

Key Performance Indicators and Individual Factors on Penalty Kicks



Joao Fialho

Abstract In the recent years quite a few papers have been dedicated to the study of penalty kicks in soccer. With either the intent of predicting the direction or the final outcome of the kick, several different factors have been analyzed, from kinematics, biomechanics, stress levels, individual skills and fatigue as just some examples. In this paper, the author studies a group of four different international soccer players with the objective of identifying key performance indicators on kicks from the penalty spot. Using data analysis techniques, with emphasis on Cramer's V correlation and hypothesis testing, several variables are analyzed, with the intent of identifying global and individual factors, that might provide a signal for which side of the goal post the penalty kick will be aimed at. This study's primary objective is then to provide the goalkeeper with some attributable information that can be used in his advantage, to predict the side for where the penalty is more likely to be aimed at.

Keywords Penalty kicks · Sports analytics · Individual performance indicators in football

1 Introduction

When analyzing a soccer match, one can not exclude the penalty kick. Even more when one specifically considers World Class tournaments, such as the World Cup, European Cup, Champions League, or other international competitions, the penalty kick becomes even more important, as the knockout stages or and even the trophy are sometimes decided on penalty shootouts.

According to informal statistics collected by ESPN, the current rate of conversion of penalty kicks, ranges from 70 to 80%, depending on the League or tournament

J. Fialho (✉)
British University of Vietnam, Hanoi, Vietnam
e-mail: joao.f@buv.edu.vn

Centro de Investigacao em Matematica e Aplicacoes (CIMA-UE),
University of Evora, Evora, Portugal

© Springer Nature Switzerland AG 2021

D. M. Kilgour et al. (eds.), *Recent Developments in Mathematical, Statistical and Computational Sciences*, Springer Proceedings in Mathematics & Statistics 343, https://doi.org/10.1007/978-3-030-63591-6_13

being played. In addition to this high conversion rate, it takes on average 400 ms for a ball to reach the top corner, with an average shot speed of 113 km/h, as shown in [3]. The goalkeeper needs 100 ms to process plus 100 ms to decide and initiate movement, and then needs 700 ms to jump and try to reach the ball.

With this information, it becomes clear that, currently, the advantage is on the kicker side, not on the goalkeeper, whether we are looking at response time or even at the current estimated efficiency percentage. It becomes important to counteract this advantage. In order to do so, several papers and authors approach the penalty kick in soccer using several different paradigms, such as biomechanics and kinematics [6–8, 10] or psychology [2, 5, 11], as examples. However as they aim for a generalization, they do not provide the goalkeeper with any clear guidance on how to reduce the kicker advantage.

In this paper the author proposes an individual approach to each penalty taker, in an attempt to identify key performance factors. The *a priori* identification of such factors, would clearly provide the goalkeeper with some ability to predict the side for where the shot is more likely to be taken and therefore “even the odds” in a penalty kick.

Two different case studies will be presented, one at a global level covering 2 former players and 2 current players from the Portuguese National squad, and then an individual analysis of two of those players, to better understand the level of specific factors. In both cases, key factors will be exhibited and proposed. The author would like to emphasize on the case study characteristic of this research. Given the fact the the sample is somewhat limited, the factors and testing should not to be extrapolated to be a bigger population than the one in consideration.

2 Data Set and Variables Definition

For this particular case study a total of 176 penalty kicks were analyzed from 4 international professional soccer players from the Portuguese National squad. Two are former players and 2 are current players. The rationale to select the four players was based on the following: three were the players in the Portuguese National team with more penalty kicks taken, in official competitions at the time of the World Cup 2018 and the other player (Player 3 in Table 1) was a youth player. As some of the players are still currently playing for their teams, their identity has been kept confidential. Data recorded covers official league and cup games as well as international club and national team competitions, from 16 different competitions. For these four players, this represent their totality of penalty kicks in official competitions, from the season 2005/2006 to May 2018.

Data was analyzed and compiled from video recordings of each penalty shot, a second observer confirmed the observations by taking a random sample of the initial observations. For each penalty kick, 17 different variables were analyzed. The distribution in terms of penalty kicks taken, over the four players, is not even. Individual distribution is given in the Table 1.

Table 1 Players and number of penalty kicks considered

Player	Number of penalty kicks
Player 1	122
Player 2	26
Player 3	9
Player 4	19

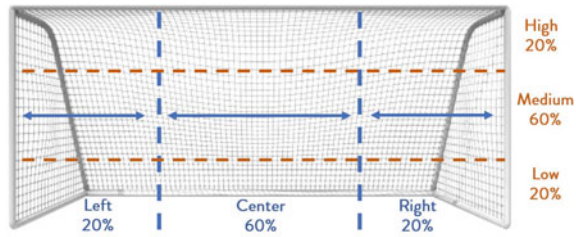
Table 2 Variables considered

Variable	Details	Data type
Side for which GK dive	Right, Center, Left	Nominal
Penalty scored	Yes, No	Nominal
If not, saved or missed	Saved, Missed	Nominal
Shot side	Right, Center, Left	Nominal
Looked at the side before the shot	Yes, No	Nominal
Player faked	Yes, No	Nominal
Step count	Number of steps	Numerical
Shooting technique	Inner part, Front part	Nominal
Shooting type	Skill, Power	Nominal
Shot height	Low, Medium, High	Nominal
Shot speed	Low, Medium, High	Nominal
GK faked	Yes, No	Nominal
GK stayed with open arms	Yes, No	Nominal
GK looked for visual contact	Yes, No	Nominal
Supporting fans location	Behind the goal, Opposite side	Nominal
Moment of the game	0 to 15 min, 16 to 30 min, 31 to 45 min, 46 to 60 min, 61 to 75 min, 76 to 90 min, Over 90 min	Nominal
Result at the time	Winning, Drawing, Losing	Nominal

In terms of variables collected, they are listed in Table 2, along with the details

The variables collected are in line with variables suggested in [2, 5, 7–9] and cover kinematic and psychological observable factors. As mentioned previously, one of the main objectives in this study was to concentrate on variables that could be assessed and inferred by the goalkeeper during a match. Variables such as Speed and Shot height cannot be observed before the penalty is taken, but they provide a more in depth analysis of each of the penalty takers.

Fig. 1 Considerations in terms of side and height



2.1 Variable Clarification

Some of the variables defined require some more clarification and detail.

As specified in [8], due to goalkeeper's position, the author considers center as the central 60% portion of the goal, the left side and right side cover the remainder, as illustrated in Fig. 1.

A similar approach was made for the height. The "medium height" area was considered as the region from the goalkeeper's knee up to 80% of full arm extension region, as suggested in [8].

In terms of speed, the split was made based on the information cited in [3]. Therefore, shots that took between 350 and 450 ms (inclusive) to reach the goal were considered medium speed, less than 350 ms high speed and more than 450 ms, low speed. This was analyzed by an approximate measure from the time the shot was taken until it crossed the goal line. A second observer confirmed a sample of the observations.

As per the variable "Player faked", the binary input Yes/No refers to the deceiving action of the player. If the player slows down or tries to deceive the goalkeeper, during his run to the ball, before taking the shot, that action is recorded as Yes. If the player does not attempt such actions, it is recorded as No. The variables collected that are related to goalkeeper behavior (GK faked, GK stayed with open arms, GK looked for visual contact) were included to understand if the GK behavior could have a significant influence in the choice of side selected by the penalty taker. In terms of the player variables, the binary input Yes/No was used. The "Moment of the game" variable was split in 15 min intervals. This split mimics the influence of both stress and fatigue levels, as mentioned in [4, 5]. The "Result at the time" and "Supporting fans location" are recorded, with the intent to measure the external pressure on the penalty kick taker.

3 Methodology

The approach taken in this paper focuses mainly on identifying key performance factors, first at a more global level for group of four players, and then uses the same process to analyze one individual player to assess potential indicators that can provide some insight to a goalkeeper, during a penalty situation.

The techniques used rely on the measure of association Cramer's V, as suggested in [1], combined with hypothesis testing. The reason for such is related to the fact that the main variables under scrutiny are nominal variables.

For the global approach, a series of factors will be analyzed and some hypothesis testing will be done to study the independence of the factors under consideration. In terms of the the individual player analysis, the author will identify overall accuracy, current tendency and efficiency, key performance indicators and then present a probability cross tabulation table, emphasizing the player's tendency, based on the main factors previously identified. Hypothesis testing on the factors will be conducted for each individual player as well. A level of significance of 5% was considered.

These dependent factors, can then be seen as a predictive model for each players choice of side, under those specific conditions.

4 Key Performance Factors in Penalty Kick

As mentioned in the introduction to this study, four different international soccer players are analyzed. Combined, a total of 176 penalty kicks were analyzed.

4.1 Global Analysis

As mentioned previously, the penalty kick analyzed represent the universe of all penalty kicks taken, in official games (domestic or international competitions) for these four players. The overall level of efficiency in this sample is 65%, meaning that globally 65% of the penalties resulted in goal.

To identify the key performance indicators, Cramer's V correlation coefficients were calculated for every combination of variables. The resultant graph is shown in Fig. 2.

From Fig. 2, it is clear that the most relevant factors that influence the choice of side are, "Player faked", with a coefficient of 0.34, "Moment of the game", with a coefficient of 0.19 and the "Shooting Type", with a coefficient of 0.19. In terms of analysis of Cramer's V coefficient, these values show that "Player faked" has a strong connection with the choice of side, where "Shooting type" and "Moment of the game", seem to have a weak to moderate connection. A Chi-squared test of independence was ran on the above mentioned factors, at a level of significance of 5%. Results are detailed in Table 3.

Table 3 clearly shows that none of the potential connections is statistically significant. However this analysis is a global one. In the next section a more individual approach is taken.

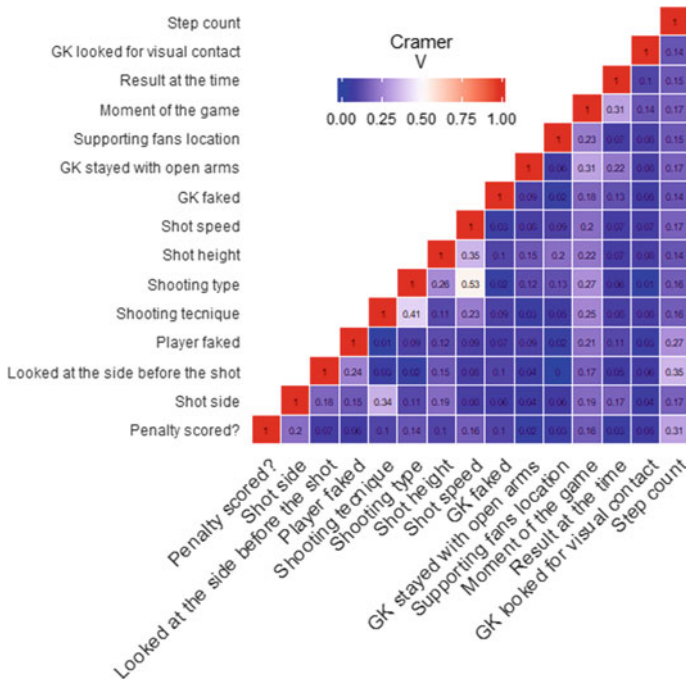


Fig. 2 Heatmap with Cramer’s V coefficients—global analysis

Table 3 Chi-squared test of independence

Hypothesis	Chi-squared	p-value	Outcome
H0: Choice of side is independent of Player faked	3.5601	0.1686	Do not reject H0
H0: Choice of side is independent of Moment of the game	12.326	0.7213	Do not reject H0
H0: Choice of side is independent of Shooting type	1.983	0.371	Do not reject H0

4.2 Individual Players

The individual player selected has a total of 122 official penalties taken in 13 different international or domestic competitions. This player shoots preferably with his right foot and all the penalties considered were shot with the right foot. His current level of efficiency is 82%, meaning he successfully scored 100 of the 126 penalties taken.

The player’s preference and efficiency are shown on Fig. 3.

From Fig. 3 it is also clear that there is dominant choice in terms of the left side, as it is chosen 55% of the times. However shots taken to the right side, even though they are less frequent they occur 35% of the time, seem to be more successful (91%

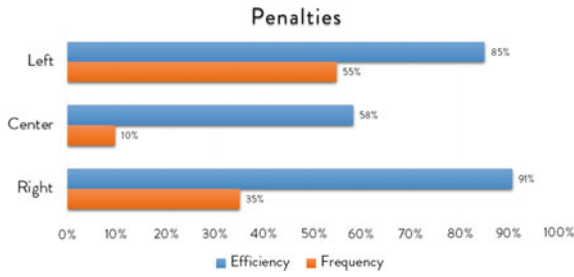


Fig. 3 Graph illustrating tendency and efficiency by player’s choice of side for Player 2

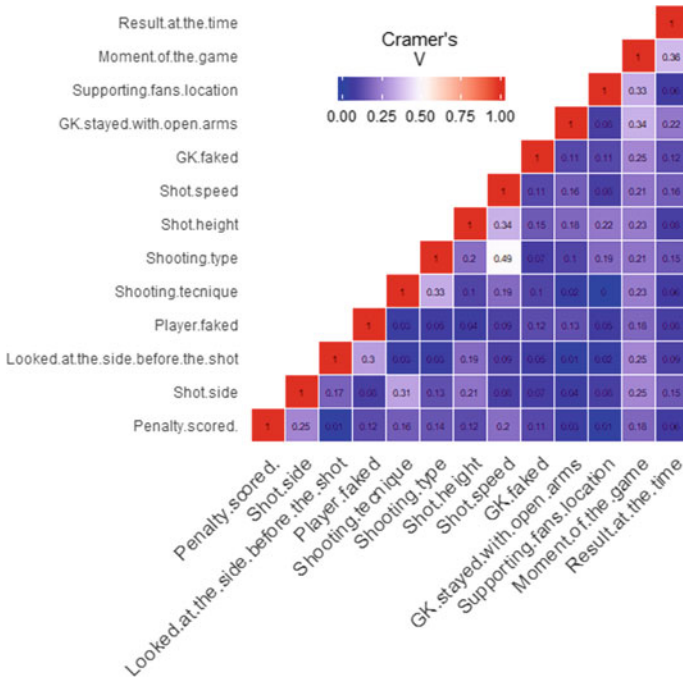


Fig. 4 Heatmap with Cramer’s V coefficients for Player 1

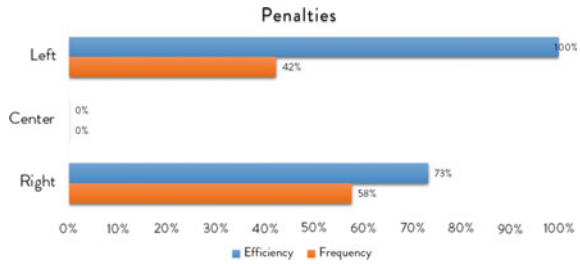
of the times). To identify the key performance indicators, Cramer’s V coefficients were calculated for every combination of variables. The resultant graph is shown in Fig. 4.

From the analysis of Fig. 4, one can identify as most relevant factors for the choice of side, the “Shooting technique”, with a coefficient of 0.31 and the “Moment of the game” with a coefficient of 0.25. These are considered to be strong to moderately strong factors. Results are detailed in Table 4.

Table 4 Chi-Squared test of independence

Hypothesis	Chi-squared	p-value	Outcome
H0: Choice of side is independent of Shooting Technique	11.971	0.002515	Reject H0
H0: Choice of side is independent of Moment of the game	14.868	0.3872	Do not reject H0

Fig. 5 Graph illustrating tendency and efficiency by player’s choice of side for Player 1



From the factors considered only “Shooting technique” is statistically significant. This factor is however harder to identify to the goalkeeper. Nevertheless, looking at the player bio-mechanics, the test shows that there is a statistically significant “give away” of side. Looking at the original data, when the player shoots with the front part of the foot, 70% of the shots will go left.

To highlight the gain in terms of detail when analyzing individual players, another individual player is analyzed using the same process. This player has a total of 26 official penalties taken in 3 different international or domestic competitions. His preferred foot is the right foot and all the shots analyzed in this paper were taken with the right foot. His current efficiency is 85%, as he successfully scored 22 of the 26 penalties taken.

The player’s preference and efficiency are shown on Fig. 5.

Cramer’s V coefficients were calculated for every combination of variables. The resultant graph is shown in Fig. 6.

the most relevant factors for the choice of side are, the “Moment of the game”, with a coefficient of 0.54, the “Shooting speed”, with a coefficient of 0.42 and the “Result at the moment of the shot”, with a coefficient of 0.26. The table with the hypothesis testing is shown below (Table 5).

Showing in this case that the only statistically relevant factor for this player is the Result at the moment of the shot.

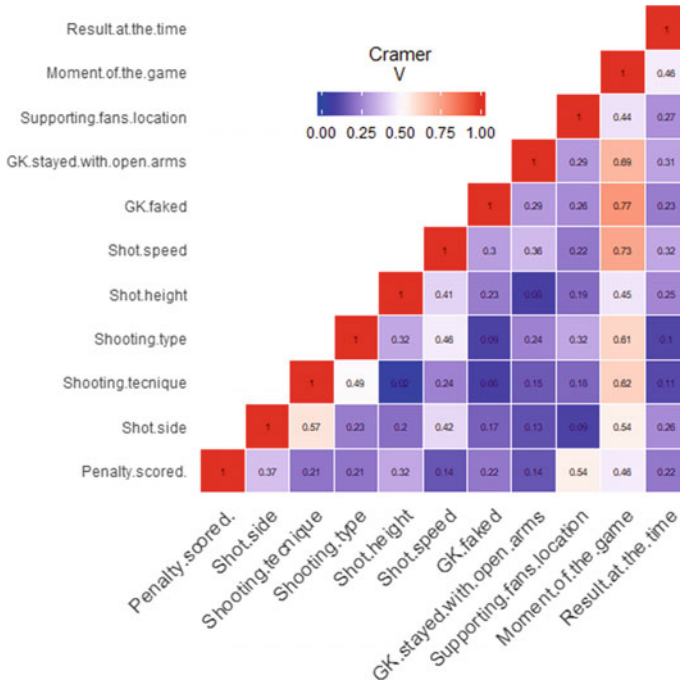


Fig. 6 Heatmap with Cramer’s V coefficients for Player 1

Table 5 Chi-squared test of independence

Hypothesis	Chi-squared	p-value	Outcome
H0: Choice of side is independent of Moment of the game	6.9333	0.4359	Do not reject H0
H0: Choice of side is independent of Shooting speed	4.2386	0.1201	Do not reject H0
H0: Choice of side is independent of Result at the moment of the shot	6.7394	0.0344	Reject H0

5 Conclusion

In an initial approach in this same study, more than 176 penalty kicks were analyzed, from different leagues and competitions and the connections found between variables at a global level were not significant.

In this study the focus is on taking an individual approach to determine key indicators for each player that might “give away” their choice of side, when taking the penalty kick. As the literature shows, these factors can range from biomechanical, to kinematics, to psychological.

In the first part of this study, the generalization, shows that it is very difficult to find common factors on a penalty kick situation, even on a specific team or smaller subset of players. However when the analysis focuses on a specific player, individual characteristics seem to emerge. In both of the cases analyzed it was possible to identify observable factors, that can provide the goalkeeper with some “a priori” information, to offset the player advantage in a penalty kick, in soccer. Predicting the side or outcome of a penalty, in a generalized manner, was not the goal of this study, but more to provide an overview on a technique that can be useful in turning the penalty kick lottery, into a more balanced event. On an individual basis and based on historic player data it was possible not only to identify those factors but also to use them to build an individual predictive model, based on those same factors.

Acknowledgements The author would like to thank Alexandre Real, Rodrigo Silva and Pedro Zorro. Their contribution in terms of data collection and feedback about the variables to collect was essential. For that and all the support provided, my deepest thanks.

References

1. Cramer, H.: *Mathematical Methods of Statistics*. Princeton University Press, Ch. 21 (1946)
2. Diaz, G., Fajen, B., Phillips, F.: Anticipation from biological motion: the goalkeeper problem. *J. Exp. Psychol.: Human Percept. Perform.* **38**(4), 848–864 (2012)
3. Franks, I., Harvey, T.: Cues for goalkeepers. High-tech methods used to measure penalty shot response. *Soccer J.* **42**, 30–33 (1997)
4. Hughes, M., Caudrelier, T., James, N., Redwood-Brown, A., Donnelly, I., Kirkbride, A., Duschesne, C.: Moneyball and soccer—an analysis of the key performance indicators of elite male soccer players by position. *J. Hum. Spt. Exe.* **7**, 402–412 (2012)
5. Jordet, G., Hartman, E., Visscher, C., Lemmink, K.A.P.M.: Kicks from the penalty mark in soccer: the roles of stress, skill, and fatigue for kick outcomes. *J. Sports Sci.* **25**(2), 121–129 (2007)
6. Katis, A., et al.: Mechanisms that influence accuracy of the soccer kick. *J. Electromyogr. Kinesiol.* **23**(1), 125–131 (2013)
7. Li, Y., Alexander, M.J.L., Glazebrook, C.M., Leiter, J.: Prediction of Kick Direction from Kinematics during the Soccer Penalty Kick. *IJKSS.* **3**(4), 1–7 (2015)
8. Lopes, J., Jacobs, D., Travieso, D., Araújo, D.: Predicting the lateral direction of deceptive and non-deceptive penalty kicks in soccer from the kinematics of the kicker. *Human Movement Science* **36**, 199–216 (2014)
9. Mackenzie, R., Cushion, C.: Performance analysis in football: a critical review and implications for future research. *J. Sport. Sci.* **31**(6), 39–676 (2013)
10. Scurr, J., Hall, B.: The effects of approach angle on penalty kicking accuracy and kick kinematics with recreational soccer players. *J. Sports Sci. Med.* **8**(2), 230–234 (2009)
11. van der Kamp, J., Dicks, M., Navia, J.A., et al.: Goalkeeping in the soccer penalty kick. *Ger. J. Exerc. Sport Res.* **48**(2), 169–175 (2018)