Quantitative analysis of in-match penalty kicks from 2009/10 to 2018/19 in the English Premier League

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Thesis presented in partial fulfilment of the requirements for the degree Master of Science in the Department of Sport Science, Faculty of Medicine and Health Sciences at Stellenbosch University.

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DECLARATION

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SUMMARY

Football association (hereafter referred to as soccer), which is played across several playing levels and ages, is regarded as the most popular sport globally and has been subject to the highest number of scientific studies in relation to any other sport. Currently there is an excess of well-documented studies highlighting many aspects related to soccer. However, studies on quantitative measures on in-match penalty kicks and the influence of factors on penalty kick outcomes are scarce or only briefly touched on in the literature. The importance that successful or unsuccessful in-match penalty kicks could have towards the outcome of a match, or potentially a competition, is essential and requires close assessment through performance analysis.

The aim of this study was to conduct a video-based performance analysis of in-match penalty kicks during the English Premier League (EPL) seasons from 2009/10 to 2018/19 in order to identify the relationships between selected technical and match classification Key Performance Indicators (KPIs) and in-match penalty kick outcomes and direction.

The thesis was presented in five main parts, namely the Introduction (Chapter One), Literature review (Chapter Two), Methodology (Chapter Three), Research article titled, In-match penalty kick analysis of the 2009/10 to 2018/19 English Premier League competition (Chapter Four) and Summary, conclusion, limitations and future research (Chapter Five). The Senate of Stellenbosch University approved the article format theses and dissertations. The Faculty of Medicine and Health Sciences at Stellenbosch University stipulates one article as a requirement for a Master of Science thesis. The research article of the current study was presented in accordance with the guidelines outlined by the respective journal.

In-match penalty kicks (N=952) in the EPL between the 2009/10 to 2018/19 seasons were analysed by means of video analysis to identify the relationship between selected technical and match classification KPIs and in-match penalty kick outcomes. The KPIs included footedness of the penalty kick taker, match score line at the time of the penalty kick, match status (winning/losing/drawing at time of the penalty kick), match period (time in match), match location (home/away) and in-match penalty kick directions.

The results indicated that of the KPIs analysed only in-match penalty kick direction, particularly in relation to the top vertical zone significantly related to penalty kick outcomes ($p<0.01$). Grid area frequencies for K3 (278) and F3 (235) were the highest of the in-match penalty kick directions and had the lowest success rates (K3 – 79.2%, F3 – 77.3% together

with M3 – 74.3%). Optimal grid areas for penalty kick directions were identified (K1 – 97.7%, M1 – 100%, F1 – 100% and M2 – 94.3%), which indicated a greater probability of success in relation to the other areas of penalty kick directions. Other KPIs, such as match location, match status, score line and footedness did not present a significant influence on penalty kick outcomes or direction.

Penalty kick takers may possibly have a perception bias in relation to the perceived miss factor indicating that they would rather go low and in the bottom corners and be saved by the goalkeeper than aim for a higher penalty kick direction in the goal and miss the goal all together. The practical implications of training in-match penalty kicks for an optimal strategy in relation to penalty kick directions could assist coaches, players and goalkeepers in optimising the in-match penalty kicks for the desired outcome. Future studies should consider using the goalkeeper's movement direction prior to a penalty kick to save it and the penalty kick taker's run up speed, speed of shot, stutter vs non-stutter as part to the penalty kick outcome and direction analysis. Future research should include penalty kicks that were not placed on target as part of the direction analysis, either by allocating them into the nearest grid area to the missed kick, or possibly by using 'missed zones' around the goal to track and analyse missed penalty kicks, and therefore, cater for the 'miss factor'. Based on the current study's findings and that of previous studies, penalty kick takers should be encouraged to direct their penalty kicks to the upper areas of the goal in order to achieve optimal penalty kick outcomes.

Keywords: Penalty kick, performance analysis, soccer, success rates, key performance indicators

OPSOMMING

Voetbal vereniging (voortaan na verwys as sokker) word wêreldwyd deur spelers op alle vlakke en ouderdomme gespeel en as die mees populêre sport in die wêreld beskou word, is die onderwerp van die meeste wetenskaplike studies in vergelyking met enige ander sport. Huidig is daar ’n oorvloed van goed gedokumenteerde studies wat baie aspekte met betrekking tot sokker beklemtoon. Daar is egter ’n tekort aan studies rakende kwantitatiewe metings van strafskoppe tydens sokker wedstryde en die invloed van spesifieke faktore op strafskop uitkomste is skaars of word slegs kortliks in die literatuur aangeraak. Die rol van ’n suksesvolle of onsuksesvolle strafskop in sokker, met betrekking tot die uitslag van ’n wedstryd of ’n kompetisie is belangrik en verg noukeurige assessering deur prestasie-analise.

Die doel van hierdie studie was om ’n video-gebaseerde prestasie-analise van strafskoppe in die wedstryde van die Engelse Premierliga (EPL) tussen die 2009/10 tot 2018/19 seisoene uit te voer om sodoende die verband tussen geselekteerde Sleutel Prestasie Aanwysers (SPAs) vir tegniese en wedstryd klassifikasie te bepaal, asook om die uitslag en rigting van strafskoppe in die wedstryde te identifiseer.

Die tesis word in vyf dele aangebied, naamlik ’n Inleiding (Hoofstuk Een), Literatuuroorsig (Hoofstuk Twee), Metodologie (Hoofstuk Drie), Navorsingsartikel getitel: *In-match penalty kick analysis of the 2009/10 to 2018/19 English Premier League competition* (Hoofstuk Vier) en Opsomming, gevolgtrekking, beperkings en toekomstige navorsing (Hoofstuk Vyf). Die Senaat van Stellenbosch Universiteit het die artikelformaat van tesisse en proefskrifte goedgekeur. Huidig vereis die Fakulteit Geneeskunde en Gesondheidswetenskappe aan Stellenbosch Universiteit een artikel vir ’n Magister tesis. Die navorsingsartikel is aangebied volgens die riglyne soos uiteengesit in die betrokke joernaal.

Strafskoppe tydens wedstryde (N=952) in die EPL tydens die 2009/10 tot 2018/19 seisoene is geanaliseer deur gebruik te maak van video-analises om die verband tussen geselekteerde SPAs vir tegniese en wedstryd klassifikasie en die uitkomste van strafskoppe in die wedstryde te bepaal. Die SPAs het onder meer die voetigheid van die strafskopnemer, die wedstryd tellinglyn ten tye van die strafskop, wedstrydstatus (wen/verloor/gelykop tydens die strafskop), wedstryd periode (tyd in die wedstryd), wedstryd ligging (tuis/weg) en die strafskop rigting ingesluit.

Die resultate het aan die lig gebring dat van die SPAs wat ontleed is, slegs die rigting van die strafskop, veral in verhouding tot die boonste vertikale sone van die doelhok,

betekenisvol verband hou met die uitslag van die strafskop ($p<0.01$). Roosterareas K3 (278) en F3 (235) het die hoogste frekwensie van in-wedstryd strafskoppe getoon en het die laagste suksessyfers behaal (K3 – 79.2%, F3 – 77.3% saam met M3 – 74.3%). Optimale roosterareas vir strafskop rigtings is geïdentifiseer (K1 – 97.7%, M1 – 100%, F1 – 100% en M2 – 94.3%) wat ’n groter waarskynlikheid van sukses ten opsigte van die ander gebiede getoon het. Ander SPAs, soos waar die wedstryd plaasvind, die status van die wedstryd, die tellinglyn en die voetigheid van die strafskop waarnemer, het geen beduidende invloed op die uitslag of rigting van die strafskop gehad nie.

Strafskop waarnemers kan moontlik ’n persepsie vooroordeel in verhouding tot die waargenome misfaktor hê wat daarop dui dat hulle eerder laag en in die onderste hoeke sal mik en die strafskop deur die doelwagter gered word eerder as om na ’n hoër vertikale area in die doelhok te mik en die doelhok geheel en al mis. Die praktiese implikasies van die opleiding in wedstryd strafskoppe in verhouding tot die rigting van strafskoppe kan afrigters, spelers en doelwagters help om die strafskop te optimaliseer vir die gewenste uitslag.

Die voorafgaande bewegingsrigting van die doelwagter om ’n strafskop te red en die strafskop waarnemer se aanloopspoed, spoed van die skop, huiwer vs. nie-huiwer as deel van die strafskop uitkoms en rigting analise word vir toekomstige navorsing aanbeveel. Toekomstige navorsing moet as deel van die rigting analise strafskoppe insluit wat nie op teiken was nie deur hulle óf op die naaste rooster area naas die mislukte skop te plaas óf om moontlik van ‘mis-sones’ rondom die die doel gebruik te maak om onsuksesvolle strafskoppe te analiseer om sodoende vir die ‘mis faktor’voorsiening te maak. Gebaseer op die bevindinge van die huidige studie en vorige studies moet strafskop waarnemers aangemoedig word om hulle skoppe te rig op die boonste areas van die doelhok om hierdeur optimale strafskop uitkomste te behaal.

Sleutelwoorde: Strafskop, prestasie-analise, sokker, suksessyfers, sleutelprestasie-aanwysers

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LIST OF ABBREVIATIONS

EPL	English Premier League
FIFA	Fédération Internationale de Football Association
IFAB	International Football Association Board
UEFA	Union of European Football Associations
UCL	UEFA Champions League
UEL	UEFA Europa League
EURO	The UEFA European Football Championship
FC	Football Club
GEE	Generalized Estimating Equation
MCA	Multiple Correspondence Analysis
ICC	Intraclass Correlation Coefficient
KPI	Key Performance Indicator

CHAPTER ONE

INTRODUCTION

The chapter is included herewith in accordance with the referencing guidelines of the Department of Sports Science, Stellenbosch University.

BACKGROUND

Association football (hereafter referred to as soccer), in addition to having the most players globally, is the most studied sport worldwide (Kirkendall & Urbaniak, 2020). Despite the popularity of research in soccer, literature addressing objective data by means of quantitative measures on in-match penalty kicks and the influence of additional factors on penalty kick outcomes is scarce, or only briefly touched on (Gilmore-Jones *et al*., 2015; Almeida *et al*., 2016). Goldblatt (2014:18) questioned whether "there [is] any cultural practise more global than football" with no single continent or country owning the sport, and therefore, it is entwined within a country's social identity. The game of football has resulted in a 'global interconnectedness', having transitioned from a 'chaotic' traditional ritual to becoming one of the globe's largest entertainment industries (Goldblatt, 2014).

Soccer as a sport, career and business has become increasingly competitive for all stakeholders involved, which include players, coaches, owners and shareholders. According to Palacios-Huerta (2003:400), Bar-Eli and Azar (2009:183), Fariña *et al*. (2013:96), Almeida *et al*. (2016:509) and Gürkan *et al*. (2017:142), the average total number of goals per soccer game is 2.5 to 2.7 goals per game, which demonstrate the importance that a successful or unsuccessful in-match penalty kick could have towards the outcome of a match. This is because of the weight that a goal, scored from a potential successfully converted penalty kick, could contribute (±40%) towards the average number of goals per game.

The success rate of penalty kicks in professional soccer is approximately 70 to 85% (McGarry & Franks, 2000; Morya *et al*., 2005; Jordet *et al*., 2007; Bar-Eli & Azar, 2009; Palao *et al*., 2010; White & O'Donoghue, 2013; Almeida *et al*., 2016). The outcomes of penalty kicks in soccer are of the utmost importance because they are often match deciding moments (Bar-Eli & Azar, 2009). In addition, a penalty kick may be a decisive event in a match, as well as an opportunity to progress in a knockout competition, or ultimately the final standings of a league (Grant *et al*., 1999; Morya *et al*., 2003; Bar-Eli & Azar, 2009; Fariña *et al*., 2013; Almeida *et al*., 2016; Gürkan *et al*., 2017). Therefore, when considering the fine margins in determining success in modern soccer, the penalty kick is of great importance because it can be a decisive event in a game and could often be the deciding factor between winning and losing. The reason that penalty kicks are considered to be both decisive (Grant *et al*., 1999) and of utmost importance (Bar-Eli & Azar, 2009), is owed to its association with a goal and a high rate of success for the attacking team in such a scenario. Gilmore-Jones *et al*., (2015) reported the

English Premier League (EPL) in-match penalty kick success rate to be 79.5% between the 2009 to 2014 seasons.

A penalty kick is awarded if a player commits a direct free kick offence inside his/her penalty area, or off the field as part of play as outlined in Laws 12 and 13 of the International Football Association Board laws of the game 2020/2021 (IFAB, 2020). A penalty kick is taken from a stationary position on the penalty spot, 11 meters away from and in the centre of the goal, which is 7.32 meters wide and 2.44 meters high. A penalty is successful when the outcome of the penalty kick results in a goal directly from the kick and is unsuccessful when a goal is not the direct outcome of the penalty kick. A goal may be scored off the rebound of a saved penalty, or if the penalty rebounds off the post, however, this is an indirect result of that penalty.

O'Donoghue *et al*., (2010:6) defined performance analysis as "the investigation of sports performance during training or [in] competition". Performance analysis is used to develop an understanding of a sport that can inform decision-making, enhance performance and inform the coaching process (Hodges & Franks, 2002). Research in the field of Sport Science aims to improve knowledge regarding sport performance, and in turn, identify what leads to success in relation to team competition (McGarry, 2009). Improved accessibility to performance analysis and a focus on research in Sport Science could result in coaches' and players' performance and interpretation of their roles being enhanced. Notational analysis is a technique used to generate a data base of measures relating to a specific sporting action or event, which is frequently used by individuals and teams (James, 2006). Several approaches of notational analysis are used in the performance analysis of soccer in order to provide information to players and coaches that may be used to further assess or understand a performance (Abdullah *et al*., 2017). Notational analysis of performance could assist in identifying key factors, allowing for achievement that is greater than what is possible by means of personal observation (Abdullah *et al*., 2017).

Key Performance Indicators (KPIs) are the selection of specific characteristics or action variables of some, or all aspects of a performance (Hughes & Bartlett, 2002; Jones *et al*., 2004; James *et al*., 2005). KPIs in sport are separated into four categories, namely: 1) biomechanical indicators; 2) technical indicators; 3) tactical indicators; and 4) match classification indicators, which can be further separated into scoring indicators or indicators measuring the quality of a performance (Hughes & Bartlett, 2002:742). Some examples of scoring indicators include: the total number of shots; shots inside the box versus (vs) shots from outside the box; and ratios of successful shots on goal from total number of shots at goal. Whereas examples of quality

indicators include: tackles; pass completion rates; and possession statistics (Hughes & Bartlett, 2002). Within an individual sport, such as tennis this could be the number of successful first serves completed as a percentage of the total number of serves, while in a team sport such as rugby this could be the number of rucks formed during the game (Hughes & Bartlett, 2002). Statistics derived from the analysis of KPIs could either be used to compare different performances by an individual, within a group, between groups, within a team, or of the team's performances (Hughes & Bartlett, 2002; O'Donoghue *et al*., 2010).

Developing performance profiles by means of collecting data using KPIs could assist coaching staff to understand certain loads on players (i.e. training, high-speed running, moderate running and long-distance running) (Vahed *et al*., 2014). Performance profiles describe the pattern of performance from an analysed individual or team. The aim of performance profiles is to assist in the prediction of future performances by identifying specific KPIs that are of direct importance to the player, group or team (Hughes & Bartlett, 2002; Jones *et al*., 2004). Furthermore, setting up performance profiles can help specialist coaches to understand the events and tactics implemented by team's better, which could also provide some predictions for future performances (Jones *et al*., 2004). However, O'Donoghue *et al*. (2010) assert that it is crucial to select the correct KPIs when choosing to develop performance profiles.

Performance analysis research on soccer penalty kicks are categorized as one of the following frameworks: 1) in-match situations that facilitate the examination and identification of prominent factors that affect both penalty kick outcomes and players' performance (Chiappori *et al*., 2002; Jordet *et al*., 2007; Bar-Eli & Azar 2009; White & O'Donoghue, 2013; Almeida *et al*., 2016), or 2) laboratory or controlled settings that analyse the strategic, physical and perceptual aspects of performance (Savelsbergh *et al*., 2002; Dicks *et al*., 2010; Lopes *et al*., 2012; Weigelt & Memmert, 2012; Navarro *et al*., 2013). Studies in the first framework, such as Almeida *et al*. (2016), studied the penalty kick and its outcomes during the 2010 to 2015 UEFA Champions and Europa League in relation to situational, individual and performance factors. The 536 penalty kicks studied by Almeida *et al*. (2016:pp.518) reported to have a 75.9% success rate, which was within the range of values reported by previous research from top leagues and championships worldwide (McGarry & Franks, 2000; Morya *et al*., 2005; Jordet *et al*., 2007; Bar-Eli *et al*., 2009; Palao *et al*., 2010; White & O'Donoghue, 2013). Notably, match periods (middle 30 minutes in comparison to the first and last 30 minutes of a match) and shots in vertical and horizontal directions (shots directed into the upper areas were

more likely to be successful than those directed into the lower areas of the goal), significantly influenced penalty outcomes (Almeida *et al*., 2016).

Bar-Eli and Azar (2009:186) described probability distributions of penalty kicks in order to identify optimal performance strategies for goalkeepers' decision making based on the percentages of these probability distributions. This study was conducted using 286 penalties across various top leagues and championships worldwide and was based on the respective goalkeepers' decision-making processes. The more common approach showed that goalkeepers mostly chose to dive, even though it was found that the optimal strategy was to stay in the centre of the goal. Furthermore, the best shooting strategies for penalty kick takers have been contrasted in previous papers, moving from being in the centre of the goal (Bar-Eli & Azar, 2009) to the upper corners of the goal (Almeida *et al*., 2016). In the second framework the majority of research was performed mostly on re-created penalty kicks, based on laboratory or controlled settings in order to analyse the strategic, physical and perceptual aspects of performance (out of match). In these studies the focus was on factors, such as player cues, gaze control, qualitative approaches, player decision-making and technical aspects (Hughes & Wells, 2002; Savelsbergh *et al*., 2002; Dicks *et al*., 2010; Lopes *et al*., 2012; Weigelt & Memmert, 2012; Navarro *et al*., 2013).

According to Mohr *et al*. (2003) the amount of high intensity running is decreased during the last 15 minutes of a soccer match. During this period of play, physical constraints, as well as psychological fatigue and loss of concentration increases the chances of goals being scored (Aragón-Vargas *et al.*, 2009). According to Bompa and Buzzichelli (2015), the higher a player's playing level, the greater the in-match performance demands, which results in more stress during the game. Stress is a very complex element that is multifactorial, having a negative influence on a player's performance (Leite, 2013). Certain factors, in particular situational factors, such as match time and match status have been described to have an effect on the psychological status of players and, therefore, the penalty kick's outcome (Almeida *et al*., 2016).

Silva, (2007) conducted an analysis on eight national championships of professional football during which 7599 goals were scored in 2902 games, showed that there was a higher percentage of goals scored during the final 15 minutes of the game. Multiple studies have found that the last 15 minutes of the game are marked as resulting in a higher rate of goals, which may be attributed to player fatigue (Leite, 2013; Zhao & Zhang, 2019). However, the aforementioned

studies did not explain whether this increase in the number of goals in the final 15 minutes was true for both goals from open play and/or in-match penalty kicks. Almeida *et al*. (2016) found that match periods (time periods in a match) significantly predicted the success rate of a penalty kick, but also showed that penalty kicks were more successful in the first and last 30 minute periods of a match. This contrasts the findings of Chiappori *et al*. (2002) who found that there was a decline in the success rate of penalty kicks towards the end of a match.

Although research related to penalty kicks exists on the action bias of goalkeepers in penalty kicks (Bar-Eli *et al*., 2007), penalty kicks as an alternative method for testing mixed-strategy equilibria (Coloma, 2007), shooting strategies and goalkeepers' preferences in penalty kicks (Bar-Eli & Azar, 2009), modelling soccer penalty kicks (Comissiong & Leela, 2009), penalty kick outcomes and the roles of situational, individual and performance factors (Almeida *et al*., 2016), and an analysis of goals scored in UEFA Champions League by the time periods (Gürkan *et al*., 2017), research on quantitative analysis of penalties in relation to in-match penalty kick directions, as well select technical and match classification KPIs, such as the time of the match, score line, home vs away, right and left footed shots over a period of multiple seasons. The current study, being quantitative and descriptive, aimed to research the success rate and direction of in-match penalty kicks of the 2009 to 2019 EPL seasons through the lens of selected technical and match classification KPIs, which included: match period; score line; match status; match location; and footedness. The findings will allow for an additional view on which quantitative KPIs are related to in-match penalty kick outcomes and direction in soccer.

PROBLEM STATEMENT

Sport is constantly progressing and developing thereby resulting in finer margins between success and failure. Performance analysis has become increasingly useful in the process of identifying KPIs that are predictive of successful outcomes. The in-match penalty kick is a critical moment in soccer match play because it represents a direct opportunity to score a goal, with the aforementioned average total goals per game being 2.5 to 2.7 (Palacios-Huerta 2003:400; Bar-Eli & Azar, 2009:183; Fariña *et al*., 2013:96; Almeida *et al*., 2016:509; Gürkan *et al*., 2017:142). Therefore, it is essential that more research be conducted on in-match penalty kicks in order to allow a greater understanding of optimal penalty kick strategies for coaches and players.

RESEARCH QUESTION, AIMS, SPECIFIC OBJECTIVES AND HYPOTHESES

Research questions

1) What was the relationship between selected technical and match classification KPIs and in-match penalty kick outcomes in the EPL between the 2009/10 to 2018/19 seasons?
2) What was the relationship between selected technical and match classification KPIs and in-match penalty kick directions in the EPL between the 2009/10 to 2018/19 seasons?

Aims

1) To conduct a video-based performance analysis of in-match penalty kicks in the EPL between the 2009/10 to 2018/19 seasons to identify the relationship between selected technical and match classification KPIs and in-match penalty kick outcomes.
2) To conduct a video-based performance analysis of in-match penalty kicks in the EPL between the 2009/10 to 2018/19 seasons to identify the relationship between selected technical and match classification KPIs and in-match penalty kick directions.

Specific objectives

1) The specific objectives related to research aim one were to describe the effect of the following match classifications or technical KPIs on in-match penalty kick outcomes:
    a. footedness of penalty kick taker;
    b. match score line at the time of penalty kick;
    c. match status (winning/losing/drawing at time of the penalty kick);
    d. match period (time in match);
    e. match location (home/away);
    f. in-match penalty kick direction; and
2) The specific objectives related to research aim one were to describe the effect of the following match classification or technical KPIs on in-match penalty kick directions:
    a. footedness of penalty kick taker;
    b. match score line at time of the penalty kick;
    c. Match status (winning/losing/drawing at time of the penalty kick);
    d. match period (time in match);
    e. match location (home/away); and

Hypotheses

$1aH^1$ – The footedness of the player taking the penalty kick will influence the penalty kick outcome.

$1aH^0$ – There is no relationship between the footedness of the player taking the penalty kick and the penalty kick outcome.

$1bH^1$ – The score line of a penalty kick will influence the penalty kick outcome.

$1bH^0$ – There is no relationship between the score line of a penalty kick and the penalty kick outcome.

$1cH^1$ – The match status at the penalty kick will influence the penalty kick outcome.

$1cH^0$ – There is no relationship between the match status at the penalty kick and the penalty kick outcome.

$1dH^1$ – The match period of the penalty kick will influence the penalty kick outcome.

$1dH^0$ – There is no relationship between the match period of the penalty kick and the penalty kick outcome.

$1eH^1$ – The match location of the penalty kick will influence the penalty kick outcome.

$1eH^0$ – There is no relationship between the match location of an in-match penalty kick and the penalty kick outcome.

$1fH^1$ – The penalty kick direction will influence the penalty kick outcome.

$1fH^0$ – There is no relationship between the in-match penalty kick direction and the penalty kick outcome.

$2aH^1$ – The footedness of the player taking the penalty kick will influence the penalty kick direction.

$2aH^0$ – There is no relationship between the footedness of the player taking the penalty kick and the penalty kick direction.

$2bH^1$ – The score line of a penalty kick will influence the penalty kick direction.

$2bH^0$ – There is no relationship between the score line of a penalty kick and the penalty kick direction.

$2cH^1$ – The match status at the penalty kick will influence the penalty kick direction.

$2cH^0$ – There is no relationship between the match status at the penalty kick and the penalty kick direction.

$2dH^1$ – The match period of the penalty kick will influence the penalty kick direction.

$2dH^0$ – There is no relationship between the match period of the penalty kick and the penalty kick direction.

$2eH^1$ – The match location of the penalty kick will influence the penalty kick direction.

$2eH^0$ – There is no relationship between the match location of an in-match penalty kick and the penalty kick direction.

MOTIVATION FOR THE STUDY

Soccer is currently recognised as the most popular sport in the world in which men, women and children compete at different levels. The Fédération Internationale de Football Association (FIFA) recognise more than 265 million amateur players globally (Stølen *et al*., 2005; Paterson, 2009). While soccer is the most studied sport in the world (Kirkendall & Urbaniak, 2020) there is a current shortage of literature of objective data by means of quantitative measures on in-match penalty kicks and the influence of specific factors on penalty kick outcomes (Gilmore-Jones *et al*., 2015; Almeida *et al*., 2016). This study will aim to build on limited related research and attempt to identify new data on in-match penalty kicks that have been analysed through in-game situations, facilitating the examination and identification of prominent factors that affect both penalty kick outcomes and players' performance.

STRUCTURE OF THE THESIS

The thesis will be presented in research article format. The research article (Chapter four), will be prepared according to the guidelines of the specific journals.

Chapter One: Background: The chapter is included herewith and an adapted Harvard method of referencing was used in accordance with the guidelines of the Department of Sport Science, Stellenbosch University.

Chapter Two: Theoretical background. The chapter is included herewith and an adapted Harvard method of referencing was used in accordance with the guidelines of the Department of Sport Science, Stellenbosch University.

Chapter Three: Methodology. The chapter is included herewith and an adapted Harvard method of referencing was used in accordance with the guidelines of the Department of Sport Science, Stellenbosch University.

Chapter Four: Research article titled: In-Match Penalty Kick Analysis of the 2009/10 to 2018/19 English Premier League Competition. This chapter is included herewith in accordance with the guidelines of the International Journal of Performance Analysis in Sport.

Chapter Five: Summary, conclusion, limitations and future research. The chapter is included herewith and an adapted Harvard method of referencing was used in accordance with the guidelines of the Department of Sport Science, Stellenbosch University.

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CHAPTER TWO

LITERATURE REVIEW

The chapter is included herewith in accordance with the referencing guidelines of the Department of Sports Sciences, Stellenbosch University.

INTRODUCTION

In 1863 association football, (hereafter referred to as soccer), was formalised by the Football Association (Reilly, 2003). Globally, among men, women and children soccer is currently recognised as the most popular sport between contrasting cultures and backgrounds competing on different levels (Stølen *et al*., 2005). The International Federation of Football Association (FIFA) recognise more than 265 million amateur players globally (Paterson, 2009). The outcomes of in-match penalty kicks in soccer are of utmost importance because they are often match deciding moments and may play a role in concluding progression or elimination in cup competitions and the final standings of a league or championship (Morya *et al*., 2003; Bar-Eli & Azar, 2009; Fariña *et al*., 2013; Almeida *et al*., 2016; Gürkan *et al*., 2017).

The aim of this chapter was to summarise literature relating to soccer, more specifically the factors influencing in-match penalty kick outcomes. Performance analysis in sport, through quantitative and video-based analysis, allows coaches and players to assess and improve their own and other's performances in order to create optimal strategies to ensure success in match outcomes (Hodges & Franks, 2002; McGarry, 2009; O'Donoghue, *et al*., 2010; Herold *et al*., 2019). Within the context of the current study, the focus will be on quantitative and video-based analysis of in-match penalty kicks during the 2009/2010 to 2018/2019 seasons of the English Premier League (EPL) and the Key Performance Indicators (KPIs) of these penalties in relation to penalty kick outcomes. Literature regarding in-match penalty kicks in relation to KPIs of these penalties are currently limited.

This chapter aims to review the available literature regarding: 1) the background and history of soccer and the EPL, including the laws of the game; 2) goals in soccer; 3) implementation of performance analysis in sport and soccer; 4) the penalty kick; 5) KPIs in sport and soccer; 6) factors in relation to in-match penalty kick outcomes (time period, penalty kick direction, footedness and match location); 7) other factors influencing penalty kicks; and 8) concluded with a summary.

BACKGROUND AND HISTORY OF SOCCER

Goldblatt (2014:18) questioned whether "there [is] any cultural practise more global than football" with no single continent or country owning the sport, and therefore, it is entwined within a country's social identity. The game of football has resulted in a 'global interconnectedness', having transitioned from a 'chaotic' traditional ritual to becoming one of

the globe's largest entertainment industries (Goldblatt, 2014). Popularity in female soccer has also grown vastly and has seen its professionalism increased remarkably in recent years, with top players playing and being employed on either a professional or semi-professional basis (Datson, 2014). The game of soccer has resulted in a 'global inter-connectedness', having transitioned from a 'chaotic' traditional ritual to become one of the globe's largest entertainment industries (Maguire, 2004:pp.479).

English Premier League (EPL)

The EPL, established in 1992 (Premier League, 2020), is regarded as the top European league, with 20 teams challenging one another in a battle to be champions. It is at the top tier of English soccer with teams hoping to be crowned the champions (Premier League, 2020). The EPL is the most watched league in the world with over 188 countries viewing the live action (Premier League, 2020). Because teams play each other at 'home' and 'away' across the season, a total of 380 matches are being played from August to May (Premier League, 2020). The team that has the most points at the end of the seasons wins the title. Points are accumulated as follows: winning results in three points, drawing a match results in one point and a defeat results in none (Premier League, 2020). Depending on the final league standings, the bottom three teams are relegated to the second tier of English soccer, namely the Championship League. The position of teams that finish the season on the same points, are determined by goal difference (Premier League, 2020).

There have been seven different winners of the league, namely: Manchester United Football Club (FC); Manchester City FC; Arsenal FC; Blackburn Rovers; Chelsea FC; Leicester City FC; and Liverpool FC. The most successful team in the EPL is Manchester United FC by having won 13 of the titles in 25 seasons (Premier League, 2020). Currently, Liverpool FC are the defending champions. In total 49 clubs have taken part in the EPL, with six of the clubs being 'ever-present' in the league since it has started, namely: Everton FC; Chelsea FC; Liverpool FC; Manchester United FC; Arsenal FC; and Tottenham Hotspurs (Premier League, 2020). Finishing in the top three of the EPL results in teams qualifying for the next seasons group stages of the Union of European Soccer Associations (UEFA) Champions League (referred to as UCL) (Premier League, 2020). Teams placed fourth in the league are entered into the UCL qualifying round, while the fifth and sixth placed teams will play in the UEFA Europa League (referred to as UEL), during the next season (Premier League, 2020). This leads to the highly competitive nature of the league with fine margins that could result in significant

monetary repercussions (i.e. qualifying for the Champions League and the revenue that it brings in or being relegated out of the premier league and the loss of revenue suffered as a consequence). This highlights the critical role that the penalty kick can have in match outcomes and may ultimately play a role in the final standings of a league (Morya *et al*., 2003; Bar-Eli & Azar, 2009; Fariña *et al*., 2013; Göral, 2016; Almeida *et al*., 2016).

Laws of the game

There are 17 laws in the game of soccer, also known as "The Laws of the Game". They are applied to every soccer match played worldwide, whether it is a match played in a remote village or during a FIFA World Cup final (IFAB, 2020). The preservation and impartial implementation of these laws by referees is considered essential in the process to ensure a safe and fair soccer environment for everyone. The laws for taking penalty kicks are summarized under Laws 12 and 13 (IFAB, 2020) whereby:

> *A penalty kick is awarded if a player commits a direct free kick offence inside their penalty area or off the field as part of play as outlined in Laws 12 and 13* (IFAB, 2020:122).

The procedure for an in-match penalty kick is as follows: 1) the ball is placed to a stationary point on the penalty mark with one player being identified to take the kick; 2) the goalkeeper who is defending the goals will face the kicker while remaining on the goal line; 3) the goalkeeper is not allowed to touch the goalpost, goal net or crossbar until the player has kicked the ball;, 4) other players who are not involved in the penalty kick must be behind the penalty mark and 9.15m away from the penalty mark (Figure 2.1); 5) players must be inside the field, but outside of the penalty area; 6) the referee will signal for the kick to be taken; 7) until the ball is kicked the defending goalkeeper needs to have a part of one of his/her feet in line with or touching the goal line; 8) as soon as the ball has been kicked it is in play and the kicker may not play the ball again, unless another player has touched the ball; 9) the penalty kick is over and completed as soon as the ball goes out of the field, stops moving or an offence takes place which causes the referee to stop play (IFAB, 2020). A penalty kick can be taken during additional time at the end of each half of the match or during extra time (IFAB, 2020).

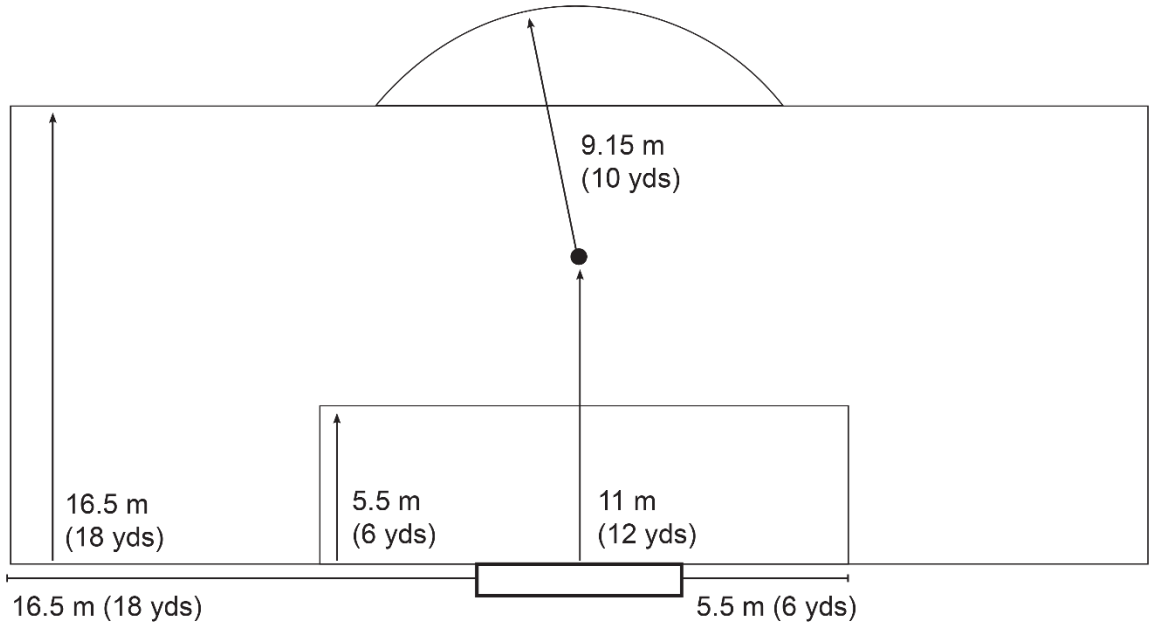

FIGURE 2.1: **SOCCER PENALTY AREA** (IFAB, 2020)

The rules of soccer clearly state that the goalkeeper must remain on the goal line before the ball is struck, however, Hughes and Wells (2002:pp.67) found that 80% of goalkeepers moved off the line. Moving forward results in the highest number of shots being saved (Hughes & Wells, 2002).

GOALS IN SOCCER

Soccer, regardless at which level it is played is concerned with winning and being victorious over one's opponent and the only way that it is achieved is through scoring more goals than the opposition. A goal is scored and awarded to a team when the soccer ball crosses over the goal line, as well as under the crossbar, granted that the team scoring the goal has not committed any offence (The IFAB, 2020). A soccer match is won when one team outscores another (who would then be the losers) (The IFAB, 2020). A draw can occur when either, both teams score the same amount of goals, or no team scores goals (The IFAB, 2020). The most successful outcomes have been shown to occur when teams create more attacking or goal-scoring opportunities in the opponent's penalty area (Herold *et al*. 2019).

In a study by Gürkan *et al.* (2017:pp144), on which the amount of goals scored over a 10-year period in the UEFA Champions League from 2006/2007 to 2015/16 was analysed, it was found that 3426 goals were scored in 1250 games. Furthermore, they found that the average total

number of goals scored per match were 2.74 (Gürkan *et al.*, 2017:pp.142). These findings correlate with the findings of Palacios-Huerta (2003:400), Bar-Eli and Azar (2009:183), Fariña *et al*. (2013:96) and Almeida *et al*. (2016:509), who reported an average of 2.5 goals per match across numerous professional soccer leagues. Relatively few in-match goals, out of the total number of in-match goals scored, are from penalty kicks in top-level soccer matches and/or leagues. Almeida *et al.* (2016) reported that 7.3% of all in-match goals scored in the 2011 to 2015 UEFA Champions and Europa league seasons were from penalty kicks, while Gelade (2014) reported that 7.7% of all goals scored in the English Premier League between 2006 and 2012 were because of penalty kicks.

The FIFA World Cup is of vital importance to the game of soccer as it is regarded as the last step of development in soccer and it shows and reflects the advanced level of modern soccer (Leite, 2013:pp.102). Çobanoğlu (2019) studied the data collected on the goals scored at the 2018 FIFA World Cup hosted by Russia. The data of this study included 64 games with 169 goals being scored, 12 of these goals were own goals, therefore, only 157 of the 169 goals were analysed (Çobanoğlu, 2019:pp.185). During the above-mentioned study, 11 different KPI's were analysed, namely: the time the goal was scored; the effect of the first goal on the outcome of the game; the type of play; the set play type; actions leading up to the goal; the type of shot; the goal zone (mainly whether it was inside or outside the penalty area, as well as the different zones); the playing position of the goal scorer; and the zone of the assist of the goal, as well as the playing position of the player who assisted in scoring the goal (Çobanoğlu, 2019). The results showed that teams who scored first won 71.42% of the games (Çobanoğlu, 2019:pp.186). This is in close correlation to the findings of Leite (2013:pp.103) who found that 70.97% of teams in the Euro 2012 ended the match as winners when scoring the first goal. In a study completed by Michailidis (2014:pp.1021) during the 2014 FIFA World Cup, 75.44% of teams that scored first won the match. A study that examined 240 games in the Portuguese Premier League (Primera Liga), showed that teams who scored the first goal won 70% of the games (Pratas *et al*., 2016). Numerous studies have shown the effect that an early goal scored will have on the final score of the game (Olsen & Larsen, 1997; Jones & Harwood, 2008). Due to a goal scored from a potential successfully converted penalty kick potentially contributing toward the aforementioned average number of goals per game - 2.5 to 2.7 (±40%) (Palacios-Huerta 2003:400; Bar-Eli & Azar, 2009:183; Fariña *et al*., 2013:96; Almeida *et al*., 2016:509; Gürkan *et al*., 2017:142) it could be argued that the penalty kick can have a potentially critical role in the outcome of a match.

According to the study of Çobanoğlu (2019:pp.186), 63.69% of the goals scored were after an organized attack (open play), while 36.30% were scored after set play. The following types of set play were examined: free kick; corner; penalty kick; and throw in. Of these types of set play, 38.59% of the goals came from a penalty kick (Çobanoğlu, 2019:pp.187). During the UEFA Euro 2012, 72.40% of goals scored were scored during open play (Mitrotasios & Armatas, 2014:pp.4). According to Cerrah *et al*. (2016:pp.40) 71.78% of goals were scored after organised attacks, while 28.22% were scored after set play during five seasons of the Turkish Super League (Süper Lig). Cerrah *et al*. (2016:pp.41) denoted that 72.61% of the actions leading up to the goal were scored with one touch, while only 15.28% were scored with control and shot (Çobanoğlu, 2019:pp.187). During the UEFA Champions League for season 2009 to 2010, it was found that 73.75% of the goals were scored from within the penalty area (Charalampos *et al*., 2013:pp.53).

Goals scored both within the penalty area, as well as outside of the penalty area were examined. Most of the goals though (84.71%) were scored from inside the penalty area, leaving only 15.28% that took place from outside the penalty area (Çobanoğlu, 2019:pp.188). Similarly, in the EUFA Euro 2012 tournament a very high percentage (90%) of goals scored came from inside the penalty area (Mitrotasios & Armatas, 2014:pp.5), while during the 2006 FIFA World Cup, 83.40% of goals scored came from inside the penalty zone (Armatas & Yiannakos, 2010:pp.121).

Although in the minority, approximately one third of in-match goals scored are from set pieces of which penalty kicks are the most common form of goals scored from set pieces. It is very important to understand the distribution of goals in soccer and where a current lack of literature needs to be updated in order to have a more holistic understanding of goal scoring in soccer in its entirety. The current study can guide coaches and managers to develop real like competition training sessions and develop the game plan according to the match situation (Çobanoğlu, 2019). This type of valuable information can allow the coach and manager to set goals and create systematic training programmes for players and teams (Çobanoğlu, 2019).

IMPLEMENTATION OF ANALYSIS IN SPORT

Research in the field of Sport Science aims to improve the understanding of performance and, in turn, identify the factors that play an important role in determining the results for success (McGarry, 2009). Performance analysis is used to develop an understanding of sport that can inform decision-making, enhance performance and improve the coaching process (Hodges &

Franks, 2002). O'Donoghue (2010:6) defines performance analysis as "the investigation of actual sport performance" which refers to the objective measurement of performance, rather than a subjective one.

Games are no longer played as they used to be and with new technology developing consistently, statistical analysis allows one to not only find the truth, but also allow the coach and players to attain a greater understating of the game (Çobanoğlu, 2019). As the world of professional sport is growing and developing at a rapid speed, so too is the importance of procedures that are used to measure the game of soccer and the players' quality (Çobanoğlu, 2019). Lately, coaches and managers are moving away from traditional training and implementing more systematic and competitive training to achieve success (Gürkan *et al*., 2017). No longer are only professional coaches looking to improve the game and their players, but amateur teams are striving to improve the quality of both the game and players (Çobanoğlu, 2019).

A method commonly used to achieve success is game analysis. In soccer, game analysis methods, as well as technological developments changed and improved over the years with an emphasis on results by systematically examining opportunities whereby goals are and can be scored (Gürkan *et al*., 2017). One of the most vital skills of a coach is the ability to witness and remember all important moments in the sporting activity. However, the number of important moments are far greater than a coaches' capacity to remember them resulting in a subjective analysis of game performance (Borrie *et al*., 2002).

Teams and clubs employ game analysts to contribute to soccer team's successes (Gürkan *et al*., 2017). Specialists study game systems and styles and observe the movement of players (Balyan *et al*., 2009). The purpose of game analysis is to objectively observe and analyse games and training sessions and extract numerical data pertaining to the parameters that are being analysed (O'Donoghue *et al*. 2010). Through this, feedback is provided to the coach and managers regarding the players and the team as a whole, thereby allowing them to make objective assessments and decisions (Carling *et al*., 2005). The data obtained allows the coach to use various strategies to identify the strengths and weaknesses of individual players and the team, as well as the opposition, in order to strive for success (Sarmento *et al*., 2014).

Improved accessibility to notational analysis and research in Sport Science could result in the performance enhancement of coaches and players, as well as the interpretation of their roles

and activities. Quantitative analysis can be defined as the analysis of an event or situation by means of complex mathematical or statistical modelling, as well as notational analysis, the study of movement patterns, strategy and tactics, could assist in identifying key factors for achievement that is greater than what is possible through personal observation (O'Donoghue *et al*. 2010).

KEY PERFORMANCE INDICATORS (KPIs)

KPIs are the selection of specific characteristics or action variables of some or all aspects of a performance (Hughes & Bartlett, 2002; Jones *et al*., 2004; James *et al*., 2005). In sport KPIs are placed into four categories, namely: 1) biomechanical indicators; 2) technical indicators; 3) tactical indicators; and 4) match classification indicators. These indicators can be further divided into scoring or indicators measuring the quality of performance (Hughes & Bartlett, 2002). Identification of goal-scoring KPIs has become of the greatest interests to coaches, analysts and researchers in elite soccer. The ability to identify these KPIs has been greatly enhanced during the last 10 years because of video-based automation advancements (Herold *et al*., 2019). Some examples of scoring indicators include: total number of shots at goal; shots inside the box vs shots from outside the box; and ratios of successful shots at goal from total shots at goal. Examples of quality indicators include: number of tackles; pass completion rates; and possession statistics. Within an individual sport, such as tennis, this could be the number of successful first serves completed as a percentage of the total number of serves. In a team sport, such as rugby this could be the number of rucks formed during a game. Statistics derived from the analysis of KPIs, could either be used to compare performances by individual players, a team compared to other teams or a team's performances. In addition, statistical analysis can be used in isolation to assess the performance of a player or team alone (Hughes & Bartlett, 2002).

With most sport being more complex and faster because of increased professionalism, the application of simplistic analyses of raw data could be highly misleading. Thus, the development of KPIs has led to the formation of performance profiles, which could help coaching staff to understand player loads (Vahed *et al*., 2014). Performance profiles describe the pattern of performance for an analysed individual or team. The aim of performance profiles is to assist in the prediction of future performances (Hughes & Bartlett, 2002; Jones *et al*., 2004). This is achieved by setting up performance profiles that can help specialist coaches to better understand the events and tactics implemented by teams, which can also provide some

prediction for future performances (Jones *et al*., 2004). However, O'Donoghue *et al*. (2010) stated that it is crucial to select the correct KPIs when developing performance profiles. In-match penalties are of major importance to match results, however, notwithstanding objective data gathered by means of quantitative measures on penalty kicks, their success rates and the influence of other factors on penalty kick outcomes are scarce (Gilmore-Jones *et al*., 2015). This has, however, not seemed to affect the approach toward penalties by goalkeepers relying more on intuition rather than research (Bar-Eli and Azar, 2009:183).

In recent years, success in soccer has been attempted through systemic training and analysis rather than traditional approaches, such as hand notations or on match day visuals (Carling, 2016). The employment of game analysts has increased over recent years in not only top tier teams but also at many levels and has contributed to the rise in emphasis placed on analysis in soccer. Almeida *et al*. (2016) studied the penalty kick and its outcomes during the 2010 to 2015 UEFA Champions and Europa League in relation to situational, individual and performance factors. Penalty kicks were analysed in two contexts, namely: 1) in-match situations that facilitated the examination and identification of prominent factors that affect both penalty kick outcomes and players' performance (Chiappori *et al*., 2002; Jordet *et al*., 2007; White & O'Donoghue, 2013): and 2) in laboratory or controlled settings in order to analyse the strategic, physical and perceptual aspects of performance (Savelsbergh *et al*., 2002; Dicks *et al*., 2010; Lopes *et al*., 2012; Weigelt & Memmert, 2012; Navarro *et al*., 2013). Performance analysis in sport by means of quantitative and video-based analyses can provide feedback to those concerned, allowing them to enhance their performance and interpretation of the activity beyond what can be achieved by personal observation in order to create optimal strategies to ensure success in match outcomes (Hodges & Franks, 2002; McGarry, 2009; O'Donoghue *et al.*, 2010; Herold *et al*., 2019).

THE PENALTY KICK

Penalty kicks are awarded when a player "commits a direct free kick offence inside their penalty area, or off the field as part of play, as outlined in Laws 12 and 13" (IFAB, 2020). Following a penalty kick awarded to a team a goal can be scored against the opposition (IFAB, 2020). Because of the higher stakes involved within soccer as a sport and as a business, the outcome of a penalty kick has been presumed to be of the utmost importance in determining match results over the past 10 years (McGarry & Franks, 2000; Bar-Eli & Azar, 2009). For some players, taking a penalty kick is exciting, while others fear and dread them (Hughes &

Wells, 2002). Many coaches have stated that penalty kicks are a "lottery" and practising them would be a complete "waste of time" because of the near impossibility of replicating the pressure of these situations in a practise or training context (Hughes & Wells, 2002:pp.59). It has been argued that the strategy used during the penalty kick is more dependent on a player's intuition than on research (Bar-Eli & Azar, 2009).

Over the last few decades, penalty kicks in soccer have become more and more important (Bar-Eli & Azar, 2009). Penalty kicks can take place during a game or after a tied game and they count the same number of points as any other goal (Bar-Eli & Azar, 2009). Hence, goals scored from penalty kicks can determine the winner of a match (Bar-Eli & Azar, 2009). When the ball is struck it takes 0.3 seconds for the ball to reach the goal from the penalty mark, therefore, the behaviour and actions of the kicker and goalkeeper are extremely important in determining the outcome of the kick (Palacios-Huerta, 2003; Bar-Eli & Azar, 2009). Amongst top professional male soccer players, the success rate of penalty kicks falls between 75 and 85% (Bar-Eli & Azar, 2009:pp.183). Other studies have affirmed these findings of success rates between 70 and 85% (McGarry & Franks, 2000; Morya *et al*., 2005; Jordet *et al*., 2007; Palao *et al*., 2010; White & O'Donoghue, 2013; Almeida *et al*., 2016).).

FACTORS IN RELATION TO IN-MATCH PENALTY KICK OUTCOMES

Match period

Most of the goals in the Champions League 2006/2007 to 2015/2016 seasons were scored between the 76th and 90th minutes of the game, whilst the lowest number of goals were scored during the first 15 minutes of the game (Gürkan *et al*., 2017). Coaches and managers can improve their teams' goal scoring ability and prevent opponents from scoring goals by taking the time periods into consideration, as well as the types of goals that were scored (Gürkan, *et al*., 2017). Likely, this could be done by implementing tactical prevention strategies based upon these factors.

During the 2018 FIFA World Cup, 61.14% of the goals scored took place in the second half of the game, with most of the goals being scored in the last 15 minutes of the game (Çobanoğlu, 2019). Similar results can be found in the following studies: Yiannakos and Armatas (2006) during the UEFA Euro 2004; Armatas *et al*. (2007) during the 1998, 2002 and 2006 FIFA World Cup; Leite (2013) during the UEFA Euro of 2012; Michailidis (2014) during the 2014 FIFA World Cup; Göral (2016) during the 2013 U-20 FIFA World Cup; Çobanoğlu and Terekli

(2018) during the UEFA Euro of 2016, whereby the majority of goals (>50%) were scored in the second half of matches.

Leite (2013:pp.104) found that 44 (57.89%) goals were scored in the second half of the matches during the UEFA Euro of 2012, while in 2016 66 goals (61.11%) were scored in the second half of the matches (Çobanoğlu, 2019:pp.186). An analysis of three FIFA World Cups indicated that more goals were scored in the second half of a match, namely: 60.80% in the 1998 FIFA World Cup, 59.00% in the 2002 FIFA World Cup and 52.50% in 2006 FIFA World Cup (Armatas *et al*., 2007:pp.54). During the 2014 FIFA World Cup, 98 goals (57.30%) were scored in the second half (Michailidis, 2014:pp.1020). According to Yiannakos and Armatas (2006:pp.172), 57.40% of the goals scored in the UEFA Euro 2004 were scored in the second half of the matches. During the U-20 FIFA World Cup in 2013, 53.94% (82 goals) were scored in the second half of the games (Göral, 2016:pp.33).

In competitive sport performance is determined by a number of inter-correlated abilities, such as technique including coordination, tactics (which consists of planning and cognitive abilities) and fitness, as well as psychological elements, such as a player's motivation, willingness and desire (Rienzi *et al*., 2000). Winning a soccer match dependents on the capability to score goals and it requires a combination of skills and abilities to be implemented for performances during the 90minute soccer match (Leite, 2013). Vital information has been drawn from numerous studies regarding the characteristics of goals, excluding that of in-match penalty kicks, because the game of soccer continues to evolve and change (Leite, 2013). The information collected needs to be shared with coaches and managers who in turn will transfer it to their players by designing their training sessions, choosing the correct tactics and applying it to the game of soccer (Yiannakos & Armatas, 2006). Leite (2013:pp.103) analysed 772 games that took place in 19 soccer World Cups from 1930 to 2010 in which 2208 goals were scored.

A study conducted on the Euro 2012, soccer competitions were divided games into 15minute time periods with the playing time being divided into 10 periods: 1^{st} to 15^{th} minutes; 16^{th} to 30^{th} minutes; 31^{st} to 45^{th} minutes; increases the 1^{th} time, 46^{th} to 60^{th} minutes, 61^{st} to 75^{th} minutes; 76^{th} to 90^{th} minutes; increases the 2^{nd} time, 1^{st} extra time (91^{st} to 105^{th} minutes) and 2^{nd} extra time (106^{th} to 120^{th} minutes) (Leite, 2013:103). Of the 2,208 goals scored in the 772 games played in the 19 World Cups, 951 (43.07%) were scored in the first half, while 1,202 (54.44%) were scored in the second half and 55 (2.49%) were scored during extra time (Leite, 2013:pp.104).

Taking the time periods and goals scored in the Euro 2012 into consideration (a total of 76 goals were scored), it was reported that in the 1st to 15th minute period. 7 goals (9.21%) were scored, in the 16th to 30th minute, 13 goals (17.11%) were scored, in the 31st to 45th minute, 11 goals (14.47%) were scored and in additional time for the 1st half, 1 goal (1.31%) was scored, totalling 32 goals (42.11%) in the first half of the games. In the 46th to the 60th minute of the second half, 15 goals (19.74%) were scored, in the 61st to 75th minute, 13 goals (17.11%) goals were scored, in the 76th to 90th minute, 13 goals (17.11%) were scored and in additional time of the 2nd half, 3 goals (3.95%) were scored, totalling 44 goals (57.89%) (Leite, 2013). Almeida *et al*. (2016) reported that penalty kick takers were more effective in the first and final half-hours of the match than that of the middle. This finding contrasts the findings of Chiappori *et al*. (2002) who reported a decline in success rates near the end stages of a match. According to Almeida *et al*. (2016), this may be because most matches are decided in the final game stages, which enhances the focus on the task and shot effectiveness because of an increase in psychological pressure (Jordet *et al.*, 2007).

According to Leite (2013:pp.104) most goals took place during the 76th to the 90th minute of the games. Similarly, an analysis conducted on eight national championships of professional soccer during which 7,599 goals were scored in 2,902 games, showed that there was a higher percentage of goals scored during the final 15 minutes of the game (Silva, 2007:pp.112). Multiple studies have been completed and found that the last 15 minutes of the game are marked as resulting in a higher rate of goals, which can largely be attributed to player fatigue (Leite, 2013). There can be multiple reasons that lead to the deterioration of player's performance, such as the accumulation of metabolic by-products, a decrease in the muscle glycogen level, failure in the stimulus-contraction and a player's nervous system (Spencer & Katz, 1991; Bianchi *et al*., 1997; Rienzi *et al*., 2000; Wilmore & Costill, 2001; Mohr *et al*., 2005). The goals scored in the second half of the matches can possibly be attributed to teams losing concentration and rising fatigue levels, as well as tactical changes whereby losing teams take more risks by playing offensively, risking their defence during the end part of the match (Gürkan *et al.*, 2017).

Due to soccer being such a competitive sport, teams and coaches are compelled to rely on science to obtain positive performance and match outcomes (White & O'Donoghue, 2013). In-match physiological demands can be too high because of the nature of the game, resulting in increased levels of fatigue, which in turn could have an influence on psychological techniques,

as well as the physical performance of players, affecting the tactics and motor actions of players during a game (Mohr *et al*., 2005). A decrease in explosive force because of physical and physiological fatigue could result in negative effects on player's performance during the end of the match (Reilly, 1997).

According to Mohr *et al*. (2003), the amount of high intensity running decreases during the last 15 minutes of play. In addition to physical constraints, psychological fatigue and loss of concentration increases the chances of goals being scored (Solera *et al*., 1999; Aragón-Vargas, 2009). According to Bompa (2005), the higher a player's level, the greater the requirement (match demand), and therefore, results in more stress during the game. Stress is a very complex element that is multifactorial, having a negative influence on player's performance (Leite, 2013). Having a greater aerobic capacity can decrease the impact of match demand on the player's performance during the last 15 minutes of play (Wilmore & Costill, 2001). Changing match tactics and strategies can also decrease the negative effects of the players' increasing fatigue levels (Reilly, 1997; Drubscky, 2003). In summary, the last 15 minutes of a game are characterized by high levels of both psychological and physical fatigue, which leads to a skewed number of goals scored during this time period (Njororai, 2004).

While it is clear from the literature that more goals are scored in the second halves of matches, mostly in the last 15minutes, it is not clear yet whether penalty kicks follow the same trend given the physiological and psychological fatigue and stressors attached to the penalty kick, particularly taking a penalty kick toward the end of a match (Mohr *et al*., 2003; Aragón-Vargas *et al*, 2009; Leite, 2013).

Penalty kick direction

A study by Bar-Eli and Azar (2009) was performed on the vertical dimensions of 311 penalty kicks. Three judges observed the penalties using a diagram, determining the part of the goal where the ball landed in, as well as the direction in which the goalkeeper jumped (Bar-Eli & Azar, 2009). Kicks shot at the goal-posts, crossbar and outside the goal were excluded because the sample was used to determine the probability of stopping the kick within the different areas of the goal, therefore, the kicks shot at the above mentioned areas were irrelevant (Bar-Eli & Azar, 2009). In cases where two judges chose the same area and one judge the adjacent area, the recorded area was where the two judges agreed (Bar-Eli & Azar, 2009). When a judge chose a cell that was not adjacent to the other two judges' area, or all three judges chose

differently, the kick was excluded from the data, resulting in a sample of 286 penalty kicks (Bar-Eli & Azar, 2009:pp.185). In order to determine the probability of what the goalkeepers' chances were to stop the kicks, the number of kicks stopped in each of the nine areas were divided by the total number of kicks shot to that grid area (Bar-Eli & Azar, 2009:pp.185). Balls kicked in the lower part of the goal were most often stopped and they were also the most often kick used by players. A total of 19.80% of the kicks shot at the lower part of the goal were stopped by the goalkeeper, while 12.60% of the kicks were stopped in the middle part of the goal (Bar-Eli & Azar, 2009:pp.186). Kicks shot at the upper part of the goal were not stopped (Bar-Eli & Azar, 2009).

Therefore, it can be concluded that kicking the ball towards the upper area of the goal is the best strategy for kickers (Bar-Eli & Azar, 2009). Focusing on the horizontal direction of the kick and kicking towards the centre of the goal seems to be the best option (Bar-Eli & Azar, 2009). The reason for this is that the chance for missing the goal is smaller and the chance of the goalkeeper stopping the penalty kick is the smallest (Bar-Eli & Azar, 2009). It was found that during 95% of the kicks, the goalkeeper would either jump to their right or left, leaving a small opportunity of them stopping the balls kicked towards the centre of the goal (Bar-Eli & Azar, 2009:pp.188). The optimal direction to kick a penalty according to coaches, however, is on the ground as close to the goalpost as you can get (Bar-Eli & Azar, 2009). Through performance analysis, however, it was found that the optimal strategy was either into the top corners or into the centre of the goal (Bar-Eli & Azar, 2009).

In contrast, it was reported that the centre of the goal was not the optimal penalty kick direction but rather into the upper corners of the goal (Almeida *et al*., 2016), even though penalty kicks directed into the top corners were reported to have an increased 'miss factor' because this may result in a penalty kick missing the goal (Hughes & Wells, 2002; Palao *et al*., 2010; White & O'Donoghue, 2013). However, this was reported to be a lower risk than the chances of the goalkeeper saving the penalty kick directed into the lower areas of the goal (Palao *et al*., 2010; White & O'Donoghue, 2013; Almeida *et al*., 2016). Although the horizontal direction is debatable, it is clear that the optimal direction consideration is vertical in the upper third of the goal. However, players characteristically still go low, which may be because of coach and player perceptions, possibly linked to the chances of missing being less when aiming low even though the chances of having their penalty saved being greater, rather than to base the penalty kick direction into optimal areas of the goal (Bar-Eli & Azar, 2009; Palao *et al*., 2010; White

& O'Donoghue, 2013; Almeida *et al*., 2016). Furthermore, it has been suggested that by lifting the ball during the strike there is an increased chance that the shot will not be saved (Hughes & Wells, 2002).

Bar-Eli & Azar, (2009:188) found that no kicks towards the top of the goal were stopped, 12.60% of kicks in the middle and 19.80% of the kicks in the lower area were stopped by the goalkeeper. This indicates that the least successful kicking strategy and most used strategy, is kicking the ball towards the lower part of the goal, while the least used strategy and the more successful one would be to target the upper part of the goal (Bar-Eli & Azar, 2009). The probability of winning a penalty shoot-out can be increased with systemic practise. Bar-Eli and Azar (2009) also argues that with proper training, targeting the upper area of the goal does not need to result in high miss rates. They also shows that shooting towards the top two corners is better than shooting at the centre (Bar-Eli & Azar, 2009). The reason why players have fail to use these strategies targeting the upper area of the goals can be that coaches instruct their players to kick low. The reason for this instruction can be that kicking high increases the kicker's chance of missing the ball (Bar-Eli & Azar, 2009). However, with proper, correct and enough training the 'miss' rate can be reduced, allowing players to make use of the high kick and take advantage of the possibility that the goalkeeper will miss these shots (Bar-Eli & Azar, 2009).

A study on penalty kicks conducted during the 1986 FIFA World Cup in Mexico, it was found that 20.00% of the 42 kicks landed in a two meter wide area from the centre of the goal, while 50.00% of the kicks landed in a two meter wide area on each side of the above mentioned zone (Bar-Eli & Azar, 2009:pp.188). Therefore, most of the kicks during the 1986 FIFA World Cup did not end up in the suggested optimal area. Goalkeepers choose to jump to one side or the other, more often than they did to stay in the middle, even though staying in the middle results in greater chances of stopping the penalty kick (Bar-Eli & Azar, 2009). Research looked at players' behaviour during the penalty kick, focusing on the cognitive processes, which include anticipation, response time of the goalkeepers, as well as cue utilization. Other studies found that the behaviour of soccer players during penalty kicks was close to predictions of game theory, in particular when the concept of a mixed-strategy equilibria was used (Chiappori *et al*., 2002; Bar-Eli & Azar, 2009). This suggests that players need to pick not a single action but rather a mixture of probabilities over certain actions, every time choosing an action at random (Bar-Eli & Azar, 2009). This has been further researched through the keeper-dependent and

keeper-independent strategies (Noël et al., 2015). Although, it seems that the utmost importance is with the penalty kick taker who should randomize where he/she kicks, choosing between right, left and centre, where the consideration for vertical direction is of great importance to penalty kick outcomes (Bar-Eli & Azar, 2009: Almeida *et al*., 2016).

Footedness

Footedness, referring to the foot, which a player or penalty kick taker uses when taking a shot or penalty kick shot (ie. right or left). Goals in football are distributed (in terms of right foot; left foot or with the head) as follows: 63.70% of the goals were scored with one touch (Mitrotasios & Armatas, 2014:pp.6), while another study found that 42.60% of goals scored came from the right foot, 33.30% from the left foot and 24.10% came from the head (Çebi *et al*., 2016:pp.9). Çobanoğlu (2019:pp.186) found that the right foot resulted in 49.68% of the goals, while 29.29% came from the left foot and 21.01% were scored with the head.

Footedness has been studied for its effect on penalty kick outs (Chiappori *et al*., 2002; White & O'Donoghue, 2013; Almeida *et al*., 2016). Chiappori *et al*. (2002) investigated penalty kick taker footedness, in relation to the natural side, middle and far side, making the penalty kick direction relative to footedness in association to penalty kick outcome. The natural side for a right footed player would be on the left side of the goal (side on which one's body is when kicking a soccer ball with your right foot), while the far side would be on the right side of the goal (this would be the opposite for a left footed player – i.e. natural side would be the right side of the goal and far side would be the left side of the goal). It has been reported that not only are kicks to the natural side less likely to go out, they are also less easily saved (Chiappori *et al*., 2002). In contrast, Almeida *et al*. (2016) reported that their findings did not completely support this natural side finding. Even though players have been found to shoot more times to their natural side, only right-footed players have been shown to have a higher effectiveness in their natural side (Almeida *et al*., 2016). Previous studies found footedness to have no significant influence on penalty kick outcomes (White & O'Donoghue, 2013; Almeida *et al*., 2016).

Match location

Match location in respect to the current study refers to whether the in-match penalty kick was awarded to the home or away team. Literature on match location and its effect on penalty outcomes is very scarce. It has been described as "never been examined" in relation to penalty

kick outcomes (Almeida *et al*., 2016:510). According to Pollard and Armatas (2017:pp.131) penalties were reported to be exactly twice as likely to be awarded to the home team (230 against 115 of their sample). It is important to note that these findings do not prove a bias by the referee, but it was noted that red cards and penalty kicks did have a potential major impact on match outcomes and occurred more regularly in favour of the home team (Pollard & Armatas, 2017).

Almeida *et al*. (2016:pp.516) reported that more penalties were awarded to home teams in comparison to that of away teams with a very similar success rate between home (76.5%) and away (74.9%) penalties in the UEFA Champions and Europa leagues. This may be attributed to the players' playing level and training status because these two competitions are regarded to be of the highest playing levels in world football and despite the location may not have any effect on a player's ability to achieve a similar rate of success for penalty kick outcomes.

OTHER FACTORS INFLUENCING THE PENALTY KICK

Goalkeeper and kicker's preference and behaviour during the penalty kick

Bar-Eli and Azar (2009) conducted a study in which 69 goalkeepers playing in the top three leagues in Israel were shown pictures of penalty kicks. They were asked to respond on whether they would be less or more satisfied saving or not saving the penalty kick. Four top Israeli soccer experts were asked to rank these goalkeepers on a 1 to 5 Likert type scale (1 being very low and 5 being very high). Goalkeepers who exceed 2.5 based on the experts' ranking were eligible to participate, resulting in 23 goalkeepers participating in the study (Bar-Eli & Azar, 2009:pp.187). During the study goalkeepers were shown a picture of an actual goal taken from the penalty point. The goalkeepers were asked to look at the picture with the different balls representing different locations of penalty kicks that they had saved in a hypothetical scenario and asked to mark the kick they saved that resulted in the most satisfaction for them (Bar-Eli & Azar, 2009). The results showed that stopping the ball in the top area of the goal was considered the most difficult (Bar-Eli & Azar, 2009). Goalkeepers are more satisfied when stopping a kick to the top area, while they are less dissatisfied when missing kicks to the top area (Bar-Eli & Azar, 2009). Therefore, it can be stated that goalkeepers are more satisfied when completing a more difficult task (the top area) and more dissatisfied when they are unable to complete a perceived easy task, such as stopping a ball in the lower area of the goal (Bar-Eli & Azar, 2009).

Goalkeepers were then asked to look at a picture with the different balls representing different locations of penalty kicks that they did not save successfully, marking the kick that they did not stop that resulted in the most dissatisfaction for them (Bar-Eli & Azar, 2009). The results here also show that goalkeepers consider it significantly more difficult to stop a ball at the top corner than at the top centre of the goal (Bar-Eli & Azar, 2009). It also showed that no one was dissatisfied when missing a ball in the top corners of the goal (Bar-Eli & Azar, 2009). Therefore, it can be assumed that it is difficult to stop balls that are high and come to both sides (corners) of the goal (Bar-Eli & Azar, 2009). Stopping a ball that is high, but close to the centre of the goal, is therefore, considered easier to stop (Bar-Eli & Azar, 2009). Therefore, based on the mentioned study, the optimal strategy for the kicker has been suggested to shoot towards the top two corners of the goal (Bar-Eli & Azar, 2009).

The reason for this is that if the goalkeeper stops the kicker's shot, it won't seem like it was his/her fault, while missing the goal will be (Bar-Eli & Azar, 2009). Therefore, this preference can result in players making the wrong decisions, affecting their team. The results showed that 20.00% of the low kicks were stopped (Bar-Eli & Azar, 2009:pp.185). Both the kicker and goalkeeper's behaviour during the penalty kick might result in biased decision-making and psychological effects (Bar-Eli & Azar, 2009). Regardless, players should be instructed to kick penalty kicks towards the upper areas of the goal, especially the corners. Proper training is needed so that they can perform these tasks successfully under pressure and as mentioned before coaches perceive penalty kick taking as a waste of time or a lottery and this exact type of mind-set needs to be changed in order to adopt a more successful penalty kick strategy (Bar-Eli & Azar, 2009; Almeida *et al*., 2016).

The goalkeeper has to decide to jump or to stay in the centre in the same time that the kicker has kicked the ball to his/her choice of penalty kick direction (Bar-Eli *et al*., 2007). Therefore, Chiappori *et al*. (2002) and Palacios-Huerta (2003) model penalty kicks as a simultaneous-move game, however, that is not always the case because goalkeepers can pick up on cues about the direction in which the kicker is going to direct the ball by observing the behaviour when he approaches the ball or if the goalkeeper knows the history of the kickers previous penalty kicks (Bar-Eli *et al*., 2007). Hughes and Wells (2002:pp.68) analysed 129 penalty shoot-outs from the finals of both the FIFA World Cup and the European Champions League. Specific focus was given to analyse the time taken to prepare for the shot, the amount of steps taken to approach the ball, the speed of the pace, the speed of the shot, where the ball was

placed and the result of the shot (Hughes & Wells, 2002). Whilst analysing the penalty taker, the goalkeepers actions were also taken into consideration, such as the body position and shape, how the goalkeeper moved as the kicker approached, the first movements made and the direction, as well as the result (Hughes & Wells, 2002).

It has been suggested that a goalkeeper's behaviour during the penalty kick may be affected by preference for action (Bar-Eli *et al*., 2007). The norm would be to jump either left or right instead of staying in the centre (Bar-Eli *et al*., 2007). Based on the norm theory, it is worse for the goalkeeper to not stop a penalty kick when it resulted from them not obeying the norm and staying in the centre, instead of obeying the norm and jumped (Bar-Eli *et al*., 2007). Based on the above-mentioned Bar-Eli *et al*. (2007) hypothesized that goalkeepers would choose to jump more than is optimal. "The action bias" means that the norm is to act rather than to choose not to act (Bar-Eli *et al*., 2007:pp.614).

This study was used to estimate the probability of stopping a penalty kick by jumping to the side or staying in the centre (Bar-Eli *et al*., 2007). Balls that did not reach the goal were excluded from the data. During the study, different judges marked a different cell, therefore, when two judges chose the same and the other judge the adjacent cell, the data recorded was where the two judges chose the same cell (Bar-Eli *et al*., 2007). In a case where the one judge did not choose the adjacent cell to the other two judges, the observation was excluded from the study (Bar-Eli *et al*., 2007). Therefore, the study resulted in 286 observations taking place (Bar-Eli *et al*., 2007:pp.618). The data shows that both the kicker and goalkeepers decisions were taken at the same time (Bar-Eli *et al*., 2007). If the goalkeeper observed the direction in which the ball was heading and then chose to jump, he/she would always jump in the direction of the kick, while if the kicker observed the direction in which the goalkeeper jumped and then decided where to kick, it would always be in a different direction to which the goalkeeper jumped (Bar-Eli *et al*., 2007). It was found that "the direction of the kick and the jump matched in 43% of the kicks rather than in 0 or 100% of the kicks, suggests that neither the kicker nor goalkeeper can clearly observe what the other chose when choosing their action" (Bar-Eli *et al*., 2007:pp.611).

In order to maximise the chances of winning, the goalkeeper needs to make the optimal decision, namely choosing the direction whereby the probability of stopping the ball is highest. According to the study by Bar-Eli *et al*. (2007), the optimal direction would be the centre. Despite the centre being the optimal decision, goalkeepers usually choose to jump right or left

(Bar-Eli *et al*., 2007). In 6.3% of the observations the goalkeepers remained in the centre, suggesting that goalkeepers is biased in making decisions, which is referred to as action bias (Bar-Eli *et al*., 2007:pp.612). The norm is that goalkeepers jump (choosing an action) rather than staying in the centre (choosing no action) (Bar-Eli *et al*., 2007). According to the norm theory, a negative outcome would be much worse if it follows no action rather than action (Bar-Eli *et al*., 2007). Therefore, a goal being scored following no action is worse than a goal being scored following action (Bar-Eli *et al*., 2007). Based on the analyses of penalties taken in shootouts from the finals of both the FIFA World Cup Finals and of the European Champions League, optimal strategies exist to conduct penalty shoot-outs, for both penalty kick takers and goalkeeper (Hughes & Wells, 2002).

Decision facing a penalty kick taker

The player who is tasked to take the penalty shoot-out has many simple decisions to consider, such as where to place the ball and how hard to kick (Hughes & Wells, 2002). In addition to these decisions, the player needs to determine the pace of the run up, as well as how many paces to take.

Speed of the strike

Based on the study of Hughes and Wells (2002:pp.63) most of the penalty kicks took place at 75% of maximum power. This could be regarded as the most efficient way of kicking a penalty shoot-out (Hughes & Wells, 2002). Slow shots only achieved a success rate of 47%, while fast shots (100% effort) resulted in a 63% success rate (Hughes & Wells, 2002:pp.64). Important to note is that when the pace of the shot increases, less kicks were saved and more were missed (Hughes & Wells, 2002). In order for players to score more goals the accuracy of pace needs to improve (Hughes & Wells, 2002).

Approach to the ball

As previously mentioned Hughes and Wells (2002) specifically focused on the time taken to prepare the shot, the amount of steps taken to approach the ball, the speed of the pace, the speed of the shot, where the ball was placed and the end result of the shot. Whilst analysing the penalty kicker, it was suggested that cues, such as the body position and shape are often linked to a general penalty kick direction (Hughes & Wells, 2002). Players frequently try to disguise their shot and deceive the goalkeeper by changing their pace, direction and run up style

(Hughes & Wells, 2002). The ball is most frequently kicked at 75% of maximum power. Different run up styles are used to achieve this, with medium being the most frequently used pace (Hughes & Wells, 2002:pp.62). A medium run results in a higher level of success, which results in lower and fewer misses and saves (Hughes & Wells, 2002). Often players try to disguise their shot by running slower, but ending in a high amount of saves (Hughes & Wells, 2002). Similarly, high-speed approaches also result in a high number of misses and saves. The study of Hughes and Wells (2002) found that players struggled to maintain accuracy when mixing the run up speed and the pace of the strike. Furthermore, it was observed that in order to be successful in a penalty kick shoot-out the optimal run up should be five paces, which allows the player a suggested higher rate of success (Hughes & Wells, 2002:pp.67).

SUMMARY

Penalty kicks are crucial elements among the factors contributing to match outcomes because of the high conversion rate (70 to 85%) (McGarry & Franks, 2000; Palacios-Huerta, 2003; Morya *et al*., 2005; Jordet *et al*., 2007; Bar-Eli & Azar, 2009; Palao *et al*., 2010; White & O'Donoghue, 2013; Gilmore-Jones *et al*., 2015; Almeida *et al*., 2016), as well as the possible contribution to match outcome a goal carries in relation to the average number of goals per game being - 2.5 to 2.7 (Palacios-Huerta 2003:400; Bar-Eli & Azar, 2009:183; Fariña *et al*., 2013:96; Almeida *et al*., 2016:509; Gürkan *et al*., 2017:142). Through the identification and creation of important KPIs (time period, footedness, in-match penalty kick direction and match location), in relation to kick direction in penalty kicks, a person could potentially maximise or minimize the potential outcome of a goal from a penalty kick contributing to the total number of the goals in a match.

As discussed, many potential factors to examine and complete video-based performance analyses of the penalty kick, to gain a better understanding of trends and potential outcomes that need to be considered, exist . Factors, such as match time, score line, kick direction, anxiety and other factors all contribute to the potential outcome of the penalty kick. Professional and amateur teams and clubs are employing game analysts to contribute to desired soccer outcomes and their success (Gürkan *et al*., 2017; Çobanoğlu, 2019). The aim of this chapter was to summarise the literature relating to soccer and more specifically the penalty kick. The points discussed aimed to highlight the literature surrounding this and bring forward the notion that literature surrounding the penalty kick is deficient, suggesting that research is required in this field.

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CHAPTER THREE

METHODOLOGY

This chapter is included herewith in accordance with the referencing style of the Department of Sport Science, Stellenbosch University.

INTRODUCTION

This chapter provides information on how the methodology of the study was carried out with the necessary specifics for it to be replicated by future research. Firstly, an overview of the study design will be provided, followed by the Key Performance Indicators (KPIs) involved in the penalty kick, as well as the inclusion and exclusion criteria. Secondly, the study outline will be covered with a focus on the in-match penalties taken in the televised matches that took place in the English Premier League (EPL) between the 2009/10 to 2018/19 seasons, as well as KPIs viewed and captured. KPIs listed and defined (Table 3.2) prior to the data capturing process were used to sort the data. Lastly, the statistical analysis used to interpret the data are described.

THEORETICAL PERSPECTIVES ON THE RESEARCH DESIGN

According to Mouton (2011), research is a systematic and logical search for novel and valuable information for further interpretation of the newly gained information on a particular topic. Descriptive research is a general overview of a subject or event by means of observation and a description of its behaviour without any influence (Grobbee, 2004). Quantitative research it is characterized by; (1) objective, (2) systematic, and (3) making use of numerical data from a selected sub-group in order to come to a broader understanding of the findings of that of specific population (Bryman, 2006). Quantitative research also enable researchers to study variables that differ in magnitude by means of scientific and statistical analyses (Bryman, 2006).

STUDY DESIGN

The current study followed a descriptive and quantitative design with no intervention, where in-match penalty kicks of the EPL between the 2009/10 to 2018/19 seasons were quantified through video analysis and the lens of selected KPIs. During the coding, the primary researcher was at liberty to pause, rewind and watch the in-match penalty kick footage in slow motion.

SAMPLE

Television video recordings of 3,800 matches in the EPL between the 2009/10 to 2018/19 seasons were coded using Nacsport video software (Version: Scout Plus – Spain, 2018). The match recordings were accessed via the IMG Replay website (technical footage partner of the EPL). The in-match penalty kick events were identified and downloaded via the IMG Replay

internet site (www.imgreplay.com). All 952 penalties that took place across the 10 seasons were initially analysed, however, a total of 45 penalty kicks were excluded in the analysis section of the study because they either missed the target or hit the goalposts without resulting in a goal and were not on target (Bar-Eli & Azar, 2009).

Inclusion and exclusion criteria

The inclusion and exclusion and criteria are presented in Table 3.1 below.

TABLE 3.1: **THE INCLUSION AND EXCLUSION CRITERIA**

Inclusion	**Exclusion**
Penalties in the English Premier League between the 2009/10-2018/19 season	Illegitimate Penalty (Needed to be retaken/Foul)
Successful (Goal) and Unsuccessful (Saved) on initial penalty kick only	Penalty kicks that miss the target or hit goalposts without resulting in a goal (Only for penalty kick direction)
Legitimate Penalty (No infringement or need to retake penalty)	
The retaken penalty after an infringement on original penalty	

DATA COLLECTION PROCEDURE

The study made use of internet sites in the public domain (www.premierleague.com/stats & www.statbunker.com) in order to collect all relevant available data on each of the in-match penalty kicks for the 10 consecutive EPL seasons (2009 to 2019). All relevant information was captured and stored in the KPIs categories (Table 3.2) on Microsoft Excel 2018 (Microsoft Corporation, 2018). Video footage access was obtained through IMG Replay (www.imgreplay.com). In-match penalty kicks were coded using set KPIs with operational definitions. The coding was completed using Nacsport video software (Version: Scout Plus - Spain, 2008). Each in-match penalty kick was viewed and analysed for penalty kick direction as per the areas denoted in Figure 3.1 and Figure 3.2. All relevant raw data was collected and stored on the master data excel sheet. Data was transferred to an external hard drive for storage

and safety purposes. The raw data was categorised by season and in the order (overall and per season) that the in-match penalty kicks occurred. Each in-match penalty kick was further categorised by match location (home/away), time of match, match status (winning/drawing/losing), score line difference, footedness (left/right), penalty kick taker (each represented by a number) and in-match penalty kick direction (post in-match penalty kick analysis).

Key Performance Indicators and description

The KPIs analysed based on the aims of the study are cited in Table 3.2 and Figure 3.1.

TABLE 3.2: **KEY PERFORMANCE INDICATORS AND DESCRIPTION**

KPIs	Descriptions
Match classification indicators	
Match period	Time when the penalty kick was taken. Categorised into 15-minute periods (i.e. 1st to 15th minute of the match 16th to 30th minute of the match, etc.).
Score line during match	The difference in score line between the penalty kick taker's team and the goalkeepers team (i.e. -2, 0, +1 etc.).
Match location	Whether the penalty kick was awarded to the home or away team.
Technical indicators	
Direction / placement of shot	The grid area in which the penalty kick was kicked into, which would indicate shot (1) direction (Figure 3.2), (2) direction relative to footedness (Figure 3.3).
Footedness	The penalty kicker's foot (left or right) used for taking the penalty kick.
Outcome	Successful - Ball crosses the goal line within the goal frame from the initial penalty kick resulting in a goal. Unsuccessful - Ball does not cross the goal line within the goal frame from the initial penalty kick.

Coding

The in-match penalty kicks were analysed using the Nacsport video software (Version: Scout Plus - Spain, 2008). The software allows an incident to be coded and presented as a KPI (Table 3.2).

	Left	**Centre**	**Right**
Top			
Middle			
Bottom			

FIGURE 3.1: **GOAL GRID** (adapted from the goal grid described by Bar-Eli & Azar, 2009)

Goal grid

The goal grid for the current study was adapted from the version in Figure 3.1 to create two grids for the measurement requirements of the study. These are as follows:

	A	B	C
1			
2			
3			

FIGURE 3.2: ***GOAL GRID – KICK DIRECTION***

Note: A1 – Top row & left column of goal area, A2 - Middle row & left column of goal area, A3 – Bottom row & left column of goal area, B1 - Top row & middle column of goal area, B2 - Middle row & middle column of goal area, B3 – Bottom row & middle column of goal area, C1 - Top row & right column of goal area, C2 - Middle row & right column of goal area and C3 - Bottom row & right column of goal area.

Thereafter, the grid area was recoded to represent penalty kick directions in relation to footedness.

	K	M	F
1			
2			
3			

FIGURE 3.3: ***GOAL GRID – KICKERS/MIDDLE/FAR SIDE***

Note: A kick into the top left corner of the goal (A1 on previous goal grid) was coded as K1 (Kickers side) for right footed penalty kick takers and F1(Far side) for left footed penalty kick takers as to represent the in-match penalty kick direction relative to footedness.

Reliability

After initial coding the primary researcher (Coder 1) and a group of external coders – a honours student (Coder 2), a goal keeper academy coach (Coder 3) and a soccer player that takes penalty kicks (Coder 4) re-coded 50% (N=455) of the in-match penalty kicks that were randomly selected by the statistician to check for intra and inter-coder reliability. The analysis showed that that the strength of the agreement between all variables was almost perfect and thus very agreeable (Table 3.3).

TABLE 3.3: **INTRA- AND INTER-CODER RELIABILITY (r) FOR SHOT DIRECTION AND PENALTY KICK OUTCOME**

Reliability	KPI		
	Direction	Outcome	Kappa total
Intra-coder	1.00	1.00	1.00
Inter -coder: 1 vs 2	0.934	1.00	0.967
Inter -coder: 1 vs 3	0.880	1.00	0.940
Inter -coder: 1 vs 4	0.811	1.00	0.906
Inter -coder: 2 vs 3	0.850	1.00	0.925
Inter -coder: 2 vs 4	0.958	1.00	0.979
Inter -coder: 3 vs 4	0.882	1.00	0.941

STATISTICAL ANALYSIS

Professor Martin Kidd from the Centre for Statistical Consultation at Stellenbosch University completed the statistical analysis. GEE Pack (GEE specific analysis) and Statistica (version, 13.5.0.17) were used for the statistical analysis of the data. Relationships between KPIs and penalty kick outcomes/directions were tested using cross tabulation and the Pearson's Chi-square test. Multiple correspondence analysis was used to descriptively investigate how outcomes of more than two KPIs tend to occur together (correspond). Generalized estimating equation (GEE) analysis with binomial distribution was used to test for combined effects of KPIs on the success (yes or no) of penalty kicks. Fisher least significant difference (LSD) was used for post-hoc testing. The level of significance was set at 95% ($p \leq 0.05$). Correlation coefficient (ICC) to determine the inter and intra-coder reliability was used (Gratton & Jones,

2014). The inter and intra-coder reliability was interpreted as follows: poor (0 to 0.20), fair (0.30 to 0.40), moderate (0.50 to 0.60), strong (0.70 to 0.80) and almost perfect (>0.80) (Liporace et al., 2012).

IMPLEMENTATION OF FINDINGS

The data will be presented in the form of a research article. This article will provide a description of the data collected and the main relationships that existed amongst the KPIs for in-match penalty kicks. The findings from the current study could provide valuable information to players, both outfield and goalkeepers and coaches regarding kick directions, as well as all other KPIs covered and identified in relation to in-match penalty kicks and the success rates thereof. The results should also provide players and coaches with valuable information that can be used to review data and KPIs relating to in-match penalty kicks, to best implement systematic practices towards penalty kick directions for optimal success into training programs and ultimately when approaching in-match penalties.

ETHICAL ASPECTS

The study protocol was approved by the Departmental Ethics Screening Committee (DESC) at Stellenbosch University (REC-2019-8888). The study was in line with the declaration of Helsinki and was considered low-risk and did not involve any active participants. All data were treated with strict confidentiality and remained anonymous when reported in the article. Data was stored on a password-protected computer and on a protected file within the programs used to store the data. Hard copies were stored in a locked storeroom with an alarm system and with limited access at the Department of Sport Science at Stellenbosch University. The researcher and two supervisors had access to the data. The statistician who assisted with data analysis only worked with an anonymous coding system. Data will be kept for six years where after it will be shredded and destroyed and electronic copies deleted. The goal is to publish an article in which in-match penalty kick data will be discussed and compared with the existing standards in literature. Only group data will be reported and no player or team will be identified.

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CHAPTER FOUR

RESEARCH ARTICLE

IN-MATCH PENALTY KICK ANALYSIS OF THE 2009/10 TO 2018/19 ENGLISH PREMIER LEAGUE COMPETITION

This chapter is included herewith in accordance with the referencing style of the International Journal of Performance Analysis in Sport (Appendix C). The article is included herewith in accordance with the guidelines for authors of this esteemed journal. However, to provide a neat and well-rounded final product for this thesis, the article has been edited to represent an actual published article, as it would appear in this particular journal. This does not imply that the article has been accepted or will be accepted for publication. Consequently, the referencing style used in this chapter may differ from that used in the other chapters of this thesis.

Title page

Title: In-match penalty kick analysis of the 20018/19 to 2018/19 English Premier League competition.

Field of study: Sport Science (Performance Analysis)

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In-match penalty kick analysis of the 2009/10 to 2018/19 English Premier League competition

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ABSTRACT

The in-match penalty kick is of great importance in soccer and can be the deciding factor in a match outcome. The penalty kick may be a decisive event in a match, as well as an opportunity to progress in a knockout competition or ultimately the final standings of a competition. The aims of the current study were to conduct a video-based performance analysis of in-match penalty kicks in the English Premier League (EPL) between the 2009 to 2019 seasons to identify the relationship between selected technical and match classification Key Performance Indicators (KPIs) and in-match penalty kick outcomes and directions. All the in-match penalty kicks (N = 952) that took place in the EPL across 10 consecutive seasons were analysed using Nacsport video analysis software. In-match penalty kick direction, specifically vertical direction, significantly influenced in-match penalty kick outcomes ($p < 0.01$). Match period, score line, match venue and footedness had no significant effect on in-match penalty kick outcomes or direction of kick. The study revealed that in-match penalty kicks should be directed toward the top vertical zones of the goal area to optimise the opportunity for success of in-match penalty kicks. Importantly, the risk factor of aiming high and missing is lower than aiming low and being saved, as such; coaches and players should implement systematic penalty kick training programmes aimed at improving penalty kick placements and control into the top areas of the goal.

KEYWORDS: penalty kick, performance analysis, soccer, success rates, key performance indicators

4.1 Introduction

Association football (hereafter referred to as soccer), along with having the largest amount of global participants of all sports, it is also the most studied sport in the world (Kirkendall & Urbaniak, 2020). Despite this, literature of objective data through quantitative measures on in-match penalty kicks and the factors of prospective influences on penalty kick outcomes is scarce, or only briefly touched on (Gilmore-Jones et al., 2015; Almeida et al.,

2016). Soccer matches that were played in the Union of European Football Associations (UEFA) Champions League between 2006 and 2016 averaged 2.7 total goals per match (Gürkan et al., 2017), therefore, the outcome of a single in-match penalty kick (one goal) could have had a significant impact on the result of a soccer match. Successful penalty kicks may play a critical role in match outcomes, particularly in knockout ties and may ultimately effect the final standings of a league or competition (Morya et al., 2003; Bar-Eli & Azar, 2009; Fariña et al., 2013; Göral, 2016; Almeida et al., 2016)

The success rate of penalty kicks in professional soccer leagues ranges from 70 to 85% (McGarry & Franks, 2000; Palacios-Huerta, 2003; Morya et al., 2005; Jordet et al., 2007; Bar-Eli &Azar, 2009; Palao et al., 2010; White & O'Donoghue, 2013; Gilmore-Jones et al., 2015; Almeida et al., 2016). Considering the fine margins for success in modern soccer the penalty kick is of great importance because it can be a decisive event in soccer and can often be the deciding factor between winning and losing (Bar-Eli & Azar, 2009; Fariña et al., 2013; Almeida et al., 2016). Furthermore, relatively few goals, out of the total number of goals scored, result from penalty kicks in top-level soccer matches and/or leagues. Almeida et al., (2016) reported that 7.3% of all goals scored in the 2011 to 2015 UEFA Champions and Europa League seasons were from penalty kicks, while 7.7% of all goals scored in the EPL between 2006 and 2012 were as a result of penalty kicks (Gelade, 2014).

Research on objective data through quantitative analysis on in-match penalty kicks, their success rates and the influence of other factors on in-match penalty kick outcomes is scarce (Gilmore-Jones et al., 2015). Studies that make use of improved data collection procedures through the use of video analysis have a major strength because they are based on the high ecological validity of examining elite performances and performers in the actual sporting context in which they participate and compete (Jordet et al., 2009; Almeida et al., 2016).

Almeida et al., (2016) categorised penalty kick analyses research into two frameworks, namely: 1) laboratory or controlled settings in order to analyse the strategic, physical and perceptual aspects of the performance (Savelsbergh et al., 2002; Dicks et al., 2010; Lopes et al., 2012; Noël, 2015; Tay et al., 2012; Weigelt & Memmert, 2012; Navarro et al., 2013); and 2) in-match situations, facilitating the examination and identification of prominent factors that affect both penalty kick outcome and players' performance (Chiappori et al., 2002; Jordet et al., 2007; White & O'Donoghue, 2013). In the first framework, a progressive increase in the

task representativeness was attempted in order to examine new methods to improve the performance and strategies of both the penalty kick participants (penalty kick taker and goalkeeper), In the second framework, data collection procedures were improved by the use of video analysis concluded from the use of televised soccer matches (Almeida et al., 2016).

Almeida et al. (2016) conducted an exploratory study on the main and interaction effects of situational, individual and performance factors on in-match penalty kick (N=536) outcomes in the UEFA Champions League and Europa League between 2010 to 2015 seasons and noted that, "although performance factors were the most decisive for determining the penalty outcomes, situational factors, such as match period may also influence the success of penalty kicks" (Almeida et al., 2016:508). It was reported that of the 536 penalties analysed in the study, 28 (5.2%) were missed and 101 (18.8%) were saved by the goalkeeper, while 407 (75.9%) resulted in a goal, with the highest rates of success reported when shots were directed into the upper corners of the goal (Almeida et al., 2016). Furthermore, it was reported that the probabilities of penalty kicks being saved were significantly increased when the shot direction was to the lower centre-left zone of the goal (Almeida et al., 2016). Shot direction, in relation to the penalty kick, has been reported to have a close relationship with penalty kick outcomes (Lopez-Botella & Palao, 2007; Bar-Eli et al., 2007; White & O'Donoghue, 2013; Almeida et al., 2016).

Based on the above background and the lack of quantitative research on penalty kicks in professional soccer, the aims of this study were to conduct a video-based performance analysis of in-match penalty kicks in the EPL between the 2009/10 to 2018/19 seasons to identify the relationship between selected technical and match classification KPIs and in-match penalty kicks outcome and directions.

4.2 Methodology

4.2.1 Research design

This research study followed a descriptive and quantitative study design with video analysis being the primary data collection tool and secondary information was collected from different websites. Ethical approval (REC-2019-8888) was obtained from the Research Ethics Committee: Human Research at Stellenbosch University (Appendix A). The study was in line with the declaration of Helsinki and was considered low-risk and did not involve any active participants.

4.2.2 Sample

All legitimate in-match penalties (N=952) that took place over the 10 EPL seasons (2009/10 to 2018/19) (N=3,800 matches), were included in the study and only valid penalty kicks were coded (Lopez-Botella & Palao, 2007; Bar-Eli & Azar, 2009; Palao et al., 2010; Almeida et al., 2016). Successful penalties were recorded when a goal was the direct result of the penalty kick and not if a goal was scored off the rebound, saved, missed the target or hit the goal posts and did not go into the goal. All illegitimate penalties, those needed to be retaken or classified as foul were excluded from the final study sample. For retaken penalty kicks, the original penalty kick was excluded and only the retaken penalty included.

4.2.3 Data collection procedures

Video footage access was obtained through IMG Replay (www.imgreplay.com) (Appendix B). In-match penalty kicks were coded using set select technical and match classification KPIs with operational definitions. The coding was completed using Nacsport video software (Version: Scout Plus - Spain, 2008). Each in-match penalty kick was viewed and analysed for penalty kick direction as per the areas denoted in Figure 4.1. All relevant raw data was collected and stored on the master data Microsoft Excel 2018 spreadsheet (Microsoft Corporation, 2018). The raw data was categorised by season and order (overall and per season), in which the in-match penalty kicks occurred. Each in-match penalty kick was further categorised by match location (home/away), time of match, match status (winning/drawing/losing), score line difference, footedness (left/right), penalty kick taker (each represented by a number) and in-match penalty kick direction (post in-match penalty kick analysis). The current study made use of internet sites in the public domain (www.premierleague.com/stats & www.statbunker.com) in order to collect all relevant additional available data on each of the in-match penalty kicks for the 10 consecutive EPL seasons (2009/10 to 2018/19).

4.2.3.1 Key Performance Indicators (KPIs)

All relevant information was captured and stored in the selected match classifications and technical indicators listed in Table 4.1.

Table 4.1: Key performance indicators and descriptions

KPIs	Descriptions
Match classification indicators	
Match period	Time when the penalty kick was taken. Categorised into 15-minute periods (i.e. 1st to 15th minute of the match 16th to 30th minute of the match, etc.).
Score line during match	The difference in score line between the penalty kick taker's team and the goalkeepers team (i.e. -2, 0, +1 etc.).
Match location	Whether the penalty kick was awarded to the home or away team.
Technical indicators	
Direction / placement of shot	The grid area in which the penalty kick was kicked into, which would indicate shot (1) direction (Figure 4.1), (2) direction relative to footedness (Figure 4.2).
Footedness	The penalty kicker's foot (left or right) used for taking the penalty kick.
Outcome	Successful - Ball crosses the goal line within the goal frame from the initial penalty kick resulting in a goal. Unsuccessful - Ball does not cross the goal line within the goal frame from the initial penalty kick.

4.2.3.2 Coding

Each penalty kick was recorded into the data set using the grid area indicated in Figure 4.1 (adapted from Bar-Eli & Azar, 2009). In order to assist in the penalty kick direction analysis decision, additional camera angles were used for any penalty kicks that, from the primary video observational view of the penalty kick, were a challenge to accurately conduct the analysis. The penalty kick direction and data were recoded to represent penalty kick directions in relation to footedness. These were represented as K; M; & F (Figure 4.2) (kickers; middle; and far side

respectively), with K being on the left for a right footed players and on the right for a left footed players (from the perspective of the kickers view), referred to as the player's natural side (Chiappori et al., 2002; White & O'Donoghue, 2013). Data on penalty kick direction was obtained through watching each in-match penalty kick using the viewpoint from behind the penalty kick taker towards the goal, which was set as the primary video observational view of the penalty kick.

	A	**B**	**C**
1			
2			
3			

Figure 4.1: Goal Grid – Kick Direction (adapted from Bar-Eli & Azar, 2009)

Note: A1 – Top row & left column of goal area, A2 - Middle row & left column of goal area, A3 – Bottom row & left column of goal area, B1 - Top row & middle column of goal area, B2 - Middle row & middle column of goal area, B3 – Bottom row & middle column of goal area, C1 - Top row & right column of goal area, C2 - Middle row & right column of goal area and C3 - Bottom row & right column of goal area.

	K	M	F
1			
2			
3			

Figure 4.2: Goal Grid - Kickers/Middle/Far Side (adapted from Bar-Eli & Azar, 2009)

Note: A kick into the top left corner of the goal (A1 on previous goal grid) was coded as K1 (Kickers side) for right footed penalty kick takers and F1(Far side) for left footed penalty kick takers as to represent the in-match penalty kick direction relative to footedness.

4.2.3.3 Reliability

After initial coding the primary researcher (Coder 1) and a group of external coders – a honours student (Coder 2), a goal keeper academy coach (Coder 3) and a soccer player that takes penalty kicks (Coder 4) re-coded 50% (N=455) of the in-match penalty kicks that were randomly selected by the statistician to check for intra and inter-coder reliability. The analysis showed that that the strength of the agreement between all variables was almost perfect and thus very agreeable (Table 4.2).

Table 4.2: Intra- and inter-coder reliability (r) for shot direction and penalty kick outcome

Reliability	KPI		
	Direction	Outcome	Kappa total
Intra-coder	1.00	1.00	1.00
Inter -coder: 1 vs 2	0.934	1.00	0.967
Inter -coder: 1 vs 3	0.880	1.00	0.940
Inter -coder: 1 vs 4	0.811	1.00	0.906
Inter -coder: 2 vs 3	0.850	1.00	0.925
Inter -coder: 2 vs 4	0.958	1.00	0.979
Inter -coder: 3 vs 4	0.882	1.00	0.941

4.2.4 Statistical analysis

GEE Pack (GEE specific analysis) and Statistica (version, 13.5.0.17) were used for the statistical analysis of the data. Relationships between KPIs and penalty kick outcomes/directions were tested using cross tabulation and the Pearson's Chi-square test. Multiple correspondence analysis was used to descriptively investigate how outcomes of more than two KPIs tend to occur together (correspond). Generalized estimating equation (GEE) analysis with binomial distribution was used to test for combined effects of KPIs on the success (yes or no) of penalty kicks. Fisher least significant difference (LSD) was used for post-hoc testing. The level of significance was set at 95% ($p \leq 0.05$). Correlation coefficient (ICC) to determine the inter and intra-coder reliability was used (Gratton & Jones, 2014). The inter and intra-coder reliability was interpreted as follows: poor (0 to 0.20), fair (0.30 to 0.40), moderate (0.50 to 0.60), strong (0.70 to 0.80) and almost perfect (>0.80) (Liporace et al., 2012).

4.3 Results

4.3.1 General descriptive statistics

The 952 in-match penalty kicks analysed had a total of 743 successful (78.0%) and 209 unsuccessful (22.0%) kicks of which 164 were saved (17.2%) and 45 missed (4.7%). The total number of goals scored from in-match penalty kicks (N=743) from that of the total goals scored in the EPL between the 2009 and 2019 seasons (N = 10,452) was 7.1%. For the 952 in-match penalty kicks, 572 (60.0%) were awarded to the home team, while 380 (40.0%) were awarded to the away team. 263 (28.0%) in-match penalty kicks were awarded to the team who was winning, with 293 (31.0%) and 396 (42.0%) awarded to the losing and drawing teams respectively. 771 (81.0%) of the in-match penalty kicks were taken by right footed kickers with the remaining 181 (19.0%) taken by left footed kickers. In-match penalty kick occurrence increased as the time in match progressed (Figure 4.3). 394 (41.4%) of the in-match penalty kicks were awarded at a score line difference of 0 (Figure 4.4).

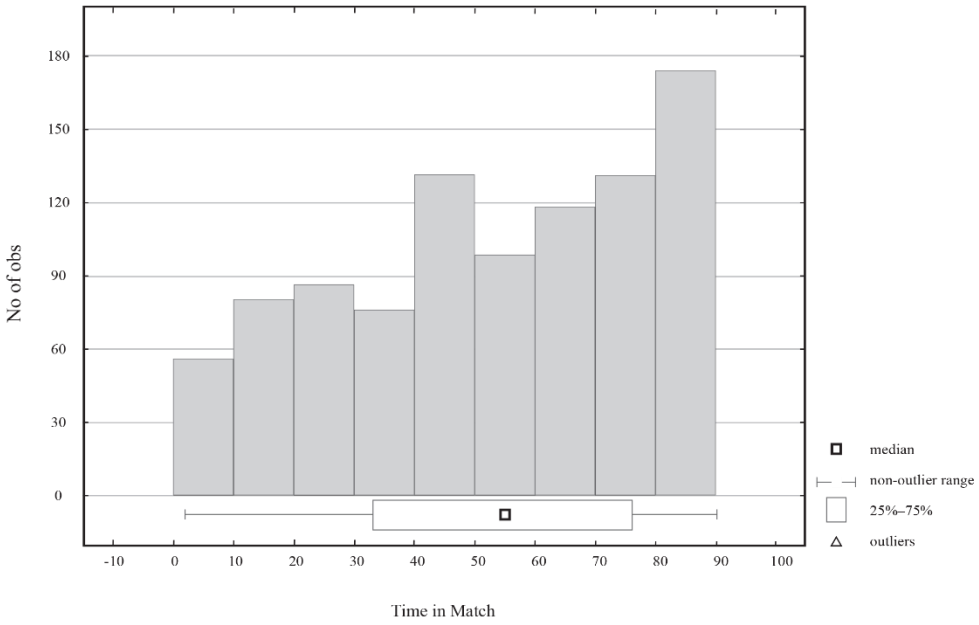

Figure 4.3: Match period distributions

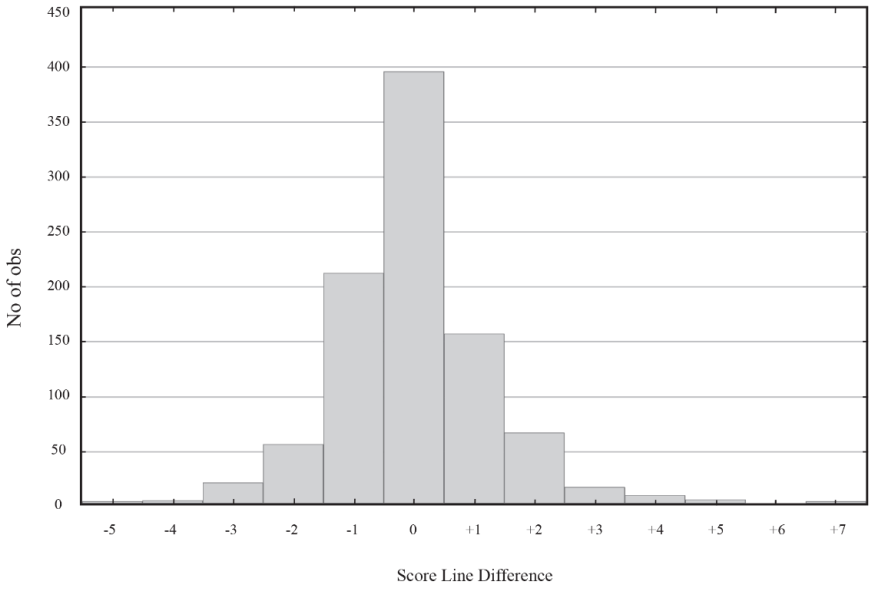

Figure 4.4: Score line difference distributions

In-match penalty kick direction and success rates are denoted in Figure 4.5, whereby the missed (n=45) penalty kicks were excluded from the final number of in-match penalty kicks analysed in the direction based analysis (n=907).

VERTICALE ZONES	KICKERS SIDE		MIDDLE		FAR SIDE	
	HORIZONTAL ZONES					
	S	US	S	US	S	US
1	97.7%		100%		100%	
	42	1	23	0	26	0
2	81.1%		94.3%		85.7%	
	77	18	50	3	72	12
3	77.3%		74.3%		79.2%	
	215	63	52	18	186	49

Figure 4.5. On target in-match penalty kick (N = 907) direction distributions and success rate percentages relative to kick taker footedness

Note: Kickers side = left for right footers/right for left footers; success S-Successful; US-Unsuccessful).

4.3.2 Effect of match classification and technical KPIs on in-match penalty kick directions

The Pearson's Chi-square test indicated no difference in penalty kick directions (categorical grid areas: K1 to F3) based on time in match (1 to 15 minutes, 15 to 30 minutes, 30 to 45 minutes, 45 to 60 minutes, 60 to 75 minutes and 75 to 90 minutes), with the majority (21 to 37%) of the kicks in each time period being directed into grid areas F3 and K3, regardless of time in match. Similarly, no difference in penalty kick directions were observed based on score line (> 2 goals, + 1 goal, 0 goals, -1 goal, < 2 goals), with the majority of kicks (24 to 33%) directed into grid areas F3 and K3 regardless of the score line. Lastly, there was no difference in penalty kick directions based on player footedness (right/left foot), as indicated in Figure 4.6 below.

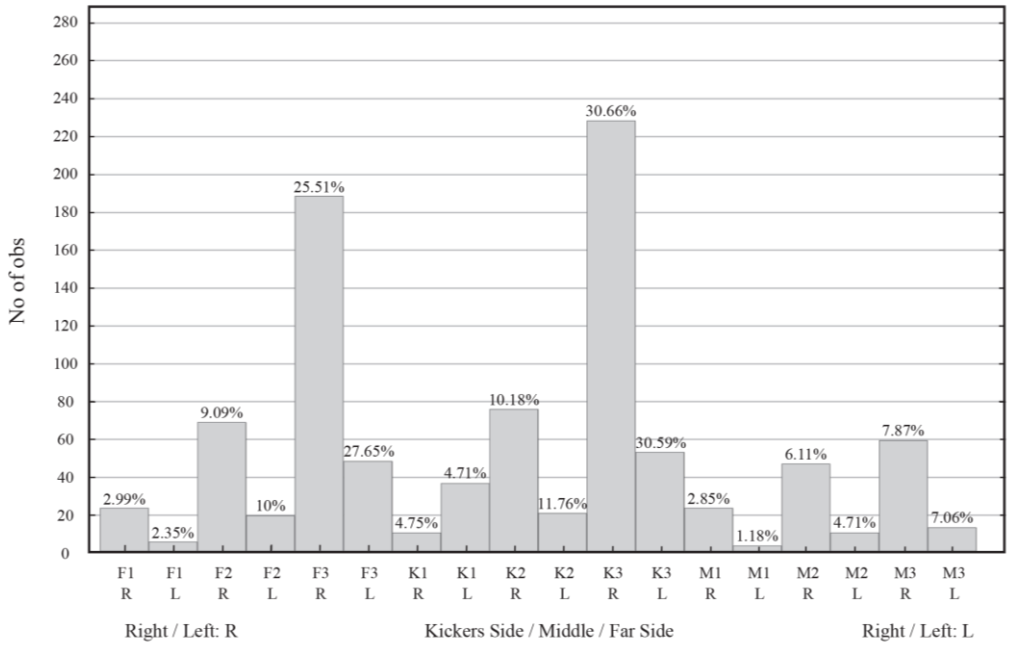

Figure 4.6. Direction distributions in relation to penalty kick taker footedness

4.3.3 Effect of match classification and technical KPIs on in-match penalty kick outcomes (success rate)

Table 4.3 represents the in-match penalty kick outcomes and their respective frequencies in relation to the various match classification and technical KPIs, whereby $p \leq 0.05$ indicates a significant difference in penalty kick outcomes between categories within respective KPIs (i.e. Home vs Away or Winning vs Losing vs Drawing, etc.).

From the analysis in Table 4.3 below, it is clear that none of the selected technical and match classification KPIs were related to penalty outcome rates, except for vertical shot directions. Further investigation into the relationship between in-match penalty kick directions and outcome via a GEE revealed that there was a statistically significant difference in penalty kick outcomes between penalties kicked into various areas of the goal (Figure 4.7).

Table 4.3 Frequencies and frequency distributions (%) of KPIs in relation to penalty outcomes (success rate %).

KPIs	Total *f* (%)	Penalty outcome	
		Successful *f* (%)	Unsuccessful *f* (%)
Match location (p = 0.95)			
Home	572 (60.1)	446 (78.0)	126 (22.0)
Away	380 (39.9)	297 (78.2)	83 (21.8)
Match status (p = 0.51)			
Winning	262 (27.5)	206 (78.6)	56 (21.4)
Drawing	394 (41.4)	302 (76.6)	92 (23.4)
Losing	296 (31.1)	235 (79.4)	61 (20.6)
Score line (p = 0.64)			
≥ 2	102 (10.7)	81 (79.4)	21 (20.6)
1	160 (16.8)	125 (78.1)	35 (21.9)
0	394 (41.4)	302 (76.6)	92 (23.4)
-1	214 (22.5)	166 (77.6)	48 (22.4)
≤ -2	82 (8.6)	69 (84.1)	13 (15.9)
Footedness (p = 0.30)			
Right	771 (81.0)	607 (78.7)	164 (21.3)
Left	181 (19.0)	136 (75.1)	45 (24.9)
Match period (p = 0.36)			
1-15	91 (9.6)	70 (76.9)	21 (23.1)
16-30	131 (13.8)	111 (84.7)	20 (15.3)
31-half-time	172 (18.1)	130 (75.6)	42 (14.4)
46-60	135 (14.2)	101 (74.8)	34 (15.2)
61-75	182 (19.1)	140 (76.9)	42 (23.1)
76-full-time	241 (25.3)	191 (79.3)	50 (20.7)
Shot direction horizontal zone (p = 0.33)			
Kicker's Side	416 (45.9)	334 (80.3)	82 (19.7)
Middle	146 (16.1)	125 (85.6)	21 (14.4)
Far Side	345 (38.0)	284 (82.3)	61 (17.7)
Shot direction vertical zone (p < 0.01)			
1 (Top)	92 (10.1)	91 (98.9)	1 (1.1)
2 (Middle)	232 (25.6)	199 (85.8)	33 (14.2)
3 (Bottom)	583 (64.3)	453 (77.7)	130 (22.3)

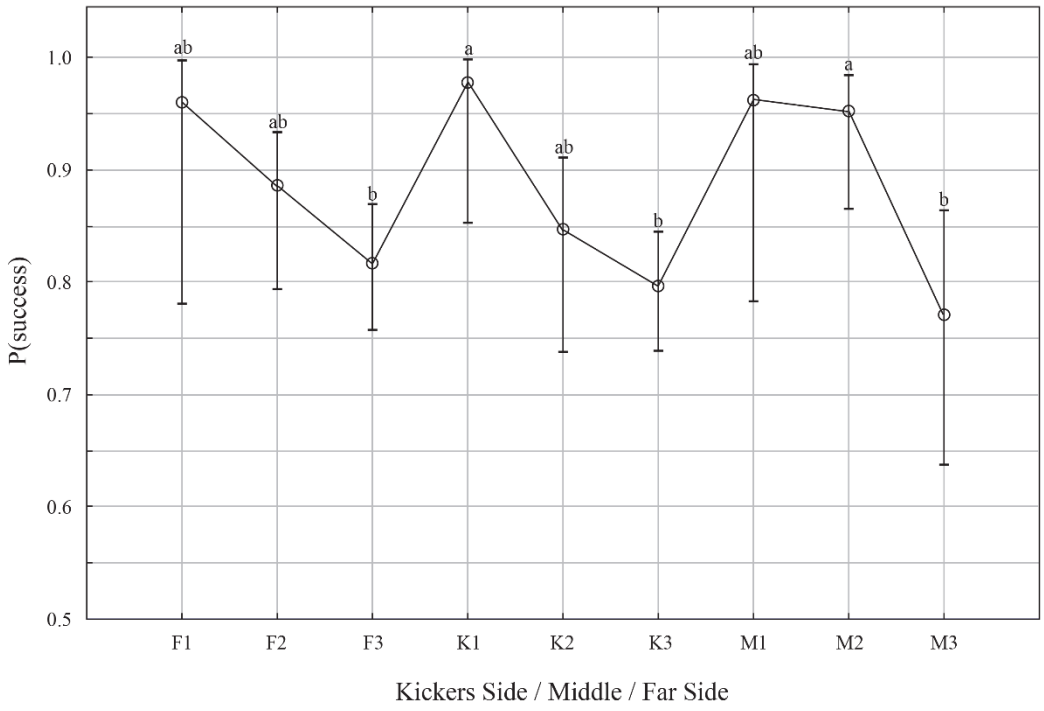

Figure 4.7: Fishers Least Significant Difference Post-Hoc Test for penalty kick directions

A Fisher's Least Significant Difference Post-Hoc Test (Figure 4.7) revealed that there was a statistically significant difference in penalty kick outcomes ($p < 0.05$) for the following grid areas: K1 (97.7%) vs F3 (79.2%), K2 (81.1%) vs K1, K3 (77.3%) vs K1, M3 (74.3%) vs M1 (100%), K2 (81.1%) vs M2 (94.3%). Additionally, there was a statistically significant difference in penalty kick outcomes ($p < 0.01$) for the following grid areas: M2 vs M3, F3 vs M2, K1 vs M3, K3 vs M2, and M2 vs K1.

To further explore the relationship between penalty kick directions and penalty kick outcomes, penalty kicks were grouped and a Pearson's Chi-square test was done on two groups (Group 1: K1, M1, F1 and M2; Group 2: K2, F2, K3, M3 and F3), whereby a statistically significant difference in success rate was reported between Group 1 (97.0%) and Group 2 (79.0%) ($p < 0.01$).

Table 4.4 Fisher's Least Significant Difference Post-Hoc Test whereby a value of ≤ 0.05 indicates a significant difference in penalty success rate between two grid areas

Kickers Side / Middle / Far Side	F1	F2	F3	K1	K2	K3	M1	M2	M3
	0.97	0.88	0.82	0.99	0.85	0.80	0.96	0.95	0.77
F1		0.23	0.09	0.74	0.14	0.07	0.94	0.76	0.06
F2	0.23		0.14	0.1	0.48	0.06	0.24	0.15	0.07
F3	0.09	0.14		0.03*	0.58	0.44	0.09	0.01**	0.35
K1	0.74	0.1	0.03*		0.05*	0.02*	0.69	0.47	0.01**
K2	0.14	0.48	0.58	0.05*		0.29	0.15	0.05*	0.27
K3	0.07	0.06	0.44	0.02*	0.29		0.07	0.01**	0.64
M1	0.94	0.24	0.09	0.69	0.15	0.07		0.83	0.05*
M2	0.76	0.15	0.01**	0.47	0.05*	0.01**	0.83		0.01**
M3	0.06	0.07	0.35	0.01**	0.27	0.64	0.05*	0.01**	

*Note: * statistical difference*

4.3.4 Effect of multiple combined match classification and technical KPIs

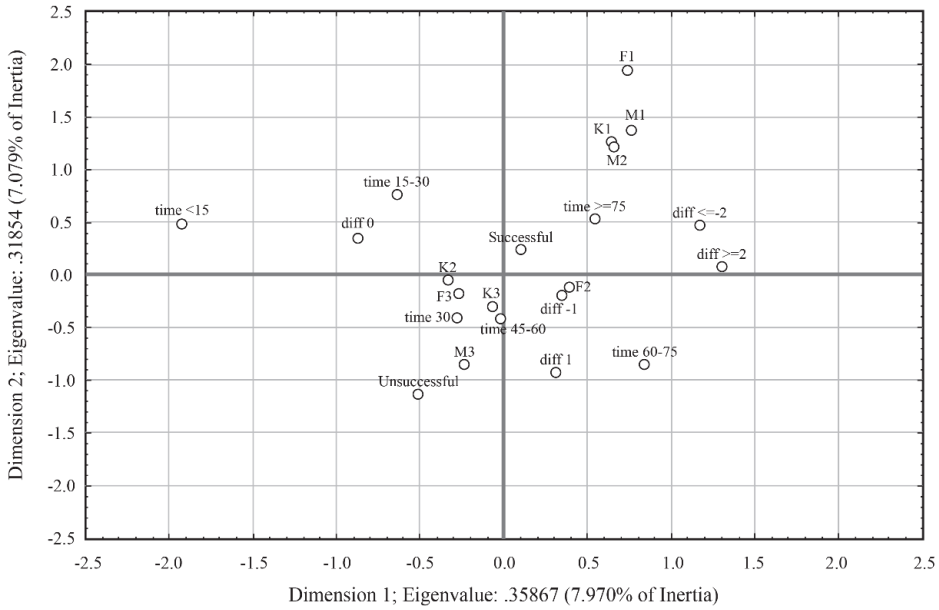

Figure 4.8. Multiple correspondence analysis of the relationship between all variables

The Multiple Correspondence Analysis (MCA) above (Figure 4.8) indicated no distinct relationships, or likely occurrences between the majority of variables in the study. However, a goal difference of 0 was more closely associated with time <15 minutes and 15 to 30 minutes than it was with 60 to 75 minutes or > 75 minutes. Directions K1, M1, F1 and K2 were more

closely associated with successful penalties than unsuccessful penalties. Higher score line differences (-2 to +2) were more closely associated with later time periods (60 to 75 and >75).

4.4 Discussion

For the convenience of understanding and flow of discussion, this section will be presented with the following sub-headings.

4.4.1 General descriptive statistics

The total number of goals scored from in-match penalty kicks out of the total number of goals scored in the EPL between the 2009/10 to 2018/19 seasons, as well as the penalty kick outcome percentages obtained in the current study (% successful) are in accordance with previous research in professional soccer leagues and competitions across the world (Palacios-Huerta, 2003; Morya et al., 2005; Bar-Eli et al., 2007; Jordet et al., 2007; Palao et al., 2010; White & O'Donoghue, 2013; Gelade, 2014; Gilmore-Jones et al., 2015; Almeida et al., 2016).

The similar success rates across the aforementioned range of studies (70 – 85%), including this study, could be attributed to professional soccer players being well trained and therefore effective in the penalty kick task. However, it is unclear whether it is only the professional training status of the soccer players which leads to such high success rates in the penalty kick, or whether the inherent nature of the penalty kick – with the goalkeeper at a distinct disadvantage – could lead to similar success rates across varying levels of soccer player.

4.4.2 Match periods

In-match penalty kick occurrences, in relation to match periods, notably increase as the particular half of the match progressed for both the first and second halves of matches. Remarkably, almost half of the in-match penalty kicks occurred within the final 30 minutes of matches (61 to 90minutes). This could possibly be because of the increase of fatigue, loss of concentration, temporary decrease in performance after periods of high intensity, as well as physical and psychological fatigue (Mohr et al., 2003; Aragón-Vargas et al., 2009; Leite, 2013; Zhao & Zhang, 2019). In the current study, similar success rates were observed across time periods, with match periods 31 to 45, and 46 to 60 being the lowest and 76 to 90 being the highest. Previous literature on time in match and penalty kick outcomes are both in line with

the findings of the current study, reporting higher success rates in the first and final half-hours of the match than in the middle (Almeida et al., 2016) and contrasting with reports of a decline in success rate near the latter stages of the match (Chiappori et al., 2002). The match period KPIs did not present an effect on penalty kick outcomes or direction and may also be because of the possible inherent nature of the penalty kick. Importantly, the increased fatigue, loss of concentration and temporary decrease in performance including physical and psychological fatigue do not seem to extend to the penalty kick itself, but are rather factors that seem to increase the likelihood of a penalty kick being awarded.

4.4.3 Footedness

The KPI of in-match penalty kick takers' footedness was found to have similar rates of success between right and left footed penalty kick takers, although the majority of the penalty kicks were taken by right footed penalty kick takers. This finding is similar to that of Almeida et al., (2016) who reported similar success rates between footedness (77.4% for right footed (who had majority representation) and 70.1% for left footed penalty kick takers), indicating insignificant to no differences in professional penalty kick taker footedness success rates. This is likely because of footedness being representative of the general population statistics.

4.4.4 Match location

In the current study, more in-match penalty kicks, in relation to match location, were awarded to the home team. A total of 572 of which 446 were successful (78.0%), were awarded to the home team, while a total of 380 were awarded to the away team, of which 297 were successful (78.2%). These findings were in close accordance with previous literature (Almeida et al., 2016). According to Pollard and Armatas, (2017) penalties were reported to be exactly twice as likely to be awarded to the home team (230 against 115), with red cards more often awarded to the away team. While outside the scope of the current study, Pollard and Armatas (2017) attributed these favourable relationships to referee bias towards the home team. The location or venue that an in-match penalty kick occurs in doesn't have an effect on the success rate of penalty kicks, with the professional training status possibly having an effect on the ability of players at the EPL level to effectively block out the external or environmental stimulus.

4.4.5 Match status and score line

Match classification KPIs match status and score line did not present an effect on penalty kick outcomes or direction. It was hypothesized that match status and score line would add a pressure stimulus to the penalty kick, resulting in poor kicker performance when losing, but through the findings of the current study revealed no relationship between penalty kick outcome and match status / score line was observed. This may indicate that these selected match classification KPIs are to some degree irrelevant to the penalty kick taker and that the task is more closed than initially anticipated. This may be because of prior suggestions that professional players are able to cope with the pressure of taking a penalty kick in a losing position and seems to be a standard range of success in professional penalty kick outcomes.

4.4.6 Penalty kick direction

Grid areas K3 and F3 had the highest frequency of in-match penalties and had of the lowest success rates (together with M3), significantly lower than that of K1, M1 and M2, which showed the highest probability of success. Furthermore, the in-match penalty kick's shot direction, particularly in relation to the top vertical zone, significantly associated with penalty outcome ($p < 0.01$). These results are in accordance with previous findings that penalty kicks directed into the upper part of the goal were more likely to be successful in comparison to that of the lower part of the goal (Almeida et al., 2016). This may be because of the goalkeeper's ability to jump and reach the base of the posts on either side, but lacking the ability to reach the upper corner areas of the goal, which is described as the "diving envelope" (Kerwin & Bray, 2006). This further highlights the possible inherent nature of penalty kick success rates and the goalkeeper being at a natural disadvantage. Notably, the 'miss factor' associated with penalty kicks directed toward the top areas of the goal is crucial when discussing and analysing penalty kick direction (Palao et al., 2010; White & O'Donoghue, 2013). The findings of the current study are in accordance with Almeida et al. (2016) who describe the risk to be lower in missing the penalty kick in the high zones of the goal than in comparison to the risk of having the penalty kick saved by the goalkeeper when directing it into the lower zones of the goal. This could possibly be because of penalty kick takers having a perception bias in relation to the perceived miss factor resulting in them preferring to kick low and in the bottom corners and be saved than aim for a higher penalty kick direction in the goal and miss.

4.4.7 Practical application

The practical implications of training the in-match penalty kick for an optimal strategy in relation to penalty kick direction can assist coaches, players and goalkeepers in optimising the in-match penalty kick for the desired outcome. The findings from the current study may also assist in having an enhanced understanding that in-match penalty kick direction is of the utmost importance in comparison to the select technical and match classification KPIs addressed in this study. The 'miss factor' is an important consideration in taking an in-match penalty kick and is consequently essential for coaches and players to understand that the risk is lower in missing the penalty kick in the high zones of the goal than in comparison to the risk of having the penalty kick saved by the goalkeeper when directing it into the lower zones of the goal. Therefore, coaches and players should implement a systematic training programme in order to have complete control of their ability to direct an in-match penalty exactly where it would be optimal. Based on the current study's finding and that of previous research, it is recommend that in-match penalty kicks be directed toward the top vertical zone to optimise the opportunity for success in in-match penalty kick outcomes.

4.5 Conclusion

In-match penalty kick direction, specifically vertical direction, significantly influence in-match penalty kick outcome ($p < 0.01$), while match period, score line and footedness were not related to penalty kick outcomes. Based on the current study's findings and that of previous research, it is recommended that in-match penalty kicks are directed toward the top vertical zone to optimise the opportunity for success in in-match penalty kick outcomes. Limitations of the current study include not conducting an analysis of any contextual factors that may possibly play a role or have an effect on in-match penalty kick outcomes or direction, such as physical and psychological fatigue and increased loss of concentration as matches progress (Aragón-Vargas et al., 2009; Leite, 2013; Zhao & Zhang, 2019). Another possible limitation could be that the goalkeeper's action on the outcome of the in-match penalty kick, such as timing and direction of the goalkeeper's dive, was not addressed (Almeida et al., 2016), which should be a consideration for future research. Similarly, to Bar-Eli and Azar (2009) penalty kicks that were not on target (within one of the nine areas of the goal) were excluded. This was done in order to only distinguish actual figures of in-match penalty kicks that were on target. This could be a point of consideration for future studies. By accessing their aims and objectives and adjusting the exclusion criteria accordingly (penalty kicks that hits the post or missed the target entirely to be allotted into the nearest one of the nine areas of the goal), because this may have

an impact on the results in the penalty kick direction analyses. Furthermore, lower level or amateur players should be considered in future studies' samples to allow a measure of the effect that player training status has on penalty kick outcomes and direction.

The current study, and the results reported, are in accordance with the limited published research available today. The results are to further the understanding and application of these and related findings for goalkeepers, players, coaches and academics when addressing in-match penalty kicks and the related KPIs. Although the sample size and observational design were improved on from that of previous research, the current study still had some key limitations in establishing relationships between KPIs and the complexity of penalty kicks. The generalisation of the present findings should be carefully considered in future studies involving different samples of in-match penalty kicks. Further research on in-match penalty kicks in relation to select technical and match classification KPI's should be completed in order to better understand in-match penalty kicks.

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CHAPTER FIVE

SUMMARY, CONCLUSION, LIMITATIONS AND FUTURE RESEARCH

This chapter is presented herewith in accordance with the referencing style of the Department of Sport Science, Stellenbosch University.

SUMMARY

Soccer, which is regarded as the most popular sport globally, has been subject to of the highest number of scientific studies in relation to any other sport (Stølen *et al*., 2005; Paterson, 2009; Kirkendall & Urbaniak, 2020). Currently, there is an excess of well-documented studies available that highlight many related aspects of soccer. However, currently data gathered by means of quantitative measures on in-match penalty kicks and the influence of additional factors on penalty kick outcomes are lacking in the literature, or only briefly touched on (Gilmore-Jones *et al*., 2015; Almeida *et al*., 2016). The aims of the current study were to conduct a video-based performance analysis of in-match penalty kicks in the European Premier League (EPL) between the 2009/10 to 2018/19 seasons to identify the relationship between selected technical and match classification Key Performance Indicators (KPIs) and in-match penalty kick outcomes and direction.

The thesis is presented in five main sections, namely an Introduction (Chapter One), Literature review (Chapter Two), Methodology (Chapter Three), Research article (Chapter Four) and Summary, conclusion, limitations and future research (Chapter Five). Stellenbosch University Senate approved the article format and the research article is presented in accordance with the guidelines outlined by the respective journal. Currently, the Faculty of Medicine and Health Sciences at Stellenbosch University stipulates one article as a requirement for an article format Master of Science thesis.

Research article: In-match penalty kick analysis of the 2009/10 to 2018/19 English Premier League competition.

The results showed that of the KPIs analysed only penalty kick directions, particularly the vertical penalty kick direction, had a statistically significant relationship with in-match penalty kick outcomes. Optimal grid areas for penalty kick directions were identified (K1, M1, F1 and M2), which indicated a greater probability of success in relation to the other areas of penalty kick directions. Other KPIs, such as match location, match status, score line and footedness did not present a significant influence on the success of penalty kicks. The findings of the current study indicated an absence of a direct relationship between the majority of KPIs and in-match penalty kick success, besides that of penalty kick directions. The study revealed that in-match penalty kicks should be directed toward the top vertical zones of the goal area to optimise the opportunity for success of in-match penalty kicks. Importantly, the risk factor of aiming high

and missing is lower than aiming low and being saved. Therefore, coaches and players should implement systematic penalty kick training programmes aimed at improving penalty kick placements and control into the top areas of the goal. The practical implications of training in-match penalty kicks for an optimal strategy, in relation to penalty kick directions, could assist coaches, players and goalkeepers in optimising the in-match penalty kick for the desired outcome. In summary, published research on in-match penalty kicks and the related KPIs are limited. Training methodology could benefit from using penalty kick data to identify an optimal penalty kick direction strategy desired for in-match penalty outcomes.

CONCLUSIONS

The conclusions derived from the current study are presented according to the specific objectives and hypotheses set in Chapter One.

The penalty kick outcome percentages (78.1% success) are within the ranges (70 to 85%) reported by previous literature in professional soccer leagues across the world (McGarry & Franks, 2000; Palacios-Huerta, 2003; Morya *et al*., 2005; Jordet *et al*., 2007; Bar-Eli & Azar, 2009; Palao *et al*., 2010; White & O'Donoghue, 2013; Gilmore-Jones *et al*., 2015; Almeida *et al*., 2016). This may suggest that at the professional level there seems to be a standard range of success in penalty kick outcomes. This may be because the penalty kick taker has a greater chance of scoring than the goalkeeper does of saving the penalty kick and in combination with the possible standard of success at the professional level penalty kick outcomes are more likely to result in a goal.

Hypotheses

$1aH^1$ – The footedness of the player taking the penalty kick will influence the penalty kick outcome.

Rejected $1aH^1$

$1aH^0$ – There is no relationship between the footedness of the player taking the penalty kick and penalty kick outcome.

Accepted $1aH^0$: The study revealed no relationship between the footedness of the player taking the penalty kick and the penalty kick outcome.

$2aH^1$ – The footedness of the player taking the penalty kick will influence the penalty kick direction.

Rejected $2aH^1$

$2aH^0$ – There is no relationship between the footedness of the player taking the penalty kick and penalty kick direction.

Accepted $2aH^0$: The study revealed no relationship between the footedness of the player taking the penalty kick and the penalty kick direction.

The technical KPI of in-match penalty kick takers' footedness was found to be of similar rates of success between right- and left-footed penalty kick takers, although the majority of penalty kicks were taken by right-footed penalty kick takers. These findings are similar those of Almeida *et al*. (2016) who reported similar success rates between right- and left-footed penalty kick takers with right-footed players having the majority of representation. The current study revealed that footedness did not influence penalty outcomes or direction, which is supported by previous findings (López-Botella & Palao, 2007; Palao *et al*., 2010; White & O'Donoghue 2013; Almeida *et al*., 2016). This further indicates the possible inherent nature of professional penalty kick success rates and may be because of the professional penalty kick taker's ability being representative of the general population statistics regardless of footedness.

$1bH^1$ – The score line of a penalty kick will influence the penalty kick outcome.

Rejected $1bH^1$

$1bH^0$ – There is no relationship between the score line of a penalty kick and the penalty kick outcome.

Accepted $1bH^0$: The study revealed no relationship between the score line of a penalty kick and the penalty kick outcome.

$2bH^1$ – The score line of a penalty kick will influence the penalty kick direction.

Rejected $2bH^1$

$2bH^0$ – There is no relationship between the score line of a penalty kick and the penalty kick direction.

Accepted $2bH^0$: The study revealed no relationship between the score line of a penalty kick and the penalty kick direction.

The score line match classification KPI did not reveal a relationship between the score line of a penalty kick and penalty kick outcome or direction. Penalty kick success rates and penalty kick directions remained representative of the general population statistics regardless of score line. The score line was perceived to have a pressure stimulus related to that of the penalty kick task. There has been limited research on the score line's effect on penalty kick outcomes and direction and the current study's findings could possibly indicate that the selected match classification KPIs may be irrelevant to the penalty kick taker and his/her ability to be effective with the task of the penalty kick. This may also be because of the professional nature of the player, resulting in him/her being able to cope with the pressures of taking a penalty kick in a situation where he/she is behind in relation to the score line or need to score to go ahead.

$1cH^1$ – The match status at the time of penalty kick will influence the penalty kick outcome.

Rejected $1cH^1$

$1cH^0$ – There is no relationship between the match status at the time of penalty kick and the penalty kick outcome.

Accepted $1cH^0$: The study revealed no relationship between the match status at the penalty kick and the penalty kick outcome.

$2cH^1$ – The match status at the time of the penalty kick will influence the penalty kick direction.

Rejected $2cH^1$

$2cH^0$ – There is no relationship between the match status at the time of penalty kick and the penalty kick direction.

Accepted $2cH^0$: The study revealed no relationship between the match status at the time of penalty kick and the penalty kick direction.

The findings of the current study revealed no relationship or effect of match status on in-match penalty kick outcomes or direction. This match classification KPIs relates to the findings of match score line and relates closely to that of the limited previous literature (Almeida *et al*., 2016). Penalty kick success rates and penalty kick direction remained representative of the general population statistics regardless of match status. This may be because of the prior suggestions that at the professional level there seems to be a standard range of success in penalty kick outcomes regardless of match status.

$1dH^1$ – The match period of the penalty kick will influence the penalty kick outcome.

Rejected $1dH^1$

$1dH^0$ – There is no relationship between the match period of the penalty kick and the penalty kick outcome.

Accepted $1dH^0$: The study revealed no relationship between the match period of the penalty kick and the penalty kick outcome.

$2dH^1$ – The match period of the penalty kick will influence the penalty kick direction.

Rejected $2dH^1$

$2dH^0$ – There is no relationship between the match period of the penalty kick and the penalty kick direction.

Accepted $2dH^0$: The study revealed no relationship between the match period of the penalty kick and the penalty kick direction.

The occurrences of penalty kicks increased as the match progressed for both the first and second halves. The current study revealed that 44.43% of the total number of 952 in-match penalty kicks occurred within the final 30 minutes of a match (61 to 90 minutes). It has been found by previous research to possibly occur because of an increase in fatigue, loss of concentration, temporary decrease in performance after periods of high intensity, as well as physical and psychological fatigue (Reilly, 2003; Aragón-Vargas *et al.*, 2009; Leite, 2013; Zhao & Zhang, 2019). Match periods in the middle of the game, specifically the middle half-hour were of the lowest success rates, closely relating with the findings of previous literature for this period of the match, where it was reported that penalty kick takers were more effective in the first and final half-hours of the match than in the middle (Almeida *et al*., 2016). The findings of the current study, however, did not find any statistical significance between success rates across match periods. Furthermore, the final match period 76 to 90 (79.3%), was the second most successful match period, which contrast the findings of Chiappori *et al*. (2002) who reported a decline in success rate near the end stages of the match. Match periods, as well as previously discussed match classification KPIs, researched in the current study revealed no relationship to either penalty kick outcomes or direction and remained representative of the general population statistics.

$1eH^1$ – The match location of the penalty kick will influence the penalty kick outcome.

Rejected $1eH^1$

$1eH^0$ – There is no relationship between the match location of an in-match penalty kick and the penalty kick outcome.

Accepted $1eH^0$: The study revealed no relationship between the match location of an in-match penalty kick and the penalty kick outcome.

$2eH^1$ – The match location of the penalty kick will influence the penalty kick direction.

Rejected $2eH^1$

$2eH^0$ – There is no relationship between the match location of an in-match penalty kick and the penalty kick direction.

Accepted $2eH^0$: The study revealed no relationship between the match location of an in-match penalty kick and the penalty kick direction.

In-match penalty kicks, in relation to match location, were awarded more to the home team (n=572) than that of the away team (n=380). These findings correspond to that of Almeida *et al*. (2016), but are in slight contrast to the findings of Pollard and Armatas (2017). Pollard and Armatas (2017) found that penalties were reported to be exactly twice as likely to be awarded to the home team (230 against 115). It is important to note that these findings do not prove a bias by the referee, but did found that red cards and penalty kicks had a major impact on match outcomes and occurred more regularly in favour of the home team (Pollard & Armatas, 2017). Similarly, to the other match classification KPIs in the current study, match location of in-match penalty kicks did not have an effect on penalty kick outcomes or direction. This too may be because of the professional nature of the players resulting in them being able to cope with the pressures of taking a penalty kick regardless of the match location (home or away).

$1fH^1$ – The penalty kick direction will influence the penalty kick outcome.

Accepted $1fH^1$: The most successful in-match penalty kick directions for penalty kick takers were into the higher areas of the goal.

$1fH^0$ – There is no relationship between in-match penalty kick directions and penalty kick outcomes.

Rejected $1fH^0$

The results showed that of the KPIs analysed only penalty kick directions, specifically vertical penalty kick directions, had a statistically significant influence on in-match penalty kick outcomes. Optimal areas of penalty kick directions were identified (K1, M1, F1 and M2), which indicate a greater probability of success in relation to the other areas of penalty kick directions. Grid areas K3, M3 and F3, which had the highest number of in-match penalty kicks frequencies, were of the lowest success areas. The Fisher least significant difference (LSD) post-hoc testing results of the GEE indicated that F3, M3 and K3 showed the lowest probability of success and were significantly lower than that of K1, M1 and M2, which showed the highest probability of success. Furthermore, an in-match penalty kick directed into the upper area of the goal was significantly more likely to be successful than one directed into the middle or lower areas of the goal. Results here are in accordance to the findings of previous research in describing that penalty kicks directed into the upper part of the goal, specifically the upper corners, were more likely to be successful in comparison to that of the lower part of the goal (Almeida *et al*., 2016).

Notably, the 'miss factor' associated with penalty kicks directed toward the top areas of the goal is crucial when discussing and analysing penalty kick directions (Palao *et al*., 2010; White & O'Donoghue, 2013). The findings of the current study are in accordance with those of Almeida *et al*. (2016) who described the risk to be lower in missing a penalty kick in the high zones of the goal than in comparison to the risk of having the penalty kick saved by the goalkeeper when directing it into the lower zones of the goal because the high areas of the goal are practicably unreachable for the goalkeepers (López-Botella & Palao, 2007; Navarro *et al*., 2013; White & O'Donoghue, 2013; Almeida *et al*., 2016). This could potentially be because of penalty kick takers having a perception bias in relation to the perceived miss factor indicating that they would rather go low and in the bottom corners and be saved than aim for a higher penalty kick direction in the goal and miss the goal all together. Based on the current study's findings and that of previous literature, penalty kick takers should be encouraged to direct their penalty kicks to the upper areas of the goal to achieve optimal penalty kick outcomes.

The practical implications of training in-match penalty kicks for an optimal strategy in relation to penalty kick directions can assist coaches, players and goalkeepers in optimising the in-match penalty kick for the desired outcome. Importantly, the risk factor of aiming high and missing is lower than aiming low and being saved; therefore, coaches and players should implement systematic penalty kick training programmes aimed at improving penalty kick placements and control into the top areas of the goal. Although the sample size and observational design were improved on from that of previous research, the current study still had some key limitations in establishing relationships between KPIs and the complexity of the penalty kick. The generalisation of the present findings should be carefully considered in future studies involving different samples of in-match penalty kicks.

LIMITATIONS

- Limited previous research to base study on (lack of previous literature to assist with the study design).
- The effect of exclusion of missed penalty kicks on data recording/statistics. Excluding penalty kicks that were not on target could mislead the data to a certain degree.
- Not analysing and considering the goalkeeper's actions (movement prior to a penalty kick, movement to save and direction moved in order to attempt a save), and the penalty kick

taker's actions (run up speed, speed of shot, stutter vs non-stutter) in penalty kick outcomes and direction analysis.

FUTURE RESEARCH

- Future studies should consider using goalkeeper's (movement prior to a penalty kick (to save or attempt to save a goal) and penalty kick taker's actions (run up speed, speed of shot, stutter vs non-stutter) as a part to the penalty kick outcomes and direction analysis.
- Future studies should include penalty kicks that were not placed on target as part of the direction analysis either by allocating them into the nearest grid area to the missed kick or possibly by using 'missed zones' around the goal to track and analyse missed penalty kicks, and therefore, catering for the 'miss factor'.
- A mixed method study whereby the roles of stress, skill and fatigue in conjunction with selected technical and match classification KPIs are analysed in relation to penalty kick outcomes and are examined further as opposed to quantitative data alone.
- Research conducted on amateurs and within women's football to assess whether the professional nature of players has a distinct effect on penalty kick outcomes (success rate) and direction.
- A meta-analysis of all in-match soccer penalty kick studies should be performed in order to create norms for professional leagues because it may allow for the creation of a base set of some form of normative data on which possible further analyses may be derived from.

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APPENDIX A: ETHICS APPROVAL LETTER

PROJECT EXEMPT FROM ETHICS CLEARANCE

8 July 2019

Project number: REC-2019-8888

Project title: Quantitative analysis of in-match soccer penalty kicks from 2009 to 2019 in the English Premier League

Dear Mr Michael Horn

Co-investigators:

Dr Wilbur Kraak

Mr. Simon De Waal

Your application received on 13 June 2019 was reviewed by the REC: Humanities.

You have confirmed in the proposal submitted for review that your project does not involve the participation of human participants or the use of their data. You also confirmed that you will collect data that is freely accessible in the public domain only.

The project is, therefore, exempt from ethics review and clearance. You may commence with research as set out in the submission to the Research Ethics Committee: Humanities.

If the research deviates from the application submitted for REC clearance, especially if there is an intention to involve human participants and/or the collection of data not in the public domain, the researcher must notify the DESC/FESC and REC of these changes well before data collection commences. In certain circumstances, a new application may be required for the project.

Please remember to use your project number (REC-2019-8888) on any documents or correspondence with the REC concerning your project.

Sincerely,

Clarissa Graham

REC Coordinator: Research Ethics Committee: Human Research (Humanities)

APPENDIX B: PERMISSION LETTER

Hello Michael

Having discussed internally I have upgraded your access so you can now download 2Mbps (H264 mp4) watermarked clips. If you would like unwatermarked higher resolution, please share the collection URLs with us and we'll provide a quote.

It would be really useful for us (and possibly for you) if you could create 6 collections and add the penalties from each season to those and then simply share the URL with us.

Do let me know if you have any further questions.

Thanks, Julian

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APPENDIX C: INSTRUCTIONS TO AUTHORS: INTERNATIONAL JOURNAL OF PERFORMANCE ANALYSIS IN SPORT

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As a result of the significant disruption that is being caused by the COVID-19 pandemic we understand that many authors and peer reviewers will be making adjustments to their professional and personal lives. As a result they may have difficulty in meeting the timelines associated with our peer review process. Please let the journal editorial office know if you need additional time. Our systems will continue to remind you of the original timelines but we intend to be flexible.

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International Journal of Performance Analysis in Sport is an international, peer-reviewed journal publishing high-quality, original research. Please see the journal's Aims & Scope for information about its focus and peer-review policy.

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Please include a word count for your paper.
A typical paper for this journal should be no more than a typical Original Research Paper for this journal should be no more than 7500 words, inclusive of tables, references, figure captions, footnotes, and endnotes. Words, inclusive of tables, references, figure captions, footnotes, endnotes.

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APPENDIX D: LANGUAGE EDITOR LETTER

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17 September 2020

TO WHOM IT MAY CONCERN

I, Prof Karel J. van Deventer, hereby declare that I conducted the language and technical editing of an MSc Master thesis titled, Quantitative analysis of in-match penalty kicks from 2009 – 2019 in the English Premier League, authored by Mr Michael Fredrick Horn.

Yours sincerely

KJ van Deventer

(Emeritus Associate Professor [Retired])

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