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The Application of Principle Components Analysis to Identify Essential Performance Parameters in Outfield Soccer Players

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Abstract: The selection of vital Performance Parameters (PPs) in soccer game might differ from coach to coach. However, if sets of PPs can be recognized and precise operational definitions characterized, there is substantial gain since it is through the selection of the PPs that players can be successfully evaluated. This study aims to identify the most essential PPs in outfield soccer players. Two professional head coaches from different teams defined their PPs and performances of the players from both teams were analyzed during three competitions. A total of 27 PPs actions from 31 players were quantified and Principle Components Analysis (PCA) was employed to identify the most significant PPs in the game. The initial PCA identified eight essential PPs out of the 27 as the most significant for the game with eigenvalues (>1). However, the PCA after varimax rotation revealed eight varifactors (VF) with higher positive factor loadings containing crosses (0.87), dribbles (0.92) and through passes (0.90) while further VFs contain interception at back third (1/3) (0.82), interception at mid1/3 (0.88), interception at front1/3 (0.77), tackling at mid1/3 (0.71), tackling at front 1/3 (0.92), free kick won back 1/3 (0.72), free kick won mid 1/3 (0.72), free kick won front 1/3 (0.87), shot outside box (0.81), shot inside box (0.72), clearings (0.93), headings (0.86), distribution of passes (0.62), fouls (0.82), passes back 1/3 (0.63), chasing loose balls (0.67) and open-space (0.87). Technical and tactical ability PPs are required for successful evaluation of outfield soccer players.

Key words: Notational analysis, outfield players, performance parameters, principle component analysis, soccer

INTRODUCTION

Performance analysts and coaches utilize performance parameters to assess individual and team performances for the sole purpose of improving training and competition (Hughes and Bartlett, 2002). In the most recent two decades, there has been a growing interest in match analyses of soccer (Ali and Farrally, 1991; Bangsbo *et al*. 1991). The practical value of such analysis is that well-chosen performance parameters can help coaches to identify good and bad performances of individuals or teams. In this respect, match-analysis has been helpful in the identification of the most important performance parameters of the game and in examining how a particular player performs compares to the other both during match and training sessions.

Experts, coaches, specialists and sports researchers continue to investigate consistently to enhance player's productivity of performance for accomplishment either in portion or as a whole (Carling *et al*., 2005). As a guide to accomplish this; performance analysis provides an actual record of series of events covering both individual and team performance with the view of providing insights into the capability, strength or weakness of the team or an individual player. It has in fact been the basis for drawing conclusion, provision of feedback on performance and making an informed decision. It also served as a guide to dissecting efficient technique for improving technical, tactical and physical skills in soccer for which has all been part of the coaching process. However, this is achievable when there is a definite set of clear PPs covering the most crucial parts of the performance a coach might like to review. Some studies have been conducted to provide information on PPs that could be useful to coaches.

Reilly and Thomas (1976) developed a technique with a specific aim to examine player's actions and work rate in distinctive playing positions and roles in a first division football team. Sums of 51 (both home and away) competitive matches were examined over a course of a season. Player's actions were subdivided into several distinct action organizations. Particular action features of various positional roles were built up and related

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alteration of training systems to be attempted. This methodological layout or otherwise performance parameters in motion analysis have been refined and reworked in basically all games in the course of the most recent three decades. Furthermore, Subsequent studies have evaluated match status in game performance (Jones *et al*., 2004; O'Donoghue and Tenga, 2001) and their interactions with other situational variables, such as match location and quality of opposition (Lago, 2009; Lago and Martin, 2007; Taylor *et al.* 2008). Nevertheless, these studies focused mainly on the PPs describing the motion analysis and research rate of the players during matches.

A strategic assessment of soccer was carried out by Yamanaka *et al.* (1997) that performed an electronic notational examination of 8 games in the 1994 World Cup Asian qualifying matches. The particular playing patterns of the teams were evaluated, with a specific attention to the Japanese national team. The analysis evaluated 32 activities of players in connection with an 18 cell division of the pitch. The researchers concluded that Japan utilized more passes ($p<0.01$), more often utilized a clearing kick ($p<0.05$) and used dribbling more as a strategy ($p<0.05$). However, although their finding is crucial in understanding the strategic style of play, their study focused on a particular team with no or less attention to other vital parameters such as tactical indicators.

Partridge built up a specific PC analysis framework to examine a far reaching technical assessment of performance. Two specific levels of performance, the 1990 FIFA World Cup and the 1990 World Collegiate Soccer Championships were investigated utilizing 38 key instances entered in real time. From the outcomes they inferred that collegiate coaches must be specific while selecting World Cup teams as a proper model of performance as many contrasts do happen which makes any examination invalid. The researchers in this regard focused primarily on the technical indicators as a guide for a selection of a soccer team.

Performance analysis in soccer has been based on ascertaining and recognizing primarily important game actions from a large sum of data. All the studies mentioned above have fully investigated certain actions in relation to successful performance in soccer game. However, the studies focused mainly on some parameters attributed to certain selected teams. Moreover, the opinions of the coaches were not considered based on the parameters explored. The current study endeavor to identify the most essential PPs in outfield soccer players taken consideration in to the opinions of the professional head coaches through the application of PCA.

MATERIALS AND METHODS

Participants: The research participants of this study comprise of two soccer clubs contending in the Malaysian Super League (Terengganu and T. Team). A total number of 31 elite players with the mean age of ±25 year old. The head coaches of the two teams and eleven notational analysts with two Control Persons (CP) who were responsible for analyzing the player's performances. This study was undertaken in Malaysia during 2015-2016 Malaysian Super League Season.

Instruments: A StatWatch application which is an Android based application developed for notational analysis in sports was set up on eleven tablets and utilized as the device for the gathering of the player's performances based on the PPs selected by the two coaches of the clubs.

Procedure: The head coaches of the two clubs selected their PPs (Table 1) and the eleven notational analysts who were trained on notational analysis were responsible for gathering of the player's performances in such a manner that each performance analyst observes and notate the performance of a particular player during the competitions. To ensure the reliability and the accuracy of the data collected, operational definition was set to each performance parameter such that the coaches, the controller of the analysis and the performance analysts were using the term universally. The player's performances were evaluated based on the PPs initially selected by the two coaches. The information gathered was analyzed by the controller of the analysis. The performances of the teams for 3 competitive weeks were assessed in relation to the PPs approved by the head coaches of the two teams.

Table 1 shows the selected parameters by the two head coaches. From the table, it can be seen that a total

Table 1: Selected PPs by the head coaches of the teams

Coach A (Terengganu) (performance parameters)	Coach B (T. Team) (performance parameters)
Successful passing at back third (1/3)	Clearings
Successful passing at mid third	Crosses
Successful passing at front third	Dribbling's
Turnover at back third	Headings
Turnover at mid third	Chasing loose balls
Turnover at front third	Open-spaces
Interception at back third	Distribution of passes
Interception at mid third	Shots
Interception at front third	Fouls
Tackling at back third	Through- passes
Tackling at mid third	Shooting inside the box
Tackling at front third	Shooting outside the box
Free kick won at back third	
Free kick won at mid third	
Free kick won at front third	

number of 15 PPs were selected by coach (A) while a total of 12 Pps were selected by coach (B). This explains that the number of parameters and their importance could differ from one coach to another.

Application of PCA to the study: Principal Component Analysis (PCA) is a robust statistical technique that involves recognition of pattern from an observed group or any given parameters. It offers insights into the most essential components through considering the spatial and temporal variability that explains an entire data set and consequently excluding the less essential components without loss of the original information from the data (Singh *et al*., 2004). PCA is extremely important in extracting the most needed information from a large volume of data set. This can assist in saving time, cost and energy since the original information is often retained. Moreover, the dimension of a huge data set can be trimmed down by using Principal Component Analysis (PCA) which is considered as one of the most prevalent and useful statistical methods for uncovering the potential structure of a set of variables. This method is used for explaining the variance of a large set of interrelated variables by transforming them into a new, smaller set of uncorrelated (independent) variables, Namely Principal Components (PCs) (Simeonov *et al*., 2003; Dominick *et al*., 2012). PCs are orthogonal and uncorrelated to each other and have linear combinations of the original variables (Skrbic and Durisic-Mladenovic, 2007; Juneng *et al.* 2009). PCA can recognize the most significant variables pattern which can indicate the key source of relative performance indicators.

Because of the ability of PCA to identify the most significant variables pattern which can indicate the key source of corresponding performance indicators. Thus, by using PCA in this study, we eliminated the variables that have less factor loading based on distinct eigenvalue from the set of data as suggested by Singh *et al*. (2004, 2005), Shrestha and Kazama (2007). The performance parameters were standardized through a-z scale transformation to a mean of 0.0 and variance of 1.0 by applying the following Eq. 1:

$$Z_{ij} = (X_{ij} - \mu)/\sigma$$

Where:

- Z_{ij} = The jth value of the standardize score of the measured variable i
- X_{ij} = The observation of jth on i variable
- μ = The mean value of the variable's
- σ = The standard deviation

The Z-scale modification technique was utilized to guarantee that the distinctive relative performance parameters had similar weights in the statistical analysis procedure. Furthermore, these changes were applied in the study to homogenize the fluctuation of the distribution and avert any classification errors that may occur from groups defined by variables of completely different sizes (Simeonov *et al*., 2002). At that point, the data matrix was decomposed into scores or components and loadings (relationships between the original variables and the new PCs that extracted from the analysis) for the variables. Bartlett's test of sphericity was performed at the start of the PCA to inspect the relationship between the variables utilized as a part of the PCA (Osterlind *et al*., 2001). According to Bartlett (1950) this test was able to estimate the probability that there were correlations in a matrix. Null hypothesis (H_0) in this test states that there is no correlation significantly different from 0 between the variables. While the alternative hypothesis (H_a), states that at least one of the correlations between the variables is significantly different from 0. As the calculated p-value is lower than the significant level of $\alpha = 0.05$, one should discard the null hypothesis (H_0) and receive the alternative hypothesis (H_a). The risk to reject the null hypothesis (H_0) while it is true is <0.01%. When the null hypothesis, H_0, the result is rejected, then it is confirmed that the variables used in the PCA are correlated.

Nevertheless, the Kaiser-Meyer-Olkin (KMO) test was carried out to measure the sampling adequacy. These matrices measure the sampling adequacy for each variable along the diagonal and the negatives of the partial correlation/covariances on the off-diagonals. The diagonal elements should be >0.5 at the barest minimum when the sample is sufficient for a given pair of variables (Field, 2000). If any pair of variables has a value which is <0.5, consider dropping one of them from the analysis. The PCs generated by PCA sometimes are not readily interpreted and should be rotated using any of a number of applicable methods such as varimax rotation. The goal of varimax rotation is to lessen the density of the constituents by rendering the higher loadings greater and the minor loadings smaller within each component. The varimax rotation method was applied because this method simplifies the factor structure and therefore, makes its interpretation easier and more reliable. In the varimax rotation method, only the PCs with eigenvalues >1(>1) are used and considered significant (Kim and Mueller, 1997) and to construct the new variables, known as VariFactors (VFs) or factor loadings. This approach is known as the Kaiser Criterion. The Kaiser Criterion is used to solve the problem of the number of components to be retained (Kaiser, 1958). The numbers of VFs extracted by varimax rotations are equal to the number of variables in harmony with collective features and can include unobservable, hypothetical and latent variables. The VFs are values that are used to measure the correlation between variables. VF values which are >0.75 (>0.75) are considered "strong," the values ranging from 0.50- 0.75 (0.50 = factor loading = 0.75) are considered "moderate" and the values ranging from 0.30-0.49 (0.30 = factor loading = 0.49) are considered "weak" factor loadings (Liu *et al*., 2003). In this study, the VFs with absolute valuesgreater than or equal to 0.60 were standardized as the selection threshold.

Data analysis: A total of 837 matrices sets of data point (27 variables×31 datasets) were computed in this analysis. The normalcy of the data set was checked and the outliers from the data were removed. All the data analysis was conducted using XLSTAT version 2014 add-in software USA.

RESULTS AND DISCUSSION

Table 2 shows the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. This test was implemented to determine the adequacy of the sampling to quantify as well as to make a reasonable interpretation based on the data gathered as suggested by Field (2000). Similarly, the test was conducted to ensure that the variables are not related to each other. From the table, the KMO value shows 0.77 which contributed for 77% sampling adequacy. Therefore, based on this results it is apparent that there is no multicollinearity observed among the original variables and that enabled us to proceed further with the analysis having satisfied the measure of the sampling adequacy. Figure 1 reveals the Eigenvalue for the initial PCA. From the figure, it can be observed that the PCA identified eight components as the most essential due to their higher Eigenvalues >1(>1). These components were retained and used as an input variable for further analysis.

Table 3 discloses the PCA after varimax rotation. It can be seen from the table that from VF1 three PPs out of the 27 fulfilled the 0.60-factor loading threshold. Likewise, the VF 2 identifies six PPs, VF3 two, VF4 three, VF5, VF6 and VF7 with one while VF8 identifies two with a positive higher factor loading. These parameters are then classified as the most essential that are primarily required for the performance in soccer game.

Figure 2 projects the most significant PPs after varimax rotation. Furthermore, the contribution of each varifactor within the components as well their variability is shown. It can be observed from the figure that VF1 and VF 2 contributed to about 31.78% of the total data set and the variability of 14.91 and 16.87%, respectively.

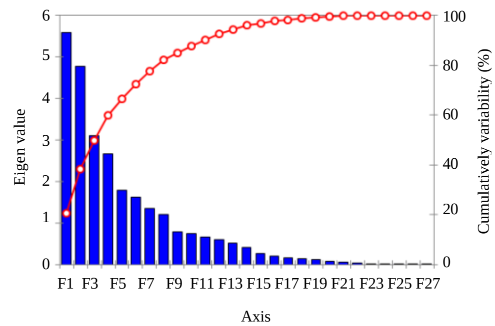

Fig. 1: Scree plots for PCA

Table 2: Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy

Performance parameters	Values
Clearings	0.89
Crosses	0.78
Dribbling's	0.62
Headings	0.69
Chasing loose balls	0.66
Open-spaces	0.91
Distribution of passes	0.75
Shots	0.55
Fouls	0.63
Through-passes	0.79
Successful passes at back third	0.92
Successful passes at mid third	0.86
Successful passes at front third	0.71
Turnover at back third	0.99
Turnover at mid third	0.09
Turnover at front third	0.75
Interception at back third	0.82
Interception at mid third	0.74
Interception at front third	0.93
Tackling at back third	0.65
Tackling at mid third	0.90
Tackling at front third	0.61
Shot inside box	0.82
Shot outside box	0.91
Free kick won at back third	0.84
Free kick won at mid third	0.99
Free kick won at front third	0.97
KMO	0.77

The purpose of the current study is to identify the most essential performance parameters in outfield soccer players. To achieve the aim of the study, a total number of 31 soccer players were recruited from two varied soccer clubs contending in Malaysian Super League. Two professional head coaches from different teams selected their PPs and performances of the players from the two teams were evaluated during three competitive matches. A total of 27 PPs actions from 31 players were quantified and PCA was engaged to identify the most significant PPs in the game. In the current study, VFs with absolute values >0.60 were standardized as the selection threshold due to the fact that these values are considerably solid

Table 3: Factor loading of PCA after varimax rotation

Variables	VF1	VF2	VF3	VF4	VF5	VF6	VF7	VF8
Clearings	-0.15	0.09	-0.05	0.93	0.15	-0.06	-0.02	-0.07
Crosses	0.87	0.10	0.02	0.27	0.02	-0.17	0.10	0.04
Dribbling's	0.92	-0.04	0.00	0.11	0.02	0.21	-0.09	0.09
Headings	0.15	0.08	0.10	0.86	0.18	-0.04	-0.03	0.13
Ch. loose balls	0.21	0.13	-0.23	0.43	0.04	0.27	-0.09	0.67
Open-spaces	0.25	0.04	0.00	0.09	0.08	-0.13	-0.05	0.87
Distr. passes	0.52	-0.09	-0.10	0.62	0.06	0.19	-0.19	0.06
Shots	0.59	-0.24	-0.15	-0.08	0.15	0.49	-0.05	0.23
Fouls	0.06	-0.02	-0.11	0.82	-0.13	0.08	0.13	0.21
Through (PS)	0.90	0.03	-0.06	-0.17	0.02	-0.11	0.01	0.22
S.P. at B. third	0.30	-0.39	0.22	-0.05	0.65	-0.24	-0.11	-0.13
S.P. at M. third	-0.29	-0.14	0.08	-0.13	-0.08	-0.24	-0.70	0.12
S.P. At F. third	0.05	-0.25	-0.04	-0.11	-0.79	-0.05	0.03	-0.02
T.O. At.B. third	-0.09	-0.05	0.16	0.14	0.59	0.18	0.27	0.35
T.O.At. M. third	0.09	0.02	-0.02	-0.26	-0.32	-0.68	-0.28	0.07
T.O.At F. third	-0.32	-0.32	-0.07	-0.02	-0.66	-0.16	0.38	-0.08
Icptn.B. third	0.01	0.03	0.88	0.11	0.31	0.01	0.12	-0.10
Icptn.M. third	0.22	0.82	0.13	0.14	0.04	0.02	0.17	-0.03
Icptn.F. third	0.13	0.20	0.48	-0.18	-0.16	0.77	-0.07	0.00
Tckl.B. third	0.47	0.42	0.50	0.19	0.39	0.15	0.02	-0.23
Tckl.M.t third	0.01	0.71	0.29	0.18	0.32	0.18	-0.16	-0.14
Tckl.F. third	-0.02	0.92	-0.25	0.08	0.01	-0.02	0.12	0.04
Sht.In. Box	-0.24	0.27	0.07	-0.12	-0.19	-0.08	0.72	0.02
Sht.Ou. box	-0.19	0.04	0.81	-0.27	-0.02	0.14	-0.10	0.02
F.K.W.B. third	-0.26	0.72	-0.34	-0.13	0.29	0.06	0.04	0.00
F.K.W.M. third	-0.29	0.72	0.21	-0.19	0.15	0.12	0.33	0.12
F.K.W. F. Third	0.11	0.87	0.21	-0.02	-0.19	-0.15	0.03	0.13
Eigenvalue	5.58	4.78	3.10	2.68	1.80	1.63	1.36	1.21
Variability (%)	14.91	16.87	9.22	12.47	9.63	6.72	5.93	6.22
Cumulative (%)	14.91	31.78	41.00	53.46	63.10	69.82	75.75	81.97

Abbreviations: Ch. Loose Balls = Chasing loose balls, Through-PS = Through Pass, S. P. At B. Third = Succesful Pass at Back Third, SP. At M. Third = Succesful Pass at mid Third, S.P. At F. Third = Succesful Pass at Front Third, T.O.At.B. Third = Turover at Back Third, T.O.At.M. Third = Turover at mid Third, T.O.At.F. Third = Turover at Front Third, ICPTN.B. Third = Interception at Back Third, ICPTN.M. Third = Interception at mid third, ICPTN.F. Third Interception at Front Third, TCKL. B. Third = Tackling at back third, TCKL. M. Third = Tackling at mid third, TCKL. F. Third = Tackling at front third, Sht. in. Box = Short Inside Box, Sht. ou. Box = Short Outside Box, F. K.W. B. Third = Free Kick Won at Back Third, F. K.W. M. Third = Free Kick Won at mid Third, F. K.W. F. Third = Free Kick Won at Front Third

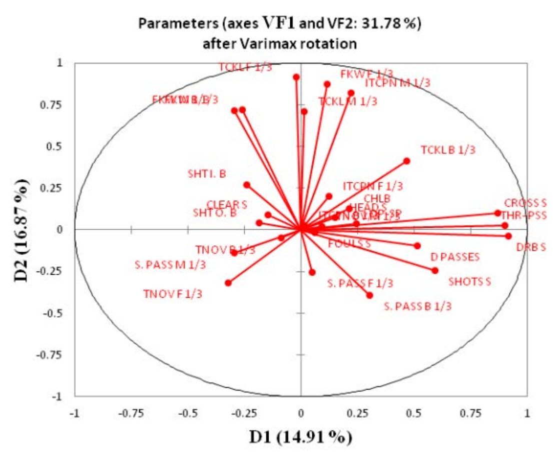

Fig. 2: Factor loading plot after varimax rotation

and stable which indicates moderate to strong loadings on the extracted factors. VF1, contributes to about 14.91% of the total variability of the data set (Fig. 2). It reveals a positive factor loading from crosses (0.87), dribblings (0.92) and through-passes (0.90), (Table 3). These parameters can be deduced as technical skills. Technical skills define the true players, who are looking for more than just having fun but wanting to become better and always striving for more (Claessens, 1999). These skills are the basis of becoming a worthy or great soccer player, depending on how much work and effort a player places into it. The technical ability of a player helps him to develop an awareness to make a decision while striking the ball, getting the ball with either foot, passing the ball with diverse parts of the foot, rotating out of pressure, dribbling the ball at speed, controlling the ball from the air. However, Abdullah *et al.* (2015) inferred that soccer is a complex sport which deals with making quick decision and rapid execution, for this reason, players must function as a whole and to achieve this ultimate goal, a soccer player needs to have dribbling skills, good passing abilities as well variety of kicking techniques for a successful delivery of performance in the game. The game of soccer is predominantly played with lower body parts particularly the legs. All the outfield players in the game are expected to play the ball with their legs occasionally using their torso to intercept the ball at the mid-air, dribble or make a pass (Mala *et al.*, 2015). The finding of this study has further stressed the importance of technical abilities and recognized them as the most crucial parameters a coach should consider during the process of performance evaluation. VF2, contributes to about 16.87% of the total variability of the data set (Fig. 2). It projects a positive factor loading from interception at back third (0.82), tackling at mid third (0.71), tackling at front third (0.92), free kick won at back third (0.72), free kick won at mid third (0.72) and free kick won at front third (0.87) while VF3 indicates postive factor loading from interception at mid 1/3(0.88) shot outside box (0.81), VF4 reveals clearings (0.93), headings (0.86), distribution of passes (0.62), fouls (0.82), VF5 shows succesful passes at back 1/3 (0.65), VF6 describes intreception at front 1/3 (0.77) and VF7 reflects shot inside box (0.72) where as VF8 demonstrates chasing loose balls (0.67) and open-spaces (0.87) (Table 3). These parameters can be interpreted as tactical skills. Tactical abilities in soccer are needed to interchange the ball from one end to the next in order to advance, score and stay in the game as well as respond to the compression from the opposing team. In this manner, fundamental abilities for progressing and controlling the ball, tackling, intercepting the ball both on the ground and at the midair, winning tackles and free kicks are key to soccer play since the easiest way to overcome the opponents is to tactically outplay them. Ability in soccer relies on upon the precise and effective execution of progressive actions and game strategic variables (Williams *et al*. 1993). To be fruitful, a soccer player needs the capacity to execute these vital actions inherent in the game and the capacity to execute these actions at the suitable time. Tactical abilities depend on procedural learning structures which often enables a soccer player to understand when to make a move, where and how to do it (McPherson, 1994), so it is not astounding that expert soccer players have predominant definitive and procedural cues which guided them to respond to the endless pressure from the opponents which have all been part of the essential components of the successful performance in the game (Thomas *et al*. 1988). Research on tactical abilities has so far concentrated primarily on the contrasts between novice and expert players, demonstrating that expert players have better tactical abilities as opposed to novice players, implying that expert players have more condition and activity ideas that are connected with the objective structure of the game (McPherson and Thomas, 1989; Carling *et al*., 2005). The importance finding of the current study, however, is the identification of these tactical skills parameters that are needed at every level of soccer performance.

CONCLUSION

The choice of fundamental PPs in soccer may vary from one coach to another. In any case, if the sets of PPs can be identified and clear operational definitions described, there is a considerable benefit since it is through the choice of the PPs that players can be effectively assessed. Assessing soccer players give the coach information on individual and collective team performances both during training sessions and matches. The present study has successfully identified that crosses, dribbles, through passes, interception at back third, interception at mid third interception at front third, tackling at mid third, tackling at front third, free kick won at back third, free kick won at mid third, free kick won at front third, shot outside box, shot inside box, clearings, headings, distribution of passes, fouls, successful passes back at third, chasing loose balls and open-space are the most essential PPs in outfield soccer players. Although, the study has primarily involved elite soccer players nonetheless, the PPs identified and discussed in this article could be required in the game at the different level of participation. The finding of this study, however, can be useful for coaches, sports managers and performance analysts alike to define and to recognize the most essential PPs for outfield soccer players as this might help the coach and the performance analysts to structure a more robust game analysis template for analyzing their player's performance to enhance the overall development of the players as well as the entire coaching process.

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