

The supporting foot as a kinematic indicator of penalty kick direction in soccer

OSAMA ABDEL FATTAH^{1*}, KHALED ATIYAT², JAD MAZAHREH³, MAHA JARRAD⁴

¹School of sports science, the University of Jordan, Amman, JORDAN

²School of sports science, the University of Jordan, Amman, JORDAN.

³ School of sports science, the University of Jordan, Amman. , JORDAN.

⁴Faculty of Physical Education and Sports Sciences, Palestine Technical University – Kadoorie, JORDAN.

Published online: November 30, 2023

(Accepted for publication : November 15, 2023)

DOI:10.7752/jpes.2023.11358

Abstract

The objective of this study was to discern the direction of the supporting foot, contact time, and patterns involved in penalty kicks in soccer. The researchers employed a descriptive analytical approach, utilizing videos from the World Cup spanning the years 2002 to 2022, downloaded from the official website of the International Federation of Association Football (FIFA). The analysis of 160 penalty kicks was conducted using sports analysis software, Kinovea (version 0.9.5-x64.exe). The study's goals were accomplished through the application of means, frequencies, and percentages, using SPSS version 24, with a confidence level of 95%. The study results revealed that the supporting foot direction in (83.75) % of the analyzed penalty kicks was in the same direction as the ball's trajectory, while (16.25) % were not in the same direction. The researchers also found that (82.83) % of the penalty kicks where the supporting foot direction matched the ball's direction resulted in goals, while (17.17) % were unsuccessful attempts. In addition, the contact time means (0.122) seconds. Also, the pattern of penalty kick placement in the World Cup indicated that (36.25) % were directed to the left, (55) % to the right, and (8.75) % toward the central. Based on the study's findings, it can be concluded that the direction of the supporting foot, contact time, and analysis of the penalty kick pattern in the FIFA World Cup can serve as additional indicators for goalkeepers. Hence, these indicators can be utilized to develop goalkeeper strategies for predicting the motion trajectory of a penalty kick. Therefore, the coaches should focus more on drills that enhance goalkeepers' reactions and further studies could also be conducted on different samples, such as youth players and female athletes.

Keywords: World Cup, Biomechanics, Football, Penalty kicks, Analysis

Introduction

Soccer is widely regarded as the most popular sport globally, often referred to as the world's game. This is evident from the numerous sports associations affiliated with the International Federation of Association Football (FIFA), its extensive following, and the considerable number of players involved in the sport (Alcock, 2010; Castellanos et al., 2014). However, soccer requires players to master various skills by players, such as passing, dribbling, and kicking (Lees et al., 2010). Among these skills and events within soccer, penalty kicks emerge as a pivotal and exhilarating aspect. The execution of a penalty kick is influenced by a range of factors; including psychological, physiological, technical, tactical, and biomechanical aspects (Gilbourne, 2002). Previous studies reveal that the goal-scoring pattern in the World Cup between 1998 and 2018 was $29.33 \pm 5.57\%$ for free kicks, with penalty kicks accounting for $25.71 - 47.56\%$ (Kubayi, 2020; Kubayi & Toriola, 2019). Generally, there are two types of penalty kicks utilized in football competitions. The first type is awarded for fouls occurring in the penalty area during both regular and extra time of the match, such as for deliberately touching the ball or obstructing an opponent. The second type is used to determine the winner of the match after the conclusion of regular and extra time when the result is a draw, commonly known as a penalty shoot-out (Farina et al., 2013; Mu et al., 2013). A penalty kick entails a direct face-off between the player and the goalkeeper, with professionals achieving a success rate ranging from 75- 85% (Bar-Eli et al., 2007). A penalty kick represents a unique opportunity for a player to score a goal, but it presents a formidable challenge for the goalkeeper to save the ball and prevent a goal within a constrained and short timeframe. The ball typically takes approximately 0.29–0.50 s to reach the goal line after being kicked, whereas scientifically adept goalkeepers require an average of 0.75 s to save the ball. Moreover, a penalty entails the dynamic interaction between two participants the player and the goalkeeper each with distinct objectives (Furley et al., 2017). Consequently, players strive to improve their accuracy in executing penalty kicks, while goalkeepers concentrate on developing strategies to defend against them (Hun, 2014; Fainnoff et al., 2002; Mu et al., 2013). Numerous factors influence the execution of a penalty kick. Aspects pertaining to the player performing the kick encompass their reputation, ball trajectory, and body positioning during the execution. Additionally, there are factors associated with the strategies employed by goalkeepers to save the ball, including adjusting their

movement based on the penalty taker's body position or taking the risk of diving toward the anticipated corner of the ball's trajectory (Memmert et al., 2013; Noel et al., 2015).

Upon reviewing previous studies in this area, we have noted that the majority of studies have focused on the biomechanical analysis of penalty kicks, particularly examining factors such as ball speed at the moment of the kick (Dorge et al., 2002; Katis & Kellis, 2010). Some studies have delved into ball accuracy and approach angle (Scurr & Hall, 2009). However, there is a considerable gap in research gap regarding the directions of ball kicks and the cues that may prove beneficial for goalkeepers. For example, the penalty taker's body position and the direction of their supporting foot as indicators of the ball's trajectory have been insufficiently explored (Lee & Owens, 2011).

Through a review of studies related to goalkeepers in football, Marco et al (2022) indicated trends and developments in goalkeeper performance. Accurate data in sports science contribute to addressing questions related to the individual and collective performance requirements of players, which are increasingly imposed on goalkeepers. Additionally, Gaetano (2023) compared the technical and tactical aspects of the performance of some elite goalkeepers in various tournaments. The results suggested that modern football goalkeepers play a fundamental tactical role in protecting the goal area and covering a larger area, allowing defenders to play near the midfield players.

Building on the forthcoming presentation and recognizing the vital role of motion analysis in football penalty kicks (Paterson et al., 2020), we believe that conducting scientific studies can improve the efficiency of goalkeepers in saving penalty kicks and address the current research gap. Therefore, this study aimed to scrutinize penalty kicks in the World Cup from 2002 to 2022, with a specific focus on the direction of the supporting foot and the time required for the player to execute the kick after the supporting foot makes contact with the ground. In addition, we anticipate that the findings of this study can assist goalkeepers by affording them more time to react and make informed decisions. Furthermore, this study may prompt coaches to place greater emphasis on training that enhances goalkeepers' reaction abilities.

Materials and Methods

To achieve the objectives of this study, we adopted a descriptive analytical approach. The penalty kick videos from the World Cup spanning 2002 to 2022 were obtained from the International Federation of Association Football (FIFA) website (<https://www.fifa.com/fifaplus/ar>). A total of 160 penalty kicks were analyzed, and Table 1 details the distribution of the evaluated penalty kicks.

Table 1. The number of penalty kicks that were analyzed (n= 160)

World Cup	Total analyzed kicks	Percentage %
Qatar 2022	59	36.875
Russian 2018	29	18.125
Brazil 2014	20	12.5
South Africa 2010	14	8.75
Germany 2006	21	13.125
Korea & Japan	17	10.625
Total	160	100

For the analysis of the downloaded penalty kicks from FIFA, we utilized sports analysis software, Kinovea (version 0.9.5-x64.exe), which can be downloaded from <https://www.kinovea.org/download.html>. Through this software, the study variables were extracted, with a focus on the direction of the supporting foot and the support time. The direction of the supporting foot indicates the orientation of the supporting foot in relation to the goal (Figure 1). On the other hand, contact time is defined as the duration from the moment the supporting foot touches the ground until the kicking foot makes contact with the ball, measured in seconds.



Figure 1. Shows the supporting foot and the ball direction relative to the goal

Data analysis

To achieve the study's objectives, we determined frequencies, percentages, and means using SPSS version 24 (IMB, Armonk, NY, USA), with a confidence level of 95% (p value = 0.05).

Results

The primary focus of this study was to evaluate penalty kicks in the World Cup spanning from 2002 to 2022, focusing on the direction of the supporting foot and the duration it takes for the player to execute the kick after the supporting foot makes contact with the ground. Table 2 presents the correlation between the direction of the kick, the supporting foot direction, and the supporting foot time.

Table 2. The results of the penalty kick analysis based on the supporting foot direction and the contact time (n=160)

World Cup	Total analyzed kicks	The kicks direction matching to the supporting foot direction	Percentage %	Supporting foot time/ s
Qatar 2022	59	47	79.66	0.122
Russian 2018	29	24	82.75	0.123
Brazil 2014	20	17	85	0.126
South Africa 2010	14	12	85.7	0.123
Germany 2006	21	18	85.71	0.114
Korea & Japan	17	16	94.11	0.124
Total	160	134	83.75	0.122

Table 3 illustrates the count of successful and unsuccessful kicks where the direction of the supporting foot aligns with the direction of the ball.

Table 3. Summary of successful and unsuccessful attempts at kicks in which the direction of the ball and the supporting foot are in the same direction (n=134)

World Cup	The kicks direction matching to the supporting foot direction	The successful attempts	Percentage %	The unsuccessful attempts	Percentage %
Qatar 2022	47	38	80.85	9	19.15
Russian 2018	24	22	91.66	2	8.34
Brazil 2014	17	14	82.35	3	17.65
South Africa 2010	12	10	83.33	2	16.67
Germany 2006	18	13	72.22	5	27.78
Korea & Japan	16	14	87.5	2	12.50
Total	134	111	82.83	23	17.17

Table 4 presents the count of successful and unsuccessful kicks where the direction of the supporting foot does not align with the direction of the ball.

Table 4. Summary of successful and unsuccessful attempts at kicks in which the direction of the ball and the supporting foot are not in the same direction (n=26)

World Cup	The kicks direction not matching to the supporting foot direction	Percentage %	The successful attempts	Percentage %	The unsuccessful attempts	Percentage %
Qatar 2022	12	20.34	5	41.66	7	48.34
Russian 2018	5	17.20	3	60	2	40
Brazil 2014	3	15	3	100	0	0
South Africa 2010	2	14.3	2	100	0	0
Germany 2006	3	14.29	2	66.66	1	33.34
Korea & Japan	1	5.89	1	100	0	0
Total	26	16.25	16	61.53	10	38.47

Table 5 shows the position of the goal in which the ball was kicked, considering it in three sectors: left, right, and central.

Table 5. Summary of the position of the goal in which the ball was kicked (n=160)

World Cup	Total analyzed kicks	Left	Percentage %	Right	Percentage %	Central	Percentage %
Qatar 2022	59	19	11.88	33	20.63	7	4.38
Russian 2018	29	11	6.88	15	9.37	3	1.87
Brazil 2014	20	8	5	11	6.88	1	0.625
South Africa 2010	14	5	3.13	8	5	1	0.625
Germany 2006	21	8	5	12	7.5	1	0.625
Korea & Japan	17	7	4.38	9	5.62	1	0.625
Total	160	58	36.25	88	55	14	8.75

Discussion

In line with the study's objectives, which aimed to identify supporting foot direction, contact time, and penalty kick patterns in soccer, we examined 160 penalty kicks from the World Cup spanning the years 2002 to 2022. These kicks were downloaded from FIFA's official website and underwent meticulous analysis. The analysis revealed that in 83.75% of the evaluated penalty kicks, the supporting foot direction coincided with the ball's trajectory, while in 16.25% it did not. Furthermore, 82.83% of the penalty kicks in which the supporting foot direction matched the ball's direction resulted in goals, while 17.17% were unsuccessful attempts. We interpret this outcome as a promising sign for enhancing goalkeepers' ability to accurately anticipate the ball's direction, preventing goals.

In this context, Piras & Vickers (2011) suggested that goalkeepers rely on visual cues from the kicker to anticipate the direction before the ball is kicked. This approach minimizes the risk of jumping prematurely to the anticipated corner, providing the kicker with a better chance of scoring. Similarly, Dicks et al. (2012) suggested that successful penalty kick takers can increase their scoring chances by concealing the direction of the kick. These findings align with a study by Lees & Owens (2011), emphasizing visual cues based on the direction of the supporting foot as an indicator for predicting the kick's direction. On the basis of these results, we propose that the direction of the supporting foot, along with the direction of the kicker's trunk and hips, could serve as an additional strategy for goalkeepers. Furthermore, the direction of the supporting foot allows goalkeepers to perform arm movements or body feints opposite to the supporting foot's direction, influencing the kicker to shoot in the same direction.

Our results also underscore contact time as another crucial indicator for goalkeepers, with a mean of 0.122 s. Given that the ball's speed during a penalty kick ranges from 25 to 30 m/s, the calculated contact time offers goalkeepers an additional time window spanning from 27.72% to 33.9% of the kick's total time (0.36–0.44 s). This extra time is important for decision-making, enabling goalkeepers to implement additional strategies in saving penalty kicks. Moreover, this surplus time allows coaches to concentrate on enhancing goalkeepers' reaction times.

Regarding the pattern of penalty kick placement in the World Cup, the study revealed that 36.25% were directed to the left, 55% to the right, and 8.75% towards the center. We believe that these analyses are invaluable for both goalkeepers and coaches, contributing to a comprehensive understanding of soccer skills. This underscores the significance of motion analysis in achieving optimal performance by quantitatively identifying the characteristics and variables influencing skill performance.

In conclusion, the main objective of this study is to improve goalkeepers' knowledge of football, enabling them to more accurately predict the trajectory of a penalty kick before it is taken. Such knowledge is critical, particularly in competitions where penalty kicks can determine the winner. We assert that goalkeepers equipped with insights into visual indicators can enhance their efficiency in competitive situations, and the study results can be strategically applied to counter the tactics employed by penalty kick takers.

Conclusion

Our finds show that the direction of the supporting foot, contact time, and penalty kick pattern analysis in the FIFA World Cup can serve as additional indicators for goalkeepers. These indicators provide valuable insights that can be used to develop strategies for predicting the penalty kick motion trajectory. We emphasize the importance of incorporating these indicators into goalkeeper training sessions to enhance their proficiency in handling penalty kicks. Additionally, we recommend focusing on drills specifically designed to improve goalkeepers' reaction times.

This study suggests that future research could broaden its scope to encompass different samples, such as youth players and female athletes. Exploring these diverse groups may yield additional insights into how these

indicators apply across various demographics and playing styles. Such studies may contribute to a more comprehensive understanding of penalty kick dynamics and further refine goalkeeper training strategies

Conflicts of Interest

We declare no competing interests.

Funding Statement

There are no sources of funding.

References

- Alcock, A. (2010). Analysis of Direct Shots at Goal from Free Kicks in Elite Women's Football. Thesis, Doctor of Philosophy, Sports Science (Biomechanics) Liverpool John Moores University.
- Bar-Eli, M., Azar, O., Ritov, I., Keidar-Levin, Y. & Schein, G. (2007). Action bias among elite soccer goalkeepers: The case of penalty kicks. *Journal of Economic Psychology*, 28, 606–621.
- Castellanos, S., Farhadi, A., & Suarez, D. (2014). Motion Analysis and Biomechanics of the Side-Foot Soccer Kick. *Aquila: The FGCU Student Journal*, 1: 1-9
- Dicks, M., Button, C. & Davids, K. (2010). Availability of advance visual information constrains association-football goalkeeping performance during penalty kicks. *Perception*, 39, 1111–1124.
- Dorge, H.C., Andersen, T.B., Sorensen, H. & Simonsen, E.B. (2002). Biomechanical differences in soccer kicking with the preferred and the non-preferred leg. *Journal of Sports Sciences*, 20, 293- 299.
- Fariña, A. R., Fábica, G., Tambusso, P. S., & Alonso, R. (2013). Taking the goalkeeper's side in association football penalty kicks. *Int. J. Perform. Anal. Sport*, 13, 96–109. <https://doi.org/10.1080/24748668.2013.11868634>.
- Finnoff, J. T., Newcomer, K., & Laskowski, E. R. (2002). A valid and reliable method for measuring the kicking accuracy of soccer players. *Journal of Science and Medicine in Sport*, 5(4), 348-353. [https://doi.org/10.1016/S1440-2440\(02\)80023-8](https://doi.org/10.1016/S1440-2440(02)80023-8).
- Furley, P., Noël, B., & Memmert, D. (2017). Attention towards the goalkeeper and distraction during penalty shootouts in association football: A retrospective analysis of penalty shootouts from 1984-2012. *Journal of Sports Sciences*, 35(9), 873–879. <https://doi.org/10.1080/02640414.2016.1195912>.
- Gaetano, A. (2023). Analysis and comparison of the goalkeeper's role in past and modern soccer: a pilot study. *Journal of Physical Education and Sport*, 23(3), 564-568. *Journal of Physical Education and Sport*, 19(SI 6), 3411-3419. <https://doi.org/10.7752/jpes.2023.03070>
- Gilbourne, D. (2002). Sports participation, sports injury and altered images of self: An autobiographical narrative of a lifelong legacy. *Reflective Practice*, 3, 71 – 88.
- Hun, L. J. (2014). Science hidden in penalty kicks Sport" *The Sport Kyunghyang Shinmun*.
- Katis, A., & Kellis, E. (2010). Three-dimensional kinematics and ground reaction forces during the instep and outstep soccer kicks in pubertal players. *Journal of Sports Sciences*, 28:11, 1233-1241
- Kubayi, A. & Toriola, A.(2019). Trends of goal scoring patterns in soccer: A retrospective analysis of five successive fifa World Cup Tournaments. *J. Hum. Kinetics*, 69, 231–238.
- Kubayi, A.(2020). Analysis of goal scoring patterns in the 2018 FFA world Cup. *J. Hum. Kinetics*, 71, 205–210.
- Lees, A. Asai, T. Andersen, H. Nunome & Sterzing, T. (2010). The biomechanics of kicking in soccer: A review. *Journal of Sports Sciences*, 28(8), 805-817.
- Lees, A., & Owens, L. (2011). Early visual cues associated with a directional place kick in soccer. *Sports Biomechanics*, 10:02, 125-134.
- Marco, O., Pavol, P., Martin, M. & Matej, B. (2022). Technical–tactical profile of an elite soccer goalkeeper. *Journal of Physical Education and Sport*, 22(1), 38-46. <https://doi.org/10.7752/jpes.2022.01005>.
- Memmert, D., Hüttermann, S., Hagemann, N., Loffing, F., & Strauss B. (2013). Dueling in the penalty box: Evidence-based recommendations on how shooters and goalkeepers can win penalty shootouts in soccer. *Int Rev Sport Exerc Psychol*, 6(1):209-229. <https://doi.org/10.1080/1750984X.2013.811533>
- Mu, S. J., Jeong, K. J., Rim, P. H. & Seon, K. S. (2013). Kinematic analysis of lower extremity segments according to changes in goals during soccer inside penalty kick motions. *Korean Journal of Sport Biomechanics*, 23(2), 117-123.
- Noël, B., Furley, P., van der Kamp, J., Dicks, M., & Memmert, D. (2015). The development of a method for identifying penalty kick strategies in association football. *J. Sports Sci.* 33, 1–10. <https://doi.org/10.1080/02640414.2014.926383>
- Paterson, G., van der Kamp, J., & Savelsbergh, G. (2020). Moving advertisements systematically affect gaze behavior and performance in the soccer penalty kick. *Front. Sports Act. Living.* 1, 69. <https://doi.org/10.3389/fspor.2019.00069>
- Piras, A., & Vickers, J.N. (2011). The effect of fixation transitions on quiet eye duration and performance in the soccer penalty kick: Instep versus inside kicks. *Cogn. Process*, 12, 245–255.
- Scurr, J., & Hall, B. (2009). The effects of approach angle on penalty kick accuracy and kick kinematics with recreational soccer players. *Journal of Sports Science and Medicine*, 8, 230- 234.