



## Research article

# Disciplinary measures defining referee activity in top-European football leagues: A cross-sectional investigation

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## ABSTRACT

The success and enjoyment of a football match depend heavily on referees and their ability to ensure fair play and uphold the rules of the game. However, there is limited research investigating the disciplinary measures and booking activities of referees in top European football leagues. In the current investigation, we explored the disciplinary measures and booking activities of top-European football league referees. The dataset of the referee activities concerning 15 indicators containing 602 matches from five consecutive seasons across the five top European leagues, namely, the English Premier League, Spanish LaLiga, Italian Serie A, French Ligue 1, and German Bundesliga were utilized for this study. K-means cluster analysis was used to define the activity levels of the referees. The Mann-Whitney *U* test was employed to determine the differences in the levels of the referees' activity with respect to the disciplinary measures, while binary regression analysis was applied to examine the association between the disciplinary measures and the activity levels of the referees. Two groups of activities were defined by k-means, that is, high and low activity. The Mann-Whitney *U* test revealed statistically significant differences in all 15 indicators examined between high and low activity. However, the regression model demonstrated that only fouls, yellow cards, and air challenges could significantly describe referees' activity levels. These indicators appear to be predictors of high referee activity in elite European Football. Specific training on dealing with increased aggression and foul behaviour coupled with improved game organisational management could be further incorporated into referees' training programmes amongst other measures.

## 1. Introduction

Football is a physically and mentally demanding sport that requires a high level of competition, technical and tactical skills, and endurance [1]. As a result, referees face significant challenges in officiating matches and making correct decisions according to the

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rules of Game [2]. The introduction of the video assistant referee (VAR) was intended to assist and improve the decision-making of on-field referees; however, its implementation has been met with criticism and controversy. While the VAR system has been successful in increasing the accuracy of refereeing decisions and promoting fairness in the game, it has also been criticised for disrupting the flow of play and being confusing for players, coaches, and fans, as well as many issues related to fouls [3]. Hitherto, despite the inclusion of the VAR into the present officiating duty, referee performance remains controversial, particularly during bookings or dismissals of players [4].

The popularity of football reflects its wider acceptability, which is watched and enjoyed by millions of people all over the world [5]. The success and enjoyment of the game relies heavily on referees and their ability to ensure fair play and uphold the rules of the game [6,7]. Referees are officials responsible for the enforcement of the rules of the game, and hence, are considered an important part of the matchday experience [8,9]. Owing to the important roles of referees coupled with the increasing popularity of European football throughout the world, several studies have been conducted in recent years to evaluate the performance of referees in European football.

In a previous study, offsides, optical errors, and flash-lag indicators of assistant referees in a running line were investigated during football matches that covered two World Cups and one Premier League season [10]. The authors reported an overall error rate of 26.2 %. There were substantially more errors (38.5 %) throughout the opening 15 min of the matches than during any subsequent 15-min stretch. The accuracy of offside calls for assistant referees in the English Premier League has been previously investigated [11]. The study found that incorrect decisions were triggered in 17.5 % of the 4960 scenarios analyzed due to the moment in the match and the positional movement speed of the assistant referees, strikers, and center back. This equates to 868 scenarios in which incorrect decisions were made. In addition, a study on referees' decision-making accuracy in relation to their specific location was investigated [12]. A total of 380 foul play events and 165 offside instances were analyzed. It was revealed that the referees' error percentage while flagging the events averaged 14 %. The lowest number of errors occurred in the central part of the field, where the involvement of the assistant referee was restricted. Assistant referees were reported to have committed a total error of 13 %. In a more recent study, the influence of different types of stress on the decision-making performance of skilled and less skilled football referees was evaluated [13]. The results also indicate that the experienced referees learned to cope better with fatigue and psychological stress than the less experienced ones.

In general, studies suggest that experience, pressure, coordination, and fatigue can impact the performance of referees in European football. However, further research is needed to gain a comprehensive understanding of referees' activities, particularly concerning disciplinary measures and booking in various leagues. This is because, although, rules are designed to objectively standardize what represents a foul in football. However, a typical referring task involves making subjective decisions about unique events in real time, which can be challenging owing to the objective nature of the rules. Moreover, research has shown that referees have different styles, including varying levels of strictness when calling fouls, suggesting that they may interpret rules differently [14]. Additionally, data from the UEFA Champions League matches indicate that caution rates can vary based on the nationality of the referee, hinting at potential cultural influences on decision-making [15]. This highlights the complexity of refereeing and the need to consider various disciplinary and foul-related offences that intensify the activity level of referees in elite European football leagues.

In the current investigation, we explored the activities of referees based on several disciplinary and tactical indicators. The demands placed upon referees in elite European football leagues are extensive, with disciplinary and foul-related incidents intensifying their activity levels. Hence, we envisage that identifying patterns of referee activity related to the indicators could improve the quality of officiating. This could be done by identifying areas where referees are expected to pay more attention, or where they could benefit from additional training to ensure their ability to enforce the rules of the game effectively and consistently.

## 2. Materials and methods

### 2.1. Data source

This study used data obtained from *InStat Scout*, a company that specializes in providing motion-tracking data for high-performance sports upon subscription. The *InStat Scout* is one of the leading sports performance analysis companies founded in Moscow in 2007, with currently over 900 offices globally. These data are made available to users upon subscription. *InStat* reported that the company examines referee performance in greater depth than any other statistics firm. *InStat Scout* includes a profile for each referee and generates a unique report after each match. The company developed and tracked several indicators for each referee and ensured the reliability and validity of these indicators by linking them to videos showing the referee's activity profile and comprehensive reports on their overall activity in a match [16]. The data set for this study included 602 matches from 5 consecutive seasons in the English Premier League, Spanish La Liga, Italian Serie A, French Ligue1, and German Bundesliga.

### 2.2. Data description and treatment

The dataset included various types of misconduct and fouls, including fouls, challenges per foul, yellow cards, direct red cards, red cards for two yellow cards (RC for two YC), fouls per card, air challenges, ground challenges, handball, challenge off the ball, dangerous play, misconduct, simulation/diving, attack wrecking, and professional fouls. A foul is a violation of the rules of the game committed by a player that interferes with active play and is penalized by awarding the opposing team a free or penalty kick. Misconduct refers to any behaviour by a player that warrants disciplinary action such as a warning or dismissal. It can occur at any time, even when the ball is not in play, and both players and substitutes can be punished for misconduct [3]. Yellow and red cards may

be shown to indicate warnings and dismissals, respectively. Before performing the full analysis, data were preprocessed for missing information. Rows with missing data were removed from the dataset [17,18].

### 2.3. Statistical analysis

#### 2.3.1. K-means cluster analysis

K-means clustering is an unsupervised learning algorithm that divides datasets into  $k$  clusters. It selects  $k$  centroids or centres for clusters and iteratively assigns each data point to the closest centroid [19–21]. The centre is then updated to the average of the points assigned to it, and the process is repeated until the centre no longer moves significantly. The goal is to minimise the total distance between the data points and assigned centroids [22]. In this study, we used k-means clustering to divide the dataset of errors committed by players during games across all leagues into subgroups with  $k$  distinct and non-overlapping clusters. Each cluster was assigned to a single group. This approach aims to make the data points within a cluster as similar as possible while maintaining the differences between the data points in different clusters. The Euclidean distance was used as a metric to determine the formation of clusters. The Shapiro-Wilk test was applied to verify the normality of the data. The data did not follow a normal distribution; hence, the Mann-Whitney  $U$  test was used to analyse the differences in activity levels between the referees. The group level of the referees, that is, high and low activity, were used as independent variables, while all the disciplinary and foul-related indicators were treated as dependent variables.

#### 2.3.2. Logistic regression analysis for model development

In this study, a logistic regression analysis was used for model development. It is important to note that while normality assumptions are often desirable for certain statistical tests and models, binary regression is known to be robust to moderate deviations from normality, especially when the sample size is large [23]. Owing to the large sample size involved in the study, binary regression analysis was applied in accordance with the central limit theorem, which states that as the sample size increases, the distribution of the sample means approaches a normal distribution [24]. Moreover, prior to the model development in the current investigation, we carried out a diagnostic test using the errors of the residuals to examine their distribution, which was found to follow a regular pattern [25].

The Forward stepwise selection method (Likelihood Ratio) was used to analyse the data. Results are reported in terms of odds ratios (OR) and 95 % confidence intervals (CI). Nagelkerke’s  $R^2$  was used to evaluate the model’s explanatory power, with the effect size interpreted as follows: small (0.02–0.13), medium (0.13–0.26), and large ( $>0.26$ ). The model’s goodness of fit was assessed using the Hosmer-Lemeshow test, and the discriminant capacity of the model was evaluated using the area under the curve (AUC) of the Receiver Operating Characteristic (ROC) curve, which was generated using the predicted probabilities for each variable. All statistical analyses were conducted using XLSTAT2014 and the Statistical Package for the Social Sciences (SPSS) software. Statistical significance was set at  $p < .05$ .

### 3. Results

Fig. 1 shows the grouping determined using k-means analysis in relation to the various errors committed by the players that in turn reflects the magnitude of the referees’ activity in issuing cards, warning, or stopping the game for fouls related offences. The figure demonstrates a noticeable difference between the high and low activities of the referees based on the indicators examined. From the

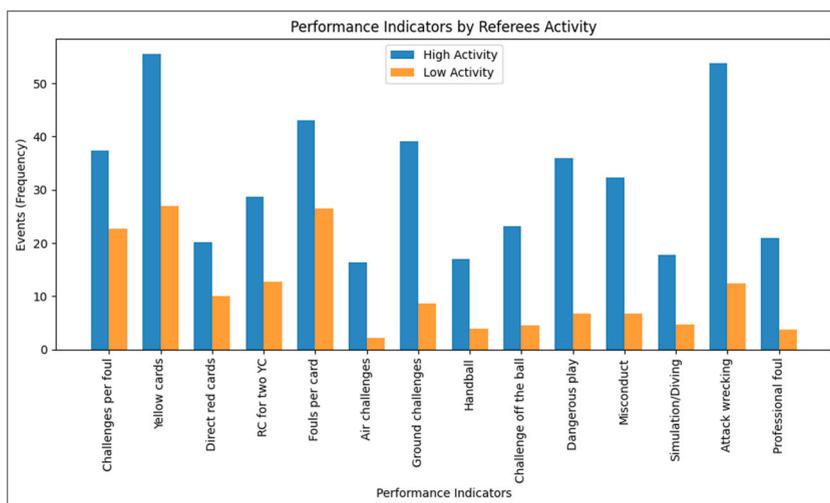


Fig. 1. Profile plot for cluster analysis in determining the activity level of referees based on various errors committed by players.

profile plot, it can be observed that the fouls and disciplinary-related events are highly skewed towards high-activity matches compared to low-activity matches.

Table 1 tabulates the differences in the referees' activity levels based on the 15 performance indicators examined in this study. It can be seen from the table that there are statistically significant differences in the number of errors committed by the players between the two groups of referees. This indicates that referees in high-activity matches face higher levels of misconduct and foul-related actions compared to referees in low-activity matches in top European football leagues' tournaments.

Table 2 shows the multivariate binary logistic regression model performed to ascertain the significant disciplinary measures that could explain the activity level of the referees. In this analysis, all disciplinary measures were used as inputs for the model based on the results obtained from the Mann–Whitney analysis ( $p < .05$ ). The overall model presented a well-fitting value (Hosmer-Lemeshow  $> 0.05$ ), an excellent correct global classification (100 %), and its discriminant capacity was also notable, with an AUC of 100 % at a 95 % confidence level. The model accounts for 100 % of the referee's level of activity in relation to various errors committed by players in European Football Leagues (Nagelkerke  $R^2 = 1.00$ ).

Fouls, yellow cards, and air challenges were found to be highly influential in explaining the activity level of referees ( $p < .05$ ). The results further revealed that for each occurrence of foul in a match, the chances of the match becoming high activity increased by 23 times ( $OR = 22.85$ ,  $CI_{95\%} = [-70.44-74.22]$ ). Similarly, with the issuance of a yellow card, a match has 12 times the likelihood of becoming high activity ( $OR = 12.41$ ,  $CI_{95\%} = [-54.49-58.33]$ ), while executing challenges in the air increases the chance of a match being high activity by four times ( $OR = 4.33$ ,  $CI_{95\%} = [-47.219-59.71]$ ). This revealed that fouls, yellow cards, and air challenges are crucial aspects of disciplinary measures that could determine the level of referee activity in elite European football.

#### 4. Discussion

Referees are responsible for regulating the flow of the game, issuing cards, warning, and mediating players. Therefore, it is expected that a higher level of misconducts and errors committed by players will keep the referee busier during the game compared to a game with low levels of misconducts and errors. Referees in high-activity matches face higher levels of misconduct and foul-related actions compared to referees in low-activity matches in top European football leagues' tournaments. This study analyzed disciplinary measures and booking activities of top-European football league referees using data from 602 matches across 5 consecutive seasons in the English Premier League, Spanish La Liga, Italian Serie A, French Ligue1, and German Bundesliga. We employed a data mining technique to effectively transform raw data into meaningful insights and mitigate subjectivity issues. Our results offer insights into referees' contributions to game flow and fairness, revealing hidden patterns in referees' actions. This inherent connection between player behaviour and the referee's level of engagement highlights the essential role referees play in officiating a match.

**Table 1**  
Differences in performance indicators between high and low activity levels.

Variable	Group	Median	N	U Statistics	p-value
Fouls	High Activity	437.00	200	13709	0.001**
	Low Activity	184.50	402		
Challenges per foul	High Activity	100.25	200	18929	0.001**
	Low Activity	50.70	402		
Yellow cards	High Activity	70.50	200	10888	0.002*
	Low Activity	29.00	402		
Direct red cards	High Activity	1.00	200	26380	0.003*
	Low Activity	0.00	402		
RC for two YC	High Activity	1.00	200	22637	0.002*
	Low Activity	0.00	402		
Fouls per card	High Activity	112.35	200	20925	0.004*
	Low Activity	55.55	402		
Air challenges	High Activity	2.00	200	9937	0.003*
	Low Activity	0.00	402		
Ground challenges	High Activity	17.00	200	2947	0.002*
	Low Activity	3.00	402		
Handball	High Activity	1.00	200	19549	0.002*
	Low Activity	0.00	402		
Challenge off the ball	High Activity	1.00	200	18135	0.003*
	Low Activity	0.00	402		
Dangerous play	High Activity	12.00	200	4153	0.002*
	Low Activity	2.00	402		
Misconduct	High Activity	13.00	200	4019	0.002*
	Low Activity	2.00	402		
Simulation/Diving	High Activity	0.00	200	29964	0.002*
	Low Activity	0.00	402		
Attack wrecking	High Activity	21.00	200	2255	0.003*
	Low Activity	4.00	402		
Professional foul	High Activity	1.00	200	22467	0.002*
	Low Activity	0.00	402		

\* Mann-Whitney  $U$  test; \*\* $p < .01$ ; \* $p < .05$ .

**Table 2**

Regression analysis for extracting significant indicators in differentiating high and low referees' levels of activity.

Variables	B	OR (CI 95 %)	p
Fouls	-1716	22.85(-70.44-74.22)	0.0001
Challenges per foul			
Yellow cards	122.9	12.41 (-54.49-58.33)	0.0001
Direct red cards			
RC for two YC			
Fouls per card			
Air challenges	75.87	4.33 (-47.219-59.71)	0.004
Ground challenges			
Handball			
Challenge off the ball			
Dangerous play			
Misconduct			
Simulation/Diving			
Attack wrecking			
Professional foul			
Nagelkerke R <sup>2</sup> = 1.00	Hosmer-Lemeshow = test (p = 1.00)		Correct global classification = AUC = 1 1.00 %

**Note:** OR - Odds ratio; AUC - Area under the ROC curve.

The findings from the current investigation demonstrated that foul is a significant indicator of the activity level of referees in the top European football leagues. High occurrences of fouls in a football match may indicate aggressive play and the team's tactical errors which led to the issuance of warnings or cards. It is documented from the previous study that fouls are common in European football leagues, with rates ranging from 23 to 32 fouls per game, which can trigger referees to be highly engaged thereby becoming high activity game [26]. Fouls are committed when a player breaks the rules of the game, such as tackling an opponent without the ball or handling the ball. Fouls can result in a free kick for the opposing team, a penalty kick, or even a red card for the offending player.

Referees are responsible for monitoring and enforcing the rules of the game, and must be active and alert to spot fouls and take appropriate action. Moreover, data from a previous study showed that aggressive plays have substantially increased in the Premier League alone, with referees issuing 300 red cards, which is 60 per year, and translates to approximately one card for every six games [27]. Referees are responsible for enforcing the rules of the game and ensuring that it is played fairly. As a result, they are required to be active and vigilant throughout the match to spot fouls and other infractions. This can be a physically demanding job, especially in fast-paced, high-level matches, which is why referees are trained to be in good physical condition [14]. This finding is also in agreement with previous studies that reported that highly experienced referees are better at recognising fouls than less experienced referees due to their focus on the game and their ability to recognize rule infractions [28,29]. Therefore, it is not surprising that fouls were found to be one of the important indicators that predict a high level of activity of referees in the current investigation.

The current investigation also demonstrated that yellow cards and air challenges are important indicators that could describe the high activity of referees during matches. These variables projected disciplinary-related issues and aggressive play, which corroborates the fact that the nature of the game has changed drastically over the years, with many teams adopting more aggressive strategies. The surge in aggressive tactics by numerous clubs reflects a strategic shift driven by eagerness to win, defending the title, sportsmanship or fair play. Additionally, aggressive play may help teams control the pace of the game and dictate the flow of play. It can also be used as a way to intimidate opponents and disrupt their game plan. However, it's important to note that aggressive play can also lead to disciplinary issues.

This is supported by data showing that the number of fouls and yellow cards issued during professional soccer matches has increased in recent years. For example, a study of the English Premier League found that the average number of fouls per match increased from 2006 to 2007 season to 2016–2017 season [30,31]. Similarly, another Italian Series A study found that the average number of yellow cards per match increased over each season across the league [32]. These trends highlight the increasing physical and aggressive nature of modern games as a result of many factors including eagerness to win, defending the title, sportsmanship, or fair play. This could place greater demand on referees to maintain control and enforce the rules.

Refereeing is a demanding and complex task that requires a high level of perceptual-cognitive skills to prioritise and analyse information in real time and make appropriate decisions [33,34]. This includes being in the right position in the field, paying close attention to players' behaviour, and having a thorough understanding of rules. The speed of modern games can make it especially challenging for referees to meet these demands, as they are required to make quick and accurate judgments within seconds [35]. The difficulty in this task is that, in a professional soccer match, a referee may need to make more than 100 decisions on average, many of which have significant consequences for the outcome of the game. For example, they may need to decide whether to award a penalty kick or a red card or whether to stop playing for an injury. Given the importance of these decisions, referees are expected to be well-trained and prepared to handle the demands of the game.

Beyond referee training, an effective approach to navigating these shifts involves enhancing tournament supervision and management. By refining soccer competition rules, a more precise identification of serious fouls and a reduction of violent behaviour can be achieved. However, while consistency in rule application and stricter penalties for repeated offences can contribute to fair play, criticism persists regarding uneven rule implementation and potential biases. To address these concerns, it is essential to focus on areas

for improvement such as player simulation and enhancing communication transparency. Collaborative efforts between leagues and regulatory bodies to define clearer parameters for fouls and aggressive conduct are crucial for fostering a safer and more competitive football environment.

While our study sheds light on disciplinary measures and booking activities of top European football league referees, it is important to acknowledge its limitations. Firstly, the data set used in the study only covers the top European football leagues, and therefore, the findings may not be generalizable to other leagues or regions. Second, while our study identified certain predictors of high referee activity, it did not account for other potential influencing factors. Finally, our recommendations for specific training and organizational management improvements are based on our findings and may require further validation and consideration of additional variables.

## 5. Conclusion

In the current investigation, we showed that certain disciplinary measures consisting of fouls, yellow cards, and aerial challenges are strong predictors of high levels of referee activity during matches. Additionally, the nature of the game has changed in recent years, with more clubs adopting aggressive tactics and engaging in misconduct related offences. To better prepare referees for these challenges, referee training programs should incorporate elements related to dealing with increased aggression and foul-related incidents. Moreover, enhancing tournament supervision and management can be an effective approach, thereby refining competition rules to promote a more precise identification of serious fouls. Stricter penalties for repeated offences can be introduced to discourage aggression while promoting fair play and reducing violent behaviour. Collaborative efforts between leagues and regulatory bodies should be harnessed to define clearer parameters for fouls and aggressive conduct. These will help equip referees with the necessary skills to effectively handle the demands of the game in de-escalating conflicts and maintaining control of the game geared toward improving the overall safety and enjoyment of the game that could further foster a safer and more competitive football environment for all.

## Ethics statement

Informed consent was obtained, and all the participants have agreed to the publication of this data. The data used for the current study was provided by INSTAT in secondary form upon subscription. Approval to carry out the study was obtained from the departmental ethics committee of Universiti Malaysia Terengganu (UMT/PPAL/500-28 JILID; October 10, 2021).

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## Data availability

Data will be made available on request to the corresponding authors due to the subscription nature of the dataset used in the study.

## CRediT authorship contribution statement

**Mohamad Nizam Nazarudin:** Resources, Project administration, Methodology. **Anwar P.P. Abdul Majeed:** Visualization, Formal analysis, Data curation. **Ahmad Bisryi Husin Musawi Maliki:** Visualization, Software, Formal analysis, Data curation. **Mohamad Razali Abdullah:** Writing – original draft, Project administration, Methodology, Investigation. **Garry Kuan:** Writing – review & editing, Visualization, Validation, Supervision, Software. **Rabiu Muazu Musa:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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