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Preliminary evidence of a circadian rhythm effect on English premier league match outcome

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Abstract

The body's circadian rhythm regulates energetics, metabolism, and muscle physiology. While studies have examined the effects of circadian rhythm on the performance of individual athletes, little research has explored its impact on team performance. This study investigated the effect of kick-off time, match location, travel distance, and the opposition ranking on match outcomes in the English Premier League over four consecutive seasons (2021/22–2024/25). Results revealed a potential effect of kick-off time on win probability, suggesting that kick-off time may affect team performance. Across the range of kick-off times (12:00-20:15), predicted win probability increased by 1.8% for home teams (4.4% relative increase), whereas for away teams, win probability decreased by 3.2% (relative reduction of 10.3%). These findings suggest that circadian misalignment, travel fatigue, and routine disruption may influence match outcome, and may ultimately affect final league position, title races, European qualification and relegation. Although other factors (e.g., travel, accommodation, crowd energy) may also contribute, this analysis identifies kick-off time as a potential effect, reinforcing the notion that chronobiology should be considered in performance planning. Scheduling authorities may inadvertently disadvantage teams in late kick-off matches, raising questions of competitive fairness.

Keywords

circadian rhythm, English premier league, match outcome, travel distance, kick-off time

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Introduction

An athlete's performance changes considerably throughout the day, owing in part to their circadian rhythm (Facer-Childs et al., 2018; Lok et al., 2020; Reilly and Waterhouse, 2009). Genetic and environmental factors influence an individual's circadian rhythm and therefore underpin the timing of an athlete's peak physical performance (Facer-Childs and Brandstaetter, 2015). Understanding how athletic performance changes throughout the day is crucial to help optimize training strategies to enhance athletic performance and mitigate risk of injury (Facer-Childs et al., 2018; Schiffner et al., 2024).

Historically, individuals have been classified according to chronotype; either a morning chronotype ("morning lark") or evening chronotype ("night owl"), which has been shown to correlate with physical performance (Natale and Cicogna, 2002). Typically, the diurnal effect of time on physical performance has been assessed at an individual level (Heishman et al., 2017; Kline et al., 2007; Lericollais et al., 2009; Pałka et al., 2021) and research has suggested that physical performance in individual sports can vary based on the time of day (Brown et al., 2008; Edwards et al., 2005; Turner et al., 2023). However, it is unclear whether positive physical and technical outcomes can be observed in team sports. Owen et al. (2023) reported temporal performance-related changes in soccer, observing that training metrics across a

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squad of 30 elite-level soccer players were improved on days when training was scheduled at 11:00 compared to days when training was completed at 16:00. Physical performance fluctuations observed at the team level may be linked to the chronotype composition of the squad. For example, teams made up primarily of "night owls" may perform better later in the day. Additionally, habitual training times may play a pivotal role, as athletes who consistently train at the same time of day can undergo temporal adaptation (Ruiz et al., 2019). Some research has shown that athletes tend to reach peak short-term maximal performance, such as in Wingate and repeated sprint ability tests, at the time of day that matches their regular training schedule (Chtourou and Souissi, 2012). Although, how temporal changes in physical performance translate to competitive match outcomes remains underexplored. Circadian-influenced performance changes reflect changes in individual physiological readiness e.g., body temperature, muscle physiology, and hormonal cycles (Augsburger et al., 2025). Incidentally, team ranking may also reflect underlying physiological differences that allows maximal perfomance expression. Chmura et al. (2022) found that higher-ranked teams covered greater total and sprinting distances in possession, completed more sprints with the ball, and reached higher maximal velocities than lower-ranked teams. In team environments, diurnal variations in aggregated individual performance metrics, including physical output, cognitive function, and visual reaction (Kurak et al., 2025; McElroy and Dickinson, 2019), may influence tactical cohesion, execution, and communication efficiency. Furthermore, time-of-day effects on match outcomes may also reflect changes beyond biology, for example, sub-optimal strategic preparation and psychological routines, which may become misaligned from training to competition. Building on this framework, this study examines whether kick-off time may affect match outcomes in elite soccer, using it as a proxy for circadian alignment at the team level. This approach captures the combined influence of individual physiological readiness, chronotype variation, and potential misalignment between training and competition timing. In doing so, it assesses whether these circadian-driven mechanisms translate into measurable differences in competitive performance. Given the likely variation in chronotype composition and training schedules within and between teams, it is reasonable to expect that match-day physical performance and, therefore, match outcome, may be influenced by timing.

Many studies have used a number of metrics to predict sporting success across a variety of disciplines (Agrawal, 2024; Berrar et al., 2018; Chen, 2019; Davoodi and Khanteymoori, 2010; Owramipur et al., 2013). For soccer, in-game tactical data such as corners, shots on/off target, and fouls are common factors considered when attempting to predict match outcome (Wheatcroft, 2021). In contrast, there is limited research into the potential effect of temporal fluctuations in individuals' athletic ability on English Premier League (EPL) match outcomes. Thus, the aim of this study was to assess the probability of teams winning as a function of kick-off time, whilst controlling for other important predictors of match outcome; travel distance, home/away status, and rank difference between teams. Based on the understanding of chronobiology and the influence of time on physical performance, the study hypothesized that kick-off time may affect match outcome.

Materials and methods

Match report data and match outcome

Match report data recorded for EPL teams from and including the 2021/22 to 2024/25 seasons were extracted from the publicly available Sky Sports website (Sky Sports, 2025). Thus, ethical approval was not required. The variables collected included match date, match outcome (win/loss/draw), kick-off time, match location (home/away), focal team name, and opposition team name. A total of 3040 observations were extracted, comprising two observations per match (one from each team's perspective) across 1520 matches. The unit of analysis was hence the team-match observation (Mattera, 2023), with each record representing the probability that a given focal team won a given match. This structure allows covariate effects on focal-team win probability to be estimated directly whilst controlling for within-match dependence (see *Statistical modelling*). Match outcome was classified as win (1) or not a win (0). Hence, the response variable represents the marginal probability that a focal team wins a match, conditional on covariates, rather than the joint probability of all possible match outcomes (Mattera, 2023). The data were compiled and analyzed using R (version 4.4.1 2024-06-14) via RStudio (version 2024.4.2.764).

Quality of opposition/rank difference

To account for variation in team quality, the difference in league position between the focal team and the opposition was calculated for each match by subtracting the opposition team rank from the focal team rank. Following Morgans et al. (2025), rankings were based on the final EPL table from the previous season. For example, if the focal team ranked 5th and the opposition ranked 12th, the rank difference would be −7, indicating a weaker opponent. Conversely, if the focal team ranked 14th and the opposition ranked 6th, the rank difference would be +8, indicating a stronger opponent. For newly promoted teams, rankings were assigned according to the finishing positions in the previous season's Championship League table; the Championship winner was ranked 18th, the runner up was ranked 19th, and the playoff winner was ranked 20th.

Calculating the travel distance to matches

To calculate the distance each team had to travel to reach the competing team's home ground for each match, the primary road route distance from the focal team's home stadium to the stadium of the away team was recorded in miles using Google Maps (Google, 2025). If the focal team played at home, the travel distance was recorded as 0 miles (Goumas, 2014).

Kick-off time

Time was considered either as a continuous variable, recorded as minutes after the earliest recorded kick-off time; 12:00 (e.g., 15:00 = 180 min after 12:00) or as a categorical variable, segmented into approximately two-hour intervals. i.e., 12:00 - 14:00, 14:01-16:00.

Statistical modelling

We modelled focal-team win probability as a function of the four predictor variables (home/away status, travel distance, rank difference, and kick-off time) using a generalized linear mixed-effects modelling (GLMM) framework, with a binomial error distribution and logit link. Model formulations with differing combinations of fixed and random effects of the four predictor variables, as well as their potential interactions, were considered. To account for potential non-linear relationships, first, second, and third order polynomial terms were considered for continuous predictor variables. Because travel distance was always zero for focal teams' home matches, this variable was structurally correlated with home/away status. We therefore did not include an interaction between home/away status and travel distance as this was redundant, hence the effect of travel distance (see *Results*) is estimated for away games only (Goumas, 2014). To account for clustering and hierarchical structure in the data, all models included random intercepts for match, team, and season. The match-level random intercept accounts for unobserved match-specific factors (e.g., weather conditions, officiating characteristics) that may influence both teams' baseline win probabilities, thereby accounting for within-match clustering rather than encoding logical complementarity between outcomes. Team- and season-level random intercepts capture differences in team performance and temporal shifts in league-level conditions, respectively.

We fitted a total of 285 models (Appendix S1) using the *glmer* function from the *lme4* package (Bates et al., 2015). The bobyqa optimiser (Powell, 2009) was specified via *glmerControl* to mitigate convergence issues.

Multi-model averaging

Multi-model inference was conducted using an information-theoretic approach (Harrison et al., 2018). Specifically, candidate models were ranked using Akaike's Information Criterion (AIC), and models within $\Delta AIC \leq 2$ of the best-supported model were considered to have equivalent support (Burnham and Anderson, 2004); hereon "top-performing models".

Akaike weights (ω_i) were calculated for each top-performing model, representing the relative likelihood of each model given the data. Following Burnham and Anderson (2002), model-averaged parameter estimates were then calculated as weighted averages across the set of top-performing models. We report conditional model average estimates (β), in which coefficients are averaged across only those models in which the predictor is present (Burnham and Anderson, 2002), together with standard errors (SE) and relative importance values (ω_i). Relative variable importance was quantified as the sum of Akaike weights across all top-performing models in which the predictor occurred. Multi-model averaging was implemented using the *MuMIn* package (Bartoń, 2025).

Results

Win probability across 2021/22–2024/25 English premier league teams

There were notable differences in win probability at different kick-off times between teams (Fig. 1). For example, some teams achieved more wins in earlier fixtures (e.g., Liverpool had 64% wins from 12:00-14:00 vs 38% from 18:01-20:15; Brentford had 48% wins from 12:00-14:00 vs 17% from 18:01-20:15, respectively) while others won more at later kick-off times (e.g., Manchester City won 24% from 12:00-14:00 vs. 64% from 18:01-20:15; and Chelsea won 40% of their matches during 12:00-14:00 vs. 58% from 18:01-20:15). Descriptive statistics from earlier seasons are also reported in Appendices S2-S4.

Results of AIC-based model selection

Six models fell within $\Delta AIC \leq 2$ of the best-supported model (AIC = 3626.42) with Akaike weights (ω) ranging from 0.22 to 0.08 (Table 1). Thus, inference is based on a small set of parsimonious, similarly supported models, reducing the risk of overfitting. Note that of the 285 candidate models, only the six top-performing models are shown in Table 1 for brevity (full details of all candidate models are provided in Appendix S1 and S5-S6).

Across the top-performing models, rank difference and home/away status appeared in all six models and had the highest predictor importance ($\Sigma\omega = 1.00$ each), indicating strong support for their influence on win probability. Travel distance had moderate support ($\Sigma\omega = 0.51$) as a main effect, being retained in half of the top models, however, no interactions with travel distance were retained. Support for kick-off time was also present, albeit at a lower importance ($\Sigma\omega = 0.40$, retained in two models), but was

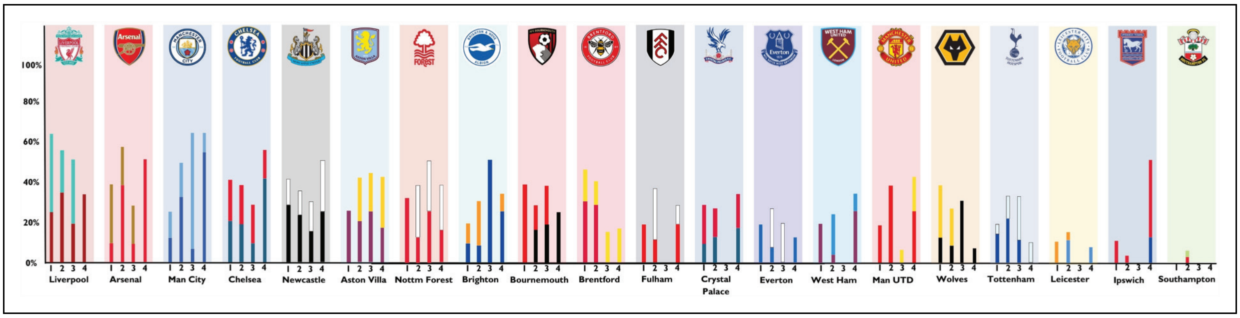

Figure 1. Percentage of wins for each 2024–25 English premier league team according to kick-off time (1 = 12:00-14:00 2 = 14:01–16:00, 3 = 16:01–18:00, and 4 = 18:01–20:15). Home (top) and away (bottom) wins are distinguished within each bar.

Table 1. The top six GLMMs fitted to EPL match data from and including 2021/2022 to 2024/2025 seasons. Each model includes a unique combination of predictor variables, included either as a fixed term (✓), an interaction term (*) or both (✓*).

Model number	Fixed effects				AIC score	Akaike weight (w)
	Kick-Off Time	Distance Travelled	Rank Difference	Home/Away status		
1	✓*	✓	✓	✓*	3626.417	0.22
2		✓	✓	✓	3626.636	0.2
3			✓	✓	3626.739	0.19
4	*		✓	✓*	3626.867	0.18
5	*		✓*	✓	3627.734	0.12
6	✓	✓	✓	✓	3628.389	0.08

found higher than rank difference (Σω = 0.12, retained in one model). The total summed Akaike weight across kick-off time terms was 0.83, reflecting support for the inclusion of kick-off time in some capacity. Akaike-weighted R^2 values across the top models indicated that they explained 17.7% of the variance in win probability (conditional R^2), with 14.5% attributable to fixed effects (marginal R^2).

The effect of home/away status and kick-off time on win probability

Home/away status had a moderate, positive effect on win probability (β = 0.401 ± 0.215; model-averaged coefficient ± SE), such that the predicted probability of winning was 9.3% higher for home than away fixtures (a relative increase of 29.1%). This coefficient represents the baseline home-advantage effect, independent of any additional influence of travel distance on away teams (see later). This was further modified by the interaction between home/away status and kick-off time (Fig. 2). Specifically, for matches scheduled later in the day, there was a slight increase per unit time (minutes after 12:00) in predicted win probability for home teams (β = 0.00081 ± 0.00063) and a slight decrease in predicted win probability for away teams (β = -0.00072 ± 0.00042). For example, for kick-off times ranging from 12:00–20:15, the predicted win probability fell from 31.3% to 28.1% for away teams (an absolute decline of 3.2%, equivalent to a 10.3% relative decrease), while for home teams, win probability rose from 41.3% to 43.1% (an absolute increase of 1.8%, equivalent to a 4.4% relative increase).

The effect of rank difference and travel distance

Rank difference had the largest effect on win probability (β = -0.082 ± 0.0077). Specifically, a one-unit increase in rank difference (i.e., relatively stronger opponent) decreased the absolute predicted win probability by 2%. The interaction effect between rank difference and kick-off time was negligible (β = 0.0000384 ± 0.0000363) i.e., kick-off time had essentially the same effect on win probability regardless of the rank difference between teams (Fig. 3).

When focal teams played away, longer travel distances saw a lower predicted win probability (β = -0.00107 ± 0.00071 per mile). Although the per-mile effect was small, when applied across the observed range of 0.9-353 miles, predicted win probability declined from ~32% to ~28% (an absolute decrease of 4% and a relative decrease of 12.5%).

Discussion

The present study aimed to assess the impact of travel distance, match location and ranking difference on match

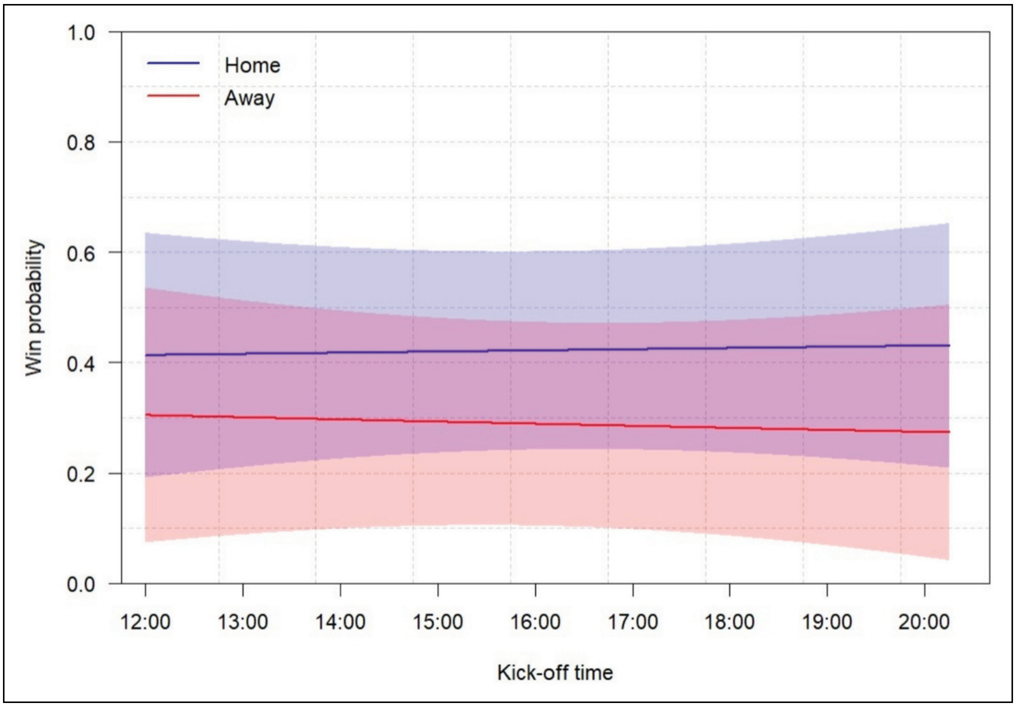

Figure 2. Predicted win probability as a function of kick-off time for home (blue) and away (red) teams. Predictions are based on model-averaged estimates for mean distance travelled and rank difference. Shaded areas represent 95% confidence intervals.

outcome and to assess the probability of winning as a function of kick-off time. We provide preliminary evidence that kick-off time may affect match outcome, which warrants further investigation. Furthermore, the present study suggests that, while effect sizes are modest, away disadvantage is more influential than home advantage, particularly at later kick-off times. These findings may have implications for fixture scheduling; even though each team plays every other team both home and away to ensure fairness, the timing of these fixtures may unintentionally disadvantage certain teams. The results presented here also suggest that temporal factors may compound the effects of travel-induced fatigue/disruption in shaping team performance.

Impact of home advantage

Research into the influence of kick-off time on performance in soccer is gaining momentum. In a study on the Europa League, Krumer (2019) found that later games reduced attendance, diminishing home advantage for lower-ranked teams. In contrast, O'Leary (2024) proposed a "night owl effect" in the EPL, where later matches increased home advantage, potentially due to reduced away support (as supporters were less willing to travel), and increased alcohol consumption potentially amplifying aggressive behavior among fans and influencing the decision of the referee in favor of the home team. Both studies demonstrated that kick-off time alters competitive dynamics, although the conclusions differ regarding which team (home vs away) benefits and why.

The present study suggests that while home team performance may not improve substantially in evening fixtures, the concurrent disadvantage experienced by away teams contributes to a heightened home advantage, especially at later kick-off times. While previous research supports the idea that crowds can influence match outcomes, there is a lack of consensus on whether audiences support or hinder the home team (Correia-Oliveira and Andrade-Souza, 2022; Goumas, 2013; Krumer, 2019; Van de Ven, 2011). Böheim et al. (2019) suggest that strong home support may increase psychological stress, causing teams to "choke under pressure," potentially reducing win probability. Indeed, Taylor et al. (2010) found that supportive audiences can elevate physiological stress markers. Conversely, Leota et al. (2022) examined National Basketball Association (NBA) games played without crowds during the COVID-19 pandemic and found no evidence for referee bias or audience size impacting outcomes. Instead, it was concluded that crowd presence boosted home team effort, although that study did not consider the quality of the opposition or match timing.

Travel distance and circadian misalignment

McHill and Chinoy (2020) analysed the NBA's COVID-19 bubble season when teams were based in a single location

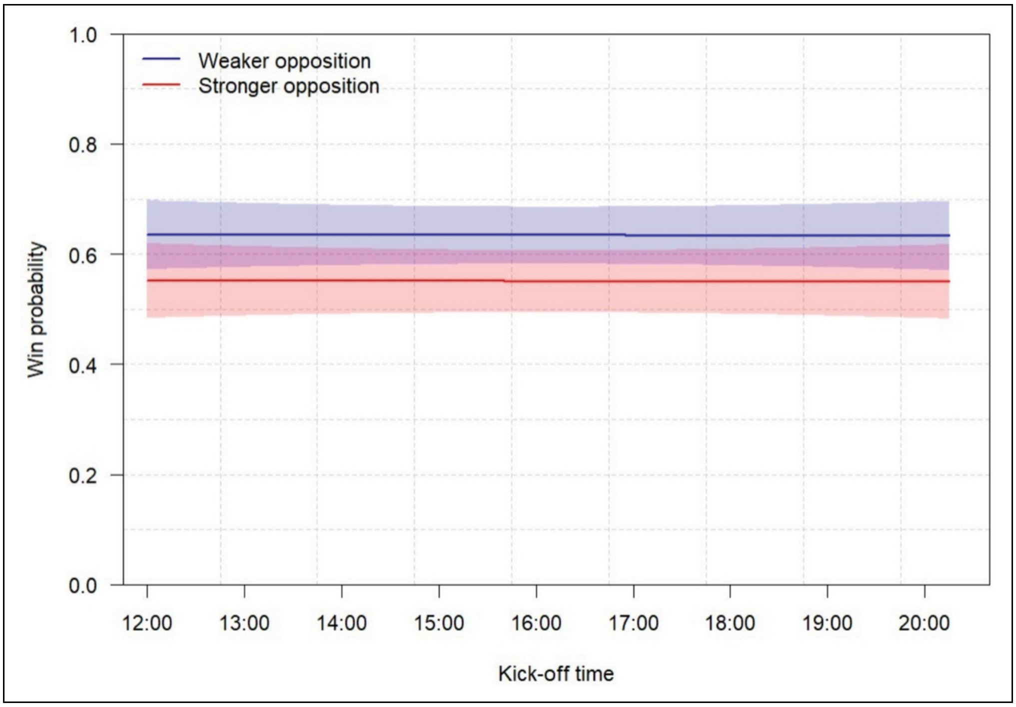

Figure 3. Predicted win probability as a function of kick-off time, with predictions for focal teams playing weaker opposition in red, and focal teams playing stronger opposition in blue. Predictions are based on model-averaged estimates for mean distance travelled. Shaded areas represent 95% confidence intervals.

and travel was eliminated. Home teams won 55.7% of games in the bubble compared to 63.8% pre-COVID-19, suggesting that travel is a key contributor to home advantage (McHill and Chinoy, 2020). Many studies suggest long-distance travel can disrupt circadian alignment, resulting in reduced athletic performance (Botonis et al., 2025; Doherty et al., 2023; Heller et al., 2024; Leatherwood and Dragoo, 2013) substantive enough to impact match outcomes (Krumer, 2019). However, Smith et al. (1997) showed that circadian alignment may offset travel fatigue, finding that West Coast teams traveling east won more late night games (65.3%) than East Coast home teams (55%) when match times aligned with their circadian rhythms. The present study provides support for this, showing that later kick-off times and longer travel distance may reduce win probability, consistent with short-term circadian effects. The relatively weak effect of travel distance found in the present study, likely reflects the shorter domestic travel distances and the absence of time zone changes within the EPL.

There is broad evidence for home advantage across sports (Boyd et al., 2025), though its underlying mechanisms remain debated. The findings here suggest that home advantage may be moderated by kick-off time, with away teams experiencing a slight reduction in win probability in later fixtures regardless of team quality. This contrasts Krumer (2019), who found that later kick-off times reduced home advantage for lower-ranked teams in the UEFA Europa League. This discrepancy may reflect contextual differences, as Krumer (2019) examined multiple timezones and narrower kick-off windows, whereas the present study focuses on a single league with no time zone variation but a wider range of match timings.

Physiological readiness and contextual fatigue

Athletic ability changes throughout the day owing to circadian influences on energy reserves, metabolism, and muscle physiology (Augsburger et al., 2025). The results presented here suggest a small increase in win probability at later kick-off times for home teams and a small decrease for away teams. While the present study cannot determine whether these changes reflect diurnal variation in performance driven by circadian-controlled physiological processes (i.e., causality), these patterns are consistent with circadian misalignment between biological readiness and match timing. This may be exacerbated for away teams, who are more likely to experience fatigue and routine disruption following travel (Fowler et al., 2014; Fullagar et al., 2014; Rensburg et al., 2021). Such disruption has been examined in the context of long-haul travel across time zones (Clements et al., 2023; Fowler et al., 2015; Özdalyan et al., 2024; Lo et al., 2022), and it remains unclear whether shorter travel, as examined here, is sufficient to meaningfully impair performance (Lim et al., 2021), though colloquially, soccer managers often lament the 12:30 kick-off (unpublished).

Evidence on the relationship between time of day and athletic performance is mixed. Anaerobic performance generally improves throughout the day and peaks in the early evening ≈ 18:00 (Chtourou and Souissi, 2012; Pałka et al., 2021), aligning with circadian increases in core body temperature and metabolic activity (Baxter, 1983; Cappaert, 1999; Edwards et al., 2005; Reilly et al., 2007; Rutenfranz and Colquhoun, 1979). However, some studies report superior morning performance or reduced evening output depending on the activity. For example, declines in sprint performance (torque) and neuromuscular recovery have been observed in the evening (Giacomoni et al., 2006). Similarly, tennis performance metrics such as winners and serve success have been shown to decrease in later matches (Turner et al., 2023). In contrast, skill-based measures in soccer, including dribbling and shot accuracy, have been reported to improve in late afternoon and evening under controlled conditions (Reilly et al., 2007; Tiwari and Deol, 2016). These inconsistencies suggest that optimal performance timing depends on the specific sporting demands, as well as individual chronotype. Previous research has also shown that time of day may influence micro-performance indicators in team sports (Glinski and Chandy, 2022; Martin-López et al., 2025). To our knowledge, the present study is one of the first to report a potential (albeit small) effect of time of day on a higher-level performance outcome; overall match result.

Limitations and future research recommendations

While this study highlights a potential effect of kick-off time, supporting the relevance of chronobiology in performance planning, it is important to acknowledge some limitations. Here, we quantified rank difference as a static metric (Morgans et al., 2025). Future research could incorporate dynamic measures of team strength, such as rolling Elo ratings or mid-season points. Additionally, incorporating additional contextual variables such as environmental conditions (Iskandaryan et al., 2020; Mantzios et al., 2021), match attendance (e.g., Buraimo et al., 2009; Cross and Uhrig, 2023) and days between fixtures (Field et al., 2023; Julian et al., 2021) may provide a broader understanding of how external factors influence performance. Future research could also consider match outcome as a three-level response (win, draw, loss).

Kick-off times were based on scheduled listings (Sky Sports, 2025), and although minor deviations are possible, these are likely negligible given strict broadcast schedules (Tweedale et al., 2025). Finally, while the observed effects are small and should be interpreted cautiously, marginal gains can still be meaningful in elite sport. Hence, these findings may have practical relevance for player routines, recovery strategies, and individual chronobiological profiles, especially around late fixtures. Although causation cannot be established, circadian disruption remains a plausible contributing factor that warrants further investigation. Applying similar modelling approaches across other leagues and sports would help determine the generalizability of these effects.

Conclusion

This study provides insight into the extent that kick-off time influences match outcomes in the EPL. Away teams experienced a relative 10.3% decline in win probability over 8 h; between 12:00 and 20:15. This trend, which was observed for both stronger and weaker ranked teams, suggests that fixture timing may disadvantage away teams regardless of their relative quality. This challenges the assumption that fairness is achieved by ensuring all teams play each other home and away. From a practical standpoint, clubs and governing bodies should acknowledge kick-off timing as a modifiable factor that can subtly, although meaningfully, affect competitive balance. For away teams, mitigating this temporal disadvantage could involve adjusting travel schedules to preserve routines, promote rest, and align more closely with players' circadian-aligned physiological readiness. To our knowledge, this study is the first to provide evidence of a small yet potentially meaningful effect of fixture timing on match outcome at the elite level. Beyond their biological relevance, these findings may have applied implications for fixture scheduling and performance planning.

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Supplemental material

Supplemental material for this article is available online.

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