α1) Trunk°**/ (α2 Pivot foot)** Knee° Pi **/ (α3)** Shank° **/ (α4)** Thighs° **/ (α5 Shoot foot)** Knee° Sh **/ (α6)** Inclination Body° **/ (Distance ᵐ);** Distance Pivot Foot &Ball **/ (Time ˢ);** T Beginning, T Back Swing, T FootContact, T Follow-Through

SPSS software (version 20.0; SPSS, Inc., Chicago, IL) in p value was set at p<.05. We based on Standard statistical methods were used for the calculation of mean ± SD. While Pearson product—moment correlations were used to assess the relationships between variables. Shapiro-Wilk and Levine were accompanied to analyse the normality and homogeneity of our total sample.

Results

Descriptive Analysis. The mean, standard deviation, minimum and Maximum values of variables analysed during penalty kicking performance are shown in Table 1, that in each phase of Soccer penalty kick performance phases (The Backswing, Ball Contact, Follow-through). In addition, the table 2 shows the significant correlations coefficients between variables analysed in all phases of penalty-kicking performance and point achievements of Accuracy test.

The statistical analyse results of the study show that there are a significant correlations, as follows:

**Accuracy (point achievements).* Accuracy kicking test results shows that there are obvious significant correlations between the achievements points and variables of performance analysed in all phases of penalty-kicking performance; positive correlation of the achievements points with knee pi angle at level .01 and with time of back swing at level .05 in the backswing phase. In the ball contact phase, positive correlation of the achievements points with trunk and knee pi angles. Also, negative correlation with inclination_body angle and the time of foot contact at level .01. And with the distance pivot foot&ball at level .05. In the follow-through phase, positive correlation of the achievements points with trunk angle in level .05, and with thighs angle at level .01.

**The Backswing.* At level .01, Positive correlation of Shank angle with the Knee Pi and Sh angles. And negative correlation of Trunk angle with the Thighs angle.

**The Backswing & Ball Contact.* Negative correlation of the Beginning time with Trunk angle and Distance Pivot Foot&Ball at level .05, and with Inclination Body angle at level .01. Positive correlation of Trunk, Shank and Knee Pi angles in the Backswing and Ball Contact phases at level .01. Positive correlation of Shank angle with Knee Pi angle, and at level .05. negative correlation of Knee Pi angle with Foot Contact Time, and Knee Sh angle with Inclination Body angle at level .05. also, angle of Thighs with Inclination Body angle at level .01.

**The Backswing & Follow-through.* Positive correlation of Trunk, Shank and Knee Pi angles in the Backswing and Follow-through phases at level .01. and between Knee Pi angle and Shank angle at level .05. Negative correlation of Knee Sh angle with Thighs angle at level .01, and For this last one with Back Swing Time at level .05.

**Ball Contact.* at level .01, Positive correlation of Shank angle with the Knee Pi angle. and the Inclination_ Body angle with the Distance of PivotFoot&Ball.

**Ball Contact & Follow-through.* at level .01, Positive correlation of Trunk, Shank and Knee Pi angles in the Ball Contact and Follow-through phases. Also, Knee Pi angle with Shank angle, and the Inclination_Body angle with the Thighs angle.

Table 1. Mean, standard deviation, minimum and Maximum values of variables

Variables	Mean ± Std.D	Min	Max
Points	2.839±1.225	1.000	3.000
The Backswing			
T Beginning	1.822±0.906	0.400	4.520
Trunk°	96.806±4.420	87.000	106.000
Shank°	94.528±5.433	83.000	111.000
Knee° Pi	144.111±9.639	123.000	159.000
Knee° Sh	92.194±18.279	43.000	126.000
Thighs°	73.917±10.691	58.000	109.000
T Back Swing	1.133±0.390	0.560	2.240
Ball Contact			
Trunk°	103.889±6.735	87.000	118.000
Shank°	78.611±7.256	68.000	106.000
Knee° Pi	133.861±11.041	107.000	156.000
Inclination Body°	65.167±7.284	52.000	77.000
Distance Pivot Foot &Ball	0.272±0.037	0.200	0.340
T Foot Contact	0.133±0.018	0.120	0.160
Follow-through			
Trunk°	107.917±10.573	81.000	128.000
Shank°	66.500±10.627	45.000	102.000
Knee° Pi	128.500±14.328	100.000	154.000
Thighs°	62.389±31.523	10.000	117.000
T Follow Through	0.412±0.209	0.160	0.840

**Follow-through.* Positive correlation of Shank angle with Knee Pi angle, Thighs angle with the time of Follow Through at level .01. in addition, at level .05 there are Positive correlation of Trunk angle with Thighs angle, and Shank angle with time of Follow Through, and Knee Pi angle with Thighs angle and with time of Follow Through.

Discussion

The results obtained showed the importance of body kinetic course like an important factor in the performance of accurate penalty-kicks. And because the soccer penalty-kick performance is a complex movement being the result of multiple movements coordination performing for kicking the ball with accuracy [26]. We referred to the characteristics in the kinetic performance and their relationships with the accuracy and coordination in penalty-kick. And this coordination of the movement needs stability [14, 35] in kinetic groups [36].

Previous literature in ball kicking, identified that accurate kickers had greater pelvic tilt and hip flexion [5, 37, 38]. Thus, the players lower centre of gravity during the penalty-kick, helping to stabilise and balance the player throughout the kick [29, 39]. This finding suggests conditioning the support leg to maintain a more flexed position during kicking may contribute to kicking accuracy. Increased kick-leg knee flexion is required to ensure the foot does not strike the ground during the penalty-kick, with the lower kicking position [6]. This explanation is partly supported by the knee and trunk angles reported in this study compared those reported from [40]. Accurate kicking requires control and regulation of the kick-leg motion during the kicking phase [14]. Accurate kicks were associated with moderately less hip and knee , with slower knee and shank angular velocities throughout the kicking phase [41].

In addition, minimal corelations were reported in hip and pelvis kinematics of accurate penalty-kicks in this study. Further, in previous literature the players demonstrated slower foot speeds and shank angular velocities during accurate penalty-kicks, representative of a speed-accuracy trade-off [42, 43]. Accurate kicks had greater support knee flexion, with increased knee flexion during the swing phase in the kick-leg [44]. Support and kick leg knee kinematics were found to be associated with kicking accuracy in all players. Support-leg knee motion is important for kicking accuracy, supporting previous findings in kicking [37]. These findings are in agreement with our results.

Another possible explanation may be that when kicking over shorter distances players might have purposely attempted to increase the relative target area by adopting a flatter ball flight trajectory to improve accuracy [45]. Also, the mechanism adopted by players to regulate and control the intersegmental movement of the kick-leg to optimise foot position during impact, helping to control the ball flight trajectory in an accuracy task [46]. It is possible that this represents a continuum of technique strategy. However, these findings are in contrast

Table 2. The correlation coefficient of variables.

Points		
The Backswing	Knee°Pi	.001**
	T Back Swing	.046*
Ball Contact	Trunk°	.003**
	Knee°Pi	.000**
	Distance Pivot Foot&Ball	-.026*
	Inclination_Body°	-.003**
	T Foot Contact	-.001**
Follow-through	Trunk°	.034*
	Thighs°	.005**

The Backswing								
The Backswing	**Variables**	**T Beginning**	**Trunk°**	**Shank°**	**Knee° Pi**	**Knee° Sh**	**Thighs°**	**T Back Swing**
	Knee°Pi			.006**				
	Knee°Sh			.004**				
	Thighs°		-.004**					
Ball Contact	Trunk°	-.035*	.007**					
	Shank°			.004**	.037*			
	Knee°Pi			.037*	.005**			
	Inclination Body°	-.005**				-.038*	-.004**	
	Distance Pivot Foot&Ball	-.036*						
	T FootContact				-.033*			
Follow-through	Trunk°		.000**					
	Shank°			.039*	.043*			
	Knee°Pi				.511**			
	Thighs°					-.004**		-.030*

Ball Contact					
Ball Contact	**Variables**	**Trunk°**	**Shank°**	**Knee°Pi**	**Inclination_Body°**
	Knee°Pi		.004**		
	Distance PivotFoot&Ball				.003**
Follow-through	Trunk°	.000**			
	Shank°		.001**	.001**	
	Knee°Pi		.005**	.000**	
	Thighs°				.004**

Follow-through					
Follow-through	**Variables**	**Trunk°**	**Shank°**	**Knee°Pi**	**Thighs°**
	Knee°Pi		.001**		
	Thighs°	.039*		.071*	
	T FollowThrough		.034*	.025*	.001**

*Correlation is significant at the P<0.05 level.

**Correlation is significant at the P<0.01 level.

to [42, 47–49], who reported a more extended support leg knee was correlated to larger foot speeds for kicking distance. Also in [37, 50, 51] lifting the whole-body upward through the motion of the support leg (through knee extension) has been identified as an effective action to help generate faster foot speed's through achieving a more extended kick-leg (and hence a longer lever arm) during the swing phase .

These inconsistencies may be indicative of different strategies adopted by players when penalty-kicking performance for accuracy. Also, these findings may be indicative that variations in the task constraints leads to significant changes in the movement pattern required to complete the task. In addition, this is important as coaching recommendations may need to be tailored to the individual rather than applying a theoretical model of 'good' technique. The ball kicking accuracy may be affected by the positions of the body joints during the

performance. Thus, we recommend our coaches to focus on the biomechanical details during penalty-kicking performance, in order to achieve accuracy in kicking and goal. As well as a group-based analysis, supporting previous work in rugby goal-kicking. Future work with a larger samples should examine if differences exist for technical method in penalty-kicks performance, and to determine if results can be generalised or whether accuracy are made dependent on kinetic performance the penalty-kick.

Conclusion

The present preliminary investigation indicates where the use of kinematical analysis technology was effective in clarifications the relationships between variables analysed during penalty kicking phases (backswing, ball contact and follow-through) and accuracy. Support-leg characteristics demonstrated in knee angle values a significant positive relationship in backswing, ball contact phases with the accuracy of penalty kicking. Also, angle values of trunk in ball contact and follow-through phases. Accurate kicks demonstrated lower hip and knee flexion. At the end of follow through, and it is an important factor. During the ball contact phase, accurate penalty-kicks were associated with foot contact time and inclination_body angle. Also, with thighs angle in follow-through phase. In addition, a number of substantial linear relationships were reported between technical parameters analysed and accuracy. Many factors of movement course of the body were found to interact with accurate penalty-kicking, ranging from a backswing phase, ball contact, kick-leg swing motion, through to the end of follow through. Also, our results showed, the gradual decrease in the knee angle of the support-leg during the performance phases 144.11°, 133.86°, 128.50° in succession, and this indicates a decrease in the path of the body gravity center during the performance. This decrease is offset by a gradual increase in trunk angle during the performance 96.806°, 103.889°, 107.917°. Where it was confined between 81°and 128°. The researchers attribute this to the increase in the inclination body angle , as this may be in order to increase the accuracy degree in penalty-kicking on the sides of goal. The ball kicking accuracy may be affected by the positions of the body joints during the performance. Thus, we recommend our coaches to focus on the biomechanical details during penalty-kicking performance, in order to achieve accuracy in kicking and goal.

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Conflict of Interests

The authors have no conflict of interests to declare.

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