ORIGINAL ARTICLE

Impact of substitutions on elite soccer team performance based on player evaluation system

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ABSTRACT

This research aimed to explore the performance characteristics of substitutions and to evaluate the performance of substitutions based on the player evaluation system. Event data of 643 substitutions identified from the Chinese Super League teams in the 2019-2020 season were used. The team ratings, ball possession, and expected threat of four periods (5 minutes per period before and after the substitution) of each substitution were computed. Two-step cluster analysis was performed on the team ratings at different times, and the Scheirer–Ray–Hare test was used for the two-factor design based on the cluster and the substitutions across four periods. The cluster analysis revealed 5 clusters with a Bayesian Information Criterion (BIC) value of 1,360.50. The interactions of team ratings between the periods and the clusters in different groups were detected (H = 531.96, $p < .001$, $E_R^2 = 0.47$). The group comparisons suggested that the ratings of Cluster 3 showed a significant decline after substitutions, which was caused by the lower ball possession while showing greater aggressiveness in terms of expected threat. The study shows how player evaluation systems can be used to measure the effectiveness of substitutions in soccer games and provides insight for further analysis of decision-making situations.

Keywords: Performance analysis, Soccer, Match analysis, Substitution, Technical-tactical performance, Player evaluation.

Cite this article as:
Wu, J., Li, Y., Zhou, C., Xiong, X., Qin, X., & Cui, Y. (2025). Impact of substitutions on elite soccer team performance based on player evaluation system. *Journal of Human Sport and Exercise, 20*(1), 316-327. https://doi.org/10.55860/sbh12g81

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Submitted for publication September 19, 2024.
Accepted for publication November 08, 2024.
Published December 08, 2024. Amended publication December 10, 2024.
Journal of Human Sport and Exercise. ISSN 1988-5202.

doi: https://doi.org/10.55860/sbh12g81

INTRODUCTION

Decision-making has been an important topic in the study of team sports performance analysis, ranging from the choice of technical actions or movement types made by players on the field, as well as those made by managers and coaches (Nosek et al., 2021). Research on strategic decision-making in football includes a variety of aspects such as substitutions, structures of formations, playing styles, and physical distribution (Castillo-Rodríguez et al., 2023; Gollan et al., 2018; Passos et al., 2016). Among these, substitutions that can influence physical demands and tactics have garnered increasing attention in recent years. This is partly due to the implementation of FIFA's new rules (*International Federation of Association Football*, 2020) , which increased the maximum number of substitutions per team from three to five (García-Aliaga et al., 2023; Hills et al., 2020). Not only does the decision of substitution counteract team fatigue to prevent injuries, but it also allows for a change in the game's pace by adjusting the team formations (Bradley et al., 2014; Hills et al., 2018). It might be one of the most direct and effective ways for coaches to get involved and help in the game, which therefore demands more scientific investigation.

The current analysis of substitution performance in soccer matches could be divided into several aspects, namely the timing of substitutions (Myers, 2012; Silva & Swartz, 2016), modifying tactical behaviour through substitutions (Amez et al., 2021; Gómez et al., 2016), exploring the running performance and physical demands of substitutions (Bradley et al., 2014; Carling et al., 2010), assessing the psychological state of substitutions (Woods & Thatcher, 2009). In contrast to earlier academic investigation, which proposed that three substitutions occurring before the 58th, 73rd, and 79th minutes (Myers, 2012), another study that considered team quality and game status suggested that simply evaluating substitution timings in isolation to measure their effectiveness within the game context might be inadequate (Silva & Swartz, 2016). Extensive research has elucidated that trailing teams tend to substitute at an earlier stage in the match compared to their leading counterparts, and such tactical changes often lead to more favourable outcomes (Amez et al., 2021; Gómez et al., 2016). A study based on substitution types has found that different types of substitutions can reflect a team's tactical intention and simultaneously enhance offensive efficiency or reinforce defensive resilience (Lorenzo-Martínez et al., 2021). It seems widely acknowledged that offensive substitutions increase the probability of goal-scoring (Wittkugel et al., 2022), yet the effectiveness of defensive substitutions in preventing goal-scoring opportunities remains a subject of ongoing debate (Conte et al., 2016; Del Corral et al., 2008; Gómez et al., 2016). When it comes to running performance, there have been various studies showing that the total distance and the high-intensity runs by midfield substitutes in the second half are greater than those covered by the replaced players or teammates of the same position (Bradley et al., 2014; Bradley & Noakes, 2013; Coelho et al., 2012). Meanwhile, the interval between their high-intensity runs is shorter (Carling et al., 2010).

These studies consider the effects of various contextual variables, including scoreline, home advantage, and team rankings, thereby elucidating more profound insights derived from practical experiences. Nonetheless, it is worth noting that a substantial portion of these substitution studies tends to overlook the on-field position and behaviours of players. The criteria employed to assess the impact of substitutions are often confined to goal differences or changes in the scoreline (Leeuwen, 2020). As a consequence, the scope is relatively limited when it comes to providing comprehensive evaluation of substitutions made for the diverse tactical objectives of teams.

Therefore, adopting a multivariate approach could be a potential solution for the research topic. Specifically, advanced or hybrid performance indicators were proposed and could be used to evaluate the effect of substitution. For instance, the ball possession, which is widely known for assessing the team's performance

in soccer, suggests that the high percentage of ball possession in the penalty box may contribute to goals scored (Link & Hoernig, 2017; Parziale & Yates, 2013; Wang et al., 2022). Recently, expected threat (xT) was introduced as an aggregated metric of the expected goal (xG) (Eggels et al., 2016; Rathke, 2017) and ball possession to evaluate individual actions related to attacking (Singh, 2019). Following this development, several innovative frameworks were put forward to achieve a more comprehensive evaluation of match performance. Decroos et al. (2019) estimated the probability of goals and concedes and used it as a value to rate single action. Other researchers combined the value of multiple players to evaluate team performance (Bransen & Van Haaren, 2020). Moreover, some studies further refined the on-ball value of attacking and organizing behaviours (Li et al., 2020), and adopted performance indicators of both competing teams to determine the defensive effectiveness (Ruan et al., 2022). These models offer specific references for coaches and players and are the main components of the player evaluation approach selected in this research.

Given the above rationale, the purpose of this study was to explore the effectiveness of substitutions from the perspective of team evaluation and analyse the timing of substitutions and offensive performance metrics before and after substitutions. The hypothesis was that differences in team performance ratings, xT, and ball possession percentages before and after substitutions would be statistically significant, and that ratings could be affected more by the period of substitutions than by the other two evaluation methods. Meanwhile, it is expected that the findings could provide a practical framework that applies a player evaluation system to the decision-making scenario of substitutions, offer insights into team dynamics during different phases of the match, and inform coaches and players about the impact of different evaluation methods on substitution decisions.

METHOD

Sample

The study considered 643 substitutions from 240 matches played by 16 Chinese Super League (CSL) teams during the 2019 season. Match event datasets were retrieved from the public-access football statistics website named "*whoscored.com*", whose data were provided by the international sports data provider OPTA Sports with verified reliability (ICC ranging from 0.88-1.00) (Liu et al., 2013). Originally, there were a total of 1368 substitutions, and 725 of them failing to meet the following criteria were excluded: i) The time segment contains 5 minutes prior to and 15 minutes posterior to each substitution, e.g. if a match ended at 90 minutes, any substitutions made after the 75th minute were excluded; ii) Substitutions resulting from unexpected injuries and dismissals (red card) (Gómez et al., 2016); iii) Players entering as substitutes had to have appeared in at least one game in the previous season. Ethical approval for this study was granted by the local ethics committee and conformed to the recommendations of the Declaration of Helsinki.

Variables and procedures

According to the scientific literature that analysed substitutions during soccer matches (Hills et al., 2018), 4 contextual and 15 individual indicators were chosen from the raw data as independent variables in the analysis. The description and definitions of these two types of performance indicators are presented in Table 1. Since the study does not focus on comparisons in match behaviour between substitutes and starters, these variables were selected to describe both contextual factors and team performance.

Instead of using potentially biased goal scores to assess substitution effects, the study considered several approaches of on-the-ball action rating during the match after comprehensively comparing their characteristics. Firstly, the percentage of ball possession was included as it could provide intuitive and

understandable information about the rhythm and momentum of the match (Wang et al., 2022). Additionally, the study incorporated Expected Threat (xT), which quantifies the threat associated with on-the-ball events based on ball possession data (Singh, 2019; Sumpter, 2021; Van Roy et al., 2020). The study has undertaken the selection of pertinent features, encompassing the three-dimensional coordinates of the ball within the goal area, shot locations, the length and angle between the goal and the ball, the body parts involved in player actions, assist types, and the ultimate outcomes of shots. These features collectively form the foundation of the expected goal (xG) model. The approach adopted involves the allocation of xG values to distinct regions on the football pitch, contingent upon the likelihood that possessing the ball in each area will culminate in a goal during a possession phase. Furthermore, the effectiveness of these actions is assessed by calculating changes in grid values before and after ball movements, thus quantifying the expected threat associated with these actions.

Table 1. Description and definition of the performance indicators.

Variables	Description
Contextual	
Match location	The team making the substitution playing home or away
Match status	The goal difference between the team making the substitution and the opponent
Ranking	The substitution team's ranking
Opponent Ranking	The opponent team's ranking
Individual	
Number of minutes remaining	Time remaining in the current match
Number of substitutions remaining	The number of substitutions remaining in the current substitution team
Substitution type	Three types of substitutions constructed according to the position the player is replaced, which are offensive substitution, neutral substitution and defensive substitution; Positions were categories in 5 by player vector last season, including strikers, central midfielders, wing forwards, fullbacks and central backs
Rating/Possession/Expected threat within 5 minutes before substitution	Team rating/possession/expected threat of the game performance in the first 5 minutes before the substitution based on the player evaluation system
Rating/Possession/Expected threat within the first 5 minutes after substitution	Team rating/possession/expected threat of the game performance in the first 5 minutes after the substitution based on the player evaluation system
Rating/Possession/Expected threat within the second 5 minutes after substitution	Team rating/possession/expected threat of the game performance in the second 5 minutes after the substitution based on the player evaluation system
Rating/Possession/Expected threat within the third 5 minutes after substitution	Team rating/possession/expected threat of the game performance in the third 5 minutes after the substitution based on the player evaluation system

Moreover, the study employs Li's (2022) player assessment system, which relies on four key individual player attributes to formulate rating models: shot, organization, skill, and defence, each considering event types and qualifiers. These models integrate the risk-reward paradigm (Goes et al., 2022) and yield two distinct models per attribute. For shot ratings, the model calculates the value of a shot by subtracting xG_2 (considering only on-target shots) from xG_1 (considering all shots), normalized relative to the player's total number of shots per match. In organization and skill ratings, threatened situations encompass events like shots, penalties, crosses, opponent clearances, opponent goalkeeper strikes, and the opponent's own goals. The models differentiate between situations arising after 5 and 3 events, respectively. Ratings for organization and skill are derived from the difference between threatened and lost values of a player's total actions (e.g., passes and dribbles per match). Defence ratings are determined by comparing the probability of maintaining possession after 3 defensive actions and the probability of conceding a shot after 5 defensive actions. All models use XGBoost, LightGBM, and CATboost, which are three Gradient Boosting Decision Tree-based frameworks. After training and optimization, the LightGBM model was selected as optimal due to its superior

performance. Player and team ratings are then calculated by summing ability ratings after min-max normalization, offering a precise measure of individual and team performance during matches.

Statistical analyses

The two-step cluster analysis was suitable for handling both ordinal and nominal data based on the distance measure (Chiu et al., 2001), which was performed accordingly on the team ratings at various times before and after substitutions. The time intervals included 5 minutes prior to substitutions and three subsequent 5-minute periods following each substitution. The Bayesian Information Criterion (BIC) and the Ratio of Distance Measures were the statistical measures of fit in a two-step cluster analysis (Bacher et al., 2004; Kent et al., 2014) for assessing team ratings. The Scheirer–Ray–Hare test, a nonparametric test (Scheirer et al., 1976), was used for the two-factor design when the hypothesis of sphericity and normality was not satisfied ($p < .05$) based on the cluster and the substitutions over four periods (5 minutes per period before and after the substitution). The variables of team ratings, ball possession, and the expected threat during the four periods of the substitutions were analysed using the Scheirer–Ray–Hare test. Post-hoc multiple comparisons were conducted with the Mann-Whitney U test with the significance level adjusted. The effect size estimations for the Scheirer-Ray-Hare test were computed using epsilon-squared (E_R^2) whose thresholds of magnitude: negligible, <0.01; weak, 0.01-0.04; moderate, 0.04-0.16; relatively,0.16-0.36; strong, 0.36-.64 (Tomczak & Tomczak, 2014). In addition, the value of the correlation coefficient (r) was computed as the effect size estimations for the post-hoc Mann-Whitney U test with thresholds of magnitude: negligible, <0.1; weak, 0.1-0.39; moderate, 0.39-0.69; strong,0.69-0.89; and very strong, >1.00 (Hopkins et al., 2009; Schober et al., 2018). The level of significance was set at $p < .05$. All analyses were performed using the statistical software R version 4.2.2 and Python 3.

RESULTS

According to the descriptive statistics, the ratio of home (48.1%) and away (51.9%) games was nearly equal in all samples. The proportion of samples ranked higher (50.4%) than their opponents was roughly equivalent to those ranked lower (49.6%). The distribution of the frequency of substitutions of different types and numbers during the game period is shown in Figure 1. The stacked column diagram represents the type of substitution, and the area diagram represents the number of substitutions.

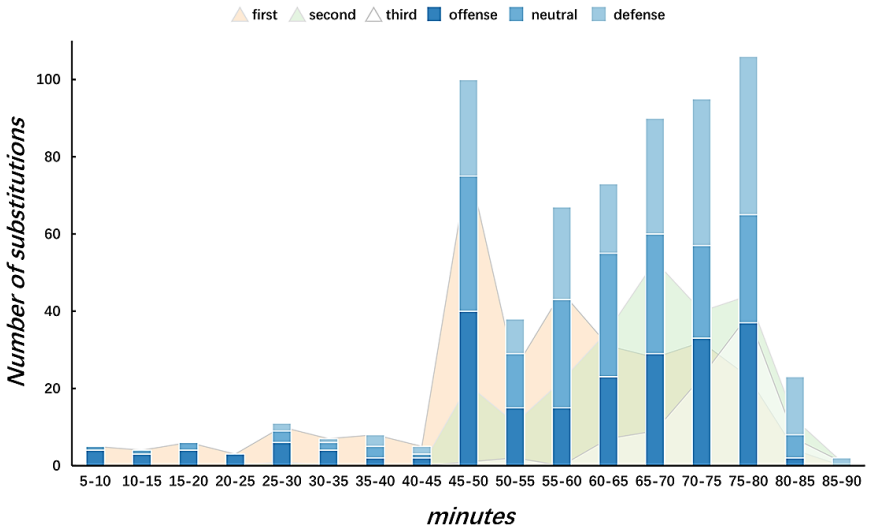

Figure 1. Stacked diagram of the substitution types and numbers during different match periods.

The two-step cluster revealed five groups according to the ratings in different periods before and after substitutions. Clusters 1, 2, 3, 4, and 5 comprised 15.2, 17.3, 18.5, 22.9, and 26.1% of the sample size, respectively. The BIC value of the cluster analysis was 1,360.50, and the ratio of distance measures was the maximum (1.70). The cluster analysis showed the Predictor Importance (PI) of the four periods in descending order: the first 5 minutes after substitutions (PI = 1), the third 5 minutes after substitutions (PI = 0.91), 5 minutes before the substitutions (PI = 0.85), and the second 5 minutes after substitutions (PI = 0.55). The clusters of team ratings according to the periods are shown in Figure 2. Each cluster is represented by a coloured polyline, with cluster 1 scoring relatively high and cluster 5 relatively low. Additionally, in cluster 3 there were about 35% of substitutes with a drawn match status, and over 40% of all clusters substituted with a negative goal differential.

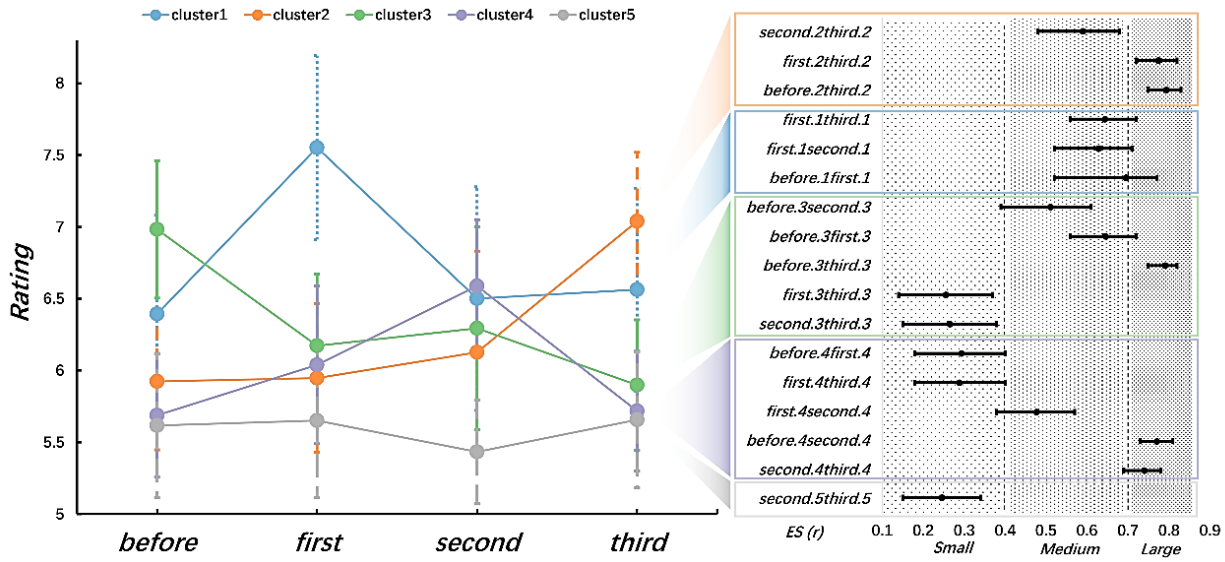

Figure 2. Line diagram of the clusters during periods before and after substitutions and the forest diagram of the interactions' main effect sizes.

As shown in Figure 2, the mean and standard deviation of team ratings and the interactions (H = 531.96, p < .001, E_R^2 = 0.47, 95%CI = [0.44,0.49]) between the two factors of the periods and the clusters in different groups were detected (see Supplementary Table 1 for detailed interaction analysis results). The main effects of team ratings were statistically significant (H = 662.06, p < .001, E_R^2 = 0.26, 95%CI = [0.23,0.29]). The interaction between clusters and periods of substitutions in expected threat did not show any statistically significant differences, and neither did ball possession.

The main effects of expected threat showed on the two factors (clusters: H = 13.56, p < .05, E_R^2 = 0.001, 95%CI = [0.002,0.013]; periods: H = 203.02, p < .001, E_R^2 = 0.08, 95%CI = [0.06,0.11]), and the main effects of ball possession only showed on the clusters (H = 45.41, p < .001, E_R^2 = 0.02, 95%CI = [0.01,0.03]). The post-hoc Mann-Whitney U test on clusters of expected threat and ball possession showed that group comparisons revealed significant differences (p < .05) with specific results in Figure 3. Moreover, the pairwise comparisons of expected threat on periods of substitutions were as follows: before-first (p < .001, r[95%CI] = 0.35[0.30, 0.41]), before-second (p < .001, r[95%CI] = 0.29[0.24, 0.35]), before-third (p < .001, r[95%CI] = 0.31[0.26, 0.37]).

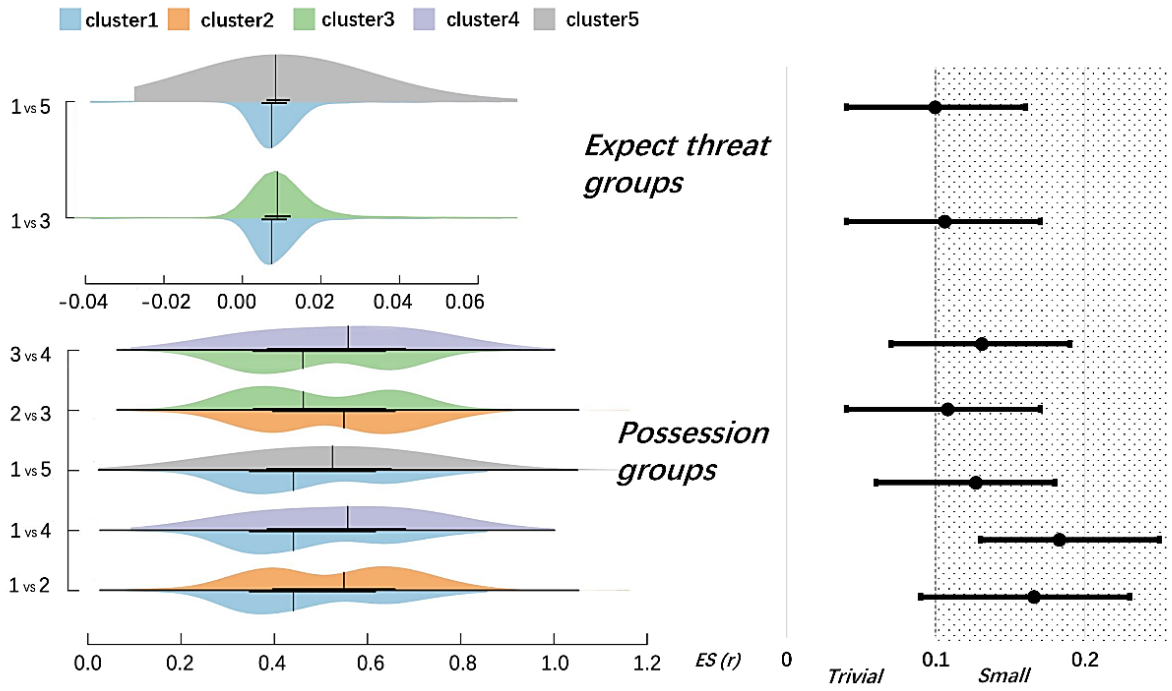

Figure 3. Violin and forest diagrams of Expected Threat and ball possession group comparisons on clusters.

DISCUSSION

The primary objective of the present study was to investigate the effectiveness of substitutions through the lens of team assessment, with a particular focus on analysing the temporal and match performance dynamics before and after substitutions. As previously mentioned, this research delved into team performance using diverse evaluation methodologies, seeking to discern performance fluctuations attributable to the strategic implementation of substitutions.

The study found that substitutions were made with around 28 minutes remaining in the match. The finding is consistent with previous literature (Del Corral et al., 2008) that reported most of the substitutions were made at half-time and in the second half. In contrast to previous research (Gómez et al., 2016; Myers, 2012), this study's substitution periods are earlier, with a heavier focus on the 45-50 minutes and 75-80 minutes intervals. Regarding substitution types, offensive types were often introduced at halftime more than others. This situation might suggest that coaches often adopt an aggressive tactical approach during halftime substitutions (Amez et al., 2021). The neutral and defensive substitutions were observed to increase in frequency in the second half of the games, which may align with the notion that defensive substitutions become more prevalent when a team is leading, aiming to maintain lineup stability (Lorenzo-Martinez et al., 2022).

The ratings of all the clusters fluctuate after substitutions. Notably, except for cluster 3, which experienced a significant decline, the ratings of the remaining clusters either remained unchanged or exhibited an upward trend. Accounting for the expected threat and ball possession, Cluster 3 demonstrated great offensive intention with poor possession in pairwise comparison. Cluster 2 indicated a gradual increase in ratings after substitutions and had high ball possession relative to Clusters 1 and 3, which implies that the teams were capable of converting possession into goals (Lago-Peñas & Dellal, 2010). They may be trailing in score but

have the upper hand in the game momentum. Both Cluster 1 and Cluster 4 rose and then stabilized within 15 minutes after substitutions. However, Cluster 4 has a higher ball possession than Cluster 1, which might be the reason why it can keep the ratings high for longer. For Cluster 5, its rating is the lowest and the steadiest among the clusters, with a small effect size.

In general, a player coming on as a substitute may have a longer high-intensity running distance than their colleagues who are already on the field (Bradley & Noakes, 2013; Carling et al., 2010), indicating that substitutes typically possess more physical energy and stronger ambition to get better performance. However, the distinctions must be specific about the players' positions or roles (Bush et al., 2015; Tierney et al., 2016). Physical information can be a fundamental reference of the physiological and fatigue of players which still need the events and positions to obtain a comprehensive team performance. Combined with the analysis of events and player positions (see Supplementary Table 2 for detailed results), it was found that the change in Cluster 3 might be attributed to the wingers being replaced and the tactics being similar to the counterattack (Lago-Peñas et al., 2017) to get more ball recoveries but ignore the scoreline or the opponent's strength. For Cluster 2, ratings did not start to rise until the third five-minute interval after the substitutions, revealing that these substitutes could take time to adapt to the game tempo (Dancy, 2009). According to events and positions, possession, crosses, and long passes are vital for creating better attacking opportunities with these midfield substitutes. The ratings decline of Cluster 1 may be in line with earlier research (Amez et al., 2021) in that making substitutions enhances the likelihood of goal-scoring, with less fluctuation during the first five minutes and a gradual decline after that. It can be hypothesized that the substitutions involve the insertion of playmakers, individuals known to encourage their teammates to receive and engage with the ball, as highlighted by prior research (Bush et al., 2015; Li et al., 2022). The observed alterations in the ratings within Cluster 4 might be attributed to defensive player replacements, potentially fortifying the defensive line, especially during closely contested ball possession scenarios. However, both clusters suggest that the resulting rating improvements may prove transient, potentially owing to the team's overall suboptimal physical condition (Tierney et al., 2016). The low ratings of Cluster 5 might be related to the ranking, which might replace the defensive centres to guard the goals. In the meantime, these substitutions showed a decent expected threat that might depend on the defenders who transfer the ball to create shots for teammates (Singh, 2019; Van Roy et al., 2020).

Interestingly, the subtle changes in team performance were easier detected on ratings than ball possession or the expected threat of teams. The evaluation framework of player or team ratings may distinctly explain the match report in a given scenario, although the other two approaches are more suited to summarize the overall momentum of the game or monitor team playing styles (Singh, 2019; Van Roy et al., 2020; Wang et al., 2022).

Even though the study provides novel knowledge about the assessment of substitutions, there are some limitations to be acknowledged. Firstly, the research did not consider factors such as fitness status and internal load of players (Aquino et al., 2022; Hills et al., 2020), although the changes in substitution rules could introduce more physically prepared players into the pitch and increase more possible tactical adjustments (García-Aliaga et al., 2023; Meyer & Klatt, 2023). At the same time, specific match scenarios were not integrated into the analysis to inspect the influence of different substitutions on their teammates. Finally, the counteracting tactics adopted by opposing teams from team and individual perspectives were unable to be included, which also limits the generalizability of the findings.

The current study provides practical information at two different levels. At a team tactical level, the research can provide references for coaches on substitution decisions and lineup setting when deciding players who

can bring instant benefits to the team's counterattack or defence. It is acknowledged that most coaches prefer offensive substitutions with strong explosiveness or more consistent performance when the team is trailing in the score (Wittkugel et al., 2022), and the current findings could further help them to evaluate how effective these players are and their impact on teammates. From a match scouting perspective, coaches and analysts could estimate the meaningful effects of opponents' substitution tactics and their span at the rest of the game.

CONCLUSION

This study has elucidated 5 distinct substitution clusters employed across various assessment methods within association football competitions. A further exploration of the effectiveness of substitutions was undertaken by leveraging a player evaluation system. The findings indicated that the ratings of Cluster 3 showed a significant decline after substitutions, attributed to low ball possession despite high aggression in terms of expected threat. The ratings of Cluster 2 showed a significant rise after substitutions caused by the possession play and midfielder substitutes. The remaining clusters displayed varying ratings within a 15-minute window post-substitution. Furthermore, the player evaluation system was employed for substitution analysis to verify the compatibility of ratings, ball possession, and expected threat in this regard.

AUTHOR CONTRIBUTIONS

Each author contributed individually and significantly to the development of the manuscript. Jiale Wu: writing, statistical analysis and preparation of the entire research project. Yuesen Li: data collection, statistical analysis. Changjing Zhou: writing and revision. Xiuyuan Xiong: data collection and analysis. Xiaoru Qin: data collection and analysis. Yixiong Cui: intellectual concept, writing and revision.

SUPPORTING AGENCIES

This work was supported in part by the National Natural Science Foundation of China under grant 72101032, and the Fundamental Research Funds for the Central Universities of China (2024JCYJ006).

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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