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Performance optimization in football: Advances in theories and practices

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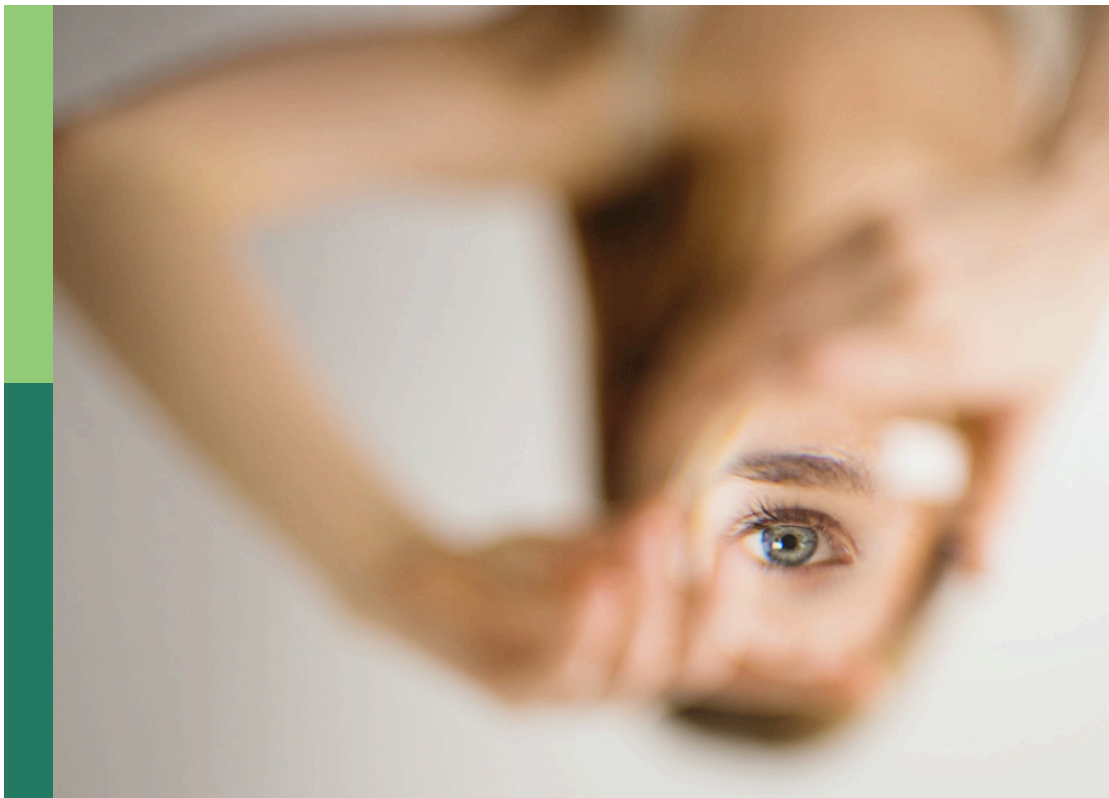

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Performance optimization in football: Advances in theories and practices

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Quantifying the Effectiveness of Defensive Playing Styles in the Chinese Football Super League

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Establishing and illustrating a predictive and prescriptive model of playing styles that football teams adopt during matches is a key step toward describing and measuring the effectiveness of styles of play. The current study aimed to identify and measure the effectiveness of different defensive playing styles for professional football teams considering the opponent's expected goal. Event data of all 1,120 matches played in the Chinese Football Super League (CSL) from the 2016 to 2020 seasons were collected, with fifteen defense-related performance variables being extracted. The PCA model (KMO = 0.76) output eight factors that represented 7 different styles of play (factor 6 and 8 represent one style of play) and explained 85.17% of the total variance. An expected goal (xG) model was built using data related to 27,852 shots. Finally, the xG of the opponent was calculated in the multivariate regression model, outputting five factors that ($p < 0.05$) explained 41.6% of the total variance in the xG of the opponent and receiving a dangerous situation (factor 7) was the most apparent style (31.3%). Finally, the predicted model with defensive styles correlated with actual xG of the opponent at $r = 0.62$ using the 2020 season as testing data which showed that the predicted xG was correlated moderately with the actual. The result indicated that if the team strengthened the defense closed to the own goal, high intensity confrontation, and defense of goalkeeper, meanwhile making less errors and receiving less dangerous situations, the xG of the opponent would be greatly reduced.

Keywords: defense, multivariate regression, match analysis, xG, PCA

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INTRODUCTION

Football match performance incorporates the interactive effects of technical, physical, and tactical activities among players (Moura et al., 2013). Such interaction is conditioned by the strategical plans and match dynamics (Grehaigne et al., 1997) and can be explained by measuring the offensive and defensive behavior of teams and opponents (Carling et al., 2005). Consequently, various types of match approaches were adopted to integrate these dynamical interactions adopted by teams under distinct competition scenario (Fernandez-Navarro et al., 2016; Hewitt et al., 2016; Lago-Peñas et al., 2018). Hence, the tactical approach of a team in a particular match can be defined and depict how the football match unfolds (Lago-Peñas et al., 2018). Specifically, the term "style of play" refers to the

dominant and recurring pattern demonstrated by a team in a specific competitive situation where the measurement of some performance indicators may reflect the team's playing styles (Fernandez-Navarro et al., 2016; Hewitt et al., 2016; Zhou et al., 2021). Compared with "model of game" defining a complete technical and tactical process for the game (Sánchez et al., 2021) and "game philosophy" including the culture and ethos of a team (Fernandez-Navarro et al., 2016), the term "style of play" refers more to the behavioral pattern demonstrated by a team in a specific competitive context. Determining and measuring playing styles in elite soccer have a direct application into practice and competition (Kubayi and Toriola, 2020), such as modeling performance improvement in team's strategies, player's evolution, and scouting (Zhou et al., 2021).

Currently, the available research focusing on playing style in football has evolved in its approach measuring those key playing patterns which defined the styles of play. Hewitt et al. (2016) pointed out that a playing style pattern was represented by a team at five moments in a match: set offense, transition from offense to defense, set defense, transition from defense to offense, and set pieces. Fernandez-Navarro et al. (2018) classified playing styles of English Premier League into eight factors based on traditional techniques and tactics: direct play, counterattack, maintenance, build up, sustained threat, fast tempo, crossing, and high pressure. Yi et al. (2019b) defined three types of playing styles to characterize the matches of 2018 FIFA World Cup by a machine learning algorithm: direct play, possession play, and mixed play. Moreover, in the most recent studies, the statistical model is factor analysis (PCA: Principal Component Analysis) focusing on the identification of football playing styles (Gómez et al., 2018; Lago-Peñas et al., 2018; Zhou et al., 2021). The first study defined eight plying styles *via* selecting over sixty match performance variables in Greek professional football which jointly influencing how teams alternated their styles (Gómez et al., 2018). Meanwhile, both the second study (Lago-Peñas et al., 2018) and the recent study (Zhou et al., 2021) encountered different playing styles from the consideration of enough match performance indicators in Chinese football league. However, compared to the wide range of studies focusing on the attacking styles, few attempts have been done for the defense. Fernandez-Navarro et al. (2019b) tried to classify the defensive styles of play according to the zones of the pitch where the ball was regained, but not conducting deep research on the defensive styles.

In light of such phenomenon, quantifying the effectiveness of more styles of play has also been analyzed to explain a broader concept of tactical behaviors, to which these tactical variables and performance indicators contribute. Recent studies proposed a theoretical framework for measuring styles of play (Fernandez-Navarro et al., 2018), quantify the use of attacking and defensive strategies in football matches (Villa and Lozano, 2019), and predict a pattern of tactical–strategic behaviors with major probabilities of success in transitions (Casal et al., 2016). Behavior indicators (Kempe et al., 2014), multivariate statistical methods (Moura et al., 2014), and spatio-temporal analysis (Memmert et al., 2016) have also been used for potential tactical evaluation. In addition, new effectiveness metrics that take into account multiple variables have been developed recently. Expected goals (xG) is a metric used to assess the chance of a shot resulting in a goal which is useful for coaches and practitioners (Rathke, 2017). Fernandez-Navarro et al. (2019a) used xG as a metric to evaluate the effectiveness of playing styles in different contextual variables. Nevertheless, the effectiveness of playing styles in football is still inconclusive due to previous studies which were concentrated on an isolated attacking performance dimension (Liu et al., 2019). What's more, previous studies have acknowledged that the defensive styles of play and performance indicators related to defense in different studies were not clear or comprehensive which might produce partially biased outcomes (Vogelbein et al., 2014; Bradley et al., 2016; Souza et al., 2019).

The lack of relevant studies evaluating the effectiveness of defensive styles could be attributed to the fact that most of the defensive events are recorded along with ball-related offensive behaviors, so that the tactical intention and the off-ball performance behind certain defensive technical actions may not be fully represented to produce reliable outcomes. Additionally, definitions and measurement of football defensive playing styles were varied among different studies. More styles of play should be considered when evaluating the defensive effectiveness. Therefore, the aim of the current study was: (i) to describe defensive playing styles in professional football *via* considering more comprehensive set of defensive actions and spatial information of teams, and (ii) to rate the effectiveness of different styles, accounting for opponent's scoring opportunities (xG). It has been hypothesized that teams could be classified and evaluated according to their playing styles and the xG of the opponent could evaluate the effectiveness of defensive styles adopted by coaches.

MATERIALS AND METHODS

Sample

The sample was composed of teams that played all 1,120 matches in the CSL from the 2016 to 2020 seasons (There are 160 matches of CSL in the 2020 season due to prevention and control of COVID-19). The Chinese Super League (CSL) is the top-professional soccer league in China, which starts in March (spring) and ends in November (winter) every season. Sixteen teams ($n = 240$ matches per season) play each other in a balanced schedule (each team plays against different opponents (home and away) twice). Match statistics were retrieved from the website of "Whoscored",[1] whose data were provided by OPTA Sports. The data provider has been previously verified to have high intra-class correlation coefficients (ranged from 0.88 to 1.00), low standardized typical errors (varied from 0.00 to 0.37) a, and very good strength of Cohen's Kappa (>0.9) for inter-operator reliability of data collection (Liu et al., 2017).

[1]www.whoscored.com

Performance Indicators and Procedure

Based on the scientific literature that included defensive aspects in football match analysis (Yi et al., 2018, 2019a; Fernandez-Navarro et al., 2019b), a total of 15 defensive performance indicators related to technical and tactical performance were extracted from the raw data as dependent variables in the analysis due to their importance for measuring performance related to recovery the possession of the ball and match outcomes (Zhou et al., 2021). The description and definitions of defensive performance indicators are presented in **Table 1**. In addition, the pitch was divided into six spaces parallel to the goal lines for the extraction of the following performance indicators: pass in zone 3 and zone 4, and ball gain in the zone 1 (see **Figure 1**).

Expected goals (xG) measures the conversion probability of a shot based on pitch location and types of start (e.g., cross and counterattack) and finish (e.g., shot and headed shot). The xG assigns a quality value ranging from 0 to 1 for each shot toward the goal (scored or not scored) with a higher value indicating a greater likelihood of a scoring opportunity. For instance, a headed shot from the central position on the edge of the six-yard box has an xG value of 0.669. In other words, head shots taken from this position would have 66.9% probability of scoring a goal. The study regarded the xG of opponent teams as the reference to evaluate the effectiveness of each defensive playing style. The expected goal (xG) of the opponent team with a lower value in a match meant that the defensive team had a better performance in recovering the ball or preventing the opponent from scoring a goal. On the contrary, the defensive team with a higher xG of opponent teams had less effect on preventing offense through technical and tactical actions of defense. Therefore, the study extracted a total of 16 features related to offensive and defensive performance from the raw data based on the previous studies (Bransen et al., 2019; Yi et al., 2020; Haaren, 2021) to construct the xG model: X position of shot, Y position of shot, body part, counterattack, shooting distance to goal line, shooting distance to center, whether using the weak foot, shooting by head distance to goal line, last action prior to the shooting (cross, corner, key pass, dribble, and duel), angel of shooting, free kicks, and penalties. Finally, the distribution of xG values were plotted in the following figure (**Figure 2**).

TABLE 1 | Description and definition of the defensive performance indicators.

Variable	Definition
Related to own team	
1. Interception	A player reads an opponent's pass and intercepts the ball by moving into the line of the intended pass. The interception could be finished with or without the ball recovery
2. Clearance	A player kicks the ball away from his own goal with no intended recipient, and the clearance included that the ball kicked from the offensive filed or kicked to the sideline
3. Ball gain zone 1	The analyzed team gained the ball in zone 1 (see **Figure 1**)
4. Error total	The number that a defensive player makes total errors, which leads to goals or shots conceded
5. Error in own half (%)	The number that a defensive player makes errors in own half divided by total errors
6. Keeper claim	The number of times that the goalkeeper get possession of the ball positively
7. Keeper smother	The number of times that the goalkeeper who comes out and claims balls at the feet of a forward gets smothers, similar to tackles
8. Foul total	The number of times that a player commits a foul for defense
9. Creating danger	After gaining the ball, the analyzed team made a shot or entry into the opposing penalty area
Related to opponent team	
10. Deep completion	The number of pass (excluding crosses) that was received in a 20-meter radius from the opponent goal line
11. Cross unsuccess	The number of teams crossed unsuccessfully
12. Dribble success	The number of teams dribbled successfully
13. Shot accuracy (%)	The number that a player shot accuracy
14. Pass in the zone 3	Any kind of pass made by the team in zone 3 (see **Figure 1**). And the of the pass is in the designated zone 3
15. Pass in the zone 4	Any kind of pass made by the team in zone 4 (see **Figure 1**). And the of the pass is in the designated zone 4

Statistical Analysis

Firstly, exploratory factor analysis using principal component analysis (PCA) was conducted on the defensive performance indicators with orthogonal rotation (varimax) running with all 15 performance indicators in order to pool the variables into factors (dimensions of defensive playing styles). This technique allowed the data set to be reduced to factors by grouping the measured variables (Field, 2013). To facilitate the comparison of teams' defensive performance in each factor, the scores were later normalized to unify different scales of all factors. The normalized factor score for each team was obtained *via* dividing the original factor score by the median. For each factor, the performance indicators with the highest factor loading (i.e., the correlation between the performance indicator and the factor) are identified. This technique pools performance indicators into fewer factors that represent different styles of play.

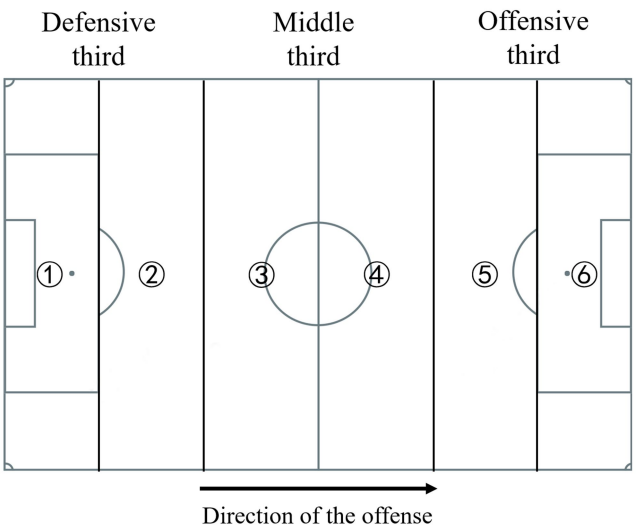

FIGURE 1 | Pitch divisions in six zones parallel to the goal lines. ① represents zone 1; ② represents zone 2; ③ represents zone 3; ④ represents zone 4; ⑤ represents zone 5; ⑥ represents zone 6.

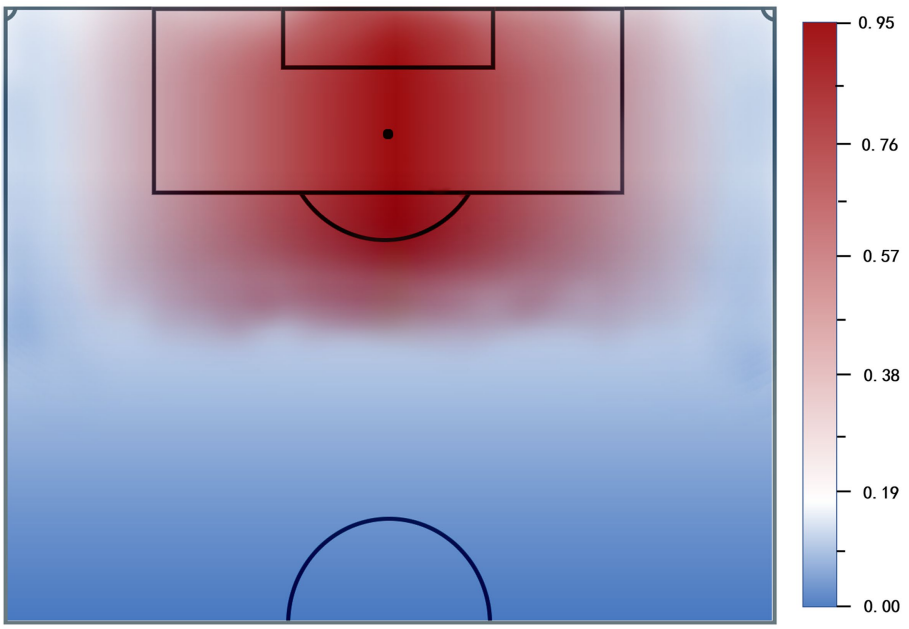

FIGURE 2 | Expected conversion probabilities of shots on the pitch. The darker the red, the higher the expected goal.

The Kaiser–Meyer–Olkin measure (Kaiser, 1974) and communalities values after extraction (Maccallum et al., 1999) were employed to verify the sampling adequacy for the analysis. The adequacy of inter-item correlations is based on Bartlett's sphericity test. Performance indicators with factor loadings greater than |0.6| showed a strong positive or negative correlation and indicated a substantial value for factor interpretation (Daniel, 1993).

Secondly, a xG model (a machine learning model—logistic regression analysis) was calculated using 27,852 shots from five seasons of CSL data (2016–2020). In order to improve the interpretability of the result and the accuracy of the model, there were more performance indicators related to shots were chosen as independent variables in the model. The metric of xG model was called AUC. The AUC of a model is the probability that the model ranks a random positive example (i.e., a successful shot) more highly than a random negative example (i.e., unsuccessful shot). For instance, 73.32% (AUC) meant that when randomly selecting a successful shot and an unsuccessful shot, there was a 73.32% chance that the model gave the successful shot a higher probability than the unsuccessful shot. Thus, this provided the basis for the expected goals model to calculate the likelihood of a shot resulting in a goal. A detailed explanation of the xG model and multiple performance indicators that covered this metric could be found in the study by Bransen et al. (2019) and Haaren (2021).

Lastly, the study performed a multiple regression analysis in a stepwise interactive mode in order to assess the influence that each defensive playing style had on the effectiveness of defense. The team's score of each factor in a match was used as an independent variable. And xG of the opponent team in the same match was a dependent variable. The training model was calculated from the 2016 to 2019 seasons. And the 2020 season was used for a testing model to measure accuracy and validity of the multiple regression model. When testing the multiple regression model, Pearson's correlation analysis of the predicted xG and the real xG was conducted. And the correlation coefficient (r) was calculated with absolute values of the thresholds being 0- to 0.3-weak correlation, 0.3–0.5 low correlation, 0.5–0.8 moderate correlation, and 0.8–1.0 high correlation (Field, 2013). To check the normality of the data, the Kolmogorov–Smirnov test was used. The homogeneity of variance was tested by Levene's test. This analysis was inspired by similar investigations in professional football leagues (Aquino et al., 2017; Souza et al., 2019). In the regression analysis, all match statistics were introduced based on their correlation with the residual and their intercorrelation with variables that already included in the equation. Redundant variables were excluded to avoid multicollinearity by using the variance inflation factor (VIF). The R^2 values were adjusted for the number of cases and parameters in the analysis. Using the standardized regression coefficients, the relative contribution of each different variable in relation to the explained variances was calculated as follows:

$$R^2_{adjusted} = \frac{B_{standardized}}{B} \quad (1)$$

where $R^2_{adjusted}$ = partial contribution R^2 adjusted of a style, $B_{standardized}$ = standardized regression coefficient for parameter, B = sum of all standardized regression coefficients in equation.

All the analyses were performed using Python 3.6 and statistical significance level was set at $p < 0.05$.

RESULTS

The Kaiser–Meyer–Olkin (KMO) measure verified the sampling adequacy for the analysis with a score of 0.76, and the communalities after extraction were greater than 0.6 in all performance indicators, deeming sample size to be adequate for factor analysis. Bartlett's test of sphericity (χ^2 =3,258, df = 105, $p < 0.05$) indicated that correlations between items were sufficiently large for PCA. Eight components had eigenvalues (rotation sums of squared loadings) over one and explained 85.17% of the total variance. The percentage of variance explained by each factor decreased from factor 1 to 8. The rotated component matrix for the factor loadings determined the performance indicators associated with each factor (**Table 2**).

Descriptions of factors were interpreted based on the group of associated performance indicators. A new factor score obtained after the team's factor score was normalized according to the median determining how much a team relies on one specific defensive style or a combination of these styles of play. Factor 1 (Defense closed to the own goal) included clearance, ball gain zone 1, deep completion, and cross unsuccess. A team with a high score on this factor tended to defend in the defensive third. Factor 2 (mid-positioning defense with pressure) included dribble success, pass in the zone 3 and pass in the zone 4. The team that scored positively had a lower percentage of possession in the central third. Factor 3 (High intensity confrontation) included interception and foul total. A team with a high score regained more balls by fouling and dueling. Factor 4 (Error) defined teams that tended to makes an error leading to a goal or shot conceded if they scored highly. Factor 5 (Defense in advanced zones) defined teams creating a dangerous situation after giving more pressure in the offense third. Factor 6 and factor 8 (Defense of goalkeeper) identified the importance of keeper smother and keeper claim. Finally, factor 7 (Receiving a dangerous situation) defined teams with a high score which was not so good at defending that the opponent teams made dangerous situations frequently.

The process of improving the ROC curve of the models in xG was showed in **Figure 3**, with the value of AUC increasing from model 1 (AUC = 72.90%) containing X position of shot, Y position of shot, body part, and counterattack to model 4 (AUC = 79.83%) including free kicks, and penalties constantly, showing that when randomly selecting a successful shot and an unsuccessful shot, there was a 79.83% chance that the model gave the successful shot a higher probability than the unsuccessful shot.

Table 3 summarized the results of the multiple linear regression. Regarding degree of importance, the factor 7 (receive a dangerous situation) explained 31.3% of the variance in xG of the opponent in the model. Adding the factor 1 (defense closed to the own goal), this percentage reached 38.9%. Factor 4 (error) and factor 8 (keeper claim) explained 1.4 and 1% of the variance in the model. Finally, the styles of play adding the factor 3 (high intensity confrontation) explained 41.6% of the total variance in the model. On the contrary, factor 2 (mid-positioning defense with pressure), factor 5 (defense in advanced zones), and factor 6 (keeper smother) were excluded from the multiple regression model of prediction (all $p > 0.05$). Overall, the multiple regression analysis explained 41.6% of the total variance in the xG of the opponent. In this case, factor 7 (receive a dangerous situation) was the defensive style of play with the highest association to the xG of the opponent. **Figure 4** included a comparison between the predicted and actual xG of the opponent with the multiple regression model of prediction by using the data of 2020 season. The predicted xG of the multiple regression model correlated with actual xG of the opponent at $r = 0.62$ ($p < 0.05$) showing a moderate correlation.

Predictive Model of xG of the Opponent Based on Defensive Styles of Play

Expected goals of the opponent = 0.219 + (receive a dangerous situation × 2.405) + (defense closed to the own goal × − 1.053) + (error × 0.155) + (keeper claim × − 0.040) + (high intensity confrontation× − 0.175) (2).

TABLE 2 | Rotated component matrix for the performance indicators showing a strong positive or negative correlation.

	Component							
	1	2	3	4	5	6	7	8
Interception			0.625					
Clearance	0.888							
Ball gain zone 1	0.875							
Error total				0.970				
Error in own half				0.974				
Keeper claim								0.986
Keeper smother						0.948		
Deep completion	0.746							
Foul total			0.622					
Cross unsuccess	0.833							
Dribble success		−0.687						
Shot accuracy							0.943	
Pass in the zone 3		−0.810						
Pass in the zone 4		−0.876						
Creating danger					0.799			

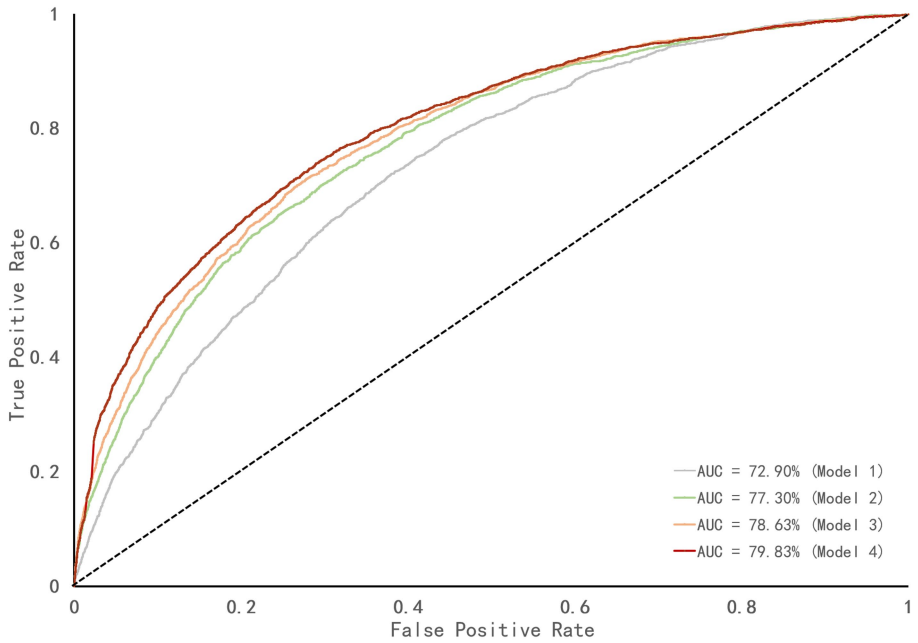

FIGURE 3 | The ROC curve of different logistic regression models in xG. The diagonal dotted line represents a line of zero discrimination, also known as pure chance line.

TABLE 3 | Relative contribution of defensive styles of play to the variance of excepted goals (xG) of the opponent frequency.

Predictors	Non-standardized β coefficients	Standardized β coefficients	Adjusted R^2	*t*	*p*	Tolerance	VIF
Constant	0.219			2.561	0.01*		
Receiving a dangerous situation	2.405	0.917	0.312	31.872	<0.01**	0.68	1.46
Defense closed to the own goal	−1.053	−0.441	0.389	−15.375	<0.01**	0.61	1.64
Error	0.155	0.109	0.403	6.216	<0.01**	0.60	1.66
Keeper claim	−0.040	−0.101	0.413	−5.688	<0.01**	0.58	1.71
High intensity confrontation	−0.175	−0.051	0.416	−2.923	<0.01**	0.58	1.72
Mid-positioning defense with pressure	−0.021			−1.042	0.30	0.79	1.27
Defense in advanced zones	−0.042			−1.946	0.05	0.65	1.54
Keeper smother	0.009			0.497	0.62	0.99	1.02

VIF, Variance inflation factor. Adjusted R^2 is cumulative, with each incremental step adding to the variance explained.
**p <0.05; **p <0.01.*

DISCUSSION

The main aim of the current study was to identify and measure defensive playing styles used by the CSL teams during a five seasons period (from the 2016 to 2020 seasons) *via* considering a more comprehensive set of defensive techniques and spatial information; and to investigate the effectiveness of defensive styles of play during the seasons under analysis. As it was hypothesized, this study identified specific defensive playing styles based on fifteen technical–tactical indicators that varied along the matches as an adaptation of teams in various situational variables to perform at the highest level in the competition. To the best of our knowledge, although some investigations have described partially different styles of play in elite soccer (Fernandez-Navarro et al., 2016; Gómez et al., 2018; Lago-Peñas et al., 2018), no previous study has examined the effectiveness of the defensive playing styles used by teams and their association with the success of defense.

The current study identified 8 factors from the PCA: factor 1 (defense closed to the own goal), factor 2 (mid-positioning defense with pressure), factor 3 (high intensity confrontation), factor 4 (error), factor 5 (defense in advanced zones), factor 6 (keeper smother), factor 7 (receive a dangerous situation) and factor 8 (keeper claim). Meanwhile, the PCA results showed scores of 8 factors for teams indicating their reliance on specific defensive styles of play. Compared to the study of Castellano and Pic (2019) that classified playing styles of the Spanish first division (LaLiga) into two offensive phases (direct attack versus elaborate attack) and two defensive phases (deep defending versus high-pressure defense), the current study is able to achieve a complex classification of defensive styles *via* including the spatio-temporal and zonal information of more defense

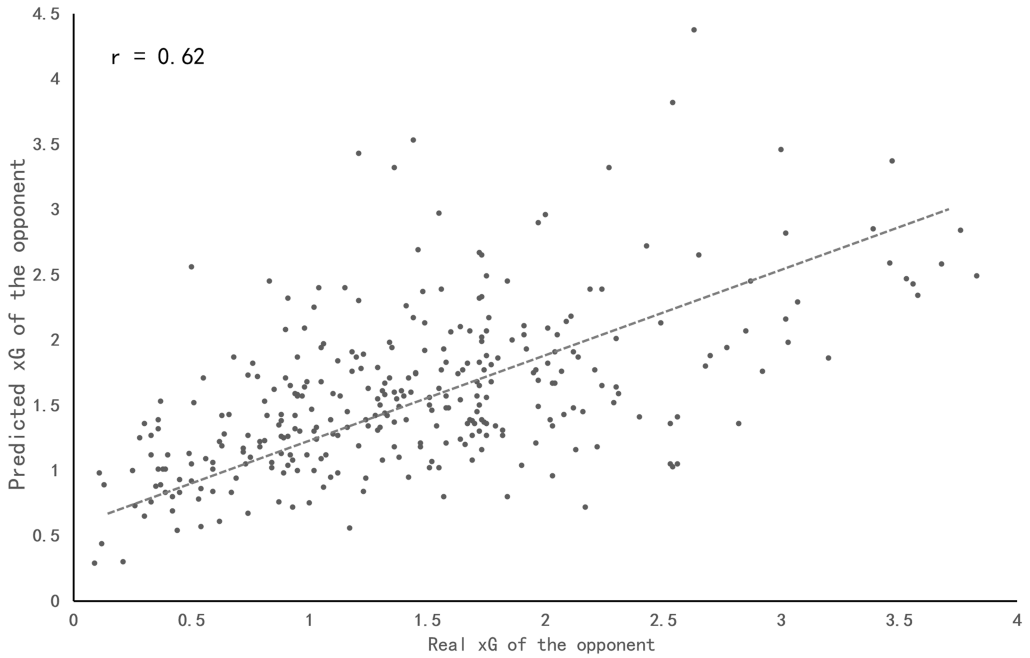

FIGURE 4 | Correlation between the actual and predicted xG of the opponent of 2020 season in CSL. Each dot represents one team in a match, for a total of 320 real-predicted comparisons. The dotted line represents the trend of correlation between the actual and predicted xG of the opponent.

performance indicators. Such approach could therefore facilitate the assessment of defensive effectiveness. Moreover, these findings might not only allow analysts to identify their own team's defensive playing styles in order to recognize their own strengths and weaknesses, but also inform coaches when designing specific trainings where teams are required to play against simulated opponents of different defensive styles or to strive to defend with the most efficient style (Díaz-Díaz et al., 2019).

The accuracy of the logistic regression model for xG was improved (AUC = 79.83%) after the training process, and the variables have considerably high interpretability for explaining offensive behaviors. Meanwhile, the predicted xG by the multiple regression model were consistent with actual xG ($r = 0.62$). Defense closed to the own goal (factor 1), high intensity confrontation (factor 2), error (factor 4), receive a dangerous situation (factor 7) and factor 8 (keeper claim) were found to be the most important variables of the model, implying that teams with the above styles achieved greater efficiency in preventing opponents from scoring. Interestingly, factor 7 was the variable that explained more proportion of the variance, and it is defined as whether the goal was threatened after teams losing possession of the ball. Higher scores in this variable could mean that teams were slow in transition so that it created a disadvantageous situation for themselves. Such claim is supported by the previous finding that shot accuracy (one of the variables in factor 7) could differentiate the best-ranked and least-ranked teams in LaLiga (Lago-Ballesteros and Lago-Peñas, 2010). Therefore, it is crucial for the defending team to be fast in transition once losing the possession and try to undermine the opponent's offensive *via* forcing them to make non-threatening passes (Ali, 2011; Kempe et al., 2014). In addition, error (factor 4) including error and error in own half was also positive with xG of the opponent, which suggested that teams had higher scores in this factor tended to commit mistakes so frequently that the possession was easily lost. Previous research showed that ball recoveries closer to the attacking goal produced seven times more goals and 19 times more entries into the penalty area (Yi et al., 2019a), compared to ball recoveries in the defensive zones. Therefore, it was actually rather essential for defensive teams to make less errors especially in their own half.

Besides, factor 1 (defense closed to the own goal), factor 3 (high intensity confrontation) and factor 8 (keeper claim) were negative with xG of the opponent in the multiple regression model. Defense closed to the own goal (factor 1) explained the highest percentage of variance among them, while high intensity confrontation (factor 3) higher than factor 8. These defensive styles of play occupying a large proportion may be due to two reasons. On the one hand, it is widely believed that the growing presence of non-Chinese players in the CSL could account for these alterations in technical, tactical, and confrontational performance. In fact, it was plausible for non-Chinese players to encourage Chinese players to improve their physical and technical performance. Bush et al. (2015) found that the English Premier League has underwent substantial changes over the last decade with the distances of high intensity and sprinting increasing by 30–50% and the number of passes rising by 40%. On the other hand, it may be due to their traditional playing tactics for most CSL teams: dropping the line to avoid losing the ball and waiting for the chance to counterattack which might reduce xG of the opponent. It suggested that the tactical principle of counterattacking caused

imbalances in the opposition's defense and offense, therefore increasing the success of the attacking sequence and the chance to score a goal (Tenga et al., 2010). As for keeper claim (factor 8), it suggested that goalkeepers scoring highly tended to get possession of the ball positively which led to reduce xG of the opponent. In the modern football matches, goalkeepers were required not only to defend the goal, but also to actively cooperate with their teammates both during defending and attacking as an organizing role (Hughes and Bartlett, 2002; Dellal et al., 2011). Szwarc et al. (2019) who showed that the goalkeepers in the bottom 5 teams have a higher distance of sprint compared to the top five teams in the English Premier League.

In contrast, factor 2 (mid-positioning defense with pressure), factor 5 (defense in advanced zones), and factor 6 (keeper smother) were excluded from the regression analysis ($p > 0.05$). Mid-positioning defense with intense pressure (factor 2) suggested that the team which scoring lower paid more defensive attention to and put more pressure on the middle third so that the team gained much possession in the middle third and forward players had time and space to come into the box and seize the opportunity to shot. And defense in advanced zones (factor 5) identified teams that used high- or low-pressure defensive styles of play in the advance zones. Defense in advanced zones could influence scoring opportunities as the ball could be recovered closer to the opponent's goal and increased the likelihood of facing an imbalanced defense (Wright et al., 2011). To sum up, concentrating more on the middle third suggested a possession style, while putting more pressure on the attacking third suggesting a high-pressure style. Nevertheless, there were two reasons for the two styles of defense being excluded. On the one hand, in the CSL, there were few teams having their playing philosophy for high-pressure and the highly skilled middle players in the team for passing abilities to have an impact on xG of the opponent where progress and breakthroughs should be made in the future for CSL teams. These findings were in accordance with available research suggesting top teams prefer to "control" the game by dictating it instead of giving the initiative to the opponent to protect own goal (Collet, 2013). On the other hand, these outcomes suggested that a more vertical style of play, where shot finalization on the goal became the main offensive objective, may be a more successful strategy to succeed in football instead of the prevalent idea of maintaining ball possession and passing over the opponent (Souza et al., 2019). As for keeper smother (factor 6), this was mainly because the defense was closer to the midfield and the forward which resulted in smothering for goalkeepers when the opponent got a chance of a single-pole ball. And realizing successful smother was too difficult for goalkeeper to influence xG of the opponent.

With regard to the limitations of the present study, some aspects should be highlighted to improve the applicability of its results. Firstly, the multiple regression analysis explained relatively low percentage (41.6%) of the total variance in the xG of the opponent. Such result could be due to two reasons. On the one hand, using xG of the opponent alone might not be able to comprehensively measure the defense of teams, as the former was highly relevant to the opposing offense. On the other hand, the physical, technical–tactical, and positional related variables concerning off-ball actions were not included in the current research, and should be considered in the future (Liu et al., 2015; Zhou et al., 2021). Secondly, the analysis of interactive effect of contextual-related variables (e.g., in-home vs. visitor; match status—winning, losing, or drawing; and the moment of match—begin of championship, middle, and end) need to be addressed to determine their impact on the selection of defensive indicators and the effectiveness of defensive playing styles. In fact, previous studies have emphasized the importance of situational variables in assessing offensive performance (Fernandez-Navarro et al., 2018; Zhou et al., 2018), but not during the defensive phase. Lastly, different countries and competitions should be analyzed in order to verify the generalizability of the findings base on the CSL.

CONCLUSION

In summary, this study allowed to identify and measure eight factors that represent seven different styles of play from fifteen defensive performance indicators based on a more comprehensive set of defensive techniques and spatial data by the PCA model. The team's ranking showed different performance trends according to each team. After selecting these defensive styles of play and xG of the opponent to run the multiple regression model, five defensive styles were identified to have an influence on the effectiveness of defense in the CSL. If the team strengthened the defense closed to the own goal, high intensity confrontation, and defense of goalkeeper, meanwhile making less errors and receiving less dangerous situations, the discipline for opposing team to shoot and score would be greatly reduced. According to their team's effectiveness and efficiency of defensive styles, coaches can deploy specific tactics and teams can choose appropriate players in the player markets. Further research should attempt to establish the influence of situational variables and off-ball actions on defensive style when measuring performance and outcomes.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found at: www.whoscored.com.

AUTHOR CONTRIBUTIONS

LR, SZ, and YC: conceptualization and data curation. LR and YC: formal analysis. LR, HG, SZ, and YC: investigation. LR, HG, YS, ZP, SZ, and YC: methodology, software, writing—original draft preparation, designing the experiments and performing the statistical analysis, writing—review and editing, and writing and revising the manuscript. LR, ZP, and YC: visualization. YS, ZP, and YC: funding acquisition. HG, YS, ZP, SZ, and YC: supervising the design and reviewing the manuscript. All authors have made a substantial and direct contribution to manuscript and approved the final version of the manuscript.

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Factors That Influence Actual Playing Time: Evidence From the Chinese Super League and English Premier League

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This study explored factors that influence actual playing time by comparing the Chinese Super League (CSL) and English Premier League (EPL). Eighteen factors were classified into anthropogenic and non-anthropogenic factors. Fifty CSL matches (season 2019) and 50 EPL matches (season 2019–2020) were analyzed. An independent sample t-test with effect size (Cohen's d) at a 95% confidence interval was used to evaluate differences in the influencing factors between the CSL and EPL. Two multiple linear regression models regarding the CSL and EPL were conducted to compare the influencing factors' impact on actual playing time. The results showed that the average actual playing time ($p < 0.05$, $0.6 < ES = 0.610 < 1.2$) and average game density ($p < 0.05$, $0.2 < ES = 0.513 < 0.6$) in the EPL were significantly higher than in the CSL. The average time per game for general fouls ($p < 0.05$, $1.2 < ES = 1.245 < 2.0$) and minor injuries ($p < 0.05$, $0.2 < ES = 0.272 < 0.6$) in the CSL was significantly higher than in the EPL. The average time allocated to off-field interferences in the CSL was significantly higher than in the EPL, while the average time allocated to throw-ins (out-of-bounds) in the CSL was significantly lower than in the EPL ($p < 0.05$, $0.2 < ES = 0.556 < 0.6$). The study showed that actual playing time in CSL games was more affected by anthropogenic factors than in the case of EPL games, while both leagues were equally affected by non-anthropogenic factors. This study provides a reference for coaches to design effective training and formulate game strategies for elite soccer leagues.

Keywords: playing time, Chinese Super League, English Premier League, football (soccer), soccer (football), game stoppage time

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INTRODUCTION

In a soccer game, actual playing time is defined as the duration of play after subtracting the time taken up by stoppages, substitutions, goals, injuries, and other incidences (Castellano et al., 2011), which are added on as extra time at the end of the game. The Fédération Internationale de Football Association (FIFA) calculates the actual playing time to assess the continuity, quality, and watchability of a game (Peng, 2017) as it is an important indicator of the level of a league. The actual playing time of a soccer game can be considerably

less than 90 min due to stoppages caused by free kicks, corner kicks, substitutions, goals, player injuries, and other interferences (Cook and Goff, 2006; Lago-Peñas et al., 2012). The level of the players, the match status of the game, the level of play, and the team's playing style (Boyko et al., 2007; Dong, 2012; Greve et al., 2019) can also have an impact. All these factors can increase the total playing time. The use of a video assistant referee (VAR) in recent years has led to more stoppages, resulting in an increase in total playing time (Han et al., 2020).

An elite soccer games can be stopped approximately 108 times and account for up to 38% of the total game (Siegle and Lames, 2012a). Stoppages during a game have a significant impact on a player's performance. Previous studies have found that stoppages cause extended extra time and reduce players' running performance (Linke et al., 2018); moreover, running distance in the second half of a game may decrease because of too many stoppages rather than a decrease in physical capacity (Carling and Dupont, 2011; Rey et al., 2020). Some soccer teams will deliberately create opportunities for stoppages (place kicks, out-of-bound goals, etc.) when they are ahead or stall at dead balls (Siegle and Lames, 2012a,b; Augste and Cordes, 2016) to disrupt the continuity of the other team's attack, especially in the final stages of a game (Carling and Dupont, 2011).

Stoppages are directly associated with some of the indicators of soccer games and play an important guiding role in the time, frequency, density, and intervals of team training. Chinese soccer is gaining more public attention and social influence, and the Chinese Super League's (CSL) games have increased in both pace and quality (China Football Federation, 2019). For example, the CSL's average actual playing time in the 2008 season was 51 min and 25 s (Dong, 2012), and it rose to 54 min in the 2014–2017 seasons (Zhao, 2019). Nevertheless, the CSL's actual playing time is still shorter than the world's elite leagues. In 2006, the average actual playing time of the 18th FIFA World Cup was 60 min and 36 s, with an average match density of 62%. The 13th European Football Championship in 2008 had an average actual playing time of 62 min and 23 s. Since the CSL players have a lower load and match intensity than the five major European soccer leagues (Li, 2007), they cannot perform high-quality technical and tactical movements in high-intensity matches to produce a satisfactory performance.

The CSL is growing rapidly and the amount of research on the CSL is increasing (Jiang, 2013; He, 2016; Liu and Hopkins, 2017; Li, 2019), yet few studies have focused on the factors that impact actual playing time. The English Premier league (EPL)—a well-established league—is known as one of the best soccer leagues in the world; the CSL league—a developing league—has modeled itself on the EPL. Thus, this study aims to understand the nature of soccer from the two different contexts and compares the important factors that influence the actual playing time in the CSL and EPL, as the two typical leagues in the East and West. The results of this study may assist coaches in understanding the causes for stoppages in soccer games. Moreover, this study may offer a realistic guide for the coaches of professional clubs to design training programs that improve players' ability under pressure and help referees to control different situations during a game.

MATERIALS AND METHODS

Sample and Variables

This study randomly selected 50 matches in the CSL during the 2019 season and 50 matches in the EPL during the 2019–2020 season, prior to the 30th round. Matches after the 30th round were excluded because some rules were changed due to the COVID-19 pandemic. The matches were recorded onto a hard drive and included all 16 teams in the CSL and all 20 teams in the EPL. Three matches from each league were selected for pre-testing, and expert interviews were conducted to refine the statistical concepts and measurements. Following previous studies (Li, 2007; Yang et al., 2018; Gai et al., 2019; Zhao, 2019; Han et al., 2020), 18 stoppage-related variables were determined, which were then categorized as either non-anthropogenic or anthropogenic factors (**Table 1**). Non-anthropogenic stoppage factors were defined as stoppages that resulted from the "FIFA Laws of the Game" and the nature of soccer games, whereas anthropogenic stoppage factors were defined as stoppages that resulted from the behavior of players and other people at the venue.

Afterwards, an experienced specialist examined the games and collected the data. The specialist recorded the time taken up by stoppages in the effective time of each game and exported the results onto Excel spreadsheets.

Data Collection and Data Reliability

To test the reliability of the data, another experienced observer examined ten randomly selected games (10% of the sample: 5 CSL and 5 EPL games; Hernández-Moreno et al., 2011). Intraclass Correlation Coefficient (ICC) values ranged from 0.968 to 1.0 (**Table 2**), which exceeded 0.9 and thus proved excellent reliability (Koo and Li, 2016).

Procedure and Statistical Analysis

A descriptive analysis of each variable was conducted for the two leagues. Data normality was calculated using the Kolmogorov–Smirnov test and was found to be normally distributed. Subsequently, an independent samples *t*-test ($p < 0.05$) was conducted to compare and analyze actual playing time, game density, duration of each game, and then tabulated 18 stoppage variables in the two leagues. The results were recorded as mean ± standard deviation ($M \pm SD$). The effect size (ES, Cohen's *d*) at 95% confidence intervals (CIs) was then used to measure the range of differences. ES was classified as follows: < 0.1 = insignificant difference, ≤ 0.2 = small difference, ≤ 0.6 = moderate difference, ≤ 1.2 = large difference, ≤ 2.0 = very large difference, and ≤ 4.0 = extremely large difference based on previous research (Hopkins et al., 2009; Zhou et al., 2019).

A multiple linear regression analysis was conducted to determine the differences in influencing factors between the

TABLE 1 | Classification of factors of stoppages.

No	Category	Factors of stoppages	Definition
1	Non-anthropogenic factors	Out-of-bounds (X_1)	The time consumed for out-of-bounds is calculated from the time the ball is outside of the playing field till the player of the opposing team kicks off the ball
2		Goal kick (X_2)	The time consumed for the goal kick is calculated from the time the whole of the ball kicked by the attacking team player passes over the goal line till the player of the defending team kicks off the ball at the penalty area
3		Resumption of play after a goal (X_3)	The time consumed for resumption of play after a goal is calculated from the time the ball enters the goal line till the player of the opposing team kicks off the ball at the centre spot
4		Corner kick (X_4)	The time consumed for corner kick is calculated from the time the player of the defending team kicks off the ball out of his own goal line till the player of the opposing team kicks off the ball from the corner area
5		Substitution of player (X_5)	The time consumed for substitution of player is calculated from the time there is a dead ball situation till a player is replaced and the play is restarted
6		General foul (X_6)	The time consumed for a general foul is calculated by the time on fouls without disciplinary penalties and building a defensive wall
7		Offside (X_7)	The time consumed for offside is calculated from the time the referee blows the whistle till the player of the opposing team kicks
8		Building a defensive wall (X_8)	The time consumed for building a defensive wall is calculated from the time the referee blows the whistle of foul (the defending team building a defensive wall) till the ball is kicked off
9		VAR intervention (X_9)	The time consumed for VAR intervention is calculated from the time the referee blows the whistle of foul (with VAR intervention) till the tall is kicked off by the opposing team player
10		Team doctor intervention (X_{10})	The time consumed for team doctor intervention is calculated from the time a player gets injured till the medical stoppage ends
11		Presentation of yellow card (X_{11})	The time consumed for presentation of yellow card is calculated from the time the referee blows the whistle and presents the yellow card till the play is restarted
12		Presentation of red card (X_{12})	The time consumed for presentation of red card is calculated from the time the referee blows the whistle and presents the red card till the play is restarted
13		Award of penalty kick (X_{13})	The time consumed for award of penalty kick is calculated from the time the referee blows the whistle and awards a penalty kick till the ball enters the goal
14		Dropped ball (X_{14})	The time consumed for dropped ball is calculated from the time the referee stops the play temporarily as necessary till he drops the ball to restart the play
15	Anthropogenic factors	Player minor injury (X_{15})	The time consumed for player minor injury is calculated from the time a player gets injured without the need of team doctor treatment till the play is restarted
16		Player conflict (X_{16})	The time consumed for player conflict is calculated from the time the referee stops the play due to a player conflict till the play is restarted
17		Off-field (X_{17})	The time consumed for off-field is calculated by the time on the stoppages caused by factors including the coaches, substitutes, officials, fans, etc.
18		Player complaint (X_{18})	The time consumed for player complaint is calculated by the time of the stoppage because a player may complain about the referee for not calling it a foul which a player reckons it is
19		Actual playing time	Actual playing time refers to the pure time of a soccer game. It includes 90 min plus stoppage time added and minus stoppage time. (actual playing time = 90 min + injury time–stoppage time)
20		Match density	Match density refers to the percentage of the actual playing time of the actual total time in a match.
21		Average total time consumption per match	Average total time consumption per match is the average time consumption derived from any of the 18 stoppage indicators

VAR, video assistant referee.

CSL and EPL. In this analysis, the time consumed by each stoppage factor was taken as the independent variable, while the actual playing time was the dependent variable.

$$Y_i = a_{i1}x_{i1} + a_{i2}x_{i2} + \ldots + b_i + \varepsilon_i,$$

where i represents either the CSL or EPL, b is the constant term, and ε is the error term. The independent variables (X_1–X_{18}) and the dependent variable (Y) of the two leagues were subsequently inserted into the multiple linear regression model. In the results, the significance value, as the standardized coefficient, determined whether the independent variable (i.e., stoppage factors) contributed to the dependent variable (i.e., actual playing time). The beta value determined the degree of influence of the independent variables on the dependent variable. The analyses were done using IBM SPSS 22.0 (Statistical Package for the Social Sciences, SPSS Inc.). This study was complied according to the ethical principles stated by the Declaration of Helsinki.

RESULTS

Comparison of Actual Playing Time and Stoppage Factors Between the CSL and EPL

Table 3 shows that the average actual playing time between the CSL and the EPL was statistically different ($p = 0.03 < 0.05$), and the effect size values showed a moderate difference ($0.6 < \text{ES} = 0.610 < 1.2$). The average match density (%) also showed a statistically significant difference ($p = 0.008 < 0.05$), the effect size values showed a minor difference

TABLE 2 | Interclass correlation coefficient and correlation values for variables.

Independent variable		Intraclass correlation coefficient (ICC)
X_1	Out-of-bounds	0.995
X_2	Goal kick	0.990
X_3	Resumption of play after a goal	0.968
X_4	Corner kick	0.977
X_5	Substitution of player	0.985
X_6	General foul	0.995
X_7	Offside	0.999
X_8	Building a defensive wall	0.993
X_9	VAR intervention	0.999
X_{10}	Team doctor intervention	0.993
X_{11}	Presentation of yellow card	0.996
X_{12}	Presentation of red card	0.993
X_{13}	Award of penalty kick	1.000
X_{14}	Dropped ball	0.991
X_{15}	Player minor injury	1.000
X_{16}	Player conflict	0.999
X_{17}	Off-field	×
X_{18}	Player complaint	0.999

($0.2 < ES = 0.513 < 0.6$), and the average game time did not show any statistical difference.

The average time spent on out-of-bounds between the CSL and the EPL was statistically different ($p = 0.007 < 0.05$), and the effect size showed a minor difference ($0.2 < ES = 0.556 < 0.6$). The average time spent on general fouls was also statistically different ($p = 0.001 < 0.05$), and the effect size showed a large difference ($1.2 < ES = 1.245 < 2$). The average time spent on players' minor injuries was statistically different ($p = 0.015 < 0.05$), and the effect size showed a minor difference ($0.2 < ES = 0.272 < 0.6$). The time spent on field interferences by off-field factors was statistically different ($p = 0.042 < 0.05$).

Comparison of Factors Impacting the Actual Playing Time Between the CSL and EPL

As is shown in **Tables 4**, **5**, the models of actual playing time of CSL and EPL are significant. X_1–X_{11} had an important impact on stoppage times for both the CSL and EPL. In the CSL, penalty kicks (X_{13}), player conflict (X_{16}), and player complaints (X_{18}) influenced stoppage time, while in the EPL, minor player injuries were an impact factor. The remaining variables were not significant in the regression models.

DISCUSSION

This study compared the factors that influenced actual playing time between the CSL and EPL. The results showed that the actual playing time in the CSL was less than in the EPL. The CSL spent more time on general fouls (X_6), player minor injuries (X_{15}), and off-field interferences (X_{17}), while the EPL spent more time on out-of-bounds (X_1). The factors that affected actual playing time also differed. For the CSL, anthropogenic factors dominated, and the primary factors included penalty kicks (X_{13}), player conflict (X_{16}), and player complaints (X_{18}), while the primary factor for the EPL was minor player injuries (X_{15}).

The CSL match density in the 2019 season reached 54.76%, slightly lower than for the EPL, which is generally consistent with the findings of studies by Augste and Lames (2008) and Siegle and Lames (2012a). Tschan et al. (2001) also found that in the European leagues, 32% of game time is consumed by stoppages; the same study found that in the World Cup, only 61–69% of the game time was dedicated to actual playing time. Similar to previous studies (Sun et al., 2014), in the CSL's games, general fouls took more time and had a greater impact on actual playing time. Additionally, minor player injuries and off-field interruptions took more time. Out-of-bounds and throw-ins took more time in the EPL games than in CSL games. Another study found that the time consumed by free kicks and player injuries in CSL games in the 2008 season was higher than in the 13th European Football Championship in 2008 (Dong, 2012), which is consistent with the results of the current study. In other words, referees in the CSL stopped the game more frequently for minor fouls, which led to more interruptions to the game and a consequent increase in time consumption. Comparatively, the fluidity of the EPL games was better than in the CSL games, and referees were able to control the pace of the game and make good use of advantage rules. Moreover, a free kick after a foul in the CSL tended to be slightly slower due to various interferences, such as improper positioning or player blocking (Greve et al., 2019). Furthermore, players sometimes pretended to be injured after a foul, which increased the time consumed in a game.

Previous studies found that high-intensity games tend to be accompanied by longer intervals (Hernández-Moreno et al., 2011). Compared to other leagues, the EPL has a faster rhythm (Jamil and Kerruish, 2020); thus, players may take advantage of stoppages to recover from a high-intensity game, which can explain the greater time consumption during throw-ins in EPL games. In addition, Siegle and Lames (2012b) found that throw-ins in the defensive zone took more time. This may be because losing possession in the defensive zone could more easily lead to conceding a goal. Another possible reason may be that players face more intense running in the defensive zone and they want to recover from fatigue by taking opportunities to rest when the ball is out of play, like during throw-ins.

Stoppages in CSL games included off-field interferences, which were not found in the EPL games. Zhao and Zhang (2021) found that spectators also impacted the actual playing time by negatively affecting both players and referees. For example, referees in Major League Soccer (MLS) tend to add an extra 33 s when the home team is down by one goal (Yewell et al., 2014). EPL referees also demonstrate a preference for the home team (Boyko et al., 2007). In the CSL, home teams also enjoy an advantage (Peng et al., 2016; Liu et al., 2019) as the home teams are better off than the away team regarding offense indicators. Han et al. (2020) showed that after the introduction of objective VAR technology, home advantages conferred by referees decreased partially, based on the indicators for red and yellow cards and fouls, which were previously largely determined by referees' vulnerability to the home team

TABLE 3 | Comparison of average data of matches of the Chinese Super League (CSL) and English Premier League (EPL; time unit: minutes).

Factors/indicators		CSL (n = 50)		EPL (n = 50)		T-test on independent sample		
		M	SD	*M*	SD	*p*	ES	95% CI for Cohen's d
	Actual playing time	52.91	5.35	56.24	5.19	0.003	0.610	± 0.207
	Match density (%)	54.76	5.88	57.70	5.58	0.008	0.513	± 0.113
	Playing time	96.68	1.52	97.24	2.08	0.151	0.165	± 0.061
Non-anthropogenic factors	Out-of-bounds (X1)	7.56	1.70	8.74	2.46	0.007	0.556	± 0.155
	Goal kick (X_2)	6.64	2.10	5.96	1.93	0.092	0.193	± 0.400
	Resumption of play after a goal (X_3)	3.23	1.77	3.43	1.73	0.746	0.038	± 0.187
	Corner kick (X_4)	4.77	2.04	4.80	1.80	0.940	0.015	± 0.377
	Substitution of player (X_5)	2.22	1.10	2.60	1.32	0.130	0.176	± 0.050
	General foul (X_6)	7.85	2.53	5.11	2.13	<0.001	1.245	± 1.671
	Offside (X_7)	0.82	0.88	1.05	0.77	0.063	0.215	±0.009
	Organization of wall (X_8)	2.05	1.68	2.43	1.52	0.197	0.150	±0.076
	VAR intervention (X_9)	1.43	1.42	1.11	1.21	0.324	0.113	±0.328
	Team doctor intervention (X_{10})	3.27	2.11	2.99	2.25	0.488	0.130	±0.523
	Presentation of yellow card (X_{11})	1.71	1.25	1.56	1.29	0.942	0.009	±0.232
	Presentation of red card (X_{12})	0.16	0.38	0.13	0.40	0.619	0.035	±0.257
	Award of penalty kick (X_{13})	0.48	0.92	0.36	0.64	0.699	0.037	±0.258
	Dropped ball (X_{14})	0.03	0.12	0.06	0.15	0.243	0.077	±0.663
Anthropogenic factors	Player minor injury (X_{15})	1.06	1.04	0.61	0.89	0.015	0.272	±0.468
	Player conflict (X_{16})	0.24	0.55	0.11	0.34	0.273	0.086	±0.303
	Off-field (X_{17})	0.04	0.13	0	0	0.042		
	Player complaint (X_{18})	0.17	0.49	0.06	0.24	0.126	0.283	±0.677

VAR, video assistant referee.

TABLE 4 | Linear regression coefficient for stoppage time and actual playing time.

Indicators	CSL			EPL		
	Beta	*t*	Sig.	Beta	*t*	Sig.
(Constant)		41.035	<0.001		52.961	<0.001
Out-of-bounds (X_1)	−0.350	−7.535	<0.001	−0.493	−10.428	<0.001
Goal kick (X_2)	−0.402	−7.883	<0.001	−0.347	−7.812	<0.001
Resumption of play after a goal (X_3)	−0.317	−6.537	<0.001	−0.273	−5.690	<0.001
Corner kick (X_4)	−0.397	−8.708	<0.001	−0.347	−7.818	<0.001
Substitution of player (X_5)	−0.232	−4.807	<0.001	−0.246	−5.143	<0.001
General foul (X_6)	−0.430	−8.888	<0.001	−0.389	−7.751	<0.001
Offside (X_7)	−0.174	−3.775	0.001	−0.180	−3.711	<0.001
Organization of wall (X_8)	−0.289	−6.998	<0.001	−0.311	−6.632	<0.001
VAR intervention (X_9)	−0.161	−3.393	0.002	−0.118	−2.689	0.011
Team doctor intervention (X_{10})	−0.331	−7.526	<0.001	−0.203	−3.892	<0.001
Presentation of yellow card (X_{11})	−0.287	−5.169	<0.001	−0.099	−2.247	0.032
Presentation of red card (X_{12})	−0.066	−1.515	0.140	−0.057	−1.280	0.210
Award of penalty kick (X_{13})	−0.116	−2.370	0.024	−0.093	−1.721	0.095
Dropped ball (X_{14})	−0.020	−0.429	0.671	−0.062	−1.344	0.188
Player minor injury (X_{15})	−0.102	−1.948	0.061	−0.108	−2.336	0.026
Player conflict (X_{16})	−0.187	−3.735	0.001	−0.081	−1.875	0.070
Off-field (X_{17})	−0.021	−0.444	0.660			
Player complaint (X_{18})	−0.095	−2.095	0.044	−0.091	−1.851	0.073

Since the Off-field factor for the effect size (ES) shows zero, it is automatically not counted in the regression model.
VAR, video assistant referee.

spectators. Although the use of new technology such as VAR has reduced home advantage in recent years (Han et al., 2020), the influence of spectators cannot be completely eliminated. Thus, a higher level of professional skills in both players and referees is required to reduce the impact of spectators.

In CSL games, penalty kicks, player conflict, and player complaints impacted actual playing time. Although there was no significant difference in total time compared to the EPL, these factors significantly impacted actual playing time in CSL games. Typically, when a penalty kick is awarded in CSL games, the player complains to the referee, which may result in the referee presenting a yellow card or even sending a player off the field. Players' behaviors not directly related to the game actions, such as gathering and inter-player conflict, also waste

TABLE 5 | Model summary of actual playing time of CSL and EPL.

Model	*R*	*R* square	Adjusted *R* square	Std. Error of the estimate	Change statistics					Durbin-Watson
					R square change	*F* change	*df*1	*df*2	Sig. *F* change	
CSL	0.979	0.957	0.933	1.38761	0.957	38.792	18	31	<0.001	2.040
EPL	0.975	0.951	0.926	1.41616	0.951	36.844	17	32	<0.001	1.207

time in a game. Previous studies have suggested that actual playing time in the CSL is likely influenced by referees' ability to control the game, players' professional and ethical qualities, the presentation of red and yellow cards, players disregarding referees' decisions, players' attitude toward the game, and players' technical and tactical abilities (Jiang, 2013; Li and Lu, 2013; Sun et al., 2014; He, 2016; Li, 2019; Zhao, 2019). Penalty kicks, player conflict, and player complaints may reflect the players' attitude to the game, or lack of technical and tactical ability; moreover, it has been suggested that players in the CSL are not afraid of being shown a second yellow card (Jamil and Kerruish, 2020). Such an attitude may lead to players committing fouls in the penalty area or being prone to taking excessive defensive actions that cause player conflict and penalties, or even lead to being sent off the field. Referees may also contribute to this situation. In CSL games, referees are often too hesitant to show a second yellow card (Mao et al., 2016), consequently, referees find it more difficult to act in time to control a situation on the field in the case of player conflict or player complaints, which encourages such behaviors.

The EPL games are typically played at a fast pace (Jamil and Kerruish, 2020), with fierce confrontation and frequent player minor injuries (Rahnama et al., 2002), especially in the first and last 15 min of the game. In the first 15 min, player injuries may result from intense player confrontation due to excitement, while player injuries in the last 15 min may be due to fatigue. Studies have also shown that stoppages are more likely to occur toward the end of a game (Carling and Dupont, 2011) and that many minor injuries are caused by fatigue. In contrast, more frequent stoppages and time consumption in the CSL dilute the intensity of a game; however, whether this reduces player injuries still needs to be examined in a further study.

Although this study provided significant findings, the study has a few limitations due to the small number of samples and the fact that contextual variables were not considered. Future studies should thus include these two aspects to ensure a more comprehensive view of influencing factors in the elite soccer league and soccer games in general.

CONCLUSION

The study's main findings demonstrate that the average actual playing time and average density of EPL games were significantly higher than in the CSL games, showing moderate differences and minor differences, respectively. The average time consumed by general fouls, minor player injuries, and off-field interferences in the CSL games was significantly higher than in the EPL games, while the average time consumed by out-of-bounds was significantly lower than in the EPL. Thus, more anthropogenic factors affected the actual playing time in the CSL than in the EPL, while non-anthropogenic factors affected the two leagues almost similarly. These results provide a reference for coaches to design effective training and develop strategies before a game to enhance players' ability under high intensity conditions. Furthermore, they can also guide referees to make proper plans for the coming game; thus, securing a more favorable outcome.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the (patients/participants or patients/participants legal guardian/next of kin) was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

YZ conceptualized the study, wrote the original draft preparation, and contributed to the methodology and data collection. TL reviewed and edited the manuscript and helped to improve this work. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.907336/full#supplementary-material

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Impact of absent crowds on technical and physical performances in the Chinese Soccer Super League

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Purpose: Spectators have a significant impact on match performances in soccer, but to what extent crowd support contributes to the technical and physical performances remains unclear. This study aimed to (1) investigate the differences in terms of technical and physical performances with and without spectators; and (2) identify the key factors differentiating between win and loss when playing with and without the presence of an audience.

Methods: Our study examined 794 performance records from 397 matches during the 2019–2020 seasons in the Chinese Soccer Super League. The least absolute shrinkage and selection operator (LASSO)-logistic regression was utilized to select significant predictors. Using an independent *t*-test and the Mann–Whitney non-parametric test explores the difference between matches with and without spectators. Key factors between win and loss were explored using univariate and multivariate logistic regression analyses.

Results: Our study found that cross ($p < 0.01$, ES $= -0.24$), shots ($p < 0.001$, ES $= -0.25$), and shot accuracy ($p < 0.05$, ES $= -0.18$) displayed decreasing trends whereas sprint distances ($p < 0.05$, ES $= 0.16$) presented an increasing trend without spectators comparing with the crowd support. Moreover, the above three technical variables were the main factors differentiating between wins and losses. Similarly, team and opponent quality remained important potential factors affecting the match outcome.

Conclusion: Match outcome or team performance is determined by a myriad of factors, but there are clear differences in technical and physical performances between matches with and without the presence of an audience. Similarly, our study provides a better explanation for the impact of crowd support on match performances whereby coaches can deploy players and adjust match strategies for ultimate success.

KEYWORDS

team sports, soccer, home advantage, sports performance analysis, Chinese Super League

Introduction

The consistently better performance observed by teams in various sporting contexts when playing at home is known as the "Home Advantage" (HA) (Jiménez Sánchez and Lavín, 2021). Factors that affected the documented phenomena have been paid constant attention over the past years (Pollard and Pollard, 2005; Lago-Peñas et al., 2017; Ruano and Pollard, 2022). Crowd support, territoriality, familiarity with the stadium, referee bias, and travel fatigue seem to be common consensus for home advantage in team sports (Pollard et al., 2017; Zhang et al., 2017, 2018; Ruano and Pollard, 2022). Furthermore, the majority of studies verified that crowd support and density may be the two most important factors that contribute to the home advantage in football (Pollard, 1986; Correia-Oliveira and Andrade-Souza, 2021).

The influence of home advantage on technical and physical performance has been well-documented in professional soccer. For example, home teams presented greater running demands (Aquino et al., 2018), higher total distances (Assis, 2016), and greater deceleration (Díez et al., 2021) than away teams. Similarly, playing away against strong opposition decreased team possession compared with playing at home (Lago, 2009). Recently, Travassos et al. (2022) investigated three balanced home matches from a Premier League team with 91 ball possessions in which a pass was performed into the opposition defensive area and overpassed the first defensive line. This study found that higher values of the width ratio between teams and the width of the attacking team for unsuccessful penetrative passes compared with successful penetrative passes, while a general decrease in distances and an increase in angles between attacking and defending players were observed between successful and unsuccessful penetrative passes.

There is a vast literature about HA in the Chinese Super League (CSL). For example, the existence of the HA in the CSL presented a decreasing trend from about 63.8 to 59.7% between the 2006 and 2016 seasons (Liu et al., 2019). Mao et al. (2016) suggested that HA had only trivial effects on the match outcome for upper-ranked teams when playing against upper-ranked opponents, whereas HA had positive effects on shot on target and shot accuracy for upper-ranked teams when playing with lower-ranked teams and for lower-ranked teams when facing the opposition of whatever strengths. Similarly, HA had a clear influence on ball possession and scoring first (Liu et al., 2021). Although the above-mentioned studies identified that HA had a significant impact on match performance and that spectators play a key role in winning a match in the CSL, these studies did not directly identify spectators' influence because it is difficult to design a randomized controlled trial to compare the difference between matches with and without crowd support.

The COVID-19 pandemic created a natural experimental condition to identify the direct impact of local crowds on match performance. From a global perspective, European and American top-class soccer matches played without spectators during the COVID-19 pandemic have been well-investigated. For example, shots on goal (accuracy) decreased for the home team without a crowd in the European soccer matches, and players' high-intensity running activities did not change but total distance and high-speed running distance decreased during the entire match (McCarrick et al., 2021; Rampinini et al., 2021; Wunderlich et al., 2021). Moreover, there was a reduction in HA for Serie A, but no change in HA for Serie B was reported in Brazilian Elite Soccer (Ribeiro et al., 2022). However, to the best of our knowledge, there is no investigation about the direct effects of absent crowds on match performance in the Asian football league. The 16 teams in the Chinese Soccer Super League were divided into two groups and played in a tournament-style behind closed doors during COVID-19 (Zhang et al., 2020). To minimize the risk of infection, all players, coaches, match officials, and other staff involved in the CSL had been required to stay inside a specific area during this period without any physical contact with the outside (Zhang et al., 2020). This policy counteracts the effects of crowd support, familiarity with the stadium, and travel fatigue on match performance. Thus, it is necessary to utilize this unique circumstance to determine which factors had the greatest impact on technical and physical performances in the CSL.

Based on the above rationales, this study aimed to (1) investigate the differences in terms of technical and physical performances with and without spectators; (2) identify the key factors differentiating between win and loss when playing with and without the presence of an audience. We hypothesized that there might be better performances in the technical and physical performances with crowd support compared to without spectators.

Materials and methods

Sample, data resource, and variables

The sample consisted of 474 performance records from 237 matches during the 2019 competitive season (with spectators) and 320 performance records from 160 matches during the 2020 competitive season (without spectators) in the CSL. These performance records were collected using a semi-automatic computerized video tracking system, Amisco Pro®. The validity and reliability of this system have been verified in previous studies (Di Salvo et al., 2007; Randers et al., 2010; Castellano et al., 2014).

Based on previous literature (Gong et al., 2021), seven physical performance-related parameters, 18 technical performance-related parameters, and two situational variables

TABLE 1 Category and definition of the physical, technical, and situational variables.

Physical performance-related parameters (unit): operational definition
Total distance (m): distance covered in a match by all the players of a team.
Sprint distance (m): distance covered at a speed of over 25.1 km/h in a match by all the players of a team.
Sprint efforts: number of sprints (speed >25.1 km/h) in a match by all the players of a team.
HSR distance (m): distance covered of high-speed (19.7–25.1 km/h) running in a match by all the players of a team.
HSR efforts: number of high-speed (19.7–25.1 km/h) running in a match by all the players of a team.
HIR distance (m): high-intensity running consists of running, high-speed-running, and sprinting (running speed >14.4 km/h).
HIR efforts: number of high-intensity running in a match by all the players of a team.
Technical performance-related parameters (unit): operational definition
Possession (%): the duration when a team takes over the ball from the opposing team without any clear interruption as a proportion of total duration when the ball was in play
Shots: attempts to score a goal made with any (legal) part of the body, either on or off target.
Shot accuracy (%): shots on the target as a proportion of the total shots.
Passes: intentional played balls from one player to another.
Pass accuracy (%): successful passes as a proportion of the total passes.
Forward passes: intentional played balls from one player to another who is located in the opponent's half of the pitch.
Forward pass accuracy (%): successful forward passes as a proportion of the total forward passes.
Cross: any ball sent into the opposition team's area from a wide position.
Cross accuracy (%): successful crosses as a proportion of total crosses.
Ground duel: challenge between two players competing for ball possession above the hip height of the player who touched the ball.
Ground duel won (%): successful air duels as a proportion of the total air challenges.
Air duel: challenge between two players competing for ball possession above the hip height of the player who touched the ball.
Air duel won (%): successful air duels as a proportion of the total air challenges.
Tackles: attempt of players to get the ball from an opposition player in possession of the ball.
Tackle won (%): successful tackles as a proportion of the total tackles.
Fouls: any infringement penalized as foul play by a referee.
Corner: ball goes out of the play for a corner kick.
Offside: being caught in an offside position resulting in a free kick to the opposing team.
Situational variables: operational definition
Team quality: competitive level of the competing team according to the end-of-season ranking. A team was classified as "strong" (ranking from the 1st to 8th place) or "weak" (ranking from the 9th to 16th place).
Opponent quality: competitive level of the opposing team according to the end-of-season ranking. A team was classified as "strong" (ranking from the 1st to 8th place) or "weak" (ranking from the 9th to 16th place).

The unit of the physical and technical performance-related parameters without units are in counts.

(team and opponent quality) were chosen in the analysis. The categories and definitions of the variables are presented in Table 1. The speed thresholds of the physical parameters were similar to those of previous reports (Bradley et al., 2009, 2016). The ethics committee approval for this study was obtained from the local university.

Statistical analysis

The logistic least absolute shrinkage and selection operator (LASSO) model is a shrinkage method that can actively select from a large and potentially multicollinear set of variables in the regression, resulting in a more relevant and interpretable set of predictors (Tibshirani, 2011). To obtain the subset of predictors, the LASSO regression analysis minimizes prediction error for a quantitative response variable by imposing a constraint on the model parameters that causes regression coefficients for some variables to shrink toward zero (Fu, 1998). Variables with a regression coefficient equal to zero after the shrinkage process are excluded from the model. In contrast, variables with nonzero regression coefficients are most strongly associated with the response variable (Tibshirani, 1997). Followed by the logistic regression procedure, our approach improves the

regression performance and reduces the number of features in the final model, thus improving the interpretability of the model. Subsequently, the most significant features selected by the LASSO regression analysis were entered into the following study.

The selected variables are presented as the mean and standard deviation (SD) for data that were normally distributed and the frequencies and percentages for categorical variables. The Kolmogorov–Smirnov test was used to inspect the normality and homogeneity of variance of all the data. For two-group comparison, *p*-values were derived from an independent *t*-test to determine differences between groups with normally distributed data and a Mann–Whitney non-parametric test with other data. Cohen's *d* effect sizes and 95% confidence intervals (*CI*) were calculated (Cohen, 1988; Fritz et al., 2012). Effect sizes were interpreted as follows: ≤0.2 trivial, >0.2–0.6 small, >0.6–1.2 moderate, >1.2–2.0 large, >2.0–4.0 very large, and >4.0 extremely large (Hopkins et al., 2009). To examine the extent to which selected variables could be used to explain match outcome between matches with and without the presence of an audience, the association was initially evaluated using univariable logistic regression. Subsequently, multivariable logistic regression analysis with the backward stepwise method was used to explore variables that were independently associated with match outcome (Win = 1, Loss = 0). Only variables that were significant in univariable analyses were introduced into the multivariable logistic regression.

All analyses were performed using the statistical programming environment R (version 4.1.2). Specifically, the LASSO algorithm was performed using the "glmnet" package; the *t*-test and the Mann–Whitney non-parametric test were calculated by the "effect size" and "performance" package; univariable and multivariable logistic regression was performed using the "autoReg" package. All probabilities are two-tailed and $p < 0.05$ was considered statistically significant.

Results

A total of 27 features were reduced to nine potential predictors (Figure 1) with nonzero coefficients ultimately selected in the LASSO logistic regression model including four technical variables, such as cross (0.048), air dual won (−0.018), shot accuracy (−0.040), and shots (−0.056), three physical variables, such as total distance (−0.001), sprint distance (−0.001), and HIR efforts (−0.001), and two situational variables team (0.941) and opponent quality (−0.983).

The match dominance indicators, such as cross ($p < 0.01$, ES = −0.24), shots ($p < 0.001$, ES = −0.25), and shot accuracy ($p < 0.05$, ES = −0.18) displayed decreasing trends without spectators comparing with the crowd support. It is worth noting that sprint distances ($p < 0.05$, ES = 0.16) presented an increasing trend without crowd support in Table 2 and Figure 2.

Univariable and multivariable analysis revealed that four technical variables were associated with winning matches in the 2019 competitive season (with spectators). These variables included both cross [odds ratio (OR), 1.08; 95% *CI*, 1.05–1.12; $p < 0.001$], air dual won (OR, 0.96; 95% CI, 0.94–0.99; $p < 0.01$), shot accuracy (OR, 0.95; 95% CI, 0.94–0.97; $p < 0.001$), and shots (OR, 0.95; 95% CI, 0.86–0.96; $p < 0.01$). In the 2020 competitive season (without spectators), three technical variables associated

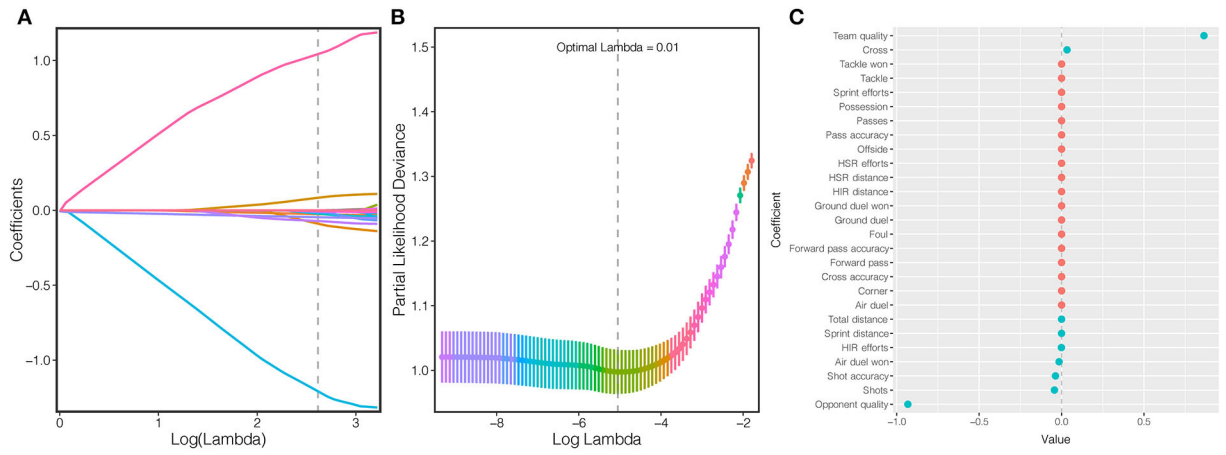

FIGURE 1
Feature selection using the least absolute shrinkage and selection operator (LASSO) binary logistic regression model. **(A)** LASSO coefficient profiles for key features, each coefficient profile plot is produced vs. log(λ) sequence. The dotted vertical line is set at the nonzero coefficients selected *via* a 10-fold cross-validation, where nine nonzero coefficients are included. **(B)** By verifying the optimal parameter (lambda) in the LASSO model, the partial likelihood deviance (binomial deviance) curve is plotted vs. log(λ). At the log (λ) of the optimal values, where features are selected, dotted vertical lines are set using the minimum criteria and the one standard error of the minimum criteria. **(C)** The specific coefficient of each variable is presented by (LASSO) binary logistic regression. The red dot means the variable is excluded while the green dot means the variable is selected in the following study.

TABLE 2 The difference in technical and physical variables between matches with and without spectators.

Name	With spectators ($N = 474$)	Without spectators ($N = 320$)	P	ES (95% CI)	Interpretation
Cross	22.2 ± 8.5	20.1 ± 8.9	<0.01	−0.24 (−0.38, −0.10)	Small
Air duel won	50.0 ± 10.2	50.0 ± 11.6	0.995	0.01 (−0.14, 0.14)	Trivial
Shot accuracy	37.6 ± 15.8	34.8 ± 16.6	<0.05	−0.18 (−0.32, −0.03)	Trivial
Shots	12.8 ± 4.8	11.6 ± 4.9	<0.001	−0.25 (−0.39, −0.11)	Small
Total distance	106,443.5 ± 4,769.1	106,757.4 ± 5,050.3	0.375	0.06 (−0.08, 0.21)	Trivial
Sprint distance	1,386.1 ± 358.3	1,443.2 ± 337.4	<0.05	0.16 (0.02, 0.31)	Trivial
HIR efforts	427.2 ± 69.2	432.0 ± 64.9	0.329	0.07 (−0.07, 0.21)	Trivial

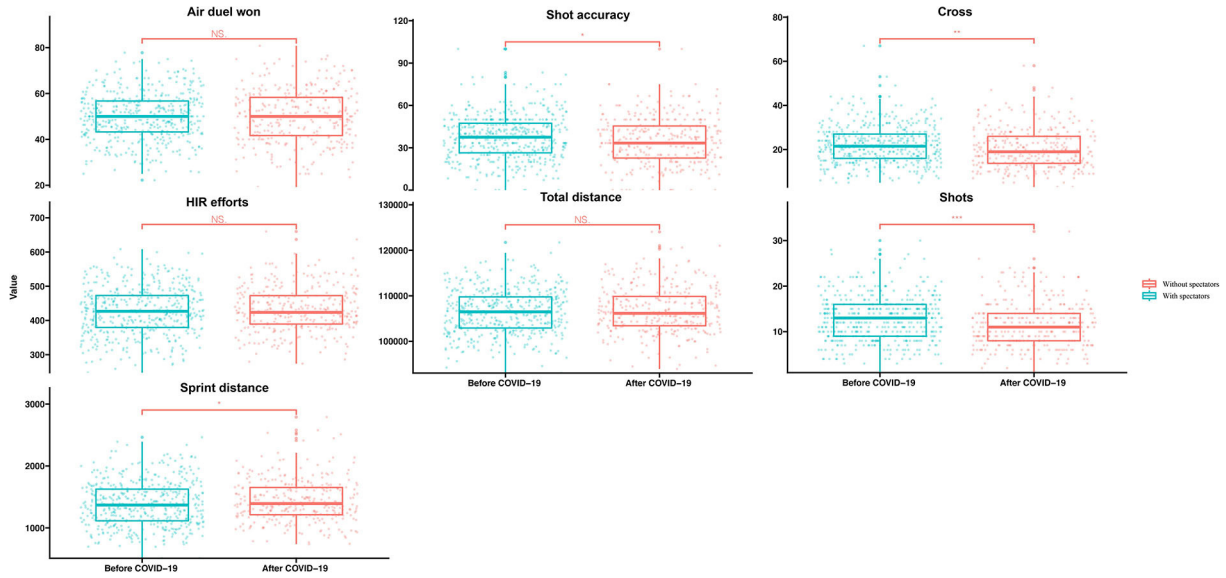

FIGURE 2
The visualization of the difference in technical and physical variables between matches with and without spectators. Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. NS. means no statistical significance.

with winning probability, such as cross (OR, 1.08; 95% CI, 1.04–1.12; $p < 0.001$), shot accuracy (OR, 0.95; 95% CI, 0.93–0.97; $p < 0.001$), and shots (OR, 0.88; 95% CI, 0.82–0.95; $p < 0.01$). In addition, physical performance parameters had no impact on winning matches with and without spectators in Table 3.

Strong teams have a clear advantage over weak teams to win the match in the 2019 season (OR, 3.43; 95% CI, 2.14–5.50; $p < 0.001$) and 2020 season (OR, 3.05; 95% CI, 1.62–5.74; $p < 0.001$). Moreover, compared with playing with weak teams, playing with strong teams leads to a decrease in winning probability with spectators (OR, 0.29; 95% CI, 0.18–0.47; $p < 0.001$) and without spectators (OR, 0.18; 95% CI, 0.09–0.34; $p < 0.001$) in Table 3.

Discussion

This study aimed to (1) investigate the differences in terms of technical and physical performances with and without spectators; (2) identify the key factors differentiating between win and loss when playing with and without the presence of an audience. Our study highlighted that the match offensive indicators, such as shots, shots accuracy, and cross presented decreasing trends during match-play without spectators compared to playing with spectators. In addition, the sprint distance increased when playing without spectators, which is in contradiction with the current majority of studies from European football leagues. The determining factors of winning matches almost do not change between matches with and without crowds. Team and opponent quality remain the important factors to influence the match outcome. Our findings identify the hypothesis we made before this study.

Our study is consistent with the previous study (Almeida and Leite, 2021; Rampinini et al., 2021; Santana et al., 2021; Wunderlich et al., 2021), which found that significant decreases were observed for total shots and shots on target in five European domestic leagues (German Bundesliga, Spanish La

TABLE 3 The key variables discriminated between a win and loss when playing with and without spectators.

Indicators	Before COVID-19 (with spectators)				After COVID-19 (without spectators)			
	Win ($N = 184$)	No win ($N = 290$)	OR (Univariable)	OR (Multivariable)	Win ($N = 115$)	No win ($N = 205$)	OR (Univariable)	OR (Multivariable)
Cross	20.7 ± 7.9	23.1 ± 8.8	1.03 (1.01–1.06, $p = 0.004$)	1.08 (1.05–1.12, $p < 0.001$)	18.3 ± 7.5	21.1 ± 9.4	1.04 (1.01–1.07, $p = 0.008$)	1.08 (1.04–1.12, $p < 0.001$)
Air duel won	52.1 ± 10.2	48.7 ± 9.9	0.97 (0.95–0.99, $p < 0.001$)	0.96 (0.94–0.99, $P < 0.01$)	52.9 ± 11.7	48.3 ± 11.3	0.97 (0.95–0.99, $p < 0.001$)	0.99 (0.96–1.01, $p = 0.288$)
Shot accuracy	44.3 ± 12.4	33.4 ± 16.3	0.95 (0.94–0.97, $p < 0.001$)	0.95 (0.94–0.97, $p < 0.001$)	42.6 ± 13.0	30.4 ± 16.8	0.95 (0.94–0.97, $p < 0.001$)	0.95 (0.93–0.97, $p < 0.001$)
Shots	13.5 ± 4.5	12.3 ± 4.9	0.95 (0.92–0.99, $p = 0.014$)	0.91 (0.86–0.96, $P < 0.01$)	12.7 ± 4.1	11.0 ± 5.2	0.93 (0.89–0.98, $p = 0.003$)	0.88 (0.82–0.95, $P < 0.01$)
Total distance	107,179.0 ± 4,681.6	105,976.9 ± 4,773.2	1.00 (1.00–1.00, $p = 0.008$)	1.00 (1.00–1.00, $p = 0.617$)	107,121.4 ± 4,874.3	106,553.1 ± 5,146.8	1.00 (1.00–1.00, $p = 0.334$)	
Sprint distance	1,465.7 ± 359.1	1,335.6 ± 349.1	1.00 (1.00–1.00, $p < 0.001$)	1.00 (1.00–1.00, $p = 0.568$)	1,471.6 ± 344.9	1,427.3 ± 333.0	1.00 (1.00–1.00, $p = 0.261$)	
HIR efforts	441.1 ± 68.8	418.4 ± 68.2	1.00 (0.99–1.00, $p < 0.001$)	1.00 (0.99–1.00, $p = 0.209$)	435.9 ± 68.5	429.8 ± 62.8	1.00 (1.00–1.00, $p = 0.422$)	
Team quality								
Strong	129 (70.1%)	108 (37.2%)	3.95 (2.66–5.87, $p < 0.001$)	3.43 (2.14–5.50, $p < 0.001$)	75 (65.2%)	85 (41.5%)	2.65 (1.65–4.25, $p < 0.001$)	3.05 (1.62–5.74, $p < 0.001$)
Weak	55 (29.9%)	182 (62.8%)	Reference	Reference	40 (34.8%)	120 (58.5%)	Reference	Reference
Opponent quality								
Strong	63 (34.2%)	174 (60%)	0.35 (0.24–0.51, $p < 0.001$)	0.29 (0.18–0.47, $p < 0.001$)	36 (31.3%)	124 (60.5%)	0.30 (0.18–0.48, $p < 0.001$)	0.18 (0.09–0.34, $p < 0.001$)
Weak	121 (65.8%)	116 (40%)	Reference	Reference	79 (68.7%)	81 (39.5%)	Reference	Reference

Liga, English Premier League, Portuguese Primeira Liga, and Italian Serie A). This finding gives further evidence that these performance variables related to goal scoring were negatively affected in the European leagues as well as the Asian League (CSL). Similarly, our study is in line with the previous studies (McCarrick et al., 2021), which found that the extent of the decrease in dominance parameters, such as a cross, shots, and shots accuracy was clear during match-play when playing without spectators. Although this phenomenon can be caused for complex reasons, it indeed leads to a decreasing trend of offensive dominance during match-play without spectators. Our study speculated that social factors were deemed to be critical, due to the fans' proximity to the playing area and the more constant, loud, inspiring sounds from the crowd, where enthusiastic cheers and chants can inspire entertaining, attacking play, and encourage home players to try harder (Almeida and Leite, 2021; McCarrick et al., 2021).

Notably, our study highlighted that the overall increase in sprint distance was achieved without spectators, which is contrary to the previous study that suggested sprinting, acceleration, and deceleration distances did not change or showed a clear reduction compared to playing with spectators in the most soccer leagues (Brito de Souza et al., 2021; Rampinini et al., 2021; Santana et al., 2021; García-calvo et al., 2022). A possible explanation is that ball possessions ended without realizing the pre-prepared tactical strategies, which caused the counterattacks from the opponent. Thus, players have to cover more high-intensity running or sprint distances to recover ball possession during match-play (Raya-González et al., 2022). In general, players need several weeks of pre-season matches to achieve steady technical and tactical performances, but soccer players had difficulty with adequate preparation due to the absence of the friendly and official matches during the COVID-19 pandemic. Another possible explanation is that the Chinese football association reduced the matches during the COVID-19 lockdown and arranged all of the players into a specific area without any physical contact with the outside. This way can decrease travel fatigue, which may lead to abundant energy in physical performances applied to match-play during the limited match schedule.

Our study found that the dominance indicators, such as cross, shots, shot accuracy, and team and opponent quality are associated with match outcome whether playing with or without spectators. These results are in line with Gong et al. (2021) and Zhou et al. (2021b) that found that the dominance indicators were positively associated with match outcome and higher ball possession can increase the likelihood of shot frequencies occurring in the CSL. Based on the sustaining positive impact of the shot-related variables on winning matches, soccer coaches are required to set more practice to improve players' dribbling, precision, and tempo as well as the coordination of the crosser and the receiver to beat the offside trap (Ferraz et al., 2018; Coutinho et al., 2019). In addition, our study noted that air

duals are not the key factors differentiating between win and loss when playing without spectators. Air duels in the CSL are often caused by a long pass (i.e., a header), which leads to the ball possession being reorganized as an offensive advantage (Gong et al., 2021). We suggest the coaches may change this traditional playing style and utilize more dynamic tactics to win the match without crowd support. Moreover, Zhou et al. (2021a) revealed that team and opponent quality were significant predictors associated with match outcome, especially for higher quality home teams experiencing an increased chance of winning in the CSL. Our study further identified this evidence that team and opponent quality were the potential factors that influenced match outcome, whether playing with or without crowd support.

Although the current study provided novel findings, some limitations should be acknowledged for consideration in future research. First, our study is based on the new league policy issued by the Chinese football association during the COVID-19 breakdown, which created a unique circumstance to perform the current empirical study. This policy eliminated the effects of crowd support, familiarity with the stadium, and travel fatigue on match performance, but technical and physical performances have been exclusively discussed in the current study only based on a unique factor—crowd support. Future research is recommended to explore the interactive effects of these potential factors on match performances. Second, the comparison of technical and physical performances between matches with and without crowd support had been verified in the European, American, and Asian domestic soccer leagues. Future studies could extend to African soccer leagues, the international club tournaments (e.g., UEFA Champions League), and national team events to explore more evidence. Third, future studies should seek empirical validation for our findings by applying multivariate analyses as well as new statistical techniques. A longitudinal design could be developed to perform the depth analysis.

Conclusion

Match dominance indicators such as shots, shots accuracy, and cross presented decreasing trends during match-play without spectators, whereas the sprint distance increased when playing without spectators. In addition, shots, shots accuracy, cross, and team and opponent quality were the common factors discriminating between win and loss, whether playing with or without spectators. Match outcome or team performance is determined by a myriad of factors, but there are clear differences in technical and physical performances between matches with and without the presence of an audience.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ludong University. Written informed consent from the patients/ participants or patients/participants legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

JC, SZhai, and ZX contributed to the conception and design of the study. JC and SZhai collected and organized the data. PL and SZhan performed the statistical analysis. JC wrote the first draft of the manuscript. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Influence of crowd size on home advantage in the Japanese football league

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This study aimed to investigate the influence of crowd size on home advantage (HA). Data of the 2019 and 2020 seasons of the J1 League (Japan Professional Football's First Division League) were analyzed. Matches during the 2019 season were played under regular conditions, while there was low stadium occupancy during the 2020 season to prevent the spread of COVID-19. Regarding average points won, HA disappeared. By using multiple group structural equation modeling, it was examined the routes of influence *via* which a reduction in crowd size influenced HA. The results indicated that the influence from the crowd size to the referee's decisions disappeared during the 2020 season. However, the factors including the referee's decisions have lower effects on the outcome factor. Hence, no dominant route was detected in the present study.

KEYWORDS

home advantage, crowd size, football, structural equation modeling, natural experiment

Introduction

Home advantage (HA) is a phenomenon wherein a home team has an advantage over an away team. Schwartz and Barsky (1977)—often cited as authors of early research on HA—defined that HA is a phenomenon whereby home victories exceed 50% of all matches won when the schedule of matches held at home and away is balanced. The researchers noted that HA occurred in several professional sporting events at the time. The results of professional sports at the time indicated marked HA for indoor sports such as basketball and hockey but poor HA for the outdoor sports of football and baseball (Schwartz and Barsky, 1977; Losak and Sabel, 2021). However, in recent years, values modified by Pollard's method have been used to determine HA. These focus on the degree of deviation from the winning percentage of 50% (Matos et al., 2020). Researchers have highlighted that HA is consistently seen in regular season football league matches (Almeida and Leite, 2021; Leitner and Richlan, 2021).

Courneya and Carron (1992) have cited four major game location factors thought to affect the degree of HA: (1) learning/familiarity factors; (2) rule factors; (3) travel factors; (4) crowd factors. The learning/familiarity factors pertain to the home team's familiarity with the characteristics of the venue where a match is to be played, which positively affects their score. The travel factors concern players' performances and the effect of the following: (a) mental and physical fatigue resulting from the visiting team's travel

to the next venue and the difference in the environment of hotels from everyday living; (b) changes in players' condition due to differences in climate, such as temperature and humidity, and differences in food culture on game results. However, some researchers observed that these influences have faded in recent years with the development of better means of transportation and improvements in hotel environments (Courneya and Chelladurai, 1991; Pace and Carron, 1992). Coincidentally, on 24 June 2021, the Union of European Football Associations (UEFA) announced the abolition of the away goals rule, which was applied to determine the winner of a two-legged knockout tie in cases where the two teams had scored the same number of goals on aggregate over the two matches. In such cases, the team which had scored the higher number of goals away from home was considered the winner of the tie and qualified for the next round of the competition. This rule had been in use since 1965 in UEFA Champions League competitions and had been put in place to correct for HA. The UEFA cited improvements in conditions since the rule had been adopted, a reduction in the gap in winning percentages, and the reduction in the average goals per match at home/away matches as reasons for abolishing the rule. The rule factor refers to the differences in the rules between the home and away teams that created an HA. However, the rule factor is said to have the weakest influence of the four factors, and the types of sport on which it shows an influence are limited (Courneya and Carron, 1992).

Of the four factors pointed out by Courneya and Carron (1992), crowd factors appear to have an especially strong influence on HA. Crowd factors relate to crowd density affecting the mental state of the home team, causing changes in the players' actions/behaviors and performances and bringing about HA consequently (Agnew and Carron, 1994). Other than exerting a direct influence on the players, crowd factors are perceived to influence the referees' decisions (Leitner and Richlan, 2021; Wunderlich et al., 2021). In both cases, the anticipated processes are the crowd's behaviors of cheering and supporting the home team and/or booing the away team, which creates an advantageous environment for the home team and the contrary for the away team.

Previous studies (e.g., Almeida and Leite, 2021; McCarrick et al., 2021) suggest that stadium-packed crowds influence HA and predicted that the effects of crowd factors would disappear in games held without any spectators. After 2020, the worldwide spread of COVID-19 created an opportunity to verify this prediction. Matches became a large-scale social experiment as they were held in the absence of spectators due to the restriction of crowds in stadiums. This created an opportunity to investigate the mechanism by which HA occurs. To verify the influence of matches without any spectators on HA, researchers have, since 2020, been actively conducting studies to compare the results of matches played in the leagues of various countries between the 2018–2019 season and the 2019–2020 season. The results, supported by most studies, indicate that matches played without spectators caused HA to disappear (For systematic review, see Leitner et al., 2022). For example, McCarrick et al. (2021) analyzed data from 15 leagues in 11 countries and reported that HA could no longer be seen in matches with no spectators. Other researchers have also reported that HA was no longer evident in many cases (Almeida and Leite, 2021, Germany, Spain, England, Portugal; Leitner and Richlan, 2021, Spain, England, Germany, Italy, Russia, Turkey, Austria, and the Czech Republic; Hill and Van Yperen, 2021, Spain, Italy, and England). However, some studies claimed that in certain cases, HA had been maintained in matches without any spectators (Almeida and Leite, 2021, Spain) and, conversely, reported that an HA had occurred (Tilp and Thaller, 2020, Germany). Overall, most studies reported the disappearance of HA.

These results suggest that HA is a function of crowd size. In addition to the previously described reports on the top leagues of various countries, it has been indicated that HA has not occurred in amateur leagues where crowd sizes tend to be small (Fischer and Haucap, 2021; Wunderlich et al., 2021), suggesting that HA is facilitated by crowd size. Major hypotheses put forward in past research can be broadly summarized as follows. First, spectators cheering for the home team increases the players' attacking opportunities during play, which contributes to capturing victory (McCarrick et al., 2021). Second, for the away team, conversely, having numerous spectators who cheer for their opponents and getting booed occasionally cause a reduction in their performance, which leads to their defeat (Greer, 1983). Third, referees face the risk of being booed for decisions that go against the home team because of the numerous spectators who support them (Nevill et al., 2002). This may exert a psychological influence on the referees, such as pressure, making them more reluctant to make decisions disadvantageous to the home team, such as handing out yellow and red cards (Leitner and Richlan, 2021; Wunderlich et al., 2021).

In this study, I have used data from the Japan Professional Football's First Division League (hereafter J1 League) to investigate these hypotheses. I used a point-based system to examine whether HA disappeared in 2020 when the number of spectators was restricted. Here, I employed points, rather than percentages of wins and their variations modified using the Pollard method (Matos et al., 2020). This is because points are indices for determining ranking within a league: they affect whether a team remains within the league or is promoted. Next, I built a structural equation model that hypothesized that the crowd size influences team activity (running distance, number of sprints), team performances (number of goal shots, corner kicks), and the referee's decisions (number of warnings issued and send-offs). Data of the 2019 season, wherein the league operated as usual, were compared with those of the 2020 season, wherein matches were played with smaller crowds, on account of COVID-19. The J1 League eased the restrictions placed on the number of spectators during the 2020 season in phases.

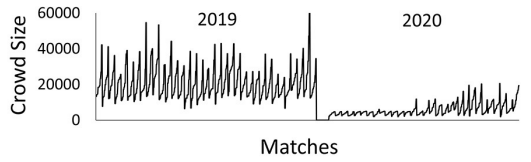

FIGURE 1
The fluctuations of crowd size during 2019 and 2020 seasons. In the round 2 and 3 of 2020 season, there were no spectators in all matches.

Thus, the crowds gradually increased in size in response to the infection countermeasures implemented at each time point (Figure 1). A statistically significant influence must be found vis-à-vis various types of explanatory variables unique to each game to determine whether crowd size is a dominant variable. Therefore, I statistically verified (a) the primary route by which the crowd size influences points through player performances and (b) the secondary route by which the crowd size influences points through referee decisions both by season (2019 or 2020) and by game location (home or away).

Methods

Targeted matches

In this study, I used the results of matches played (305 and 298) during both the 2019 and 2020 seasons of the J1 League as my targets of analysis, the results of which are reflected in rounds 1–34. The matches played during the 2019 season were treated as the data for regular matches, and those played during the 2020 season were treated as the data for matches in which a limit was placed on crowd size. Matches played from rounds 2 and 3 in 2020, however, were played without any supporters. During the 2019 and 2020 seasons, the J1 League had 18 teams. Each time the season changes, the J1 League's bottom two teams are replaced by the J2 League's top two teams. Considering the impact of COVID-19, the League matches for the 2020 season took the form of "not demoting any teams but promoting teams" to secure fairness.

Variables

I used the following variables of the home and away teams and compared them: number of points, goals, goal shots made, corner kicks, running distance, number of sprints, warnings, and send-offs. All the data were based on the database published by the J1 League. The definitions of variables are shown in Table 1.

TABLE 1 Definitions of variables.

Crowd size

The number of attendances that officially published in the database of the J1 League.

Team activity

- Running distance

The value that indicates the distance that a player in a team traveled during a game. The distance run by the 11 starting players, plus that of any substituted players, is totalled.

- Number of sprints

The value that indicates the number of moves that a player in a team makes for more than a set amount of time during a game. According to the J League's regulations, a sprint is recorded if a player continues to run at a speed of more than 24 km/hr for more than a second. As with running distance, the distance run as sprints by the 11 starting players, plus that of the players who entered the game midway, is totaled.

Team performance

- Number of goal shots

The number of attempts to score a goal. Other than plays clearly aimed at scoring a goal, plays that depart from what the player had intended, such as crosses and other balls threatening to score a goal, were also recorded as the number of goal shots made.

- Number of corner kicks

The number of set plays made when an opponent sends the ball from their own goal line. The game is resumed after the ball is kicked in from the corner of the field, located to the right and left of the goal, called the corner arc. A corner kick is unique in that it can be aimed directly at the goal.

Referee's decisions

- Number of warnings issued

The number of times a yellow card was presented during a game. A yellow card is presented in response to dangerous fouls or fair-play-violation. If it is presented twice during a game, the player is sent off.

- Number of send-offs

The number of times a player is ordered off the pitch on being presented with a yellow card twice or having a red card issued against them. A red card is issued when acts more dangerous or violent than those that warrant a yellow card take place.

Outcome

- Points

A numerical value that determines a team's ranking within the League, with three points for a winning game, one point for a draw, and zero for a losing game. The interval between points is made uneven to prevent the teams from gaming the system by aiming for draws rather than wins and motivate teams to engage in even more offensive play (Aylott and Aylott, 2007).

- Goals

The number of times a player puts the ball in the opponent team's goal.

Analysis policies

First, a two-way analysis of variance (ANOVA) was performed to verify HA in the J1 League. It used seasons (2019 or 2020) × game locations (home or away) as the independent

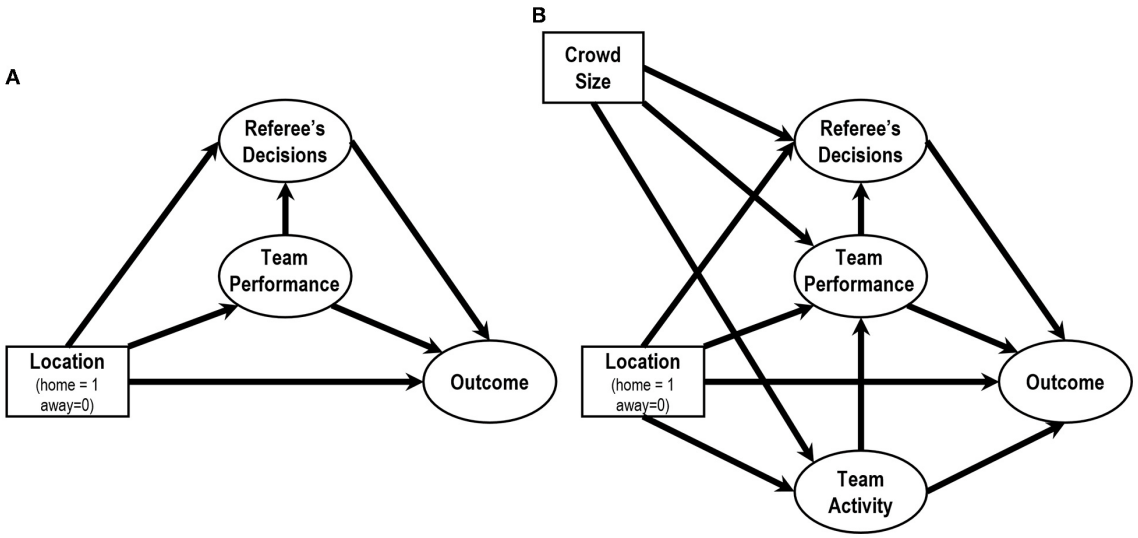

FIGURE 2
(A) The basic structure of home advantage mediated (HAM) model proposed by Bilalić et al. (2021) and **(B)** the model proposed in the present paper.

variables and points as the dependent variable. Second, a two-way ANOVA was performed to verify the independent effects of each variable. For this analysis, I used seasons (2019 or 2020) × game locations (home or away) as the independent variables and each variable of performance and referee judgement (points, goals, goal shots made, corner kicks, running distance, number of sprints, warnings, and send-offs) as the dependent variables. Finally, a SEM (structural equation modeling) was conducted to test whether crowd size predicted these variables and whether these variables, in turn, predicted the outcome variables.

Regarding the process of HA, Bilalić et al. (2021) proposed home advantage mediated (HAM) model to represent the relationships among variables. In the first step of the model, HA predicts the factor of team performance (corner kicks, shots, and shots on target) and the factor referee's decisions (fouls, yellow cards, and red cards). In the second step, these factors predict the outcome factors (points and goals). The process would be applicable to data obtained from J1 League as well because the basic structure of HA would be consistent among football leagues. Thus, I adopt a model considering these basic relationships (Figure 2A), although the observed variables were not the identical to the original HAM model. Moreover, I then additionally consider a factor of team activity (running distance and the number of sprint) as a first step factor. This is because that the team performance factor would be determined by the observable variables of team activity. I therefore set a path from the factor team activity to the factor team performance.

Then, I originally add the observed variable crowd size as a variable that predict the above first step factors, i.e., the factors of team activity, team performance, and referee's decisions. This depends on the main assumption of this paper; The crowd size influences each player's and referee's behaviors, resulting outcomes such as points scored and goals. Finally, I construct a proposed model as shown in Figure 2B. In this model, I did not include the interaction between the game locations and the crowd size. In other words, these variables are treated as being independent of each other. To compare the results of 2019 and 2020 seasons directly, a multiple group SEM was applied to the dataset simultaneously. For these analyses, I used SPSS Statistics ver. 27 (IBM Corporation) and SPSS Amos ver. 27 (IBM Corporation).

Results

Descriptive statistics and summary of crowd size

Table 2 demonstrate the descriptive statistics of predictive variables and the outcome variables. Regarding the crowd size, the minimum value of the size was zero in round 2 and 3 in the 2020 season under the restriction due to the COVID-19. The maximal value 34,521 of 2020 was recorded in round 1, thus the number of spectators was not restricted within this period. The maximal value including both periods was 63,854 recorded at the match between Yokohama F. Marinos and F. C. Tokyo at the round 34 in the 2019 season. Figure 1 show the crowd size at each time points.

TABLE 2 Descriptive statistics of variables.

	2019					2020					Full				
	Min.	*Mean*	*Med.*	*Max*	*SD*	*Min.*	*Mean*	*Med.*	*Max*	*SD*	*Min.*	*Mean*	*Med.*	*Max*	*SD*
Crowd size	6,491	20,755	4,698	63,854	9,007	0	5,840	18,390	34,521	4,456	0	13,384	11,744	63,854	10318
Point	0	1.38	1.00	3	1.332	0	1.39	1.00	3	1.337	0	1.39	1.00	3	1.334
Goals	0	1.30	1.00	8	1.2	0	1.41	1.00	6	1.23	0	1.35	1.00	8	1.215
Running distance	95.94	112.14	114.22	127.8	4.725	99.84	114.5	111.78	131.4	5.129	95.94	113.3	113.01	131.4	5.064
Number of sprints	19	160.57	164.50	245	28.5	86	164.4	159.00	261	25.59	19	162.47	161.00	261	27.16
Number of GS	1	10.19	10.00	23	4.102	1	10.62	10.00	33	4.397	1	10.4	10.00	33	4.254
Number of CK	0	4.89	5.00	15	2.502	0	4.89	5.00	17	2.768	0	4.89	5.00	17	2.636
Number of WI	0	1.08	1.00	6	1.034	0	1.08	1.00	6	1.13	0	1.08	1.00	6	1.082
Number of send-offs	0	0.04	0.00	3	0.232	0	0.04	0.00	2	0.209	0	0.04	0.00	3	0.221

GS, goal shots; CK, coner kicks; FK, free kicks; WI, warnings issued.

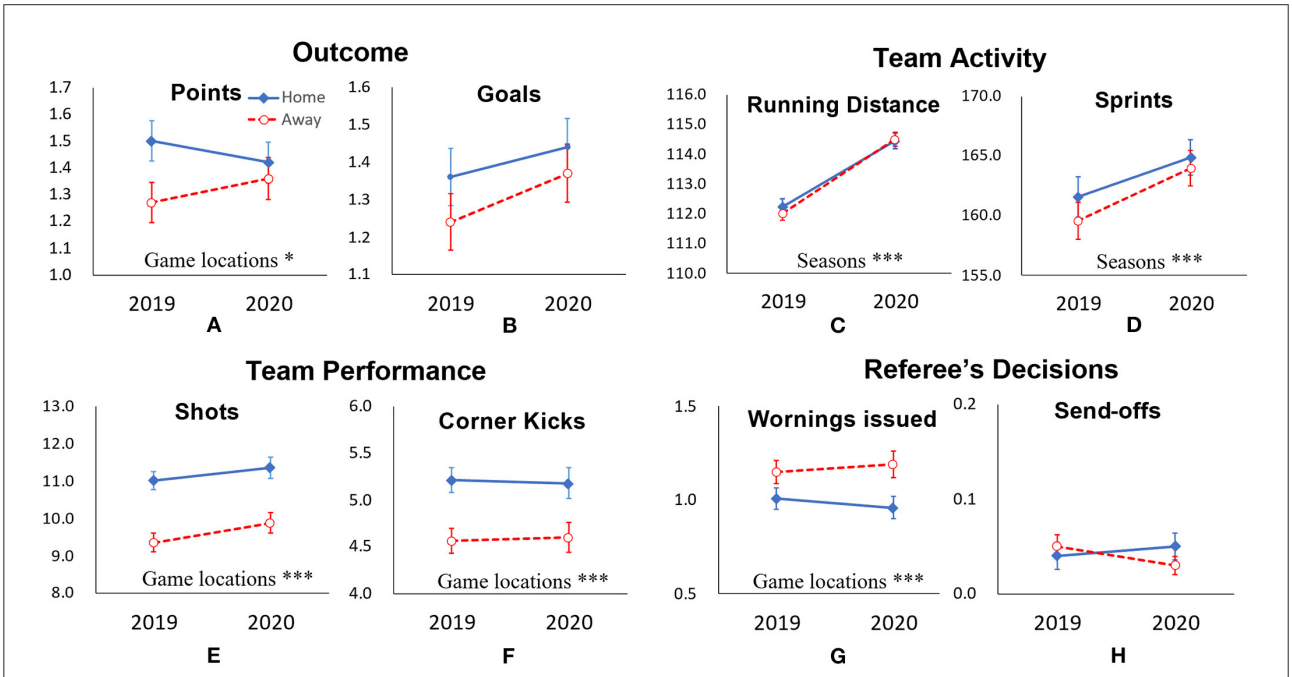

FIGURE 3
Descriptive statistics for seasons × game locations. Outcome (upper left panel): **(A)** average number of points scored per game and **(B)** average number of goals; Team Activity (upper right panel): **(C)** average number of the running distance and **(D)** average number of sprints; Team Performance (lower left panel): **(E)** average number of shots and **(F)** average number of corner kicks; and Referee's Decisions (lower right panel): **(G)** average number of warnings issued and **(H)** average number of send-offs. The independent variables described in insets represent that the main effect of the variable was significant. Error bars indicate ±1.0 standard error of the mean. *$p < 0.05$; ***$p < 0.01$.

Examination of HA (a two-way ANOVA of points scored)

A two-way ANOVA was performed using seasons (2019 or 2020) × game locations (home or away) as the independent variables and points scored as the dependent variable. As shown in Figure 3A, a significant main effect of game location was found in terms of points scored ($F_{(1,1202)} = 3.56$, $p < 0.05$). As a result of a simple main effects test, a significant difference was seen only in 2019 ($p < 0.05$). Conversely, differences in points scored according to game location seen in 2019 were no longer observed in 2020. This suggests the disappearance of HA in 2020.

Two-factor ANOVA of variables

A two-way ANOVA was performed using seasons (2019 or 2020) × game locations (home or away) as the independent

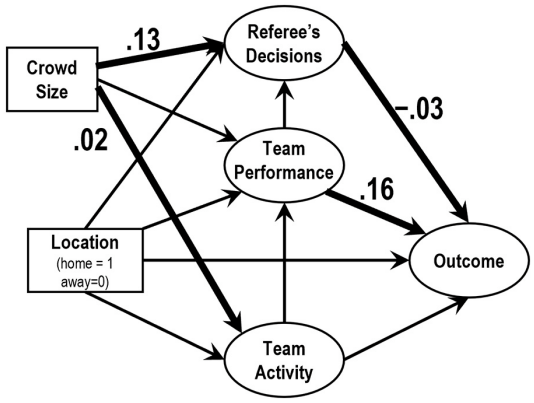

FIGURE 4
The results of SEM of data observed during 2019 season. The numbers show the statistically significant ($p < 0.05$) normalized coefficients. Non-significant coefficients were omitted.

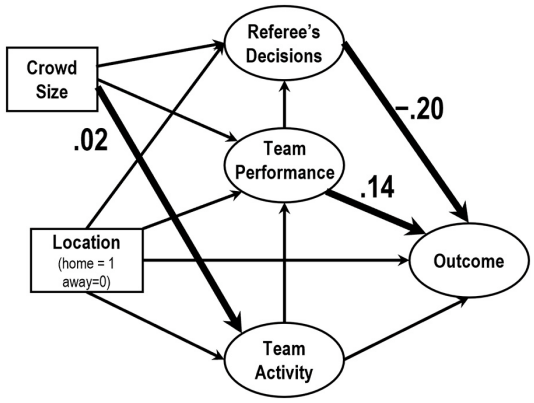

FIGURE 5
The results of SEM of data observed during 2020 season. The numbers show the statistically significant ($p < 0.05$) normalized coefficients. Non-significant coefficients were omitted.

variables and the number of goal shots, corner kicks, running distance, number of sprints, warnings issued, and send-offs as the dependent variables. Figures 3B–H show the results of the analyses. A significant difference was observed consistently, with the values of the number of goal shots and corner kicks being higher at home (Home > Away in both 2019 and 2020). Conversely, the number of warnings issued was greater in away matches (Away > Home in both 2019 and 2020). A significant difference was also observed with the running distance and the number of sprints being higher in the 2020 season at both home and away matches. Other variables were not significant in terms of either main effects or interactions.

A process model analysis

As the result of a multiple group SEM assuming the same structure between 2019 and 2020, the goodness of fit indices exhibited that the model was acceptable (*CMIN/df* = 2.82, *GFI* = 0.974, *AGFI* = 0.950, *CFI* = 0.931, and *RMSEA* = 0.039).

Figure 4 depicts the SEM using matches played in 2019. The crowd size significantly influenced the factor referee's decision (0.13); the factor team performance also influenced the factor outcome (0.16). The paths from crowd size to the factor team activity and that from the factor referee's decisions to the factor outcome were significant but the coefficients were negligible.

Figure 5 depicts the SEM using matches played in 2020. The factor referee's decisions significantly influenced the factor outcome (0.20); the factor team performance influenced the factor outcome (0.14). The path from crowd size to the factor team activity was significant but the coefficients was negligible.

Discussion

Home advantage

In terms of points scored, HA was seen in 2019, which was a regular season; however, the difference between the mean point of home matches and that of the away matches was not significant in the 2020 season. This result suggests that HA in the J1 League disappeared during the period of COVID-19, as similar to the observations in many European Leagues (Almeida and Leite, 2021; Hill and Van Yperen, 2021; Leitner and Richlan, 2021; McCarrick et al., 2021). Because the crowd sizes were limited to a maximum of 20,000 people in the 2020 season, one possible interpretation of this result is that the influence of crowd size had diminished due to the restrictions in admission. Contrary to this, team activity consistently increased in the 2020 season than the 2019 season, regardless of home or away games. Small crowds had an effect of facilitating the team activity, although it remains unknown whether the effect due to imaging fans outside the stadium or not.

As for variables of factor team performance, the number of goal shots and corner kicks was consistently higher at home than away, regardless of the season. Although both variables had the potential to contribute to HA, they could not be explained by crowd size as they were attributed to the game location in both seasons. Thus, the effect of game location is even more influential while small crowds did increase the team activity. It is possible to deduce that the learning/familiarity and travel factors, as noted by Courneya and Carron (1992), are manifested in this effect. The characteristics of each stadium were not used as targets of analysis in my study because of which the factor that had the strongest influence on HA was not ascertained. Nonetheless, there is a need to identify this with more detailed studies in the future. With variables related to referee decisions,

the number of warnings issued was consistently higher away than at home game. Thus far, this has been regarded as a variable liable to be influenced by crowd size. However, this too cannot be explained simply by crowd size as it was confirmed as the main effect of game location in both seasons. The number of send-offs had a low frequency, and its interaction was statistically negligible. The influence of crowd size on referees such as this has traditionally been regarded as a problem of psychological pressure (Leitner and Richlan, 2021; Wunderlich et al., 2021). Notably, these effects were also observed in 2020 as the matches played during that season had over 2,000 spectators except for the round 2 and 3 in the 2020 season. This suggests the possibility that although the crowd may have occupied a small percentage inside the stadium, they will have sufficient influence if they exceed a set number. This finding suggests that crowds in units of several thousands are sufficient to influence the referees, which supports the observations of researchers who stated that HA did not occur in amateur leagues that generally have small crowd sizes in the first place (Fischer and Haucap, 2021; Wunderlich et al., 2021).

The interpretations on three first step factors provide a perspective that increase of team activity would not simply lead team performance and/or referee's decisions to approach points won in the matches. Therefore, the process of HA would be considered.

Routes through which crowd size influences the outcome

The results of a multi group SEM indicated that, at least in the J1 League, the crowd size weakly influenced referee's decision during 2019 seasons and the indirect effect from crowd size to outcome factor had almost no influence [0.13 $\times$ ($-$0.03) = 0.039]. This effect was no longer observed in the 2020 season when the number of spectators was restricted. In the 2020 season, however, crowd size did not significantly influence referee's decisions. In this season as well, the indirect effect from crowd size to outcome factor also had almost no influence. Thus, routes that crowd size influences the outcome was not found in the present study. The consistent influence found in this study was that from the team performance to the outcome, but this would be trivial from the viewpoint of football games.

Conclusion

This study aimed to investigate the influence of crowd size on HA. The differences of points averagely won per game between home game and away game disappeared in J1 League in small crowd; and the team activity, i.e., the running distance and the number of sprits, increased during COVID-19. However, the influence of crowd size was weak and thus no dominant route was detected in the present study.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://www.jleague.jp/stats/.

Author contributions

RN conceived the study, analyzed the data, and wrote the manuscript.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The evaluation of playing styles integrating with contextual variables in professional soccer

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Purpose: Playing styles play a key role in winning soccer matches, but the technical and physical styles of play between home and away match considering team quality in the Chinese Soccer Super League (CSL) remain unclear. The aim of this study was to explore the technical and physical styles of play between home and away matches integrating with team quality in the CSL.

Materials and methods: The study sample consists of 480 performance records from 240 matches during the 2019 competitive season in the CSL. These match events were collected using a semi-automatic computerized video tracking system, Amisco Pro®. A k-means cluster analysis was used to evaluate team quality and then using principal component analysis (PCA) to identify the playing styles between home and away matches according to team quality. Differences between home and away matches in terms of playing styles were analyzed using a linear mixed model.

Results: Our study found that PC1 presented a positive correlation with physical-related variables such as HIRD, HIRE, HSRD, and HSRE while PC2 was positively associated with the passing-related variables such as Pass, FPass, PassAcc, and FPAcc. Therefore, PC1 typically represents intense-play styles while PC2 represents possession-play styles at home and away matches, respectively. In addition, strong teams preferred to utilize intensity play whereas medium and weak teams utilized possession play whenever playing at home or away matches. Furthermore, the first five teams in the final overall ranking in the CSL presented a compensated technical-physical playing style whereas the last five teams showed inferior performance in terms of intensity and possession play.

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Conclusion: Intensity or possession play was associated with the final overall ranking in the CSL, and playing styles that combine these two factors could be more liable to win the competition. Our study provides a detailed explanation for the impact of playing styles on match performances whereby coaches can adjust and combine different playing styles for ultimate success.

KEYWORDS

styles of play, principal component analysis, soccer, match performance, team sports

Introduction

There is a universal phenomenon in the world of football commentary and coaching that refers to how a game "unfolds" or what playing styles are typically executed in the competition (Hewitt et al., 2016). The culture of soccer clubs may refer to styles of play with colloquiums such as "Total Football" or "Tika-taka." It is thus clear that a style of play could be considered as the general behavior of the whole team to achieve the attacking and defensive objectives during the match (Zhang et al., 2019). Therefore, coaches and coaching staff should be aware of the different contexts where various playing styles occur based on each phase of the game to better adjust strategies and tactics and improve match performance.

Playing styles have been identified in different national soccer leagues using principal component analysis (PCA) as a common and robust method to extract the main components of the team's performance, and then verify the playing styles of the teams in the respective soccer league (Pino-Ortega et al., 2021). Specifically, Castellano and Pic (2019) investigated the twenty teams from the Spanish first division in the 2016–2017 season using nine interaction performance indicators. This study found that deep or high-pressure defending, and elaborate or direct attack were the key winning factor based on the first two PCs. Furthermore, Gómez et al. (2018) reported that extracting eight factors allowed to identify playing styles according to team quality and match location. This study found that ball possession and shot-related variables, defined by PC 1 and PC 2, were the most apparent styles in Greek professional soccer. Likewise, Gollan et al. (2018) identified that match success for the top-ranked team was associated with dominance in transition moments, and playing styles vary across teams but are associated with the final ranking position in the English Premier League. In addition, the previous studies investigated the 380 matches of the 2015-2016 English Premier League season and pointed out that contextual variables must be considered in future studies when quantifying the styles of play in elite soccer because match status, match location, and quality of opposition influence playing styles (Fernandez-Navarro et al., 2018, 2019).

Optimizing match performance in the Chinese Super League (CSL) has received widespread attention in recent years. The related studies have largely focused on the strategy of ball possession (Liu et al., 2021), the evolution of performance indicators (Zhou et al., 2020), and the influence of contextual variables on match performance (Gai et al., 2019; Zhou et al., 2021a). Particularly, several technical variables such as foul, pass, air duel, tackle, shot, and corner kick and physical variables like sprint and high-speed running distance were associated with ball possession in the CSL (Gong et al., 2021). In addition, performance variables generally showed significant upward trends from the 2012 to 2017 seasons in the CSL, specifically, there were ∼23% more crosses, ∼12% more shots on target, and ∼11% more opponent penalty area entries (Zhou et al., 2020). Furthermore, superior teams at home have better performance in terms of shot, shot on target, shot off target, penalty, and shot from the outside box, while visiting teams tend to take a more stable strategy (Liu et al., 2019). Likewise, shot on target, shot accuracy, cross accuracy, tackle, and yellow card were the five key performance indicators that showed consistent effects on winning matches; other effects varied depending on the strength of the team and opposition (Zhou et al., 2021a).

The results of the aforementioned investigations are difficult to be applied to football teams as it is hard and non-contextualized to train all the factors associated with performance. From a practical perspective, the application of a specific playing style is a simpler way to increase the rating of performance indicators within a team (Lopez-Valenciano et al., 2021). To the best of our knowledge, there are only two studies (Lago-Peñas et al., 2017; Zhou et al., 2021b) exploring the playing styles of teams, but one study only selected technical variables to evaluate playing styles and another one added physical variables to explore the evolution of styles of play without controlling for situational variables in the CSL. Therefore, this study aims to explore the styles of play between home and away matches integrating with team quality in the CSL. We hypothesized that there could be a considerable difference in terms of playing styles for each team between home and away matches in the CSL.

Materials and methods

Subjects

The study sample consisted of 480 performance records from 240 matches during the 2019 competitive season in the CSL. These match events were collected using a semi-automatic computerized video tracking system, Amisco Pro®. The validity and reliability of this system have been verified in previous studies (Carling et al., 2008; Castellano et al., 2014).

Procedures

Based on previous literature (Lago-Peñas et al., 2017; Gong et al., 2021; Zhou et al., 2021b), nine physical performance-related parameters, 12 technical performance-related parameters, and two situational variables were chosen for the analysis. The categories and definitions of these variables are presented in **Table 1**. The speed thresholds of the physical performance parameters were similar to that of the previous report (Bradley et al., 2009, 2016). The ethics committee approval for this study was obtained from the Shanghai University of Sport.

Statistical analysis

First, the k-means clustering algorithm was used to separate teams into different clusters based on the final ranking positions in the CSL. The optimal number of clusters was determined upon visual inspection of a scree plot (i.e., the elbow method) whereby the highest number of clusters that reduced the within-cluster variation substantially was identified (Zhang et al., 2017, 2018; Shelly et al., 2020). The results identified three clusters as follows: cluster 1 (Strong, final ranking in the league from 1st to 5th), cluster 2 (Medium, final ranking in the league from 6th to 11th), and cluster 3 (Weak, final ranking in the league from 12th to 16th).

Second, the central idea of the principal components analysis method (PCA) is to reduce the dimensions of data that have a large number of interrelated variables while preserving

TABLE 1 Category and definition of the technical and physical variables.

Abbreviation – Physical performance-related parameters (unit): operational definition
TD – Total Distance (m): distance covered in a match by all the players of a team.
SprintD – Sprint Distance (m): distance covered at a speed of over 25.1 km/h in a match by all the players of a team.
SprintE – Sprint Efforts: number of sprints (speed > 25.1 km/h) in a match by all the players of a team.
HSRD – High-speed running distance (m): distance covered of high-speed (19.7–25.1 km/h) running in a match by all the players of a team.
HSRE – High-speed running efforts: number of high-speed (19.7–25.1 km/h) running in a match by all the players of a team.
HIRD – High-intensity running distance (m): High-intensity running consisted of running, high-speed-running, and sprinting (running speed > 14.4 km/h).
HIRE – High-intensity running efforts: number of high-intensity running in a match by all the players of a team.
MSRD – Moderate-speed running distance (m): distance covered at moderate-speed running (14.3–19.7 km/h) in a match by all the players of a team.
LSRD – Low-speed running distance (m): distance covered at low-speed running (7.1–14.3 km/h) in a match by all the players of a team.
Abbreviation – Technical performance-related parameters (unit): operational definition
Shots: attempts to score a goal made with any (legal) part of the body, either on or off target.
ShotAcc – Shot Accuracy (%): shots on the target as a proportion of the total shots.
Passes: intentional played balls from one player to another.
BP – ball possession (%): The duration when a team takes over the ball from the opposing team without any clear interruption as a proportion of total duration when the ball was in play.
PassAcc - Pass Accuracy (%): successful passes as a proportion of the total passes.
FPass – Forward Passes: intentional played balls from one player to another who is located in the opponent's half of the pitch.
FPAcc – Forward Pass Accuracy (%): successful forward passes as a proportion of the total forward passes.
Challenges: actions when two players are competing for ball possession, which is not in control of any player, i.e., both players have approximately 50% chance of gaining control of the ball; includes ground and air challenges.
ChallengeW – Challenge Won (%): successful challenges as a proportion of the total challenges.
Fouls: any infringement penalized as foul play by a referee.
Corner: ball goes out of the play for a corner kick.
Offside: being caught in an offside position resulting in a free kick to the opposing team.
Situational variables: operational definition
Match location: venue of the match—playing at home or away.
Team quality: competitive level of a team was evaluated by cluster analysis. A team was classified as "strong" (ranking from the 1st to 5th place), "medium" (ranking from the 6th to 11th place), and "weak" (ranking from the 12 to 16th place).

The unit of the physical and technical performance-related parameters without units are in counts.

the maximal variance (Abdi and Williams, 2010). Specifically, the principal component analysis consisted of the calculation of eigenvectors and eigenvalues from the covariance matrix of *M* (O'Donoghue, 2008). Eigenvectors are the vectors of coefficients corresponding to eigenvalues and were used to calculate the results (Nguyen and Holmes, 2019). Thus, the coefficients represent the loading factors of each original variable to obtain the newly transformed data, and the positive or negative value represents a direct or inverse proportionality, respectively (Weaving et al., 2019). Finally, the original data were subsequently projected onto the eigenspace of the covariance matrix which provided the PC scores (Abdi and Williams, 2010). Furthermore, in order to perform principal component analysis (PCA), our study first examined the data for suitability by Bartlett's test of sphericity and the KMO measure of sampling adequacy. Specifically, Bartlett's test of sphericity was computed to provide the statistical significance that the correlation matrix has significant correlations among at least some of the variables. The measure of sampling adequacy was also developed with Kaiser-Meyer-Olkin (KMO) and computed to evaluate the appropriateness of applying factor analysis, considering that values above 0.50 for the entire matrix or an individual variable indicate appropriateness. In addition, the number of PCs to be retained was based on eigenvalues (greater than 1.0) and that explained higher than 60% of the percentage of variance. Furthermore, although factor loadings of ±0.30 to ±0.40 are minimally acceptable, values greater than ±0.60 were considered for practical significance (Gonçalves et al., 2019).Notably, the first and second PCs were extracted according to the previous studies since they explain the most amount of variance in the dataset (McCormack et al., 2021; Racinais et al., 2021) and 2 PCs were required to identify the individual and variable responses in a two-dimensional space as well as visualize the playing styles of each team between home and away matches in the CSL (Weaving et al., 2019; Lopez-Valenciano et al., 2021).

Third, linear mixed models were used to assess differences in terms of playing styles between home and away matches considering team quality. The variables of match and team were regarded as random effects while contextual variables (i.e., match venue and quality of opposition) were the fixed effects in the models. The assumptions of homogeneity and normal distribution of the residuals were also verified for each model. Pairwise comparisons between different levels of teams were conducted *via* Bonferroni adjusted *post hoc* test (Lago-Peñas et al., 2022). Effects sizes (ES) were calculated using Cohens' d according to the formula d = (M2 – M1/SDpooled), where M1 and M2 are the means of the two groups and SDpooled is the square root of the weighted average SD of each group. Values greater than or equal to 0.2, 0.5, and 0.8 were considered to represent small, medium, and large differences, respectively (Fritz et al., 2012).

All analyses were conducted using the statistical programming environment R (version 4.1.2). Specifically, the k-means clustering algorithm was performed using the "*kmeans*" function from the "*stats*" R package; principal component analysis (PCA) was conducted by the "*factoextra*" and "*FactoMineR*" package; linear mixed model and *post hoc* tests were performed using "*lme4*" and "*emmeans*" package. Visualization of difference was conducted according to the "*ggstatsplot*" package. $P < 0.05$ was considered statistically significant.

Results

The principal components model accounted for 55% of the total variance for home matches and 54.2% of the total variance for away matches in **Table 2**, with the first and second component factors extracted for home and away matches. It is worth noting that the first components mainly consisted of HIRD, HIRE, HSRE, HSRD, SprintE, SprintD, and TD while the second highlighted FPAcc, PassAcc, FPass, Pass, and BP at home and away matches in **Table 2**.

Figure 1 displays a Principal component analysis (PCA) biplot of individuals and explanatory variables at home (**Figure 1A**) and away matches (**Figure 1B**). PC1 presented a positive correlation with physical-related variables such as HIRD, HIRE, HSRD, and HSRE while PC2 was positively associated with the passing-related variables such as Pass, FPass, PassAcc, and FPAcc. As such, PC1 typically represents intense-play styles while PC2 represents possession-play styles at home and away matches, respectively.

Figure 2 shows the differences among three levels of teams for both PCs at home and away matches. There was an overall significant difference (see **Figures 2A,B**) at home matches between teams on PC1 ($F = 15.173$, $P < 0.001$, $\eta^2 = 0.115$) and PC2 ($F = 12.286$, $P < 0.001$, $\eta^2 = 0.095$). The pair-wise comparison showed a significant difference between strong and medium teams ($P < 0.001$, ES = 0.863), between medium and weak teams ($P < 0.05$, ES = 0.401) on PC1 (**Figure 2A**). Similarly, significant difference was found between strong and weak teams ($P < 0.001$, ES = 0.779) on PC2 (**Figure 2B**). In addition, there was an overall significant difference (see **Figures 2C,D**) at away matches between teams on PC1 ($F = 9.368$, $P < 0.001$, $\eta^2 = 0.074$) and PC2 ($F = 20.227$, $P < 0.001$, $\eta^2 = 0.147$). The pair-wise comparison showed a significant difference between strong and medium teams ($P < 0.001$, ES = 0.680) on PC1 (**Figure 2C**). Similarly, significant difference was found between strong and medium teams ($P < 0.05$, ES = –0.601), between strong and weak teams ($P < 0.001$, ES = 0.986) on PC2 (**Figure 2D**).

The playing styles between home and away matches preferred by each team are presented in **Figure 3**. The first five

TABLE 2 Component factor loadings, component statistics, Bartlett's test of sphericity and Kaiser-Meyer-Olkin measure of sampling adequacy of the factor analysis (principal component methods) between home and away matches.

Variables	Component factors (Home match = 240)					Component factors (Away match = 240)				
	1	2	3	4	5	1	2	3	4	5
BP	0.223	**0.776**	−0.271	−0.110	−0.250	0.325	**0.782**	0.207	0.131	0.264
Foul	−0.007	−0.351	−0.085	0.329	−0.461	−0.075	−0.353	0.139	0.193	0.502
Corner	0.354	0.145	−0.336	−0.515	0.158	0.137	0.259	0.445	0.531	−0.342
Offside	0.055	−0.081	−0.269	0.425	0.031	0.181	0.121	0.182	−0.124	0.246
Shot	0.441	0.363	−0.300	−0.365	0.201	0.212	0.396	0.438	0.300	−0.336
ShotAcc	0.118	−0.153	0.002	**0.612**	0.383	−0.091	−0.014	−0.104	**−0.671**	0.444
Pass	0.367	**0.869**	0.147	0.035	−0.159	0.424	**0.856**	−0.116	0.059	0.155
PassAcc	0.176	**0.909**	0.094	0.183	0.088	0.197	**0.895**	−0.116	−0.231	−0.009
FPass	0.401	**0.832**	0.121	0.015	−0.194	0.447	**0.823**	−0.074	0.107	0.182
FPAcc	0.217	**0.903**	0.042	0.159	0.118	0.234	**0.902**	−0.042	−0.206	−0.015
Challenge	0.121	−0.371	−0.068	−0.574	−0.345	0.134	−0.276	0.142	0.546	0.499
ChallengeW	0.076	−0.035	0.116	−0.234	**0.607**	−0.085	−0.024	0.254	−0.356	**−0.672**
TD	**0.742**	−0.166	**0.619**	−0.052	−0.012	**0.778**	−0.151	−0.532	0.166	−0.133
SprintE	**0.842**	−0.201	−0.276	0.156	0.059	**0.798**	−0.258	0.305	−0.208	−0.022
SprintD	**0.817**	−0.194	−0.276	0.171	0.089	**0.734**	−0.273	0.363	−0.201	−0.056
HSRE	**0.945**	−0.182	−0.042	0.025	−0.054	**0.941**	−0.210	0.005	−0.050	0.037
HSRD	**0.944**	−0.178	−0.060	0.005	−0.013	**0.939**	−0.206	0.038	−0.044	0.010
HIRE	**0.960**	−0.193	−0.097	0.056	−0.030	**0.953**	−0.230	0.070	−0.087	0.026
HIRD	**0.959**	−0.193	−0.130	0.056	0.017	**0.946**	−0.240	0.135	−0.093	−0.008
MSRD	**0.834**	−0.163	0.295	−0.054	−0.121	**0.849**	−0.146	−0.226	0.124	0.014
LSRD	0.313	−0.091	**0.844**	−0.072	0.042	0.360	−0.058	**−0.761**	0.226	−0.214
Eigenvalues										
Total	7.128	4.416	1.787	1.385	1.092	6.916	4.461	1.777	1.313	1.259
% of variance	33.9	21.0	8.5	6.6	5.2	32.9	21.2	8.5	6.3	6.0
Cumulative%	33.9	55.0	63.5	70.1	75.3	32.9	54.2	62.6	68.9	74.9
Bartlett's test of sphericity										
$\chi 2$			5521.94					5517.76		
p			< 0.001					< 0.001		
KMO measure of sampling adequacy			00.67					0.66		

Bold represent loadings greater than ± 0.60. TD, Total Distance; SprintD, Sprint Distance; SprintE, Sprint Efforts; HSRD, High-speed running distance; HSRE, High-speed running efforts; HIRD, High-intensity running distance; HIRE, High-intensity running efforts; MSRD, Moderate-speed running distance; LSRD, Low-speed running distance; ShotAcc, Shot Accuracy; BP, ball possession; PassAcc, Pass Accuracy; Fpass, Forward Passes; FPAcc, Forward Pass Accuracy; ChallengeW, Challenge Won.

teams in the final overall ranking in the CSL were located in the upper-right quadrant whereas the last five teams were located in the lower-left quadrant. The rest of the teams gathered around the origin of the coordinates. Specifically, Beijing Guoan and Shandong Luneng tended to utilize an intense-play style at home whereas they used a possession-play style at away. Furthermore, Guangzhou Evergrande presented balanced performances in terms of intensity and possession plays at home and away matches. In addition, Jiangsu Suning prefers to use more ball possession styles wherever they played, at home or away while Shanghai SIPG used the same style of play only at away matches. The team located in the lower-left quadrant represented the worst performance in terms of intensity and possession styles compared with other teams.

Discussion

Our study provides novel evidence based on the previous study by adding physical and situational variables. In addition, the styles of play utilized by each team between home and away matches have shown different trends. Specifically, the first two components accounted for 55% of the total variance for home matches and 54.2% of the total variance for away matches. Our study noted the major significant contribution of PC1 included HIRD, HIRE, HSRD, and HSRE while PC2 mainly consisted of Pass, FPass, PassAcc, and PassAcc. Therefore, PC1 typically represented intensity-play styles while PC2 was associated with possession-play styles at home and away matches, respectively. In addition, strong teams preferred to utilize intensity play

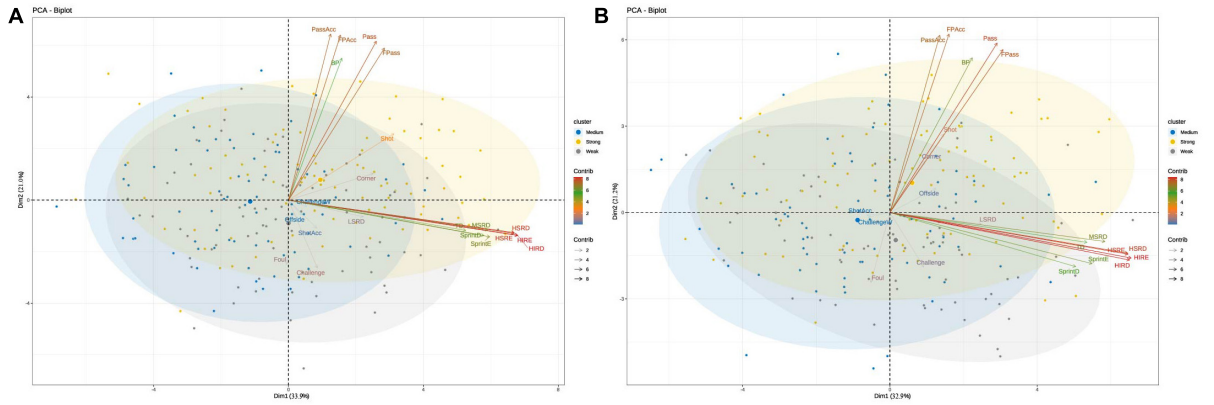

FIGURE 1
Principal component analysis (PCA) biplot of individuals and explanatory variables at home **(A)** and away matches **(B)**. The biplot shows the PCA scores of the explanatory variables as vectors and individuals among the three levels of teams in a two-dimensional space. Individuals on the same side as a given variable should be interpreted as having a high contribution on it. The magnitude of the vectors (lines) shows the strength of their contribution to each PC. The angle between the lines approximates the correlation between the explanatory variables they represent. The closer the angle is to 90, or 270 degrees, the smaller the correlation while An angle of 0 or 180 degrees reflects a correlation of 1 or −1, respectively. Colored concentration ellipses (size determined by a 0.95-probability level) show the observations grouped by mark class. TD, Total Distance; SprintD, Sprint Distance; SprintE, Sprint Efforts; HSRD, High-speed running distance; HSRE, High-speed running efforts; HIRD, High-intensity running distance; HIRE, High-intensity running efforts; MSRD, Moderate-speed running distance; LSRD, Low-speed running distance; ShotAcc, Shot Accuracy; BP, ball possession; PassAcc, Pass Accuracy; Fpass, Forward Passes; FPAcc, Forward Pass Accuracy; ChallengeW, Challenge Won.

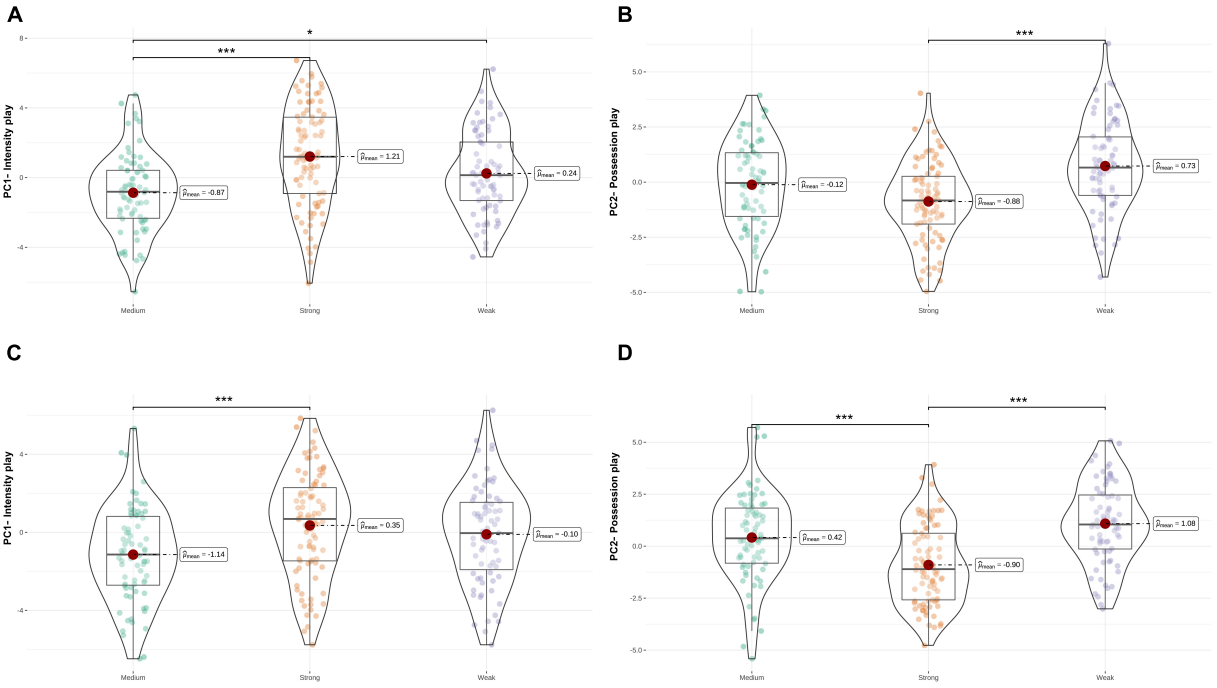

FIGURE 2
The differences among three levels of teams for both PCs at home **(A,B)** and away matches **(C,D)**.

whereas medium and weak teams tended to be possession play when playing at home or away matches. Furthermore, the first five teams in the final ranking position in the CSL presented a compensated technical-physical playing style whereas the last five teams in the league showed inferior performance in terms of intensity and possession play. These investigations can provide coaches and managers a better understanding of competition patterns in the CSL to effectively improve the tactical and

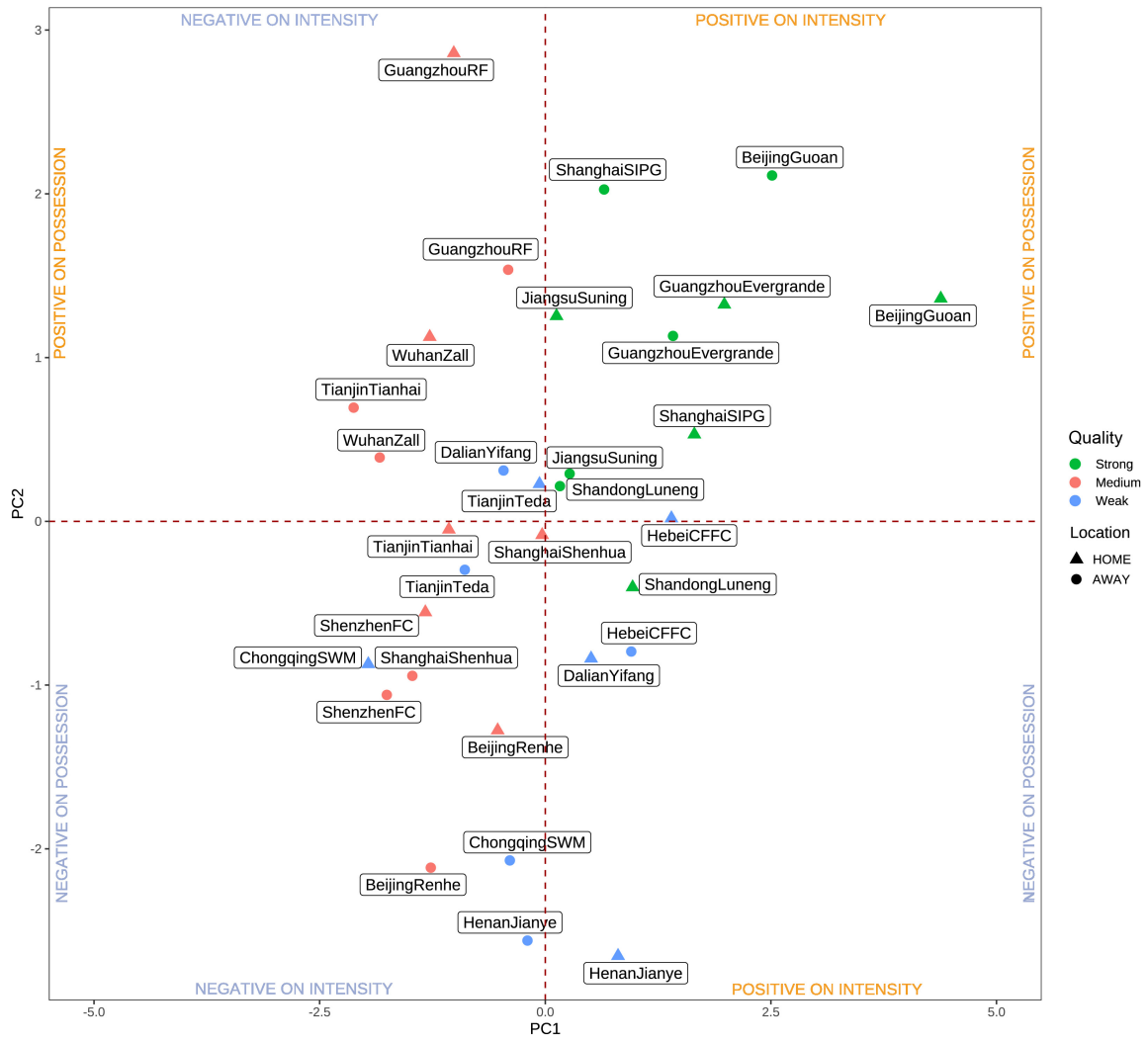

FIGURE 3
Combined graph of each team between home and away matches based on the principal components PC 1 and PC2 (X-axis dimension 1; Y-axis dimension 2).

physical strategies when facing different opponents in their stadium or on the road.

Our study found that strong teams preferred to utilize high-intensity playing styles which are contradicted by Lago-Peñas et al. (2017) identified that top teams in the CSL preferred to maintain possession instead of giving the initiative to the opponent. A possible reason is that the previous study failed to consider the influence of physical-related variables on playing styles. In fact, the current study is in line with Zhou et al. (2021b) found that high-intensity and possession-play styles were considered the most important components of the playing patterns adopted by teams, and the overall trend showed an increase in terms of intensity play in the CSL. Indeed, top teams in the CSL preferred to play counter-attacking or direct play (Zhou et al., 2021a). For example, moving the ball quickly to within scoring range often utilized long passes or long balls downfield, which provides a higher requirement for high-intensity running and sprints (Gong et al., 2021). Furthermore, top teams within the CSL often recruit the best foreign players in different playing positions to activate more domestic players to participate in the overall offensive and defensive strategies which lead to accumulating distance at different ranges of velocity (Gai et al., 2019). Likewise, top teams could be required to maintain a high level of activity for players when not directly involved in play to create space to receive passes or to pressurize opponents into making mistakes in order to regain possession (Bradley et al., 2009; Gollan et al., 2020). Conversely, weak teams tended to perform more possession play in the CSL. The strategy of "maintaining possession" may involve more slow play with defensive movements, lower risk when passing, and greater

emphasis on regaining possession relative to teams who might place less importance on this strategy (Lago, 2009; Fernandez-Navarro et al., 2018, 2019). This playing style is also called indirect play, which is slower than direct play and uses many short passes, while weaknesses in the opposition defense are sought (Lago, 2009; Gómez et al., 2018). In addition, our study found that high-intensity running with the aforementioned ball possession and passing ability is the key to a high ball possession strategy based on the first and second PC (Bradley et al., 2013). Therefore, coaches should design training tasks with continuous role changes, ensuring players concentrate to coordinate sudden movements with teammates from greater areas; and then improve positional decision-making due to a combination of a high number of ball controls, passes, and shots. Simultaneously, they need to perform many ball controls, passes, and shots during high-intensity aerobic endurance, combined with a higher number of accelerations and decelerations (Ade et al., 2016).

The first five teams in the final ranking are located in the upper-right quadrant, which indicates that these teams possess the best performance in terms of possession and intensity play (Miñano-Espin et al., 2017). Guangzhou Evergrande was the championship that won the league competition at the end of the season and its position in the chart was almost the same between home and away games suggesting that part of its success was associated with maintaining a balanced playing style and efficacy during the match-play. Beijing Guoan, Shandong Luneng, and Shanghai SIPG tended to employ intensity play at home matches whereas they used a possession play style at away matches. This result is in accordance with previous studies indicating that the tactical strategies of fast tempo, crossing, and high pressure in the offense phase were higher at home in comparison with away matches (Lago, 2009). These styles of play also were regarded as the aggressive play that aims to create as many scoring opportunities as possible and seems to be the overall trend when the team is playing at home (Castellano and Pic, 2019; Praça et al., 2021). Likewise, regaining ball possession in advanced zones of the pitch as a consequence of high-pressure strategies is linked to success (Almeida et al., 2014). Consequently, these results may support the influence of home advantage on playing styles in soccer. Although home advantage has been widely mentioned, the reasons remain unclear (Carron et al., 2005). Crowd support seems to be one of the major factors; however, referee bias, psychological factors, familiarity with the pitch, and travel impact seem to be the rest of the contributing factors (Nevill and Holder, 1999). Interestingly, Jiangsu Suning preferred to use more ball possession styles wherever they play, at home or away. Our result may further support the idea that when considering the effect of match location on technical and physical performances, the quality of the team and opponent should also be taken into account (Praça et al., 2021). In addition, teams with higher ball possession between home and away matches might utilize more set plays that increase the chance of obtaining a successful ball possession, especially when facing an intense defensive pressure situation (Bradley et al., 2013). On the other hand, the last five teams in the final ranking position are located in the lower-left quadrant, which indicates that these teams presented the worst performances in terms of possession and intensity play when playing at home or away. In addition, the rest of the teams are located in the upper-left or the lower-right quadrant where these teams present less compensated locations in the plot with a high predominance of components 2 or 1, respectively (Lopez-Valenciano et al., 2021). Collectively, intensity or possession play was associated with the final ranking positions in the CSL, and playing styles that combine these two factors could be more liable to win the competition (Lopez-Valenciano et al., 2021; Zhou et al., 2021b).

Some limitations need to be considered in future research. First, although the playing styles were identified for each team between home and away matches, the playing styles may be different which are subject to the policy and rules of the competition in their soccer league as well as the tactical strategies of each team (Lago-Peñas et al., 2017; Gómez et al., 2018). Second, playing styles may be adapted depending on several contextual factors such as match outcome, fixture congestion, and opposition quality (Fernandez-Navarro et al., 2018; Gollan et al., 2020). Future studies are recommended to consider the interactive effects of situational variables on playing styles based on the principal component analysis. Third, detailed analysis is required to determine match-to-match changes in playing style and efficacy variables in teams competing in the CSL.

Conclusion

High-intensity and possession-play styles were considered the most important components of the playing patterns which were associated with the final overall ranking in the CSL. Strong teams preferred to utilize intensity play whereas medium and weak teams utilized possession play whenever playing at home or away matches. Furthermore, the first five teams in the final overall ranking in the CSL presented a compensated technical-physical playing style whereas the last five teams showed inferior performance in terms of intensity and possession play. Finally, playing styles that combine these two factors could be more liable to win the competition.

Data availability statement

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

LK, SZ, M-AG, and CZ contributed to the conception and design of the study. CZ and SZ collected and organized the data. YH and TZ performed the statistical analysis. LK wrote the first draft of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Influence of different playing styles among the top three teams on action zones in the World Cup in 2018 using a Markov state transition matrix

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Purpose: In football, attacking has seen evolving for decades and attacking pattern detection is an important topic in this sport. The purpose of this study was to identify the general and threatening attacking patterns of different playing styles in world top football matches, which represented the latest evolvement of soccer attacking.

Methods: Attacking sequence data of the top three teams from 21 matches in the 2018 World Cup were collected. The three teams were classified into two playing styles according to a previous study, France was a direct-play team, and Croatia and Belgium were possession-play teams. The football field was divided into 12 zones and Markov transition matrix-based zone models were applied to assess the attacking pattern in the 21 matches. Both descriptive analysis and simulative analysis were conducted using this model.

Results: The results revealed that (1) flanker attacks were frequently taken among all three teams, and possession playing teams (Croatia and Belgium) played more often than direct playing teams (France) in their center of the midfield zone and (2) forward passes across/through zones toward the middle of attacking quarter (A1/4) have a positive impact of creating a chance of a goal.

Conclusion: Using Markov transition matrix, general and threatening attacking patterns were found. The combination of possession play and counterattack was a new trend that emerged in the 2018 World Cup. These findings can help coaches to develop corresponding strategies when facing opponents of different playing styles.

KEYWORDS

soccer, Markov chain, stochastic process, playing behaviors, playing style, offensive sequence, zone, performance analysis

Introduction

For team sports such as football, the overall strength of the team is not equal to the linear accumulation of the athletic abilities of all of the players on the pitch. The team's performance is influenced by many factors; thus, the traditional descriptive statistical method can neither provide global information about the game (Glazier, 2010) nor convert a single variable into tactical information (Pfeiffer and Perl, 2006). Therefore, some studies have used nonlinear models to evaluate the performance of collective events (such as ball games). Lames (2006) believes that football matches are complex systems. Therefore, the concept of the relative phase is introduced into the game analysis to analyze football matches by establishing a nonlinear model (Lames, 2006). Afterward, decision tree technology (Lin, 2011), the Apriori algorithm (Pan, 2010; Liu and Hohmann, 2013a) and its improved version (Tianbiao and Andreas, 2016), and the sequential pattern mining algorithm (Liu et al., 2018) are used to analyze the set-piece tactics and attack patterns in football matches. Moreover, by applying social network analysis methods, Cao et al. (2019) analyzed the group combination of players in the football game, and Wu et al. (2020) and Yu et al. (2020) analyzed the importance of player positions in the match and the performance of foreign players. These studies analyzed the relationship between players by constructing a passing network and used network parameters to evaluate the performance of the players. The lines connecting the nodes in these passing networks represent passing activities.

Passing is one of the most important behaviors in the football field. The team organizes the offense by passing the ball, thus creating scoring opportunities. Current research on passing has mainly focused on counting the number of passes in the game and evaluating the relationship between various passes and winning (Shafizadeh et al., 2013; Liu et al., 2016, 2019). However, simple quantitative research cannot describe complex passing behaviors (Rein et al., 2017), nor can it support the research of passing decision-making. In particular, it is difficult to help coaches and players to apply any behavioral data in practice (Rein et al., 2017). Due to the characteristics of using technical and tactical behaviors in different areas of the football ground, as well as the different pressures given by opponents (Chen et al., 2015), it is particularly important to add position and field information when studying passing, technical, and tactical indicators (Fournier-Viger et al., 2019; Li and Zhang, 2019).

For each team, the passing and the use of the court area have their own characteristics. Camerino et al. (2012) studied the playing style of FC Barcelona and identified two different attacking patterns (T-Patterns), which contained different areas and passing routines. Moreover, Yi et al. (2019) observed that the technical and tactical performance and running of teams of different playing styles are different; in addition, by using technical and tactical indicators, it is possible to distinguish teams of different game styles (Lago-Peñas et al., 2017). Traditionally, it is believed that there are two typical playing styles (possession play and direct play; Hughes and Franks, 2005; Kempe et al., 2014) during offending. Later, combining with defending styles, researchers developed this playing style theory and more styles were identified (Fernandez-Navarro et al., 2016; Lago-Peñas et al., 2017; Castellano and Pic, 2019). The difference in the playing style is related to culture, football philosophy, and the skill levels of players. Ball possession is one of the most commonly used indicators to distinguish these two styles of play (Hewitt et al., 2016), which also influences the technical and physical performances of teams and players (Bradley et al., 2013; Liu et al., 2021). Additionally, situational variables also play an important role and affect playing styles (Fernandez-Navarro et al., 2018).

As a vital algorithm for the mathematical simulation of performance diagnoses, the Markov chain model has been applied to diagnostic analysis of net sports, such as table tennis (Zhang, 2003; Pfeiffer et al., 2010; Wenninger and Lames, 2016), tennis (Lames, 1991), and volleyball (Miskin et al., 2010; Hileno et al., 2020). In invasion games, the Markov chain state transition matrix can be used to describe and diagnose important passes in football (Liu and Hohmann, 2013b; Liu, 2014) or important connections in frisbee (Lam et al., 2021). Although there have been other important pattern detection technologies in the research of football (Liu and Hohmann, 2013a; Sarmento et al., 2014b), such as T-pattern (Borrie et al., 2002; Camerino et al., 2012; Pic Aguilar, 2017), these studies only aimed to describe general attacking pattern and did not offer a simulative way to discover threatening patterns. Moreover, most of the previous studies in this field did not include different playing styles in the analysis (Hirotsu and Wright, 2002; Wright and Hirotsu, 2003). Therefore, this study considers the attack sequences of the top three teams in the 2018 World Cup (the champion France, the second place Croatian, and the third place Belgium teams) as the research objects and explores the offensive routes and covering areas of the world's top national teams with different playing styles in the World Cup.

Materials and methods

Samples

As shown in Table 1, this study recorded a total of 13,666 passing events in 21 games (7 games per team) of the top three teams (France, Croatia, and Belgium) in the 2018 World Cup in Russia. The dataset contained the time, area, and player of each pass. In the 21 recorded games, there were 10 games against possession-play opponents and 11 games against direct-play opponents. According to the division of Yi et al. (2019), among the top three teams, France was a direct-play team, and Croatian and Belgian teams exhibited possession-play styles. Among the opponents in the competition, Denmark, Russia, Iceland, Nigeria, Panama, Tunisia, Uruguay, and Peru were direct-play teams, whereas England, Argentina, Brazil, Japan, and Australia were possession-play teams.

TABLE 1 General description of research samples.

Match ID	Date	Observed team	Opposing team	Playing style of opposing teams	Observed team passing numbers	Observed team possession	Opposing team possession	Match result	Phase
1	2018-07-07	Belgium	Brazil	Possession play	493	46.03%	**53.97%**	2–1	1/4 final
2	2018-07-11	Belgium	England	Possession play	587	**56.76%**	43.24%	2–0	3–4 final
3	2018-06-29	Belgium	England	Possession play	647	**50.72%**	49.28%	1–0	group stage
4	2018-06-16	Belgium	France	Direct play	709	**54.52%**	45.48%	0–1	semifinal
5	2018-07-11	Belgium	Japan	Possession play	723	**55.31%**	44.69%	3–2	1/8 final
6	2018-06-18	Belgium	Panama	Direct play	710	**56.85%**	43.15%	3–0	group stage
7	2018-06-23	Belgium	Tunisia	Direct play	542	**55.97%**	44.03%	5–2	group stage
8	2018-06-22	Croatia	Argentina	Possession play	564	48.05%	**51.95%**	3–0	group stage
9	2018-07-02	Croatia	Denmark	Direct play	650	**53.94%**	46.06%	4–3	1/8 final
10	2018-07-12	Croatia	England	Possession play	662	47.01%	**52.99%**	2–1	semifinal
11	2018-07-15	Croatia	France	Direct play	713	47.15%	**52.85%**	2–4	final
12	2018-06-24	Croatia	Iceland	Direct play	697	**62.61%**	37.39%	2–1	group stage
13	2018-06-27	Croatia	Nigeria	Direct play	650	**53.87%**	46.13%	2–0	group stage
14	2018-07-08	Croatia	Russia	Direct play	803	**51.26%**	48.74%	6–5 (2–2)	1/4 final
15	2018-06-30	France	Argentina	Possession play	513	38.63%	**61.37%**	4–3	1/8 final
16	2018-06-16	France	Australia	Possession play	728	**69.23%**	30.77%	2–1	group stage
17	2018-07-11	France	Belgium	Possession play	557	45.48%	**54.52%**	1–0	semifinal
18	2018-07-15	France	Croatia	Possession play	515	**52.85%**	47.15%	4–2	final
19	2018-06-26	France	Denmark	Direct play	866	**54.88%**	45.12%	0–0	group stage
20	2018-06-21	France	Peru	Direct play	595	**56.46%**	43.54%	1–0	group stage
21	2018-07-06	France	Uruguay	Direct play	742	**55.16%**	44.84%	2–0	1/4 final

Bold values mean higher ball possession in the match.

Division of football field

The World Cup football field is based on FIFA standards, with a length of 105 m and a width of 68 m. According to a previous study (Pfeiffer et al., 2006), the football field is divided into four fields according to the front field, center front field, center backfield, and backfield. Each field is divided into three areas: left, center, and right areas, with a total of 12 areas (Figure 1A). Moreover, the division of the field is divided according to the grass stripes. Each half of the World Cup venue has 10 horizontal grass stripes; therefore, each field section contains 5 horizontal grass stripes (Figure 1B).

Data collection

All of the game videos were collected from the World Cup 2018 homepage of CCTV (China Central Television), which holds exclusive media rights to FIFA World Cup 2018. Two experienced observers observed the game video and recorded the passing information in the game according to the division of the field. To verify the reliability of the data, two matches were randomly selected; furthermore, a Cohen's Kappa test was run for the two sets of data, and $k = 0.61$. According to Landis and Koch (1977) and Fleiss et al. (2013), the data have good consistency (Substantial) and can be used in research.

Game observation model

Based on previous studies (Liu and Hohmann, 2013b; Liu, 2014), during the game, each area that the ball passes through is regarded as a state, the process consisting of passing is regarded as a ball control sequence (chain), and each ball control sequence (Chain) is composed of several intermediate states (zones). The sequence of possession (chain) is initiated with the possession of the ball (specifically, the starting state) and ends with the loss of possession (Figure 2; Liu and Hohmann, 2013b). The absorbing state is defined as whether a scoring opportunity is created when there is a loss of possession of the ball (TC = opportunity is created; NTC = opportunity is not created; Tianbiao and Andreas, 2016).

Statistical model and data processing

Constructing the game state transition matrix

Passing between different zones is regarded as the transition between the game states. A two-dimensional state transition probability matrix can be constructed through the state transition probability. Each element in the matrix is a positive percentage number that is not greater than 100%, and the sum of any row elements in the matrix is 100%. Table 2 shows an example of state transition probability matrix from one match. Therefore, besides calculating general descriptive results of the passing paths, according

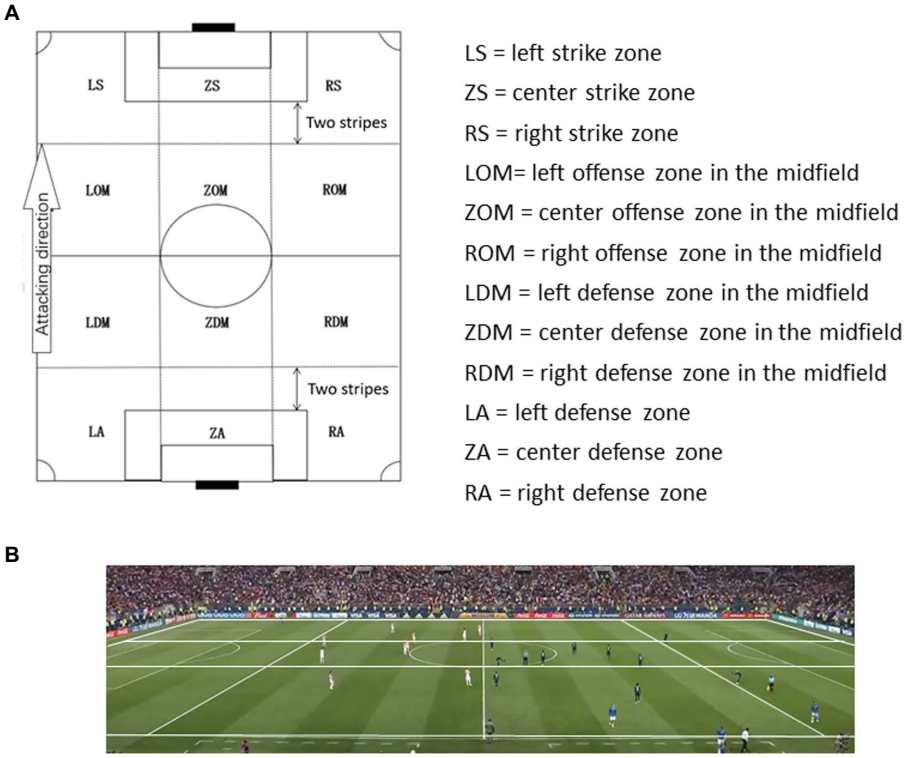

FIGURE 1
(A) Division of football ground. **(B)** Zone and turf band of football ground.

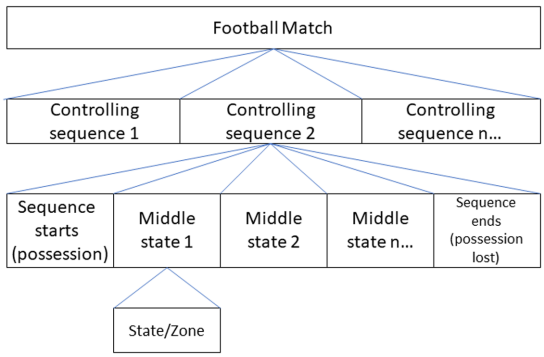

FIGURE 2
Sequence of ball possession and state in football.

to Lames (1991), the state transition probability matrix of the game can be used to calculate the probability of creating a scoring opportunity through a Markov chain (Liu and Hohmann, 2013b).

Markov chain

In this study, zone was used as the research variable. In the game, players pass the ball from one zone to the next. This study regards the ball's trajectory as a random system, and the zone where the ball is located at a certain moment is defined as a state.

Let X_n be the state of the ball at time n; then, according to the Markov chain formula (Ching and Ng, 2006):

$$P\{X_{n+1} = k | X_n = j\} = P_{jk}\left(j,k = 1,2,\ldots,n\right) \quad (1)$$

It can be expressed as follows: at the n^{th} time, the ball is in zone j, and at the $(n+1)^{th}$ time, the probability of the ball passing to zone k is the probability of the transition from state j to state k.

In the game, the state of the ball (the zone where the ball is located) at a certain time in the future is only related to the current state (zone) and has nothing to do with its previous state (zone), which is consistent with Markov chain's "no aftereffect." In addition, the time parameter of the possession chain is a discrete process, which can be represented by a sequence of X_n random variables. The value of n is *0, 1, 2* …, then $\{X_n, n \in T\}$ is called a Markov chain. When supposing that the random process is $\{X_n, n \in T\}$; if it satisfies any integer $n \in T$, any $j_0, j_1, \ldots, j_{n+1} \in J$, its state transition probability is (Ching and Ng, 2006):

$$P\begin{Bmatrix} X_{n+1} = j_{n+1} | X_0 = j_0, \\ X_1 = j_1, \ldots X_n = j_n \end{Bmatrix} = P\{X_{n+1} = j_{n+1} | X_n = j_n\} \quad (2)$$

Subsequently, for the transition matrix M containing the absorbing state, the Markov chain whose initial state row vector is S, after n rounds of iterations, reaches its final state S_{final} as:

$$SM^n = S_{final}$$

TABLE 2 Example of state transition probability matrix for zones.

To / From	LA	ZA	RA	LDM	ZDM	RDM	LOM	ZOM	ROM	LS	ZS	RS	NTC	TC
LA	30.95%	4.76%	0.00%	30.95%	0.00%	0.00%	4.76%	2.38%	0.00%	0.00%	0.00%	2.38%	23.81%	0.00%
ZA	3.92%	11.76%	7.84%	0.00%	15.69%	5.88%	3.92%	19.61%	17.65%	0.00%	0.00%	1.96%	7.84%	3.92%
RA	0.00%	6.25%	37.50%	3.13%	0.00%	21.88%	0.00%	6.25%	3.13%	0.00%	0.00%	0.00%	21.88%	0.00%
LDM	4.36%	0.00%	0.00%	42.03%	8.70%	0.00%	18.84%	2.90%	0.00%	2.90%	1.45%	1.45%	17.39%	0.00%
ZDM	2.94%	5.88%	0.00%	5.88%	20.59%	11.76%	5.88%	2.94%	14.71%	0.00%	0.00%	5.88%	23.53%	0.00%
RDM	1.79%	1.79%	1.79%	5.36%	3.57%	41.07%	3.57%	1.79%	8.93%	0.00%	0.00%	5.36%	23.21%	1.79%
LOM	3.28%	0.00%	0.00%	4.92%	4.92%	1.64%	29.51%	1.64%	1.64%	11.48%	0.00%	3.28%	34.43%	3.28%
ZOM	0.00%	2.94%	0.00%	0.00%	2.94%	0.00%	11.76%	26.47%	8.82%	2.94%	0.00%	5.88%	38.24%	0.00%
ROM	0.00%	0.00%	0.00%	0.00%	1.60%	4.76%	0.00%	1.59%	42.86%	1.59%	0.00%	7.94%	36.51%	3.17%
LS	0.00%	0.00%	0.00%	7.14%	0.00%	0.00%	14.29%	0.00%	0.00%	7.14%	0.00%	0.00%	57.14%	14.29%
ZS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.67%	8.33%	0.00%	75.00%
RS	0.00%	0.00%	0.00%	0.00%	0.00%	2.17%	0.00%	0.00%	0.00%	0.00%	0.00%	36.96%	41.30%	19.57%

where n is a sufficiently large positive integer, and the probability of a transition state (zone state) in S_{final} is close to 0. In this study, the probability of the absorbing state represents the probability of creating a scoring opportunity (*TC*) and the probability of failing to create a scoring opportunity (*NTC*).

Calculating competitive relevance (performance relevance)

After calculating the probability of creating a scoring opportunity, a new state transition probability is calculated according to a deflection formula (Lames, 1991)

$$\delta TP = C + B \times 4 \times TP\left(1 - TP\right) \tag{3}$$

where TP is the transition probability, δTP is the transition probability after the change, the constant $C = 1$, $B = 5$ (Lames, 1991; Pfeiffer, 2005). In this process, every element (transition probability) in the initial matrix will be modified. To ensure that the sum of the rows of the modified matrix would still be 1, other cells in the same row in the matrix are calculated by using the compensation formula (Liu and Hohmann, 2013b)

$$\delta TP_{yi} = -\left(TP_{yi} / \left(1 - TP_x\right)\right) \times \delta TP_x \tag{4}$$

Afterward, the Markov chain model is used to calculate the probability of creating a scoring opportunity for the newly obtained matrix, and this new probability is compared with the result of the initial matrix calculation to determine the impact of changes between the states of the game (changes between the zones = passing) on the creation of scoring opportunities.

Data processing

First, the descriptive statistics of the passes between the different zones derived from the state transition matrix were calculated. The chi-square test was used to compare the general passing data of the top three teams in the 2018 World Cup against different opponents ($n_{\text{possession vs. possession}} = 6$; $n_{\text{possession vs. direct}} = 8$; $n_{\text{direct vs. possession}} = 4$; $n_{\text{direct to direct}} = 3$). Afterward, the Markov chain transition matrix was used to simulate and calculate the influence of the change of state in the game on the creation of scoring opportunities. The significance level was set to $\alpha = 0.05$. According to Cohen (1988), the effect size is Cramer's $\varphi(Phi)$, and the threshold is $0 < Small < 0.1/\sqrt{k-1} < medium < 0.3/\sqrt{k-1} < large < 0.5/\sqrt{k-1} < larger < 1.0/\sqrt{k-1}$; in this study, the k value was 4. Data were processed by using SPSS (ver. 26, IBM, Chicago, United States) and Python (ver. 3.8), and graphical visualization was performed by using the online drawing tool draw.io (v. 14.8.4).

Results

Descriptive analysis of the passing paths of the top three teams in the 2018 world cup

Figure 3 shows the descriptive analysis of the passing paths of the top three teams in the 2018 World Cup. The depth of the color of the field zones represents the frequency of technical and tactical activities in the area, and the thickness of the arrow represents the closeness of the connection between the areas. The top three teams rarely passed the ball across regions (with only a few long passes being observed), and all of the teams focused on using the wing area to organize their offenses. However, the differences in the passing and active areas of the different playing style teams were significant (Possession play vs. direct play, $\chi^2 = 437.871$, Cramer's $\varphi = 0.179$, $p < 0.001$). Moreover, Croatian and Belgium teams, which exhibit possession playing

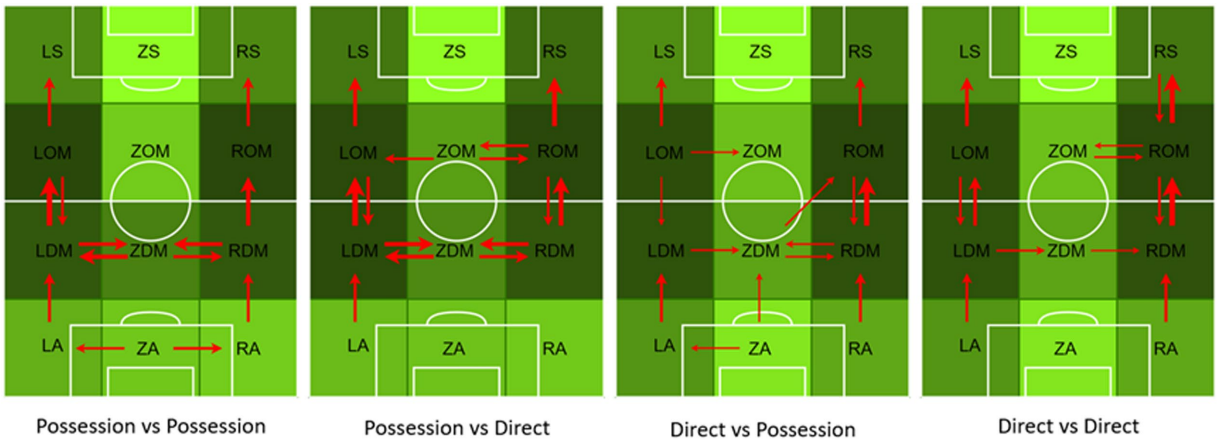

FIGURE 3
Descriptive analysis of actions zones and passing paths among top three teams in the World Cup 2018.

styles, tended to use their own midfield zones (LDM, ZDM, and RDM) to organize their offenses, whereas France, which is a direct-play style team, tended to directly form an offense through their own backside zones (LA and RA). Furthermore, the differences in the passing and active areas of the same style of play teams against opponents of different styles were also significant (possession play vs. different opponents, $\chi^2 = 210.606, Cramer's\ \varphi = 0.152, p < 0.001$; direct play vs. different opponents, $\chi^2 = 180.596, Cramer's\ \varphi = 0.200, p = 0.007$).

Diagnostic analysis of the passing paths of the top three teams in the 2018 World Cup

Table 3; Figure 4 illustrate the diagnostic analysis of the passing paths of the top three teams in the 2018 World Cup. For the top three teams, regardless of whether Croatia and Belgium teams focused on possession, or France focused on direct play, the diagnostic analysis observed that cross-regional passes (long passes) to the forward center (ZS) and to the side of the opponent's half (LS and RS) have a positive effect on the creation of scoring opportunities. Especially for the direct playing style of France, when facing the same direct playing opponent, increasing side-way attack can increase its chance of scoring.

Discussion

The aim of this study was to analyze the paths and covering zones in the offensive sequence of high-level football games. The results found that (1) the top three teams in the 2018 World Cup tended to form offenses in the wing area, and possession-play teams (Croatia and Belgium) had more passes in their own midfielder zones than direct-play teams (France); and (2) cross-regional forward passes, especially passes toward the forward middle zone, had a particularly important positive impact on creating scoring opportunities.

From the offensive mode of the top three teams in the 2018 World Cup, the flanker areas are still effective offensive areas, which is also consistent with the studies on previous international football tournaments (Xue et al., 2015; Yamada and Hayashi, 2015; Mitrotasios et al., 2022). As attacks through middle zones will encounter greater defensive resistance, the side-way attack is a more effective offensive method (Grehaigne et al., 2002; Diana et al., 2017), which can disrupt the opponent's defensive balance and increase the probability of a successful offense (Fernandez-Navarro et al., 2016). However, this study found that teams with different playing styles used the field areas differently. The possession playing Croatia and Belgium exhibited more lateral passes in the midfield than direct playing France, whereas France made more use of side areas on its own backcourt. For the top three teams in the 2018 World Cup, the difference in the use of covering areas and paths may be due to teams of different playing styles actively adopting their own style of play. Evidence indicates that stronger teams dominated ball possession against their opponents and shows that more stable patterns of play independently of the evolving score-line (Lago, 2009; Lago-Peñas and Dellal, 2010). Previous studies also have shown that both FC Barcelona and Manchester United (in the 2011 UEFA Champions League Finale) were possession-play teams (Sarmento et al., 2014a), although Manchester United was not as strong as FC Barcelona in that match, the players still had been trying and insisting on passing and controlling in the midfield area in the Finale (Liu and Hohmann, 2013a). During a football game, the team with the higher ball possession rate tends to be stronger (Hughes and Franks, 2005); therefore, they are also able to maintain possession of the ball in the midfield area (Casal et al., 2017) and have a higher possession rate in the opponent's half and the 35-m area of the frontcourt (the attacking 1/3; this does not consider match status). In addition, the center of the formation (the centroid) in the game will also move forward accordingly (Clemente et al., 2013). In contrast, direct-play (counterattack)

TABLE 3 Diagnostical analysis of passing routines among top three teams in the World Cup 2018.

Rank	Possession						Direct					
	vs. Possession			vs. Direct			vs. Possession			vs. Direct		
	From	To	PR	From	To	PR	From	To	PR	From	To	PR
1	LOM	ZS	0.490%	ROM	ZS	0.449%	ROM	ZS	0.425%	ROM	ZS	0.545%
2	ROM	ZS	0.447%	LDM	ZS	0.449%	RDM	ZS	0.387%	RDM	ZS	0.441%
3	LDM	ZS	0.443%	LOM	ZS	0.415%	LDM	ZS	0.380%	ROM	RS	0.428%
4	LOM	LS	0.423%	RDM	ZS	0.402%	LOM	ZS	0.353%	LOM	ZS	0.422%
5	RDM	ZS	0.407%	ZDM	ZS	0.306%	LOM	LS	0.253%	LDM	ZS	0.379%
6	ROM	RS	0.373%	ROM	RS	0.304%	ROM	RS	0.216%	LOM	LS	0.328%
7	ZDM	ZS	0.343%	RS	ZS	0.279%	ZDM	ZS	0.213%	RDM	RS	0.190%
8	LS	ZS	0.308%	LOM	LS	0.236%	LS	ZS	0.207%	ZDM	ZS	0.177%
9	RS	ZS	0.294%	LS	ZS	0.235%	RS	ZS	0.201%	RS	ZS	0.176%
10	ZA	ZS	0.261%	ZOM	ZS	0.233%	LA	ZS	0.200%	LDM	LS	0.175%

PR, Performance relevance.

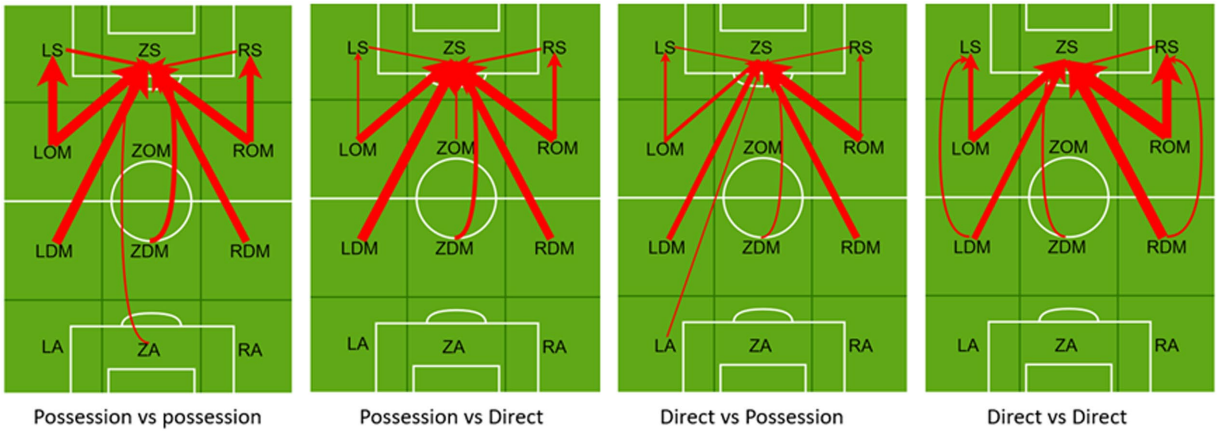

FIGURE 4
Diagnostical analysis of passing routines among top three teams in the World Cup 2018.

teams have a relatively low ball possession rate in the game, especially in the midfield. Therefore, direct playing teams are more inclined to use the wing to organize and launch offenses, especially from the sidelines of their own backcourt. This finding is also consistent with the research of Yi et al. (2019).

This study also found that for teams with both styles of play, passing from the side toward the forward center of the field (the ZS area) can better help in creating scoring opportunities. Therefore, the possession playing style teams can appropriately increase the cross-area long pass with the target of the front middle. Research on the European Cup and World Cup has shown that teams do not easily change the playing style in the game (Casal et al., 2017); however, teams that flexibly combine possession play and direct play in different situations can achieve better results (Yi et al., 2019). These findings also support the results of our study. During a football game, researchers have long known that the middle area of the frontcourt is an important area that is used to create scoring opportunities (Worthington, 1975; Hughes, 1990; Xue et al., 2015); thus, the early research of Pollard and Reep (1997) proposed that the ball should be introduced into this area as soon as possible to form a shot. This theory has considerably affected England and Norway teams (Larson, 2001). An early study (Grehaigne et al., 2002) showed that the area most likely to be intercepted and counterattacked by the opponent in the offense is the opponent's middle area of the backcourt (ZOM, for the attacking team, the middle of the forecourt); however, the opponent's penalty area (which is located in the frontcourt for the attacking team) is not the area where the defenders are most likely to steal the ball and counterattack (Grehaigne et al., 2002). Therefore, after combining the data of Bate (1988) and Dufour (1993), the target area of a cross-area long pass (the counterattack) should be the area between the goal area and the penalty area (around the penalty point). However, it should be noted that the abovementioned studies were conducted several decades ago. With the development of football, high position press and formation forward pressure tactics have gradually become a trend. Therefore, the target area of the pass in a quick counterattack and a positional attack is also different. The target area of a long pass for a quick counterattack and a positional attack should

be combined with the area where the opponent's formation is located; generally, the target is the area between the opponent's central defender and the goalkeeper (Larson, 2001), which likely represents the attacking team's middle front. Therefore, in a quick counterattack, the target area may be slightly far from the defender's penalty area, whereas in a positional attack, the target area may be closer to the defender's goal area.

Furthermore, pattern analysis is always an interesting topic in sports, which provides coaches and players with important information and helps to win the match. Previous studies also introduced pattern detection using T-pattern (Pic Aguilar, 2017) or Polar coordinates (Castañer et al., 2016; Maneiro Dios and Amatria Jiménez, 2018) or mixed method (Castañer et al., 2017) which are already sophisticated methods (Magnusson, 2019). Comparing with these studies, the current study used Markov Chain transition matrix model to describe and diagnose zone patterns of World Cup top teams, combining with style of play, it offers a new perspective to solve such problems. A difference between current method and T-pattern is that Markov Chain transition matrix method is based on event-sequence and not temporal sensitive for the temporal distances between events. It is worth noting in the future study to add some temporal factors.

The limitation of this study was that only the data of three teams were used. The current sample size between teams of two playing styles is not balanced enough and may not fully reflect the general situation of the two styles of play, but the characteristics of the top teams in the 2018 World Cup were still representative and showed the latest development trend of playing style and attacking pattern in football games. Through this study, coaches can understand different styles of play and development trends of football, as well as combine the data from this study with other studies, to make proper tactical responses in future games. In future research, situational factors (such as different playing styles, team strengths, match statuses, and match time) can be incorporated to analyze the changes in team play.

Conclusion

This study analyzed and diagnosed the offensive patterns of the top three teams in the 2018 World Cup based on the Markov chain transition matrix. By constructing a transfer matrix, we demonstrated the methods that the top teams with different playing styles used in their offenses. Both playing style teams mainly used the wing area in their offense. Furthermore, the possession playing team organized more passes in the midfield, whereas the direct-play teams made more use of the side zones of their backcourt. In addition, the combination of possession play and counterattack was a new trend that emerged in the 2018 World Cup.

Although the possession playing style has prevailed in the past decade, the success of the French national team in the 2018 World Cup and the failure of Germany and Spain (who were in pursuit of pass and control tactics) have caused researchers to re-examine the game style. The efficiency of offense in the game has become increasingly important. Furthermore, possession-play football and direct play football are not incompatible, and offensive efficiency and scoring are ways to achieve game success.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

TL conceptualized the study and wrote the original draft preparation. TL and CZ contributed to the methodology. XS, LZ, and CZ contributed to data collection and visualization. TL, JZ, and LY reviewed and edited the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The Qatar 2022 World Cup warm-up: Football goal-scoring evolution in the last 14 FIFA World Cups (1966–2018)

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The aim of this study was to elucidate pattern of attacking actions leading up to goal scoring during the 14 FIFA World Cups from 1966 to 2018. The study analysed 1881 goals scored during a total of 732 matches. We employed observational methodology design. Before goal analysis began, it was developed the observing protocol in which data related to selected variables, by system of notation, was entered after reviewing each individual goal scoring action. The analysis of all video material was carried out independently by four experienced examiners (three of them are Ph.D in sports science and one is Ph.D. candidate in sports science with at least 7years of coaching and experience as analyst in football). The inter-and intra-observer reliability presented good level of agreement. The kappa values ranged from 0.82 (goal scoring through open play) to 1.00 (action leading up to goal), showing a very high agreement for all performance variables. Interclass correlation was very high (ICC = 0.966, 95% upper and lower confidence intervals were between 0.933 and 1.00). A statistically significant trend ($p<0.05$) from 1966 to 2018 was identified towards a higher relative frequency of goals scored from set play and collective actions from open play. The Chi-square did not reveal significant differences in the frequency of goal scoring patterns and goal-scoring zones. The results also revealed that the majority of goals were scored between the 76th and 90th minutes of a match (22.7%), from open play (70.5%), inside the penalty area (54.7%), one touch finishing (62.5%), and collective attacks in open play (55.8%). These findings may provide a possible strategic direction for improving goal-scoring performance in football, as well as practical implementation in World Cup tournament preparation.

KEYWORDS

football (soccer), goal scoring, World Cup, tactics, performance analysis

Introduction

In football, the team's performance is affected by a complex interaction of technical, tactical, physical, and mental factors (Drust et al., 2007). Due to this complexity, by only watching live matches, coaches cannot accurately collect, analyse, understand and interpret the necessary information to draw proper conclusions about the football game (Franks and Miller, 1986). Therefore, it is necessary to examine competitive actions in to collect meaningful data on the performance of football teams and individual players. For this purpose, the observational methodology is used to collect information in team sports, as it allows for the collection of multiple variables that interact in the sporting context (Anguera, 2003; Anguera and Hernandez-Mendo, 2015). The use of observational methodology in the sports context provides coaches and other sports professionals with flexible tools that adapt to their needs (Ortega-Toro et al., 2019).

The most important factor that determines the result in football is goal (Carling et al., 2005; Hughes and Franks, 2005; Cachay and Thiel, 2000; Cebi et al., 2016). Goal scoring, as a key factor in a team's success, is one of the variables more investigated during match analyses (Yiannakos and Armatas, 2004; Armatas and Yiannakos, 2010; Lago-Peñas et al., 2011; Muhammd et al., 2013; Wallace and Norton, 2014; Rumpf et al., 2017; Vergonis et al., 2019). However, the majority of previous research has been limited to a single championship, either at the national or international level (Durlik and Bieniek, 2014; Janković et al., 2011; Cebi et al., 2016; Vergonis et al., 2019; Kubayi, 2020). However, there is little data regarding how the football play has evolved over multiple decades.

The overall tactics of football entail a permanent interrelationship between the patterns of attacking and defensive play (Barreira et al., 2014). The evolution of football has resulted in changes in the physical, tactical, and technical requirements of the game. In a tactical sense, the changes mostly refer to a reduction in the playing area (Wallace and Norton, 2014). By examining the final matches of FIFA World Cups from 1966 to 2010, it was noted that the movements of the ball and, therefore, the speed of play increased by 15% (Wallace and Norton, 2014). A major change has been observed in the number of passes, which increased from 10.75 passes/min in 1966 to 14.71 passes/min in 2010 (35% increase). Moreover, ball recovery form represents important patterns of attacking play in the World Cup semi-final stage (Barreira et al., 2014). All of these physical, tactical, and technical changes have shaped football into more dynamic game. The question is whether and how all these changes have affected goal scoring actions in recent decades, specifically goal scoring at World Cups as a key indicator of football development.

By an overview of the latest research, it may be concluded what a goal scoring action looks like in various professional tournaments. In the 2016/17 UEFA Champions League season, 75.9% of goals were scored from open play (González-Ródenas et al., 2021). Most of the previous studies have shown that between 20 and 30% of goals were scored from set play (Yiannakos and Armatas, 2004; Armatas and Yiannakos, 2010; Njororai, 2013; Gonzalez-Rodenas et al., 2019). In addition, 63.9% of goals started from the offensive third of the pitch, 23.1% from the middle third of the pitch, and 13.0% from the defensive third of the pitch (Vergonis et al., 2019). Moreover, 50.5% of goals were scored with less than two passes performed in the action, 19% of goals with 3 to 4 passes, and 31.1% goals with more than 4 passes (Kubayi, 2020). Short passing (<30 metres) were performed in 69.9% of the goal scoring actions (Kubayi, 2020). Collective attacking actions represented 51.6% of the goal scoring actions, whereas 10.5% of the actions leading up to goals were achieved through individual attacks 60.3% of the goals from open play were scored with one touch (González-Ródenas et al., 2021).

Only few studies have examined the goals scored in multiple consecutive World Cups. Leite (2013) analysed the goal scoring periods in the FIFA World Cups from 1930 to 2010 whilst Armatas et al. (2007) examining three consecutive World Cups (1998, 2002 and 2006) and both studies concluded that most goals were scored in the period from the 76th minute until the end of the match. However, aforementioned authors did not provide a complete movement pattern ahead of goal scoring, therefore it is hard to identify key technical and tactical elements from their studies. In contrast, Kubayi and Toriola (2019) analysed the ways in which goals were scored in five consecutive World Cups in the period between 1998 and 2014 and found that most goals were scored from inside the goal area (23.8%) and penalty area (53.6%) in addition to the results regarding the goal scoring periods (most goals scored in the period from the 76th minute to the end of the match, i.e., 24.7%). This study provided a more complete picture regarding how goals were scored over a 20-year period. Generally there is a lack of analysis over a longer period to draw parallels between different periods of football development and stay still unknow how these specific elements related to goal scoring situations have changed through the history of football.

Therefore, the aim of this study was to elucidate pattern of attacking actions leading up to goal scoring during the 14 FIFA World Cups from 1966 to 2018 including an analysis of the moment of the goal, the technical action and some tactical aspects prior to the goal being scored. We hypothesised that game period and goal scoring zones as well as players' individual characteristics will change constant throughout football World Cups history.

Materials and methods

Sample of matches

732 matches played during 14 consecutive FIFA World Cups in the period between 1966 and 2018 were analysed. In that period, there were a total of 1881 goals scored in FIFA World Cups, which represented the sample analysed in this study (the goals scored in penalty shootouts were not taken into account). The research was conducted according to the postulate of the declaration of Helsinki and with permission of the Ethics Committee of the University of Belgrade Faculty of Sport and Physical Education (02 No. 484–2).

Data collection procedures

The video material for the analysis was obtained from the website https://footballia.net, which contains videos of all of the previous 14 FIFA World Cup matches. Each goal scoring action was captured in a video clip using the iMovie software. The data for goal scoring timing were obtained from the FIFA website, https://www.fifa.com. Before goal analysis began, it was developed the observing protocol (Carling, 2008), in which data related to selected variables, by system of notation, was entered after reviewing each individual goal scoring action (O'Donoghue, 2010). The analysis of all video material was carried out independently by four experienced examiners (three of them are Ph.D in sports science and one is Ph.D. candidate in sports science with at least 7 years of coaching and experience as analyst in football). The operational definitions of the variables considered in this study are displayed in Table 1, and the ICC values for each of the variables are included.

Reliability testing

An intra-observer test using the Cohen's kappa measure of agreement was performed to assess the reliability of all variables, and rated using the following criteria: ≤0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement (Cohen, 1960). We randomly selected 244 out of the 1881 goals (13%) and the main researcher analysed and re-analysed them 3 weeks later to reduce the learning effect (O'Donoghue, 2010). The kappa values ranged from 0.82 (goal scoring through open play) to 1.00 (action leading up to goal), showing a very high agreement for all performance variables (Kubayi, 2020). We used Interclass Corelation coefficient (ICC) to calculate inter – observer reliability. ICC estimates and their 95% confident intervals were calculated using a mean-rating, absolute-agreement, two-way mixed-effects model (Koo and Li, 2016). Interclass correlation was very high (ICC = 0.966, 95% upper and lower confidence intervals were between 0.933 and 1.00).

Statistical analysis

All the variables were entered into a Microsoft® Excel® for Mac 2011, Microsoft Corporation, spreadsheet. All data analyses were performed using IBM SPSS Statistics (v19.0; IBM Corp., Armonk, NY, United States). A Chi-square test was used to identify statistically significant differences in goal scoring frequency. For effect size calculating we used Cramer's V (Akoglu, 2018). Effect sizes (Cramer's V) were determined for each test and rated using the following criteria: small = 0.10; medium = 0.30; strong/large = 0.50 (Cohen, 1988). A linear regression analysis was used to determine the trend of change in the investigated variables with World Cups serving as the independent variable. Statistical significance was set at $p \leq 0.05$ (O'Donoghue, 2010).

Results

There have been 1881 goals scored in the previous 14 FIFA World Cups. The 1970 World Cup had the most goals (an average of 2.97 per match), whilst the 2010 World Cup had the fewest (an average of 2.27 per match). The second-half scoring rate was 56.3%, whilst the first-half and overtime scoring rates were 41.1 and 2.6%, respectively. The majority of goals were scored between the 76th and final minutes of the game (22.7%). However, no significant differences through the examined period (1966–2018) were found for the distribution of goal scoring periods [χ^2 (65, $n = 1831$) = 81.4, $p = 0.082$, $V = 0.094$] (Table 2).

The distribution of goal scoring zones did not significant change through the examined period [χ^2 (39, $n = 1{,}881$) = 41.6, $p = 0.359$, $V = 0.086$], whilst significant differences were obtained for the distribution of actions leading up to goals [χ^2 (26, $n = 1{,}648$) = 40.1, $p = 0.038$, $V = 0.110$] and the body parts used to score the goals [χ^2 (52, $n = 1{,}881$) = 78.1, $p = 0.011$, $V = 0.102$] (Table 3). Most goals were scored from inside the penalty area (54.7%), followed by inside the goal area (21.3%), outside the penalty area (15.6%), and finally from the penalty spot (8.9%). One touch finishing was the dominant way of scoring goals (62.5%), followed by two-touches (19.2%), and finally more than two touches (18.3%). Most of the goals were scored with the right leg (51.6%), followed by the left leg (28%), head (17.8%) and own goals (2.6%).

No significant differences between the examined period were noted for the distribution of different types of final passes performed in collective attacks [χ^2 (39, $n = 739$) = 37.5, $p = 0.068$, $V = 0.143$] or the distribution of occurrences of individual actions leading up to goal scoring [χ^2 (39, $n = 686$) = 49.7, $p = 0.116$, $V = 0.155$] (Table 4). According to the data from the final pass analysis, the majority of goals from collective attacking actions (46.6%) were scored following deep passes, followed by crosses (39.1%), and back passes (14.3%). When it comes to individual actions that resulted in goals, 39.7% were scored after collecting a free ball, 33.4% from shots from distance, 19.6% from dribbling, and 7.3% from carrying the

TABLE 1 Operational definition of the dependent variables analysed in the present study.

Variable	Description	Crombah's alpha	ICC (95% confidence interval)	*p*
Frequency of goals scored Kubayi and Toriola (2019) and Vergonis et al. (2019)	Per half (first half, second half, extra time), 15 – min period (1–15, 16–30, 31–45+, 46–60,61-75,76–90+), and 15-min period of extra time (91–105+, 106–120+)	0.835	0.795 (0.566–0.924)	0.000
Type of play Vergonis et al. (2019) and Kubayi (2020)	Open play or set play	0.781	0.776 (0.302–0.928)	0.006
Goal scoring zones Njororai (2013) and Cebi et al. (2016)	Penalties, inside the goal area (5 m), inside the penalty area (<16 m) and outside the penalty area (16 m>)	0.777	0.722 (0.372–0.900)	0.001
Actions leading up to goal Gonzalez-Rodenas et al. (2019)	One touch (1), two touches (control + shot, 2) and more than two touches (2+)	0.686	0.523 (−0.170–0.834)	0.053
Body part used to score a goal Njororai (2013) and Durlik and Bieniek (2014)	Right leg (RLEG), left leg (LLEG), head and own goal (OwnG)	0.780	0.689 (0.297–0.888)	0.002
Penultimate action - goals from open play Gonzalez-Rodenas et al. (2019)	Technical – tactical action performed immediately before the final action that allows the final player to have the opportunity of shooting at goal. This action may be performed by the same player that shoots at goal (individual action) or by a teammate that passes the ball to the final player (collective play). Individual action: • *Dribbling* (the final player dribbles the ball past defenders to create a goal scoring opportunity), • *Running with the ball – Carrying* (the final player carries the ball towards a goal scoring situation), • *Collecting a free ball (Free ball)* (the final player collects a free ball that allows him to have an immediate scoring opportunity) • *Shot from distance (Shot FD)* (the final player shoots outside the penalty area). Collective play: • *Deep-pass* (pass that breaks the opposing defensive line and allows the receiver to have an immediate scoring opportunity in front of the goalkeeper), • *Cross* (pass performed from the wide channels of the field in the opposing half towards the penalty box that allows the receiver to have an immediate scoring opportunity), • *Back pass* (pass that is performed backward in relation to the player who performs the final pass and that allows the receiver to have an immediate goal scoring opportunity).	0.065 0.628	−0.110 (−1.506–0.601) 0.604 (0.029–0.862)	0.560 0.022

ball. There were 70.5% of goals scored from open plays, whilst 29.5% of goals were scored from set plays. In terms of the final actions leading up to goals from open play, 55.8% of goals were scored after a teammate's pass and 44.2% as a result of individual actions.

Linear regression analyses only showed a statistically significant trend through the succession of 14 FIFA World Cups for the different types of play (open play or set play; $R^2 = 0.49$, $F = 11.6$, $p = 0.001$; Figure 1) and the penultimate action preceding the goal (collective action or individual action; $R^2 = 0.33$, $F = 7.3$,

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TABLE 2 Relative distribution (%) of the frequency of goals scored per 15-min period and 15-min period of extra time.

Interval (minutes)	1966	1970	1974	1978	1982	1986	1990	1994	1998	2002	2006	2010	2014	2018	χ^2	Cramer'sV	p
0–15	18.0	12.6	13.4	11.8	11.0	13.6	7.0	15.6	14.0	16.1	15.6	9.7	10.5	11.8	81.4	0.094	0.082
16–30	12.4	14.7	17.5	9.8	15.1	13.6	11.3	14.2	11.7	13.0	16.3	15.9	15.8	10.1			
31–45+	16.9	8.4	15.5	28.4	8.2	13.6	10.4	16.3	15.2	16.1	15.6	15.2	11.7	15.4			
46–60	12.4	21.1	17.5	13.7	19.9	15.9	16.5	16.3	18.1	16.8	12.2	15.2	14.0	21.3			
61–75	14.6	18.9	16.5	18.6	26.7	18.9	20.0	15.6	14.6	18.0	8.8	18.6	19.3	17.8			
76–90+	23.6	16.8	19.6	15.7	17.1	20.5	30.4	19.9	25.7	18.0	29.3	24.1	24.0	21.9			
Extra time																	
91–105+	1.1	3.2	0.0	1.0	2.1	1.5	0.9	1.4	0.0	1.2	0.7	0.7	1.8	0.6			
106–120+Games	1.1	4.2	0.0	1.0	0.7	2.3	3.5	0.7	0.6	0.6	1.4	0.7	2.9	1.2			
	32	32	38	38	52	52	52	52	64	64	64	64	64	64			
GPM	2.78	2.97	2.55	2.68	2.81	2.54	2.21	2.71	2.67	2.52	2.3	2.27	2.67	2.64			

Games – Number of games; GPM – Goals Per Match.

TABLE 3 Relative distribution (%) of goal scoring zones, actions leading up to a goal, and body parts used to score a goal.

		1966	1970	1974	1978	1982	1986	1990	1994	1998	2002	2006	2010	2014	2018	χ^2	Cramer'sV	p
Scoring	5 m	24.7	22.1	22.7	12.7	21.9	22.0	19.1	16.3	21.1	21.7	25.2	24.1	24.6	18.3	41.6	0.086	0.359
zones	<16 m	55.1	51.6	54.6	56.9	52.1	58.3	56.5	51.1	56.1	55.3	49.0	51.7	57.3	54.4			
	16 m>	11.2	21.1	16.5	18.6	20.5	10.6	13.0	22.0	12.3	14.3	17.0	17.9	11.1	14.2			
	Penalty	9.0	5.3	6.2	11.8	5.5	9.1	11.3	10.6	10.5	8.7	8.8	6.2	7.0	13.0			
Action	1	64.6	53.5	69.0	53.5	61.1	66.1	62.9	58.3	54.8	73.4	61.4	62.8	60.6	70.9	40.1	0.110	0.038
leading	2	16.5	16.3	20.7	26.7	16.8	19.5	19.6	20.0	26.0	13.7	17.3	19.4	23.2	14.9			
up to	2+	19.0	30.2	10.3	19.8	22.9	14.4	17.5	21.7	21.2	12.9	21.3	17.8	16.1	14.2			
goal																		
Body	RLEG	59.6	53.7	49.5	53.9	47.3	52.3	55.7	57.4	52.0	41.6	59.9	57.2	40.9	46.7	78.1	0.102	0.011
part	LLEG	22.5	32.6	26.8	30.4	35.6	31.1	19.1	24.8	25.1	33.5	19.0	22.8	36.8	27.2			
	Head	13.5	12.6	20.6	12.7	16.4	14.4	25.2	17.0	18.1	21.1	18.4	17.2	18.7	18.9			
	OwnG	3.4	1.1	3.1	2.9	0.7	1.5	0.0	0.7	3.5	3.1	2.7	2.1	2.9	7.1			

5 m – Inside the goal area; <16 m – Inside the penalty area; 16 m > – Outside the penalty area; 1 – One touch; 2 – Two touches; 2+ – More than two touches; RLEG – Right leg; LLEG – Left leg; OwnG – Own goal.

$p = 0.019$; Figure 2). In the period between 1966 and 2018, per each World Cup the frequency of goals scored from the set plays increased by 0.27% and the goals promoted by collective actions increased by 0.28%.

Discussion

The aim of this study was to elucidate pattern of attacking actions leading up to goal scoring during the 14 FIFA World Cups from 1966 to 2018. In line with previous studies (Armatas et al., 2007; Leite, 2013) here was an upward trend in the number of goals scored as the game progressed. Most goals were scored in the last 15 min of a match. There are same findings found by many previous research of major professional competitions: UEFA Champions League, English Premier League, French Football League 1, Italian Seria A, Spanish football Liga (Alberti et al., 2013; Durlik and Bieniek, 2014; Michailidis et al., 2018; Zhao and Zhang, 2019).

In 11 out of the last 14 World Cups, most goals were scored during the last period of the match. Since 1986, i.e., in each of the 9 previous tournaments, the majority of goals were scored between the 76th minute and the end of the match. These findings indicate that this period of the game is critical for changing the score at World Cups. It is important to note that, since 1990, a greater number of goals have been scored after the 90th minute of a match (overtime). This trend reached its peak in the last two tournaments (2014 and 2018).

A change in scoring in the final 15 min of a match, particularly in the final minutes, could be attributed to several factors. Physical performance has been proven to decline throughout the second half (Carling and Dupont, 2011) whereas mental fatigue increases as the match progresses towards the end (Barte et al., 2017). All of this could result in a higher number of technical errors, which could directly affect the score (Russell et al., 2011). In a tactical sense, teams that want to and strive to score a goal will take more risks and organise attacks with more players, attempting to reach the opponent's goal as quickly as possible (Abt et al., 2002). Such

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TABLE 4 Relative distribution (%) of penultimate actions leading up to goal scoring.

		1966	1970	1974	1978	1982	1986	1990	1994	1998	2002	2006	2010	2014	2018	χ^2	Cramer'sV	*p*
Collective play	Deep pass	48.3	33.3	31.7	44.7	43.8	55.0	42.9	58.8	59.7	42.6	55.9	40.0	42.3	42.3	37.5	0.143	0.068
	Back pass	4.2	17.9	26.8	15.8	21.1	5.0	11.9	7.8	8.1	9.3	15.3	18.3	20.5	17.3			
	Cross	37.5	48.7	41.5	39.5	35.1	40.0	45.2	33.3	32.3	48.0	28.8	41.7	37.2	40.4			
Individual Action	Dribbling	16.7	35.0	3.1	23.8	13.2	21.6	20.0	20.5	27.5	29.7	14.7	15.2	14.9	16.7	49.7	0.155	0.116
	Carrying	4.8	5.0	12.5	2.4	11.3	0.0	11.4	9.1	11.8	2.7	5.9	4.3	10.6	8.3			
	Free ball	57.1	20.0	43.8	35.7	34.0	48.6	37.1	29.5	33.3	27.0	32.4	34.8	36.2	35.4			
	Shot FD	21.4	40.0	40.6	38.1	41.5	29.7	31.4	40.9	27.5	40.5	47.1	45.7	38.3	39.6			

a style of play can create more opportunities for the opposing team's counter-attacks and make the attacking team's defence more vulnerable (Gonzalez-Rodenas et al., 2019). As a result, physical and mental fatigue, combined with changes in technical and tactical aspects, can evidently lead to a higher number of goals in the final minutes of the game.

Since the 1970 World Cup, when most of the goals were scored from open play (83.2%), there has been an upward trend in the number of goals scored from set play. Before 1990 the percentage of goals scored from set play ranged from 21.6 to 26.5%, whilst after 1990 ranged from 30.5 to 36.8% (with exception of WC 2010 and 2014). The significance of set play in World Cup goal scoring reached its peak in 2018, when this type of attack produced 69 goals (40.8%). Those findings coincide with those found in study from Kubayi and Toriola (2019) which analysed the 795 goals scored during a total of 320 matches played in five successive FIFA World Cup tournaments (1998–2014). Results shown that most set plays goals were scored in 1998 (36.3%) and 2006 (31.3%), declining to 24.1% and 22.2% in 2010 and 2014, respectively. Also, finding from other studies, focused on elite, shown that set pieces have been shown to produce approximately 30% of goals in recent international tournaments (Armatas and Yiannakos, 2010; Mitrotasios and Armatas, 2014; Gonzalez-Rodenas et al., 2019).

It is possible that scoring goals from open play is becoming more difficult in the World Cup due to a decrease in the free playing area, an increase in player density in space, and a need to make technical and tactical decisions faster (Pollard et al., 2004; Wallace and Norton, 2014). However, when set play is used, it is easier to shoot the ball because it remains stationary on the ground, opposing players must remain at some distance from the ball, and the attacking team can choose the moment to start the action. Being close to the opponent's goal enables sending the ball into the penalty box with the immediate intention to score a goal and more players can be positioned in front of the opposing goal (Zileli and Söyler, 2020). All of the aforementioned characteristics could influence training plans to devote more time to set play (both attacking and defending), particularly in the few weeks that national teams have to prepare for a major tournament.

In each of the tournaments analysed, most of the goals were scored inside the penalty area followed by the goal area. Other studies dealing with the zones from which goals are scored in football have confirmed a significantly higher number of goals scored from within the penalty box (inside the penalty area + inside the goal area; Yiannakos and Armatas, 2004; Armatas and Yiannakos, 2010; Janković et al., 2011). This is not surprising since the penalty box is the zone located nearest to the goal within which a goal-scoring probability is much higher compared to zones that are more distant from the goal (Pratas et al., 2018). Another possible explanation for the higher number of goals scored from within the penalty area is the players' preference to be near the goalpost, but not in the goalkeeper's range so that they can shoot the ball with less distraction (Muhammd et al., 2013). The fact that fewer goals were scored by

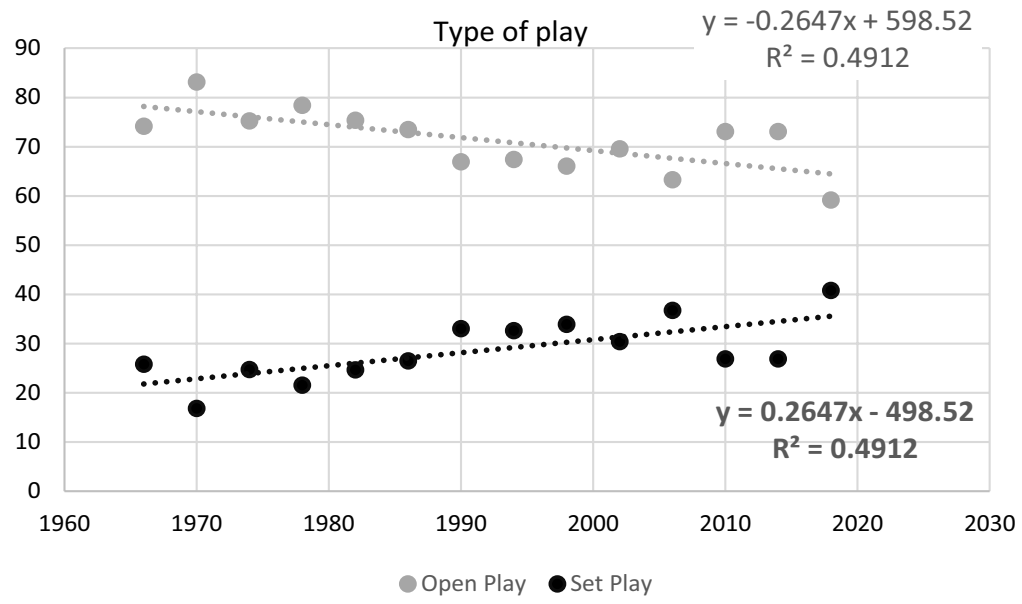

FIGURE 1
Regression analysis of the frequency of the different types of play (open and set play) through the 14 FIFA World Cups.

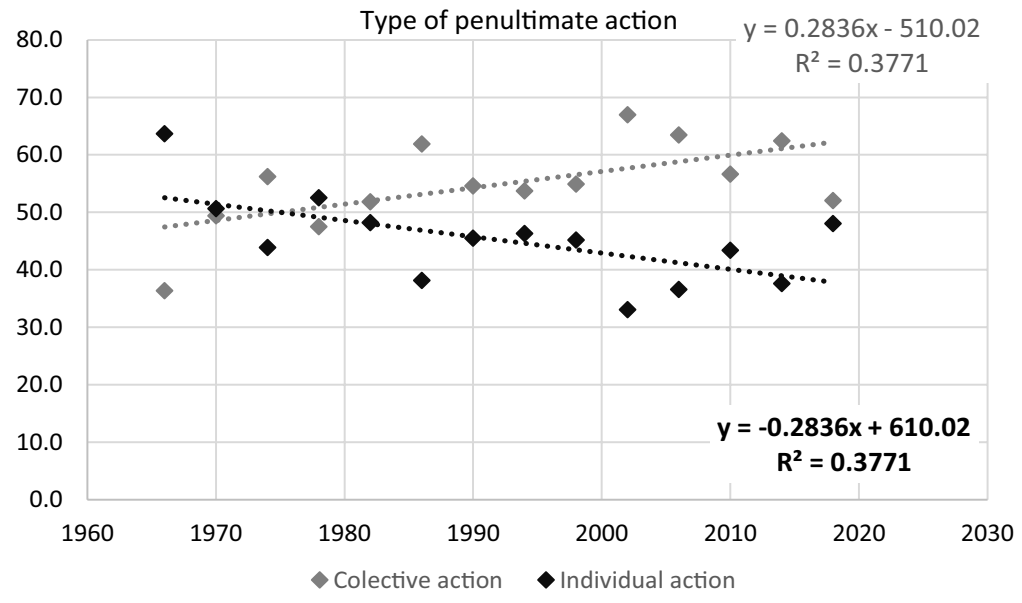

FIGURE 2
Regression analysis of the frequency of the type of penultimate action (collective and individual actions) through the 14 FIFA World Cups.

shooting from outside the penalty box can be attributed to compact defence structures in this zone as well as to the goal-scoring probability that decreases as the distance between the goal and the location of a player is increased (Pollard et al., 2004). It should be hereby highlighted that there was a record number of goals scored from penalty kicks in the last World Cup (22, i.e., 13.8%). An increased number of goals scored from penalty kicks can also be explained by using the VAR technology in 2018 (Vergonis et al., 2019).

Players rarely have time for extra contact with the ball due to the close proximity of the opposing team's players and goalkeeper in the zones where most goals are scored (penalty box; González Rodenas et al., 2020). Furthermore, the goalkeeper's ability to react is hampered by the player's quick shot (Durlik and Bieniek,

2014). From a technical standpoint, a decent level of technical training is required to shoot the ball with one touch towards or into a desired area because quick reactions and precise shots are required, it is recommended that attackers spend the majority of their training time shooting the ball with one touch (Sarmento et al., 2018).

When it comes to goals scored from open play (Figure 2), the results of this study have indicated that the number of goals scored after individual actions have been decreasing in favour of collective actions. In accordance with our results, previous literature that analysed goal patterns in the Eurocup 2004 (Yiannakos and Armatas, 2004), World Cup 2006 (Armatas and Yiannakos, 2010), English Premier League 2008/2009 (Durlik and Bieniek, 2014) and Eurocup 2012 (Mitrotasios and Armatas, 2014) found that less than 20% of goals were scored after individual actions.

In the evolution of football, the collaboration of two players in the finishing actions of an attack is becoming a more important element. Consequently, the player who is capable of delivering a final pass to his teammate can be considered as important as a goal-scorer (Gonzalez-Rodenas et al., 2019). An increase in the number of goals scored as a result of collective play can be explained by the growing quality of team's defence (Santos et al., 2017). It is obvious that much more time was devoted to defence during the preparations for World Cups, which only last a few weeks, because it is much easier to train and adopt defensive positions than it is for players to take attacking movements (Vergonis et al., 2019).

An efficient defence play, in order to decrease the opponents' free playing area, can be accomplished by reducing the distance between the vertical lines and narrowing the space in width (Moura et al., 2012; Sarmento et al., 2018; Lepschy et al., 2021). This tendency towards compactness of the defence players is exactly what leads to an increase in the space behind the defence line and results in the open positions on the lateral sides. According to the data from the final pass analysis, the majority of goals from collective attacking actions (46.6%) were scored following deep passes, followed by crosses (39.1%), and back passes (14.3%). These findings are with line with previous studies (Durlik and Bieniek, 2014; Gonzalez-Rodenas et al., 2019) that's showed that deep passes were the most frequent action performed by penultimate player in collective attacks.

The data relating goal scoring after individual actions have indicated that, regarding the individual characteristics of football players, the anticipation of events on the field, as is collecting a free ball, is of utmost importance for goal scoring in World Cups. Results of study which analyse goal scoring patterns in European elite soccer (Gonzalez-Rodenas et al., 2019) shown that most of the goals scored from individual actions comes from collecting a free ball, support our findings. Players who can perform quality shots from a distance can also demonstrate a special scoring quality. Dribbling is a technical and tactical element that shows the beauty of the football game and the players who are capable of dribbling through, i.e., outwitting their opponents are found to be very attractive for spectators. However, data show that this individual attribute has little bearing on goal scoring at World Cups. This is in line with findings of study. Gonzalez-Rodenas et al. (2019) where they found that goals scored after dribbling produced the 7.6% of goals. This fact may be due to the tactical development and greater defensive preparation in the current professional soccer, where disrupting the opponent to achieve shooting possibilities by means of individual actions require excellent skills (Barreira et al., 2014; Gonzalez-Rodenas et al., 2019).

This study has a multiple limitations. In the first place, the fact of using observational methodology may not capture the entire complexity of soccer actions and interactions, as previous studies based on ecological models have claimed (Glazier, 2010; Vilar et al., 2012). Also, specific limitation of our study is very specific selection of variables. In order to get a more complete picture of the development of football over a longer period of time, future studies need to be focused on a more comprehensive analysis of spatial and temporal as well as technical and tactical parameters which relate to starting and organising attacks leading up to a goal. The findings of such studies will contribute to a better understanding of the football evolution through history. In addition to that we would like to emphasise unequal total number of matches (there were more matches in recent competitions than in older ones) through the history of the World Cups which could bias the comparison.

Conclusion

The results of the study have shown consistency for the World Cups played between 1966 and 2018 with regards to the following variables: *Game period* which is crucial for changing the score of a match (from the 76th minute until the end of a match), *Goal scoring zones* (most goals scored from inside the penalty area), and *Actions leading up to goals* (most goals scored by one touch finishing). Also, players' individual characteristics which are essential to goal scoring at World Cups have been determined to be constant throughout football history, and they include: *Retrieving possession of a free ball* and *Shot from distance*. On the other hand, the findings of this study revealed that changes in physical, tactical, and technical terms over time caused a change in technical and tactical rules applied to the execution of goal-scoring attacking actions related to the *Type of play* and *Penultimate action*. An upward trend regarding the number of goals scored from set play and from collective attacking actions can be observed through the analysis of the last 14 FIFA World Cups. The rising quality of the team's defence, which primarily reduces the opponent's free playing area, can explain such an increase in goal scoring.

Based on the findings of this study, several recommendations can be made. First, coaches should ensure an adequate level of players' physical readiness, which will enable them to endure the entire period of 90+ minutes of the match. Well-prepared players will be more focused and, as a result, make fewer mistakes. This especially

refers to the period from the 76th minute until the end of the match. In terms of technical and tactical preparation for World Cups, coaches should focus on factors that can contribute to success whilst also being applied quickly from training to competition due to the limited time for national teams to practise. 11 versus 11 drills on a smaller pitch will enable a faster adjustment to offensive and defensive phases of the game. This kind of training requires quick decision making, prompt marking of the player in possession of the ball, diverse movement, and accurate passing during attacks. All of these factors contribute to the effectiveness of the collaborating open play, which is the most effective goal scoring strategy. Simultaneously, defensive play is being practised in response to the attacking phase of the game. The result of this study shown consistency in terms from which area in how goals were scored, accordingly to this the majority of the time spent training for individual improvement in finishing should be devoted to one touch finishing from the penalty box.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Comparison of the physiological responses and time-motion characteristics during football small-sided games: effect of pressure on the ball

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Introduction: This study aimed to compare the effects of pressure on the ball on physiological responses and time-motion characteristics during football small-sided games between elite youth male players.

Methods: 56 elite male youth football players (age: 15.43 ± 0.52 years) performed a 2+GK vs. 2+GK game on a 30 m × 15 m pitch area with two playing conditions: 1) free play (FP), the player has no limitation to play; 2) pressure on the ball (PB), the player has directly and aggressively closed down space (located within 1.5 m) between themselves and the opposition player with the ball and can compete for possession. The percentage of time spent in different maximum heart rate (HRmax) zones, mean heart rate, blood lactate acid concentration, total distance covered, distance covered in three speed zones (sprint, high speed, and moderate speed), number of high speed runs, number of sprint runs, top speed, number of direction changes, and ball recovery time were monitored.

Results: We found very significantly higher number of high speed runs ($p < 0.001$; ES = 1.154), number of direction changes ($p < 0.001$; ES = 2.347), ball recovery time ($p < 0.001$; ES = 3.529), percentage of time spent in 90%–100% HRmax ($p < 0.001$; ES = 3.033), mean heart rate ($p < 0.001$; ES = 1.940), blood lactate acid concentration ($p < 0.001$; ES = 2.245) and significantly higher high speed running distance covered ($p = 0.004$; ES = 0.520) in the PB condition. Conversely, the FP condition showed very significantly higher moderate speed running distance covered ($p < 0.001$; ES = 1.814) and significantly higher percentage of time spent in 80%–90% HRmax ($p = 0.012$; ES = 0.440). No significant differences were revealed on sprint running distance covered ($p = 0.407$; ES = 0.140), number of sprint runs ($p = 0.103$; ES = 0.279), top speed ($p = 0.130$; ES = 0.258) and percentage of time spent in 60%–70% HRmax ($p = 0.106$; ES = 0.276), 70%–80% HRmax ($p = 0.358$; ES = 0.155).

Discussion: We found that pressure on the ball had a substantial impact on the intensity of training, as evidenced by a significantly increased high speed running performance, number of directional changes, percentage of time spent at 90%–100% of maximum heart rate, mean heart rate, and blood lactate acid concentration. Additionally, ball recovery time decreased significantly.

KEYWORDS
pressing, heart rate, running, games, football (soccer)

Introduction

Small-sided games (SSGs) are often described as a small version of the real game (FIFA, 2014). It is commonly used as a training modality that includes a reduced pitch area, adjusted game rules, and a smaller number of players than a real game (Hill-haas et al., 2011). Compared to other training methods, it not only provides training with realistic game situations (Gregson and Drust, 2000; Owen, 2003), but also ignites players' enthusiasm to participate in training. By adjusting different factors, coaches can also enable players to practice different types of movement in a real game situation (Aroso et al., 2004) as well as different types of technical under pressure (Gabbett et al., 2009). Moreover, it trains players to make various tactical decisions when they are physically exhausted (Castelao et al., 2014) and increases their mental toughness (Diogo et al., 2017). In order to reproduce the physical, technical and tactical requirements of real match play, coaches often use SSGs in their training programs.

The evolution of GPS and heart rate monitor devices (Edwards, 1993; Barbero-Álvarez et al., 2010; Coutts and Duffield, 2010) and the observational tactical instrument tools (Gonzalez- Villora et al., 2015) help coaches and scientists to study the physiological, biomechanical, technical and specific tactical characteristics of different SSGs has increased exponentially in the last years. Most of the studies were focused on the following aspects:

1) The number of players. Studies showed that lower number of players (1v1 to 4v4) significantly increase the physiological demand compared to medium-sided games (5v5–8v8) and large-sided games (>9v9). Heart rate, blood lactate acid, and rating of perceived exertion decreased as the number of players increased (Aroso et al., 2004; Owen et al., 2004; Williams and Owen, 2007; Katis and Kellis, 2009; Dellal et al., 2011; Aguiar et al., 2013). Other studies found that the total distance covered increased with an increasing number of players (Dellal et al., 2011; Clemente et al., 2014a), but the number of accelerations, decelerations, changes of direction, and sprints decreased (Hill-Haas et al., 2008; Aguiar et al., 2012; Clemente et al., 2017; Lacome et al., 2018). There is an increase in the number of technical actions performed per player with smaller-sided games (Almeida et al., 2013; Clemente et al., 2014b; Joo et al., 2016), but more tactical decisions are made in larger-sided games (Katis and Kellis, 2009; Teoldo et al., 2010; Owen et al., 2014; Joo et al., 2016).
2) Pitch size. A number of studies have shown that physical loads (heart rate, blood lactate and RPE) increase when the pitch size per player increases (Aslan, 2013; Köklü et al., 2013; Hodgson et al., 2014; Pantelic et al., 2019). On the other hand, some studies reveal that the larger pitch area leads to an increase intotal running distance, high-speed running, as well as number of accelerations and decelerations (Casamichana and Castellano, 2010; Hodgson et al., 2014). Meanwhile, the number of movements that player off the ball (Almeida et al., 2013; Joo et al., 2016) and tactical behaviors (Castelao et al., 2014; Silva et al., 2014) were increased in larger pitch area, while the number of actions that player perform with the ball tends to decrease (Katis and Kellis, 2009; Da Silva et al., 2011; Almeida et al., 2013).
3) The game rules. Different game rule modifications may lead to different responses during SSGs. Research has shown that rule changes also have a major impact on the physiological, technical and tactical performance, such as different types of marking (man-to-man, double marking, and zonal) (Casamichana et al., 2015; Clemente et al., 2016), number of ball touches (Clemente et al., 2014a; Sousa et al., 2019), scoring method (Clemente et al., 2014b), goal format (Craig et al., 2016; Coutinho et al., 2018), goalkeepers (Köklü et al., 2015) and floater player (Mallo and Navarro, 2008).

In recent years, pressure on the ball, popularised by coaches such as Jürgen Klopp and Pep Guardiola, has become a highly influential defensive tactical action within the game. The importance of defense in football has been highlighted in various studies (Bojan et al., 2019; Lepschy et al., 2021; Low et al., 2021). Defensive tactics like the high-intensity pressing and counter pressing (Nassis et al., 2020; Harper et al., 2021) are considered the most important tactical concepts in how the defensive game will be played in the future. Pressing is all about applying pressure of the players with the ball so that they no longer have the freedom to decide what to do with it and influencing their decision making (Link et al., 2016; Andrienko et al., 2017), which is also very important for the team to have back the ball (Casal-Sanjurjo et al., 2020) and as a starting point for counter attacking (Herold et al., 2022). However, to the best of our knowledge, no studies have reported the effects of the pressure on the ball on physiological responses and time-motion characteristics during football SSGs. Therefore, this leads to the hypothesis that restricting this factor has an impact on training effects, and that it influences the behavior of players during training. The aim of this study was to compare the effects of free play and pressure on the ball on physiological responses and time-motion characteristics during football SSGs.

Methods

Experimental approach to the problem

For the SSGs, previous studies have shown that more intensity and higher frequency of running (Owen et al., 2004; Williams and Owen, 2007; Koklu et al., 2015) are generally found in a smaller number of players, resulting in very high levels of effort (Clemente et al., 2014a). In addition, the use of goalkeepers can stimulate the enthusiasm of players to participate in training (Koklu et al., 2015). Moreover, a larger goal also encourages players to keep moving so they can shoot from different angles (Coutinho et al., 2018), leading to more transitions of the ball possession. Based on the pitch size, the individual area for each player (the relative pitch area per player) is determined (Pantelic et al., 2019). Studies have shown that the greater the area per player, the greater the physical

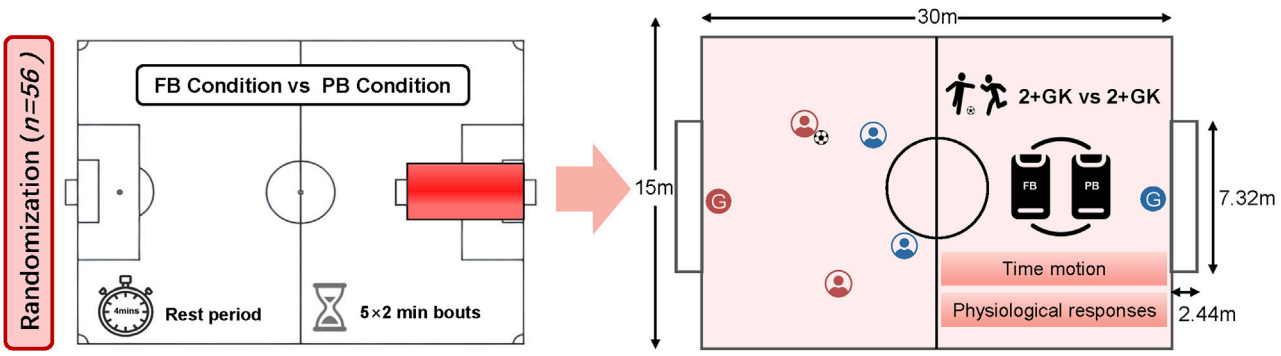

FIGURE 1
The field design of small-sided games.

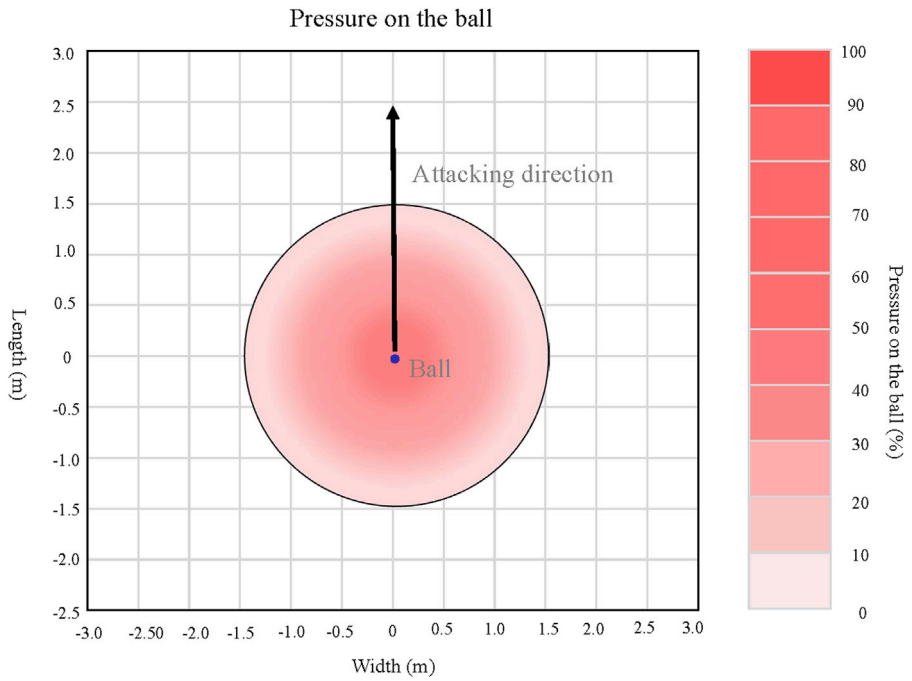

FIGURE 2
Pressure on the ball.

load (Aroso et al., 2004). To provide a frame of reference, the average area per player ranged from 83.2 to 117 m^2 in the 2018 Russia World Cup (FIFA, 2018). The shape of the pitch is also considered because a rectangular shape is more likely to increase the penetrations rather than going wide (Coutinho et al., 2018).

Based on the above factors, the SSGs in this study consist of 2+ GK vs. 2+ GK sessions on a 30 × 15 m pitch area (length × width, 117 m^2 relative pitch area per player) with two standard goals (7.32 × 2.44 m). Players score a goal by shooting into the normal goals; the goalkeeper restarts the game after the ball goes out of play. Several balls are placed beside the two goals to ensure that the game can be restarted as quickly as possible (See Figure 1). The offside rule was not enforced in either condition, while no coach feedback or encouragement was allowed during the SSGs (Batista et al., 2019). The SSGs includes 5 × 2-min bouts interspersed with a 4-min passive recovery period.

The experiment was based on repeated SSGs with two different conditions: FP = Free play condition, PB = Pressure on the ball condition. The FP condition was the experiment under the free play (FP) condition in which player has no limitation to play, it was carried out 5 times a week for 3 weeks, totally 15 times. In the PB conditions, the experiment was conducted the pressure on the ball (PB) condition in which player has directly and aggressively closed

down space (located within 1.5 m) between themselves and the opposition player with the ball and can compete for possession (See Figure 2). It also carried out 5 times a week for 3 weeks, for a total of 15 times. All the participants were randomly assigned to the experiment. In addition, the inter-trial interval was randomized between 3 weeks to prevent any potential physiological adaptation that may have influenced the results.

Subjects

56 elite male soccer players consisting of 48 field players and 8 goalkeepers (age:15.43 ± 0.52; height: 176 ± 5.4 cm; weight: 61 ± 6.1; years of training: 7 ± 1.3; mean maximum heart rate: 208 ± 9.3 beats/min). All players were selected from four professional soccer clubs (12 outfield players and 2 goalkeepers for each) by their team's head coach based on their level of skill (technical, tactical and fitness) and without consideration of their on-field positions. All of them participated in the National Youth Super League. They had been training with the club for at least 5 years, for approximately 40 weeks per year, with each week consisting of 6–8 training sessions (each session lasts 90–120 min). Although goalkeepers participated in this study, the relevant data was not recorded owing to the limited activity at their position. All players were informed of the research design and the potential benefits and risks, while written consent was obtained prior to participation. Ethical approval was granted by the institutional human research ethics committee.

Procedures

The experiment was conducted during the pre-match preparation period of each team. The SSGs were played on a natural grass surface at the same time of day (16:00–17:30) under sunny conditions (19.5°C ± 1.4°C) to avoid the effects of circadian rhythms on the results. Prior to each session, participants were instructed to refrain from caffeine (4 h), strenuous exercise and alcohol consumption (48 h), and to arrive in a fully rested and hydrated state. Participants were also provided with a 24 h food diary and asked to record their diet for the 24 h before each trial.

Each session started with a standardized 20-min warm-up that included jogging, stretching, quick feet, and a ball possession game (6-a-side without goals). Goalkeepers warmed up individually with the goalkeeping coach, and warm-up activities included jogging, stretching, quick feet, and catching. Then, the players were randomly assigned into two balanced teams and instructed to perform the relevant tasks. For each session, the players remained in the same team and played with the same pairs in 2v2.

Data collection

Physiological responses data

Heart rate was recorded at 5-s intervals during each SSG via short-range radio telemetry (Polar Team Sport System; Polar Electro Oy, Kempele, Finland). The heart rate monitors were worn during the 20-m shuttle run assessments (Bangsbo, 1994) to determine the player's HRmax. Training intensity was expressed as a percentage of HRmax and classified as the percentage of time spent in the following zones of intensity (Eniseler, 2005): Zone 1 (60%–70% HRmax), Zone 2 (70%–80% HRmax), Zone 3 (80%–90% HRmax), and Zone 4 (90%–100% HRmax). The mean heart rate under both conditions was determined to indicate the overall intensity. Blood lactate samples were taken 4 min after the end of each bout from each player in both conditions, while blood samples were taken from their ear lobes and immediately analyzed using a Lactate Pro (LT-1710; Arkray, Kyoto, Japan) analyzer that had been previously validated (Hill-Haas et al., 2008).

Time-motion characteristics data

Movement patterns during the games were measured using a portable global positioning satellite system (GPS) (GP Sports SPI Elite System, Canberra, Australia), in which the distance travelled was recorded at 5 Hz. This technology has been previously determined to be reliable for monitoring high-intensity and sprinting activities in soccer (Coutts and Duffield, 2010), especially during exercises that include repeated sprints (Barbero-Álvarez et al., 2010). For data analysis, three running intensity zones were selected (FIFA, 2018): Zone 1 (moderate speed running, 15–20 km/h), Zone 2 (high speed running, 20–25 km/h), Zone 3 (sprint running, ≥25 km/h). The software calculated the total distance, the distance covered in the three intensity running zones, the number of high speed runs and sprint runs, top speed, the number of direction changes, and ball recovery time were monitored.

Statistical analysis

Data are presented as mean ± standard deviation (M±SD). Before using parametric statistical analyses procedures, the normality of the data was verified by the Shapiro-Wilks test. A paired sample *t*-test was used to compare the differences in physiological responses and time-motion characteristics under the FP and PB conditions. Differences were considered significant at $p < 0.05$. Cohen's effect sizes were also calculated to describe any trends apparent in the data. The scale identified an effect size of 0.2 as representing a small effect, 0.5 a moderate effect, and 0.8 or greater as a large effect (Rhea, 2004; Tomczak and Tomczak, 2014). Statistical analysis was performed using SPSS software (version 26.0; SPSS Inc., Chicago, IL, United States).

Results

Table 1 presents the results of the comparison between the FP and PB conditions for physiological responses. Compared with the FP condition, the PB condition notably revealed a significantly increase in the percentage of time spent in 90%–100% HRmax ($p < 0.001$; ES = 3.033), mean heart rate ($p < 0.001$; ES = 1.940), blood lactate acid ($p < 0.001$; ES = 2.245). However, the percentage of time spent in 80%–90% HRmax ($p = 0.012$; ES = 0.440) was

TABLE 1 Comparison of physiological responses in different conditions.

Physiological variables	FP condition	PB condition	t	*p*	Cohen' d
60%–70% HRmax (%)	13.25 ± 1.68	12.78 ± 1.05	1.66	0.106	0.276
70%–80% HRmax (%)	25.57 ± 2.87	26.11 ± 1.74	−0.93	0.358	0.155
80%–90% HRmax (%)	39.83 ± 3.87	37.43 ± 3.25	2.64	0.012*	0.440
90%–100% HRmax (%)	21.36 ± 3.19	23.82 ± 3.10	−18.19	<0.001**	3.033
Mean heart rate (beats/min)	179.24 ± 2.86	182.01 ± 2.80	−11.64	<0.001**	1.940
blood lactate acid (mmol/L)	8.83 ± 1.12	10.91 ± 1.17	−13.47	<0.001**	2.245

Notes: FP, free play condition; PB, Pressure on the ball condition. Legends: * = $p < 0.05$, ** = $p < 0.001$.

TABLE 2 Comparison of time motion analysis in different conditions.

Movement variables	FP condition	PB condition	t	*p*	Cohen' d
Moderate speed running (m/min)	33.63 ± 4.50	22.36 ± 3.15	10.88	<0.001**	1.814
High speed running (m/min)	10.63 ± 2.88	12.46 ± 2.22	−3.11	0.004*	0.520
Sprint running (m/min)	6.24 ± 1.90	6.50 ± 0.72	−0.83	0.407	0.140
Total distance (m/min)	132.56 ± 9.12	136.22 ± 6.74	−1.73	0.092	0.289
Numbers of high speed runs (times/min)	5.19 ± 2.25	8.80 ± 1.80	−6.92	<0.001**	1.154
Numbers of sprint runs (times/min)	1.27 ± 0.51	1.50 ± 0.77	−1.67	0.103	0.279
Top speed (m/s)	7.44 ± 0.20	7.48 ± 0.24	−1.55	0.130	0.258
Numbers of direction changes (times/min)	5.25 ± 1.50	12.13 ± 2.23	−14.08	<0.001**	2.347
Ball recovery time(s)	6.36 ± 0.68	3.11 ± 0.55	14.97	<0.001**	3.529

Notes: FP, free play condition; PB, Pressure on the ball condition. Legends: * = $p < 0.05$, ** = $p < 0.001$.

significantly decreased. There was no significant difference in the percentage of time spent in 60%–70% HRmax ($p = 0.106$; ES = 0.276) and 70%–80% HRmax ($p = 0.358$; ES = 0.155).

For the movement pattern, Table 2 presents the time-motion analysis results of the FP and PB conditions. In the PB condition, there was a very significant increase in the number of high speed runs ($p < 0.001$; ES = 1.154), number of direction changes ($p < 0.001$; ES = 2.347) and ball recovery time ($p < 0.001$; ES = 3.529), and significant increase in the high speed running ($p = 0.004$; ES = 0.520), but the moderate speed running ($p < 0.001$; ES = 1.1814) was significantly decreased. However, there were no significant differences between sprint running ($p = 0.407$; ES = 0.140), total distance ($p = 0.092$; ES = 0.289), number of sprint runs ($p = 0.103$; ES = 0.279) and top speed ($p = 0.130$; ES = 0.258) between conditions.

Discussion

In general, restricting the pressure on the ball had a significant effect on training intensity, we found a significantly higher number of high speed runs, high speed running distance covered, number of direction changes, percentage of time spent at 90%–100% HRmax, mean heart rate, blood lactate acid concentration, as well as decreased ball recovery time. However, its effect on sprinting movement was not readily apparent.

The mean heart rate of the players in FP was 86% HRmax, and most of the time was spent in the zone with 80%–90% HRmax, accounting for 39.83% of the total time. This is similar to the previous researches by Halouani et al. (2017) and Dellal et al. (2011), where the mean heart rate was 84.2% HRmax and 85.1% HRmax respectively in 2V2 SSGs. The mean heart rate of players in the experiment met the requirements of a soccer match, as the average work intensity measured by HRmax in previous matches revealed a profile of activity close to the anaerobic threshold (80%–90% HRmax) (FIFA, 2014). After the restriction of pressure on the ball, the mean heart rate increased significantly to 88% HRmax, which is higher than the evidence from a U18 national team recorded during the match (FIFA, 2018). The reason is that when the pressure on the ball is restricted, the defender nearest the ball will close down to the ball more quickly to pressure the opponent, so the player in possession of the ball does not have much time to make a decision, which results in more transfer of ball possession. Meanwhile, the player who gain possession of the ball are also more likely to launch counter-attacks, which also increase the intensity of the training. The finding was consistent with previous studies showing that players using man-to-man defense strategies in SSGs tend to display improved training intensity (Aroso et al., 2004; Casamichana and Castellano, 2010).

Establishing the training intensity of players cannot solely rely on measuring their heart rate responses. There was also a very

significant increase in blood lactate acid in PB condition, that is, higher than the lactate threshold recorded in official matches (Bangsbo, 1994). The result was consistent with the findings of Gerisch et al. (1988), Hill-Haas et al. (2011); Halouani et al. (2017), who showed that players could reach peak blood lactate acid in 1v1 or 2v2 format. In addition to the aforementioned increase in transitions, the number of finishes/shots will also increase significantly, which may also lead to an increase in lactate acid concentration. Conversely, if there is no pressure on the ball restriction, players who are tired will choose to protect the ball or pass the ball, which will not stimulate higher lactate levels. Similarly, pressing immediately after losing the ball will also stimulate higher levels of blood lactate acid production (Aroso et al., 2004; Cihan, 2015). The advantage of counter-pressing allows player to restart an attack without having to go through a defending phase and to win the ball back in areas of the pitch close to the goal. Therefore, constraint the pressure on the ball has a very important effect on the tactical production of high-pressing and counter-pressing, which can help players to maintain a high intensity performance in a relatively short period of time (Bangsbo, 1994; Eniseler, 2005).

In terms of movement, there was no significant difference in total distance covered during FP and PB conditions. However, the high-speed running especially number of high-speed runs were significantly improved, while the distance of moderate-speed running was significantly decreased after the transition time was restricted. In a similar SSG study, it was reported that double man pressure has significantly increased high-intensity running (Cihan, 2015; Casamichana et al., 2015). These findings could be explained by: 1) the pressure on the ball stimulated the defenders close down the opponent more quickly both in pressing and counter-pressing scenarios, while the attacking players are also forced to perform extra movement in an attempt to lose their pressure and create space (Cihan, 2015), the result showed that the ball recovery time was very significantly decrease from 6.36 to 3.11 s; 2) Pressing towards the ball inevitably means leaving space elsewhere on the pitch, players are required to perform a higher number of direction changes and high speed runs to recover the ball. It can be confirmed by the very significant increase in number of direction changes, which was from 5.25 to 12.13 times/min. When constraint the pressure on the ball, players have to directly and aggressively close down space between themselves and opponents with the ball, but the more quickly close to the ball the more risk will leave behind (Harper et al., 2021). Therefore, it is vital that when the press occurs, players know the trigger points and the details of the press; 3) Pressure on the ball also stimulated the player's anticipation to move forward, which encouraged players to make a greater number of high speed runs. In PB situation, player attempted to closed down the space between themselves and an opposition player even the opposition player does not have the ball. Players are trying to reading body positions to anticipate where the ball is going and move out to meet it immediately, providing no respite for the opposition (Nassis et al., 2020). This is also a vital element to a good press. In addition, we also found that there is not one moment where one of the players are not completely focused in PB situation. It is a characteristic of the modern game–it demands full concentration for 90 min, especially if you want to apply the quality of that press.

However, one of the indicators was in line with experimental expectations, namely, that there was no significant difference in top speed, sprint running distance and number of sprint runs between conditions. This can be partially explained by two aspects. On the one hand, the likelihood of a pitch size effect, as we know it is difficult for the players to reach the top speed within limited area especially with short length. A study conducted in U17 players revealed that increased sprinting performance were performed in the two bigger area dimensions (175 and 273 m^2 per player) (Casamichana and Castellano, 2010). Similar observation has also been made with the bigger area dimensions (200 m^2 per player) led to an increased number of accelerations and decelerations (Hodgson et al., 2014). On the other hand, the number of players has also impacted the sprinting performance. The previous study showed that the top speed reached was greater during 9 vs. 9 SSGs than in 3 vs. 3 games (Casamichana et al., 2015). This is consistent with previous research that had found higher sprint duration in games involving more players and places (Hill-Haas et al., 2009; Brandes et al., 2011).

Limitations

However, some limitations of our work should be acknowledged. Although previous research has demonstrated that the Rating of Perceived Exertion can provide supporting evidence for post-training physiological responses, the present study was unable to obtain relevant data samples. Therefore, future research should include such measures. Owing to the lack of data on the players' focus and anticipation metrics during the experiment, the present study was unable to determine their psychological performance feedback. In addition, due to the limitations of technical equipment, many technical and tactical metrics were not collected in this study.

Practical applications

As a key factor in the development of modern football, coaches can restrict the pressure on the ball as a control factor in training, which can effectively improve the intensity of training to even surpass that of a real match. The result observed from this study just reflected the youth elite players' abilities, coaches need to adjust the distance location when the defender close down space between themself and the player in possession of the ball according to the age, skill level, tactical level, and training purpose of their players. While simultaneously monitoring the players in real-time through wearable devices to achieve different training outcomes. From the perspective of periodization of training, the two conditions of SSGs in the experiment can develop the special anaerobic endurance of athletes during pre-season training; during the season, it can better stimulate players' high-intensity load and mental concentration by PB condition.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

All authors were involved in preparing the manuscript. XC, RZ, BX, XH, and BG contributed to the design of the research framework and developed the methodology. RZ and BX constructed the empirical study and conducted the experiment. XC, BG, and XH conducted the data analysis and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Factors affecting decision-making in Gaelic Football: a focus group approach

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Objectives: Research examining decision-making in sports has predominantly used experimental approaches that fail to provide a holistic understanding of the various factors that impact the decision-making process. The current study aimed to explore the decision-making processes of Senior (expert) and Academy (near-expert) Gaelic Football players using a focus group approach.

Methods: Four focus groups were conducted; two with Senior players ($n = 5$; $n = 6$) and two with U17 Academy players ($n = 5$; $n = 6$). In each focus group, short video clips of Senior Gaelic football games were played, and the action was paused at key moments. The group then discussed the options available to the player in possession, the decision they would make in that situation, and importantly, what factors influenced the final decision. Thematic analysis was used to identify themes that emerged from the focus groups.

Results and discussion: Four primary themes emerged that affected the decision-making process. Three themes were related to information sources, namely, pre-match context (coach tactics and instructions, match importance, and opposition status), current match context (score and time remaining), and visual information (player positioning and field space, and visual search strategy), and the fourth theme related to individual differences (self-efficacy, risk propensity, perceived pressure, physical characteristics, action capabilities, fatigue) that moderated the decision-making process. Compared to the near-expert Academy players, the expert Senior players displayed a more sophisticated understanding of the various sources of information and were able to integrate them in a more complex manner to make projections regarding future scenarios. For both groups, the decision-making process was moderated by individual differences. A schematic has been developed based on the study findings in an attempt to illustrate the hypothesized decision-making process.

KEYWORDS

expertise, anticipation, perceptual-cognitive skills, situation awareness, option generation

Introduction

Gaelic football is a complex invasion sport involving two teams of 15 players. The aim is to outscore the opposition by striking an ovoid ball into an "H" shaped goal, either over the crossbar for one point, or under it for three points. As with other complex and time-constrained invasion sports, success in Gaelic football is highly dependent on players'

perceptual-cognitive skills (Williams and Jackson, 2019) and decision-making ability (Raab et al., 2019). However, research in this area has tended to focus on other invasion sports, such as soccer, and therefore the factors affecting decision-making in Gaelic football have yet to be fully explored. Furthermore, researchers investigating decision-making in sports have tended to use reductionist approaches, such as laboratory-based experiments, to compare expert and novice participants; this approach restricts our understanding of the complexity of the decision-making process and fails to explore differences between expert and near-expert athletes. With this in mind, the current study used a focus group approach to explore the factors that influence the decision-making of Senior (expert) players and U17 Academy (near-expert) players from a Gaelic Athletic Association (GAA) National Football League Division 1 team.

Research over the last 50 years has identified several perceptual-cognitive skills that underpin expert performance (Williams and Jackson, 2019). These include, but are not limited to, scanning the environment for important positional and kinematic cues (Roca et al., 2013), recognition of sport-specific patterns of play (North et al., 2009), and perception of opponents' deceptive intent (Bishop et al., 2013; Jackson et al., 2020). These perceptual-cognitive skills enable efficient and effective anticipation and decision-making. Researchers have recently demonstrated that various contextual factors also influence anticipation and decision-making (Canal Bruland and Mann, 2015), such as match status (e.g., time elapsed, score line); (Farrow and Reid, 2012; Runswick et al., 2018), opponent positioning (Loffing and Hagemann, 2014; Murphy et al., 2016), opponent action preferences (Navia et al., 2013; Gredin et al., 2018), opposition quality (Castellano et al., 2017), and game momentum (Levi and Jackson, 2018). These factors can be classified as either dynamic or stable in nature. Dynamic factors are those in a continuous state of flux, such as the score line and opponent positioning, whereas stable factors fluctuate little, if at all, over the course of a match, such as the pre-eminence of the opposition and the opponent's action preferences (Gredin et al., 2020).

The majority of previous research in this area has compared expert and novice athletes, which has been critical in enhancing our understanding of the skills underpinning expert performance. However, this approach fails to examine how these skills alter between expert athletes and younger near-expert athletes. Ward and Williams (2003) conducted a comparative study of U9 and U17 highly skilled soccer players. While correlations were found between chronological age and perceptual-cognitive skills, this relationship disappeared after 15 years of age. More recently, Klatt and Smeeton (2022) compared perceptual-cognitive skills in elite youth soccer players and found superior performance in attentional skills in the U18 group compared to the U16 group. These findings suggest that there may be differences in the perceptual-cognitive skills and decision-making processes between near-expert groups, but research examining this is currently limited. Therefore, instead of adopting the classic expert–novice paradigm, the current study will draw comparisons between a group of expert Senior players and near-expert U17 Academy players.

The ability of experts to quickly identify and prioritize relevant information typifies the concept of situation awareness (Endsley, 1995, 2018). According to Endsley (1995), three components characterize situation awareness: the individual's perception of elements within time and space, their comprehension of the meaning of those elements, and the projection of their future state. For example, a Gaelic footballer is required to identify the relative positions of teammates and opponents (perception), understand the potential opportunities afforded by that configuration (comprehension), and rapidly determine the likely outcome of any given decision that they could take (projection).

Research examining the ability of experts to utilize situation awareness to form efficient and effective decisions has identified two key processes: option awareness and option generation. Option awareness is defined as "*the perception and comprehension of the relative desirability of the available options, as well as the underlying factors, trade-offs, and tipping points that explain that desirability*" (Pfaff et al., 2012). In unpacking the definition of option awareness, it could be argued that the "underlying factors" relate to individual differences, such as risk propensity (Meertens and Lion, 2008), self-efficacy (Laborde et al., 2016), and action capabilities (Bruce et al., 2012), as these have been shown to influence the decision-making process. The "trade-offs" and "tipping points" relate to the complex process of integrating the various sources of information based on relative reliability of each source and evaluating the costs and rewards of the potential options, to generate an optimal option (Gredin et al., 2019, 2020). Option generation refers to when decision-makers map their goals, objectives, and pertinent environmental information onto their own behavioral decision patterns, which have been developed through years of experience (Endsley, 1995). Research is required to explore in more detail the factors and processes that influence situation awareness and enable skilled athletes to be aware of, and to generate, high-quality options.

Situation awareness has been examined using a Naturalistic Decision-Making (NDM) approach (Klein, 2008). In this approach, expert decision-makers are presented with real-world scenarios comprising unstructured problems, with ill-defined and evolving goals, under dynamic and uncertain environmental conditions, temporal pressure, and risk (Macquet and Fleurance, 2007). Interviews are then used to explore the experts' decision-making process in these situations (McPherson, 2000). McPherson and Kernodle (2007) interviewed advanced adult beginners and entry-level professional tennis players. Immediate recall and planning interviews were conducted between points and it was found that, compared to the beginners, entry-level professionals generated and monitored more detailed actions related to the current context during recall interviews. This more ecological approach allows for a greater understanding of the performance-environment relationship and how actions emerge through perception-action coupling and the exploitation of natural affordances (Gibson, 1983; Davids and Araújo, 2010; Silva et al., 2014).

Recently, many researchers have adopted a similar qualitative approach to explore the factors affecting decision-making in sports (e.g., Schläppi-Lienhard and Hossner, 2015; Johnston and Morrison, 2016; Levi and Jackson, 2018; Gleeson and Kelly, 2020). Levi and Jackson (2018) used semi-structured interviews to explore the contextual factors that influence soccer players' decision-making. The study found that decision-making is affected by stable factors, including match importance, personal factors

and coach instruction, and dynamic factors, such as score status and momentum. Gleeson and Kelly (2020) explored the decision-making process of 10 international female soccer players using self-confrontational interviews in combination with audio-visual data and phenomenological elicitation interviews. They found an interdependent relationship between the players' cognitive and behavioral actions and their environment and captured the influence of psychological factors, such as anxiety and self-efficacy, on decision-making. These recent papers reinforce the advantages of qualitative approaches to enable a more holistic understanding of decision-making in sports.

A qualitative approach that has not been used to examine decision-making in sports, but could be effective, is the use of focus groups. Focus groups are usually semi-structured group interviews with anywhere from four to twelve people to explore specific issues in depth (Liamputtong, 2020). The group interview approach allows participants to explore, share, and clarify their experiences (Patton, 2014), and, therefore, the researcher can benefit from the data generated through communication between participants. Focus group investigations have been implemented in sport domains such as female withdrawal from physical activity (Slater and Tiggemann, 2010), parental roles in tennis success (Gould et al., 2008), and athletic understanding of mental toughness (Jones, 2010), but not to examine the factors that impact expert decision-making.

The present study aimed to use a focus group approach with expert Senior and near-expert U17 Academy Gaelic football players to explore the information sources used to generate options, and the factors that influence the decision-making process. Discussions centered around video clips depicting a series of situations from inter-county championship matches. Situation awareness, option awareness, and option generation were used as *a priori* concepts, in combination with concepts that emerged inductively from the discussions, to organize and interpret the data.

Method

Participants

Twenty-one senior ($n = 10$) and U17 academy ($n = 11$) Gaelic Football players were recruited from a GAA National Football League club. The senior players (Mage = 27.70 yrs., SD = 3.31) had an average of 19.10 years playing experience (SD = 4.01), while the academy players (Mage = 16.63 yrs., SD = 0.50) had an average of 8.00 years playing experience (SD = 1.00). The entire sample comprised 11 attackers and 10 defenders, including midfield players who self-identified as more attacking or more defensive and labeled accordingly.

All senior and academy players were invited to attend an information session, where the principal investigator provided information relevant to the study including assurances of participants' confidentiality and anonymity (verbally and in writing). After questions or concerns had been addressed, and those who were willing to participate signed a consent form. The study was approved by the ethics committee of the lead institution. Players were randomly assigned to within-squad focus groups (i.e., each focus group comprised of either senior or academy players, not both), yielding a total of four focus groups with a maximum of 6 participants in any one group.

Equipment and materials

Match scenarios video task

In the focus group session, participants were shown eight video clips, lasting 60–150 s (M = 102.50 s; SD = 30.28), from senior men's Inter-county championship matches, none of which involved the participants. All clips depicted an attacking phase of play, in which one team advanced into their opponent's half of the pitch to varying degrees. Each clip was freezeframed approximately 120 ms before a point at which the player in possession of the ball made a key behavioral decision (cf. Johnson and Raab, 2003). Between one and six options were clearly available to the player in possession at the freezeframe. Four GAA Division 1 coaches were consulted to determine whether the clips depicted scenarios that commonly arose in Gaelic football.

Focus group interview guide

To gather relevant data from the focus groups, a semi-structured interview guide was developed in advance. The primary research team discussed at length what questions would be most beneficial to ask, as well as prompt questions for athletes to expand in their decisions. The interview guide was checked and modified over three pilot focus groups with players not involved in the study.

The interview guide comprised a short introduction into the goal of the study, a brief explanation of the procedure, and then two core questions that were asked after each video clip was paused: (1) "*What do you think the player in possession will do?*" and (2) "*What do you think is the best option for the player in possession?*". Participants were asked to write their responses to these two questions on a piece of paper at first. The answers to these questions were not necessarily identical but could be. A group discussion then took place about why they chose the options they did, what information they used to choose those options, and what factors influenced their final decision. This discussion evolved naturally, but where participants' responses were insubstantial, the lead researcher used elaboration probes (e.g., "*can you tell me more about that?*" and "*why would that affect your decision?*") to elicit further detail. After this initial discussion had taken place, the clip was played in full and the participants were asked a series of prompt questions, including "*is that decision what you expected?*", "*was that the best decision to make?*", and "*if not the best, then why do you think the player made this decision?*". The group discussion continued until saturation had been achieved and then the next video clip was played.

Procedure

The focus groups were scheduled on separate days. After reiterating the format of the focus group session, the researcher administered pens and paper sheets for participants to record their responses to the video task. Participants viewed each freezeframed

clip only once, before privately writing down their answers to the two predetermined questions. This process was used to give the participants time to reflect individually before discussing as a group. Once the participants had written down their answers and discussed the decisions, an extended version of the clip was played to show the outcomes. This task was used as a catalyst for group discussions regarding the reasons for their decisions and the player in the video. Each of the eight video scenario discussions proceeded until the data had reached a saturation point. Once all eight scenarios had been discussed in full, the lead researcher gave an additional opportunity for participants to ask further questions, before concluding the session.

Data analysis

Focus groups were audio recorded and transcribed verbatim including syntax. The software used to organize and analyze the qualitative data was Microsoft Excel. To ensure confidentiality and anonymity, participants were allocated individual codes based on the squad they were from and the position they played (e.g., "P1SD" refers to participant 1 [P1] from the senior squad [S] who was a defender [D]) and pseudonyms were assigned to players and teams referred to in the video scenarios.

After all the focus groups were transcribed, a thematic analysis was conducted, in accordance with Clarke and Braun's (2014) six stages (*timescale and authors involved in parentheses*): familiarization with the data (*∼6 months; all authors*), generation of initial codes (*∼1 month; 1st author*), searching for themes (*∼2 weeks; 1st author*), reviewing themes (*∼2 months; 1st author, 2nd author, and last author*), defining and naming themes (*∼2 weeks; 1st author, 2nd author, and last author*), and producing the report (*∼4 months; all authors*) (Clarke and Braun, 2014). The data were organized according to factors that emerged in the focus groups and during the subsequent analysis. Where appropriate, the concepts of situation awareness, option awareness, and option generation were used to characterize participants' responses (Endsley, 1995; Pfaff et al., 2012).

Based on previous suggestions for rigor in sport psychology, we selected two criteria that allow for an objective judgment of the current paper (Smith and McGannon, 2018). First, *worthiness* was captured in the introduction as we highlighted the absence of focus group methodology within decision-making literature. Second, we sought *sincerity* in our research through reflexivity; relatedly, the first author is continually exposed to and intimately familiar with Gaelic Football, thus meeting regularly with the second and last author to discuss and review their interpretation of the data.

Results and discussion

Thematic analysis revealed that participants generated four main options (pass, recycle, point, and goal) through situation awareness, which was underpinned and influenced by four primary themes: *pre-match context* (coach tactics and instructions, match importance, and opposition status), *current match context* (score and time), *visual information* (player positioning and field space, and visual search strategy), and *individual differences* (self-efficacy, risk propensity, perceived pressure, physical characteristics, action capabilities, and fatigue). Supplementary Table 1 in the Supplementary material presents the raw data for each second order theme within each first order theme. This thematic analysis table provides evidence for how the raw data was coded and understood and integrated to produce themes. Each theme will initially be discussed separately using extracts of illustrative quotes. Based on the focus group discussions, a final section is included that attempts to demonstrate the complex interaction between these themes, and the trade-offs and tipping points that explain the desirability of the available options (Pfaff et al., 2012). A schematic (Figure 1) has been developed to support this final general discussion.

Option awareness

Participants in both groups often cited passing (both hand- and kick-passing) as a plausible option, or recycling (turning back with the ball) in times of defensive pressure. Differences between the two groups were most notable in the case of attacking scenarios: the academy players often decided to shoot for a Goal (3 points) initially, rather than aiming for a Point (1 point), whereas senior players were more reluctant to select a Goal as their first option; we discuss reasons for this later. For example, participant P5SA stated that "*there is a goal on… I just don't think the lads are going to risk it*". Interestingly, the senior players often assigned percentages to shot selections referring to the likelihood of achieving that shot. For example, participant P4SA stated that "*… if you think about it you've got 80–90% chance of getting a point against Team X but like 10% less chance to get a goal against them*", and P2SA stated that "*… if you're talking percentages that's not a percentage shot like*". The academy players made no mention of percentage shots or attempted to assign percentages regarding the likelihood of achieving the shot. This demonstrates a more complex and sophisticated awareness of the available options from the expert senior players, compared to the near-expert academy players, whereby they can make future projections about the options (Pfaff et al., 2012). In line with the concept of situation awareness, the ability to assign probabilities and make future projections requires the ability to perceive and comprehend the available sources of information (Endsley, 1995). The following themes outline the sources of information that underpin situation awareness, alongside other factors that influence the decision-making process.

Situation awareness

Pre-match context

Several factors exist before the commencement of matches, which players in both squads took into account when making their decisions. These were the coach's tactics, the match's importance, and the status of the opposition.

Coach tactics and instructions

Both academy and senior players identified coach tactics as an influence on their decision-making; however, in line with previous research, the Senior players discussed tactical information

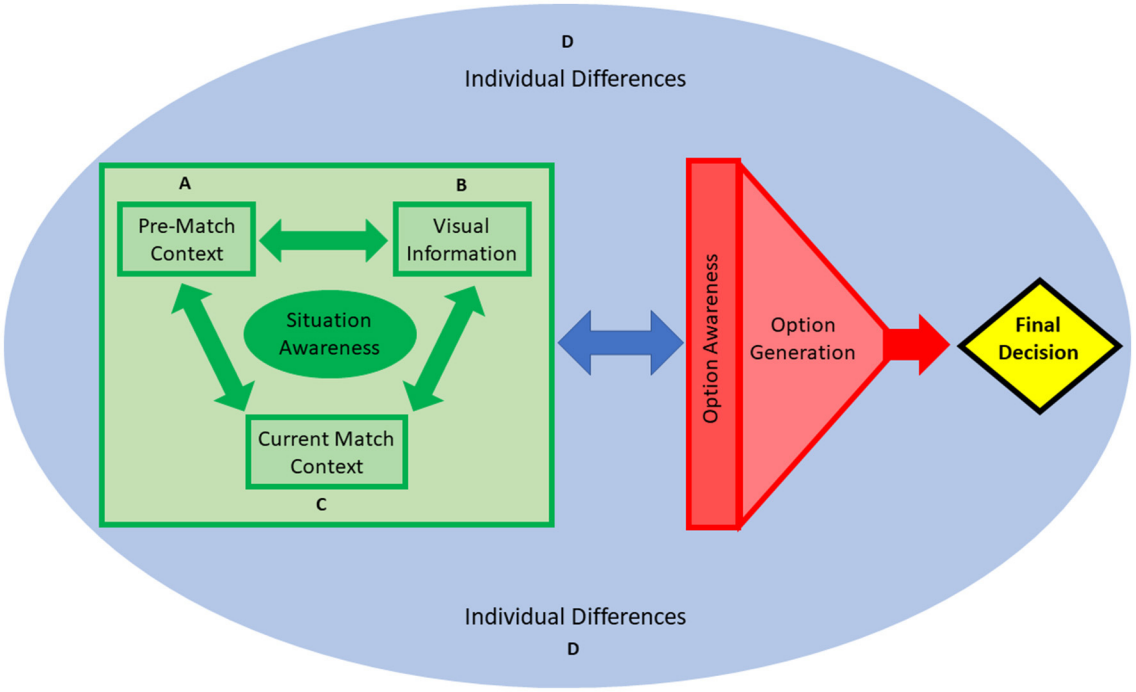

FIGURE 1
A schematic to illustrate the decision-making process of Gaelic football players based on the themes that emerged from the focus groups. The schematic is based on the overarching concepts of situation awareness, option awareness and option generation. **(A)** Pre-match context (coach tactics and instructions, match importance and opposition status), **(B)** visual information (player positioning and field space, visual search strategy), **(C)** current match context (score, time remaining), and **(D)** individual differences (self-efficacy, risk propensity, perceived pressure, physical attributes, action capabilities, fatigue status).

in a more sophisticated and detailed manner compared to the academy players (McPherson and Kernodle, 2007). In line with the tenets of situation awareness (Endsley, 1995), the Senior group was not only able to perceive a wide variety of pertinent environmental information but was also more adept at assimilating this information with coach tactics to envisage an optimal course of action. This is demonstrated in this quote by a Senior player: "*an ideal ball here would be a cross-field ball over to a target over here, but then again…it depends on the tactics you are playing against a defensive team*" [P6SD]. The senior player identified the best option and then can update this in light of their coach's tactical preferences when making the final decision. In contrast, the less experienced academy players were typically only aware of tactics on a relatively superficial level, with little evidence of comprehension or ability to project different future states. For example, participant P1AD states that "*You're just coached that way*", and participant P3AA asserted, "*that's what you'd be told to do*". This suggests that Academy players often rely upon the coach's tactics when forming their decisions as they are unable to integrate this with current environmental information.

In line with the suggestion that Academy players are over-reliant on the coach's tactics and instructions, this group made no reference to disagreement or questioning of proposed tactics, whereas the Senior players regularly discussed their concerns over "restrictive tactics" from the coach. For example, participant P1SA stated, "*some managers will just have a blueprint of how they like to play, and they will just play it regardless of actually how to facilitate players to play the best they can. Then you've players who aren't confident because they are constantly being told what to do or give it into Player X just let him make the decision.… that's why we have so many hand passes in the game now*". This suggests that coach instructions to Senior players could restrict creativity and negatively impact the decision-making process. Memmert (2011) found that more experienced athletes were more creative than that of their less experienced counterparts, and it appears that prescriptive instructions from a coach may limit this in actual competition. Academy players make no reference to restrictive coach instructions suggesting that they may require more instruction and set tactics due to their limited experience and reduced ability to perceive and comprehend other sources of information.

As well as commenting on the restrictive nature of coach instructions, the senior group referred to receiving feedback as having a negative impact on their decision-making. For example, when discussing the types of feedback received, P5SA stated "*I think performance analysis as well has a lot to do with it, he [player in possession] knows if that goal breaks down then they're going be breaking that movement down the next day and he'll be sitting there like a fool and people will be saying why didn't you just take your point*". It appears that the Senior player is fearful of negative feedback following any poor performance and this is ultimately impacting his decision-making. Having said that, other players spoke positively about the role of performance analysis in the feedback process for improving performance and motivation.

For example, P4SA said "*we have performance analysis and it 100% improves things even just as far as work rate. At one stage our full back [ran] the ball about 90 yards down the field without anyone touching him from a short kick out and the next day the pressure we put on the kick outs was unreal*". From a coaching perspective, the feedback process needs to be carefully examined such that the players feel able to make their own decisions and have the freedom to be creative without fear of negative consequences (Wulf et al., 2010). Research by Levi and Jackson (2018) found that U23 academy players perceive coach instruction as detrimental when feedback was given after the player had already decided on what decision to make, but valuable when feedback was given after poor decision-making. In the current study, the Senior players indicated that they may appreciate more autonomy where feedback is concerned, with P5SA again stating "*most lads are quite self-reflective players anyway so they will look at it and think I know what I should have done. You don't always need someone telling you. I think things can be over analyzed these days*". The potential negative impact and the need to promote autonomy are highlighted in other research findings. For example, Wulf and Shea (2004) found that providing players with prescriptive feedback (e.g., what to do) can further hinder problem-solving abilities, while Carpentier and Mageau (2013) found that feedback that leaves players with a sense of autonomy aids performance in sports.

Match importance

Following one of the scenarios, when discussing whether to go for a point or a goal, participant P2AA suggested that it depends on "*the importance of the match, is it championship or league*". In the Gaelic Athletic Association, the national league consists of 7 games regardless of previous results, whereas the championship follows a knock-out format. This feeling was shared by all the players, evidenced through agreeable comments, and suggests that their decision-making may alter depending on the importance of the competition. However, an interesting finding in this theme was the contrasting impact of match importance between the two groups.

The academy players discussed how a safer option would be selected if it were in a big game, such as when playing in Croke Park, the principal stadium of the Gaelic Athletic Association and where most championship games take place. Participant P5AA justifies the selection of a safer option because of the match status; "*it is a risk to play it in and maybe he will turn back, [it's a] big game in Croke Park*". In comparison, individuals within the Senior group appear to suggest that playing at Croke Park may result in selecting a riskier option. When the players were discussing a scenario in which a shot could be taken, but it was a high-risk option with a high chance of error, participant P4SD states "*I don't think Player X will do anything with this will he?*", suggesting the player on screen will not attempt the shot. In response participant P5SA stated, "*. . . big game in Croke Park, [he] sees his name in lights*". This suggests that in this "big game" situation, the player may select the riskier option, potentially resulting in more errors. The suggestion from participant P2SD is that the extrinsic motivation of scoring the winning points in an important match biased the decision-making such that a high-risk option was selected. Research outside of sports has suggested that for decisions in which individuals must rely on experience, older adults tend to be more risk-seeking relative to younger adults (Mata et al., 2011). This is supported by Levi and Jackson (2018) who found that while some soccer players do not appear to be affected by match importance, others found it was a direct cause of rushed and somewhat rash decision-making. Not all senior players in the current study agreed that such risky shots could be justified with participant P2SD stating "*I don't think you can make an excuse for that to be honest, not at this level. You're playing against Team X in Croke Park. You don't think that you can make a run like that up the field and score from what is he, 60 yards out? I'm sure they were told at training not to be wasting any possession*". Interestingly, this quote illustrates how coach tactics and instructions were seemingly ignored in this 'big game' situation, which was to the detriment of the actual decision made. Risk-taking may also be linked to self-efficacy and action capabilities, discussed in detail later, as individuals with high self-efficacy and greater action capabilities (e.g., Senior players) may be more likely to select the riskier option compared to those with lower self-efficacy (Hepler and Feltz, 2012).

Opposition status

In Gaelic football, the championship does not operate on a tiered basis and thus weaker teams could face an opposition perceived to be much stronger. The senior group illustrated a superior understanding of the opposition status and the related consequences on their decision-making, as shown in this conversation;

> P3SA: "*You have a much higher chance of being turned over with a strong opposition-—9 out of 10 times they will turn you over. So, you have to be cautious playing against the best players.*"
>
> P4SA: "*At club football you might take them [risks], but not at this level*".

In contrast, the Academy players made more superficial and less comprehensive statements, such as P4AA who said, "*it would depend on the opposition*". This suggests that the Academy players lacked an in-depth understanding of how and why to alter their decisions due to the opposition's status, whereas this was a critical source of information for the Senior players. This supports previous research by Schläppi-Lienhard and Hossner (2015) who found that the strengths and weaknesses of the opposition impact elite volleyball players' decision-making under temporal pressure. They found that players often make decisions on the known preferences of the opposition rather than using in-game information.

Interestingly, both groups demonstrated awareness of specific opposition team status and strengths, but while the Senior players tended to agree on how this impacted the decisions made when facing this team, the Academy players differed in how this information source influenced the decision. For example, P2AA stated "*any goal chance you get against Team X you'd want to be taking them. . .* ", which relates to the high opposition status of Team X and the limited chances you may get against this team. This player indicates that therefore they would select the high-risk and high-reward option. In contrast, P4AD states "*You know you're playing against Team X, [so] you should be taking the safe option and playing back to start the attack again*". This demonstrates the large individual differences in the impact of opposition status on

decision-making with the Academy players. The Senior players, however, tended to agree on the decisions to make when facing certain opponents. For example, P6SD said "*The only time you take it somewhat into traffic is when you're running toward one or two people if you're going for goal, but not [against] Team X*", and P3SA responded, "*Yeah know your opposition, Team X will swallow you up*". It appears that the decision-making of the Senior squad is more aligned compared to the academy players, which may just be down to experience but is something academy coaches must be aware of. While the impact of opposition status on the tactical behavior of a team has been well-documented (e.g., McGee, 2008; del Campo et al., 2011; Rein and Memmert, 2016), the inter-individual effects of opposition status on decision-making has somewhat been neglected in the literature and requires further research.

Current match context

In addition to the pre-match context, players from both squads suggested that two elements of the current match status affected the decision-making process—namely, the score and the time remaining, as illustrated by participant P3SD who said: "*Like the boys said, what time in the game [and] what's the score… all that is going to affect him [the player in possession]*".

Score

Both academy and senior players identified that the score of the game impacted their decision-making process as demonstrated in this quote by participant P1AD who said that "*it all depends on whether you're ahead or behind*". Interestingly the players identified being behind on the score board as a determinant of making more high-risk options, such as this quote by participant P2SD who stated: "*well it depends on the score too—if it's close you slot it over the bar [1 point] and if you're losing then you try work in your goal [3 points]*". In contrast, being ahead in the match was a significant contributing factor for electing the safer option on the ball for both groups as illustrated by participant P3AA who, when discussing whether to decide to take a point or not, said "*… that's only if you're ahead though*". This supports previous research by Farrow and Reid (2012) who found that knowledge of match status (score) impacts decision-making, as well as Rulence-Pâques et al. (2005) who found that experienced players consider score and the appropriate strategy important in decision-making.

Time remaining

Players also identified that the time and stage of the game had a predominant role to play in their decision-making process. Interestingly, Academy players identified earlier stages of the game as windows of opportunity. For example, P2AA stated "*if it's early on you may take chances because you have time to recover*", and P3AA said, "*what do you have to lose if it's early in the game, what have you got to lose*". In contrast, the Academy players indicated that the later stages of the game required safer play, such as P2AA who said, "*… but toward the end you take the safest option*". The Senior players, however, were the opposite and suggested that the earlier stages of the game are conducive to safer play, whereas riskier play is best suited to the latter stages of the game. This is illustrated by P3SA who said, "*the stage of the game is also very important … if it's early on in the game you'd give it back and try [to] reset yourself, [whereas in the] later stages of the game you would have to try press and break in*". Further investigation is required to understand how and why the time in the match may influence decision-making differently across skill levels.

From the focus groups, it was clear that the score and the time are inextricably linked as part of the current match context. This is demonstrated by P3SD who said, "*if it's the 5 min, you're taking it and you're saying just take your point … If its last minute and you are a few behind then it has to go to that man there [in an attacking position], and maybe even the other boy to loop around and support him*". The current match status plays a significant role in impacting the decision that is made and this has been demonstrated in numerous previous research (Rulence-Pâques et al., 2005; Farrow and Reid, 2012; Vernon et al., 2018). Levi and Jackson (2018) found that contextual factors such as score and time played a pivotal role in athletes' decision-making, as well as Bar-Eli and Tractinsky (2000) found that the end stages of a basketball game were evaluated as critical by players. While the previous research, and the current paper, have aided our understanding of the impact of the current match context on decision-making, future research is required to investigate whether this is beneficial to performance or not. The relationship between decision-making and motor skill execution is fundamental in understanding expert performance in sports (Araújo et al., 2019), but there is still a limited understanding of how factors such as the match context impact them.

Visual information

Discussions throughout the focus groups suggested that visual information that is available in the environment, such as players' positioning and field space, affected the decision-making process, but this was dependent on the use of effective search strategies.

Player positioning and field space

The senior group considered several sources of visual information, such as the positioning of teammates and the space on the pitch, when forming a decision. This is illustrated by P2SA who said "*well if there was a [player] here, a midfielder coming late, one kick pass to here and suddenly he has all that space in front of him. Then all these boys are distracted now, they have to pull over here–that there is where the scoring opportunity is because then there are not as many defenders there*" and P5SD who stated "*… but what could happen is if he draws Player X to him then this [player] might be inclined to come across here and that's going to create the extra man and the score [opportunity]*". In line with the concept of situation awareness, the Senior players were able to perceive the positioning of the players and the space on the pitch, comprehend this information, and then make projections about the future state to enable sophisticated decision-making (Endsley, 1995). In contrast, the academy players' synopsis of the visual information was much more superficial, lacked detail, and was more descriptive rather than predictive, as shown by P2AA who said "*I think he should wait for that man to the right of him to make a run*" and P3AD who stated "*it depends, I'd be hanging on to see what the man on the run did*". It appears that the Academy players wanted to wait until more visual information emerged, which would result in delayed decision-making and action execution, compared to the Senior players who could use early visual information to identify

many clear options and make future predictions of possible events. This finding supports the dearth of research demonstrating that expert athletes have superior perceptual-cognitive skills and can utilize early visual information (Mann et al., 2007) and specifically supports the article by McPherson and Kernodle (2007), who found that experts have more sophisticated knowledge stores which they can readily access mid-performance to develop more advanced action plans than that of adult beginners.

In addition to the positioning of teammates, all players referred to the positioning of the opposition players that in certain scenarios restricted the options available. For example, P4SA said "*I think he should turn back as he is limited to no options—there isn't even an option on the 21 for him, so he only has the nearest man to him on the 45 and that's going to have to be a diagonal ball, but there are at least three [opposition] defenders there, two to put him off and one to stop the support runners. So, for me I'd maybe turn back and try start the play again*". The academy players assessed similar scenarios as there being pressure on the ball based on the positioning of the opponent players. When asked why they selected turning back in one of the scenarios, P2AA said "*well he [the opponent] put him [the player in possession] under a lot of pressure, so he would have been under pressure to try and offload that ball*". Similarly, when discussing whether to play a short-hand pass, P2SD said "*I think it puts more pressure on them. They will get turnover especially if they keep playing it around the men in the middle, so maybe moving the ball further [away] will give them a bit more space*". It is evident from these quotes that, compared to the Academy players, the Senior players can project future states and provide more detail as to why the options are limited due to the opponent players positioning (Endsley, 1995). This appears to result in an ability to restart and try to create more options, compared to the academy players who seemed more likely to select an option as soon as possible to try and release pressure from themselves. This is further evidenced by the sophisticated discussions the Senior players had around player and opponent positioning often referring to numbers on each side and being able to use this to project the best options. For example, when discussing options in a certain scenario, P2SD said "*I think there's a bit of an overlap there about three quarters of the way over to the left there its about 3 vs. 1*" and followed this up by saying how this led to his final decision "*there's spare men here and if you start the video again, you'll see them, so he'll switch the play across*" [P2SD]. The Academy players did not refer specifically to the numbers of teammates and opponents when developing their options, suggesting that this advanced understanding of player positioning is developed over time.

This subcategory revealed an interesting difference between the two groups, related to the visual information that would usually be available in a match but was off-screen during the focus group due to the viewing angle of the video footage. The academy groups tended to consider, or address, only visual information displayed on the screen at the time of a freeze frame, whereas the senior group often referred to potential information that is off-screen, which they would usually have access to. For example, P2SA stated "*I just want to see if there's a spare runner coming up behind him or coming through the middle*". Similarly, P1SD said "*it is very hard to call this one because you can't see what's inside*" and P5SA said "*this is torturing me, because you don't know what is inside*". In search of this missing visual information, the Senior players referred to possible player positions off-screen based on pattern recognition and sequences of play that they would anticipate from the footage (North et al., 2009), whereas the Academy players appeared unable to predict the positioning of other players off the screen. In one scenario, when asked what they felt was the best option, the Academy players suggested giving the ball off to the full forward line; P3AD: "*I'd probably give it to the forwards, I just think there is space the far side*" and P1AD: "*I think he will give it into the forwards*". In comparison, for the same scenario, the Senior players referred to there being no full forward line in position for a pass and thus elected for retaining possession, as P3SD stated, "*Yeah recycle the ball back to the middle because there should be a person in there, because there doesn't seem to be anyone inside for him*". The senior group appears to have made calculations based on the number of men on screen and conceptualized that, due to this, these men cannot be elsewhere, whereas the academy does not appear to possess such detailed knowledge. These findings are in line with previous research that found more experiences athletes have a superior knowledge base and better probabilistic expectations related to pattern recognition (North et al., 2009).

Visual search strategies

A fundamental difference that emerged between the academy and senior players was the visual search strategies and how this moderated the use of visual information. The academy players referred to the "*need to know where to look*" [P5AD] and often referred to their inability to see all the information in the environment whilst playing. For example, when asked why the player in possession may not have seen a teammate in a better position for a goal, P4AA responded "*You're only looking at the goal… you're not looking around*", along with P6AD who stated "*you can only see what's in front of you*". The Academy players also referred to requiring other sources to aid situation awareness and option awareness, such as communication from teammates. This is illustrated by P2AA who when talking about the benefits of communication from teammates said "*you know where to look, then rather than looking everywhere, you look to where you got the call*" and P4AA said "*Calling makes it [decision-making] easier*". When asked by the researcher why they need teammates to communicate and call for a pass, P3AA responded "*because I can't see everything*".

In contrast, the senior players demonstrate a far more efficient and effective visual search strategy, which is underpinned by scanning activities to perceive all the visual information present in the environment. This is illustrated by P4SA who stated "*that is what is required now, players who can play 360 degrees*" and this was supported by quotes such as, "*you should be scanning first thing*" [P2SA] and "*you take a look around first*" [P3SD]. The Senior players do not make any reference to requiring other external factors to aid situation awareness and option awareness. This highlights the importance of experience in visual search strategies and supports previous research that demonstrates that experts possess more efficient and effective visual search strategies compared to their less-skilled counterparts (Ward and Williams, 2003; Mann et al., 2007).

Individual differences

Alongside citing the important information sources that underpin situation awareness, all players throughout the focus groups discussed the important role that individual differences have on the decision-making process, such as self-efficacy, risk propensity, perception of pressure, perceived ability, and fatigue.

Self-efficacy

Self-efficacy is described as an individual's perceptions of specific abilities and what they perceive they can achieve with these abilities (Bandura, 1994). The focus groups highlighted the importance of self-efficacy and confidence in decision-making for both groups of players. This is illustrated by P1AA who said "*you have to have the confidence in yourself… you won't succeed in anything if you don't have confidence*". The findings support previous research on the impact of self-efficacy on decision-making, such as Hepler and Feltz (2012) who found that self-efficacy was a significant predictor of decision speed in a baseball hitting task. However, this study found that experience did not have a meaningful effect on the relationship between self-efficacy and decision-making performance, which is somewhat contradicted in the current study. In line with Self-Efficacy Theory (Bandura, 1977), the players seemed to agree that mastery of skill increased confidence, although the Senior players were much clearer on the importance of previous experience. For example, when asked why some players might decide to take a man on and some would not, P2SD said it depends on "*confidence, so the forwards would be used to doing that [getting past another player to continue an attack], whereas the backs would not*". This demonstrates the understanding that certain players in a team, depending on position, will have gained more experience and a greater level of expertise for certain skills compared to other player positions, and therefore have greater confidence in making the decision to complete that skill. In contrast, the Academy players seemed to base decisions on whether they were confident in a specific moment rather than based on whether they had experience in achieving the skill, as illustrated by P4AA who said "*but if you think your confident and you think you can get past him then you will try and take him on*". The specific attribution of experience from the senior players and the absence of such attributions in the academy groups could warrant further investigations using more experimental study designs.

Risk-taking propensity

A discussion regarding the risks and rewards of the options generated was evident throughout all the focus groups and can be seen in the quotes from the previous themes (e.g., see Option Generation section). The perception of how risky a decision is and which option to select is moderated by the individual's propensity for risk-taking behavior (Kahneman and Tversky, 1973). Research has shown that some individuals are more likely to take risks compared to others, based on their personality traits (Zuckerman, 1994), upbringing (Weber, 1997), and gender (Byrnes et al., 1999). Interestingly, in the current study, while there were no clear personality differences between the Senior and Academy players with regard to the propensity to take risks, it appeared that there were personality differences depending on the position of the player. Attacking-based players more commonly selected the higher-risk option (i.e., a goal) over the lower-risk option (i.e., a point or pass). For example, P2AA, an attacker, stated "*Yeah it's the riskier of the two options, but you're most likely to get a score from that one because you put more pressure on them to get back, and you can catch a few defenders out doing that*". In comparison, P4SD, a defender, said "*I think he should wait for that man to the right of him to make a run and try play it off to him, but I think he might cut back and try play it to the man behind him*". The difference in selection strategies between players from the two positions was also illustrated in a conversation between two attackers and a defender during a senior group discussion. When asked what he thought, P1SD stated "*well I think the best option is if he's on his left [foot] then he has to go for a point*" to which P4SA replied to him "*you're some risk taker*". P4SA agreed with P2S3 who suggested the player in possession should "*step forward an inch or two until the defender comes toward you and then slot it off [pass it] to the man coming in*". In response to this conversation, P1SD said the player is possession is "*going to shoot—he's left footed and he's a forward…forwards are greedy*". While risk propensity and behaviors such as gambling (Markiewicz and Weber, 2013), participation in high-risk sport (Castanier et al., 2010), and deviant behavior (Frias-Armenta and Corral-Verdugo, 2010) have been well-documented, the possible role it plays in team invasion sports has yet to be fully understood (Raab and Johnson, 2004). The current study suggests that either individuals with a trait propensity for risk-taking gravitate toward attacking positions in team sports or that practicing and training in a certain role over years influences an individual's propensity to take risks. Future research is required to examine this in more detail.

It appears from the focus groups that there is a link between self-efficacy and risk-taking propensity. This supports previous research that suggests that higher levels of self-efficacy result in higher risk-taking behavior (Hepler and Feltz, 2012), along with an inverse relationship to perceptions of threat (Krueger and Dickson, 1994). Further investigation is required to understand individual differences that are correlated with playing positions and how this impacts decision-making in team invasion sports.

Perceived pressure

This subcategory illustrated that pressure had a much more confounding effect on the academy players than that on the seniors, with the academy players referring to external factors such as the crowd that added perceived pressure and influenced decision-making. For example, when discussing a decision, P1AA said "*for the crowd it's a clear decision and they'd be roaring where as you might not have seen it and then that just puts you under more pressure*". This supports previous research that demonstrates perceived pressure impacts decision-making, such as Johnson (2006) who found that mental stress delayed decision-making in comparison to physical stress in basketball players, and Wells and Skowronski (2012) who found that when the pressure to perform is at its highest (4th round of golfing competition), this is where scores decreased the most. However, the senior players seemed to have a much more pragmatic view of pressure indicating it is always present but is something that can be coped with. For example, P4SA

responded to a discussion by saying "*sure there is always pressure*" and similarly P1SA said, *"there is always pressure kicks*". This may suggest that the experience of playing at an elite level may have mediated the feelings of pressure in the senior group. The possible moderator of experience on perceived pressure in decision-making processes may warrant further investigation.

Physical attributes

This subcategory illustrated the effects of physical attributes, such as player size and speed, on decision-making. It is worth noting here that physical characteristics are not mentioned in isolation by either group but rather comparatively, with players weighing up their physical characteristics against opposition characteristics, as illustrated by the following conversation between the researcher [R] and Senior players:

> R: "*What is the difference in times when you think I'm not going to take him [the opposition player] on or I am going to take him on?*"
>
> P4AA: "*Well are you faster and fitter than your [opponent]. There's a difference when it's a big tall [player] and a small [player]—you know they [the small player] will be nifty [quick], so you change the way you play based on who you are up against. After the first two or three balls you think this [player] isn't major fast or this [player] is too fast for me*"
>
> P1AA: "*Yeah, the more the game goes on you can get a sense for your [opposition player], so you know if you can square up and beat him or if you can't... if you can't your intelligence will tell you to hold the ball*"

As expected, due to their age and biological maturation, the Academy players made several references to the direct impact their physical size has on decision-making. For example, P3AA stated: "*It does depend on who you are up against. If I was going through a gap and I see a small [opposition player] I'd go through, but if you see a big lad there then you'll lay it off";* and P4AA stated: *"I'm small so that's not a ball for me*". This factor was not restricted to the Academy players though, as demonstrated in this comment by a Senior player who said "*if there is a big height difference on the full forward line then you need to switch wings and work it in rather than give it in to the full forward line*" [P6SA]. Alongside the physical size of the player and opposition, the physical speed and power were also highlighted as a factor influencing the decision-making process. For example, when discussing why individuals might pick a certain option, P5AA said "*have you [got] the pace and the power to get through that traffic*" and similarly P4SA said "*If I knew, from my man marking me, that he was faster than me then I wouldn't risk it*". It is worth noting that regardless of playing level, physical attributes play a predominant role in decision-making processes (Reed, 1996), and this factor warrants further investigation in future.

Action capabilities

In line with physical attributes, the action capabilities of the player and the opposition players, were a predominant factor in the decision-making process for both groups, as illustrated by the response from P1SA when asked why they think the best option is to shoot; "*because he's in the scoring range – absolutely in the scoring [range]. The way he has his body lined up and the distance between him and the next defender, so he has the time to get the shot away and he's close enough to the goal… he should be getting them over*". The academy players often justified the option they selected according to their ability. For example, when discussing whether to go for a point, P4AD stated "*no, I wouldn't go for it, I wouldn't have the accuracy*" and P1AA said that compared to some players "*sometimes you would be stronger at point taking*". Similarly, the Senior players refer to how their ability would impact decision-making, specifically referring to their dominant foot. For example, when discussing the player in possession in the video, P2SA said "*he looks like he's right footed though so that's not a shot for a right footer*" and when reflecting on their action capabilities, P4SD said "*I would have laid if off as well as I'm right footed, so I would never even think about that kick*".

Interestingly in one scenario, a player kicks a score from a significant distance out and while the academy display surprise, such as P3AD who said "*I wouldn't have even thought about it from out there*", the senior players understood why the option was selected, as illustrated by P1SA who said, "*well he knows himself like he has obviously scored from there before and knows he can get it over from there*". This supports previous research that perceived action capabilities impact decision-making (Bruce et al., 2012). Based on previous research, it is plausible to suggest that as the performance demands increase, the academy players due to their lack of experience would perceive the situation to exceed their capabilities which increases levels of perceived pressure (McGrath, 1970), but more research is required to examine this.

Fatigue status

This subcategory illustrated the effects of physical fatigue on decision-making. In a particular scenario, the player in possession traveled a substantial distance and this played a significant factor in determining the decision made by the Senior players. For example, when discussing whether the player in possession will shoot or not, P1SA said "*Not after running 60 yards with it. Player X would find it hard to get it over [score] from there after running 60 yards*". The other senior players agreed and also discussed the role certain individuals have within a team and the coaching that the players receive. For example, P6AA said "*the best job here is to give it to the shooter… the carriers job is done, he's carried that ball 50 yards after making a solo [run] so the legs are obviously tired. That's his job done give it to the shooter*" and S5 added "*no coach coaches a team to run 60 yards with the ball and tell them to shoot from there… no one, literally no one*". This supports previous research that demonstrates that fatigue impacts skill execution and decision-making, although whether this is a positive or detrimental impact still requires further examination (Thomson et al., 2009). Royal et al. (2006) found that decision-making in water polo was enhanced by high fatigue levels, whereas Alder et al. (2019) demonstrated that anticipation performance and visual search behavior in badminton were negatively impacted by the physiological load. However, the study by Alder et al. (2019) also

demonstrated that training under a high physiological load reduced the negative impact on performance. Further research is required to investigate the impact of fatigue on performance, including physiological and mental load (Alder et al., 2020). It is interesting to note the Academy players made no reference to physical fatigue. It is plausible that less experienced athletes underestimate fatigue effects on both physical and cognitive performance, but this requires further investigation.

General discussion

Having discussed the various themes separately, it is important to consider the multifaced nature of the decision-making process, and that it evolves from a complex interaction between multiple sources of information and the moderating factors. The focus group approach allowed us to capture this complex interplay between information sources and how individual differences moderate this process. In an attempt to illustrate this, we have developed a simple schematic (Figure 1) and provide some examples below of how this schematic relates to the focus group discussions.

The findings from the current study indicate that the players were able to demonstrate option awareness, and generate an optimal option, through situation awareness derived from three primary information sources: pre-match context, current match context, and visual information. In line with the concept of situation awareness, these information sources are perceived, comprehended, and used to make future projections (Endsley, 1995). This process develops option awareness and, ultimately, option generation (Pfaff et al., 2012). The complex interaction between multiple sources of information is illustrated in the discussion below, in which the players debate the player in possession chose the wrong option:

> P3SA: "*That's not good enough…that's more a last minute [of the match decision]—you would give a long ball in, in the hope it dropped on the square, but not a ball for early on in the game*" [CURRENT MATCH CONTEXT—TIME]
>
> R: "*How does the stage of the game matter in making decisions?*"
>
> P3SA: "*I think you experiment more in the early stages of the game so you could pump a long ball in and see what happens*" [CURRENT MATCH CONTEXT—TIME]
>
> P2SD: "*I don't think you can make an excuse for that to be honest [deciding to attempt a shot]. Not at this level—you're playing against Team X in Croke park* [PRE-MATCH CONTEXT—OPPOSITION STATUS + MATCH IMPORTANCE], *you don't think that you can make a run like that up the field and score from what is he 60 yards out* [VISUAL INFORMATION—PLAYER POSITIONING]. *I'm sure they were told at training not to be wasting any possession and it's the wrong man on the ball* [PRE-MATCH CONTEXT—COACH TACTICS].

From similar discussions throughout the study, it was clear that the players, especially the Senior players, were weighting the various information sources such that one source would have more of an impact on the decision made. The three broad sources of information are all perceived, comprehended, and integrated together, to develop situation awareness, but importantly, there is a continuous trade-off between the sources of information as to which holds more weight. This is a similar process outlined by Gredin et al. (2020) when discussing the use of a Bayesian framework for anticipation in sports. This is illustrated by the discussion below about deciding between two possible options:

> R: "*some of you have said the best option would be to take the ball in [into the space], but you [P4] reckon he will actually pass the ball in—Why do we think that is?*"
>
> P4SD: "*well I think, the couple of hand passes before it, it looks like they are playing a passing game keeping it nice and short*" [PRE-MATCH CONTEXT—COACH TACTICS]
>
> P3SA: "*I actually don't think he will pass—I actually think now he has enough room to get up past the 45-yard line and take the score*" [VISUAL INFORMATION—PLAYER POSITIONING AND FIELD]

We can see that from the discussion, one individual has weighted the team tactics set out by the coach as greater than the visual information available and has therefore selected the pass option. In contrast, P3SA has weighted the visual information, specifically the space the player in possession has, greater than the tactics and has therefore selected the option of scoring. In line with situation awareness and option awareness, the desirability of the various options appears to be moderated by "underlying factors" (Pfaff et al., 2012), which as discussed in the introduction section could relate to individual differences. These individual differences moderate all aspects of the decision-making process, from integrating the various sources of information to generating the option and making the final decision. In the conversation above, the researcher followed up the discussion by asking "*when you're faced with scenarios like this what can help you make the decision between trying to make it through a gap and not taking the ball through a gap?*" [R], to which P1AA replied "*it's the confidence—you either have the confidence to run through a gap or you don't. If you don't then you might pass and let someone else take it on, but if you think you can do it and have the confidence you will take it into the gap yourself*" [INDIVIDUAL DIFFERENCES—SELF-EFFICACY]. This indicates that individuals will interpret and weigh information sources in accordance with individual differences, such as self-efficacy.

This same interaction between the information sources, and importantly that this is moderated by the fourth theme, individual differences, is seen throughout the focus group discussion. For example, the below conversation shows the interaction between visual information (teammate and opponent positioning) and pre-match context (opposition status) when forming a decision, but that this is moderated by individual differences (action capabilities, self-efficacy, and risk-taking propensity).

R: "*What would you do?*"

P1SA: "*I would bring it back and switch the point of attack*"

R: "*When you're playing can you try telling me at what point do you think 'ok, we need to change the point of attack'?*"

P1SA: "*Even if you had one more person in there you might not need to switch the play, you could play a long ball in. The fact you don't [have a player in there], he literally has nothing in front of him, so either switch the play or take on your defender*" [VISUAL INFORMATION—PLAYER POSITIONING AND FIELD SPACE]

P2SD: "*He is miles outside his scoring range*" [INDIVIDUAL DIFFERENCES—ACTION CAPABILITIES]

R: "*Does being outside what you deem to be your scoring range effect your decision making?*"

All Players: "*Yes*"

P4SA: "*It is also the amount of Team X defenders he's faced with here* [VISUAL INFORMATION—PLAYER POSITIONING AND FIELD SPACE]. *You'd look up and just see a sea of Team X players so unless you're confident to take them on and try to work it down the wing for a score then you would have to [switch the play to the other side]* [INDIVIDUAL DIFFERENCES—SELF-EFFICACY]. *You know you're playing against Team X you should be taking the safe option and playing back to start the attack again*" [PRE-MATCH CONTEXT—OPPOSITION STATUS]

R: "*Does the opposition effect your decision making?*"

P3SD: "*I think you take less risks when you are playing a strong opposition*" [INDIVIDUAL DIFFERENCES—RISK-TAKING PROPENSITY]

R: "*Why?*"

P3SD: "*You have a much higher chance of being turned over with a strong opposition-−9/10 times they will turn you over, so you have to be cautious playing against the best players*" [PRE-MATCH CONTEXT—OPPOSITION STATUS]

Interestingly, the current study suggested that this process of weighting and integrating the sources of information is mediated by individual differences but if the information source is weighted strongly enough it can take precedent. This is illustrated by P5SA who said "*say that's added time and they are down by a point… emotionally he's shooting… it depends on how your feeling and how the game is panning out, but it's the score that makes a difference to your decision*". Similarly, P3SD stated "*for me it comes back to what stage of the game it is, like no matter what your range is … if time is up and you can't get it into them then you can only do one thing and try get the shot off*". These quotes show how in this scenario, the players weigh the current match context, specifically the time and score, in such a strong manner that it overrides the individual differences of self-efficacy and action capabilities when generating the optimal option and ultimately making the final decision. What is unknown from the current study is whether this process is facilitative or detrimental to actual performance. If players are more likely to ignore individual differences, such as action capabilities, in the final stages of a match, or when behind in the score, this would suggest that more shots taken in these conditions would be missed due to poor decision-making. An approach that could be used to examine this is performance analysis of on-pitch decision-making and action execution (Lorains et al., 2013). The themes from the current study could be used to form a code window to examine on-pitch decision-making under certain pre-match contexts and current match contexts. This could have implications for coaches when training decision-making, such that the constraint of time and score is included, so the performer becomes proficient at processing this information in line with their individual differences.

Conclusion

Overall, the current study used a novel focus group approach to explore the information sources used and the factors that influence the decision-making process of Senior (expert) and Academy (near-expert) Gaelic football players. Thematic analysis revealed that participants used information sources from three primary sources, namely, pre-match context (coach tactics and instructions, match importance, and opposition status), current match context (score and time remaining), and visual information (player positioning and field space, and visual search strategy). In line with the concept of situation awareness, these sources of information are perceived, comprehended, and used to make future projections and generate options. The Senior players demonstrated a more sophisticated understanding of the various sources of information and were able to integrate them in a more complex manner to make more detailed future projections, compared to the U17 Academy players. This may be due to the extended hours of practice that the senior players had accumulated compared to the U17 Academy players (Baker et al., 2003), but may also be due to a gap in general cognitive functions between these age groups (De Luca et al., 2003). It would be good for future research to explore the decision-making processes of U20/U21 players as well who are more cognitively developed compared to the U17 players but will not have to accumulate the amount of practice hours compared to the Senior players. For both groups, the decision-making process was moderated by the final theme, individual differences (self-efficacy, risk propensity, perceived pressure, physical characteristics, action capabilities, and fatigue), as shown in Figure 1.

While the current study benefited from a focus group approach and the unique data generated therefrom, some limitations must be considered. Some participants tended to speak out more frequently, whereas others were content to listen. Moreover, some

individuals were more forceful in making their responses and points, and arguably directed the conversations more frequently, whereas others were more easily influenced by those individuals; this was more prevalent in the Academy focus groups. However, this was considered before any of the focus group sessions, and three pilot sessions were conducted with different age groups and skill levels, such that the lead researcher was well-practiced in controlling focus group discussions to ensure that each participant was able to voice their opinions and felt comfortable in doing so. Future research is required to examine the influence of, and interaction between, the various determinants of decision-making that emerged in our data. This, in turn, may provide the basis for interventions designed to enhance interceptive sports athletes' situation awareness, option awareness, and option generation—and, ultimately, their decision-making.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by College of Health, Medicine and Life Sciences Research Ethics Committee, Brunel University London. The participants provided their written informed consent to participate in this study.

Author contributions

EM, DPB, DTB, NK, and EC contributed to the conception and design of the study. EM organized the database, performed the statistical analysis, and wrote the first draft of the manuscript. EM, DPB, and DTB conducted the thematic analysis stages. All authors contributed to the manuscript revision, read, and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1142508/full#supplementary-material

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Comparisons and associations among anthropometric indices of first and second division and assistant soccer referees

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Introduction: Body composition is an important predictor of performance and a key component of health and physical fitness. Therefore, the purposes of this study were to compare soccer referees of the first and second divisions and field assistant referees from Iran and to analyze associations of a body shape index (ABSI), body adiposity index (BAI), abdominal volume index (AVI), body roundness index (BRI), conicity index (ConI), and body mass index (BMI) with body fat percentage (%BF).

Methods: A total of 270 male soccer referees from the first ($n = 124$) and second ($n = 72$) divisions and assistant referees ($n = 74$) participated in this study. Skinfold thickness (measured at the chest, biceps, triceps, subscapular, abdominal, iliac crest, and front thigh), height, weight, hip circumference, and waist circumference were assessed to evaluate waist-to-height ratio (WHtR), %BF, and also ABSI, BRI, BAI, ConI, and AVI according to the ISAK protocol.

Results: The main results indicated differences in WHR, WHtR, ABSI, BRI, AVI, ConI, and BF% with the assistant referees presenting higher values ($p < 0.05$). When considering the backward selection model, there were some associations with %BF in each group, specifically BMI, BAI, and ABSI in the first division; BMI, WHR, and ABSI in the second division; and BMI in the assistant referee group (all $p < 0.05$).

Discussion: The present study did not confirm the hypothesis that the first-division referees presented better body composition-related variables than the second division or assistant referees. Instead, it showed that the assistant referees that participated in both divisions showed a tendency to higher values which suggests that the level of division is not a major factor when analyzing body composition.

KEYWORDS

anthropometry, football, body composition, human body, height, weight

1. Introduction

Anthropometry refers to the measurements of the human individual and has been used for identifying and understanding human physical variations (Ehrampoush et al., 2017). These measurements have simple, easy, and effective characteristics that make them the first choice for structuring nutritional evaluations and interventions. Meanwhile, body composition assessment is an attempt to simplify a process that is inherently complex (Chen et al., 2016).

Research in this field illustrates that body composition has become critically important in understanding human metabolism in terms of health and performance (Thibault et al., 2012). Specifically, a high body fat percentage (%BF) is strongly associated with low fitness levels in adults (Wang et al., 2010). Furthermore, loss of muscle mass and high amounts of adipose tissue are associated with higher comorbidity (diabetes type 2, cardiovascular diseases, and cancers) and mortality (Hruby et al., 2016) rates. Similarly, in athletes, the improvement of body composition-related variables, such as lean body mass (LBM), is associated with enhanced performance and better outcomes in several exercise tests (Chiarlitti et al., 2018). Due to the importance of %BF in athleticism, its assessment is warranted. Consequently, for those working with soccer referees, the improvement of %BF is important to achieve the high physical standards required when refereeing in modern football (Casajus et al., 2014). In soccer, referees are the professionals responsible for controlling if rules are being followed during official matches (Reilly and Gregson, 2006; Schenk et al., 2018; Laws of the game 20/21, 2020). Despite their importance, only recently, research has focused on the body composition variables of soccer referees (Petri et al., 2020). When looking at the assessment of body composition, there are different methods such as measuring skinfold thickness or bioelectrical impedance measurements (U. S. Department of Health and Human Services, National Institutes of Health, 1998; Aragon et al., 2017). Recently, it has been proposed that using skinfold thickness is an easy method offering reliable results (Kasper et al., 2021). Moreover, Ashwell et al. (2012) examined some alternative indices instead of those introduced by the World Health Organization (WHO) to measure body fat, e.g., waist-to-height ratio (WHtR), conicity index (CI), and body adiposity index (BAI). Following the assessment by previous studies in overweight adolescents, it was found that there was a stronger relationship between fat mass (FM) and WHtR than between other indices such as body mass index (BMI) and body shape index (ABSI). Therefore, wherever FM cannot be measured, WHtR would be a reliable alternative to measure %BF in youth and adults (Eissmann, 1996; Ashtary-Larky et al., 2018).

In soccer, it is reported that over one million referees officiate matches every week in official competitions from all around the world (Castagna et al., 2007). A recent systematic review conducted in European and South American competitions regarding external load showed that the total average distance covered by the referees was, on average, 10–13 km throughout the entire match (Castagna et al., 2004; Mallo et al., 2009), with high-speed running distances accounting for 7%−17% of the match. This variability has been attributed to the distinct high-speed thresholds (ranging from 13.0 to 19.8 $km.h^{-1}$) adopted in published research (Weston et al., 2012), where the most predominant speed occurred below 13 $km.h^{-1}$ (Birk Preissler et al., 2023). The work rate *per* match of soccer referees is dependent on various variables, including the league level (Castagna et al., 2007), and interrelated with the work rate of outfield players, with large associations between referees and total team distance covered at a high-speed run (Weston et al., 2011).

Moreover, another study by Preissler et al. (2021) showed that the maximum heart rate and maximum speed measured during official matches were ∼170 bpm and 24 $km.h^{-1}$, respectively. The same study found a duration and percentage distance of 18% and 19%, respectively, at zones ≥90 and ≤100% of the maximum heart rate, while the speed zone (<13 $km.h^{-1}$) showed a duration and a percentage distance of 94 and 86%, respectively, during official matches. The previous findings showed that soccer is a demanding sport in terms of physical conditioning for soccer referees. Indeed, due to the intense physical and cognitive requirements of matches, attention to the anthropometric, physical, and cognitive abilities of referees is of high importance to achieve the highest performance level (Casajús and Gonzalez-Aguero, 2015). Unfortunately, a large portion of research on physical match demands in soccer referees comes from European leagues (e.g., English, Danish, and Italian) (Krustrup and Bangsbo, 2001; Castagna et al., 2004; Weston et al., 2010), while soccer referees in Asian leagues are less studied (Fernandes da Silva et al., 2022).

Nonetheless, some results mentioned before revealed higher heterogeneity because different levels of competition were evaluated (Birk Preissler et al., 2023). In this respect, another study analyzed the first vs. second-division soccer referees and found higher values for the second division over the first referees regarding repeated sprint ability. The study justified such results with the higher level of experience of first-division referees that probably used better anticipation and pitch positioning, improved decision-making skills, and economical movement patterns, which consequently decreased the need of producing more sprints during competition (Meckel et al., 2020). For the previous reasons, it is expected that body composition differences between the first and second divisions could exist although no studies could be found in this regard. On the other hand, in a study recruiting Spanish referees, no differences were found between the first- and second-division referees during the 2001–2012 pre-seasons (Casajús and Gonzalez-Aguero, 2015).

Based on the aforementioned anthropometric and body composition variables, the present study aimed to compare body composition indices among soccer referees of the first and second divisions and assistant referees who participated in both divisions from Iran. Moreover, the study also analyzed the relationships among the different indices. It was hypothesized that the first-division referees presented better body composition variables and different body composition indices presented associations with %BF.

2. Materials and methods

2.1. Experimental design

This study was designed as a cross-sectional study. All anthropometric measurements were performed during the

TABLE 1 Formulas of the anthropometric indices.

Formulas	Units
$ABSI = \frac{wc}{BMI^{2/3} \times ht^{1/2}}$	(Wc), cm/(Ht), cm/(BMI) Kg/m^2 (Krakauer and Krakauer, 2012)
$BRI = 364.2 - 365.5 \times \sqrt{1 - \frac{\left(\frac{Wc}{2\pi}\right)^2}{(0.5 \times Ht)^2}}$	(Wc), cm/Constant no. (pi = 3.14159), π/(Ht), m (Thomas et al., 2013)
$WHR = \frac{wc}{hc}$	(Wc), cm/(Hc), cm (Han et al., 1997)
$BAI = \frac{hc}{Ht^{1.5}} - 18$	(Hc), cm/(Ht), m (Wc), cm/(WHR) (Bergman et al., 2011)
$AVI = \frac{2wc^2 + 0.7(Wc - hc)^2}{1{,}000}$	Valdez et al., 1993
$ConI = \frac{Wc}{0.109 \times \sqrt{\frac{Wt}{Ht}}}$	(Wc), m/(Wt), Kg/(Ht), m (Valdez, 1991)
$WHtR = \frac{wc}{ht}$	(Wc), cm/(Ht), cm (Han et al., 1997)
$Body\ Density = 1.112 - 0.00043499\ (\Delta sf) + 0.00000055\ (\Delta sf^2) - 0.00028826\ (age)$ (Cowan, 2013) $\Delta sf = \Sigma\ Chest, Midaxillary, Triceps, Subscapular, Abdomen, Suprailiac, Thigh$ Age: Years	
$Body\ Fat\ \% = \frac{457}{Body\ density} - 414$ (Brodie and Slade, 1988)	

ABSI, A Body Shape Index; BRI, Body Roundness Index; ConI, Conicity Index; Wc, waist circumference; Ht, height; AVI, Abdominal Volume Index; BAI, body adiposity index; BMI, body mass index; Hc, hip circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; Wt, weight.

2019–2020 in-season (March–April) before the outbreak of the COVID-19 pandemic in Iran.

2.2. Participants

The participants of this study were 270 male referees (124 first-division referees with an age, mean (standard deviation), of 28.0 (3.2) years, a mass of 72.5 (4.7) kg, a height of 175.9 (4.3) cm, and 8 years of experience, 72 second-division referees with an age of 28.5 (3.5) years, a mass of 74.8 (5.1) kg, a height of 175.4 (4.3), and 11 years of experience, and 74 field assistance referees with an age of 29.1 (3.3) years, a mass of 72.9 (4.9) kg, a height of 175.8 (4.0) cm, and 11 years of experience from the Iranian Football Federation). The assistant referees participated both in the first and second divisions. All participants provided informed written consent prior to participation. This study was conducted in accordance with the Declaration of Helsinki and approved by the Sports Science Research Institute of Iran (IR.SSRC.REC.1399.062).

2.3. Anthropometric assessment

This study used the international standards of the International Society for the Advancement of Kinanthropometry (ISAK). Measurements of skinfold thickness were performed at seven sites around the body (biceps, triceps, subscapular, iliac crest, supraspinal, abdominal, anterior thigh, and medial calf) as well as of weight, height, and WHR (waist-circumference and hip-circumference). Skinfold calipers (Harpenden, UK) with a sensitivity of 10 g/mm pressure on the skin, an anthropometric meter (Lufkin W606PM, UK), a stadiometer (Jushi No. 26SM, China) with an accuracy of 0.1 cm, and a weight scale (Maxy No. 9388, China) accurate to 0.1 kg were employed. In accordance with the ISAK protocol, duplicate measures were taken at each site, and, where the technical error of measurement (TEM) was <5%, the mean value was reported, and where the TEM was >5%, a third measure was taken and the median value was reported (Gibson-Smith et al., 2020; Nobari et al., 2020). It should be noted that all anthropometric measurements were performed by a 4-year expert with level 2 of ISAK certification in this field. The subjects were instructed to refrain from strenuous exercise on the day before measurements and not to smoke and drink alcohol, tea, and coffee on the day of testing. They were also asked not to exercise for 3 h, leading them to the tests. All anthropometric measurements were executed in the morning to increase the reliability of the measurement (Rahmat et al., 2016). Table 1 presents the formulas of the indices.

2.4. Statistical analysis

Descriptive statistics were conducted: means and standard deviations were used to characterize variables for each group as well as coefficients of variation (CVs). Kolmogorov–Smirnov and the Levene tests were used to test the assumption of normality and homoscedasticity, respectively. Then, comparisons were made through one-way analysis of variance (ANOVA) among all groups of referees. The significance level considered for all tests was a two-tailed p-value of < 0.05. In the case of multiple comparisons between different indices in the first, second, and assistant group divisions, the adjustment method of false discovery rate (FDR) correction (Benjamini–Hochberg procedure) was used. The q-value has also been calculated.

The eta-squared value was used to calculate the effect size (ES) for comparisons between groups and its value was used to determine the magnitude of the effect using the following rule of thumb: 0.01 indicates a small effect, 0.06 indicates a medium effect, and 0.14 indicates a large effect. For comparisons between two groups, the ES calculated relied on Cohen's d, and its magnitude of significance was interpreted as follows: <0.2 = trivial, 0.2–0.6 = small effect, 0.6–1.2 = moderate effect, 1.2–2.0 = large effect, and >2.0 = very large (Liang et al., 2019).

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TABLE 2 Comparison of BMI, WHT, WHtR, ABSI, BRI, AVI, BAI, CI, and %BF values broken down by soccer referee groups (first, second division, and assistant referees).

Parameters	CV	Group	Mean (SD)	CI, 95%	*P*-value	Eta-squared value
Weight (kg)	6.8%	1st	73.02 (5.60)	(72.02, 74.02)	0.315	0.01
		2nd	74.02 (3.74)	(73.15, 74.90)		
		A	72.92 (4.98)	(71.76, 74.07)		
Height (cm)	2.4%	1st	175.71 (4.66)	(174.89, 176.54)	0.976	0.00
		2nd	175.78 (3.63)	(174.93, 176.63)		
		A	175.85 (4.07)	(174.91, 176.79)		
BMI (kg/m^2)	7.7%	1st	23.69 (2.04)	(23.32, 24.05)	0.408	0.01
		2nd	23.98 (1.46)	(23.64, 24.32)		
		A	23.60 (1.74)	(23.19, 24.00)		
WHR	10.7%	1st	0.81 (0.10)	(0.79, 0.83)	<0.001*	0.07
		2nd	0.80 (0.07)	(0.78, 0.82)		
		A	90.86 (0.06)	(0.84, 0.87)		
WHtR	8.7%	1st	0.43 (0.04)	(0.42, 0.44)	0.005*	0.04
		2nd	0.42 (0.03)	(0.42, 0.43)		
		A	0.44 (0.03)	(0.44, 0.45)		
ABSI [$WC/(BMI^{2/3}*height^{1/2})$]	17.0%	1st	0.010 (0.002)	(0.010, 0.011)	0.017*	0.03
		2nd	0.010 (0.001)	(0.009, 0.010)		
		A	0.011 (0.002)	(0.010, 0.011)		
BRI	27.9%	1st	2.16 (0.68)	(2.04, 2.28)	0.006*	0.04
		2nd	2.07 (0.53)	(1.94, 2.19)		
		A	2.38 (0.52)	(2.26, 2.50)		
AVI	17.1%	1st	11.48 (2.20)	(11.08, 12.59)	0.004*	0.04
		2nd	11.18 (1.75)	(10.77, 11.59)		
		A	12.21 (1.65)	(11.82, 12.59)		
BAI (kg/m^2)	14.7%	1st	22.36 (3.57)	(21.72, 22.99)	0.033*	0.03
		2nd	22.09 (2.99)	(21.39, 22.80)		
		A	21.14 (2.69)	(20.51, 21.76)		
ConI ($cm^3/2{\cdot}kg^{-1/2}$)	8.7%	1st	107.46 (10.32)	(105.62, 109.30)	<0.001*	0.05
		2nd	105.47 (8.79)	(103.40, 107.54)		
		A	111.18 (7.42)	(109.46, 112.89)		
%BF	46.4%	1st	8.65 (2.82)	(8.15, 9.15)	<0.001*	0.77
		2nd	7.92 (2.00)	(7.45, 8.39)		
		A	18.53 (2.40)	(17.97, 19.08)		

1st, first-division referees; 2nd, second-division referees; A, assistant referees; BMI, body mass index; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; ABSI, A Body Shape Index; BRI, Body Roundness Index; AVI, Abdominal Volume Index; BAI, Body Adiposity Index; ConI, Conicity Index; CV, coefficient of variation.
*$P < 0.05$.

In general, the association of %BF with other variables was studied by using regression models. Basic assumptions for conducting regressions (heteroscedasticity, collinearity, or outliers) were checked. Tolerance collinearity statistics was used to verify multicollinearity. Backward selection (known also as backward elimination) was employed to achieve the highest association possible. In the best-implemented regression model, %BF was the dependent variable and BMI, and WHR, WHtR, ABSI, BRI, AVI, BAI, and ConI variables were the independent variables.

More in detail, based on the backward selection regression model, in the first step, all variables were entered into the regression model. Then, at each step, the most insignificant variable that had the least effect on %BF was removed from the regression model. This process continued as long as it was possible, and the regression

TABLE 3 Multiple comparisons between different indices in the first, second, and assistant group divisions using the adjustment method of false discovery rate (FDR) correction (Benjamini–Hochberg procedure).

Indices	Mean difference (1st vs. 2nd)	*P*, *q*; ES (1st vs. 2nd)	Mean difference (1st vs. A)	*P*, *q*; ES (1st vs. A)	Mean difference (2nd vs. A)	*P*, *q*; ES (2nd vs. A)
Weight (kg)	−1.002	0.530, 0.815; 0.20	0.106	>0.999, 0.999; 0.02	1.109	0.543, 0.815; 0.25
Height (cm)	−0.066	>0.999, 0.999; 0.02	−0.137	>0.999, 0.999; 0.03	−0.071	>0.999, 0.999; 0.02
BMI (kg/m2)	−0.293	0.833, 0.999; 0.16	0.087	>999, 0.999; 0.05	0.381	0.623, 0.999; 0.24
WHR	0.007	>0.999, 0.999; 0.07	−0.049	<0.001*, 0.002; 0.55	−0.056	<0.001*, 0.002; 0.79
WHtR	0.005	>0.999, 0.999; 0.13	−0.014	0.031*, 0.047; 0.37	−0.019	0.006*, 0.018; 0.60
ABSI [WC/($BMI^{2/3}$* $height^{1/2}$)]	0.00046	0.219, 0.329; 0.26	−0.00036	0.476, 0.476; 0.20	−0.00082	0.013*, 0.039; 0.54
BRI	0.097	0.834, 0.834; 0.15	−0.215	0.049*, 0.074; 0.34	−0.312	0.006*, 0.018; 0.59
AVI	0.300	0.899, 0.0.899; 0.15	−0.729	0.034*, 0.049; 0.36	−1.029	0.005*, 0.015; 0.61
BAI (kg/m^2)	0.263	>0.999, 0.999; 0.08	1.220	0.030*, 0.090; 0.37	0.957	0.215, 0.323; 0.34
ConI ($m^{3/2}\cdot kg^{-1/2}$)	1.989	0.437, 0.437; 0.20	−3.717	0.019*, 0.028; 0.40	−5.706	<0.001*, 0.003; 0.70
%BF	0.733	0.151, 0.151; 0.29	−9.879	<0.001*, 0.001; 3.69	−10.611	<0.001*, 0.001; 4.80

The q-value has also been calculated.
1st, first-division referees; 2nd, second-division referees; A, assistant referees; AVI, Abdominal Volume Index; ABSI, A Body Shape Index; BMI, body mass index; BRI, Body Roundness Index; BAI, Body Adiposity Index; CI, Conicity Index; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.
*$P < 0.05$.

model could retain and obtain one or more significant variables (the so-called stopping rule).

All the statistical analyses were performed using the commercial software "Statistical Package for Social Sciences" (SPSS) for Windows (Version 28.0, IBM Corp., Armonk, NY, USA).

3. Results

The study included 270 referees, 124 (50%) from the first division, 72 (25.24%) from the second division, and 74 (24.76%) from assistant referees (A division). Comparisons of the three groups are presented in Table 2.

Weight, height, and BMI did not differ between groups. WHR, WHtR, ABSI, BRI, AVI, and ConI indices showed a significant difference among groups but with a very small ES with the assistant referees showing higher values than other referee groups. %BF was also higher in the assistant referees, with a large effect.

In the BAI index, the results also showed a significant difference between the groups with the first-division referees presenting higher values than other referees' groups. In Table 3, group-by-group comparisons were presented.

In Table 4, there was no significant effect between %BF and other variables. For this reason, the backward selection regression model was used for each division in Table 5.

Table 5 shows that BAI and ABSI had a significant effect on %BF in the first-division referees (respectively, $B = 0.174$, Beta $= 0.219$, P-value $= 0.030$; $B = 1588.1$, Beta $= 1.098$, P-value $= 0.031$). If the level ($\alpha = 0.1$) is considered, BMI had a significant effect on %BF (P-value < 0.01). In the second-division referees, BMI, WHR, and ABSI variables with level ($\alpha = 0.1$) can be considered to have a significant effect on %BF (P-value < 0.01). In the assistant referees, BMI had a significant effect on %BF ($B = 1.314$, Beta $= 0.955$, P-value < 0.001).

4. Discussion

The study aimed to compare soccer referees of three groups: first and second divisions and assistant referees from Iran and to correlate different body composition indices. Considering the comparison analysis, there were differences in WHR, WHtR, ABSI, BRI, AVI, CI, and BF%, with the assistant referees presenting higher values. Concerning the BAI values, they tended to be slightly higher for referees of the first division even though they did not achieve the significance threshold and exhibited a small ES. Between the first and second divisions, there were no differences in all measures, while weight, height, and BMI did not show significant differences among the three groups.

WHR and BRI enabled the prediction of both body fat and the percentage of visceral adipose tissue (Thomas et al., 2013; Swainson et al., 2017). According to the measured values, both %BF and AVI were higher in the assistant referees, as well as WHR. While the present research is based on the %BF and several indices, research on WHR has investigated related health aspects and its capability to predict metabolic syndrome and fatty liver (Motamed et al., 2016). Based on this, Motamed et al. (2016) indicated that there was a weak correlation between WHR and non-alcoholic fatty liver disease. However, the waist circumference, WHR, WHtR, and AVI were reported as the strongest anthropometric discriminators of metabolic syndrome (Aune et al., 2016; Fontela et al., 2017) which may be an indicator of less favorable physical fitness (Wang et al., 2018; Wu et al., 2021). On the other hand, considering previous

TABLE 4 Associations between variables, BMI, BRI, BAI, WHR, WHtR, ABSI, AVI, and ConI with BF% by using a backward selection regression model.

Division	Variable	Unstandardized coefficients		Standardized coefficients	*T*	*P*-value	%95 Confidence interval for *B*	
		B	SE	Beta			Lower	Upper
1st (R 0.34, R^2 0.12)	Constant	20.535	45.618		0.450	0.653	−69.826	110.896
	BMI	0.573	1.703	0.414	0.336	0.737	−2.801	3.946
	BRI	5.703	10.088	1.380	0.565	0.573	−14.280	25.686
	BAI	.633	0.400	0.799	1.582	0.116	−0.159	1.424
	WHR	19.463	18.241	0.687	1.067	0.288	−16.668	55.595
	WHtR	−158.992	283.430	−2.384	−0.561	0.576	−720.413	402.429
	ABSI	1,613.399	1,421.067	1.115	1.135	0.259	−1,201.461	4,428.259
	AVI	1.543	2.333	1.204	0.661	0.510	−3.078	6.163
	CI	−0.314	1.140	−1.148	−0.276	0.783	−2.573	1.944
2nd (R 0.22, R^2 0.05)	Constant	63.095	58.520		1.078	0.285	−53.813	180.003
	BMI	−1.835	1.271	−1.337	−1.444	0.154	−4.374	0.704
	BRI	1.981	6.333	0.525	0.313	0.755	−10.671	14.632
	BAI	0.380	0.752	0.568	0.505	0.615	−1.122	1.881
	WHR*	19.798	37.342	0.744	0.530	0.598	−54.800	94.396
	ABSI	−1,232.750	1,919.792	−0.872	−0.642	0.523	−5,067.975	2,602.476
	AVI	0.894	2.275	0.781	0.393	0.695	−3.650	5.439
	CI	−0.354	0.852	−1.555	−0.415	0.679	−2.056	1.348
A (R 0.96, R^2 0.92)	Constant	10.118	27.279		0.371	0.712	−44.363	64.598
	BMI	0.786	0.903	0.571	0.871	0.387	−1.017	2.588
	BRI	1.805	6.215	0.395	0.290	0.772	−10.606	14.216
	BAI	0.176	0.442	0.197	0.398	0.692	−0.707	1.059
	WHR	6.936	18.971	0.189	0.366	0.716	−30.950	44.823
	WHtR	−32.156	156.697	−0.420	−0.205	0.838	−345.102	280.789
	ABSI	−235.503	716.756	−0.158	−0.329	0.744	−1,666.964	1,195.957
	AVI	0.447	1.347	0.307	0.332	0.741	−2.244	3.137
	CI	−0.115	0.609	−0.355	−0.188	0.851	−1.331	1.102

1st, first-division referees; 2nd, second-division referees; A, assistant referees; AVI, Abdominal Volume Index; ABSI, A Body Shape Index; BMI, body mass index; BRI, Body Roundness Index; BAI, Body Adiposity Index; CI, Conicity Index; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

*In the results of the second division, WHtR has been removed from the regression model due to strong collinearity (Tolerance Collinearity Statistics <0.001) with other variables. Significance level at a *P*-value of <0.05.

studies (Aune et al., 2016; Motamed et al., 2016; Fontela et al., 2017; Wang et al., 2018; Wu et al., 2021), WHR, WHtR, and AVI seem to be less relevant in sports professionals.

The ConI is an index of abdominal obesity that was developed based on a model of geometric reasoning (Valdez, 1991) and proved to be sensitive and better than the waist-to-hip ratio as an indicator of risk for hyperlipidemia (Christakoudi et al., 2020). Despite the first and second referees in the present study did not reveal significant differences, the assistant referees showed differences. According to parameters such as weight, height, and WC, evidence of less mass tissue accumulation could be found at the abdominal level in the first and second referees (Valdez, 1991; Motamed et al., 2016). However, it was not clear why assistant referees presented higher values, which is suggested to be explored in future studies.

The ABSI, which represents an alternative index to the indices of abdominal obesity, has an important allometric component because it enables the identification of individuals with normal weight but with abdominal obesity (Christakoudi et al., 2020). No differences were found between the first- and second-division referees in this parameter, but assistant referees differed from the other categories of referees. This may also be related to anthropometric differences in height and in the quantity and pattern of body mass distribution since the allometric component has a strong influence on this index. Moreover, it is also important to note that ABSI was considered to have an effect on %BF in both

TABLE 5 Regression model (backward selection) for achieving the highest association with BF%.

Division	Variable	Unstandardized coefficients		Standardized coefficients	*T*	*P*-value	%95 Confidence interval for *B*	
		B	SE	Beta			Lower	Upper
1st (R 0.29, R^2 0.09)	Constant	−31.531	17.342		−1.818	0.072	−65.870	2.809
	BMI	1.317	0.701	0.953	1.879	0.063	−0.071	2.705
	BAI	0.174	0.079	0.219	2.203	0.030*	0.018	0.330
	WHtR	−26.378	17.474	−0.396	−1.510	0.134	−60.979	8.223
	ABSI	1,588.114	726.719	1.098	2.185	0.031*	149.138	3,027.090
2nd (R 0.21, R^2 0.05)	Constant	33.740	16.634		2.028	0.046	0.539	66.941
	BMI	−1.415	0.846	−1.032	−1.673	0.099	−3.104	0.273
	BAI	0.377	0.239	0.563	1.577	0.119	−0.100	0.853
	WHR	20.152	11.608	0.757	1.736	0.087	−3.018	43.322
	ABSI	−1,653.909	939.470	−1.170	−1.760	0.083	−3,529.100	221.282
A (R 0.96, R^2 0.91)	Constant	−12.490	1.137		−10.980	<0.001	−14.757	−10.222
	BMI	1.314	0.048	0.955	27.346	<0.001**	1.219	1.410

($\alpha = 0.1$). *$P < 0.01$; ($\alpha = 0.05$). **$P < 0.05$.
1st, first-division referees; 2nd, second-division referees; A, assistant referees; AVI, Abdominal Volume Index; ABSI, A Body Shape Index; BMI, body mass index; BRI, Body Roundness Index; BAI, Body Adiposity Index; CI, Conicity Index; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

the first and second groups, while this was not noted in the assistant referee group. The fact that there were no differences in BMI in the three categories may be due to the fact that when comparing the different indices, the distribution of body mass may not have a direct relationship with allometry. Assistant referees showed a higher value in the WHR and %BF; nonetheless, these values were classified as healthier [World Health Organization (WHO), 2021].

It could also be mentioned that individuals with normal weight and abdominal obesity can show metabolic alterations, while obese individuals without abdominal adiposity can remain "metabolically healthy." Nevertheless, while general obesity is widely evaluated with BMI (Fontela et al., 2017), according to the WHO categories (Birk Preissler et al., 2023), there is no current consensus on how best to assess abdominal adiposity, and various anthropometric indices incorporating waist circumference have been proposed in the literature (Thomas et al., 2013; Fontela et al., 2017; Woolcott and Bergman, 2018; Ofstad et al., 2019).

In summary, although BMI was similar in the three categories, it did not allow us to discern the organic distribution of the adipose tissue. Nonetheless, BMI was revealed to have a significant influence on %BF in all groups. However, the highest BAI values in the first and second referees were incongruous with respect to the rest of the results. All other differences in anthropometric parameters were in line with what is expected for referees in the first and second divisions with greater physical demands during games, regarding an external load (Preissler et al., 2021).

Despite the robustness of the present findings, this cross-sectional study had some limitations such as the fact that it was not possible to determine cause-and-effect relationships. Moreover, body composition was assessed through non-considered reference methods but, according to a recent study, anthropometry can also be used for valid FM% estimations (Campa et al., 2023). In addition, nutritional habits (Sarkar et al., 2019; Afrifa et al., 2020) could probably help justify why assistant referees tended to have higher values. This is even more important to highlight because assistant referees included professionals who performed in both the first and second divisions which makes plausible the speculation that the division level is not the most important variable to consider. However, nutritional habits were not assessed.

Future studies can include other variables from other dimensions such as internal/external measures and interventions/training protocols while controlling for nutritional habits to provide knowledge about the variations over the full soccer season. In addition, women referees should also be included to provide comparisons between sexes.

Finally, the strengths of this study were related to the large sample size and comprehensive body composition characterization of soccer referees. We provided data from Iran, which did not show significant differences between the level of divisions, which is similar to previous research (Casajús and Gonzalez-Aguero, 2015).

5. Conclusion

The present study did not confirm the hypothesis that the first-division referees presented better body composition-related variables than the second division or the assistant referees. In fact, the first- and second-division referees presented similar values for all variables, while assistant referees showed higher values in WHR, WHtR, ABSI, BRI, AVI, CI, and %BF. Instead, the present

study showed that the assistant referees that participated in both divisions showed a tendency to higher values which suggests that the level of division is not a major factor when analyzing body composition.

When considering the backward selection model, there were some associations with %BF in each group, specifically BMI, BAI, and ABSI in the first division; BMI, WHR, and ABSI in the second division; and BMI in the assistant referee group. However, given the above-mentioned shortcomings, further research in the field is urgently warranted.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the IRBs of the Iranian Universities which took part into the study. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer KI declared a shared affiliation with the author MHS to the handling editor at the time of review.

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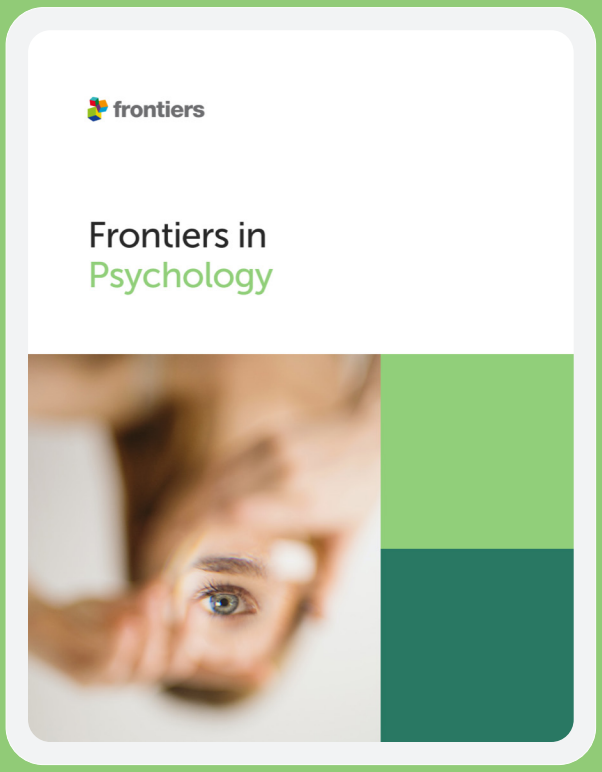

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