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Home advantage during the COVID-19 pandemic: Analyses of European football leagues

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A R T I C L E I N F O

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A B S T R A C T

The home advantage (HA) is a robust phenomenon in football whereby the home team wins more games and scores more goals than the away team. One explanation is that the home crowd spurs on home team performance and causes the referee to unconsciously favour the home team. The Covid-19 (COVID) pandemic provided a unique opportunity to assess this explanation for HA, as European football leagues played part of the 2019/2020 season with crowds present and concluded with crowds absent. Using multi-level modelling we compared team performance and referee decisions pre-COVID (crowd present) and during-COVID (crowd absent) across 4844 games from 15 leagues in 11 countries. HA (goals scored and points gained) was significantly reduced during-COVID, which reflected the inferior performance of the home team. In games without fans, home teams created significantly fewer attacking opportunities and referee-bias was diluted when controlling for the attacking dominance of teams; such that the number of fouls and yellow cards ruled against away sides, while still significant, was reduced and no effects were observed for red cards. Implications for sporting practice and directions for future research are discussed.

1. Introduction

The home advantage (HA) in sport has been widely recognised for many years. When setting their odds, bookmakers have traditionally placed an emphasis on where the competition will take place (Bookies.com, 2020), and media reports often comment on the difficulties of playing away from home (Pollard & Armatas, 2017). The classic paper by Schwartz and Barsky (1977) is frequently cited as the first empirical investigation of the extent of and reasons for the HA. The scholars conceptualized their predictions within Émile Durkheim's theory of social community and coherence (see Durkheim, 1974), which posits social and group coherence as the alignment and harmonious network of relationships among individuals who share common interests and goals. They suggested that supportive crowds are social representatives of their players and exert an invigorating, motivational influence, encouraging the home side to perform well. Their extensive data collections of home and away results in American major league baseball, professional and college football, ice hockey and college basketball revealed a pronounced home advantage, though the extent for each sport varied. The authors ruled out venue familiarity as a major causal factor, though some later researchers demonstrated moderately reduced HA effects when a team changed its stadium. Instead, social factors were deemed to be critical, such as the fans' proximity to the playing area, and the more constant, loud, and inspiring sounds that come from the crowd, where enthusiastic cheers and chants can inspire entertaining, attacking play and encourage home players to try harder and ultimately win the game (for review, see Pollard, 2008).

The second factor often cited to influence the HA in football is the impact of the crowd upon the people controlling games, otherwise known as the referees. Dosseville et al. (2016) proposed a HA framework that prominently featured the referee. Their conceptualisation notes many studies indicating that referees tend to make more decisions in favour of the home team (see, for example, Boyko et al., 2007; Nevill & Holder, 1999; Pollard, 1986; Sutter & Kocher, 2004) and includes the assertion that officials are highly susceptible to social influence. This is because their role is so challenging and difficult to implement successfully that they unknowingly rely on cues from the crowd when making their decisions. For example, they add more extra time at the end of the first half, and even moreso in the second half, when the home team are behind by a goal; and more decisions against the away team are later found to be incorrect (Dohmen & Sauermann, 2016; Garicano et al., 2005). This 'bias' is found in German, English and Italian football. The

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authors also note that while more experienced referees might be less susceptible to some of these influences by the time they reach expert levels, as they may have developed schemas that lead them to operate under certain expectations (e.g., McCarrick et al., 2020); these might include beliefs that home players will be more assertive and territorial (see, Neave & Wolfson, 2003) and thus will hold an advantage.

However, a key limitation to the aforementioned studies, and one that has been frequently noted by scholars (e.g., Agnew & Carron, 1994; Reade et al., 2020) is that they can rarely investigate playing 'at home' without a crowd in attendance. This is a significant problem given that fans are often cited as the primary factor responsible for HA (see, Pollard & Pollard, 2005). Indeed, never before has an opportunity presented itself to examine the relative influence of crowd/no-crowd conditions on team performance and referee behaviour both within, and across, multiple leagues/countries simultaneously; thus extending on the only known study to examine no-crowd conditions on the HA in a handful of Italian league games when audiences were not permitted due to safety reasons. (Van de Ven, 2011).

The 2020 coronavirus (COVID) outbreak has brought about restrictions banning the mass gathering of people at sporting events due to public health concerns, thus artificially creating a new-found lens through which HA can be investigated independent of fans in stadia. The global transmission of COVID has meant that a good large number of different European countries have prevented fans entering stadia, but at distinct points in time mapping onto the severity of the virus in each country. This therefore provides a unique chance to study the HA further.

One of the first countries to ban mass public gatherings at football matches, Germany, provided early glimpses that HA may indeed be as sensitive to crowd attendance as previously hypothesized by HA theorists. A flurry of papers providing a mixed consensus in regard to HA outcomes were soon released. Some reported that HAwas significantly reduced in games played without fans, and that referees treated home teams significantly less favorably in terms of fouls and cards awarded (e.g. Dilger & Vischer, 2020; Endrich & Gesche, 2020), while others argued that this relationship only emerged in the top divisions of German football (e.g. Fischer & Haucap, 2020). Soon after, and as lockdowns spread throughout the continent, reports from other countries quickly emerged. Bryson, Dolton, Reade, Schreyer, and Singleton (2021) and Reade et al. (2020) delivered the broadest empirical summaries, examining over 16 countries across 23 leagues throughout Europe. Both studies reported large-sized effects for the absence of crowds on referee decisions, with significantly fewer cards being awarded to the away teams. There was also a small but significant decrease in the number of red cards shown to away teams in these studies; however, subtle differences did emerge when considering team performance. Thus, while Reade et al. (2020) reported a significant reduction in the percentage of home wins (43.8% with fans to 41.2% without fans), Bryson et al. (2021) did not report significant effects. However, Schlenker, Phillips, Boniecki, and Schlenker (1995) found fewer points scored at home in Germany and Spain without a crowd but no such effects in Austria, Italy, and England, perhaps suggesting the HA is geographically sensitive. Therefore, while the analyses so far available are consistent regarding the intrusive impact of crowds upon referees, the same cannot be said unequivocally for team-related outcomes. A potential reason for these differing results may, at least in part, be due to the fact that previous studies did not consider a number of significant additional factors that are likely to influence the relationship between the removal of fans from stadia and HA outcomes. First, a team's playing style is likely to determine their chances of scoring goals and thus their likelihood of winning the game. This is significant considering that Schwartz and Barsky (1977) noted a team's offensive play, in particular, is exclusively related to performances by the home side; but this factor has only ever (see Pollard, 2008), been examined in regard to direct attempts to win a game (i.e., shots, shots on target, penalties) and has omitted other indirect efforts (i.e., possession, corner kicks, free kicks) that are known to be significant determinants of game outcomes (Goumas, 2013). This suggests the degree to which a team 'dominates' a game through its playing style is especially worthy of further explanation. Second, an objective understanding of how the home team's strength (relative to the opposition and within league merit positions) and the difficulty of their fixture schedule in terms of the opposition they face may impact the effects observed for HA, is missing from the literature. This is important as the quality of opposition a team faces is indicative of their likelihood of winning (Peeters & van Ours, 2020), and more skilled sides may well rely less on their crowds' support than their less-skilled counterparts. Third, the impact of unmeasured confounds has also not been fully considered, and while a number do exist which we cannot control for in this study (e.g., COVID infections, country-level heterogeneity in response to the pandemic, differences in training schedules, etc.), multilevel models whereby the individual matches, played home and away, are nested within individual teams, do provide some remedy in allowing us to assess the relative contribution of specific variables on performance and referee-related outcomes.

Following its suspension due to the COVID-19 pandemic, the 2019–2020 European football season resumed with approximately a quarter of games to be played 'behind closed doors.' This provided a unique opportunity to observe a naturalistic manipulation wherein differences could be analyzed between games with and without the presence of an audience on player and referee performance. This random (and unexpected) situation has manufactured a situation that has sparked an array of new and important research on the topic. However, here, across a large sample of games (N = 4844), we extend this work to consider a broader range of previously unexamined, yet important, variables (i.e., team/strength dominance, team playing style, playing schedule) that are likely to influence the relationship between removal of fans from games across 15 European leagues and HA outcomes.

Accordingly, we assessed all games from every European league that continued their respective seasons following COVID-19 suspensions on measures relating to HA both before and during the suspension, in addition to its effects on referee decisions. In line with the aforementioned literature, we predict that: A) HA will be significantly reduced within the final quarter of games played without a crowd (i.e., home teams will win significantly fewer games, as measured via points accrued and goals scored); B) referee decisions (in the form of fouls, yellow cards & red cards) will favour the home team during the games played with a crowd, such that the effects for each will be significantly reduced within games played without a crowd; and C) despite some games in Denmark, Russia, and Switzerland incorporating a small number of spectators (at various points in their 'during-COVID' periods), these will not statistically influence hypotheses A and B (reported in online supplement 1; OSM 1 Section 1).

2. Method

The present study was pre-registered via the Open Science Framework which can be viewed, along with the data used for the analysis, via the following DOI: https://osf.io/4hu8r/?view_only=1176423f8b594ddbb0d93b5c45856557 (blinded for review).

2.1. Data

All European leagues that finished the 2019/20 season without an audience were included in the analysis. Altogether, we analyzed 4844 individual games from 15 different leagues spanning 11 different countries (England Premier League & Championship, Germany Bundesliga 1 &2, Spanish La Liga 1 & 2, Italian Serie A & B, Portuguese Primeira Liga, Greek Super League, Turkish Super Lig, Austrian Bundesliga, Danish Superligaen, Russian Premier League and Swiss Super League). In total, 3515 games (72.56%) were played with the presence of the audience (pre-COVID) and 1329 (27.44%) in the during-COVID period without an audience. Data for each individual league can be seen in Table 1.

The data on the individual games were obtained fromthe football dat a website (https://www.football-data.co.uk/data.php). These include the scores, goals for each team, shots, shots on target, corners, fouls, as well as yellow and red cards for each individual game. These data were supplemented with the 'FiveThirtyEight' database, which also included team ratings (Football Power Index, SPI) and the importance of the match for both teams, based on their respective league ranking. More information on the FiveThirtyEight database can be found at(https://fivethirtyeight.com/methodology/how-our-club-soccer-predictions-work/).

The data on team performance (points, goals, corners, shots, and shots on target) were available for all leagues in the databases we used, but the data for referee performance (fouls, yellow and red cards) were available for 11 out of 15 leagues (exceptions being Austria, Denmark, Turkey, Russia & Switzerland). We excluded any play-off games across leagues as these are subject to different playing conditions (i.e. over two legs; away goals; extra time) to maximize the internal validity of the results. Data across both databases were first extracted before being independently checked in view of accuracy (Cohen's Kappa = 1).

2.2. Analysis

We focused on two aspects of the data, one related to the outcome of the game, the other associated with the performance of the referees. The outcome of the game was associated with the points won, goals scored, as well as other indicators of dominance such as number of corners, shots, and shots on target (Hypothesis A). Referees' decisions were measured by the number of fouls given, as well as the number of official warnings (yellow and red cards) (Hypothesis B). Further, as a small number of games in three countries (Denmark, Switzerland, and Russia) involved spectators during their during-COVID period, we conducted extra sensitivity analyses in which these countries were separately (and then collectively) removed to detect if these games meaningfully influenced our conclusions (Hypothesis C). These latter set of analyses are reported in OSM 1, Section 1. The entire analysis, including data preliminaries and all modelling, can be found in OSM 2.

HA reflected in team performance (points, goals, and dominance). The common way of quantifying the HA is to express the number of points (or goals) won at home as a percentage of the total number of points (goals) won, home and away (Pollard, 1986). This method has been previously validated (see Goumas, 2013) and works well with a full season of play where teams face each other at home and away. In the current context, where we wanted to compare the (approximate) first three quarters of the season played with the crowd present with the last quarter played without a crowd, it is of crucial importance to account for the schedule difficulty. Some teams may have had a much easier home schedule in the during-COVID period (playing without an audience) than in pre-COVID period (playing with an audience), which would bias the home advantage comparison between the two periods.

The possibility of adding confounding factors in our analysis is one of the reasons why we decided to use multilevel modelling (also known as mixed-effects, Wood, 2006) where the individual matches, played home and away, are nested within individual teams. Multilevel modelling is a regression approach which not only uses individual teams[1] as basic units with home and away games nested within them, but also allows for inclusion of additional factors, including possible confounds. In our particular case, we are interested in the factors Venue (home and away) and COVID period (pre and during), and most importantly, their interaction. If the HA is influenced by the audience presence, we would expect that teams win fewer points and score fewer goals at home compared to away games in the during-COVID period than in the pre-COVID period. In other words, our main interest is the interaction between Venue and COVID factors.

To control for possible differences in the pre- and during-COVID schedule and importance of the games, we used the strength of individual teams and the game importance for individual teams. FiveThirtyEight's team strength rating (SPI) includes teams' previous results and market values of players. It is updated after each game based not only on the actual results and goals scored, but also on other indicators to account for randomness of a low scoring game such as football (e.g., adjusted goals, shot-based expected goals and non-shot expected goals).

FiveThirtyEight's importance measures quantifies the impact of the match results on the team's outlook on the season. The importance is dependent on the team, as different teams play for the championship, qualification for international UEFA competitions, or not getting relegated. Similarly, the importance measure takes the situation in the individual league into account as the probabilities of achieving a team's goal are calculated depending on the outcome of the game. The difference between the probabilities is then expressed as a standardized variable. Both rating and importance measures range from 0 to 100 and are comparable not only within a single league, but also across the leagues. In our analysis we calculated the difference between both teams in rating and importance, standardized the difference (where mean is zero and standard deviation one, making the differences more interpretable), and included them as covariates in the multilevel models. As discussed earlier, we were particularly interested in their interactions with Venue and COVID period factors, as significant results would then indicate vastly differing schedules for pre- and during-COVID periods.

Although individual teams are the basic units in our analysis, they are also nested within country and division. We therefore included country and division as additional covariates of interest in our model. We do not expect, however, to find meaningful patterns between leagues and/or countries as the during-COVID period includes a small amount of data within a single league. That is also the reason why we use individual teams across the whole of Europe as single units for our multilevel level analysis and do not analyse the individual teams within a single country. Given the sparse nature of the during-COVID data, one can expect significant variation within a single country. However, the inclusion of all 15 leagues both produces considerably more data where the real underlying mechanisms are easier to detect and, given the homogeneous nature and operating conditions of the sample (i.e., elite athletes playing under the same football laws), it is doubtful that even if data were available few differences would either arise or be statistically detectable between leagues due to power issues (see, Cohen, 1992; Mooijaart, 2003). We do, however, provide the descriptive statistics for each league in Table 1 in addition to visual summaries for the top four European leagues (see, OSM 1, section 4). Figures for all leagues can be sourced via the manuscripts Open Science Framework page.

The final analysis used all individual games, where each game was coded twice, once from the perspective of the home team, and once from the perspective of the away team. The variables included in the multilevel models were Venue (home and away), COVID period (pre and during), rating difference (standardized difference of SPI ratings), importance difference (standardized difference of importance ratings), country (one of the 11 countries), and division (1st or 2nd division). The same model was run separately for points and goals. Since the dependent variables are discrete occurrences which are rarely normally distributed, we used Poisson distribution for the modelling (for similar approaches, see Goumas, 2013). In addition, as an extra safeguard, we also ran a model with linear terms (in addition to Poisson) for points, given they are sometimes considered an ordered ordinal variable (See OSM 1, Table 1). As an additional safeguard to the way in which random-effects

[1] Random parts in the models explained considerable amount of variance (see, ICC rows in Table 2 & 3). In some models, however, the random effects were not explaining additional variance (e.g., points). We provide the alternative version without the random parts of all models in OSM 2. As can be seen, the pattern of results is virtually identical.

Table 1
Sample descriptive statistics across European leagues pre-during COVID intervention.

League	Pre-COVID (with crowd)								During-COVID (no crowd)							
	Games	% home wins	Mean No. Points/goals		Mean No. Referee decisions committed a game			Percent played	Games	% home wins	Mean No. Points/goals		Mean No. Referee decisions committed a game			Percent played
			H	A	Fouls (H/A)	Yellow (H/A)	Red (H/A)				H	A	Fouls (H/A)	Yellow (H/A)	Red (H/A)	
England I	288	45%	1.59	1.16	10.32	1.57	0.06	76%	92	47%	1.62	1.16	11.12	1.44	0.06	24%
			1.51	1.22	10.89	1.81	0.06				1.54	1.17	11.24	1.59	0.06	
England	444	43%	1.55	1.16	11.59	1.49	0.04	80%	108	38%	1.38	1.38	12.74	1.35	0.06	20%
II			1.43	1.21	12.71	1.94	0.07				1.34	1.29	12.67	1.42	0.08	
Germany	223	43%	1.51	1.27	11.01	1.78	0.06	73%	83	33%	1.20	1.57	12.62	2.12	0.09	27%
I			1.74	1.51	11.62	2.17	0.12				1.42	1.66	11.51	1.91	0.09	
Germany	223	42%	1.57	1.12	12.03	1.83	0.12	73%	83	42%	1.58	1.07	13.59	2.25	0.04	27%
II			1.55	1.29	12.62	2.26	0.12				1.65	1.32	12.72	1.95	0.12	
Spain I	270	48%	1.71	1.01	13.68	2.59	0.09	71%	110	41%	1.50	1.22	13.71	2.49	0.12	29%
			1.51	1.03	14.02	2.76	0.13				1.26	1.07	13.29	2.19	0.11	
Spain II	340	39%	1.54	1.10	15.69	2.62	0.14	74%	121	44%	1.62	1.11	15.63	2.71	0.15	26%
			1.28	1.03	15.89	2.88	0.18				1.26	0.98	15.28	2.53	0.16	
Italy I	256	40%	1.43	1.34	13.76	2.55	0.13	67%	124	44%	1.55	1.23	13.69	2.22	0.11	33%
			1.54	1.38	14.29	2.89	0.16				1.80	1.49	13.03	2.14	0.09	
Italy II	279	46%	1.64	1.09	15.47	2.48	0.16	74%	101	42%	1.51	1.22	15.49	2.47	0.18	26%
			1.42	1.06	16.12	2.75	0.20				1.36	1.23	15.54	2.47	0.13	
Portugal	216	40%	1.45	1.29	15.53	2.40	0.11	71%	90	44%	1.59	1.16	17.28	2.68	0.20	29%
			1.28	1.13	15.61	2.78	0.14				1.50	1.17	16.69	2.25	0.14	
Greece	182	48%	1.71	1.02	15.78	2.48	0.10	76%	58	33%	1.36	1.24	16.12	2.58	0.15	24%
			1.51	0.93	16.55	2.97	0.20				1.16	0.97	16.63	3.13	0.09	
Turkey	234	43%	1.58	1.15	13.71	2.38	0.15	76%	72	46%	1.61	1.15	13.47	2.38	0.14	24%
			1.61	1.21	13.59	2.62	0.18				1.62	1.37	13.19	2.18	0.16	
Austria	132	36%	1.32	1.43	N/A	N/A	N/A	68%	63	30%	1.13	1.65	N/A	N/A	N/A	32%
			1.77	1.69							1.30	1.77				
Denmark	167	49%	1.68	1.11	N/A	N/A	N/A	70%	75	39%	1.43	1.31	N/A	N/A	N/A	30%
			1.56	1.24							1.48	1.29				
Russia	176	37%	1.38	1.36	N/A	N/A	N/A	73%	64	34%	1.31	1.41	N/A	N/A	N/A	27%
			1.28	1.10							1.30	1.27				
Swiss	170	42%	1.59	1.38	N/A	N/A	N/A	50%	170	42%	1.36	1.16	N/A	N/A	N/A	50%
			1.65	1.51							1.21	1.36				
Total	3515	43%	1.55	1.20	13.50	1.19	0.11	73%	1329	41%	1.45	1.27	14.13	1.20	0.13	27%
			1.51	1.23	14.23	1.57	0.14				1.42	1.29	13.83	1.39	0.15	

Note: Means in the total column are un-weighted, unlike those presented in the below figures which are weighted based on sample size; I refers to the 'top' league in that country, while II refers to the second league, e.g. in the UK I refers to the Premier League, and II refers to the Championship; No. Refers to number of games; 'H' represents home teams, 'A' represents away; 'Rounds' refers to N games played for each time in that respective league; NA reflects data that was not available for that league/country.

multi-level models deal with clustering of standard errors (see, Primo et al., 2007), we also ran models (and calculated standard errors) at match-level for both team and referee outcomes (see OSM 1, section 3).

The same multilevel models were run for the indicators of team dominance: corners, shots, and shots on target. These dependent variables were, however, normally distributed, and we consequently utilized the Gaussian distribution in our models. Given that all three predictors of dominance are highly related (correlations 0.50–0.90), we created a single 'Dominance' factor by conducting factor analysis on the three predictors. The latent factor of Dominance is thus a standardized single measure of attacking tendencies of the team, which can be used as an indicator for how much the team dominates the game. The factor analysis was conducted separately for each league, as the dominance indicators may vary greatly from league to league. Note that the Dominance latent factor based on the all available data was highly correlated with the Dominance latent factor that accounted for individual league - 0.98. Consequently, the pattern of results in our main analyses was independent of the way the Dominance factor was calculated.

HA reflected in referees' performance (fouls, yellow and red cards). We applied the same multilevel Poisson model to the number of yellow and red cards while a linear multilevel model was used for the number of fouls. In addition to the already mentioned covariates (e.g., team strength, match importance, country, and division), we also accounted for attacking tendencies by adding the latent factor of Dominance (e.g. corners, shots, and shots on target). It is known that the more dominant a team is, the more it is going to get fouled and earn yellow and red cards for the opposing team (Goumas, 2014a).

2.3. Effect size calculations

Almost all of our variables of interest feature meaningful and easily understandable metrics – points, goals, fouls, yellow and red cards. We provide incident rate ratios (IRR), instead of raw estimates (which indicate the difference in the logs of expected counts per unit), for all Poisson-based models (e.g. points, goals, yellow and red cars) to facilitate their interpretation. For example, in Table 2, for the Points model, the IRR for Venue is 0.74. This means that the away team wins 0.74 times fewer points per game than the home team (home team is coded as 0, the reference point, and away team as 1 in the model – see the note in Table 2). In other words, for every point a home teams wins, the away team wins 0.74, holding all other variables constant. Similarly, in the same model the IRR for the interaction between Venue and COVID is 1.12, which means that away teams during the COVID period gain 0.12 points per game compared to the same away teams in the pre-COVID period (pre-COVID period is the reference point, 0, here, while the during-COVID period is coded as 1 – see the note in Table 2). Therefore, the differences between home and away teams are 1.12 smaller (or 0.12 points per full point) in the during-COVID period than in the pre-COVID period.

We also leave the raw values in the model for Fouls (Table 3), where the estimates refer to the number of fouls. For example, 0.35 coefficient

Table 2
Regression models for points gained, goals and dominance across European football leagues in 2019/20 season with and without an audience.

_	Points			Goals			Dominance		
Predictors	*IRR*	*SE*	*p*	*IRR*	*SE*	*p*	*std. β*	*SE*	*p*
(Intercept)	1.51	0.01	< **.001**	1.43	0.02	< **.001**	0.28	0.02	< **.001**
Venue (away)	0.74	0.02	< **.001**	0.81	0.02	< **.001**	−0.52	0.02	< **.001**
COVID period (during)	0.95	0.03	**.036**	0.97	0.03	.234	−0.27	0.03	< **.001**
Rating difference	1.30	0.01	< **.001**	1.24	0.01	< **.001**	0.41	0.02	< **.001**
Importance difference	1.05	0.01	< **.001**	1.03	0.01	**.001**	0.04	0.01	**.001**
Venue (away) * COVID (during)	1.12	0.04	**.004**	1.10	0.04	**.017**	0.33	0.04	< **.001**
Venue (away) * Rating difference	1.07	0.02	< **.001**				−0.06	0.02	**.004**
Rating difference * Importance difference	0.97	0.01	< **.001**				0.02	0.01	**.018**
Random Effects									
σ^2	0.56			0.57			0.77		
τ_{00}	0.00 Team			0.01 Team			0.03 Team		
ICC	0.00			0.02			0.04		
N	264 Team			264 Team			213 Team		
Marginal R^2/Conditional R^2	0.182/0.183			0.096/0.118			0.198/0.227		

Note. IRR=Incident Rate Ratios; Venue is coded 0 for Home and 1 for Away; COVID is coded as 0 for pre-COVID and 1 for during COVID.

Table 3
Regression models for referees' decisions. Fouls, yellow, and red cards across European football leagues in 2019/20 season.

	Fouls			Yellow			Red		
Predictors	*Estimates*	*SE*	*p*	*IRR*	*SE*	*p*	*IRR*	*SE*	*p*
(Intercept)	13.61	0.17	< **.001**	2.16	0.02	< **.001**	0.10	0.06	< **.001**
Venue (away)	0.35	0.10	**.001**	1.13	0.02	< **.001**	1.15	0.08	.070
COVID period (during)	0.48	0.14	**.001**	1.00	0.02	.928	1.06	0.11	.606
Dominance	−0.34	0.05	< **.001**	0.95	0.01	< **.001**	0.73	0.04	< **.001**
Rating difference	0.23	0.08	**.005**	0.94	0.01	< **.001**	1.08	0.04	.056
Importance difference	−0.08	0.05	.146						
Venue (away) * COVID (during)	−0.70	0.20	< **.001**	0.83	0.03	< **.001**	0.77	0.15	.086
Rating difference * Importance difference	−0.16	0.04	< **.001**						
Venue * Rating difference	0.30	0.09	**.001**	1.07	0.02	< **.001**			
Random Effects									
σ^2	14.61			0.37			2.29		
τ_{00}	4.70 Team			0.04 Team			0.11 Team		
ICC	0.24			0.10			0.05		
N	212 Team			212 Team			212 Team		
Marginal R^2/Conditional R^2	0.014/0.254			0.025/0.127			0.040/0.085		

Note. IRR=Incident Rate Ratios; Venue is coded 0 for Home and 1 for Away; COVID is coded as 0 for pre-COVID and 1 for during COVID.

for the Venue variable means that the away team on average commits 0.35 more fouls than the home side. The interaction between Venue and COVID, −0.70, also gives a precise information on how many fouls fewer the away teams are committing during the COVID period, compared to the pre-COVID period. Here we also provide the standardized coefficient, β, in the main text.

Finally, our variable Dominance is a latent factor which is already standardized. This means that the estimates already represent the standardized estimates rather than raw values (see Table 2).

3. Results

3.1. Team performance (points and goals)

Teams gained more points during home than away games, but the difference was less marked in the period without an audience (Figure 1A). Pre-COVID, teams won on average 0.39 points per game more at home than away, but this HA was almost halved in the period without the audience - the teams won only 0.22 points more at home than away. Home teams were scoring more goals than away teams in general, but this advantage was greatly reduced when the audience was absent. The home teams scored on average 0.29 goals more per game than away teams in normal circumstances when the audience was present. The same home teams scored only 0.15 goals more than the visitors when the audience was absent (see Figure 1B).

A formal multilevel regression model confirmed that the Venue x Covid-Period was highly significant (see Table 2). The effect of an audience on HA was not driven by the difference in the schedule, or differing importance between home and away teams in the pre and during-COVID period. The stronger teams and the teams with more to play for won more points, but this was constant for home and away matches, as well as for the periods with and without an audience (see Table 2).

We found the same pattern of results when we looked at the goals instead of points (see Figure 1B). Home teams were scoring more goals than away teams in general, but this advantage was greatly reduced when the audience was absent. The home teams scored on average 0.29 goals more per game than away teams in normal circumstances when the audience was present. The same home teams scored only 0.15 goals more than the visitors when the audience was absent.

As with the goals, this interaction was highly significant in our formal regression model (Venue × Covid interaction, see Table 2). Both ratings and importance were positive predictors of the goals scored, but there were no significant interactions either with venue or Covid period (see Table 2). In other words, the effect of audience on HA was not influenced by differing schedules in the pre- and during-COVID periods.

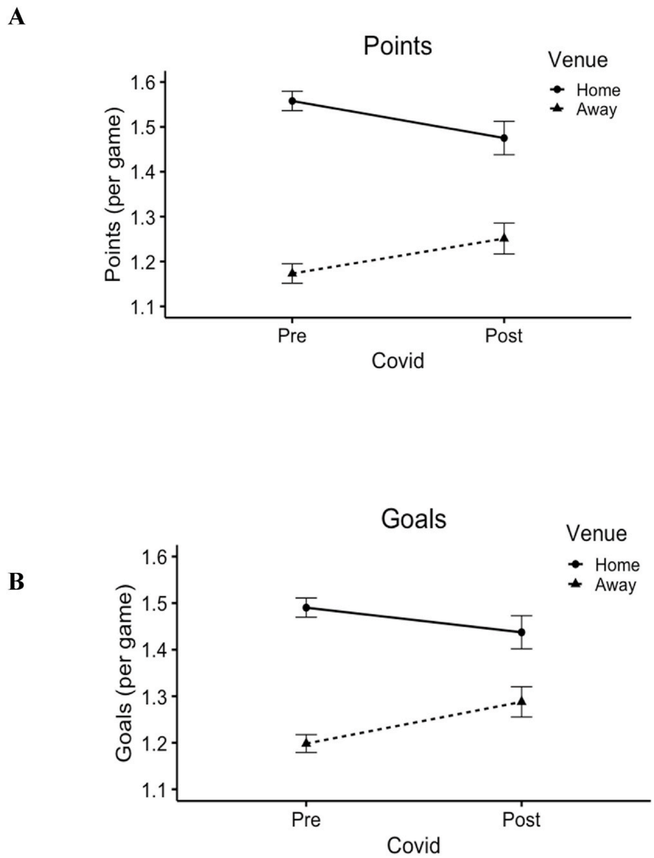

Figure 1. Home advantage. Points and goals across European football leagues in 2019/20 season with and without an audience.

We also checked more detailed indicators of game dominance such as number of corners, shots, shots on target, as well as standardized latent factor of these three indicators, called Dominance. Figure 2 confirms the trend of the wavering dominance of the home teams playing without the support of their fans. When playing without an audience, the home teams won on average per game 0.7 fewer corners, had 1.3 fewer shot attempts, and 0.4 fewer of their shots were on target. Overall, home team dominance (as measured by a standardized latent factor of corners, shots, and shots on target) was 0.24 standard deviation smaller. The away teams, in contrast, were close to their performance in the pre-COVID period played in front of fans - only 0.10 more corners, 0.17 more shots, and 0.20 more shots on target. The overall dominance of away teams improved for only 0.05 standard deviation. The extent of the decrease in home team performance for some parameters is more than tenfold compared to the away team improvement.

The multilevel regression on these indicators confirmed the negative effect of the absence of audience on the home team performance (see, Venue × COVID interactions in Table 2). Notably, the interaction for dominance revealed a significant, and medium-sized, effect for its impact on the HA ($\beta = 0.30$, $SE = 0.04$, $p < .001$, $ICC = 0.31$) and, more importantly due to their wider implications on sporting success, the difference in rating and importance (both important and significant factors on their own) were not related to audience - venue interaction (see Table 3). We can therefore be confident that the diminishing performance of the home teams without their fans is not a consequence of the unbalanced schedules in the pre and during-COVID periods.

Referees' Decisions (fouls, yellow and red cards).

Our data extend previous findings that the audience influences referees' decisions. Figure 3 shows that overall the home team received fewer yellow/red cards and fouls, but this is more pronounced when an audience is present. In the during-COVID period without an audience, there were virtually no differences in the yellow and red cards between home and away teams while a small difference was present in the number of fouls.

A closer look at the data pattern shows that the referees gave more fouls against the home team when the audience was absent, while the number of fouls against the away side remained similar. However, the yellow cards data shows that these fouls were differently judged depending on the presence of the audience. The away team was penalized far less for fouls when the audience was absent, whereas the home team, although fouling more, received similar amounts of warnings. The most drastic punishment, a red card, followed the same pattern, but the differences were less pronounced. The away team was indeed less often on the receiving end of a red card when the game was played without the

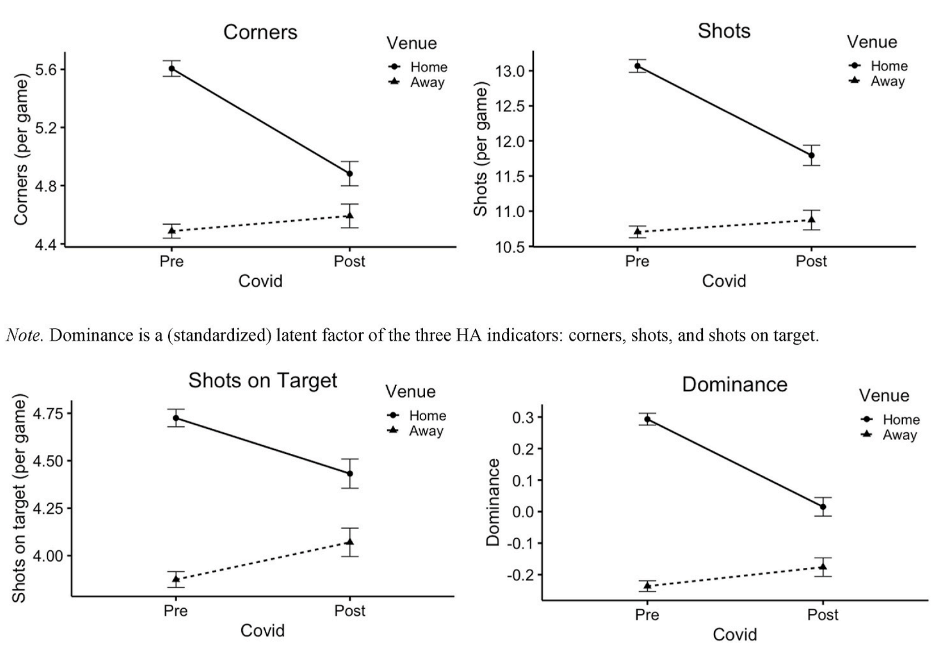

Figure 2. Home advantage indicators. Corners, shots, and shots on target across European football leagues in 2019/20 with and without an audience.
Note. Dominance is a (standardized) latent factor of the three HA indicators: corners, shots, and shots on target.

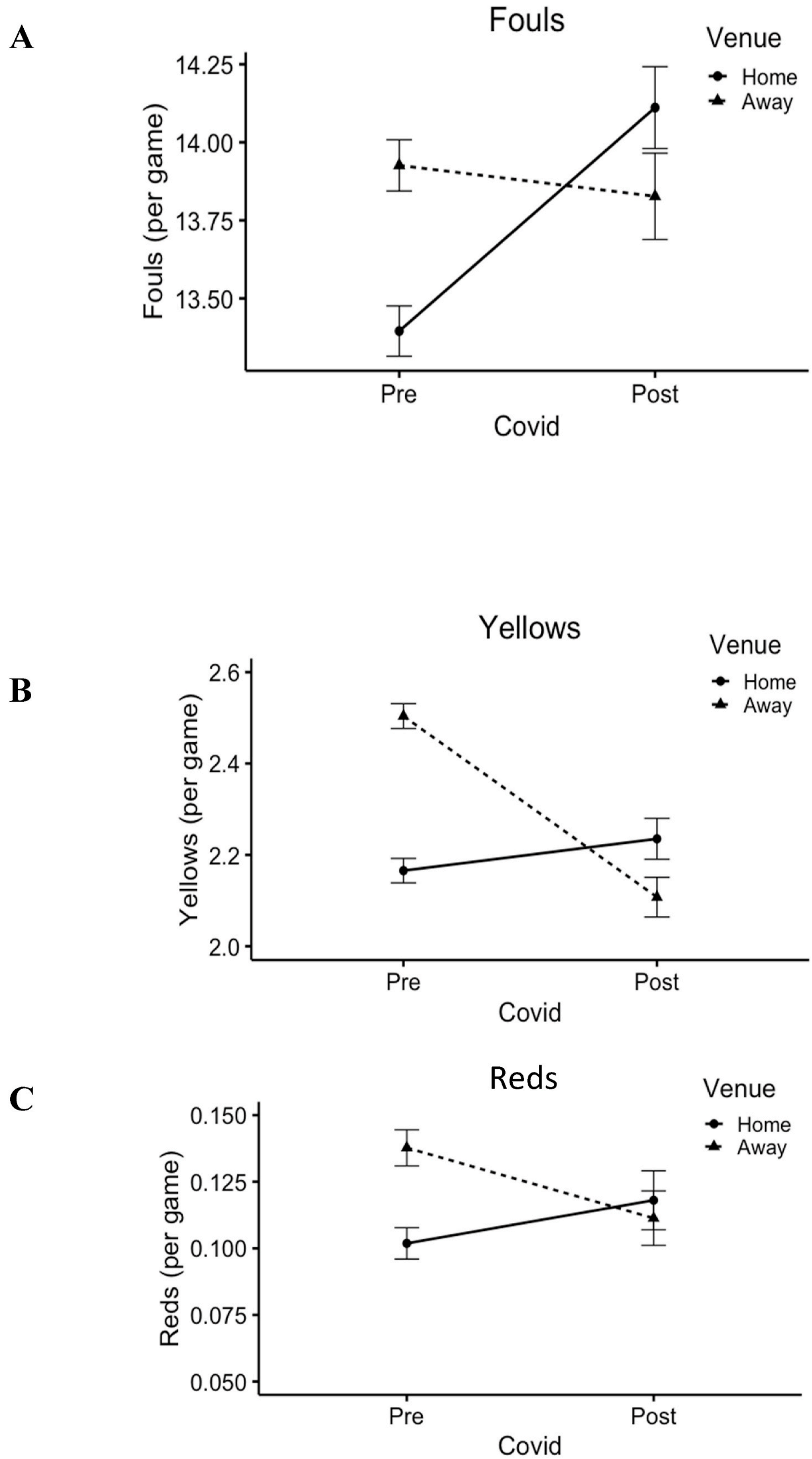

Figure 3. Referees' decisions. Fouls, yellow, and red cards across European football leagues with and without an audience during 2019/2020.

audience, but the home teams were penalized more often without the support of their home fans (see Figure 3).

Multilevel regression analyses with fouls, yellow and red cards as dependent variables and venue (home-away) and audience (pre- and during-COVID) as predictors confirmed the descriptive results (see Table 3). The interactions between venue and audience revealed significant effects for fouls (std. $\beta = -0.16$), yellow cards, and red cards. Importantly, the differences in the rating and importance between the teams were not significantly related to the referees' decisions. and there were no interactions with Venue or COVID periods (see Table 3).

Given the above results, one could think that the presence of the fans biases referees' decisions against the visiting team. The above analyses do not, however, account for the attacking tendencies of teams. Passive teams, which are content to defend as indicated by low number of shots on goal and corners, tend to foul more and receive more warnings as they try to fend off a more dominant team. The referees' decisions could, therefore, simply be a consequence of teams' attacking tendencies. Given that the dominance of the home teams decreases considerably without the support of their fans (see Figure 2), it is of paramount importance to account for this factor before we conclude that the referees are influenced by the audience. Indeed, when we include the variable 'dominance' in the multilevel regression models, the referees' decisions were much less influenced by the audience presence and where the game was taking place. The interaction between Venue and COVID period was no longer significant for red cards (IRR = 0.77, SE = 0.15, $p = .086$), while the same interaction for yellow cards (IRR = 0.83, SE = 0.03, $p < .001$) and fouls (Est. = −0.70, SE = 0.20, $p < .001$, *std.* $\beta = -0.16$) remained significant but effect-sizes were weakened (see Table 3). Together, these referee-specific analyses show referee bias is indeed an important factor in HA but its role is sensitive to context, as demonstrated when accounting for team dominance.

4. Discussion

The 2020 COVID-19 pandemic provided a unique opportunity to explore some of the key factors which are thought to make a significant contribution to the HA in sport. In European football leagues, we examined how two factors - crowd influence on the teams and crowd influence on referee decision-making - compared as a result of teams playing the majority of their season with crowds present and the remainder of the seasons with crowds absent. For team performance, our data clearly showed that when controlling for factors such as country, league, schedule, and team quality, the effect of playing in virtually empty stadia had a significant negative impact on the typical home team performance. However, for referees' decision-making processes this was more intricate; such that while the number of fouls and yellow cards ruled against away sides remained significant, it was reduced in games without an audience, and no effects were observed for red cards.

While traditional research on the HA (e.g., Agnew & Carron, 1994; Courneya & Carron, 1992; Goumas, 2014b; Nevill et al., 2005) as well as some recent reports (e.g., Reade et al., 2020; Scoppa, 2021) share the broad view that home team performance benefits from a home crowd, the discussion around the degree to which this influences performance outcomes for European teams (such as goals scored and points accrued) following the COVID lockdowns is somewhat convoluted. A likely reason for this is because of the variety in study designs employed by authors (e.g., pre-during COVID; number of leagues included; number of years HA effects are examined over). For example, Bryson et al. (2021) found that the absence of a crowd had no significant effect on the final score, whereas Schlenker et al. (1995) reported significantly fewer points gained at home in Germany and Spain without the support of a crowd, but that no such effects existed in Austria, Italy, and England. Wunderlich (2021) goes as far to conclude that the HApersists in the absence of crowds; although these findings may be of direct consequence to the substantial heterogeneity brought about via comparing games in the last season against those up to 10 years ago. On the other hand, both Schlenker, Phillips, Boniecki, and Schlenker (1995), Tilp and Thaller (2020) and Hill and Van Yperen (2021) assert that HA is heavily reliant on the presence of fans, as points, goals and shots at goal, were significantly reduced for home teams in the during-COVID period. Crucially, the results of the present study reinforce the long-held view that the HA is an important factor which boosts the odds of the home team coming out victorious in games, and are in accordance with the latter of these findings. Our data show that while there is (some) HA effect during-COVID, it is almost halved compared to the one existing pre-COVID, and that this statistic alone should be the take home message for scholars examining the HA and the COVID-19 pandemic.

We find points per game, goals per game and team dominance (see Figures 1A, 1B, and 2) were all significantly reduced in the home teams compared to the away teams (who performed similarly in the presence or absence of a crowd); even when controlling for some leagues (i.e., Denmark, Swiss & Russia) which included some spectators in their during-COVID period. For example, pre-COVID, teams won on average 0.39 points per game more at home than away, but this HA was almost halved in the period without the audience; such that the teams won only 0.22 points more at home than away. So, while the HA is present in games played without fans, its impact is reduced by nearly 50% relative to games where fans are present. On a theoretical level, our data are also consistent with the theory of social community and coherence (see Durkheim, 1974), which posits that social and group coherence is the harmonious order in which a network of relationships among individuals is responsible for the attainment of group-based goals. As observed in our data, it would follow that the absence of loyal crowds in the during-COVID period would adversely impact home teams, who no longer benefit from the invigorating and motivational influence of their supporters in the pre-COVID games.

The results for referee performance were more complex. Our initial analysis revealed that referees were indeed influenced by the absence of large crowds, penalising the away team less (awarding fewer yellow and red cards) when the home fans were absent. Broadly, these are in accord with both the traditional HAliterature, which emphasizes the valuable presence the home crowd can have on referee related outcomes for home teams (such as punishing the away team more frequently, e.g., Dohmen, 2008; Dohmen & Sauermann, 2016; Nevill et al., 2002), as well as more recent outlets showing that referees award significantly fewer punishments (in the form of fouls and cards awarded) against away teams in games played without an audience. For example, Bryson et al. (2021) found significantly fewer yellow cards were issued to the away team in the 23% of matches played without an audience. Schlenker et al. (1995) also found that referees in five European leagues (England, Germany, Italy, Spain and Portugal) favoured the home team less without an audience with regard to fouls, yellow and red cards, and penalties. Analyses of German Bundesliga divisions by Endrich and Gesche (2020) and Tilp and Thaller (2020) showed that the home team was treated less favorably in relation to fouls and cards awarded without fans, compared to games played with fans present.

However, and importantly, our formal tests of statistical inference revealed that team dominance (i.e., whether a team was more 'attack' or 'defence' minded) was a key factor in these effects. Indeed, when we controlled for this in games played without fans, the impact of the HA on referee bias was diluted such that, while still statistically significant, the number of fouls and yellow cards ruled against away sides was reduced and significant effects for red cards were no longer present. This novel finding casts new light on the well examined relationship between the presence of fans and referee decision-making within the HA literature (see Pollard, 2008) via suggesting that within-game context plays a more profound role than perhaps previously noted. Contrary to some former findings which suggest referee-bias is a hallmark of the HA phenomenon (e.g., Benz & Lopez, 2020; Boyko et al., 2007; Bryson et al., 2021; Cueva, 2020; Dohmen, 2008; Dosseville et al., 2016; Endrich & Gesche, 2020; Scoppa, 2021), our findings reveal that referees' decisions are likely a consequence of a team's attacking tendencies. In fact, closer inspection of the COVID-related studies (i.e., Reade et al., 2020, Bryson et al., 2021; Scoppa, 2021) reveals large-sized effects for yellow cards and small-sized effects for red cards (as in our original analysis, without dominance). Thus, we propose that had this factor been considered in previous reports, keeping in mind their often smaller samples (e.g., Dilger & Vischer, 2020; Haucap & Fischer, 2020), the associated effects observed would have been likely reduced, if not rendered non-significant, as was the case in our larger analysis.

While the exact causal mechanism is unclear, we expect this is because passive teams, which are content to defend (as indicated by low number of shots on goal and corners), tend to foul more and receive more warnings in an attempt to fend off their more dominant opponents. This would therefore suggest referee behaviours are reactive in nature and simply reflect the circumstances presented before them, rather than being subconsciously loaded with intentions to favour the home side in the presence of a crowd as previously hypothesized (Dohmen, 2008; Nevill et al., 2002; Nevill & Holder, 1999). Therefore, while these findings broadly support the view that referees are implicated in the HA, we propose that more work is required to understand the degree to which the crowd (rather than the players and in-game context) is responsible for seemingly biasing decisions in favour of the home side. Chiefly, it is of primary concern to comprehend the objectivity of referees' decisions within the framework of the HA; future studies should aim to go beyond the descriptive reporting of fouls, yellow cards and red cards and account for whether these decisions are deemed correct by football governing bodies.

Another potential factor to consider is that we were comparing games at the beginning and middle of the season with those at the end of the season, when key outcomes are much more likely to be relevant to the teams (e.g., promotion, relegation and final placings). Even so, our results provide little evidence to support this assumption often made by the games' community. The effect of an audience on HA was indeed not driven by the difference in the schedule, or differing importance between home and away teams in both the pre and during-COVID period. We can therefore be quite certain that the diminishing performance of the home teams without their fans is not a consequence of the unbalanced schedules in the pre and during-COVID periods. Equally, for these analyses, the strength of teams was not related to the presence of a crowd in the during-COVID period. The stronger teams and the teams with more to play for won more points, but this was constant for home and away matches, as well as for the periods with and without an audience. Thus, our data suggest the relative strength of teams (i.e., their previous results, market values of players, expected goal-scoring opportunities) is not a significant determinant of the HA. This finding has several implications pertinent to footballing stakeholders, namely how team coaches and players may use these findings in the build-up to games. Knowing that the home side's likelihood of winning is reduced without the support of their crowd is an important tactic for away teams to remember, which may result in teams attacking early in the game to put their opponents on the 'back-foot' in the knowledge that their crowd cannot spur them on to 'bounce-back' Equally, teams being aware that the attacking dominance of their opponents is directly related to how many fouls they ae likely to commit is an important message, as coaches may wish to implement tactics or set out interventions for their players to take on board.

We acknowledge that there are some limitations to this study, such as that there may be other variables which we were unable to control for which might have influenced these results, such as changes in teams training schedules, more fixtures to be played, or the impact of national lockdowns pausing play. Notwithstanding this, we affirm that this was the case for both teams; our data are so broad, and conclusions so clear, that we feel that this is unlikely. It is also possible that more data from different sports around the world may confirm our findings or demonstrate the influence of other variables which we have not considered. For example, despite some interesting differences brought to light by the descriptive statistics between countries, we did not explore this with inferential testing, nor did we examine differences within countries due to the sparse nature of the during-COVID data and because of the aforementioned statistical grounds. We are therefore currently exploring this further. Equally, we were not able to source statistics pertaining to the referee outcomes for a small number of countries (e.g., Russia, Denmark); however, this does highlight future avenues of research to examine the relative influence of these countries on the HA phenomena as independent entities.

Through the unique circumstances provided by the COVID-19 pandemic and in line with the theory of social community and coherence (see Durkheim, 1974), our results show a key element of the HA has been confirmed: that the home crowd has a significant impact on players. Via the incorporation of key performance variables and a large sample of games, we also extend recent work examining the impact of HA in during-COVID periods. Our findings demonstrate that home team performance is significantly negatively influenced by the lack of a home crowd, while the away team show a small improvement, both enough to halve the HA. However, we present new evidence that the HA is more sensitive to context than previously thought for outcomes relating the referees, as while significantly more fouls and yellow cards were awarded against away sides in the during-COVID period, this effect was diluted when controlling for the dominance of teams and rendered non-significant for red cards. In sum, the results of the current study have cast new light on the HA phenomenon and are extremely interesting and valuable from both a theoretical and applied perspective, taking advantage of a rare world event that hopefully will not persist much longer or happen again.

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Declaration of competing interest

As noted on the cover page, the authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2021.102013.

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