



The introduction of the Video Assistant Referee supports the fairness of the game – An analysis of the home advantage in the German Bundesliga

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ABSTRACT

The introduction of the video assistant referee (VAR) was a landmark in soccer history, yet it is not empirically examined whether the technology contributes to the most supreme value of the game: fair play. Because referees are said to be one driving cause of the home advantage (HA), the aim of this study was to examine whether the HA changed in the German Bundesliga since the implementation of the VAR in the season 2017/18. We examined a total of 2448 games during the four seasons before and after the implementation of the VAR with regards to the game outcomes (i.e., goals and points) as well as indicators of referee bias (i.e., fouls, yellow cards, 2nd yellow cards, red cards, and penalty kicks) for both the home and the away teams. Findings indicate that the VAR influences game outcomes to a fairer degree. Specifically, (i) we found statistical evidence for the HA before, but not after the implementation of the VAR. However, (ii) these results need to be interpreted with caution because direct assessments of the change induced by the introduction of the VAR are not statistically significant. Finally, (iii) with the implementation of the VAR, fewer fouls were committed by both the home and the away team.

The video assistant referee (VAR) was introduced to make the sport fairer. It is supposed to help avoid clear and obvious errors and systematic distortions of judgment, i.e. to make more accurate decisions (DFB, 2021). While decisions made by the referee can never be 100% correct, this technology has the potential to improve decision-making and therefore to remove unfair imbalances within the sport.

When the VAR was officially introduced into the rules of the game in 2018 (Fédération Internationale de Football Association, 2019), critical voices were concerned about the possible disruptions to the flow of the game (Winand et al., 2021). Spitz et al. (2020) showed that in the main national leagues in the world, the check has a median duration of 22 s with an increasing rate of accuracy for the initial referees' decision of 92.1%–98.3%. Another study by Lago-Peñas et al. (2019) found a decrease in the number of offsides, fouls and yellow cards after the implementation of the VAR in the German Bundesliga and the Italian Serie A and an increase of the number of minutes added to the playing time in the first half and the full game, but not in the second half. Similar results are found for the Spanish LaLiga (Lago-Peñas et al., 2021) and the Chinese Super League (Han et al., 2020), namely a decrease in the

number of offsides and a slight increase in the number of minutes added to the playing time. Studies concluded that the VAR does not substantially modify the game in elite soccer although Lago-Peñas et al. (2021) suggest reducing the number of on-field reviews to retain the flow of the game.

However, the question remains whether the introduction of the VAR has affected the game in another way. When soccer became a professional team sport at the end of the 19th century, the concept of playing the same number of home and away games was introduced for almost every soccer league (Gómez-Ruano & Pollard, 2022). In this “balanced schedule” design there is a tendency for the home team to win more games, which is known as the home advantage (HA). The evidence of the existence of the HA is well documented (Pollard & Pollard, 2005). Many potentially contributing factors have been identified, such as effort of travel (Pace & Carron, 1992), familiar environment (Loughead et al., 2003), social pressure exerted by the crowd influencing the performance of the players (Neave & Wolfson, 2003) and the decision-making of the referee (Dohmen & Sauermann, 2016). In recent decades, it has been found that the HA has declined (Pollard & Pollard, 2005; Strauss et al., in

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Although referees are meant to be impartial, their performance is limited by physical and perceptual factors (Raab & Helsen, 2015) as well as the influence of social pressure and crowd noise (Dohmen & Sauer-mann, 2016; Garicano et al., 2005; Nevill et al., 2002; Sutter & Kocher, 2004). Thus, with their decisions, referees are cited as a causative factor for HA. Studies have shown that referees systematically favor the home team in their decision-making. For example, Garicano et al. (2005) showed that the stoppage time is significantly longer when the home team is behind by one goal, compared to the situation in which the away team is behind by one goal. Moreover, studies found that away teams were awarded a significantly higher number of yellow cards than home teams (Unkelbach & Memmert, 2010) and that home teams were legitimated more penalties than the away teams (Sutter & Kocher, 2004). Such systematic favoritism of a team represents a systematic distortion of judgment and should be avoided. It represents an unfair and unbalanced decision. The referee, as an impartial authority, should not favor any team.¹

Since spectator noise also contributes to this systematic judgment bias related to referees, the ghost games enforced by the COVID-19 pandemic are particularly interesting. During this time, the VAR was already systematically in use. This natural experiment revealed a significant decrease of the HA in games played without spectators, but could not show a total vanishing of the HA (e.g., Endrich & Gesche, 2020; Fischer & Haucap, 2021; Hill & Van Yperen, 2021; Leitner et al., 2022; McCarrick et al., 2021; Reade et al., 2022; Scoppa, 2021; Sors et al., 2022). Overall, the HA persists in the absence of spectators, suggesting that even though the home team gains an advantage of playing at home, it cannot be fully explained by the influence the spectators have on either the team's performance or the decision-making of the referee (Wunderlich et al., 2021). Therefore, other factors apart from the behavior of the crowd influence the HA. Tactical behavior, for example, does not exclusively develop due to the crowd and can still be present due to psychological effects, as the players and coaches are still aware of playing at home, consequently expecting a higher game outcome (Staufenbiel et al., 2015; Wunderlich et al., 2021). Another argument in this regard is that the HA can already be found in youth leagues, yet increases with age and can therefore be described as a social construct and a consequence of learned behaviour (Staufenbiel et al., 2018). Consequently, the HA remains a sports phenomenon, which can still not be reduced to a single factor. We make use of the HA as a parameter for fairness, as a decrease implicates less systematic favoring of one team and more balanced decisions.

1. Purpose of the present study

The aim of this study is to examine if the introduction of the VAR changed the decision-making of the referee in the German Bundesliga. Our present paper builds on the latest studies suggesting that the VAR impacts referees' decisions (e.g., Han et al., 2020; Holder et al., 2021; Lago-Peñas et al., 2021) by providing a larger dataset over several seasons from one specific league. Specifically, our study added the analysis of 2448 games to the previously analysed 3984 games ($n = 480$, Han et al., 2020; $n = 1520$ and $n = 1224$ for Italy and Germany respectively, Holder et al., 2021; $n = 760$, Lago-Peñas et al., 2021), providing a larger sample size from a single league. As we checked four seasons before and after the implementation of the VAR, our dataset is much larger and therefore more reliable compared to the studies mentioned above. The question remains whether the VAR has a direct influence on the accuracy of the referee's decision and consequently on the HA. We expect that the introduction of the VAR changes the decision-making of the referee to a more balanced outcome for both the

home and the away team. This leads to the hypothesis that the introduction of the VAR in the German Bundesliga decreases the magnitude of the HA. Specifically, the VAR has now been implemented for a sufficient period of time to empirically test its effect on the fairness of the game. As we combine the effect the VAR has on the HA during the seasons played with spectators and games played without spectators during the season 2019/20 due to COVID-19, our study provides a combination that has not been examined in previous research.

2. Method

2.1. Data

We mainly retrieved our data from the website football-data.co.uk (<https://www.football-data.co.uk>), added penalty kicks from transfermarkt.de (<https://www.transfermarkt.de>) and separated the 2nd yellow cards from the direct red cards, which gives us the opportunity to trace the difference in direct red cards to the implementation of the VAR. Our constructed dataset included all games in the German Bundesliga four seasons before (2013/14–2016/17) and four seasons after (2017/18–2020/21) the introduction of the VAR. Altogether, we analysed 2448 games. Half of the games ($n = 1224$) were played before the introduction of the VAR. The other half was played after the introduction of the VAR, consequently fulfilling all the VAR protocol and implementation requirements as set out in the International Football Association Board (IFAB). Specifically, we obtained different variables for the game outcome (i.e., goals and points) and the referee bias indicators (i.e., fouls, yellow cards, 2nd yellow cards, red cards, and penalty kicks) separated for home and away teams. Note that in the season 2019/2020, there is the additional condition of having 83 of 306 games played without spectators during the COVID-19 pandemic, while the 2020/2021 season was played almost completely without spectators.

2.2. Analysis

To assess the home advantage before and after the introduction of the VAR, we first computed within-game differences between the home and away teams for all variables across the eight seasons. This approach yields a direct assessment of the change in game outcomes and corresponding referee bias indicators. Thus, to test whether the home advantage exists in the four seasons before and after the implementation of the VAR, we applied one-sample t-tests for the difference scores. Then, we examined whether the average difference score from the four seasons before the VAR introduction differs significantly from zero when compared with the average difference score from the four seasons following the VAR introduction. Furthermore, to control the impact of the COVID-19 pandemic, which was particularly strong in the German Bundesliga (Endrich & Gesche, 2020; Fischer & Haucap, 2021; Hill & Van Yperen, 2021), we repeated the same procedure with only seasons before and after the introduction of the VAR. Given the large sample sizes, we implement the recommendations by Sors et al. (2022) and do not consider test outcomes with $p < .05$ alone as significant, but also require effect sizes to be larger than $d = 0.2$. This means that despite statistical significance, the effect sizes need to breach the threshold for small effects (Cohen, 2013). All statistical analyses were performed in MATLAB 2018a.

3. Results

Descriptive statistics of performance and disciplinary sanctions for the home and the away team in the eight seasons from 2013/14 to 2020/21 are presented in Tables 1 and 2.

The t-tests comparing the game outcomes and the referee bias for the home and the away team can be found in Table 3 to Table 5. Table 3 shows that the number of goals scored ($t(1223) = 7.00$, $p < .001$, $d = 0.20$), points ($t(1223) = 7.25$, $p < .001$, $d = 0.21$), and yellow cards (t

¹ Note that the indicators of referee bias may also result from the dynamics of the game, including changing playing styles of the teams.

Table 1

Descriptive statistics of the seasons 2013/14–2020/21.

| Saison variable | 13/14 | | 14/15 | | 15/16 | | 16/17 | | 17/18 | | 18/19 | | 19/20 | | 20/21 | |
|----------------------------------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Game outcome | | | | | | | | | | | | | | | | |
| Goal Home | 1.75 | 1.38 | 1.59 | 1.32 | 1.75 | 1.36 | 1.66 | 1.32 | 1.60 | 1.28 | 1.79 | 1.51 | 1.66 | 1.40 | 1.68 | 1.40 |
| Goal Away | 1.41 | 1.26 | 1.17 | 1.19 | 1.26 | 1.13 | 1.21 | 1.23 | 1.19 | 1.14 | 1.39 | 1.25 | 1.55 | 1.36 | 1.36 | 1.17 |
| Points Home | 1.63 | 1.35 | 1.69 | 1.30 | 1.56 | 1.34 | 1.71 | 1.31 | 1.63 | 1.30 | 1.59 | 1.33 | 1.43 | 1.34 | 1.53 | 1.31 |
| Points Away | 1.16 | 1.31 | 1.04 | 1.23 | 1.21 | 1.31 | 1.05 | 1.25 | 1.09 | 1.24 | 1.17 | 1.29 | 1.35 | 1.34 | 1.21 | 1.28 |
| Indicator of referee bias | | | | | | | | | | | | | | | | |
| Foul Home | 14.99 | 4.40 | 14.86 | 4.29 | 14.18 | 4.05 | 13.79 | 4.32 | 12.93 | 3.90 | 11.03 | 3.73 | 11.49 | 3.91 | 12.16 | 3.85 |
| Foul Away | 15.74 | 4.40 | 15.68 | 4.71 | 14.86 | 4.29 | 14.83 | 4.19 | 13.79 | 4.07 | 11.34 | 3.84 | 11.88 | 3.89 | 12.53 | 3.51 |
| Yellow Home | 1.61 | 1.13 | 1.72 | 1.23 | 1.83 | 1.24 | 1.75 | 1.23 | 1.53 | 1.28 | 1.51 | 1.19 | 1.85 | 1.34 | 1.73 | 1.25 |
| Yellow Away | 1.99 | 1.24 | 1.99 | 1.21 | 2.06 | 1.31 | 2.08 | 1.26 | 1.79 | 1.23 | 1.87 | 1.22 | 2.05 | 1.26 | 1.84 | 1.24 |
| 2nd Yellow Home | 0.02 | 0.15 | 0.05 | 0.21 | 0.03 | 0.16 | 0.05 | 0.22 | 0.03 | 0.18 | 0.03 | 0.16 | 0.04 | 0.19 | 0.02 | 0.14 |
| 2nd Yellow Away | 0.07 | 0.26 | 0.05 | 0.21 | 0.05 | 0.22 | 0.04 | 0.2 | 0.04 | 0.20 | 0.05 | 0.21 | 0.08 | 0.26 | 0.04 | 0.21 |
| Red Home | 0.04 | 0.19 | 0.05 | 0.22 | 0.03 | 0.16 | 0.05 | 0.21 | 0.04 | 0.19 | 0.03 | 0.18 | 0.03 | 0.16 | 0.02 | 0.15 |
| Red Away | 0.06 | 0.24 | 0.03 | 0.18 | 0.03 | 0.16 | 0.05 | 0.21 | 0.03 | 0.16 | 0.04 | 0.20 | 0.04 | 0.19 | 0.03 | 0.16 |
| Penalty Home | 0.16 | 0.38 | 0.11 | 0.34 | 0.16 | 0.38 | 0.20 | 0.43 | 0.17 | 0.40 | 0.18 | 0.40 | 0.10 | 0.30 | 0.21 | 0.43 |
| Penalty Away | 0.09 | 0.31 | 0.10 | 0.31 | 0.11 | 0.33 | 0.11 | 0.34 | 0.13 | 0.38 | 0.11 | 0.32 | 0.14 | 0.38 | 0.15 | 0.37 |

Table 2

Descriptive statistics for the four seasons before and after the implementation of VAR combined.

| Variable | | No VAR | | VAR | |
|-------------|------|----------|-----------|----------|-----------|
| | | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Goal | Home | 1.64 | 1.35 | 1.68 | 1.4 |
| | Away | 1.26 | 1.21 | 1.37 | 1.24 |
| Points | Home | 1.55 | 1.32 | 1.65 | 1.32 |
| | Away | 1.21 | 1.29 | 1.12 | 1.28 |
| Fouls | Home | 14.45 | 4.29 | 11.9 | 3.91 |
| | Away | 15.28 | 4.42 | 12.39 | 3.94 |
| Yellows | Home | 1.73 | 1.21 | 1.65 | 1.27 |
| | Away | 2.03 | 1.25 | 1.89 | 1.24 |
| 2nd Yellows | Home | 0.04 | 0.19 | 0.03 | 0.17 |
| | Away | 0.05 | 0.22 | 0.05 | 0.22 |
| Reds | Home | 0.04 | 0.19 | 0.03 | 0.17 |
| | Away | 0.04 | 0.2 | 0.03 | 0.18 |
| Penalties | Home | 0.16 | 0.38 | 0.17 | 0.39 |
| | Away | 0.1 | 0.32 | 0.13 | 0.36 |

(1223) = -6.72 , $p < .001$, $d = 0.30$) indicate the existence of the home advantage in the last four seasons before the implementation of the VAR, considering the effect size threshold. However, none of the game outcome variables and referee bias indicators indicate a home advantage after the implementation of the VAR ($d_s < 0.16$).

The tests directly comparing the seasons before and after the implementation of the VAR indicate that the change in the game outcome variables and referee bias indicators was not statistically significant (see Table 4). That is, while the analyses for points ($t(1223) = 2.60$, $p = .01$, $d = 0.07$) and fouls ($t(1223) = -2.29$, $p = .02$, $d = 0.07$) reach the necessary alpha-level, their according effect sizes are very small. Therefore, we did not find statistically meaningful changes in the

home advantage since the implementation of the VAR in the German Bundesliga. Moreover, removing the seasons played under COVID-19 restrictions also yield no statistically significant changes since the implementation of the VAR (see Table 5).

4. Discussion

The VAR was introduced to help make soccer a fairer sport. Previous research has pointed out that the referees may favor the home teams by awarding proportionally fewer fouls, yellow cards, and red cards to them (Boyko et al., 2007; Downward & Jones, 2007; Nevill et al., 2002). This referee bias is one of the main driving forces behind the home advantage. However, if the VAR indeed helps to overcome this bias, the home advantage may decline accordingly. The current study provides new information about how the implementation of the VAR has changed referee decisions and the phenomenon of the HA in the German Bundesliga. To do so, we compared the difference between home and away teams for the four seasons before and the four seasons after the

Table 4

Test NoVAR vs VAR for home and away variables.

| Variable | No VAR | | VAR | | <i>t</i> | <i>p</i> | <i>d</i> |
|-------------|----------|-----------|----------|-----------|----------|----------|----------|
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | | | |
| Goal | .38 | 1.88 | .31 | 2.02 | 1.19 | .23 | .03 |
| Points | .53 | 2.57 | .34 | 2.58 | 2.60 | .01 | .07 |
| Fouls | -.82 | 5.33 | -.48 | 5.01 | -2.29 | .02 | .07 |
| Yellows | -.30 | 1.58 | -.23 | 1.55 | -1.59 | .11 | .05 |
| 2nd Yellows | -.02 | 0.28 | -.02 | .27 | .52 | .60 | .01 |
| Reds | -.003 | 0.27 | -.005 | 0.25 | .33 | .74 | .01 |
| Penalties | 0.06 | 0.48 | 0.03 | 0.53 | 1.70 | .09 | .05 |

Table 3

T-tests for home advantage assessments before and after the implementation of VAR based on the within-game difference scores. Positive mean values represent larger numbers for the home teams, while negative mean values represent larger numbers for the away teams.

| Variable | No VAR | | | | | VAR | | | | |
|-------------|----------|-----------|----------|----------|----------|----------|-----------|----------|----------|----------|
| | <i>M</i> | <i>SD</i> | <i>t</i> | <i>p</i> | <i>d</i> | <i>M</i> | <i>SD</i> | <i>t</i> | <i>p</i> | <i>d</i> |
| Goal | .38 | 1.88 | 7.00 | <.001 | 0.20* | .31 | 2.02 | 5.37 | <.001 | 0.15 |
| Points | .53 | 2.57 | 7.25 | <.001 | 0.21* | .34 | 2.58 | 4.62 | <.001 | 0.13 |
| Fouls | -.82 | 5.33 | -5.40 | <.001 | 0.15 | -.48 | 5.01 | -3.38 | <.001 | 0.10 |
| Yellows | -.30 | 1.58 | -6.72 | <.001 | 0.30* | -.23 | 1.55 | -5.27 | <.001 | 0.15 |
| 2nd Yellows | -.02 | 0.28 | -2.16 | 0.03 | 0.06 | -.02 | .27 | -2.72 | 0.007 | 0.08 |
| Reds | -.003 | 0.27 | -0.31 | 0.75 | 0.01 | -.005 | 0.25 | -0.69 | 0.49 | 0.02 |
| Penalties | 0.06 | 0.48 | 4.19 | <.001 | 0.12 | 0.03 | 0.53 | 2.23 | 0.03 | 0.06 |

Table 5

Assessment of home advantage before and after the implementation of VAR excluding seasons under COVID-19 restrictions.

| Variable | No VAR | | VAR | | <i>t</i> | <i>p</i> | <i>d</i> |
|------------|----------|-----------|----------|-----------|----------|----------|----------|
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> | | | |
| Goal | .37 | 1.86 | .41 | 1.96 | -.40 | .69 | .02 |
| Points | .50 | 2.57 | .48 | 2.56 | .24 | .81 | .01 |
| Fouls | -.86 | 5.29 | -.59 | 5.11 | -1.30 | .20 | .05 |
| Yellow | -.29 | 1.64 | -.31 | 1.53 | .41 | .68 | .02 |
| 2nd Yellow | -.01 | .27 | -.01 | .26 | .46 | .65 | .02 |
| Reds | <.001 | .26 | -.002 | .27 | .16 | .88 | .01 |
| Penalties | .07 | .52 | .06 | .53 | .85 | .40 | .03 |

implementation of the technical support system. The main findings of our analysis show that overall, the HA exists before the implementation of the VAR (i) with regards to the points won, goals scored, and yellow cards awarded. After the implementation of the VAR, we did not find indications of the HA for any of the tested indicators (see Table 3). However, direct tests (ii) for the difference between these seasons do not yield a significant decline in any of the tested variables (see Table 4) even when controlling for the seasons played under COVID-19 restrictions (see Table 5). Finally (iii), with the VAR, away teams, on average, scored more goals and received fewer yellow cards, while the overall number of fouls decreased for both home and away teams (see Table 2).

For indicators of referee bias, we found that the home teams were sanctioned with significantly fewer yellow cards before the implementation of the VAR. However, the change induced by the implementation of the VAR did not yield a significant change regarding this disbalance. The number of fouls was not disbalanced favoring any team, but reduced overall after the introduction of the VAR (Han et al., 2020). Furthermore, we could not find a statistically significant difference for red cards, 2nd yellow cards, and penalties, which can be explained by their rare occurrence. Previous work has shown that when only considering games including red cards and penalty kicks, a favouring pattern for the home team can be detected (Holder et al., 2021). Interestingly, the total number of penalty kicks and given red cards over a season remained the same, but the referee initially called fewer penalty kicks and awarded fewer direct red cards (Holder et al., 2021). This finding indicates that the referee decides more often to wait for the VAR to intervene than make a wrong decision and be corrected afterward. The tendency to let the game continue without interference from the referees is also shown in the reduced number of offsides since the implementation of the VAR (Oliveira et al., 2021). Instead of awarding the offside as it occurs, the referee waits for the review of the VAR. This decline in the number of offsides can be explained by perceptual limitations (Kolbinger & Lames, 2017) due to the suboptimal positioning of the assistant referee (Oudejans et al., 2000) and the so-called “flash-lag” effect: the tendency to perceive a moving object ahead of its actual position (Helsen et al., 2006).

With the VAR, more goals were scored and fewer fouls and yellow card instances occurred for both the home and away team. These results are in line with other recent studies on the HA (e.g., Meneguete et al., 2022). The players might play more cautiously and provoke fewer ambiguous situations because of the plain existence of the technological assistance (Lago-Peñas et al., 2019). The VAR has the possibility to review situations from many perspectives and is therefore not limited by human perception (Kolbinger & Lames, 2017). The players are aware of this fact and have to be more careful in tackles. This means that future studies should investigate whether some indicators of referee bias actually reflect correct decisions to different playing styles or changing levels of aggression (cf. Buraimo et al., 2010; Hill & Van Yperen, 2021). Yellow cards and fouls do not have a direct effect on the game outcome and do not fall under the responsibility of the VAR but may cause the players to be less aggressive (Lago-Peñas et al., 2019). We can conclude

that the VAR indirectly influences the fair-play of elite soccer, but we cannot prove this statement with our study. Consequently, these findings indicate a first positive influence of the VAR in terms of fair-play. However, these results should be viewed with caution (Strauss et al., 2021). Other studies have shown that the German Bundesliga was an extreme example in terms of the decline in HA and COVID-19 (Bryson et al., 2021). In particular, with regards to the decision-making of the referees, Bryson et al. (2021) found that, across 17 countries, significantly fewer yellow cards were issued to the away teams. However, as Benz and Lopez (2021) point out, generalization based on findings from a single league may not be applicable. Future studies should thus examine the effects found in other soccer leagues. The question remains whether the VAR strengthens the general role of the referee or rather undermines the referee's authority and credibility. Spitz et al. (2020) point out that a high initial decision accuracy is important to limit the number of VAR interventions to ensure the quality of the game. Previous studies pointed out that decision-making at a particular instant is influenced by previous decisions (concession decisions) and prior knowledge (Plessner & Betsch, 2001).

The mentioned research question, whether the introduction of the VAR affects the HA, can therefore not be answered. Even though the data hints at a decrease of the HA and positive effects regarding fair-play, the direct tests for the changes since the implementation of the VAR are not statistically significant. Therefore, we cannot demonstrate that the VAR is the main driving factor for this development. One major limitation of the present study is that we do not analyse the interaction of the VAR with the HA. Further research should examine tactical behavioral changes during seasons and to what extent psychological expectations of important games, at the end of the season for example, affect players and referees (Staufenbiel et al., 2015). Other potential factors such as the added time bias that changes throughout the season (Garicano et al., 2005) and directions of these effects should be examined. One such example is the home advantage model by Bilalić et al. (2021) showing that HA is mediated by team performance and referees' decisions.

In conclusion, in light of the referee bias as a driving force behind the HA, our results indicate that the VAR may contribute to a fairer game. Specifically, we did not find statistical indication for the HA since the VAR has been implemented. However, these results need to be interpreted with caution because direct assessments of the change induced by the introduction of the VAR are not statistically significant. Therefore, we did not find evidence that the introduction of the VAR reduced the referee bias and by extension the HA.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

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