How the COVID-19 Pandemic has Changed the Game of Soccer

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ABSTRACT

This study explores the influence of corona-specific training and playing conditions - especially empty stadiums - on match performance, contact behavior, and home advantage in the Bundesliga (BL) and Bundesliga 2 (BL2). We analyzed the 2017/18, 2018/19, and 2019/20 seasons and compared matches in rounds 26–34 before shutdown with "ghost" matches after restart. Results show increased running activity for high intensity distance: (+6.1%) and total distance covered (+4.3%). In BL2 in particular there were also changes in tactical aspects of the game (time in last third: –6.3%, pressure on pass receiver: –8.6%, success of attacking duels: –7.9%, share of long passes completed: +15.6%, outplayed opponents per pass: –14.7%). Contact time to other players (<2 m distance) was 15:35 mins per match. After restart, contact was reduced, especially when the ball was not in the last third (–11.2%). Away wins increased by +44.2% in BL and the home-away difference in yellow cards changed in favor of the away team (+31.2%) in BL2. We conclude that empty stadiums have reduced home advantage and decreased referee bias when awarding yellow cards. Player behavior might have been affected by tactical demands and/or conscious or unconscious self-protection.

Introduction

The COVID-19 pandemic presents an unprecedented challenge for human societies. The novelty of the virus and the lack of knowledge about its potential dangers [1] have led to much uncertainty on how to respond to it [2]. Governments have introduced various restrictions that are affecting nearly all parts of public and private life, from trading [3], education [4], public transport [5], healthcare [6], and tourism [7] to the way we celebrate our birthdays. The extent of the long-term consequences is hard to predict [8], but the corona crisis is certainly one of the greatest disruptions of recent decades.

On a smaller scale, the COVID-19 pandemic has also affected the world of professional soccer. When the World Health Organization (WHO) declared the coronavirus outbreak a pandemic on March 11, 2020, soccer leagues in 105 countries canceled their competitions within seven days [9] and the European Football Federation (UEFA) postponed the European Championship until 2021. This measure puts significant financial pressure on clubs since revenues from television marketing and ticket sales were immediately lost [10, 11]. On May 16, after eleven weeks of shut down, Germany's professional soccer leagues were the first important sport

leagues worldwide to restart their competitions under strict restrictions. The most crucial ones were corona-specific rules for training and the exclusion of spectators from stadiums, which led to so-called "ghost games."

Against this background, the question arises whether and how the game of soccer has changed under the conditions of the COVID-19 pandemic. Our paper contributes to this question by exploring the influence of new conditions on match performance, home advantage, and player contact behavior in German professional soccer. There are good reasons to believe that player match performance was diminished after restart. Teams had only a very short preparation phase with non-optimal conditions for training that might have affected physical fitness and playing skills. Training routines had to be changed, e. g., by practicing in smaller groups [12], and there were no trial games against other teams. From a psychological perspective, players have had to cope with a potentially stressful situation: they were frequently PCR-tested and had to observe strict quarantine in the week before matches without being able to meet with family and friends [13]. Therefore, team managers of Bundesliga clubs sought to downplay unrealistic public expectations of player performance [14].

The second issue addressed by the present paper deals with the contact behavior of players during matches. We define contact in this context as a distance between players closer than 2 meters, which is in line with the recommendation of most national health authorities to minimize the risk of coronavirus infection [15]. Some players were afraid of infection [16] and one could argue that they might have tried, consciously or unconsciously, to reduce contact with other players – either for their own protection or by transferring social distancing rules from everyday life to the competition. Either way, this study aims to provide a systematic overview of contact time in soccer – especially in which situations players are exposed to others. Other studies have used similar approaches to quantify personal interaction in soccer during the coronavirus pandemic but focused on different aspects [17] and use data of from a single match only [18].

In the third section, this paper contributes to the discussion on home advantage, which has been reported in many sports [19, 20]. Home advantage is explained by several factors, including familiarity with the environment [21], higher self-confidence of home players [22], and travel factors, such as distance and altitude [23, 24]. Research has also shown that the crowd influences referees' decisions in favor of home teams with regard to extra time [25, 26], and awarding penalties [27, 28] and yellow cards [29, 30]. Ghost games provide a good opportunity for studying crowd influence. Previous studies analyzed 21 ghost games played in the Italian league in 2007 [31, 32], as well as 160 ghost games played between 2002 and April 2020 in multiple European leagues [33]. Although this research provides a good starting point, it lacks statistical power and control variables. Ghost games during the corona crisis are much better suited to study the effects of empty stadiums, because there are homogenous conditions in terms of performance level, participating teams, environmental factors, and a closed time frame. There are already three other studies available studying home advantage in the context of the COVID-19 pandemic [34–36]. By contrast, the present study uses a different study design, larger longitudinal sample, and partly different and more enhanced performance variables based on spatiotemporal data. A comparison of method and results can be found in the discussion section below.

This study answers the following questions: whether there was (1) a change in match performance, (2) a change in contact behavior, and (3) a decrease of home advantage in especially German Bundesliga ghost games. Match performance and home advantage are analyzed in the areas of attacking performance, passing characteristics, competing for ball and running activity. For this, we use a set of traditional and more complex performance indicators derived from spatiotemporal tracking data, such as expected goals, pressure in passing, and outplayed opponents as well as contact time for describing player contacts. According to these indicators, the study compares matches from the three seasons before shutdown with the matches after the restart. In addition, our analysis explores performance differences between the Bundesliga and Bundesliga 2, between home and away teams in general, and whether player adapted to the new conditions after a few rounds up to the end of the season. Our findings provide information about the prevalence of player contacts and can help competition owners and federations to understand the influence of officials on the game. Coaches and performance analysts might use results to counteract unwanted developments and to improve training and competition.

Materials and Methods

Sample

Our study applies a non-participating observational approach based on the natural-experimental setting during the COVID-19 pandemic. The sample comprises all matches of German professional soccer in the Bundesliga (BL) and Bundesliga 2 (BL2) during the seasons 2017/18, 2018/19, and 2019/20 (TOTAL). In order to consider potential seasonal influences, we divided the seasons into four quarters: Q1 (round 1–9), Q2 (round 10–17), Q3 (round 18–25), and Q4 (round 26–34). Analysis of home advantage uses subsample PRECORONA containing all matches of seasons 2017/18, 2018/19 and Q1-Q3 of 2019/20 before the coronavirus season break as a baseline. To analyze match performance and contact behavior, we use subsample PRECORONA Q4, which comprises the Q4 matches of seasons 2017/18, 2018/19 only (sample overview see ▶ **Table 1**). The subsample AFTER RESTART consists of the Q4 in 2019/20 season matches, which are the ghost matches after the restart. To analyze whether a player adapted to the new conditions after a few rounds, we divide AFTERRESTART in two subsamples: AFTERRESTART 1–4 (round 26–29) and AFTERRESTART 5–9 (round 30–34). Because each player agreed to data recording in matches on signing their player license, special approval for this study from an ethics committee was not required. Nevertheless, all procedures performed in the study meet the ethical standards of this journal [37].

Performance indicators

For each match, we collected the general parameters Gross Playing Time, Net Playing Time (time without match interruptions) (both in mins) and the Air Temperature (in °C) at kick off, which was

▶ **Table 1** Number of statistical units for match performance analysis (matches) and contact behavior analysis (player × matches), Gross Playing Time, Net Playing Time and Air Temperature by subsample.

Subsample		Matches	Player × Matches	Gross Playing Time	Net Playing Time	Air Temperature
PRECORONA	BL	789	11118	94:30 ± 1:59	55:54 ± 4:13	10.4 ± 7.8
	BL2	760	10764	94:42 ± 1:51	54:34 ± 4:28	10.2 ± 7.7
PRECORONA Q4	BL	138	2092	94:03 ± 2:04	57:20 ± 4:13	16.4 ± 6.9
	BL2	139	2159	94:32 ± 1:57	54:02 ± 4:16	15.0 ± 6.9
AFTERRESTART	BL	67	878	94:59 ± 2:03	57:15 ± 4:45	21.1 ± 4.2
	BL2	69	869	94:59 ± 1:46	56:27 ± 5:16	20.3 ± 4.3

gathered from the German weather service. Attacking performance was measured by the number of Goals, Shots At Goals, Expected Goals (xG) (all in #), Ball Possession and Ball Possession in Last Third (both in share of Net Playing Time) (all in %). The variable xG describes the most likely result of the match. It was modelled by using, among others parameters, distance and angle of the shooting player towards the goal, and position of defenders as shown by [38]. Match Outcome was quantified in the categories Home Win, Away Win, and Draw.

Passing characteristics are denoted by the number of Passes (#), Long Passes (> 30 m) (share of all Passes), Passes Completed, Long Passes Completed (all in %) and Outplayed Opponents, Pressure on Passing Player and Pressure on Receiving Player (all per Pass; 0.0 ≙ no pressure, 1.0 ≙ maximum pressure). Outplayed Opponents represent the difference of opponents closer to the goal before and after the pass as proposed by [39]. Pressure was modelled by using distance of the Ball Possession Player to near the nearest opponent at the moment of passing or receiving the pass such as described by [40]. Competing for ball was analyzed by number of Duels (#), Duels Won by Player with Ball Possession (%), Fouls Committed, and Yellow Cards (#). Running Activity was quantified by using Total Distance Covered and High Intensity Distance (with speed > 5.0 m/s) (in km).

To quantify contact behavior, we calculated contact times for each player and match from spatiotemporal data. The variable Contact Time (in mins) represents the time in which a player is closer than 2 m to at least one other player. Contact Time Teammate and Contact Time Opponent denote the same, but for players of the same team or the opponent team only. Comprehensive definitions and specifications of used parameters can be found here [41].

All variables were derived from raw event data and spatiotemporal data of players and the ball collected by the DFL. Positions were recorded in 25 Hz using a semi-automatic optical tracking system (TRACAB; ChyronHego Corp., Melville, NY, USA). Validity and reliability of this system was verified here [42] . Before deriving performance indicators, raw data was filtered by using a 5^{th}-order 1.0-Hz Butterworth filter. Event data was collected by professional data loggers based on video recordings. The validity and reliability of event data collection by competition service providers was secured by the DFL as in previous studies [43].

Statistical analysis

Analysis of match performance and home advantage (Questions 1 and 3) uses matches as statistical units. Matches with red cards were excluded. We calculated Match Performance (MP) per match accumulated for both teams and normalized it to mean net playing time in TOTAL. ▶ **Fig. 1** shows MP for each performance indicator in PRECORONA Q4 as mean and standard deviation (M ± SD) and the difference in Match Performance (ΔMP) between PRECORONA Q4 and AFTER RESTART per league. For performance indicators showing significant differences between PRECORONA Q4 and AFTER RESTART, we also report performance differences between PRECORONA Q4 and AFTER RESTART 1–4 as well as PRECORONA Q4 and AFTER RESTART 5–9 (▶ **Fig. 2**).

Analysis of contact behavior uses players × matches as statistical units (Question 2). Goalkeepers and players with less than 85 mins gross playing time per match and entire matches with red cards were excluded. We calculated Contact Times for various conditions: condition ALL refers to all moments of the match, conditions IN PLAY / OUT OF PLAY aggregate moments according to the ball state. Condition PLAYER WITH BALL POSSESSION comprises all situations where the ball was IN PLAY and a player had possession of the ball. The algorithm checks, among other things (as described by [44]), whether the player is the closest to the ball and not more than 2 m away. Condition IN LAST3RD indicates ball possession in the attacking third. Conditions PLAYER WITHOUT BALL POSSESSION and NOT IN LAST 3RD represent the complementary conditions. Condition AFTER GOAL refers to the next 30 seconds after a goal (or the subsequent kick-off if time is shorter). Contact Time (CT) represents the accumulated contact time in a condition; the Relative Contact Time (RCT) is defined as the quotient of CT and the total time spent in a condition. ▶ **Fig. 3** visualizes M ± SD of CT in condition ALL, grouped by season, quarter, and league. ▶ **Fig. 4** reports CT and RCT (both M ± SD) in PRECORONA Q4 and differences (ΔRCT) between PRECORONA Q4 and AFTER RESTART for all contact time variables in the conditions depicted.

To study home advantage (Question 3), ▶ **Fig. 5** reports the percentages in the categories of Match Outcome in PRECORONA and AFTER RESTART grouped by league, which includes all matches. On the level of performance indicators, home advantage was quantified by using Home Advantage (HA) and Relative Home Advantage (RHA). HA was calculated as the mean of the difference of MP between home and away teams, whereas RHA was defined as the quotient of HA and the mean of away teams in a subsample. ▶ **Fig. 6** presents HA (M ± SD), RHA (%) in PRECORONA and RHA differences (ΔRHA) between PRECORONA and AFTER RESTART.

Differences between subsamples (ΔMP, ΔRCT, ΔRHA) and differences (Δ) between other groups (e. g., leagues, home vs. away) are reported in signed (+ ,–) percentages of the baseline value. To

Match Performance Before Coronavirus Pandemic and After Restart

Indicator	PRECORONA Q4 MP (M ± SD)		AFTER RESTART ΔMP (%) ■ BL ■ BL2	d	p
Goals	3.4 ± 1.9	#	−5.8	−0.10	0.22
	2.9 ± 1.8		3.9	0.07	0.33
Expected Goals	3.2 ± 1.2	#	−5.0	−0.14	0.18
	2.8 ± 1.1		6.9	0.18	0.10
Shots At Goal	27.1 ± 5.9		−4.5	−0.21	0.09
	26.3 ± 6.1		−5.5	−0.24	0.05
Ball Possession	22.3 ± 2.8		−4.6	−0.37	<0.01*
Last Third (%)	23.1 ± 2.8		−6.3	−0.52	<0.001*
Ball Possession (%)	0.0 ± 0.0		0.0	0.00	1.0
	0.0 ± 0.0		0.0	0.00	1.0
Passes	901.3 ± 182.6	#	2.1	0.10	0.25
	729.7 ± 160.2		15.2	0.69	<0.001*
Long Passes (%)	8.9 ± 2.5	#	5.5	0.20	0.10
	10.7 ± 3.1		6.3	0.22	0.06
Outplayed Opponents	3.7 ± 0.7	#	−1.6	0.08	0.30
	4.3 ± 1.2		−14.7	0.54	<0.001*
Passes Completed (%)	82.8 ± 4.2	#	0.4	0.40	0.08
	78.7 ± 5.3		3.9	0.57	0.06
Long Passes Completed (%)	47.7 ± 8.5	#	5.2	0.29	0.03
	42.9 ± 8.6		15.6	0.78	<0.001*
Pressure on Passing player	34.2 ± 2.6		−0.7	−0.09	0.26
	34.3 ± 3.6		−3.2	−0.31	0.02
Pressure on Receiving player	20.4 ± 3.0	#	0.1	0.01	0.48
	22.7 ± 4.8		−8.6	−0.41	<0.01*
Duels	204.7 ± 30.2		4.2	0.29	0.03
	205.2 ± 27.9		1.1	0.08	0.30
Duels Won With Ball Possession (%)	50.3 ± 5.1		−1.9	−0.19	0.11
	51.6 ± 5.5		−7.9	−0.75	<0.001*
Fouls Committed	24.5 ± 5.4	#	3.1	0.14	0.18
	27.0 ± 5.0		−2.4	−0.13	0.19
Yellow Cards	2.9 ± 1.7		32.4	0.56	<0.001*
	3.3 ± 1.8		25.1	0.46	<0.001*
Total Distance Covered	236.6 ± 23.5	#	0.2	0.02	0.44
	221.3 ± 21.6		4.3	0.44	<0.01*
High Intensity Distance	29.1 ± 3.3	#	6.1	0.54	<0.001*
	27.9 ± 3.5		2.0	0.16	0.13

▶ **Fig. 1** Effects of corona-specific playing conditions on match performance. Columns report match performance (MP) per indicators in sample PRECORONA Q4 and their changes (ΔMP) (in %) in sample AFTER RESTART. Each cell contains data for the Bundesliga (grey) in first row and for Bundesliga 2 (light grey) in second row. Test statistics d and p refer to ΔMP. # indicates applicable MP differences between leagues in PRECORONA_Q4. * indicates significant changes of MP.

test the significance of differences between groups, two sided t-tests were conducted. Effect size (d) was calculated as the difference of mean values in the baseline subsamples and AFTER RESTART divided by the SD of baseline subsamples. Effect size of differences between leagues and differences between home and away teams was calculated by using the standard deviation calculated based on both teams and both leagues. We refer to differences between groups as applicable (#) if they are significant and the effect size is greater d = 0.2. To test differences between distributions of Outcome, we applied the χ^2 test, followed by χ^2 post-hoc tests, which compare each cell with the mean of all others. Cramer's V is used to describe effect size. Before using parametric statistical test procedures, we verified the assumption of normality. The significance level was set to $\alpha = 0.05$. Statistical analyses were performed using R (v3.5).

Results

After applying exclusion criteria for match performance analysis and home advantage on performance indicator level, PRECORONA includes n = 1549 matches, PRECORONA Q4 includes n = 277 matches, and in AFTER RESTART there were n = 136 matches (▶ **Table 1**). The number of excluded matches due to red cards was 261 in total. For BL2, Net Playing time was significantly increased

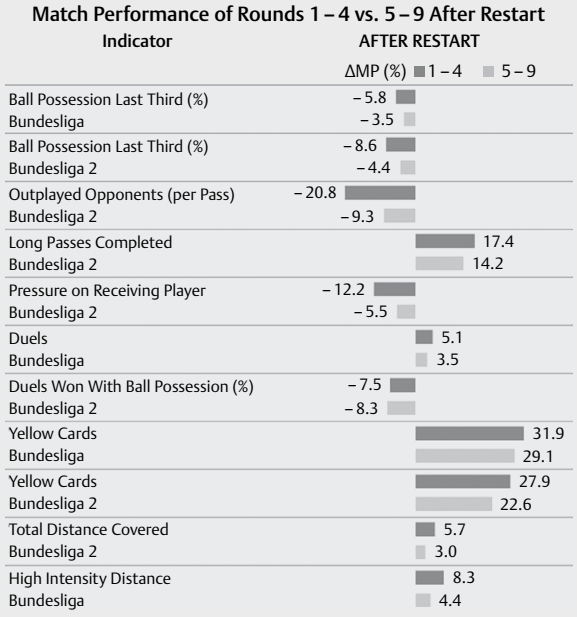
in AFTER RESTART (Δ = + 4.5 %, d = 0.52, p < 0.001). In addition, Air Temperature differs significantly between the samples PRECORONA Q4 and AFTER RESTART (BL: Δ = + 4.7 ° C, d = 0.68, p < 0.001; BL2: Δ = + 5.3 ° C, d = 0.68, p < 0.001).

Question 1: ▶ **Fig. 1** shows the results of match performance analysis. We found applicable differences between the BL and BL2 for most performance variables, especially in those describing passing behavior: Passes (Δ = + 19.5 %, d = 0.73, p < 0.001); Outplayed Opponents (Δ = –8.6 %, d = –0.34, p < 0.001); Long Passes (Δ = –16.1 %, d = –0.60, p < 0.001;, Passes Completed (Δ = + 5.1 %, d = 0.82, p < 0.001); Long Passes Completed (Δ = + 8.4 %, d = 0.42, p < 0.001); and Pressure on Receiving Player (Δ = –12.0 %, d = –0.61, p < 0.001). Total Distance Covered (Δ = + 6.5 %, d = 0.58, p < 0.001) and High Intensity Distance (Δ = + 7.0 %, d = 0.56, p < 0.001) were also higher in BL.

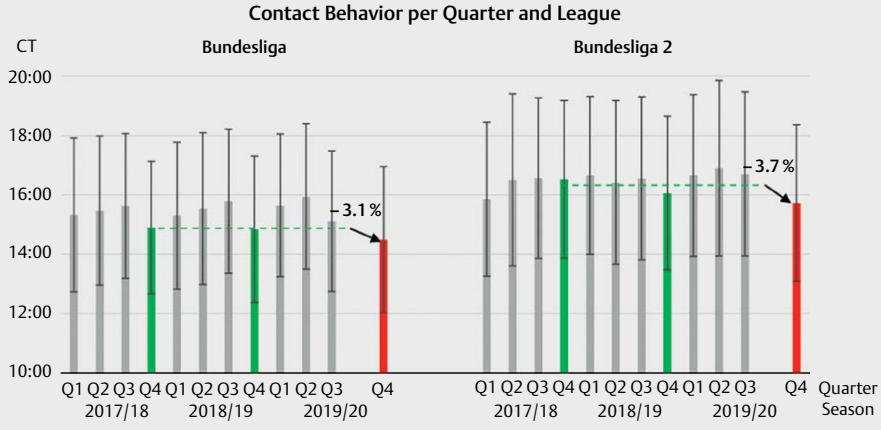
AFTER RESTART, BL2 matches show significant changes in Number of Passes, Long Passes Completed, Outplayed Opponents per Pass, Pressure on Receiving Player, and Duels Won with Ball Possession. In BL, we found no differences regarding these parameters. In both leagues, there were significant differences in Ball Possession in the Last Third and in the number of Yellow Cards. In BL, there were Δ = + 0.7 cards more for home teams and Δ = + 0.3 cards more for away teams on average. In BL2, referees awarded Δ = + 0.6 cards more for home teams and Δ = + 0.2 cards for away teams. Running Activity in BL significantly increased for High Intensity Running and in BL2 for Total Distance Covered. The absolute value of most of these indicators tended to be higher in AFTER RESTART 1–4 compared to AFTER RESTART 5–9 (▶ **Fig. 2**). Differences were not significant.

Question 2: Analysis of contact behavior uses n = 21 882 player × match datasets in PRECORONA, n = 4251 in PRECORONA Q4 and n = 1774 in AFTER RESTART. Visual inspection indicates a decline of Contact Time from Q3 to Q4 in each of the seasons in both leagues (▶ **Fig. 3**). Before the COVID-19 pandemic, players had contact with another player in 15.8 % ≙ 14:52 min (BL) and 17.3 % ≙ 16:18 min (BL2) of gross playing time (▶ **Fig. 4**). Player contacts occurred significantly more frequently with opponents (12:31 min) than with teammates (04:53 min) (Δ = + 257.2 %, d = + 2.19, p < 0.001).

AFTER RESTART, there was a marginal decline in BL (ΔRCT = –3.1 %) as well as in BL2 2 (ΔRCT = –3.7 %) over total playing time. Analysis according to various conditions showed that the decline is due to the shorter contact times of the player in possession of the ball outside the last third (BL: ΔRCT = –6.6 %, BL2: ΔRCT = –14.4 %).



▶ **Fig. 2** Analysis of adaption effects. Figure shows differences in match performance (ΔMP) between PRECORONA Q4 and AFTER RESTART 1–4 as well as between PRECORONA Q4 and AFTER RESTART 5–9 by indicator.



▶ **Fig. 3** Player contacts in the Bundesliga and Bundesliga 2 grouped by quarters. Vertical bars show mean and standard deviation of Contact Time (CT) (min). Percentages indicate change of CT from PRECORONA Q4 to AFTER RESTART.

Contact Behavior Before Coronavirus Pandemic and After Restart

Indicator	Condition	PRECORONA Q4 CT (M ± SD)	PRECORONA Q4 RCT (M ± SD (%))	AFTER RESTART ΔRCT (%) BL BL2	d	p
Contact Time	ALL	14:52 ± 4:13 16:18 ± 5:16	15.8 ± 4.9 # 17.3 ± 5.6	−3.1 −3.7	−0.10 −0.11	0.02* <0.01*
Contact Time	IN PLAY	6:49 ± 2:26 7:13 ± 2:40	12.0 ± 4.4 # 13.5 ± 5.1	−1.9 −2.7	−0.05 −0.07	0.02* 0.43
Contact Time Teammate	IN PLAY	0:44 ± 0:20 0:45 ± 0:22	1.3 ± 0.6 1.4 ± 0.7	5.4 2.9	0.12 0.06	0.10 <0.01*
Contact Time Opponent	IN PLAY	6:26 ± 2:23 6:49 ± 2:37	11.3 ± 4.3 # 12.7 ± 5.0	−2.7 −3.4	−0.07 −0.09	<0.01* 0.78
Contact Time Opponent	PLAYER WITH BALL POSSESSION	0:37 ± 0:14 0:39 ± 0:15	34.0 ± 14.7 # 37.9 ± 15.0	−5.7 −12.0	−0.13 −0.30	<0.001* <0.001*
Contact Time Opponent	PLAYER WITHOUT BALL POSSESSION	5:49 ± 2:21 6:10 ± 2:34	10.6 ± 4.3 # 11.9 ± 4.9	−2.2 −1.2	−0.05 −0.03	0.03* <0.001*
Contact Time Opponent	PLAYER WITH BALL POSSESSION IN LAST3RD	0:14 ± 0:07 0:15 ± 0:07	49.4 ± 16.9 # 53.0 ± 15.8	1.0 −2.0	0.03 −0.07	<0.01* <0.001*
Contact Time Opponent	PLAYER WITH BALL POSSESSION NOT IN LAST3RD	0:23 ± 0:10 0:24 ± 0:11	31.1 ± 17.0 # 34.6 ± 17.8	−8.2 −14.4	−0.15 −0.28	<0.001* <0.001*
Contact Time	OUT OF PLAY	8:34 ± 3:03 9:05 ± 3:10	21.8 ± 6.7 # 22.5 ± 7.0	−4.6 −2.4	−0.15 −0.08	0.05 <0.001*
Contact Time Teammate	OUT OF PLAY	4:04 ± 1:49 4:12 ± 1:52	11.0 ± 4.5 10.4 ± 4.4	−6.2 −6.4	−0.15 −0.15	<0.01* <0.001*
Contact Time Opponent	OUT OF PLAY	5:26 ± 2:21 6:20 ± 2:40	14.7 ± 5.8 # 15.6 ± 6.1	−4.3 2.6	−0.11 0.07	0.21 0.08
Contact Time Teammate	AFTER GOAL	0:24 ± 0:26 0:21 ± 0:21	21.2 ± 21.4 20.9 ± 15.4	−11.9 −26.4	−0.12 −0.25	<0.001* <0.001*

▶ **Fig. 4** Analysis of contact behavior in various conditions. Columns describe Contact Time (CT) (min) and Relative Contact Time (RCT) (%) in sample PRECORONA Q4, change of Relative Contact Time (ΔRCT) (%) compared to sample AFTER RESTART, d and p value. Each cell contains data for the Bundesliga (grey) in first row and for Bundesliga 2 (light grey) in second row. # indicates applicable differences in contact time between the Bundesliga and Bundesliga 2 in PRECORONA; * indicates significant changes of RCT.

Home Advantage Before Coronavirus Pandemic and After Restart

Sample	n	Match Outcome: Home Win	Away Win	Draw	v	p
Bundesliga						
PRECORONA	837	*> 44.7	30.8	*< 24.5	0.09	0.03*
AFTER RESTART	81	*< 32.1	44.4	*> 23.5		
Bundesliga 2						
PRECORONA	837	41.6	28.7	29.7	0.03	0.74
AFTER RESTART	81	43.2	24.7	32.1		

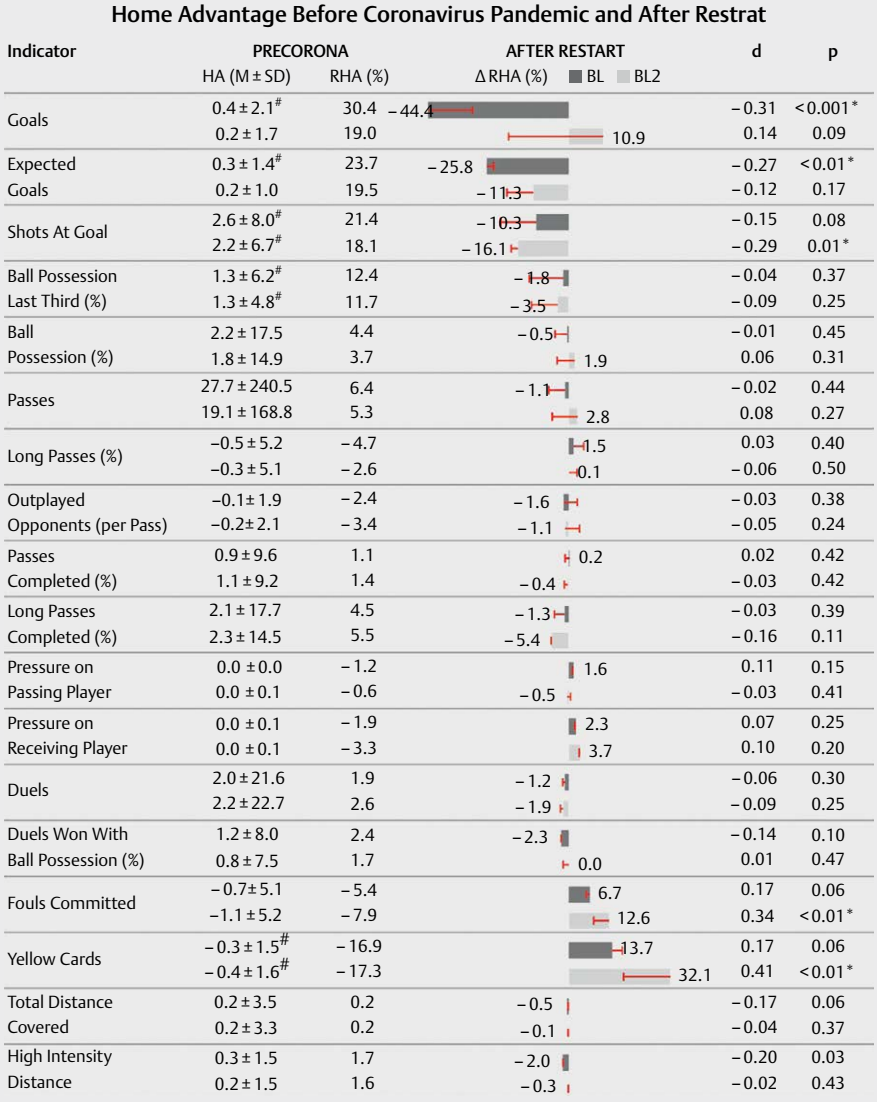
0% 20% 40% 60% 80% 100%

▶ **Fig. 5** Analysis of home advantage according to Match Outcome. We report the share (%) in each category (Home Win, Draw, Home Win) for PRECORONA (BL: n = 789, BL2: n = 760) and AFTER RESTART (BL: n = 67, BL2: n = 69) grouped by league, effect size (v), and p value. * indicates significant differences in distributions between samples. * < > indicates if cell value is significantly greater or less.

In game interruptions, a decrease in contact times after own goals can be observed for the BL (ΔRCT = –6.6 %) and BL2 (ΔRCT = –24.9 %).

Question 3: ▶ **Fig. 5** shows the home advantage in the categories of Match Outcome. There were significantly more Home Wins than Away Wins in BL (Δ = + 45.0 %, V = 0.16, p < 0.001) and in BL2 (Δ = + 45.0 %, V = –0.09, p < 0.01). There are no significant differences in the categories of Match Outcome between leagues. On the level of performance parameters, there were relevant differences between home and away teams in Goals, xG, Shots at Goal, Ball Possession in Last Third as well as for Yellow Cards (▶ **Fig. 6**). In BL, goal difference was Δ = + 0.41 in favor of home teams (d = 0.19, p < 0.001), in BL2 the difference was Δ = + 0.24 goals (d = 0.14, p < 0.001). Yellow Card difference was Δ = –0.31 (d = –0.21, p < 0.001) in BL and Δ = –0.35 (d = –0.23, p < 0.001) for BL2.

AFTER RESTART, the share of Home Wins decreased (Δ = –28.2 %) and Away Wins increased (Δ = + 44.2 %) significantly in BL. The BL home teams received Δ = + 0.4 (from 1.5 to 1.9) and away teams received Δ = + 0.1 (from 1.9 to 2.0) more Yellow Cards after the restart compared to PRECORONA. In BL2, there were no significant differences in Home Wins and Away Wins, and there was an increase in Yellow Cards for home teams of Δ = + 0.5 cards (from 1.7 to 2.2) and a decrease for away teams of Δ = –0.1 cards (from 2.0 to 1.9). For both leagues, there were no significant differences between home and away teams in OUTCOME or any other performance indicator AFTER RESTART.



▶ **Fig. 6** Analysis of home advantage according to performance indicators. Figure shows Home Advantage (HA) and Relative Home Advantage (RHA) (%) in sample PRECORONA, changes of Relative Home Advantage (ΔRHA) (%) in sample AFTER RESTART, effect size (d), and p value. Each cell contains data for the Bundesliga (grey) in first row and for Bundesliga 2 (light grey) in second row. Red lines inside bars indicate the change that would lead to home-away parity; # indicates applicable HA differences between home and away teams in PRECORONA; * indicates significant changes of RHA.

Discussion

Methods

The study aimed to explore whether there were any effects of corona-specific playing conditions on match performance, contact behavior, and home advantage in German professional soccer. To analyze match performance and contact behavior, our study used data from season quarter four as a baseline. This was intended to reduce seasonal effects on performance variables. Previous research has shown that running activity decreases with higher environmental temperature [45] and that there is less running activity and fewer fouls and duels when matches are not important in terms of post-season consequences, such as Champions League qualification [46]. ▶ **Figure 2** shows the seasonal influence on Contact Time with a decline in the fourth quarter and underlines the need to consider such effects. Nevertheless, the interpretation of results has to take into account that quarter four of the 2017/18 and 2018/19 baseline seasons were played from March to May and quarter four of the 2019/20 season was played from May to July, where the mean temperature was ~ + 5.0 ° C higher. To analyze home advantage, we used data of all quarters as a baseline since seasonal effects should affect home and away teams in the same way.

We applied additional measures to reduce potential confounding variables. Performance variables were normalized to net play-

ing time. This is advisable because playing time differed significantly between samples. We excluded matches with red cards, because an imbalanced number of players might lead to different playing characteristics [47]. Players with less than 85 mins playing time were excluded from contact behavior analysis because substitutes might show different playing behavior when joining the game [48] and there were five instead of three substitutions allowed after the restart [49]. In order to reduce variance of contact time variables, we also excluded goalkeepers, as they showed completely different contact behavior compared to field players. Because of these preprocessing steps, our results are not identical to those reported by [36]. In addition, this study used, in contrast to the others [34, 35], a different dataset as a baseline (quarters one to three, and quarter two, of the 2019/20 season) and focused mainly on home advantage and factors for home advantage, not on changes in match performance and contact behavior.

The present study is limited in certain ways because there might still be factors that could have affected baseline and after-restart samples differently: We did not check whether matches were similar in terms of home and away team skills, e. g., by comparing market values [36] or ELO rankings [33]. This factor seems to be of minor importance since the previous studies on ghost games found no differences in their samples. Another limitation is that samples contain slightly different teams due to relegation – maybe favoring different formations. We did not check whether the number of important matches was similar in the samples. Because we want to study the effect of training conditions as well, the last round before shutdown was assigned to baseline samples although it was also played without spectators. However, the potential effects of these issues should be very small and not affect results seriously.

Discussion of the results in the following paragraphs suggests causes for observed effects. These effects can be attributed to a change in tactics, physical or technical abilities (e. g., due to lack of seasonal rhythm, unfavorable periodization, or psychological stress), environmental factors (especially empty stadia) and a change in referee bias (due to absence of home crowd). Because an observational study cannot conclusively clarify the underlying reasons, causes, or mechanisms [50], our suggestions must always be speculative to some extent. In addition, all interpretations underlie the restriction of quite a small dataset of ghost games. The study reports the aggregated performance data of players and teams, which masks individual conditions. Future studies could analyze effects on individual teams and players.

Question 1: How did performance change in ghost games?

In the introduction, we enumerated arguments for assuming a change or a decrease of player performance after restart. Our data shows that changes in performance were evident for both leagues, but they were mainly significant for Bundesliga 2, or rather, the effects are much greater compared to the Bundesliga. One explanation for this might be that the Bundesliga teams were able to better compensate for the new conditions owing to their greater resources. Analyses also suggest that changes in rounds 26–29 after restart were partly compensated for in rounds 30–34 (▶ **Fig. 2**), although differences were not significant due to the small sample size. We interpret this as an adaptation of teams and players to the new conditions.

In terms of attack performance, there was a significant decrease in Ball Possession in Last Third (~ + 5.5 %) in both leagues (▶ **Fig. 1**). This may be put down to tactical requirements (more defensive team formation) or fewer offensive efforts due to a lack of encouragement from the absence of crowd support. At least for Bundesliga 2, one could also support this assumption by pointing to the decreased success rate of tackles with possession (–7.9 %). As a result, the decrease of Ball Possession in the Last Third does not lead to a significant decrease in Goals or xG, perhaps because of sample size and the large fluctuation of these variables.

Before the corona shutdown, passing characteristics differed between the Bundesliga and Bundesliga 2. Passing frequency was higher (+ 19.5 %) in the Bundesliga, and at the same there were fewer Outplayed Opponents per Pass (–8.6 %) and fewer Long Passes (–16.1 %), which might be interpreted as less passing risk. Higher passing success rates for Passes (+ 5.1 %) and Long Passes (+ 8.1 %) provide evidence of the higher technical skills of the Bundesliga players. Less Pressure on Receiving Player (–12.0 %) in the Bundesliga suggests that passes were more often played to less well-marked teammates.

After restart, passing characteristics in Bundesliga 2 changed significantly for number of Passes (+ 15.2 %), Outplayed Opponents (–14.7 %), and Long Passes Completed (+ 15.6 %). Surprisingly, these changes erased differences between the Bundesliga and Bundesliga 2. This effect is hard to interpret. One could speculate that average passing style of Bundesliga 2 players is usually more impetuous and that the "sterile" setting led them to play in a more controlled and less risky manner. This is in line with the finding of increased Net Playing Time. Deeper analysis shows that this was driven by a reduced mean number of game interruptions (113.7 vs. 105.0) in ghost games and not by shorter interruption times. Because the number of fouls did not change, this reduction was caused by fewer plays off the field, which might be an indication of less passing risk. Either way, less Pressure on Receiving Player (–8.6 %) could explain the increased success rate of Long Passes (+ 15.6 %).

Owing to the absence of crowd support, one could assume there was less engagement or "aggressiveness" among players, which should manifest in fewer Duels, Fouls, and Yellow Cards after restart. Our data does not support this: There were no significant differences in Fouls and Duels (even a slight tendency towards more tackles in the BL with + 4.2 %). In addition, there were clearly more Yellow Cards (+ ~0.9), which is in contrast to research reporting fewer yellow cards in other ghost games (–0.2) [33]. We suggest two mechanisms for the finding regarding Yellow Cards. On the one hand, the increase is mainly due to Yellow Cards against the home teams due to reduced referee bias (see discussion of home advantage). On the other hand, Yellow Cards also increased for the away teams. Maybe defenders entered tackles too late – since there was more distance between players (see contact behavior) – and therefore had to foul more often.

Bundesliga teams showed higher running activity compared to Bundesliga 2 (~6 %), which confirms findings from Spanish divisions [51]. There is no indication of physical deficits caused by the short preparation time or an unfavorable periodization. Running activity

increased significantly for High Intensity Distance in the Bundesliga (+6.1 %) and for Total Distance Covered in Bundesliga 2 (+4.3 %). This is remarkable since mean temperature was in fact ~ +5.0 ° C higher after restart compared to the baseline sample. Based on past research [45], one could expect a decline of ~ –10 % in running activity when the temperature increases from ~15 ° to ~20 ° C. Because we observed the opposite effect, this provides good arguments that players had advantages in physical fitness due to less fatigue. Further explanations would be that the rule change allowing five instead of three substitutions [49] results in less tired players at the end of the game.

Question 2: How did contact behavior change in ghost games?

Our analysis of contact behavior shows that players are exposed to others for ~15 mins per match. From the perspective of public health, playing soccer must be considered an infection risk, although it is not clear how aerosols are spread when playing soccer. We cannot confirm the results of [18], reporting a median of 0:12 mins contact time in one match of Danish professional soccer.

Our analysis of contact behavior was based on the expectation that players would reduce contacts with other players due to the corona pandemic. After the restart, we found only a marginal decrease in Contact Time over the entirety of matches sampled in the Bundesliga (–3.1 % ≙ 0:23 min) and Bundesliga 2 (–3.7 % ≙ 0:35 min) (▶ **Fig. 3**). Analysis according to various conditions showed that the in-game decrease is due to the shorter Contact Time with opponents of ball possession players outside the last third (BL: –6.6 %, BL2: –14.4 %) (▶ **Fig. 4**). We interpret this as the result of less pressing of the defending teams. When in the last third, where the situation is potentially more dangerous, there were no differences in Contact Time. For us it seems plausible that players – consciously or unconsciously – reduced contact either for their own protection or by transferring the demands of everyday life to the competition if the game situation allowed. Lower physical performance due to the training break is less likely for us since running activity should show this.

In Bundesliga 2 game interruptions, we found a significant decrease of contact time towards teammates after scoring (–26.4 %). This can be traced back to the DFL instruction of not to form clusters of players when celebrating a goal. Against this background, it is surprising that the decline in the Bundesliga is significantly lower (–11.9 %). Overall, the decrease in contact times is likely to be of little significance from the point of view of infection prophylactic. Since most contacts occurred during game interruptions – with significant contact time towards teammates – there might still be potential to reduce this time without changing the characteristic of the game. However, the DFL's corona pandemic strategy for teams is based, among other things, on coronavirus testing and quarantine regulations and less on avoiding contacts in the game [52].

Question 3: How did home advantage change in ghost games?

Analysis of the extent of the home advantage before the COVID-19 pandemic confirms most of the results of previous research. For the German Bundesliga, 53 [53] determined a distribution of 53.3 % home wins, 26.0 % draws, and 20.7 % away wins between the years 1963 and 1997. Compared to that period, the home advantage diminished in our sample (44.7 % vs. 30.8 % vs. 24.5 %) (▶ **Fig. 5**). This is in line with the results of the British Premier League, which showed a continuous decrease of the home advantage in recent decades [54]; this was attributed to better referee training [55]. In terms of goals, the size of the home advantage in the Bundesliga (+0.41) was nearly the same as reported for Italy (+0.37) and France (+0.39) between 2003 and 2020 [33] and for the Premier League (+0.45) between 1973 and 2018 [54].

Past studies have not found significant effects of division on home advantage [56–58]. Our data confirms these results as long as the home advantage is operationalized on the outcome level (win, draw, and loss). On goal level, the home advantage in Bundesliga 2 was smaller (+0.24), which could be reasonably explained by smaller crowds in Bundesliga 2 (▶ **Fig. 6**). Previous research has argued that crowd size is less important than the difference in players' reference point since players adapt mentally to the mean crowd size in a division (28). In any case, we suggest the discussion on the role of crowd size would be augmented by also looking at level of goals and other performance variables. Our data also confirm the finding of more (~ +0.33) Yellow Cards for away teams compared to home teams. This phenomenon has already been well documented in previous seasons of the Premier League and the Bundesliga with similar effect sizes [29, 30]. The research mostly agrees that this appears to be due to a refereeing bias towards satisfying the home crowd in the stadium favoring the home team – at least when decisions are afflicted by uncertainties.

After the restart of the Bundesliga, there was a significant shift in the distribution of match outcome, erasing home advantage completely. There were even more away team victories, but we suggest not referring to this as an "away advantage" since the sample is too small to reach significance level. This is in line with the results of [33], which analyzed a set of ghost games before the COVID-19 pandemic, and in contrast to [34], which found no significant effect on match outcome in the aggregated data of 17 leagues during the COVID-19 pandemic. In Bundesliga 2, there were no changes in the distribution of match outcome and scoring. At first the COVID-19 pandemic seems "surprisingly" [35] not to have affected the home advantage in Bundesliga 2. This statement does not take account of the fact that goals are rare events affected by chance [59]. Shots at Goal (–16.1 %) and xG (–11.3 %) point in the opposite direction than the number of goals (+10.9 %). This may suggest that the outcomes in Bundesliga 2 did not represent playing performance and winning probability correctly. In other words, we suggest that home teams needed an element of luck to win so many matches. From this perspective, one could argue that home advantage has also decreased in Bundesliga 2.

Fischer et al. [35] showed that erasure of the home advantage in the Bundesliga was mainly driven by reduced occupancy rate, whereas other factors were less important (e. g., crowd size, stadium tracks, travel-distance, within-week matches). There are two possible mechanisms to explain this effect: (i) there was no crowd to raise the performance of the home team relative to the away team, and (ii) there was no crowd to influence the referee in favoring the home team. We suggest that both mechanisms were present in the Bundesliga. In terms of attacking performance, we found

significant shifts of relative performance regarding xG (–25.8 %) and Shots at Goal (–10.3 %) to the disadvantage of home teams.

All other performance indicators for passing, dueling, and running show no changes in relative performance of home and away teams. Our interpretation is not that playing performance was not affected but that these indicators are simply not suited to reflecting home advantage. Before the COVID-19 pandemic, none of these parameters showed a difference in relative performance, although a clear home advantage exists regarding match outcome and goal scoring. We interpret this as an indication of the low validity of such indicators for playing performance in soccer due to missing context, which has been discussed extensively in the literature (e. g., in [60, 61]).

Secondly, our data show that the difference in yellow cards given between home and away teams evened out in ghost games. Although the decline showed no significance in the Bundesliga, there was no significant difference in the number of yellow cards awarded to home team (1.9) and away teams (2.0). These findings are in line with results in other leagues during the COVID-19 pandemic [33, 34]. In both leagues, the Bundesliga and Bundesliga 2, this relative shift is introduced by more yellow cards for the home team (home: ~ + 0.4, away: ~0.0). This is in contrast to other studies reporting that this shift comes from less yellow cards given to the away team in ghost games (home: 0.0, away: –0.4, 33; also 34). Finally, our data include no indications that an increase of yellow cards for home teams in both leagues is caused by an increase of the away teams' performance (e. g., more ball possession in the last third, more chances, and more competitions for the ball). Therefore, we suggest that the relative shift in yellow cards in favor of away teams is mainly driven by the absence of crowd pressure on referees in ghost games.

Conclusion

The corona pandemic has influenced the game of soccer in terms of match performance, contact behavior, and home advantage. We found no indications that physical fitness had significantly diminished during ghost games. In contrast, increased running activity despite warmer conditions may suggest that players had advantages due to less fatigue. Particularly in Bundesliga 2, there were minor changes in some aspects of performance, including on time spent in the last third, pressure put on the opponent when passing, effectiveness of attacking duels, and passing characteristics. Conditions during the COVID-19 pandemic have meant players reducing contacts with teammates and opponents during game interruptions as well as when the ball was in play and it was not necessary to prevent dangerous situations. This might be based on tactical demands or conscious or unconscious self-protection. The absence of crowds has erased home advantage in the Bundesliga, reduced home advantage in Bundesliga 2 regarding performance level and increased the neutrality of refereeing decisions when giving yellow cards. These findings help competition owners, coaches, and players to counteract unwanted developments and to improve training and competition.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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