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No home team bias in elite football referees: Assessing correctness of refereeing decisions in the English Premier League

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ABSTRACT

It is unclear whether referee decisions contribute to home advantage in football. This ambiguity stems from significant advancements in the development and training of officials, methodological limitations, such as the use of regression models to provide estimates, in extant research, and team behaviours. Thus, there may appear to be a bias when there is none. This study aimed to establish whether referees contribute to home advantage in elite football. Decisions (N = 4,201) from 172 games from the English Premier League 2022/23 season were analysed by 43 qualified football referees, with two officials allocated to each fixture. The referees independently assessed free-kicks, yellow cards, red cards, penalty kicks, and non-whistled penalty kicks given by the on-field official using clips from WyScout. Decisions were recorded as 'correct' or 'incorrect' in unanimous cases, or 'disputed' if the two officials did not agree. Data from the free-kick and yellow card categories were considered suitable for analysis and compared using a series of linear mixed-effects models. There were no significant differences found between home and away teams for correct, disputed, and incorrect decisions, showing that neither team were differentially favoured by the referee, and therefore their decisions could not contribute to home advantage. Findings support the efficacy of referee development and the territoriality model's explanation of home advantage in professional football.

1. Introduction

The home advantage is a universal phenomenon in sports, with no organised sporting contest showing greater success for teams and individuals in away venues compared to home venues (Allen & Jones, 2014; Gómez-Ruan & Pollard, 2021). Paradoxically, while research investigating home advantage has significantly increased over the previous three decades (Prieto, 2022), the exact contribution to home advantage of various factors remains, as Pollard (2008) previously exclaimed, an 'unsolved puzzle'. In football (i.e., soccer), this ambiguity lies in the numerous possible antecedents to home advantage, such as tactical approaches of home and away teams (Fernandez-Navarro et al., 2018; Gollan et al., 2020; Lago-Peñas & Lago-Ballestaros, 2011), biological and physical effects of playing at home (Aquino et al., 2017; Teixeira et al., 2021), and satisfaction with different game outcomes (Staufenbiel et al., 2015). These variables are evident in models that attempt to explain home advantage.

The territoriality model (Neave & Wolfson, 2003) states that home advantage is a result of physiological and behavioural responses regarding the protection of territory. For example, players exhibit increased testosterone levels before home games in ice hockey (Carré et al., 2006), football (Neave & Wolfson, 2003), rugby (Terry et al., 1998), and field hockey (Bray et al., 2002). Additionally, a long-term study of home advantage found that football teams Bastia and Ajaccio, who both play on the island of Corsica, were two of only three French teams who reported a home advantage of over 70%, while Sicilian teams

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Catania and Palermo, had the highest home advantage value in the Italian league (Pollard & Gómez, 2009). The cultural traditions on both islands that promote unity and resistance to mainland identity contribute to the notion of territoriality, with these qualities identified as the cause of enhanced home advantage reported by those teams (Pollard & Gómez, 2009). While the alternative 'classical model' (Allen & Jones, 2014) postulates factors related to territoriality (e.g., home support, familiarity with venue and travel fatigue of the opposition) contribute to home advantage, it also identifies officiating as a factor, a contention supported elsewhere (e.g., Bilalić et al., 2024; Courneya & Carron; 1992). As the role of officials is to provide impartial and fair judgements (Russell et al., 2019; Webb, 2022), this purpose combined with the increased financial implications of a team's success or failure (Jamieson, 2010) and potential impact of success and failure on supporter well-being (Dohmen & Sauermann, 2016), establishing if and how they contribute to home advantage is worthwhile.

Football is the sport that reports the highest value of home advantage (Jamieson, 2010), and therefore analysis of officiating decisions in this sport is justified to ascertain whether, and how, game location influences referees' actions. A systematic review of referee bias identified five factors that contribute to inaccurate decision-making in football referees: stake size, crowd size and composition, crowd proximity, material rewards, and referee-specific effects (e.g., age and experience; Dohmen & Sauermann, 2016). Twenty-seven studies were reviewed with bias being manifested in time allowed (e.g., increased stoppage time), goals awarded, penalty kicks awarded, and/or disciplinary sanctions. For example, Dohmen (2008) reported that, when controlling for disciplinary actions and substitutions, events that typically increase the amount of time added on, officials added an average of 22 more seconds when the goal differential was one. This finding was attributed by Dohmen and Sauermann (2016) to the impact of social pressures (e.g., the desire to be seen as impartial), as similar studies reported a greater effect when it was the home team that was losing by a one-goal margin (see Rickman & Witt, 2008; Scoppa, 2008), thus supporting the classical model's identification of the official as an antecedent to home advantage.

This support extends beyond time played, with referees in the English Premier League being reported to have a significant effect on the number of goals home teams scored, the number of goals the away team scored, penalising away team players with more yellow and red cards than home team players and being significantly more likely to award penalties to the home team than the visitors (Boyko et al., 2007). While other studies support these findings, such as legitimate penalties being more likely awarded to the home team than the away team (Sutter & Kocher, 2004), caution is advised when attributing home advantage to refereeing decisions.

The first reason to exercise caution when considering the impact of officials on home advantage is evidence to the contrary found in extant literature. For example, Adie et al. (2022a) report no bias towards the home team in cricket regarding leg-before-wicket (LBW) decisions, while similar studies refute the impact of the referee on home advantage found in football. Dohmen and Sauermann's review, for instance, did not include Riedl et al.'s (2015) investigation into injury time and home advantage. This analysis of archival data from the German Bundesliga between 2000 and 2011 found that while referees did allow more injury time when either team was trailing by a goal, even after accounting for alternative explanations for increased injury time (e.g., disciplinary sanctions, substitutions, etc.), this was the same for both teams and did not significantly affect goals scored. Consequently, while officials may have demonstrated a systematic bias towards avoiding narrow victories, this bias did not influence home advantage. Further, some studies that were included have questionable conclusions. For example, the findings of Boyko et al. (2007) that support the classical model were attributable to one official who accounted for the apparent home advantage as, once their data was removed, no effect was found (see Strauss et al., 2009, for a discussion). Therefore, individual differences such as experience may mediate the impact of game location on officiating performance, a conclusion supported elsewhere (Page & Page, 2010).

A second reason to question the officials' role in home advantage is technological and training advances, that have been identified as a significant cause of reduced home advantage in professional football over the previous century (Nevill et al., 2013; Webb et al., 2018). Technological developments, such as the introduction of microphones in 2006 that allow officials to communicate throughout the match, may help insulate elite officials from crowd influence by reducing conformity (see Asch, 1955). The introduction of video assistant referees (VAR) in 2018, has been reported to have enhanced the decision-making accuracy of officials from 92.1% to 98.3% (Spitz et al., 2021). However, while VAR has been reported as reducing home team bias (Gasparetto et al., 2023), investigation of the initial, on-field decision is recommended due to the time taken for VAR intervention and to develop the traditionally 'practice poor' environment of professional officiating (Spitz et al., 2021). Additionally, a contemporary assessment of elite officials' decision-making is warranted to evaluate whether initial, 'on-field' decision-making accuracy has been helped or hindered by technological support, with previous research indicating an error rate of 6.9% within this population (Hossner et al., 2019).

Furthermore, the development of strategies to enhance decision-making borne from experience and/or training may have helped elite officials insulate themselves from external factors such as game location. For example, gaze behaviours of elite football referees are associated with higher search rates of shorter durations than sub-elite officials (van Biemen et al., 2022). Consequently, adaptive strategies may explain why elite officials are not influenced by game location, with social pressure reported as not influencing red cards shown in the English Premier League (Reilly & Witt, 2013). Ergo, the development of technology, coupled with the improved training of football referees (see Webb, 2017; 2022) may explain a decrease in home advantage value found in European football (Nevill et al., 2022; Pollard & Gómez, 2009; Webb et al., 2018). Therefore, assessing the extent of officials' contribution to home advantage may indicate the success of such developments.

Determining whether and, if so, to what extent officials contribute to home advantage is challenging considering methodological limitations present in extant studies, giving the impression of referee bias when there may be none. For example, to calculate expected goals for home and away teams, Boyko et al. (2007) used a regression model, which Dohmen and Sauermann (2016) claimed is less effective than assessing whether decisions are correct or not. This method was also applied to conclude that away team players are more likely to be shown a yellow card than home players, with a regression model estimating the number of

free kicks and cautions (Picazo-Tadeo et al., 2017). While such research is welcome, previous research has identified that football teams adopt different strategies depending on game location, such as home teams' greater use of offensive players due to increased dissatisfaction with a tied score at half-time, higher ball possession, and implementation of proactive (e.g., attacking) strategies (Carron et al., 2005; Collet, 2013; Lago-Peñas et al., 2017; Staufenbiel et al., 2015). Such strategies may result in away teams being more likely to concede fouls leading to disciplinary sanctions, such as free kicks, yellow cards, and penalties, and therefore there is a need to consider whether officials' decisions are correct or not. The failure to assess decision correctness constitutes a methodological limitation of studies analysing descriptive statistics to conclude game location promotes referee bias (e.g., home teams receive fewer yellow cards when spectators are present; Pettersson-Lidbom & Priks, 2010), as well as studies that claim there is no referee bias when crowds are absent (e.g., no difference in number of cards between home and away teams; Sors et al., 2021). To address this methodological gap in extant research there is a need for an analysis of football referee's decisions by assessing their correctness.

Analysing the correctness of decisions to determine whether previously held assumptions of bias were accurate has been accomplished in other sports. Adie et al. (2022b) concluded that while lower-order batters in elite cricket, that are not expected to be as competent as higher-order batters, were more likely to be judged as LBW by the umpire, this was not due to expectation bias (where decisions are influenced by irrelevant criteria such as previous outcomes or order of performance; see Plessner, 1999), but to correctness. In short, lower order batters are more likely to be given LBW because they are actually out LBW. Although this study provides a justification for assessing correctness of decisions before assuming the presence of social or other bias in sports officials, LBW decisions are both reactive and objectively verifiable (e.g., the umpire decides whether the ball hit the bat first after the incident) and predictive (e.g., judging whether the ball have gone on to hit the stumps). While decisions made by football officials are mostly reactive (e.g., determining whether a foul was committed), there are also occasions when officials switch from a rule-based approach to a proactive 'game management' approach (see Raab et al., 2020). This method compromises accuracy for adequacy, reflecting game conventions (e.g., what the game 'expects') and promoting the flow of the contest (see Harper, 2022; Mascarenhas et al., 2002; Unkelbach & Memmert, 2008), but may also promote sensitivity to external influences (Plessner & Betsch, 2001; Praschinger et al., 2011). Additionally, many decisions made are ambiguous in that they not objectively verifiable (e.g., assessing whether a foul was careless, reckless, or used excessive force).

Research into correctness of decision within sports that require the official to make reactive decisions that are not objectively verifiable, while limited, have shown no support for the classical model. For instance, Corrigan et al. (2019) assessed correctness of decisions made by Australian Football League (AFL) officials, with no evidence that decisions were influenced by game location. However, game location has been found to influence ambiguous decisions in favour of the home team in football, particularly regarding punitive action (e.g., yellow cards shown; Cohen et al., 2024). However, this study used fans and not referees to assess decisions and therefore, given the importance of experience in officiating performance, assessing correctness of decisions in football officials should be made via consensus among referees who are familiar with the laws of the game and conventions of the sport. This approach is justified to determine the influence of game location as, if there is no difference in correctness of decision between home and away teams, increased win percentages at home are attributable to player and coach behaviour.

This study sought to meet two objectives. First, to determine whether decisions made by elite football referees in England are influenced by match location by ascertaining if the home team received more errors in their favour than the away team, and if the away team received less correct calls in their favour. Second, if any difference is found, to determine how any influence is manifested by assessing decisions in categories that have been identified as significant for officiating performance. It was hypothesised that, due to the experience of the officials operating in top tier football, enhanced training methods and the introduction of technology, previously identified as causes for a decrease in home advantage in football (see Webb et al., 2018), no bias would be found regarding decision-making accuracy between home and away teams.

2. Methods

2.1. Participants and procedure

Ethical approval was granted by the lead author's university. To assess correctness of decisions the research team agreed that a panel of officials should be used. This decision rejects the positivist perspective of truth, with a panel judging that what is accepted as truth, is the truth. Further, it reflects the pragmatist view of the researchers, in that to overcome the methodological limitations of existing studies assessing the referee's role in home advantage, correctness of decisions would need to be considered (see Giacobbi et al., 2005). Forty-two qualified football referees were recruited (M_{age} = 33.7 years; SD = 11.54). Thirty-five participants were from Great Britain and Ireland, six from North America (United States of America and Canada) and one from Latvia (although a practicing official in England). Participants were recruited via email invitations to relevant agents (e.g., Referee Development Officers, Referee Associations) and adverts placed on social media. Participants were also given the opportunity to attend an online information session regarding the aims of the study and what participation would require. Participants had to be over 18 years of age and a qualified football referee ($M_{years' \ experience}$ = 10.5 years, SD = 9.85). While classification systems across nations makes calibrating officiating level difficult (see Webb et al., 2021), referees ranged from Level 7 (local level) to Level 1 (professional) in the UK (M_{Level} = 4.91, SD = 1.53) and reported both 'regional' and 'national' levels in the United States and Canada. None of the officials were current or previous English Premier League officials and a breakdown of officiating classification can be found in Table 1. Officials were informed that the aim of study was to evaluate correctness of refereeing decisions, but not that decisions between home and away teams would be compared, and that they would be asked to view video clips from an English Premier League fixture every week for the duration of the season to assess correctness. Video clips were uploaded to a designated folder for each participant, which also contained a tutorial video for officials to view, providing guidance on how to access their clips and record their

assessments. The tutorial video was constructed by the authors of the study to ensure a consistent data collection approach across all referees and all games and contained information to assist participants completing their task (e.g., when clips would be uploaded to their folder, how to complete the decision assessment sheet, who to contact should they have any questions etc).[1]

Table 1: Classification of participants' officiating level.

Number of officials	*M* ± SD experience (years)	Officiating level
1	25	1 (Referees on English Premier League, English Football League)
1	10	2 (Referees on National League, Step 1 and/or Step 2 of NLS)
1	12	3 (Referees on Steps 3 & 4 of NLS)
10	9.13 ± 6.45	4 (Referees on Steps 5 & 6 of NLS)
11	13.43 ± 14.84	5 (Referees on Step 7 of the NLS & Senior County football)
4	5 ± 4.36	6 (Referees on County League Football)
6	2.25 ± 1.25	7 (Referees on County League Football)
6	18.33 ± 10.50	Regional (USA/Canada)
2	7.50 ± 3.54	National (USA/Canada)

Note: Classification descriptions taken from The Football Association (The Football Association, 2025); Level 1 participant for this study operated in the English Football League. NLS = National League System.

Following recruitment, every fixture from the 2022/23 English Premier League was assigned to four officials at random. Four officials were chosen per game in anticipation that some officials would either withdraw from the study or fail to record their assessment of the allocated game. Consequently, each game had two 'primary referees', whose decisions would be used for analysis, and two 'back up' officials, to be used if the primary officials did not complete their assessment. At the conclusion of each game week, video clips of actions involving the referee were taken from WyScout (Chiavari, Italy) and uploaded to that game's allocated officials' folder.

WyScout clips are uniformed in time per incident (10 second of footage before and after event), with cumulative length of clips dependent on the number of incidents in each game). Further, inter-operator reliability of clips collated by WyScout is 0.70, considered good agreement between operators (Pappalardo et al., 2019; Viera & Garrett, 2005). Video clips involved foul decisions given, yellow cards given, red cards given, penalty kicks awarded, and penalty kicks not awarded (definitions of these events are taken from the International Football Association Board's Laws of the Game, and can be found in the Wyscout Glossary: https://dataglossary.wyscout.com). These referee actions are justified for investigation regarding officials' contribution to home advantage based on previous studies applying these criteria without accounting for correctness (e.g., Dohmen & Sauermann, 2016; Goumas, 2014; Sors et al., 2021). None of the clips included any slow-motion features, meaning that participants were unable to adjust the playback speed of the footage as reviewing clips in slow motion has been shown to influence assessment of decisions (Pizzera et al., 2022). Clips included some contextual information (e.g., teams playing, time, and score), as this has been reported to increased decision-making accuracy over the use of randomised clips provided without context, possibly due to qualified officials understanding the importance of game management (Raab et al., 2020; Samuel et al., 2019). All clips were viewed from a camera perspective of an elevated position level with the halfway line, a position that reports significantly improved accuracy of decision-making assessment when compared to other perspectives (e.g., coaches' viewpoint from pitch side; Pizzera et al., 2022). Although assessment of decisions via the referee's perspective may have improved ecological validity, this was not a viable option as, at time of writing, officials were prohibited from wearing recording equipment (The Football Association, 2024).

Officials were asked to complete a spreadsheet, also located in their folder, per game where they were required to: (a) record the names of the teams competing, (b) select what the decision was (e.g., free kick, yellow card, penalty) by using a drop-down box, (c) state whether they agreed or disagreed with the on-field referee's decision for each event shown, and (d) at their own discretion, make notes should they wish to add any further information for each decision. For example, referees could state whether they felt a yellow or red card should, or should not, have been administered following a free kick. Only the on-field referee's decision was assessed. If a decision was made that resulted in VAR intervention, then the result of this intervention was not assessed. This was due to the VAR officials not being present in the stadium and, therefore, any decision cannot be attributed to crowd presence, noise, or proximity, previously identified as factors contributing to home team bias in referees (Dohman & Sauermann, 2016), and the importance of assessing the original decision to minimise VAR intervention (Spitz et al., 2021).

In anticipation of participant withdrawal or incomplete samples due to time commitment (5 of the original 42 participants withdrew from the study throughout the season), two primary officials were assigned to each game, with another two assigned in reserve should one or both primary referees fail to complete their allocated game. As the video clips evaluated by the participants are subjective decisions, correctness was determined by having agreement from both referees appointed to each match. Use of panels consisting of qualified officials to evaluate decisions have previously been used to evaluate on-field referee decisions (e.g., Nevill et al., 2017) and so for a decision to be considered correct or incorrect, both referees had to agree.

[1]Tutorial video available upon request by contacting the corresponding author.

However, for this study, the subjective nature of the laws of football (see Bordner, 2019, for a discussion) was considered, with 'disputed' decisions recorded when no consensus between referees was reached. There was no temporal constraint on when participants could complete their review of the clips, however they were encouraged to do so as soon as possible to minimise outside influence (e.g., media analysis of on-field referee performance).

Upon completion of the English Premier League season 2022/23, footage from each game assessed by two officials was reviewed, and every on-field decision labelled as 'against home team' or 'against away team' by the lead researcher, with 'against' determined by which team conceded possession or received a card following the incident. The decisions were categorised as one of the following for both home and away teams: correct foul given against; correct yellow for; correct red for; correct penalty for; correct 'un-whistled' penalty for; disputed foul given against; disputed yellow given for; disputed red given for; disputed penalty given for; disputed 'un-whistled' penalty given for; missed yellow for; missed red for; error foul against; error yellow for; error red for; error penalty for; error 'un-whistled' penalty for. Spreadsheets submitted for each game were compared and decisions classified as 'correct', 'disputed' or 'erroneous'.

2.2. Data analysis

Decisions from 172 games, representing 45% of the English Premier League 2022/23 season, were assessed in their entirety by two officials, resulting in a total of 4,237 decisions reviewed for correctness. Thirty-six decisions were excluded from analysis due to participants reporting that either the on-field decision was not identifiable from the footage, or that their view of the incident was not clear, thus making assessment impossible. The removal of these incidents resulted in a final sample of 4,201 decisions analysed. The number of games evaluated from each team can be seen in Table 2.

Table 2: Number of games analysed per team.

Team	Number of games assessed	Team	Number of games assessed
Arsenal	15	Leicester City	16
Aston Villa	16	Liverpool	16
Bournemouth	23	Manchester City	17
Brentford	11	Manchester United	15
Brighton	21	Newcastle United	16
Chelsea	19	Nottingham Forest	17
Crystal Palace	14	Southampton	18
Everton	17	Tottenham Hotspur	19
Fulham	20	West Ham United	18
Leeds United	17	Wolverhampton W.	14

A validity check was performed to ensure that the sample was representative of the entire season. The sample consisted of 48% of home wins, 30% of away wins, and 22% of draws. This was deemed an accurate representation of the entire season, which reported 48% of matches as home wins, 29% as away wins, and 23% as draws.

Referee decision events were coded by type and were then coded for accuracy. Decision events included fouls (correct, incorrect, disputed, missed yellow), yellow cards (correct, incorrect, disputed), and red cards (correct, incorrect, disputed). A series of linear mixed effects models predicting decision event frequencies were conducted in R (Version 4.4.2) using the lme4 package (Bates et al., 2015). Each mixed model included the team (Home v Away) as a fixed effect, and the referee as a random effect. We included the referee as a random effect to account for the unequal representation of the 19 referees assessed across matches, where some referees officiated more matches than others (the highest number of matches officiated by an observed referee was 13, whereas the lowest number of matches officiating by a referee was one). Degrees of freedom were calculated using a Satterthwaite approximation. Marginal and conditional R2 values were calculated as measures of effect size using the MuMin package (Bartoń, 2024). We did not compare red cards as only 9 red cards were awarded in this dataset.

3. Results

3.1. Descriptive statistics

A visual analysis of descriptive statistics (Table 3) indicated away teams committed more fouls than home teams (1,703 to 1,667 respectively). Furthermore, away team players were shown more yellow cards than home team players (240 to 224), with these decisions being deemed correct. Away team players had more disputed fouls against them than home team players (90 to 74) and received more disputed yellow cards than home team players (16 to 7). Home team players had more fouls awarded against them incorrectly than away team players (29 to 23), with both home and away team players receiving the same amount of incorrect yellow cards in the opinion of the officiating panel (3 each). The officiating panel believed that while both teams should have received more yellow cards, the number of 'missed' yellow cards benefitted the home team (33 to 21). If these yellow cards are included as incorrect decisions, then the officiating panel judged the on-field referees as getting 3,891 decisions correct and 117 incorrect, meaning officials got 2.92% of decisions wrong. This does not include 'disputed' decisions, where the officiating panel could not agree whether the on-field judgement was correct or incorrect. If the disputed decisions are considered incorrect, this study reports an error rate of 7.38%, consistent with results reported elsewhere (Spitz et al., 2021). If half of the disputed decisions are considered incorrect, and the other half correct, then accuracy rate is 94.9%.

Results showed that home teams were awarded 22 penalty kicks, with 14 penalty kicks awarded to away teams. Two of these decisions, favouring the home team, were disputed. Neither home nor away teams were awarded a penalty kick that the officiating panel felt was in error. Home teams were more likely than away teams to have appeals for penalty kicks turned down (12 to 4), while

Table 3: Descriptive statistics.

	Category of decision										
	Fouls against		Yellow cards		Red cards		Penalty kicks		Un-whistled penalty kicks		Total
	Home	Away	Home	Away	Home	Away	Home	Away	Home	Away	
Correct	1667	1703	224	240	6	1	20	14	12	4	3891
Disputed	74	90	7	16	1	0	2	0	2	1	193
Incorrect	29	23	3	3	1	0	0	0	2	2	63
'Missed'			33	21	0	0					54

Notes: Games $N = 172$; total decisions $N = 4201$; 'Correct' = officiating panel agreed with decision; 'disputed' = no consensus among officiating panel; 'incorrect' = officiating panel disagreed with decision.

both home teams and away teams received two penalty kicks in error. Due to limited sample size, thus casting doubt over reliability of any subsequent analysis, penalty kick decisions and red card decisions (of which there were nine), were not included in further analysis.

3.2. Awarded fouls

In total, 3,586 fouls were awarded at an average of 20.85 (SD = 5.20) fouls per match (Figure 1). On average, the home team reported 10.29 (SD = 3.51) fouls per match, while the away team reported an average of 10.56 (SD = 3.41) fouls per match, resulting in an average total foul differential score of -0.27 (SD = 4.45). This equates to one additional foul awarded against the away team every 3.7 matches. A linear mixed effects model revealed that this difference was not significant, $F(1, 324.21) = 0.53$, $p = 0.468$. The model explained <1% of the variance when considering the fixed effect of team alone ($R^2_M = .001$) and 2.7% of the variance when considering both the fixed effect of team and the random effect of referee ($R^2_C = 0.027$).

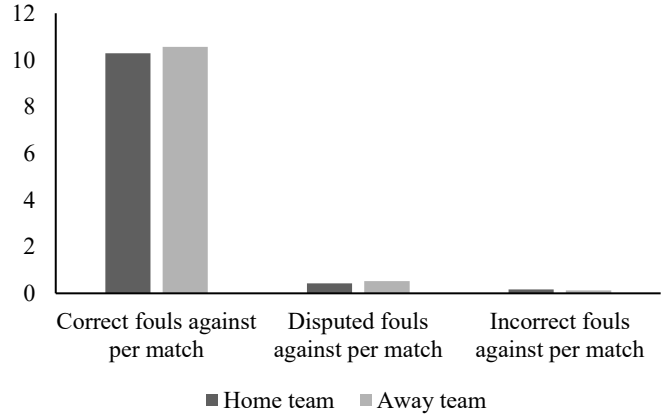

Figure 1: Correct, disputed, and incorrect foul decisions per match average for home and away teams (2022/2023 Premier League season).

A total of 52 fouls were rated as incorrect, at an average of 0.30 (SD = 0.59) decisions per match. On average, the home team reported 0.17 (SD = 0.42) fouls incorrectly per match, while the away team reported an average of 0.13 (SD = 0.40) fouls incorrectly per match, resulting in an average incorrect foul differential score of 0.04 (SD = 0.57). This can be interpreted as 1 additional incorrect foul awarded against the away team every 25 matches. A linear mixed effects model revealed that this difference was not significant, $F(1, 342) = 0.62$, $p = 0.433$. The model explained <1% of the variance when considering both the fixed effect of team alone ($R^2_M = .002$) and when considering both the fixed effect of team and the random effect of referee ($R^2_C = 0.002$).

A total of 164 fouls were coded as disputed, at an average of 0.95 (SD = 1.13) decisions per match. On average, the home team reported 0.43 (SD = 0.71) disputed fouls, while the away team reported an average of 0.52 (SD = 0.80) disputed fouls, resulting in average disputed foul differential score of -0.09 (SD = 1.00). This can be interpreted as 1 additional disputed foul awarded against the away team every 11.11 matches. A linear mixed effects model revealed that this difference was not significant, $F(1, 342) = 1.30$, $p = 0.254$. The model explained <1% of the variance when considering both the fixed effect of team alone ($R^2_M = 0.004$) and when considering both the fixed effect of team and the random effect of referee ($R^2_C = 0.004$).

A total of 54 fouls were coded as missed yellow cards, at an average of 0.31 (SD = 0.64) missed yellow cards per match. On average, 0.19 (SD = 0.48) yellow cards were missed for home team, while an average of 0.12 (SD = 0.38) yellow cards were missed for the away team, resulting in an average missed yellow card differential score of 0.07 (SD = 0.58). This can be interpreted as 1 additional missed yellow against the home team every 14.29 matches. A linear mixed effects model revealed that this difference was not significant, $F(1, 342) = -2.27$, $p = 0.133$. The model explained <1% of the variance when considering both the fixed effect of team alone ($R^2_M = 0.007$) and when considering both the fixed effect of team and the random effect of referee ($R^2_C = 0.007$).

3.3. Awarded yellow cards

In total, 493 yellow cards were awarded at an average of 2.87 (SD = 1.68) yellow cards per match (Figure 2). On average, the home team received 1.36 (SD = 1.10) yellow cards per match, while the away team received an average of 1.51 (SD = 1.2) yellow cards per match, resulting in an average yellow card differential score of -0.15 (SD = 1.54). This can be interpreted as 1 additional

yellow card awarded against the away team every 6.67 matches. A linear mixed effects model revealed that this difference was not significant, $F(1, 326.59) = 1.40$, $p = 0.238$. The model explained <1% of the variance when considering the fixed effect of team alone (R2M = 0.004) and 2.4% of the variance when considering both the fixed effect of team and the random effect of referee (R2C = 0.024).

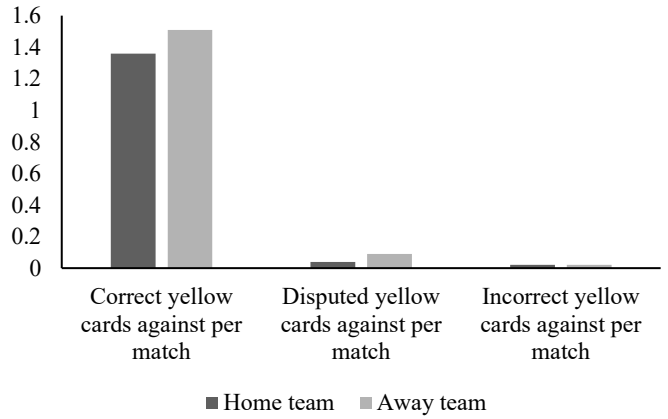

Figure 2: Correct, disputed, and incorrect yellow card decisions per match average for home and away teams (2022/2023 Premier League season).

A total of 6 yellow cards were coded as incorrect, at an average of 0.03 (SD = 0.21) incorrect yellow cards per match. We did not conduct further analyses regarding incorrect yellow cards, as both the home and away teams received three incorrect yellow cards each at an average of 0.02 (SD = 0.13) per match.

A total of 23 yellow cards were coded as disputed, at an average of 0.13 (SD = 0.37) per match. On average, the home team received 0.04 (SD = 0.23) disputed yellow cards per match, while the away team received an average of 0.09 (SD = 0.31) disputed yellow cards, resulting in a disputed yellow card differential score of -0.05 (SD = 0.39). This can be interpreted as 1 additional disputed yellow card awarded against the away team every 20 matches. A linear mixed effects model revealed that this difference was not significant, $F(1, 322.7) = 3.39$, $p = 0.067$. The model explained <1% of the variance when considering the fixed effect of team alone ($R^2_M = 0.009$) and 7.3% of the variance when considering both the fixed effect of team and the random effect of referee ($R^2_C = 0.073$). This suggests that the individual referee is a better predictor of the number of disputed yellow cards in our dataset, however this should be interpreted with caution given the unequal number of games officiating by the individual referees as referees with fewer matches may have unreliable variance estimates.

4. Discussion

The study makes a unique and important contribution to solving the 'unsolved puzzle' (Pollard, 2008) of what is responsible for home advantage in elite football. Specifically, this is achieved by concluding that although away teams accumulate more fouls, yellow cards, and concede more penalty kicks, these decisions are correct. Furthermore, while approximately 3% of decisions in these categories are erroneous, there is no statistically significant difference in the data between home and away teams and, therefore, the errors are attributed to human error and not social bias. This conclusion is strengthened by the ecological validity of the sample, in that if half of the 'disputed' decisions are considered correct and the other half incorrect, the accuracy rate of 94.9% reflects the 95% of officials' decision-making accuracy using the same criteria (e.g., fouls, yellow cards, penalty kicks) reported by the Premier League (Premier League, 2014).

As findings were derived from real data with 'correctness' analysed, this study has addressed methodological limitations (e.g., predictive modelling) extant in previous studies (see Dohmen & Sauermann, 2016). In doing so, it has provided support for studies that suggest variance in officiating decisions between home and away teams is attributable to behavioural differences (e.g., proactive approach to games, increased dissatisfaction with not winning etc) between home and away teams, not match officials (see Carron et al., 2005; Collet, 2013; Lago-Peñas et al., 2017; Staufenbiel et al., 2015). The descriptive statistics (Table 3) further support the findings for these studies as, although the data sample was not large enough for statistical analysis, home teams received more correct penalties than away teams (12 to 4 respectively). In short, away teams foul more than home teams, an expected outcome when a more proactive and possession-based approach is typically taken by the home team and a more defensive strategy adopted by the away team (Fernandez-Navarro et al., 2018; Gollan et al., 2020; Lago-Peñas & Lago-Ballestaros, 2011). Ergo, the study supports the territoriality model (Neave & Wolfson, 2003) over the classical model (Allen & Jones, 2014), with a possible explanation for its results being elite officials' ability to insulate themselves from the physiological and psychological mediators to performance found in the Home Advantage Mediation model (Bilalić et al., 2024).

Although referees did occasionally favour the home side in ambiguous situations, this occurred rarely and was not significant, in contrast with the findings of Cohen et al. (2024). The difference equates to one disputed foul against the away team every 6.67 matches, and one disputed yellow card against the away team every 12.5 matches, and therefore we found no support for the classical model. It is vital, however, to acknowledge that while data provides evidence to suggest that referees do not support the home team by erroneously awarding fouls & yellow cards against the away team, and that the study makes an important contribution to the literature by exploring differences in 'disputed' decisions, we did not assess whether there was bias in un-whistled fouls. That is, the dataset did not include decision events where the referee did not blow the whistle, and therefore it remains possible that referee bias may contribute to home advantage, but only in un-whistled fouls (e.g., potential 'missed foul' errors). This possibly warrants further exploration given previous evidence that more referee errors are made regarding action not taken, rather than sanctions given (Hossner et al., 2019).

Further, the findings cannot suggest that previous attribution of home advantage to officiating decisions was erroneous. For example, several studies that have investigated home bias in referees were conducted prior to technological developments, such as microphones, as well as being close to, or prior to, the professionalisation of officials in football (e.g., Boyko et al., 2007; Courneya & Carron, 1992; Nevill et al., 2002). Thus, these findings support conclusions that enhanced training and development of elite officials has decreased their contribution to

home advantage (e.g., Nevill et al., 2013), not that it never existed. Therefore, the pattern of results in the present study may be explained by enhanced training and development of elite officials as suggested by Nevill et al. (2013).

This study addressed methodological in extant studies investigating home advantage in sports, such as the use of predictive statistics, thus making a valuable and unique contribution to research on home advantage in elite football, with the use of clips provided with context promoting accuracy in assessment (Samuel et al., 2019). For example, participants noted that, in isolation, a transgression may not be worthy of a yellow card, but due to persistent offending was justified on that occasion. This afforded participants the opportunity to acknowledge 'adequate' decisions based on game management, rather than the robust application of law (see Mascarenhas et al., 2022; Raab et al., 2020), promoting the ecological validity of results. However, it should be noted that the results analyse the aggregate of all decisions made which assumes that all decisions are equal. For example, an incorrect penalty decision is likely to have more impact on the result than an incorrect free kick or yellow card. Further, while participants assessed decisions with context, results were analysed without it. In other words, it is unknown whether officials made errors against the home team once the game was already won, a finding reported within basketball officiating to appease visiting teams without influencing the outcome (MacMahon & Mildenhall, 2012). the sequence of decisions was not considered. As approximately 70%-75% of games in the Premier League result in less than 3 goals being scored, scoring first increases the likelihood of winning to 78% (Anderson & Sally, 2014; Lago-Peñas et al., 2016), this may be a worthwhile avenue of future research.

In addition to investigation of any temporal bias (e.g., favouring one team or another based on time played) towards the home team, future research regarding the impact of referees on home advantage should incorporate the use of VAR as a potential antecedent to bias. This study only assessed the on-field referee's decision, whereas the increased potential for decision-making reinvestment and social pressure (Picazo-Tadeo et al., 2017) justifies this avenue of research. Regarding assessment, while one Level 1 official (UK) and two National level (USA/Canada) participated as assessors, this study predominantly used non-elite officials to assess decisions which may differ from the views of professional referees, with previous literature suggesting increased training and experience enhances officiating practice and decision-making assessment performance (see Carrington et al., 2022; Pizzera et al., 2022). Therefore, it is possible that the evaluators used in this study perceived an on-field error when there was none (or vice-versa). However, as officiating performance is not always evaluated via formulism (e.g., the robust application of law) but conventionalism (e.g., making decisions on what the game expects; see Harper, 2022; Mascarenhas et al., 2002; Plessner & Betsch, 2001; Simon, 2014) a range of officials may have provided a more accurate assessment of performance than would have been provided with elite officials alone. In fact, using non-experts to assess fouls is an approach encouraged in extant literature to establish criteria for comparative judgments (Christodoulou, 2024). Therefore, this study can be considered as proof of concept regarding its methodology to assess decision-making accuracy and referee bias, with replication using an expert sample, or to compare decision-making evaluation across varied levels of officials, recommended as well as assessing reliability of the panel's judgments prior to testing to establish consistency.

A final consideration that may guide future studies is that previous research has suggested expectancy bias may influence officiating decisions in sports that require subjective and reactive decision-making. For example, figure skaters who competed later in the competition, where more accomplished athletes are placed, were scored higher than when they were judged earlier in the running order, when less accomplished skaters compete (Findlay & Ste-Marie, 2004). Additionally, biases in subjective officiating judgements have been influenced by memories of prior performance (Ste-Marie et al., 2001). While these studies involved closed activities (e.g., those performed in stable and consistent environments), extant research supports these conclusions in open activities (e.g., unpredictable and dynamic environments). For example, Jones et al. (2002) concluded that referees are more likely to penalise teams with yellow cards when informed of their aggressive reputation. Considering this evidence that subjective judgement may be influenced by previous actions and anticipation of future performance, it is possible that football officials are not influenced by game location, but by the team playing. For example, Constantinou et al. (2014) reported a bias in penalty kick decisions in favour of certain teams (e.g., Manchester United and Manchester City) but not others, regardless of game location. This conclusion is supported by Erikstad et al. (2020) who assessed correctness of penalty kick decision and reported a bias towards more successful teams. Therefore, future research may wish to explore whether certain teams, based on status (e.g., Manchester United), cultural identity (e.g., Athletic Bilbao), and geographical position (e.g., Cagliari in Sardinia), report differences in the metrics used in this study.

Conclusion

By assessing correctness of decisions, this study addressed a methodological limitation of extant research regarding referee bias in football, and results harvested from a large and representative sample found minimal evidence of home bias in the English Premier League. Consequently, the study provides support for the territoriality model to explain home advantage in sports, suggesting that crowd influence and game location is more likely to impact player and coach behaviour than elite officials. A possible explanation as to why officials were not influenced by game location is their resistance to the physiological and psychological influences found in the Home Advantage Mediation (HAM; Bilalić et al., 2024) model, therefore it is recommended that research focus on minimising errors in decision-making, such as the promotion of adaptive emotions to mediate stimulus response (see Kostrna & Tennenbaum, 2022) and promotion of support strategies to buttress referees' well-being. Finally, given the importance of contextual information on decision-making accuracy, the use of frameworks that enhance accuracy of event perception (e.g., predictive processing, see O'Brien et al., 2023), may be fruitful for stakeholders in referee development.

Conflict of Interest

The authors declare no conflict of interests.

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