

**Statement of relevance**

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The Home Advantage (HA) is a robust effect in team sports whereby the home team scores more goals and wins more points than the away team. A key factor accounting for HA is the effect of the home crowd, believed to spur on home team performance and influence referee decision-making to favour the home team. Our examination of 4,844 games from 15 different leagues across 11 European countries revealed that HA was significantly reduced during the COVID-19 pandemic, when part of the season was played without crowds. This will not only have worldwide interest to football teams, players, fans, referees, bookmakers and football governing bodies, but also has relevance to other sports where similar effects have been previously shown. As football is a global business attracting high media and public attention, and accrues billions of pounds in business investments, advertising, and merchandising, any factor which has such a strong influence on team performance is worthy of attention. The results shed light on theories proposing reasons for the home advantage

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## Introduction

21           The home advantage (HA) in sport has been widely recognised for many years. When  
22 setting their odds, bookmakers have traditionally placed an emphasis on where the competition  
23 will take place (Bookies.com, 2020), and media reports often comment on the difficulties of  
24 playing away from home (Pollard, 2006). The classic paper by Schwartz and Barsky (1977) is  
25 frequently cited as the first empirical investigation of the extent of and reasons for the HA.  
26 Conceptualising their predictions within Émile Durkheim's theory of social community and  
27 coherence (see Durkheim 1974), which posits social and group coherence as the alignment and  
28 harmonious network of relationships among individuals who share common interests and goals.  
29 They suggested that supportive crowds are social representatives of their players and exert an  
30 invigorating, motivational influence, encouraging the home side to perform well. Their  
31 extensive data collections of home and away results in American major league baseball,  
32 professional and college football, ice hockey and college basketball revealed a pronounced home  
33 advantage, though the extent for each sport varied. The authors ruled out venue familiarity as a  
34 major causal factor, though some later researchers demonstrated moderately reduced HA effects  
35 when a team changed its stadium. Instead, social factors were deemed to be critical, such as the  
36 fans' proximity to the playing area, and the more constant, loud, and inspiring sounds that come  
37 from the crowd, where enthusiastic cheers and chants can inspire entertaining, attacking play and  
38 encourage home players to try harder and ultimately win the game (for review, see Pollard  
39 2008).

40           The second factor often cited to influence the HA in football is the impact of the crowd  
41 upon the people controlling games, otherwise known as the referees. Dosseville, Edoh and  
42 Molinaro (2016) proposed a HA framework that prominently featured the referee. Their

## HOME ADVANTAGE DURING COVID-19

43 conceptualisation notes many studies indicating that referees tend to make more decisions in  
44 favour of the home team (see, for example, Nevill and Holder, 1999; Pollard, 1986; Boyko,  
45 Boyko and Boyko, 2007; Sutter and Kochera, 2004) and includes the assertion that officials are  
46 highly susceptible to social influence. This is because their role is so challenging and difficult to  
47 implement successfully that they unknowingly rely on cues from the crowd when making their  
48 decisions. For example, they add more extra time at the end of the first half, and even more so in  
49 the second half, when the home team are behind by a goal; and more decisions against the away  
50 team are later found to be incorrect (Garicano, Palacios-Huerta, & Prendergast, 2005; Dohmen  
51 and Sauermann, 2016). This ‘bias’ is found in German, English and Italian football. The  
52 authors also note that while more experienced referees might be less susceptible to some of these  
53 influences by the time they reach expert levels, as they may have developed schemas that lead  
54 them to operate under certain expectations; these might include beliefs that home players will be  
55 more assertive and territorial (Neave & Wolfson, 2003) and thus will hold an advantage.

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

## HOME ADVANTAGE DURING COVID-19

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

71           One of the first countries to ban mass public gatherings at football matches, Germany,  
72 provided early glimpses that HA may indeed be as sensitive to crowd attendance as previously  
73 hypothesized by HA theorists. A flurry of papers providing a mixed consensus in regard to HA  
74 outcomes were soon released. Some reported that HA was significantly reduced in games played  
75 without fans, and that referees treated home teams significantly less favorably in terms of fouls  
76 and cards awarded (e.g. Endrich & Gesche, 2020; Dilger & Vischer, 2020), while others argued  
77 that this relationship only emerged in the top divisions of German football (e.g. Fisher &  
78 Haucap, 2020). Soon after, and as lockdowns spread throughout the continent, reports from other  
79 countries quickly emerged. Bryson et al. (2020) and Reade et al. (2020) delivered the broadest  
80 empirical summaries, examining over 16 countries across 23 leagues throughout Europe. Both  
81 studies reported large-sized effects for the absence of crowds on referee decisions, with  
82 significantly fewer cards being awarded to the away teams. There was also a small but  
83 significant decrease in the number of red cards shown to away teams in these studies; however,  
84 subtle differences did emerge when considering team performance. Thus, while Reade et al.  
85 (2020) reported a significant reduction in the percentage of home wins (43.8% with fans to  
86 41.2% without fans), Bryson et al. (2020) did not report significant effects. However, Sanchez  
87 and Lavin (2020) found fewer points scored at home in Germany and Spain without a crowd but

## HOME ADVANTAGE DURING COVID-19

88 no such effects in Austria, Italy, and England, perhaps suggesting the HA is geographically  
89 sensitive. Therefore, while the analyses so far available are consistent regarding the intrusive  
90 impact of crowds upon referees, the same cannot be said unequivocally for team-related  
91 outcomes. A potential reason for these differing results may, at least in part, be due to the fact  
92 that previous studies did not consider a number of significant additional factors that are likely to  
93 influence the relationship between the removal of fans from stadia and HA outcomes . First, a  
94 team's playing style is likely to determine their chances of scoring goals and thus their likelihood  
95 of winning the game. This is significant considering that Schwartz and Barsky (1977) noted a  
96 team's offensive play, in particular, is exclusively related to performances by the home side; but  
97 this factor has only ever (see Pollard, 2008), been examined in regard to direct attempts to win a  
98 game (i.e., shots, shots on target, penalties) and has omitted other indirect efforts (i.e.,  
99 possession, corner kicks, free kicks) that are known to be significant determinants of game  
100 outcomes (Goumas, 2013). This suggests the degree to which a team 'dominates' a game through  
101 its playing style is especially worthy of further explanation. Second, an objective understanding  
102 of how the home team's strength (relative to the opposition and within league merit positions)  
103 and the difficulty of their fixture schedule in terms of the opposition they face may impact the  
104 effects observed for HA, is missing from the literature. This is important as the quality of  
105 opposition a team faces is indicative of their likelihood of winning (Peeters & van Ours, 2020),  
106 and more skilled sides may well rely less on their crowds' support than their less-skilled  
107 counterparts. Third, the impact of unmeasured confounds has also not been fully considered, and  
108 while a number do exist which we cannot control for in this study (e.g., COVID infections,  
109 country-level heterogeneity in response to the pandemic, differences in training schedules, etc.),  
110 multilevel models whereby the individual matches, played home and away, are nested within

## HOME ADVANTAGE DURING COVID-19

111 individual teams, do provide some remedy in allowing us to assess the relative contribution of  
112 specific variables on performance and referee-related outcomes.

113         Following its suspension due to the COVID-19 pandemic, the 2019-2020 European  
114 football season resumed with approximately a quarter of games to be played ‘behind closed  
115 doors.’ This provided a unique opportunity to observe a naturalistic manipulation wherein  
116 differences could be analysed between games with and without the presence of an audience on  
117 player and referee performance. This random (and unexpected) situation has manufactured a  
118 situation that has sparked an array of new and important research on the topic. However, here,  
119 across a large sample of games (N = 4,844), we extend this work to consider a broader range of  
120 previously unexamined, yet important, variables (i.e., team/strength dominance, team playing  
121 style, playing schedule) that are likely to influence the relationship between removal of fans from  
122 games across 15 European leagues and HA outcomes.

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

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## Method

135 The present study was pre-registered via the Open Science Framework which can be viewed,  
136 along with the data used for the analysis, via the following DOI:

137 [https://osf.io/4hu8r/?view\\_only=1176423f8b594d93b5c45856557](https://osf.io/4hu8r/?view_only=1176423f8b594d93b5c45856557) (blinded for review).

## Data

139 All European leagues that finished the 2019/20 season without an audience were included  
140 in the analysis. Altogether, we analyzed 4,844 individual games from 15 different leagues  
141 spanning 11 different countries (England Premier League & Championship, Germany  
142 Bundesliga 1 & 2, Spanish La Liga 1 & 2, Italian Serie A & B, Portuguese Primeira Liga, Greek  
143 Super League, Turkish Super Lig, Austrian Bundesliga, Danish Superligaen, Russian Premier  
144 League and Swiss Super League). In total, 3,515 games (72.56%) were played with the presence  
145 of the audience (pre-COVID) and 1,329 (27.44%) in the during-COVID period without an  
146 audience. Data for each individual league can be seen in Table 1.

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

154 The data on team performance (points, goals, corners, shots, and shots on target) were  
155 available for all leagues in the databases we used, but the data for referee performance (fouls,  
156 yellow and red cards) were available for 11 out of 15 leagues (exceptions being Austria,

HOME ADVANTAGE DURING COVID-19

157 Denmark, Turkey, Russia & Switzerland). We excluded any play-off games across leagues as these are subject to different playing  
 158 conditions (i.e. over two legs; away goals; extra time) to maximize the internal validity of the results. Data across both databases were  
 159 first extracted before being independently checked in view of accuracy (Cohen’s Kappa = 1).

160 **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 II	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%
			1.43	1.21	12.71	1.94	0.07				1.34	1.29	12.67	1.42	0.08	
Germany I	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%
			1.74	1.51	11.62	2.17	0.12				1.42	1.66	11.51	1.91	0.09	
Germany II	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%
			1.55	1.29	12.62	2.26	0.12				1.65	1.32	12.72	1.95	0.12	



## HOME ADVANTAGE DURING COVID-19

Spain I	270	48%	1.71 1.51	1.01 1.03	13.68 14.02	2.59 2.76	0.09 0.13	71%	110	41%	1.50 1.26	1.22 1.07	13.71 13.29	2.49 2.19	0.12 0.11	29%
Spain II	340	39%	1.54 1.28	1.10 1.03	15.69 15.89	2.62 2.88	0.14 0.18	74%	121	44%	1.62 1.26	1.11 0.98	15.63 15.28	2.71 2.53	0.15 0.16	26%
Italy I	256	40%	1.43 1.54	1.34 1.38	13.76 14.29	2.55 2.89	0.13 0.16	67%	124	44%	1.55 1.80	1.23 1.49	13.69 13.03	2.22 2.14	0.11 0.09	33%
Italy II	279	46%	1.64 1.42	1.09 1.06	15.47 16.12	2.48 2.75	0.16 0.20	74%	101	42%	1.51 1.36	1.22 1.23	15.49 15.54	2.47 2.47	0.18 0.13	26%
Portugal	216	40%	1.45 1.28	1.29 1.13	15.53 15.61	2.40 2.78	0.11 0.14	71%	90	44%	1.59 1.50	1.16 1.17	17.28 16.69	2.68 2.25	0.20 0.14	29%
Greece	182	48%	1.71 1.51	1.02 0.93	15.78 16.55	2.48 2.97	0.10 0.20	76%	58	33%	1.36 1.16	1.24 0.97	16.12 16.63	2.58 3.13	0.15 0.09	24%
Turkey	234	43%	1.58 1.61	1.15 1.21	13.71 13.59	2.38 2.62	0.15 0.18	76%	72	46%	1.61 1.62	1.15 1.37	13.47 13.19	2.38 2.18	0.14 0.16	24%
Austria	132	36%	1.32 1.77	1.43 1.69	N/A	N/A	N/A	68%	63	30%	1.13 1.30	1.65 1.77	N/A	N/A	N/A	32%
Denmark	167	49%	1.68 1.56	1.11 1.24	N/A	N/A	N/A	70%	75	39%	1.43 1.48	1.31 1.29	N/A	N/A	N/A	30%

## HOME ADVANTAGE DURING COVID-19

Russia	176	37%	1.38 1.28	1.36 1.10	N/A	N/A	N/A	73%	64	34%	1.31 1.30	1.41 1.27	N/A	N/A	N/A	27%
Swiss	170	42%	1.59 1.65	1.38 1.51	N/A	N/A	N/A	50%	170	42%	1.36 1.21	1.16 1.36	N/A	N/A	N/A	50%
Total	3,515	43%	1.55 1.51	1.20 1.23	13.50 14.23	1.19 1.57	0.11 0.14	73%	1,329	41%	1.45 1.42	1.27 1.29	14.13 13.83	1.20 1.39	0.13 0.15	27%

161 *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'*  
 162 *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*  
 163 *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*  
 164 *that was not available for that league/country.*

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171 **Analysis**

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

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

192 The possibility of adding confounding factors in our analysis is one of the reasons why  
193 we decided to use multilevel modelling (also known as mixed-effects, Wood, 2017) where the

## HOME ADVANTAGE DURING COVID-19

194 individual matches, played home and away, are nested within individual teams. Multilevel  
195 modelling is a regression approach which not only uses individual teams as basic units with  
196 home and away games nested within them, but also allows for inclusion of additional factors,  
197 including possible confounds. In our particular case, we are interested in the factors Venue  
198 (home and away) and COVID period (pre and during), and most importantly, their interaction. If  
199 the HA is influenced by the audience presence, we would expect that teams win fewer points and  
200 score fewer goals at home compared to away games in the during-COVID period than in the pre-  
201 COVID period. In other words, our main interest is the interaction between Venue and COVID  
202 factors.

203         To control for possible differences in the pre- and during-COVID schedule and  
204 importance of the games, we used the strength of individual teams and the game importance for  
205 individual teams. FiveThirtyEight's team strength rating (SPI) includes teams' previous results  
206 and market values of players. It is updated after each game based not only on the actual results  
207 and goals scored, but also on other indicators to account for randomness of a low scoring game  
208 such as football (e.g., adjusted goals, shot-based expected goals and non-shot expected goals).  
209 FiveThirtyEight's importance measure quantifies the impact of the match results on the team's  
210 outlook on the season. The importance is dependent on the team, as different teams play for the  
211 championship, qualification for international UEFA competitions, or not getting relegated.  
212 Similarly, the importance measure takes the situation in the individual league into account as the  
213 probabilities of achieving a team's goal are calculated depending on the outcome of the game.  
214 The difference between the probabilities is then expressed as a standardized variable. Both rating  
215 and importance measures range from 0 to 100 and are comparable not only within a single  
216 league, but also across the leagues. In our analysis we calculated the difference between both

217 teams in rating and importance, standardized the difference (where mean is zero and standard  
218 deviation one, making the differences more interpretable), and included them as covariates in the  
219 multilevel models. As discussed earlier, we were particularly interested in their interactions with  
220 Venue and COVID period factors, as significant results would then indicate vastly differing  
221 schedules for pre- and during-COVID periods.

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

237         The final analysis used all individual games, where each game was coded twice, once  
238 from the perspective of the home team, and once from the perspective of the away team. The  
239 variables included in the multilevel models were Venue (home and away), COVID period (pre

240 and during), rating difference (standardized difference of SPI ratings), importance difference  
241 (standardized difference of importance ratings), country (one of the 11 countries), and division  
242 (1st or 2nd division). The same model was run separately for points and goals. Since the  
243 dependent variables are discrete occurrences which are rarely normally distributed, we used  
244 Poisson distribution for the modelling (for similar approaches, see Goumas, 2013). In addition,  
245 as an extra safeguard, we also ran a model with linear terms (in addition to Poisson) for points,  
246 given they are sometimes considered an ordered ordinal variable (See OSM 1, Table 1). As an  
247 additional safeguard to the way in which random-effects multi-level models deal with clustering  
248 of standard errors (see, Primo, Jacobsmeier & Milyo, 2007), we also ran models (and calculated  
249 standard errors) at match-level for both team and referee outcomes (see OSM, section 3).

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

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

### 269 **Effect size calculations**

270 Almost all of our variables of interest feature meaningful and easily understandable metrics –  
271 points, goals, fouls, yellow and red cards. We provide incident rate ratios (IRR), instead of raw  
272 estimates (which indicate the difference in the logs of expected counts per unit), for all Poisson-  
273 based models (e.g. points, goals, yellow and red cars) to facilitate their interpretation. For  
274 example, in Table 2, for the Points model, the IRR for Venue is 0.74. This means that the away  
275 team wins 0.74 times fewer points per game than the home team (home team is coded as 0, the  
276 reference point, and away team as 1 in the model – see the note in Table 2). In other words, for  
277 every point a home teams wins, the away team wins 0.74, holding all other variables constant.  
278 Similarly, in the same model the IRR for the interaction between Venue and COVID is 1.12,  
279 which means that away teams during the COVID period gain 0.12 points per game compared to  
280 the same away teams in the pre-COVID period (pre-COVID period is the reference point, 0,  
281 here, while the during-COVID period is coded as 1 – see the note in Table 2). Therefore, the  
282 differences between home and away teams are 1.12 smaller (or .12 points per full point) in the  
283 during-COVID period than in the pre-COVID period.

284 We also leave the raw values in the model for Fouls (Table 3), where the estimates refer  
285 to the number of fouls. For example, 0.35 coefficient for the Venue variable means that the away  
286 team on average commits 0.35 more fouls than the home side. The interaction between Venue  
287 and COVID, -0.70, also gives a precise information on how many fouls fewer the away teams  
288 are committing during the COVID period, compared to the pre-COVID period. Here we also  
289 provide the standardized coefficient,  $\beta$ , in the main text.

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

### 293 **Results**

#### 294 **Team Performance (points and goals)**

295 Teams gained more points during home than away games, but the difference was less  
296 marked in the period without an audience (Figure 1A). Pre-COVID, teams won on average 0.39  
297 points per game more at home than away, but this HA was almost halved in the period without  
298 the audience - the teams won only .22 points more at home than away. Home teams were scoring  
299 more goals than away teams in general, but this advantage was greatly reduced when the  
300 audience was absent. The home teams scored on average 0.29 goals more per game than away  
301 teams in normal circumstances when the audience was present. The same home teams scored  
302 only 0.15 goals more than the visitors when the audience was absent (see Figure 1B).

303 A formal multilevel regression model confirmed that the Venue x Covid-Period was  
304 highly significant (see Table 2). The effect of an audience on HA was not driven by the  
305 difference in the schedule, or differing importance between home and away teams in the pre and  
306 during-COVID period. The stronger teams and the teams with more to play for won more points,



## HOME ADVANTAGE DURING COVID-19

307 but this was constant for home and away matches, as well as for the periods with and without an  
308 audience (see Table 2).

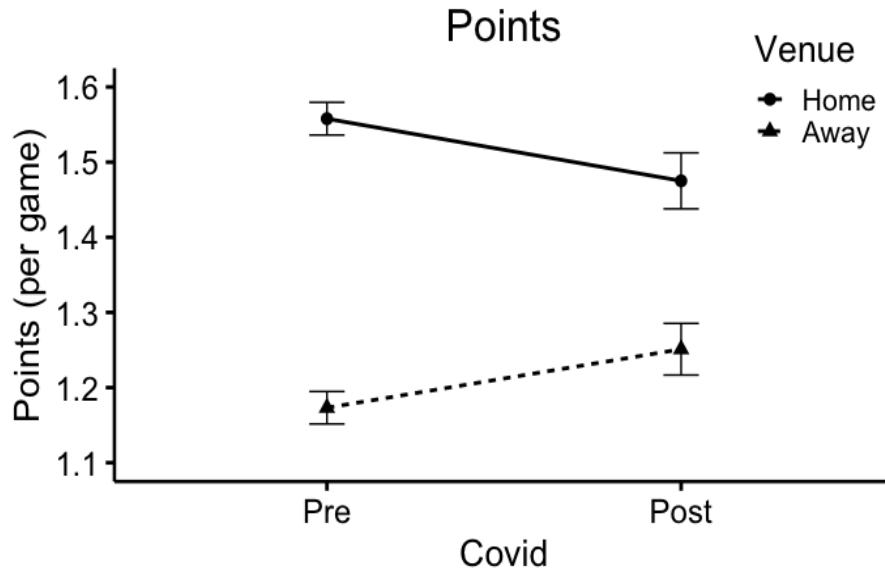
309         We found the same pattern of results when we looked at the goals instead of points (see  
310 Figure 1B). Home teams were scoring more goals than away teams in general, but this advantage  
311 was greatly reduced when the audience was absent. The home teams scored on average 0.29  
312 goals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

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

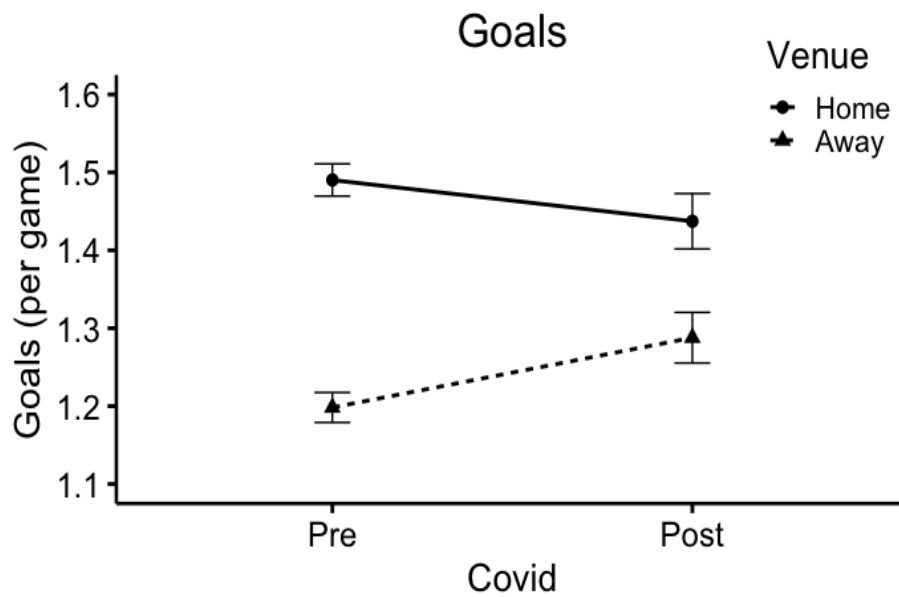
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321 **Figure 1. Home advantage. Points and goals across European football leagues in 2019/20**  
322 **season with and without an audience.**  
323

324 **A**



**B**



354 **Table 2. Regression models for points gained, goals and dominance across European**  
 355 **football leagues in 2019/20 season with and without an audience.**  
 356

Predictors	Points			Goals			Dominance		
	<i>IRR</i>	<i>SE</i>	<i>p</i>	<i>IRR</i>	<i>SE</i>	<i>p</i>	<i>std. β</i>	<i>SE</i>	<i>p</i>
(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
<b>Random Effects</b>									
$\sigma^2$	0.56			0.57			0.77		
$\tau_{00}$	0.00 <sub>Team</sub>			0.01 <sub>Team</sub>			0.03 <sub>Team</sub>		
ICC	0.00			0.02			0.04		
N	264 <sub>Team</sub>			264 <sub>Team</sub>			213 <sub>Team</sub>		
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	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.

357

358 We also checked more detailed indicators of game dominance such as number of corners,

359 shots, shots on target, as well as standardized latent factor of these three indicators, called

360 Dominance. Figure 2 confirms the trend of the wavering dominance of the home teams playing

361 without the support of their fans. When playing without an audience, the home teams won on

362 average per game 0.7 fewer corners, had 1.3 fewer shot attempts, and 0.4 fewer of their shots

363 were on target. Overall, home team dominance (as measured by a standardized latent factor of

364 corners, shots, and shots on target) was 0.24 standard deviation smaller. The away teams, in

365 contrast, were close to their performance in the pre-COVID period played in front of fans - only

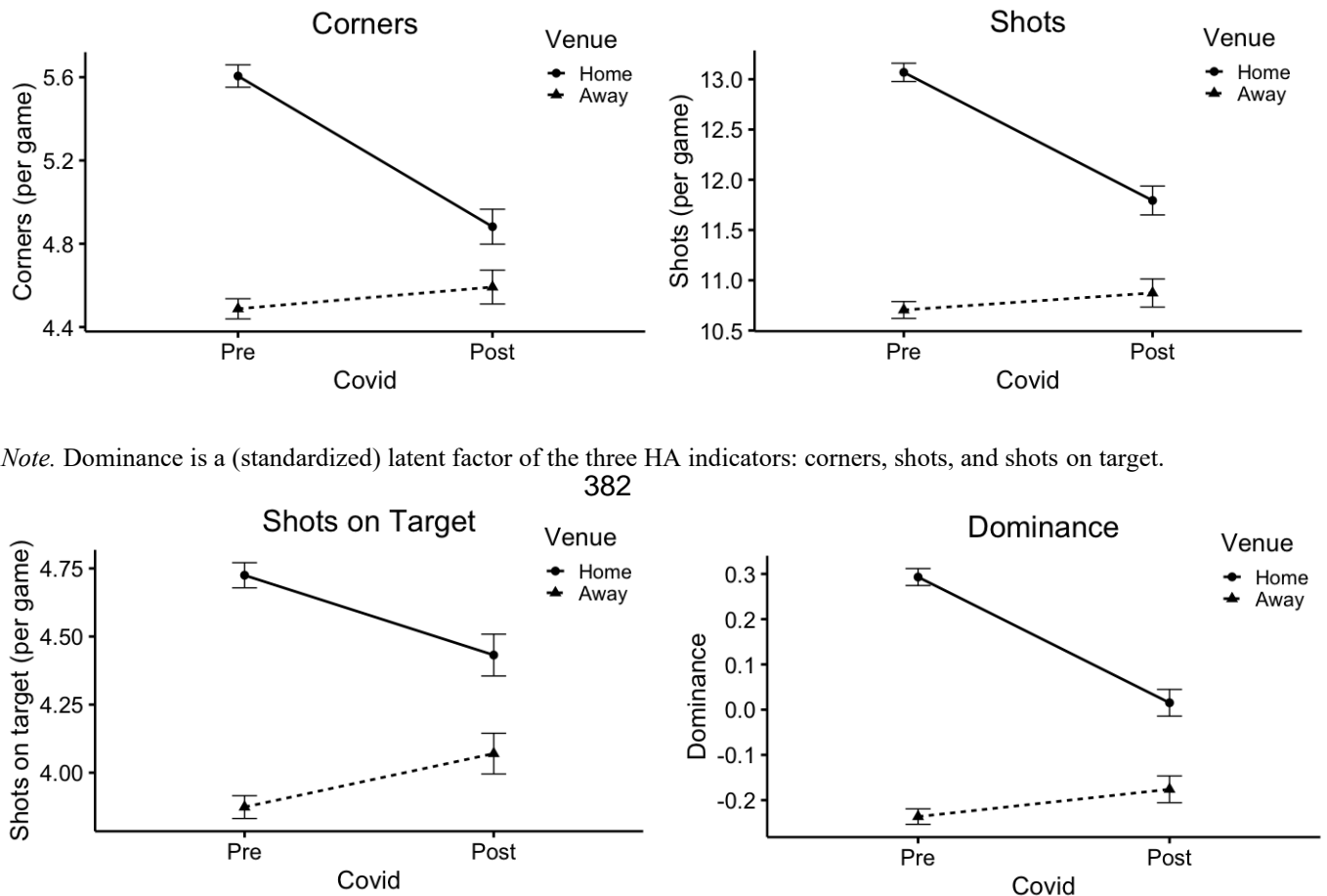
366 0.10 more corners, 0.17 more shots, and 0.20 more shots on target. The overall dominance of

367 away teams improved for only 0.05 standard deviation. The extent of the decrease in home team  
 368 performance for some parameters is more than tenfold compared to the away team improvement.

369 The multilevel regression on these indicators confirmed the negative effect of the absence  
 370 of audience on the home team performance (see, Venue x COVID interactions in Table 2).

371 Notably, the interaction for dominance revealed a significant, and medium-sized, effect for its  
 372 impact on the HA ( $\beta = .30, SE = .04, p < .001, ICC = .31$ ) and, more importantly due to their  
 373 wider implications on sporting success, the difference in rating and importance (both important  
 374 and significant factors on their own) were not related to audience - venue interaction (see Table  
 375 3). We can therefore be confident that the diminishing performance of the home teams without  
 376 their fans is not a consequence of the unbalanced schedules in the pre and during-COVID  
 377 periods.

378 **Figure 2. Home advantage indicators. Corners, shots, and shots on target across European**  
 379 **football leagues in 2019/20 with and without an audience.**



380  
 381 Note. Dominance is a (standardized) latent factor of the three HA indicators: corners, shots, and shots on target.  
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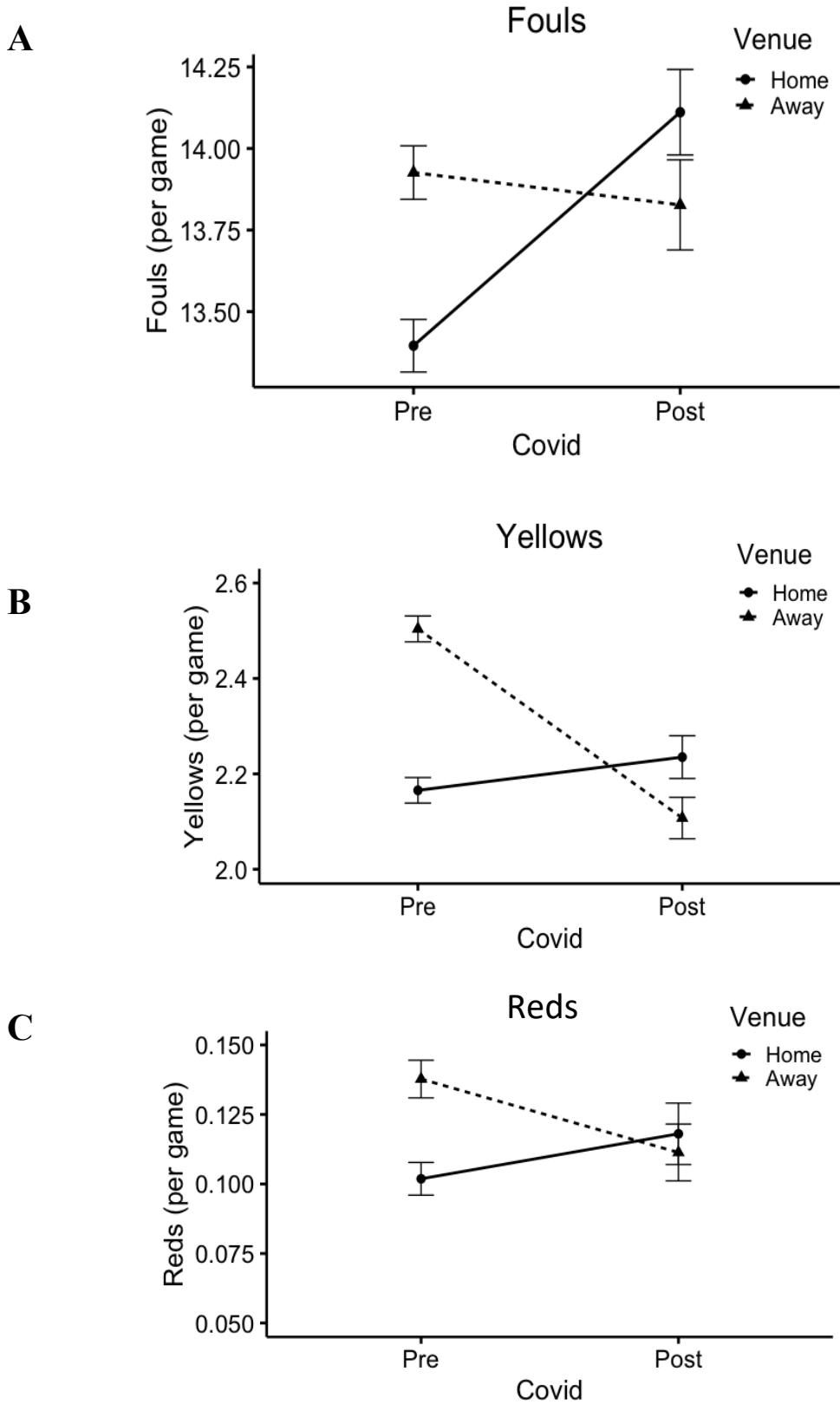
384 **Referees' Decisions (fouls, yellow and red cards)**

385           Our data extend previous findings that the audience influences referees' decisions. Figure  
386 3 shows that overall the home team received fewer yellow/red cards and fouls, but this is more  
387 pronounced when an audience is present. In the during-COVID period without an audience, there  
388 were virtually no differences in the yellow and red cards between home and away teams while a  
389 small difference was present in the number of fouls.

390           A closer look at the data pattern shows that the referees gave more fouls against the  
391 home team when the audience was absent, while the number of fouls against the away side  
392 remained similar. However, the yellow cards data shows that these fouls were differently judged  
393 depending on the presence of the audience. The away team was penalized far less for fouls when  
394 the audience was absent, whereas the home team, although fouling more, received similar  
395 amounts of warnings. The most drastic punishment, a red card, followed the same pattern, but  
396 the differences were less pronounced. The away team was indeed less often on the receiving end  
397 of a red card when the game was played without the audience, but the home teams were  
398 penalised more often without the support of their home fans (see Figure 3).

399 **Figure 3. Referees' decisions. Fouls, yellow, and red cards across European football leagues**  
 400 **with and without an audience during 2019/2020.**  
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HOME ADVANTAGE DURING COVID-19

438 Multilevel regression analyses with fouls, yellow and red cards as dependent variables  
 439 and venue (home-away) and audience (pre- and during-COVID) as predictors confirmed the  
 440 descriptive results (see Table 3). The interactions between venue and audience revealed  
 441 significant effects for fouls (std.  $\beta = -.16$ ), yellow cards, and red cards. Importantly, the  
 442 differences in the rating and importance between the teams were not significantly related to the  
 443 referees' decisions. and there were no interactions with Venue or COVID periods (see Table 3).

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

Predictors	Fouls			Yellow			Red		
	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) *	-0.70	0.20	<.001	0.83	0.03	<.001	0.77	0.15	.086
COVID (during)									
Rating difference *	-0.16	0.04	<.001						
Importance difference									
Venue *	0.30	0.09	.001	1.07	0.02	<.001			
Rating difference									
<b>Random Effects</b>									
$\sigma^2$	14.61			0.37			2.29		
$\tau_{00}$	4.70 <sub>Team</sub>			0.04 <sub>Team</sub>			0.11 <sub>Team</sub>		
ICC	0.24			0.10			0.05		
N	212 <sub>Team</sub>			212 <sub>Team</sub>			212 <sub>Team</sub>		
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	0.014 / 0.254			0.025 / 0.127			0.040 / 0.085		

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

448 Given the above results, one could think that the presence of the fans biases referees'  
 449 decisions against the visiting team. The above analyses do not, however, account for the  
 450 attacking tendencies of teams. Passive teams, which are content to defend as indicated by low

451 number of shots on goal and corners, tend to foul more and receive more warnings as they try to  
452 fend off a more dominant team. The referees' decisions could, therefore, simply be a  
453 consequence of teams' attacking tendencies. Given that the dominance of the home teams  
454 decreases considerably without the support of their fans (see Figure 2), it is of paramount  
455 importance to account for this factor before we conclude that the referees are influenced by the  
456 audience. Indeed, when we include the variable 'dominance' in the multilevel regression models,  
457 the referees' decisions were much less influenced by the audience presence and where the game  
458 was taking place. The interaction between Venue and COVID period was no longer significant  
459 for red cards ( $IRR = .77, SE = .15, p = .086$ ), while the same interaction for yellow cards ( $IRR =$   
460  $.83, SE = .03, p < .001$ ) and fouls ( $Est. = -.70, SE = .20, p < .001, std. \beta = -.16$ ) remained  
461 significant but effect-sizes were weakened (see Table 3). Together, these referee-specific  
462 analyses show referee bias is indeed an important factor in HA but its role is sensitive to context,  
463 as demonstrated when accounting for team dominance.

#### 464 **Discussion**

465 The 2020 COVID-19 pandemic provided a unique opportunity to explore some of the key  
466 factors which are thought to make a significant contribution to the HA in sport. In European  
467 football leagues, we examined how two factors - crowd influence on the teams and crowd  
468 influence on referee decision-making - compared as a result of teams playing the majority of  
469 their season with crowds present and the remainder of the seasons with crowds absent. For team  
470 performance, our data clearly showed that when controlling for factors such as country, league,  
471 schedule, and team quality, the effect of playing in virtually empty stadia had a significant  
472 negative impact on the typical home team performance. However, for referees' decision-making  
473 processes this was more intricate; such that while the number of fouls and yellow cards ruled



474 against away sides remained significant, it was reduced in games without an audience, and no  
475 effects were observed for red cards.

476         While traditional research on the HA (e.g., Agnew & Carron, 1994; Courneya & Carron,  
477 1992; Goumas, 2014b; Nevill et al., 2005) as well as some recent reports (e.g., Reade et al.,  
478 2020; Scoppa, 2021) share the broad view that home team performance benefits from a home  
479 crowd, the degree to which this influences performance outcomes for European teams (such as  
480 goals scored and points accrued) following the COVID lockdowns appears disputed. Bryson et  
481 al. (2020) found that the absence of a crowd had no significant effect on the final score, whereas  
482 Sanchez and Lavin (2020) reported significantly fewer points gained at home in Germany and  
483 Spain without the support of a crowd, but that no such effects existed in Austria, Italy, and  
484 England. Wunderlich (2021) goes as far to conclude that the HA persists in the absence of  
485 crowds; although these findings may be of direct consequence to the substantial heterogeneity  
486 brought about via comparing games in the last season against those up to 10 years ago. On the  
487 other hand, both Scoppa (2020), Tilp and Thaller (2020) and Hill and Van Yperen (2021) assert  
488 that HA is heavily reliant on the presence of fans, as points, goals and shots at goal, were  
489 significantly reduced for home teams in the during-COVID period. Importantly, the results of the  
490 present study are in accordance with the latter of these findings and go some way to support the  
491 long-held view that the HA is an important factor which boosts the odds of the home team  
492 coming out victorious in games. We find points per game, goals per game and team dominance  
493 (see Figures 1A, 1B, and 2) were all significantly reduced in the home teams compared to the  
494 away teams (who performed similarly in the presence or absence of a crowd); even when  
495 controlling for some leagues (i.e., Denmark, Swiss & Russia) which included some spectators in  
496 their during-COVID period. Our data are thus consistent with the theory of social community

497 and coherence (see Durkheim, 1974), which posits that social and group coherence is the  
498 harmonious order in which a network of relationships among individuals is responsible for the  
499 attainment of group-based goals. As observed in our data, it would follow that the absence of  
500 loyal crowds in the during-COVID period would adversely impact home teams, who no longer  
501 benefit from the invigorating and motivational influence of their supporters in the pre-COVID  
502 games.

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

518         However, and importantly, our formal tests of statistical inference revealed that team  
519 dominance (i.e., whether a team was more ‘attack’ or ‘defence’ minded) was a key factor in

520 these effects. Indeed, when we controlled for this in games played without fans, the impact of the  
521 HA on referee bias was diluted such that, while still statistically significant, the number of fouls  
522 and yellow cards ruled against away sides was reduced and significant effects for red cards were  
523 no longer present. This novel finding casts new light on the well examined relationship between  
524 the presence of fans and referee decision-making within the HA literature (see Pollard, 2008) via  
525 suggesting that within-game context plays a more profound role than perhaps previously noted.  
526 Contrary to some former findings which suggest referee-bias is a hallmark of the HA  
527 phenomenon (e.g., Boyko et al., 2007; Dohmen, 2008; Dosseville et al., 2016; Endrich &  
528 Gesche, 2020; Cueva 2020; Bryson et al. 2020; Scoppa, 2020; Benz & Lopez, 2020), our  
529 findings reveal that referees' decisions are likely a consequence of a team's attacking tendencies.  
530 In fact, closer inspection of the COVID-related studies (i.e., Reade et al., 2020, Bryson et al.,  
531 2020; Scoppa, 2020) reveals large-sized effects for yellow cards and small-sized effects for red  
532 cards (as in our original analysis, without dominance). Thus we propose that had this factor been  
533 considered in previous reports, keeping in mind their often smaller samples (e.g., Haucap &  
534 Fischer, 2020; Dilger & Vischer, 2020), the associated effects observed would have been likely  
535 reduced, if not rendered non-significant, as was the case in our larger analysis.

536         While the exact causal mechanism is unclear, we expect this is because passive teams,  
537 which are content to defend (as indicated by low number of shots on goal and corners), tend to  
538 foul more and receive more warnings in an attempt to fend off their more dominant opponents.  
539 This would therefore suggest referee behaviours are reactive in nature and simply reflect the  
540 circumstances presented before them, rather than being subconsciously loaded with intentions to  
541 favour the home side in the presence of a crowd as previously hypothesised (Dohmen 2008;  
542 Nevill & Holder, 1999; Nevill et al., 2002). Therefore, while these findings broadly support the

## HOME ADVANTAGE DURING COVID-19

543 view that referees are implicated in the HA, we propose that more work is required to understand  
544 the degree to which the crowd (rather than the players and in-game context) is responsible for  
545 seemingly biasing decisions in favour of the home side. Chiefly, it is of primary concern to  
546 comprehend the objectivity of referees' decisions within the framework of the HA; future studies  
547 should aim to go beyond the descriptive reporting of fouls, yellow cards and red cards and  
548 account for whether these decisions are deemed correct by football governing bodies.

549 Another potential factor to consider is that we were comparing games at the beginning  
550 and middle of the season with those at the end of the season, when key outcomes are much more  
551 likely to be relevant to the teams (e.g., promotion, relegation and final placings). Even so, our  
552 results provide little evidence to support this assumption often made by the games' community.  
553 The effect of an audience on HA was indeed not driven by the difference in the schedule, or  
554 differing importance between home and away teams in both the pre and during-COVID period.  
555 We can therefore be quite certain that the diminishing performance of the home teams without  
556 their fans is not a consequence of the unbalanced schedules in the pre and during-COVID  
557 periods. Equally, for these analyses, the strength of teams was not related to the presence of a  
558 crowd in the during-COVID period. The stronger teams and the teams with more to play for won  
559 more points, but this was constant for home and away matches, as well as for the periods with  
560 and without an audience. Thus, our data suggest the relative strength of teams (i.e., their previous  
561 results, market values of players, expected goal-scoring opportunities) is not a significant  
562 determinant of the HA. This finding has several implications pertinent to footballing  
563 stakeholders, namely how team coaches and players may use these findings in the build-up to  
564 games. Knowing that the home side's likelihood of winning is reduced without the support of  
565 their crowd is an important tactic for away teams to remember, which may result in teams

## HOME ADVANTAGE DURING COVID-19

566 attacking early in the game to put their opponents on the ‘back-foot’ in the knowledge that their  
567 crowd cannot spur them on to ‘bounce-back’ Equally, teams being aware that the attacking  
568 dominance of their opponents is directly related to how many fouls they are likely to commit is  
569 an important message, as coaches may wish to implement tactics or set out interventions for their  
570 players to take on board.

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

585         Through the unique circumstances provided by the COVID-9 pandemic and in line with  
586 the theory of social community and coherence (see Durkheim 1974), our results show a key  
587 element of the HA has been confirmed: that the home crowd has a significant impact on players.  
588 Via the incorporation of key performance variables and a larger sample, we also extend recent

## HOME ADVANTAGE DURING COVID-19

589 work examining the impact of HA in during-COVID periods. Our findings demonstrate that  
590 home team performance is significantly negatively influenced by the lack of a home crowd,  
591 while the away team show a small improvement, both enough to annul the home advantage.  
592 However, we present new evidence that the HA is more sensitive to context than previously  
593 thought for outcomes relating the referees, as while significantly more fouls and yellow cards  
594 were awarded against away sides in the during-COVID period, this effect was diluted when  
595 controlling for the dominance of teams and rendered non-significant for red cards. In sum, the  
596 results of the current study have cast new light on the HA phenomenon and are extremely  
597 interesting and valuable from both a theoretical and applied perspective, taking advantage of a  
598 rare world event that hopefully will not persist for long or happen again.

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