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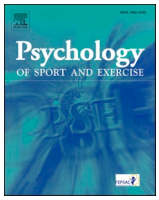

The causal impacts of empty stadiums on women's sports activities: Evidence from European football leagues

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ABSTRACT

This paper examines the effect of spectators on women's football games. COVID-19 and related restrictions provide a unique opportunity with an adequate sample size to test the effect of lockdown on sports activities. Studies have recently exploited this opportunity for men's football to better understand the potential causes of home advantage and, more specifically, assess the psychological consequences when matches are played without supporters. Despite the increased scientific interest, there was only one paper that focused on women's football. Therefore, we aim to contribute to this research field by considering matches from four major European women's football leagues. The findings suggest that for three of these leagues, lockdown has a statistically significant effect on the sanctioned yellow cards by either reducing the number of yellow cards sanctioned to the away teams or increasing the number of yellow cards sanctioned to the home teams. Nonetheless, lockdown does not affect any final match outcomes; therefore, it does not significantly affect the magnitude of home advantage for women's games.

1. Introduction

1.1. Literature review and theoretical background

Recently, increasing attention has been directed to the relation between the outcomes of sports events and fan attendance. This has been noted after the emergence of the COVID-19 pandemic that banned or severely limited away games for regular fans. In this regard, a plethora of papers have been published focusing on possible changes in game characteristics for post-COVID-19 matches. By doing so, they contribute to the literature on home advantage (Nevill & Holder, 1999; Courneya & Carron, 1992) and help better understand the main drivers of the widely accepted phenomenon that teams on average perform better when playing at their home stadium.

Regarding the causes of home advantage, several potential reasons have been proposed over the years, including the following: crowd support (Agnew & Carron, 1994; Nevill & Holder, 1999; Pollard, 2006a), travel fatigue (Nevill & Holder, 1999; Pace & Carron, 1992; Pollard, 2006a), familiarity (Barnett & Hilditch, 1993; Pollard, 1986; Pollard, 2002), referee bias (Nevill & Holder, 1999; Garicano et al., 2005; Buraimo et al., 2010), territoriality (Neave & Wolfson, 2003; Pollard, 2006b), special tactics (Seckin & Pollard, 2008; Carmichael & Thomas, 2005), rule factors (Jacklin, 2005; Thomas et al., 2004), and psychological factors (Terry et al., 1998; Thout et al., 1998). For detailed explanations, we refer the reader to reviews that summarize these articles that examine the potential causes (e.g., Legaz-Arrese et al., 2013; Nevill & Holder, 1999; Pollard, 2008). Most articles in the literature on home advantage focus on investigating the contributing effect of crowd support and referee bias. These are the two most studied factors involved with home advantage; additionally, recorded data on crowd size and sanctioned refereeing decisions yield the opportunity for precise quantitative studies. Regarding other potential factors, an increased sense of territoriality, when playing at home, has been observed, and its magnitude and contribution to home advantage can largely be explained by geographical location (Neave & Wolfson, 2003; Pollard, 2006b). On the other hand, findings indicate that familiarity with local conditions and travel-related factors only slightly contribute to the home advantage effect (Legaz-Arrese et al., 2013). The applied tactical viewpoint might differ when playing as a home or away team; still, no solid evidence has been obtained to directly link tactics with home advantage (Pollard, 2008). The rule factors are concerned with the effect of rules that might favour the home team (batting last in baseball and the last line change in ice hockey), but they have been found to only play a very minor contribution to home advantage (Nevill & Holder, 1999). Ultimately, all

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these causes interact with each other, and as they operate simultaneously, it is generally difficult to examine them separately. Both crowd support and referee bias can be interpreted with social psychological explanations, as the psychological states of the competitors and referees can be different when matches are played in front of a partisan crowd that puts social pressure on the participants.

Before the onset of COVID-19, Downward and Jones (2007) utilized FA cup games to claim that there is a relation between crowd size and the number of yellow cards awarded to the home team, indicating that an increased crowd size reduces the probability of a yellow card sanctioned to a player of the home team. Garicano et al. (2005) demonstrated that due to the pressure of the partisan crowd, referees systematically favour home teams by altering the extra time at the end of the games. They do so by shortening close games where the home team is winning and lengthening close games where the home team is losing. Due to hooligan violence, 21 professional Italian games were played in empty stadiums in 2007. Pettersson-Lidbom and Priks (2010) used these games as an experiment to find significant differences in refereeing behaviour with and without supporters, and they observed a reduced home bias without crowds. Regarding players, they found no evidence of different behaviour when games are played without spectators. On the other hand, Buraimo et al. (2010) suggested that sanctioned yellow and red cards also reflect adequate reactions to changing behaviours of teams when playing in a losing position; still, the researchers found evidence that there is referee bias in relative treatments of home and away teams.

The advent of the COVID-19 pandemic provides a unique opportunity to examine the mechanism behind home advantage more comprehensively by investigating the impact of crowd support on referees and players on a large scale. The majority of papers focused on men's football, studying European professional leagues. Among other aspects, the causal impact of an empty stadium on teams' performances and referees' decisions for men's football leagues has been investigated by Scoppa (2021); Bryson et al. (2021); McCarrick et al. (2021); Reade et al. (2021); Wunderlich et al. (2021); Benz and Lopez (2021); Hill and Van Yperen (2021). Their applied methodology and the considered matches varied to some extent; thus, their published results are also somewhat different.

Some studies revealed a significant decrease in home advantage due to the games being played behind closed doors. Scoppa (2021) ascertained this by considering data from five major European Leagues for 10 consecutive seasons and using season and league control variables, while McCarrick et al. (2021) analysed games from 15 leagues for the 2019/2020 season and used multilevel modelling that controls for attacking dominance. Others claimed that there are no significant effects on match results or in the final scorelines when games are played behind closed doors. In particular, Bryson et al. (2021) drew this conclusion by considering games from 17 leagues for the 2019/2020 season and applying controls for both the home and away teams and also for the identity of the referee. Reade et al. (2021) reached this conclusion by considering all football matches since the 2002/2003 season in seven European leagues and applying controls to account for the game-by-game strength of the two teams, the identity of the referee and the seasonal differences between the two teams. Furthermore, Wunderlich et al. (2021) ascertained the lack of significant effects by considering games from 10 professional leagues for 10 seasons and controlling for the league as a random effect. Hill and Van Yperen (2021) claimed that across four considered countries, home advantage declined significantly only for one country, and the change was insignificant for the other three countries. Interestingly, using data from 17 European leagues for five seasons and applying a bivariate Poisson model that controls for team strength, Benz and Lopez (2021) concluded that in some leagues, there is a lowered magnitude of home advantage due to lockdown, whereas in other leagues, the home advantage may have risen post-COVID-19. Nonetheless, most of the aforementioned papers that also investigated referee decisions reported a significant reduction in yellow cards—by approximately a third of yellow cards per match—sanctioned to the away teams when games are played without spectators.

In recent years, women's football has witnessed major changes. Several European women's leagues have been undergoing developmental changes to establish themselves as professionally or semi-professionally organised leagues; moreover, media coverage of women's football has been increasing. Despite the growing international recognition of female football, scarce research examines the impact of COVID-19 and home advantage on any women's sports leagues, including football. Before the emergence of the COVID-19 pandemic, a few studies investigated the magnitude of home advantage in women's sports. An early study by Gayton et al. (1987) verified the existence of home advantage in women's team sports such as basketball, field hockey, and softball without examining the drivers of this phenomenon. A few years before the appearance of COVID-19, Pollard and Gómez (2014) compared the phenomenon of home advantage between men's and women's professional football leagues. They concluded that while home advantage still exists in women's football leagues, its extent is considerably lower than the corresponding men's leagues' home advantage in any of the 26 European countries included in their analysis. Possible explanations have been provided for this difference; for instance, the effect of crowd support is smaller due to lower attendance figures, the effect of territoriality is lower due to hormonal differences, and the effect of psychological factors is lower due to status inequality between the two sexes. Note that the positive role of audience size on home advantage, in general, has been supported in some studies (Boyko et al., 2007; Inan, 2020), but it has also been questioned by others (Johnston, 2008; Pollard, 1986). Pollard et al. (2017) also reported a lower magnitude of home advantage for women's leagues across several considered sports and attributed this to the lower effect of territoriality. Nonetheless, none of the above studies particularly examined referee bias for women's sports events.

To the best of our knowledge, the only published study that exploited the opportunity provided by COVID-19 restrictions on women's games to better understand the reasons behind women's home advantage has been conducted by Krumer and Smith (2022). For this purpose, they analysed the Swedish Damallsvenskan women's soccer league and considered seasons 2019 and 2020. Controlling for the betting odds of the two teams, they found that the reduction in home advantage for games without spectators is statistically insignificant. Furthermore, interestingly, they reported that without crowds, the away team gets more yellow cards.

The literature on investigating the relation between the COVID-19 pandemic and home advantage along with referee decisions is relatively limited for sports other than soccer. Considering major North American sports leagues and using data from multiple seasons, Szabó (2022b) assessed that lockdown deteriorates the performance of the home basketball (NBA) and American football (NFL) teams but does not affect the performance of ice hockey (NHL) teams. Additionally, for these three leagues, referees' decisions in terms of sanctioned penalties are unaffected by the lockdown. Using a Bayesian framework and a slightly different dataset, Higgs and Stavness (2021) concluded that lockdown deteriorates the performance of the home teams for basketball (NBA) and ice hockey (NHL) but does not affect the performance of the home teams for American football (NFL) and baseball (MLB). Regarding major league baseball, Losak and Sabel (2021) also found no significant difference in home advantage for pre-COVID-19 and post-COVID-19 games. Considering playoff games in ice hockey (NHL), Guérette et al. (2021) concluded that referees' decisions in terms of awarded penalties were significantly different with and without crowds.

In our view, there is a need for studies beyond Krumer and Smith (2022) who were the first to investigate the effect of COVID-19 restrictions on home advantage in women's football. Thus, the primary goal of this paper is to fill this substantial gap in the literature. Namely, we consider women's games from several European leagues and include

multiple seasons in the analysis.

As we have no reason to assume that the referees' decisions would work differently if the players are female, based on the studies concerning COVID-19 and home advantage in men's football, we expect that lockdown substantially lowers the number of yellow cards sanctioned to the away teams in women's games as well. Regarding home advantage, based on the conflicting results for men's football, we are unable to form expectations. Crowd size is indeed lower in women's games even under normal circumstances; however, as discussed above, its contribution to home advantage is debatable. Note that Krumer and Smith (2022) reported effects regarding the yellow cards that opposed what we would expect based on the studies on COVID-19 and home advantage in men's football. Furthermore, they found a statistically insignificant reduction in home advantage in games without crowds. To sum up, collating all studies, we are unable to form a hypothesis. Instead, we form the following research question.

- *RQ*: Do lockdowns have a statistically significant effect on the magnitude of home advantage and on the referee decisions in women's football leagues?

The rationale of this study is to find an answer to the *RQ* by applying a methodology similar to the ones used for men's football based on an extensive dataset.

1.2. COVID-19 regulations and data availability

To conduct this research and answer the *RQ*, we use data from different first-tier European women's football leagues. Contrary to the men's professional football leagues, historical data records are scarcer for women's games. Nonetheless, accurately recorded matches are becoming increasingly available online; however, we still have to use multiple portals to reliably gather matches with the required characteristics into our final dataset.

Our main data source is SportsReferenceLLC (2022), and we also use the Football-Lineups (2022) database to double-check results and provide any missing information. In these portals, information is available for a substantial number of women's domestic leagues, including various match characteristics such as final results, match attendance, name of the referee, and the number of yellow and red cards sanctioned to the home and away teams. Depending on the league, records are available for the previous two to five seasons. While final results are well documented at SportsReferenceLLC (2022), information regarding the referee crew and accurate attendance data are not regularly reported for some of the leagues; additionally, some games from otherwise well-recorded leagues are missing attendance data or the main official's name. To decide whether a lockdown was in force for a given match, accurate attendance data is essential. Therefore, we cautiously check the leagues for each season to decide if we can include them in the analysis. We proceed with a particular league if accurate attendance data is already available at least for the prior season before the emergence of the COVID-19 pandemic. This study is conducted in this manner as we seek to examine the effect of lockdown and thus require a proper comparison with matches held under normal circumstances, which we associate with the pre-COVID-19 period.

Finally, the following leagues are incorporated: England, France, Germany, and Sweden. Regarding the English, French, and German leagues, matches are considered from season 2018–2019 until season 2021–2022. In these countries, season 2018–2019 was the last full season before COVID-19 as season 2019–2020 was already disrupted by the pandemic. The seasons of the Swedish league are structured differently, covering a calendar year rather than being split up into two consecutive years; therefore, games from the Swedish league are considered from season 2019 until season 2021. Furthermore, we also include Swedish games from season 2022 from match-week 1 until match-week 15, which marks the last round before a long summer break within the season. Even though this is not an entire season, this way, we could ensure the inclusion of post-COVID-19 data for all considered leagues. This contributes to the richness of the dataset as the timeline of this study moves beyond the COVID-19 period when regulations were implemented and also covers the period after COVID-19 when restrictions were lifted. In Sweden, season 2019 was the last full season held before the emergence of COVID-19.

As for the leagues other than the four aforementioned ones that are also recorded at SportsReferenceLLC (2022), we either do not have match scores from the pre-COVID-19 period or the attendance data for the post-COVID-19 period is poorly documented. Lockdown regulations varied among countries and even among regions; thus, without accurate attendance data, we cannot undoubtedly decide which game was held behind closed doors and which occurred in front of spectators. Table A1 in the Appendix lists these leagues and provides the reasons for exclusion from the examination.

We now discuss how the emergence of COVID-19 affected the four considered professional leagues in terms of lockdown regulations. Regarding England, attendance in the SportsReferenceLLC (2022) portal is neatly recorded. After the onset of the COVID-19 pandemic, games were cancelled for the remainder of season 2019–2020, and besides three exceptions (see Table A2 in the Appendix), all games were played behind closed doors in season 2020–2021. In season 2021–2022, all games were played in front of spectators. Similarly, games in the French league in season 2019–2020 were cancelled as well after the emergence of the COVID-19 pandemic. In the first six rounds of season 2020–2021, some games were played in front of spectators. Later on, all matches were played behind closed doors for the remainder of this season. Matches held in front of spectators were only resumed for season 2021–2022. Regarding the German league, after the onset of COVID-19 in season 2019–2020, games were postponed and played without spectators. In season 2020–2021, apart from the first seven rounds and the last round, matches were played behind closed doors. For season 2021–2022, games were once again played with regular fan attendance.

We cross-validated the reported data of SportsReferenceLLC (2022) with the Football-Lineups (2022) database. Without sufficient confirmation on the open/closed door issue, we exclude three games (see Table A2 in the Appendix), for which conflicting attendance data is given by the two data providers.

In Sweden, due to its particular timing, season 2020 started with a delay, and the first nine match-weeks were played behind closed doors; additionally, as confirmed in SVT (2020), restrictions were eased, and up to 50 spectators were allowed into the stadium for the games commencing with match-week 10. This is in line with the data obtained from SportsReferenceLLC (2022), where for most of the post-match-week 9 games, attendance is given as 50. For eight post-match-week 9 games with unrecorded attendance in SportsReferenceLLC (2022), we completed the numbers using the Football-Lineups (2022) database. Regarding season 2021, it started under the rule that allowed only eight people to attend games (Christenson, 2021; Wright, 2021). This rule is also reflected in the Football-Lineups (2022) database for the games before match-week 8. However, starting with match-week 8, normal attendance records in the range of 95–18537 are available in the Football-Lineups (2022) database and SportsReferenceLLC (2022). This indicates that the whole Swedish 2021 season was played in front of spectators, although the first seven rounds witnessed severe restrictions. Furthermore, we also include the first 15 match weeks of season 2022 as the attendance data are reported at normal levels. As discussed above, the severe restrictions led to several Swedish games being held with artificially low attendance; thus, we perform multiple tests for the Swedish league. In this regard, we perform one test in which the closed doors/open doors distinction is conducted literally by strictly separating games where no spectators were present against games with any positive number of supporters. A second test is also performed, in which games with up to 51 supporters are considered closed-doors games, and games beyond 51 supporters are considered

open-doors games. The choice of 50 spectators relies on the characteristics of the aforementioned restrictions of the Swedish 2020 season. In our view, this dual treatment supports the robustness of the analysis.

2. Methods

To comprehensively answer the *RQ*, dependent variables are chosen from the following list: home team's winning share, goals scored by the home/away teams, goal difference between the home and away teams, sum of goals of the home and away teams, yellow/red cards sanctioned to the home/away teams, difference in the yellow/red cards sanctioned to the home and away teams, sum of yellow/red cards sanctioned to the home and away teams. Apart from the variables concerning the yellow and red cards, we download data pertaining to all other dependent variables in a straightforward manner from SportsReferenceLLC (2022). Regarding the yellow and red cards, we use web scraping with Python software on a match level also from SportsReferenceLLC (2022). In line with the choice of most studies on home advantage and refereeing bias for men's football, we deem that these variables are standard to sufficiently perform the corresponding tests. The final dataset is available at Szabó (2022a).

Regarding the methodology, we apply fixed-effect panel regressions to answer the *RQ*. This method is well embedded in the literature concerning COVID-19, home advantage, and referee bias, and most studies mentioned in Section 1.1 used particular specifications of this method. By applying fixed-effect panel regressions, we can demonstrate the cause-effect relationship between two variables on panel data. The fixed effect refers to the possibility to adjust regression estimation by controlling for subject characteristics as multiple observations for the same subject exist in the panel data. We first apply the primary model; afterwards, we also run robustness tests by adding additional control variables to the primary model. In order to express the effect size, we report standardised coefficients for all regressions.

As the primary model, the following set of regression equations are estimated to answer the *RQ*:

$$y_{i,j,k,l,m} = \beta_1 \cdot Closed\ Doors_{i,j,k,l,m} + h_i + a_j + ls_k + r_l + \varepsilon_{i,j,k,l,m} \quad (1)$$

and

$$y_{i,j,l,m} = \beta_1 \cdot Closed\ Doors_{i,j,l,m} + hs_i + as_j + r_l + \varepsilon_{i,j,l,m} \quad (2)$$

where *Closed Doors* is a dummy variable taking value 1 if the game was played behind closed doors, and value 0 otherwise. The rest of the variables are fixed effects in Equation 1: h_i is a home team fixed effect, a_j is an away team fixed effect, ls_k is a league/season interaction fixed effect, and r_l is a referee fixed effect. In Equation 2, we apply stronger fixed effects; accordingly, we interact the home and away teams with the season in which the game was played, and we again apply the r_l referee fixed effect.

Equations 1–2 represent standard regressions on the research topic of this study. Applying these fixed effects, we control for time-invariant unobserved individual characteristics that can be correlated with the observed independent variables. The considered leagues are played in different countries with different players, and game characteristics change over the years; thus, it is essential to apply league/season fixed effects. As different teams have different strength levels and play styles, which can even differ when playing at home or away, we can capture these individual characteristics by controlling for the home and away teams. Furthermore, referees, as humans, have traits that distinguish them from each other. Page and Page (2010) found that the home advantage effect differs significantly among referees, and Goller and Krumer (2020) also confirmed that home advantage significantly differs between model specifications with and without a referee fixed effect. As the pool of referees is fixed for a season, and they tend to vary over time only slightly, we also control for the referee. Furthermore, one can argue that team characteristics are only fixed for a season as players leave and come after seasons are completed. Therefore, as displayed by Equation 2, we also run regressions where home and away teams are interacted with the seasons. Note that we run the regressions separately for all countries and also for the dataset that combines all observations from the four countries.

The primary model has been specified above, and our objective is also to confirm the robustness of the tests by adding further fixed effects and explanatory variables to the model. As such, we run a robustness test in which we include additional variables likely to influence the significance of the results. The additional fixed effects are the following: *Day* and *Match-up*; meanwhile, the additional explanatory variables are as follows: *Referee Season*, *Home 4 points*, *Home 4 cards*, *Away 4 points,* and *Away 4 cards*. In the following, we discuss what these controls represent exactly and provide theoretical justification for their inclusion.

Goller and Krumer (2020) discussed that games played on non-frequent days (non-frequent days are league dependent in their analysis and represent the four historically most non-frequent days when games take place) can be different in their characteristics. Thus, we seize traits caused by different days by including the *Day* fixed effect. We incorporate the *Match-up* fixed effect where we interact the two teams with each other because particular match-ups, such as derbies, can have their unique playing style, potentially substantially affecting the outcome of the match (Ponzo & Scoppa, 2018). On top of the *Referee* fixed effect, we can also control for the referees' experience by considering the number of games each referee has led in a particular season: *Referee Season*. As discussed in Gschwend and Krumer (2021), sports results are sensitive to the length of the fixed effects. It is a plausible assumption that referees' ability might vary over seasons; thus, to control for any season-to-season changes, we include the *Referee* fixed effect as an explanatory variable to the robustness test. We can similarly argue that teams, even within a given season, experience ups and downs; hence, it is useful to add related explanatory variables that are linked to a period shorter than a year. Therefore, following the treatment of Scoppa (2021), we also add explanatory variables such as *Home 4 points*, *Home 4 cards*, *Away 4 points*, and *Away 4 cards*. These variables measure the scored points/sanctioned cards over the previous four matches for the home/away teams. [1]

Regarding parameter estimations, previous studies have either used a linear model or a Poisson model. We follow the methodology of Krumer and Smith (2022) to use the Poisson regression model with pseudo-maximum likelihood (PML) estimation when the dependent variable is a count variable and the linear regression model with ordinary least squares estimation otherwise. Nonetheless, due to the issue of complete separation, we estimate specifications for the red cards dependent variables with linear regression models. Additionally, the robustness tests contain a large number of controls; thus, to again avoid complete separation, we use ordinary least squares (OLS) estimation for all the corresponding specifications. [2]

[1] For match weeks before the fifth round, we re-scaled the previous rounds' points/cards to make them comparable to the remaining match weeks' numbers. For match-week 1, we assumed that each team starts the season from the same neutral morale level; thus, we took the average of all the variables and assigned them to the teams in the first match week. Regarding cards, we included first yellow cards, second yellow cards, and also direct red cards with a factor of 2.

[2] For all PML estimations, we performed their OLS counterparts, and results in terms of significance remained unchanged. We also compared the β_1 values of the two estimation methods in Table A5 in the Appendix. Based on this, we conclude that there is no significant difference for any of the sub-samples between the effect sizes of the PML and OLS estimation methods.

3. Results

3.1. Data summary

An overview of the games from the different considered leagues and seasons can be found in Tables 1–2. Table 1 provides a breakdown of the data with respect to the number of open- and closed-doors games; additionally, the percentage of games won by the home and away teams are also presented. Overall, 427 closed-door games are considered, making up 21.54% of all considered games. Furthermore, we present seasonal attendance data for each league. Table 2 presents some descriptive statistics along with Cohen's d values of all variables treated as dependent variables in the regression framework. Table A1 in the Appendix also provides descriptive statistics and home-advantage-related information for those excluded women's football leagues that are additionally recorded in SportsReferenceLLC (2022). Moreover, we also explain why these leagues were not included in the analysis.

3.2. Regression results

Tables 3–4 present the results of the regressions corresponding to the primary model with 13 different dependent variables. Table 3 displays the results for the dependent variables linked with the final scoreline, while Table 4 displays the results for the dependent variables linked with the sanctioned yellow and red cards by the referee. The model specification follows either Equation 1 (left sub-column) or Equation 2 (right sub-column). We run the 26 regressions for all countries separately (sub-samples D-F) and also for the total dataset that combines all four countries (sub-sample A). To properly apply the fixed-effect panel regressions, we had to ensure the absence of any singleton observations; thus, we removed 75 games that were ruled by distinctive referees in the dataset. This results in a slightly lower observation number in Tables 3–4 as compared to Table 1.

As Table 3 demonstrates, none of the variables related to the final scoreline is statistically significantly affected by lockdown, no matter which group of controls we apply. These results hold for all sub-samples. Interestingly, we can see a small rise in home advantage for all sub-samples, even though the differences are insignificant.

Regarding sanctioned cards, the variables are statistically significantly affected for all sub-samples other than E, which corresponds to Sweden. Lockdown impacted the number of sanctioned yellow cards for the combined dataset and also for the sub-samples related to England, France, and Germany. When playing without spectators, referees tend to punish the players of the away teams with a significantly lower number of yellow cards (sub-samples A, C, and D) or tend to punish the players of the home teams with a significantly greater number of yellow cards (sub-sample B). Due to this behavioural change when lockdown is in force, significant differences in the variables related to yellow cards difference or total yellow cards are also observed for all the aforementioned sub-samples. Contrary to the case of yellow cards, the number of red cards awarded to any of the two teams is significantly influenced by the presence of lockdown only for sub-samples B and F and only when the controls linked with Equation 1 are used. Corresponding to sub-sample B, the referees in the Women's Super League sanction the players of the away teams with a significantly greater number of red cards when lockdown is in force; meanwhile, in sub-sample F, the referees in the Damallsvenskan sanction the players of the home teams with a significantly lower number of red cards when lockdown—considered as such up to 51 supporters—is in force.

Even though we report standardised coefficients in the corresponding tables, we now also mention the magnitude of the impact of the lockdown on the unstandardised scale. Regarding the French and German leagues, around a one-quarter to one-third drop in the number of yellow cards sanctioned to the away teams per game is observed due to the lockdown. In the English league, the increase in the number of yellow cards sanctioned to the home teams is close to one and a half cards per game, and the increase in the number of red cards sanctioned to the away teams is approximately one over twenty cards per game. In the Swedish league, regarding the significant result, the drop in the number of red cards sanctioned to the home teams is approximately one over fifty cards per game. The standardised coefficients of the tables are also called effect sizes and show how many standard deviations the dependent variable is expected to change, per standard deviation increase in the independent variable. By considering all countries, the effect size for the away yellow cards is around -0.1, no matter which set of controls is applied and the absolute effect size is smaller for all other variables. Regarding the individual countries, the largest effect sizes in absolute value are observed for the English league, where some of the absolute effect sizes exceed 0.3–0.4. We also present Cohen's f^2 (Cohen, 2013) values for all model specifications. These Cohen's f^2 values tend to be smaller when the dependent variable is linked with sanctioned cards; nonetheless, for most cases, the effect size is at least medium (Cohen's $f^2 \geq 0.15$).

The robustness of these results is confirmed in the Appendix with the

Table 1
Descriptive statistics. Categorization of the considered games.

Leagues	Seasons	# of matches			Attendance		% of wins	
		sum	open	closed	mean	max	home	away
England (Women's Super League)		459	331	128	1379	38,262	43.79%	39.43%
	2018–19	110	110	0	1008	5265	41.82%	44.55%
	2019–20	86	86	0	3101	38,262	52.33%	33.72%
	2020–21	131	3	128	8	457	38.93%	38.93%
	2021–22	132	132	0	1926	20,241	44.70%	39.39%
France (Division 1 Féminine)		491	389	102	659	30,661	44.60%	40.94%
	2018–19	132	132	0	902	25,907	46.97%	34.09%
	2019–20	96	96	0	1081	30,661	38.54%	44.79%
	2020–21	131	29	102	100	1500	48.09%	40.46%
	2021–22	132	132	0	664	13,497	43.18%	45.45%
Germany (Frauen-Bundesliga)		526	390	136	593	4520	47.53%	36.88%
	2018–19	132	132	0	833	3406	44.70%	34.85%
	2019–20	132	94	38	467	3245	53.03%	35.61%
	2020–21	131	35	96	89	752	46.56%	40.46%
	2021–22	131	129	2	799	4520	45.80%	36.64%
Sweden (Damallsvenskan)		495	434	61	547	18,537	48.48%	32.53%
	2019	132	132	0	852	3262	47.73%	28.03%
	2020	130	69	61	54	300	45.38%	38.46%
	2021	131	131	0	541	18,537	49.62%	28.24%
	2022	102	102	0	791	7877	51.96%	36.27%
Overall		1971	1544	427	781	38,262	46.17%	37.39%

Table 2
Differences between games behind closed doors and open doors for the main variables. For each variable, the first row illustrates the sample combining the four countries, and in the next four rows, we can see country-wise results.

League		Open door	Closed door	Difference	Cohen's d		Open door	Closed door	Difference	Cohen's d
England	Home win	46.24%	45.90%	−0.34%	0.007	Away win	36.91%	38.88%	1.96%	−0.040
		45.65%	39.06%	−6.58%	0.133		39.64%	38.28%	−1.36%	0.028
France		43.59%	49.02%	5.43%	−0.109		40.77%	41.18%	0.41%	−0.008
Germany		46.68%	50.00%	3.32%	−0.066		36.22%	38.97%	2.75%	−0.057
Sweden		48.63%	45.90%	−2.73%	0.055		32.05%	36.07%	4.02%	−0.085
England	Home goals	1.740	1.721	−0.019	0.010	Away goals	1.438	1.564	0.126	−0.076
		1.556	1.594	0.038	−0.022		1.414	1.555	0.140	−0.086
France		1.756	1.676	−0.080	0.041		1.456	1.529	0.073	−0.041
Germany		2.030	1.875	−0.155	0.081		1.707	1.647	−0.060	0.034
Sweden		1.607	1.721	0.114	−0.076		1.200	1.459	0.259	−0.181
England	Goal diff.	0.302	0.157	−0.145	0.051	Total goals	3.178	3.286	0.108	−0.053
		0.141	0.039	−0.102	0.037		2.970	3.148	0.178	−0.093
France		0.300	0.147	−0.153	0.050		3.213	3.206	−0.007	0.003
Germany		0.324	0.228	−0.096	0.031		3.737	3.522	−0.215	0.103
Sweden		0.407	0.262	−0.145	0.064		2.807	3.180	0.373	−0.200
England	Home yellows	0.983	1.108	0.125*	−0.123	Away yellows	1.131	1.091	−0.040	0.037
		0.907	1.078	0.171	−0.170		1.105	1.094	−0.011	0.010
France		1.190	1.529	0.340*	−0.303		1.323	1.353	0.030	−0.026
Germany		1.061	0.948	−0.113	0.113		1.219	0.941	−0.278**	0.267
Sweden		0.786	0.820	0.033	−0.040		0.902	0.984	0.081	−0.088
	Yellow diff.	−0.149	0.016	0.165*	−0.119	Total yellows	2.114	2.199	0.085	−0.055
England		−0.198	−0.016	0.183	−0.132		2.012	2.172	0.160	−0.101
France		−0.133	0.176	0.310	−0.202		2.513	2.882	0.369	−0.223
Germany		−0.158	0.007	0.165	−0.119		2.281	1.890	−0.391**	0.262
Sweden		−0.116	−0.164	−0.048	0.042		1.689	1.803	0.115	−0.085
	Home reds	0.012	0.007	−0.005	0.047	Away reds	0.022	0.014	−0.008	0.059
England		0.012	0.000	−0.012*	0.156		0.024	0.016	−0.008	0.060
France		0.018	0.010	−0.008	0.070		0.028	0.196	−0.008	0.056
Germany		0.008	0.007	−0.000	0.003		0.015	0.015	−0.001	0.005
Sweden		0.009	0.016	0.007	−0.065		0.020	0.000	−0.020**	0.204
	Red diff.	−0.010	−0.007	0.003	−0.021	Total reds	0.033	0.021	−0.012	0.072
England		−0.012	−0.016	−0.004	0.023		0.036	0.016	−0.020	0.129
France		−0.010	−0.010	0.000	−0.003		0.046	0.029	−0.017	0.076
Germany		−0.008	−0.007	0.000	−0.002		0.023	0.022	−0.001	0.006
Sweden		−0.011	0.016	0.028	−0.183		0.030	0.016	−0.013	0.088

help of the test we outlined in Section 2. Corresponding results for the whole sample are displayed in Tables A3–A4. We removed singleton match-up games; thus, the observation number decreased to 1864. These tables demonstrate that even after controlling for factors that potentially influence the outcome variables, results for the combined sample in terms of significance remain essentially unchanged. We still do not observe any statistically significant differences in the final match scorelines between games played with and without attendance. Moreover, the number of yellow cards issued to the away teams is statistically significantly lower when games are played under lockdown, and the size effect is still approximately −0.1 no matter which set of controls is used. Due to the additional explanatory variables, an increase in all Cohen's f^2 values is also observed, rendering all effect sizes to be large (Cohen's $f^2 \geq 0.35$).

4. Discussion

Table 1–2 indicate that home advantage was generally present in the considered leagues. By comparing them with Table A1, we can confirm that the magnitude of home advantage was around the same for the included and excluded leagues for the period of this study. The home teams' winning shares (46.17% and 45.21%) and away teams' winning shares (37.39% and 37.16%) were both very close to each other for the two groups, reassuring that the selected four countries are representative of women's football in terms of home advantage.

Regarding the regression framework, we have found evidence that the magnitude of home advantage is not substantially influenced by the presence of supporters. These findings hold for the aggregated sample and also league-wise as no statistically significant differences have been observed in any of the corresponding tests.

On the other hand, the related results suggest that crowds influence the referees as to how they sanction yellow cards in women's football games. This significant impact can be interpreted as the direct consequence of different levels of social pressure the referees face when games are played with and without supporters. When playing in front of the supporters of the home teams, referees' decisions might be subconsciously biased by attempts to please these supporters. As a consequent effect, referees might decide to give exceedingly severe punishment to the players of the away team or might be exceedingly forgiving towards the players of the home team. By removing this external pressure, referees' behaviour might be more adjusted. Alternatively, one can argue that the two teams' play styles are significantly different when no supporters are in the stadium, and the different number of awarded cards is only a natural reaction from the referee to the changed circumstances in the game. Nonetheless, the results concerning yellow cards hold for three out of the four examined leagues and also for the combined data sample. Therefore, we can conclude that for most leagues, the number of awarded yellow cards is influenced by the presence of supporters in women's football games. Notwithstanding, as discussed above, the substantial differences observed in the sanctioned cards do not translate to substantial differences in the final scorelines.

Tables A3–A4 reveal that the aforementioned results still hold when all the additional control variables have been added to the regression as explanatory variables. Having extended the model with the additional control variables, we still find a significant reduction in the number of yellow cards sanctioned to away players. Additionally, all the corresponding Cohen's f^2 values reveal large effect sizes, bolstering the practical implications of the results.

We can draw further conclusions. As highlighted by the comparison of Table A1 with Table 1, we have provided evidence that aligns with the literature (Pollard & Gómez, 2014) and proves the presence of a considerable home advantage in women's professional football. Based

Table 3
Estimation results to the RQ. The independent variable for all regressions is the Closed Doors binary variable. The dependent variable to the particular regression is denoted by column name. The first 12 rows contain regression results for six different sub-samples denoted by A, B, C, D, E, and F and concatenated with the examined country's name. Total refers to all four countries combined. E refers to the Swedish sub-sample, where the Closed Doors variable strictly separates games played with 0 versus greater than 0 spectators. F refers to the Swedish sub-sample, where the Closed Doors variable is 1 for games played with a maximum of 51 spectators and 0 for games played with more than 51 spectators. For all other four sub-samples, the Closed Doors variable strictly separates games played with 0 versus greater than 0 spectators. Obs. denotes the observation number in each sub-sample. Potential fixed effects are presented in subsequent rows. "YES" means the inclusion of the given fixed effect to the particular model specification, and "NO" means the omission of the given fixed effect from the particular model specification. We use OLS estimation for specifications I and IV and PML estimation for specifications II, III and V. Regarding Cohen's f^2 values, we present the corresponding results of the OLS estimation for all specifications.

	(I)		(II)		(III)		(IV)		(V)	
	Home win		Home goals		Away goals		Goals diff.		Total goals	
A Total	0.04	0.02	0.04	0.02	0.01	0.00	0.01	0.00	0.03	0.02
Obs. 1894	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
	0.85	1.23	0.94	1.30	0.85	1.17	1.50	2.02	0.29	0.49
B England	0.02	0.16	0.13	0.17	0.00	−0.05	0.05	0.07	0.00	0.02
Obs. 423	(0.10)	(0.10)	(0.09)	(0.11)	(0.21)	(0.29)	(0.15)	(0.22)	(0.11)	(0.14)
	1.06	1.54	1.02	1.32	0.78	1.15	1.50	1.97	0.28	0.49
C France	0.04	0.03	−0.01	0.00	0.05	0.03	−0.05	−0.04	0.02	0.04
Obs. 477	(0.04)	(0.04)	(0.07)	(0.05)	(0.06)	(0.07)	(0.06)	(0.05)	(0.05)	(0.06)
	0.91	1.28	0.96	1.32	0.84	1.17	1.53	2.11	0.26	0.43
D Germany	0.03	0.01	0.03	0.00	0.01	0.00	0.01	−0.01	0.01	0.00
Obs. 525	(0.05)	(0.05)	(0.04)	(0.05)	(0.05)	(0.06)	(0.04)	(0.05)	(0.04)	(0.04)
	0.85	1.22	1.00	1.42	1.01	1.23	1.78	2.32	0.24	0.41
E Sweden I	0.05	0.03	0.10	0.09	0.01	0.00	0.04	0.05	0.07	0.05
Obs. 469	(0.08)	(0.09)	(0.08)	(0.08)	(0.06)	(0.07)	(0.05)	(0.05)	(0.05)	(0.07)
	0.63	0.98	0.69	0.99	0.58	0.93	1.01	1.45	0.27	0.50
F Sweden II	0.02	0.04	0.03	0.04	−0.04	−0.04	0.05	0.05	−0.02	−0.02
Obs. 469	(0.03)	(0.07)	(0.05)	(0.05)	(0.07)	(0.09)	(0.04)	(0.06)	(0.05)	(0.05)
	0.63	0.98	0.68	0.98	0.59	0.94	1.02	1.45	0.27	0.49
Referee FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Home Team FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Away Team FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
League × Season FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Home Team × Season FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Away Team × Season FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES

Notes: ***, **; * indicate significance from zero at 0.1%, 1%, and 5% levels, respectively, two-sided tests. For each sample, the first row shows the standardised β coefficients, and the second row shows standard errors that are corrected for heteroskedasticity and to allow for clustering at the home team level. The third row shows Cohen's f^2.

on the results above, we can exclude crowd support as a possible reason for home advantage in women's football. Thus, the results imply that the source of home advantage in women's games is among other potential factors such as travel fatigue, familiarity, territoriality, special tactics, rule factors, and psychological factors (Pollard, 2006a, 2008).

Next, we compare the results of this study with the literature concerning the impact of COVID-19 on sports events. The cited papers (Scoppa, 2021; Benz & Lopez, 2021; Bryson et al., 2021; McCarrick et al., 2021; Reade et al., 2021; Wunderlich et al., 2021) agree that a drop in yellow cards given to the away teams is observed without the presence of fans. The effect of this significant drop is around one-third of yellow cards per game (see Bryson et al., 2021; Reade et al., 2021; Wunderlich et al., 2021). These results focusing on men's football are in accordance with the results of this present study. The effect of the drop in the number of cards sanctioned to the away teams is slightly lower (around one-fourth per game) for women's games but is nonetheless significant based on the majority of the tests. Other than Benz and Lopez (2021) who used a bivariate Poisson regression model for analysis, all studies observed either a significant or non-significant drop in home advantage due to lockdown. Interestingly, as for women's games, we observe a non-significant rise in home advantage due to lockdown. Additionally, the differences in referees' decision-making in terms of sanctioned yellow cards caused by lockdown are not extensive enough to have a significant impact on the final match scorelines. It is noteworthy that the magnitude of home advantage is already noticeably lower in women's football under normal circumstances than in men's football—the difference in home advantage was 5.8% for 26 European countries between 2004 and 2010 (Pollard & Gómez, 2014). Thus, there is less room for potential factors that would cause this phenomenon. The referee bias is likely not among these reasons.

We also relate the results of this study to the first and, so far, only study by Krumer and Smith (2022) who examined the effect of COVID-19 on home advantage in Swedish women's football games. They observed a non-significant drop in home advantage and a rise in the number of yellow cards sanctioned to the away teams after the emergence of COVID-19. It is to be noted, however, that the considered dataset of Krumer and Smith (2022) is different compared to the paper at hand; in this regard, Krumer and Smith (2022) only considered seasons 2019 and 2020 and made a direct comparison between the two seasons. We realise the peculiarity of the Swedish league since, as discussed in Section 1.2, restrictions caused artificially low attendance numbers. Therefore, we provide two tests for Sweden by either applying the Closed Doors variable verbatim (sub-sample *E*) or considering games with up to 51 spectators as closed-doors matches (sub-sample *F*). Thus, compared to Krumer and Smith (2022), we consider more seasons, and instead of distinguishing games by pre-COVID-19 and post-COVID-19 matches, we categorize each of the games by the number of spectators for both sub-samples *E* and *F*. We also note that Krumer and Smith (2022) compared similar sample sizes, whereas the present study over-represents open-doors games for both sub-samples *E* and *F*. Furthermore, the applied control variables are also slightly different. While both papers use a referee fixed effect, to capture the teams'

Table 4
Estimation results to the RQ. We use OLS estimation for specifications VIII, X, XI, XII, and XIII and PML estimation for specifications VI, VII and IX. Regarding Cohen's f2 values, we present the corresponding results of the OLS estimation for all specifications.

	(VI)		(VII)		(VIII)		(IX)		(X)		(XI)		(XII)		(XIII)	
	Home yellows		Away yellows		Yellow diff.		Total yellows		Home reds		Away reds		Red diff.		Total reds	
A Total	−0.01	0.00	−0.10***	−0.09**	0.08*	0.07	−0.06*	−0.05	0.03	0.02	−0.03	−0.04	0.04	0.04	−0.01	−0.02
Obs. 1894	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.02)	(0.03)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)
	0.39	0.66	0.30	0.57	0.28	0.51	0.39	0.71	0.15	0.37	0.13	0.33	0.13	0.35	0.14	0.33
B England	0.59***	0.51*	−0.17	−0.18	0.43***	0.39***	0.11	0.10	−0.12	−0.19	0.17***	−0.01	−0.21**	−0.10	0.07	−0.12
Obs. 423	(0.16)	(0.22)	(0.14)	(0.13)	(0.10)	(0.09)	(0.09)	(0.09)	(0.10)	(0.15)	(0.05)	(0.09)	(0.08)	(0.11)	(0.07)	(0.11)
	0.43	0.68	0.21	0.54	0.18	0.42	0.41	0.76	0.31	0.71	0.14	0.37	0.17	0.43	0.20	0.49
C France	0.09	0.09	−0.14**	−0.14**	0.27**	0.24**	−0.03	−0.03	0.01	0.03	−0.14	−0.15	0.12	0.14	−0.11	−0.10
Obs. 477	(0.06)	(0.06)	(0.05)	(0.05)	(0.09)	(0.09)	(0.04)	(0.04)	(0.04)	(0.06)	(0.14)	(0.13)	(0.11)	(0.10)	(0.11)	(0.12)
	0.41	0.74	0.27	0.47	0.27	0.51	0.39	0.66	0.12	0.28	0.13	0.30	0.12	0.34	0.12	0.26
D Germany	−0.09	−0.07	−0.13**	−0.09*	0.02	0.02	−0.11**	−0.08*	0.06	0.06	0.04	0.04	0.00	0.00	0.07	0.07
Obs. 525	(0.05)	(0.07)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.06)	(0.06)	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.05)
	0.29	0.51	0.37	0.62	0.32	0.55	0.33	0.59	0.13	0.27	0.13	0.30	0.13	0.28	0.13	0.30
E Sweden I	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	−0.01	−0.04	−0.09	−0.11	0.07	0.07	−0.07	−0.10
Obs. 469	(0.08)	(0.09)	(0.08)	(0.07)	(0.07)	(0.08)	(0.06)	(0.05)	(0.11)	(0.10)	(0.07)	(0.08)	(0.09)	(0.09)	(0.08)	(0.09)
	0.29	0.58	0.28	0.57	0.40	0.58	0.20	0.57	0.10	0.36	0.15	0.36	0.12	0.36	0.15	0.36
F Sweden II	0.03	0.01	−0.02	−0.05	0.03	0.04	0.00	−0.02	−0.11*	−0.01	−0.07	−0.01	−0.01	0.00	−0.12***	−0.01
Obs. 469	(0.06)	(0.08)	(0.09)	(0.08)	(0.05)	(0.07)	(0.06)	(0.06)	(0.05)	(0.01)	(0.05)	(0.01)	(0.06	(0.01)	(0.03)	(0.01)
	0.29	0.58	0.28	0.57	0.41	0.58	0.20	0.57	0.11	0.37	0.15	0.36	0.11	0.36	0.16	0.36
Referee FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Home Team FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Away Team FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
League × Season FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Home Team × Season FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Away Team × Season FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES

Notes: ***, **; * indicate significance from zero at 0.1%, 1%, and 5% levels, respectively, two-sided tests. For each sample, the first row shows the standardised β coefficients, and the second row shows standard errors that are corrected for heteroskedasticity and to allow for clustering at the home team level. The third row shows Cohen's f^2.

relative strengths and traits, we use a home-team and away-team fixed effect, whereas Krumer and Smith (2022) used betting odds for the home and away wins. The results we obtained for the Swedish leagues are different than that of Krumer and Smith (2022) as we did not find any statistically significant results for sub-sample *E* and found a significant drop in the number of red cards sanctioned to the home teams for sub-sample *F* when applying one set of the controls. This can be explained by the aforementioned differences in the treatment of the tests. Nonetheless, note that the Swedish league is also unique among the four considered leagues in this study as the shared results of the other three leagues are not in harmony with the results of Sweden.

Finally, we can answer the *RQ*. Ultimately, we found no evidence that lockdown affects the magnitude of home advantage. On the other hand, lockdown statistically significantly influences the number of sanctioned cards in a way that leads to less severe punishment for the players of the away teams.

On another note, we must acknowledge the limitations of this study. The combined dataset of this study is shorter and contains fewer leagues than the articles on men's football. This is partially due to a lack of access to more accurate datasets and partially due to a lower number of professional women's football leagues around the world. Future research is recommended to involve more leagues to confirm the conclusions and assess the uniqueness of the Swedish league. Moreover, not including any within-match dominance or performance related variable is a further limitation of this paper. By having access to broader match statistics such as the number of total shots, number of total shots on target, number of corners, and so on would help us incorporate a variable related to team dominance or team performance. By doing so, a mediation analysis could be performed (see McCarrick et al., 2021; Bilalić et al., 2021 for men's football), in which, outcome, team performance, and referee decisions can be analysed in one joint statistical model. We also note that the teams' possibility to train and travel might have been impaired during COVID-19, and these potential changes could have had an effect on travel fatigue that can be examined in future studies.

5. Conclusion

After the emergence of the COVID-19 pandemic, scores of papers have investigated the relationship between home advantage and spectator attendance for men's professional football. In this context, this study contributes to the literature and fills a substantial gap by examining the effect of lockdowns on women's professional football games. We have considered games from four women's leagues (England, France, Germany, and Sweden) where during the post-COVID-19 period, different lockdown measures were in force. The findings indicate that the magnitude of home advantage is unaffected by closed-door games as we do not observe a significantly lower or higher share of games won by the home team when spectators are not allowed into the stadium. On the other hand, the number of yellow cards sanctioned to the players of the away teams is affected by spectators. In this regard, without spectators, for three out of the four leagues and also for the combined sample, the number of sanctioned yellow cards is statistically significantly affected in favour of the away teams. We have provided possible explanations for this phenomenon; for instance, the referees are subconsciously biased by the presence of supporters, or the teams' play styles are different when no spectators are present at the stadium.

Furthermore, we have related this study to the corresponding literature. The sole paper by Krumer and Smith (2022) concerning the impact of COVID-19 on women's football only examined the Swedish league and found results that are not entirely in line with the findings of the present study. Possible reasons regarding the methods and datasets have been provided to explain these differences; however, most importantly, note that the Swedish league is unique in this study as it is the exception in terms of the significance of the obtained results. Nonetheless, our results are mostly in line with the several papers that considered men's football. Collating these articles, we are unable to provide a definitive answer whether or not home advantage is affected by the presence of supporters for men's football, but these articles all agreed that the number of yellow cards sanctioned to the players of the away teams is reduced without fans.

To sum up, we have extended the literature on home advantage and women's football. Overall, we assert that some conclusions drawn for men's football regarding lockdown are transferable to women's football. These results are important for social scientists, sports economists, and psychologists. Based on the findings, sports psychologists are advised to train referees to become immune to spectator bias. Future studies can address the aforementioned limitations of this study to gain a better understanding of the potential causes of the results.

Data availability

I have shared the link to my data at the Attach file step

Appendices.

Categorization of leagues excluded from the analysis.

Leagues	Seasons	# of matches	% of wins		Reason for exclusion
			home	away	from the analysis
Australia		232	44.83%	39.22%	No closed-doors matches
(Australian	2018–19	54	50.00%	31.48%	
A-League Women)	2019–20	54	46.30%	42.59%	
	2020–21	54	50.00%	35.19%	
	2021–22	70	35.71%	45.71%	
Austria		168	43.45%	43.45%	No pre-COVID-19 matches
(ÖFB-Frauenliga)	2020–21	78	38.46%	46.15%	
	2021–22	90	47.78%	41.11%	
Belgium		180	46.11%	43.89%	No pre-COVID-19 matches
(Belgian Women's	2020–21	90	43.33%	44.44%	
Super League)	2021–22	90	48.89%	43.33%	
Brazil		480	47.92%	33.13%	No attendance information
(Campeonato Brasileiro	2019	120	50.00%	34.17%	
de Futebol Feminino	2020	120	47.50%	40.00%	
Série A1)	2021	120	42.50%	30.83%	
	2022	120	51.67%	27.50%	
Denmark		273	44.69%	39.19%	No attendance information
(Kvindeligaen)	2019–20	71	39.44%	43.66%	

(*continued on next page*)

(*continued*)

Leagues	Seasons	# of matches	% of wins		Reason for exclusion
			home	away	from the analysis
	2020–21	86	52.33%	36.05%	
	2021–22	116	42.24%	38.79%	
Italy		491	45.21%	39.71%	No attendance information
(Serie A Femminile)	2018–19	132	46.21%	39.39%	
	2019–20	95	42.11%	38.95%	
	2020–21	132	47.73%	37.88%	
	2021–22	132	43.94%	42.42%	
Japan		110	36.36%	36.36%	No pre-COVID-19 matches
(WE League)	2021–22	110	36.36%	36.36%	
Netherlands		284	47.89%	34.51%	No attendance information
(Eredivisie Vrouwen)	2018–19	72	54.17%	33.33%	
	2019–20	48	37.50%	39.58%	
	2020–21	56	42.86%	37.50%	
	2021–22	108	50.93%	31.48%	
Norway		534	45.13%	36.33%	No closed-doors matches
(Toppserien)	2018	132	47.73%	34.85%	
	2019	132	40.91%	35.61%	
	2020	90	45.56%	32.22%	
	2021	90	50.00%	40.00%	
	2022	90	42.22%	40.00%	
Switzerland		90	50.00%	41.11%	No pre-COVID-19 matches
(Women's Super League)	2021–22	90	50.00%	41.11%	
USA		336	42.86%	32.14%	No closed-doors matches
(National Women	2018	108	39.81%	32.41%	
Soccer League)	2019	108	43.52%	35.19%	
	2020				(Cancelled season)
	2021	120	45.00%	29.17%	
Overall		**3178**	**45.21%**	**37.16%**	

Table A1
Categorization of leagues excluded from the analysis.

Leagues	Seasons	# of matches	% of wins		Reason for exclusion
			home	away	from the analysis
Australia		232	44.83%	39.22%	No closed-doors matches
(Australian A-League Women)	2018–19	54	50.00%	31.48%	
	2019–20	54	46.30%	42.59%	
	2020–21	54	50.00%	35.19%	
	2021–22	70	35.71%	45.71%	
Austria		168	43.45%	43.45%	No pre-COVID-19 matches
(ÖFB-Frauenliga)	2020–21	78	38.46%	46.15%	
	2021–22	90	47.78%	41.11%	
Belgium		180	46.11%	43.89%	No pre-COVID-19 matches
(Belgian Women's Super League)	2020–21	90	43.33%	44.44%	
	2021–22	90	48.89%	43.33%	
Brazil		480	47.92%	33.13%	No attendance information
(Campeonato Brasileiro de Futebol Feminino Série A1)	2019	120	50.00%	34.17%	
	2020	120	47.50%	40.00%	
	2021	120	42.50%	30.83%	
	2022	120	51.67%	27.50%	
Denmark		273	44.69%	39.19%	No attendance information
(Kvindeligaen)	2019–20	71	39.44%	43.66%	
	2020–21	86	52.33%	36.05%	
	2021–22	116	42.24%	38.79%	
Italy		491	45.21%	39.71%	No attendance information
(Serie A Femminile)	2018–19	132	46.21%	39.39%	
	2019–20	95	42.11%	38.95%	
	2020–21	132	47.73%	37.88%	
	2021–22	132	43.94%	42.42%	
Japan		110	36.36%	36.36%	No pre-COVID-19 matches
(WE League)	2021–22	110	36.36%	36.36%	
Netherlands		284	47.89%	34.51%	No attendance information

(*continued on next page*)

Table A1 (*continued*)

Leagues	Seasons	# of matches	% of wins		Reason for exclusion
			home	away	from the analysis
(Eredivisie Vrouwen)	2018–19	72	54.17%	33.33%	
	2019–20	48	37.50%	39.58%	
	2020–21	56	42.86%	37.50%	
	2021–22	108	50.93%	31.48%	
Norway		534	45.13%	36.33%	No closed-doors matches
(Toppserien)	2018	132	47.73%	34.85%	
	2019	132	40.91%	35.61%	
	2020	90	45.56%	32.22%	
	2021	90	50.00%	40.00%	
	2022	90	42.22%	40.00%	
Switzerland		90	50.00%	41.11%	No pre-COVID-19 matches
(Women's Super League)	2021–22	90	50.00%	41.11%	
USA		336	42.86%	32.14%	No closed-doors matches
(National Women Soccer League)	2018	108	39.81%	32.41%	
	2019	108	43.52%	35.19%	
	2020				(Cancelled season)
	2021	120	45.00%	29.17%	
Overall		**3178**	**45.21%**	**37.16%**	

Table A2
Matches regarded as exceptions.

Match		Reason
1	Chelsea vs. West Ham United – December 6, 2020	Open Door, Attendance: 266
2	Brighton & Hove Albion vs. Chelsea – December 13, 2020	Open Door, Attendance: 457
3	Brighton & Hove Albion vs. Reading – December 20, 2020	Open Door, Attendance: 365
4	Werder Bremen vs. SV Meppen – October 14, 2020	No definitive attendance information
5	Carl-Zeiss Jena vs. Turbine Potsdam – February 6, 2022	No definitive attendance information
6	Paris Saint-Germain vs. Montpellier – October 10, 2020	No definitive attendance information

Table A3
Estimation results to the *RQ*. The dependent variable to the particular regression is denoted by column name, and the applied fixed effects are also clarified for each regression. The *Closed Doors* binary variable is 0 if the match was played in front of spectators and 1 if the match was played behind closed doors. For all specifications, OLS estimation is used. Potential fixed effects are presented in different rows. "YES" means the inclusion of the given fixed effect to the particular model specification, and "NO" means the omission of the given fixed effect from the particular model specification.

	(I)		(II)		(III)		(IV)		(V)	
	Home win		Home goals		Away goals		Goals diff.		Total goals	
Closed Doors	0.06	0.05	0.03	0.02	0.01	0.00	0.02	0.01	0.03	0.06
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.05)	(0.03)
Referee Season	0.05	0.04	0.04	0.04	−0.07	−0.07	0.06	0.06	−0.02	0.05
	(0.05)	(0.06)	(0.06)	(0.07)	(0.06)	(0.07)	(0.05)	(0.05)	(0.08)	(0.05)
Home 4 Points	−0.03	−0.18***	−0.03	−0.09*	0.01	0.09	−0.03	−0.11**	−0.02	−0.03
	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.03)	(0.04)	(0.05)	(0.03)
Away 4 Points	−0.02	0.07	−0.05	0.02	0.03	−0.04	−0.05	0.04	−0.02	−0.02
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)
Home 4 Cards	−0.02	−0.05	−0.01	−0.01	0.02	0.03	−0.02	−0.03	0.00	−0.02
	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)
Away 4 Cards	0.04	0.05	−0.01	−0.02	−0.02	−0.02	0.01	0.00	−0.03	0.04
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)
Referee FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Day FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Home Team FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Away Team FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Match-up FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
League × Season FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Home Team × Season FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Away Team × Season FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Obs.	1864	1864	1864	1864	1864	1864	1864	1864	1864	1864
Cohen's f^2	1.43	2.23	1.60	2.28	1.51	2.11	2.30	3.30	0.78	1.14

Notes: ***, **; * indicate significance from zero at 0.1%, 1%, and 5% levels, respectively, two-sided tests. Standard errors (reported in parentheses) are corrected for heteroskedasticity and to allow for clustering at the home team level. Regression coefficients are standardised.

Table A4

Estimation results to the *RQ*. The dependent variable to the particular regression is denoted by column name, and the applied fixed effects are also clarified for each regression. The *Closed Doors* binary variable is 0 if the match was played in front of spectators and 1 if the match was played behind closed doors. For all specifications, OLS estimation is used. Potential fixed effects are presented in different rows. "YES" means the inclusion of the given fixed effect to the particular model specification, and "NO" means the omission of the given fixed effect from the particular model specification.

	(VI)		(VII)		(VIII)		(IX)		(X)		(XI)		(XII)		(XIII)	
	Home yellows		Away yellows		Yellow diff.		Total yellows		Home reds		Away reds		Red diff.		Total reds	
Closed Doors	0.00	0.00	−0.11*	−0.09*	0.08	0.07	−0.07	−0.07	0.01	0.00	−0.03	−0.04	0.03	0.03	−0.01	−0.03
	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)
Referee Season	0.05	0.09	0.07	0.08	−0.01	0.00	0.08	0.12	−0.07	−0.07	0.06	0.07	−0.09	−0.1	0.00	0.02
	(0.09)	(0.09)	(0.07)	(0.08)	(0.08)	(0.1)	(0.07)	(0.08)	(0.1)	(0.12)	(0.07)	(0.09)	(0.09)	(0.12)	(0.07)	(0.09)
Home 4 Points	−0.06	−0.03	−0.01	0.00	−0.04	−0.02	−0.04	−0.01	0.00	0.04	−0.03	−0.06	0.02	0.08	−0.02	−0.03
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.06)
Away 4 Points	0.02	0.00	−0.02	−0.05	0.04	0.04	0.00	−0.03	0.03	0.02	−0.04	−0.03	0.05	0.04	−0.01	−0.01
	(0.04)	(0.05)	(0.03)	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.06)	(0.04)	(0.05)	(0.04)	(0.05)
Home 4 Cards	−0.01	−0.08	0.05	0.04	−0.05	−0.09	0.03	−0.02	−0.04	−0.03	0.00	−0.01	−0.03	−0.01	−0.02	−0.03
	(0.03)	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)
Away 4 Cards	−0.01	−0.02	0.00	−0.05	−0.01	0.02	0.00	−0.05	0.00	−0.02	−0.04	−0.05	0.03	0.03	−0.04	−0.06
	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.05)	(0.03)	(0.04)	(0.03)	(0.04)
Referee FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Day FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Home Team FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Away Team FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
League × Season FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Match-up FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Home Team × Season FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Away Team × Season FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Obs.	1864	1864	1864	1864	1864	1864	1864	1864	1864	1864	1864	1864	1864	1864	1864	1864
Cohen's f^2	0.79	1.28	0.79	1.30	0.68	1.09	0.88	1.47	0.48	0.87	0.51	0.93	0.47	0.91	0.53	0.90

Notes: ***, **; * indicate significance from zero at 0.1%, 1%, and 5% levels, respectively, two-sided tests. Standard errors (reported in parentheses) are corrected for heteroskedasticity and to allow for clustering at the home team level. Regression coefficients are standardised.

Table A5

Estimation results to test equality of β_1 coefficients from the OLS($\beta_{1,\mathrm{OLS}}$) and PML($\beta_{1,\mathrm{PML}}$) estimation methods. The following Z test is applied: $= \frac{\beta 1,\mathrm{OLS} - \beta 1,\mathrm{PML}}{\sqrt{(SE_{\beta 1,\mathrm{OLS}})^2 + (SE_{\beta 1,\mathrm{PML}})^2}}$, where SE_β denotes the standard error of β.

	(II)		(III)		(V)		(VI)		(VII)		(IX)	
	Home goals		Away goals		Total goals		Home yellow		Away yellow		Total yellow	
Z test value	0.16	0.07	−0.10	−0.26	−0.42	−0.29	0.01	0.13	0.12	0.26	0.54	0.62
A Total: Obs. 1894	(0.87)	(0.95)	(0.92)	(0.79)	(0.67)	(0.77)	(0.99)	(0.90)	(0.91)	(0.80)	(0.59)	(0.53)
Z test value	0.32	0.27	0.13	−0.05	0.00	−0.10	0.40	0.27	0.01	−0.06	−0.09	−0.10
B England: Obs. 423	(0.75)	(0.79)	(0.90)	(0.96)	(1.00)	(0.92)	(0.69)	(0.79)	(0.99)	(0.95)	(0.93)	(0.92)
Z test value	0.06	−0.05	−0.19	−0.40	−0.18	−0.18	−0.51	−0.39	0.59	0.48	0.18	0.20
C France: Obs. 477	(0.96)	(0.96)	(0.85)	(0.69)	(0.86)	(0.86)	(0.61)	(0.70)	(0.55)	(0.63)	(0.86)	(0.84)
Z test value	0.10	0.13	0.07	−0.03	−0.14	0.02	0.19	0.30	0.03	0.24	0.73	0.74
D Germany: Obs. 525	(0.92)	(0.90)	(0.95)	(0.97)	(0.89)	(0.99)	(0.85)	(0.76)	(0.97)	(0.81)	(0.47)	(0.46)
Z test value	0.15	0.11	−0.14	−0.07	−0.39	−0.30	−0.03	−0.05	−0.05	0.09	−0.04	0.13
E Sweden I: Obs. 469	(0.88)	(0.92)	(0.89)	(0.95)	(0.70)	(0.77)	(0.97)	(0.96)	(0.96)	(0.93)	(0.97)	(0.90)
Z test value	0.15	0.23	0.29	0.19	0.14	0.10	0.08	0.00	−0.05	−0.13	−0.03	0.03
F Sweden II: Obs. 469	(0.88)	(0.82)	(0.77)	(0.85)	(0.89)	(0.92)	(0.94)	(1.00)	(0.96)	(0.90)	(0.98)	(0.97)
Referee FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Home Team FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Away Team FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
League × Season FE	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Home Team × Season FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Away Team × Season FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES

Notes: ***, **; * indicate significance from zero at 0.1%, 1%, and 5% levels, respectively, two-sided tests. *p* values corresponding to the *Z* test are reported in parentheses.

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